RESEARCH AND IMPACT REPORT

Republic of Zambia

Smallholder Productivity Promotion Programme (S3P)

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IFAD

Investing in rural people

Arslan A., Zucchini E. and Scheiterle L. 2021. Impact assessment report: Smallholder Productivity Promotion Programme, Zambia. IFAD, Rome, Italy.

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Acknowledgements

The authors would like to thank Martin M. Liywalii, Project Director of the Smallholder Productivity Promotion Programme, who was always available to support this impact assessment with his deep knowledge about the programme and the local institutional environment. Special thanks to Dr. Antony Chapoto, Mwamba Chishimba, Auckland Kuteya Namubi, Munguzwe Hichaambwa and the data collection team from the Indaba Agricultural Policy Research Institute (IAPRI), who supported sampling and collected data under the difficulties posed by the COVID-19 pandemic, while keeping everyone safe and healthy. The authors are also grateful to Ambrosio Barros, Zambia Country Director of the International Fund for Agricultural Development, for his support throughout the implementation process. Last, but not least, we sincerely thank all households and community leaders, who patiently provided their precious time and information to enable this study.

Acronyms

AER	Agro-Ecological Region
ATET	Average Treatment Effect on the Treated
CA	Conservation Agriculture
CAPI	Computer Assisted Personal Interview
COMACO	Community Markets for Conservation
EG	Economic Goal
E-SAPP	Enhanced Smallholder Agribusiness Promotion Programme
FCS	Food Consumption Score
FFS	Farmer Field Schools
FIES	Food Insecurity Experience Score
FISP	Farmer Input Support Programme
FRA	Food Reserve Agency
HDDS	Household Dietary Diversity Score
IA	Impact Assessment
IAPRI	Indaba Agricultural Policy Research Institute
IFAD	International Fund for Agricultural Development
IPW	Inverse Probability Weight
IPWRA	Inverse Probability Weighted Regression Adjustment
MAHFP	Months of Adequate Household Food Provision
MoA	Ministry of Agriculture of the Republic of Zambia
MT	Mainstreaming Theme
NNM	Nearest-Neighbour Matching
PCR	Programme Completion Report
PSM	Propensity Score Matching
RALS	Rural Agricultural Livelihood Survey
RIA	Research and Impact Assessment Division
S3P	Smallholder Productivity Promotion Programme
SAPP	Smallholder Agribusiness Programme Promotion
SEA	Standard Enumeration Area
SO	Strategic Objective
TLC	Total Land Care
ToC	Theory of Change

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Executive summary

The Smallholder Productivity Promotion Programme (S3P) was implemented in Luapula, Muchinga and Northern provinces of Zambia by the Ministry of Agriculture (MoA) from 2013 to 2019. It was funded mainly by IFAD, with contributions from the Government of Zambia, the Government of Finland, implementing partners and beneficiaries. The S3P aimed to increase incomes, food and nutrition security of small-scale farmers by boosting agricultural production, productivity and sales in cassava, groundnut and mixed beans systems. This impact assessment (IA) study was conducted as part of the IFAD11 IA agenda, through which IFAD is analysing the impacts of a sample of projects to learn lessons for improved programming as well as to estimate the overall impact of its portfolio using an aggregation analysis.

This study rigorously analyses the attributable impact of S3P on a large set of indicators grouped by IFAD's strategic objectives and overarching goal, as well as other indicators that measure impact pathways and mainstreaming themes. Using data from 2,052 households (both beneficiaries and non-beneficiaries) collected in October-November 2020, we find that the S3P had a positive impact on cropping income, ownership of durable assets and housing quality of its beneficiaries. Although it did not have an attributable impact on total income, cropping income makes up 50-60 per cent of beneficiary incomes and is the income source targeted by the programme.

Regarding agricultural production, the total value of crop production increased significantly for beneficiaries. Although impacts were especially strong for cassava, we also find significant positive spillover impacts on total production of maize. We find no attributable impact on production and yields of groundnuts and mixed beans. Regarding impact channels, we find increased adoption of crop rotation and crop residue management among beneficiaries. There is no attributable impact on the adoption of several other practices promoted, including full adoption of conservation agriculture (CA). By contrast, the S3P has positively affected the adoption of improved planting material for the targeted crops.

Beneficiary households are significantly more likely to sell crops, and the shares of and revenues from sales for those that sell are higher compared to the control group. The attributable impact on beneficiary households' resilience is mainly observed in terms of increased crop diversification, which is an important factor to decrease vulnerability. Their ability to recover from shocks improved, though mainly for non-climate related shocks.

Regarding IFAD's mainstreaming themes, we find that the S3P had a small yet robust positive impact on multiple indicators of food and nutrition security. On women's empowerment, although no significant impact is found on women's sole control of/decision making over resources, there are small yet robust impacts on joint decision making and asset ownership.

Overall, the S3P achieved most of its objectives, though most effects are driven by cassava and maize cultivation. Its design integrated extension service provision through a public-private partnership to improve agricultural production with promotion of farmer organizations as a means to improve market access built explicit synergies with complementary programmes, which has proved effective. The modest impacts on food and nutrition security could be improved by scaling up the small nutrition component. The significant spillover impacts on maize suggest that interventions targeting specific crops may be more effective if they incorporate farmers' tendency to use the knowledge for and increase investment in their main crops. In this context, similar crop-specific interventions should be complemented with broader rural development programmes to address constraints in access to credit, inputs, information, markets and diversification.

1. Introduction

This study features the results of the Impact Assessment (IA) of the Smallholder Productivity Promotion Programme (S3P) conducted by the Research and Impact Assessment Division (RIA) of the International Fund for Agricultural Development (IFAD). The S3P is one of the programmes selected for IFAD 11 IAs, which measure the impact attributable to IFAD operations in 15 per cent of IFAD's portfolio of programmes that are closing during 2019-2021 as part of the Development Effectiveness Framework.[1] This IA study reports on the core outcome indicators of IFAD's Strategic Framework 2016-2025, defined in the Results Management Framework of IFAD as Tier II development impact indicators.[2] The objective of the IA study is thus twofold. First, it provides the impacts attributable to the S3P and contributes to corporate reporting and accountability of IFAD operations. Second, it provides lessons and recommendations for future policy/programme design and implementation by contributing to existing empirical evidence on impacts of similar rural transformation programmes.

The S3P (hereafter also referred to as "the Programme") was implemented in Luapula, Muchinga and Northern provinces of Zambia by the Ministry of Agriculture (MoA) from 2013 to 2019.[3] The Programme was funded by IFAD (87 per cent), Government of Zambia (five per cent), the Government of Finland (three per cent), implementing partners (five per cent) and beneficiaries (one per cent) for a total cost of US$33.8 million.[4] The S3P targeted small-scale farmers cultivating no more than five hectares (ha) in 150 agricultural camps[5] by focusing primarily on cassava, groundnut and mixed beans.

The goal was to reduce rural poverty and achieve food and nutrition security by increasing production, productivity and sales of agricultural products. The Programme was organized into two components. The first focused on sustainable productivity growth by strengthening farmer organizations, improving access to agricultural extension services, increasing adoption of good agricultural practices and improved planting materials. The second component emphasized the enabling environment for productivity growth including rural infrastructure (e.g. rehabilitation of roads, farmer training centres, and investments in agricultural assets), and support to MoA policy and planning framework. The S3P framework was aligned with the main agricultural policies in Zambia and IFAD country strategy programme.[6] The IA study focuses particularly on the first

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[1] IFAD operations are planned based on three-year replenishment periods. The current replenishment period covers the years 2019 to 2021 and is the 11th replenishment period, called IFAD11. Thus, IFAD11 IAs include programmes that are completed during this three-year period. RIA conducts rigours IAs for a sample of at least 15 per cent of these programmes and IA results are then combined in a meta-analysis and projected to the overall portfolio to report on the attributable impacts of IFAD operations on overall goal, strategic objectives and mainstreaming themes (https://www.ifad.org/en/development-effectiveness).

[2] IFAD's Strategic Framework 2016-2025 presents the overarching goal, principles of engagement, strategic objectives, otucomes and pillars of results that guide IFAD operations over the period 2016-2025 (https://www.ifad.org/en/web/knowledge/-/ifad-strategic-framework-2016-20-1). Updated results and progress towards IFAD targets are presented at: https://www.ifad.org/en/rmf-dashboard. The core outocome indicators of the IA study are extensively presented in Section 2.

[3] The S3P was approved in September 2011 and the financing agreement was signed in December 2011. The official closing date was June 2019, which was postponed by one year to June 2020. Implementation of field activities started in the second half of 2013 (IFAD, 2021).

[4] A detailed discussion of financial aspects of S3P is reported in the PCR (IFAD, 2021).

[5] Agricultural camps are part of the institutional framework of the Ministry of Agriculture and are operational units established to provide extension services and develop rural infrastructure.

[6] Agricultural policies in Zambia aim to reduce rural poverty by increasing agricultural production and productivity, agricultural diversification and market-oriented agriculture. The most important agricultural policies are the Natinoal Agricultural Policy, the National Development Plan and the National Agricultural Investment Plan. The IFAD country strategy aims to increase access to and use of technologies and services for enhanced productivity, market access, sustainability and resilience of small-scale production system (https://www.ifad.org/en/web/operations/w/country/zambia).

component, which took up 54 per cent of the total budget and was expected to have the highest transformational impact on small-scale farmers.

The contribution of the agricultural sector to the Zambian economy has decreased steadily over the last decade (World Bank, 2021). Nonetheless, agriculture contributes largely to the livelihoods of the rural population, which experiences the highest rates of poverty and food insecurity in the country (Tembo and Sitko, 2013; Thurlow and Wobst, 2006).

Small-scale farmers (cultivating less than five ha) account for about 95 per cent of the farming system (Sitko and Jayne, 2014). Nonetheless, similar to other Sub-Saharan African countries, Zambia is experiencing a decrease in farm size within small-scale farmers, and simultaneously, an increase in medium- and large-scale farms (more than 5 ha). Land distribution is becoming more concentrated over time (Jayne et al., 2019; Jayne et al., 2016; Sitko and Chamberlin, 2015; Jayne et al., 2014), primarily due to land acquisition by wealthier urban and rural families (Sitko and Jayne, 2014). The presence of medium- and large-scale farmers increases the integration of nearby small-scale farmers into the maize market (Burke et al., 2020), leading them to increase maize cultivation and yields (Lay et al., 2021).

Crop production is mostly rain-fed and affected by high climate variability and worsening climatic conditions. The intensity of adverse climatic conditions is increasing, such as El Niño and La Niña events of the recent past, and projections of declining rainfall and rising temperatures are threatening the livelihoods of farmers that depend on agriculture (Mulungu et al., 2021; Hamududu and Ngoma, 2020; IAPRI, 2018). Production growth is mostly driven by expansion of the cultivated area rather than increasing crop yields, which is possible given the low population density (17 persons per km^2). However, agricultural extensification leads to loss of soil fertility associated with yield reductions and increased poverty levels (Masikati et al., 2021).

Although maize is the main crop in all provinces of Zambia, cassava contributes significantly to the food and nutrition security of small-scale farmers in the targeted provinces (Alamu et al., 2019), with high potential for growth through value chain improvements (Poole et al., 2013; Haggblade et al., 2012; Chitundu et al., 2009). Cassava cultivation has increased since the market liberalization in the 90s that reduced government support for maize to promote agricultural diversification (Dorosh et al., 2009). Cassava is a critical crop for small-scale farmers because it is more tolerant to climate shocks and low fertiliser use (Gabre-Madhin and Haggblade, 2004) that are two of the main constraints in the area. Cassava can drive poverty alleviation (Feleke et al., 2016) and mitigate lean season hunger as it is harvested throughout the year, more drought resistant and a low-cost crop (Barratt et al., 2006). Given its potential in facilitating small-scale agriculture, cassava has attracted investments and interest from national and international institutions, which have supported its production (especially through the promotion of new varieties), processing into flour and chips, and marketing for human consumption, animal feed and non-food uses (Poole et al., 2013; Haggblade et al., 2012; Chitundu et al., 2009). However, yield gaps remain high due to lack of clean planting materials and low adoption of sustainable agricultural practices and soil fertility management (Alene et al., 2018). Cassava consumption is also constrained due to limited knowledge of cassava product diversity and poor use of improved processing equipment (Alamu et al., 2019).

The combination of deteriorating climatic conditions, declining soil fertility and agricultural extensification motivated the interventions of S3P to promote sustainable agricultural practices focusing on small-scale cassava production systems. These systems also include groundnuts and mixed beans as integral components, which complement cassava from agronomic and food security perspectives (FAO, 2013).

This IA study is an *ex-post* study (i.e. data are collected at the end of the intervention) based on a non-experimental sample design that covers 198 communities and 2,052 households (both beneficiaries and non-beneficiaries). Household and community surveys were implemented in

October-November 2020 collecting detailed livelihood data for the 2019/2020 agricultural season. We apply two stages of Propensity Score Matching (PSM) at the community and the household levels by using a set of observable characteristics that might have affected selection into the Programme. This method allows to construct a valid counterfactual, which ensures that the non-beneficiary households (control group) are a good representation of what the beneficiary households (treated group) would have been like had they not received the S3P interventions. We estimate the impact attributable to S3P (Average Treatment Effects on Treated, ATET) using Inverse Probability Weighted Regression Adjustment (IPWRA), and conduct robustness checks using Nearest-Neighbour Matching (NNM). Both of these models are standard for estimating the impact of programmes attributable to the specific interventions isolated from all other factors that might affect outcomes.[7]

The remainder of the IA study is structured as follows: we present in Section 2 the Theory of Change of S3P's pathways and the main strand of current literature in the respective topics. In section 3 we describe the sampling framework, dataset and methodologies to estimate impact. We show the main characteristics of the sampled communities and households in Section 4 and discuss the results of the IPWRA in Section 5. We conclude the study in Section 6 by highlighting lessons learned and recommendations for future policy and programme design.

[7] This aspect underlines the difference between contribution and attribution analysis. While the former is the mere contribution of the Programme to the overall change, the latter is the change attributable to the Programme isolated from all other factors that might affect outcomes.

2. Theory of change and main research questions

The Theory of Change (ToC) maps the inputs and activities, outputs, outcomes and expected impacts, highlighting the casual interlinkages within and across each stage and the assumptions required for the pathways to function. The ToC describes how the programme was implemented (inputs and activities), how the interventions were expected to realize the foreseen impact through the outputs and outcomes, and which conditions needed to be in place to provide the ground for the programme impact to unfold (White, 2009). Below we first present the ToC of the S3P and then, we describe the coverage areas, target population, targeting and implementation strategies. Finally, we outline the research questions and how this study answers them.

2.1. S3P Theory of change

The S3P aimed to increase incomes, food and nutrition security of small-scale farmers by boosting agricultural production, productivity and sales. In pursuing this objective, environmental sustainability was an integrating element throughout the Programme. As a result, it was expected that beneficiary households achieved increased income, asset ownership, agricultural production and productivity, integration into agricultural markets, resilience to face climate shocks and food and nutrition security. We present the pathways through which these impacts were expected to take place in the ToC in Figure 1.

The Programme operated at producer and farmer organization levels. At the producer level, beneficiary households received extension services, which promoted the adoption of good agricultural practices and improved planting materials. At the farmer organization level, the S3P identified farmer organizations as entry points for its activities by strengthening the existent organizations or encouraging the formation of new ones.[8]

a) Producer level

Extension services were provided through Farmer Field Schools (FFS), which is a common approach in agriculture (Braun and Duveskog, 2008). FFSs has proven to be a useful approach to increase productivity, adoption of new technologies, agricultural knowledge, food security and income (e.g. Maertens et al., 2021; Larsen and Lilleør, 2014; Davis et al., 2012; Friis-Hansen and Duveskog, 2012; Van den Berg and Jiggins, 2007). In the context of the S3P, FFSs were implemented through a public-private partnership between a public service provider (MoA), and two private service providers (Community Markets for Conservation, COMACO; Total Land Care, TLC). The camp extension officers and lead farmers were initially trained through the training of trainers, who in turn trained other farmers. Especially, lead farmers ensured that extension services were provided consistently as they stayed in the communities.[9]

The FFSs addressed a variety of topics depending on farmers' needs. However, the most important topics were minimum tillage, retention of crop residues, crop rotation and intercropping, which constitute the components of conservation agriculture (CA), improved planting varieties,[10]

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[8] The S3P collaborated with all types of farmer organizations such as producer groups, associations, cooperatives or informal associations. Farmers who were not members of such groups was encouraged to join such organizations. The S3P also encouraged the membership of women, youth and vulnerable households.

[9] The S3P conducted three training sessions at provincial level (106 beneficiaries of which 20 per cent are women), 24 training sessions at district level (233 beneficiaries of which 24 per cent are women) and trained 234 lead farmers (23 per cent are women). These were the trainers of the training, which conducted training through 2,351 FFSs (IFAD, 2021).

[10] In addition to the dissemination of improved planting material, the S3P also promoted localised seed multiplication of cassava, beans, groudnuts and rice varities, which included maintenance of breeding seed and production of foundation seed by Zambia Agricultural Research Institute, and production of certified seed by small-scale farmers. To support the seed multplication chain, the Programme funded the construction of a seed testing laboratory in Luapula province (IFAD, 2021).

agroforestry with the use of Grilicidia Sepium, and organic farming (including composting and decreased use of chemicals). The S3P also promoted nutrition education courses, through which it trained lead mothers or lead fathers in selected communities to convey nutrition information to other community members. In addition to FFSs, the Programme realised 4,350 demonstration plots to promote various agricultural practices, radio broadcasting to deliver extension and agribusiness messages in some areas,[11] and several small investments to improve the capacity of field offices to provide extension services to farmers.[12]

The CA is the most relevant agricultural practice for the Programme and it consists of the combination of minimum soil disturbance (zero or reduced tillage), crop rotations and/or intercropping, and permanent soil cover through crop residue retention and/or growing cover crops (Haggblade and Tembo, 2003). Since the early 90s, several national and international organizations have promoted in Zambia CA to reverse the decline in soil fertility and crop productivity. Therefore, there is a vast literature, mainly agronomic studies, that demonstrates the effects of CA in increasing crop yields and climate resilience through improved soil fertility and water holding capacity (Thierfelder et al., 2018; 2017; 2013a; 2013b; 2013c; 2012; Kuntashula et al., 2014; Ndlovu et al., 2014; Thierfelder and Wall, 2010). However, the adoption and dis-adoption rates among Zambian farmers draw a mixed picture on the success of CA for small-scale farmers under uncontrolled environments (Ngoma et al., 2016; Andersson and D'Souza, 2014; Arslan et al., 2014).

CA implementation involves extra costs (e.g. for the cover crop seeds, sprayers and herbicides), a different allocation of resources (e.g. crop residue cannot be feed to livestock any longer or used as fuel) and increased labour requirements (for reduced tillage using hand planters instead of tractor/animal drawn ploughs) for land preparation and weeding (the latter when herbicide cannot be purchased as is common for small-scale farmers) (Giller et al., 2009). Furthermore, the positive effects of CA start realizing after around four years (Blanco and Lal, 2008; Hobbs et al., 2008), which makes the adoption of these techniques a risky option in subsistence based systems subject to credit and insurance constraints. Farmers are shown to be most likely to continue with CA if it is linked to agricultural subsides, because of the long-time they have to bridge before benefits materialize (Bell et al., 2018; Ward et al., 2018; Marenya and Barrett, 2007). Otherwise only some of the components are applied over time, without providing the benefits of adopting the full package (Arslan et al., 2014). Finally, the adoption of CA is also influenced by socio-economic aspects such as level of education, access to information through social networks, extension services or farmer organizations, access to credit, distance to markets, access or ownership of productive assets, labour cost for land preparation, soil quality and farm size (Abdulai et al., 2021; Ngoma et al., 2021; Kalinda et al., 2017; Abdulai, 2016; Manda et al., 2016; Arslan et al., 2014). This study controls for all these factors to estimate the S3P impacts.

Another important activity implemented during the FFSs was the promotion of the use of improved planting material, which has a positive impact on cropping production and is associated with a higher level of crop incomes, consumption expenditure and food security (Khonje et al. 2015). For instance, two studies in Eastern Zambia found that farmers adopting hybrid maize show a higher dietary diversity (Smale et al. 2015) and adoption of improved groundnut varieties has a positive impact on crop yields and incomes (Manda et al., 2017). However, the adoption of improved varieties in Zambia remains low and is conditioned by the educational level, membership of farmer organizations, access to extension advice and market information, ownership of productive assets and overall household wealth (Khonje et al., 2015; Langyntuo and Mungoma 2008).

[11] This activitiy was specifically implemented by COMACO in its area of intervetion (IFAD, 2021).

[12] The Programme financed the rehabilitation of 23 agricultural camp houses, and the purchase of 13 motor vehicles, three boats and 88 motorcycles (IFAD, 2021).

The combination of adopting good agricultural practices and improved varieties was expected to increase both production and productivity (Khonjie et al., 2018; Abdulai and Abdulai, 2017; Manda et al., 2017; Abdulai, 2016; Khonje et al., 2015; Manda et al., 2016). At the same time, the adoption of good agricultural practices (Alfani et al., 2021; Komarek et al., 2021; Maggio et al., 2021; Arslan et al., 2015), as well as crop diversification, (Asfaw et al., 2019; Maggio and Sitko, 2019; Arslan et al., 2018) was expected to make small-scale farmers more resilient to climate shocks.

b) Farmer organization level

The S3P targeted farmer organizations to improve and diversify the services provided to members and communities including technical advice and marketing services. The Programme strengthened the capacity building of farmer organizations by providing training on management, entrepreneurship and leadership skills.[13] Training courses were delivered to a selected number of members at the district level, which in turn trained the other members of the organization.[14] Farmers were expected to improve entrepreneurship and business understanding to enable them to assess more remunerative markets, improve sale prices and volumes to respond to market and agricultural demand. These expectations are based on existing evidence indicating that participating in farmer organisations increases access to information and bargaining power, which lead to higher market integration and revenues (Shiferaw et al., 2011; Markelova et al., 2009; Barrett, 2010). In turn, market access generally has a positive effect on food and nutrition security, as well as on agricultural production and diversification (Nandi and Ravula 2021; Mulenga et al., 2021; Ogutu et al., 2020; Sibhatu et al., 2015).

Another important pathway in increasing commercial opportunities was the synergies established between the S3P and the IFAD-financed programme of Smallholder Agribusiness Promotion Programme (SAPP).[15] SAPP was implemented throughout the country during 2009/2017 and focused on developing market-oriented agriculture through the provision of training, investment in storage, processing and marketing facilities. The S3P implemented a farming systems approach with a clear linkage to the markets and post-production stages addressed in SAPP. The rationale of this market linkage was that S3P provided a supply push to complement the market pull investments of SAPP.[16] We control for this factor in the estimation of the S3P impacts.

In addition to the benefits from market access, farmer organization members are also more likely to adopt new technologies (Wossen et al., 2017; Abebaw and Haile, 2013; Fischer and Qaim, 2012). Therefore, through the support to farmer organizations, S3P was expected to reinforce the impact pathways at the producer level in the adoption of good agricultural practices and improved varieties. Furthermore, farmer organizations positively affect household wealth and agricultural production (Bachke, 2019; Mutonyi, 2019; Abdul-Rahaman and Abdulai, 2018; Verhofstadt and Maertens, 2015).

Finally, the S3P provided matching grants to finance investments in improving rural infrastructures such as local roads to connect farmers to main road networks, rehabilitation of farmer training

[13] Training modules were: group formation and dynamics, business leadership, business operations and management, IT systems, business financial planning and management, product quality control and value addition, and project cycle and contract management (IFAD, 2021).

[14] By the end of the Programme, 2,455 (780 women) members of organizations were trained out of a target of 20,000 members. In addition, 25,520 (11,056 women) farmers were involved in farmer organizations. A total of 12 farmer organizations at district level and 497 farmer organizations at sub-district level were supported (IFAD, 2021).

[15] In the last years of the S3P another IFAD-funded programme (Enhanced Smallholder Agribusiness Promotion Programme - E-SAPP) operated in the area as a follow-up to SAPP.

[16] The objective was that each programme strengthened the other and enhanced the probability to achieve the overall objective. Although the two Programmes were managed by two different teams, they ensured that the Programmes remained coordinated and mutually supportive (IFAD, 2021).

centres, construction of small-scale storage and water management structures.[17] These investments also financed farmer organizations to acquire productive assets such as hammer mills, hand tractors and four-wheel tractors.[18] However, the limited number of realisations carried out may have limited its impact.

c) Assumptions

A number of assumptions need to be in place so that the above-mentioned pathways were able to facilitate overall impacts. Resources needed to be devoted to building the institutional and development capacities of farmer organizations so that they were able to effectively provide a wide range of production and marketing information to their members. The assumption includes the fact that there was sufficient demand for training and that the trained members were willing to share their knowledge with other members of the organization. This assumes that farmers were willing to participate actively in farmer organizations and contribute to the life of the organizations by improving their functioning.

Regarding the introduction of improved varieties, the assumption is that farmers were facing challenges in acquiring improved planting material and that the characteristics of the new varieties were appropriate to the local context and physically and economically accessible to farmers. Similarly, in the case of good agricultural practices, the assumption is that farmers faced challenges with the current techniques and crop production could benefit from such agricultural methods sustainably optimising the use of available natural resources.

Additionally, the training provided had to reflect farmers' demand to ensure that newly acquired information is used and technologies adopted. Farmers should have access to inputs and information when needed to implement the acquired techniques. The innovations should not have been at the cost of the desired features of the currently adopted technology (e.g. low labour requirement, weed control). The adoption of the innovations depended on the participation of the farmers and the procurement of production-related infrastructure through the matching grant, as well as the financial contribution of the members.

Finally, agricultural productivity and incomes depend on the availability of inputs, access to markets and credit, as well as natural factors (e.g. weather and soil quality). Therefore, one of the main assumptions is that beneficiary households did not suffer from major alterations in these factors. Furthermore, these changes required the willingness to shift from traditional techniques or long-established cropping methods to new varieties and methods.

[17] The S3P financed the rehabilitation of 28 kilometres of road from Luwingu to Chimpili and three farmer training centres (Mbala, Samfya and Isoka districts), and the construction of 15 storage sheds, 6 bridges and 8 permanent weirs (IFAD, 2021).

[18] The S3P financed 5 farmer coopertives to purchase 2 hammer mills and 3 hand tractors. These investments were below the target of 33 investements at group level because beneficiaries were not able to provide the 50 per cent cash contribution of the matching grant (IFAD, 2021).

Figure 1: Theory of change of the S3P.

INPUTS AND ACTIVITIES

Producer level

Capacity Building:

- Establishment producer groups.
- Training in agricultural practices.
- Demonstrations in food processing, preparation and utilisation.
- Distribution of nutrient dense varieties.

Extension Services:

- Enhanced access to improved technologies e.g. planting material and post-harvest techniques.
- Training related to agricultural extension, cassava and beans production.

Farmer organization level

Support to farmer organizations:

- Leadership and entrepreneurship training.
- Management support.
- Collective marketing.
- Matching grants for infrastructure as roads, water management structures, drying floors.

OUTPUTS

Producer level

- Entrepreneurship and business understanding strengthen.
- Adoption of good agricultural practices (e.g. CA).
- Access to and use of technologies and services to grow and utilize best food crops.
- Adoption of improved nutrient-dense crop varieties.
- Improve access planting material and equipment.
- Improve access, quality and sustainability of advisory services.

Farmer organization level

- Improved farmer organization governance.
- Increased access to information.
- Increased access to markets and financial services.

OUTCOMES

Producer level

- Increased yields.
- Decrease in labour.
- Decrease in costs.
- Increase in diversification of crops.
- Improved access to inputs.
- Improved outreach to farmers.

Farmer organization level

- Increased access to markets.
- Improved bargaining power (sales and prices).
- Improved services to farmer organization members.
- Decreased post-harvest losses.
- Increased business and financial opportunities.

IMPACTS

- Increase in crop production and productivity.
- Increased household-level asset ownership and savings.
- Improved food and nutrition security (reduce the prevalence of child malnutrition).
- Improved resilience of farmers to climatic variations affecting production and/or market access.

ASSUMPTION

- Farmers are willing to form farmer organizations.
- There is room to improve group and organization.
- There is sufficient demand for training.
- There is demand for improved technologies.
- There is sufficient support for the establishment of infrastructure measures.

- Improved technologies are available and appropriate
- Training reflects farmers needs.
- Farmers adopt the technologies and equipment.
- Farmer organization members participate and diffuse the notions learned in the training.

Producer level

- Markets for inputs and output are in place and functional.
- Producers face no other barriers to improving productivity such as weather conditions, soil quality, capital, etc..
- Willingness to change the traditional expectations towards gender roles.

Farmer organization level

- Reasonable support by national and local government.
- Ability to access more profitable markets.
- Women can access leadership roles.

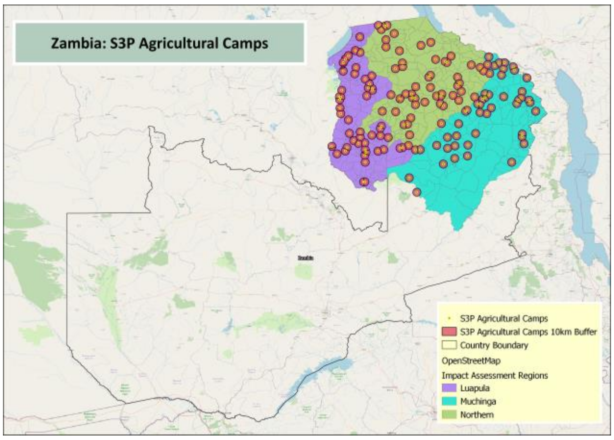
Source: Authors' revision for clarity of the ToC presented in Arslan et al. (2020).

2.2. Project coverage and targeting

The S3P was implemented in the north-eastern provinces of Luapula, Muchinga and Northern,[19] which account for 21 per cent of the total population (CSO, 2010). The Programme targeted 150 agricultural camps in 28 districts of the selected provinces accounting for about 85 per cent of the total number of districts. The agricultural camps were equally distributed among the provinces, though the S3P did not start at the same time in all camps and followed a phased implementation strategy. Initially, eight districts in Luapula and Northern provinces were targeted, then, other eight districts within the same provinces were included and finally, the remaining districts in Luapula and Northern along with the province of Muchinga joined the Programme.[20] Figure 2 shows the distribution of beneficiary agricultural camps in three provinces.

Each agricultural camp includes on average approximately 1,000 small-scale farm households and the S3P sought to reach around 20-40 per cent of them in each agricultural camp with at least half of the beneficiaries being female. Targeting criteria were: having a cultivated area of no more than five ha and being organized in agricultural associations or willing to do so. These farmers were characterised by scarce resources, poor livelihoods and extreme poverty. They were expected to be constrained by poor market access and weak bargaining power, but to have the potential to transform their farming systems into market-oriented production. The S3P reached 56,708 small-scale farm households by the end of its activities.

Figure 2: Implementation area of the S3P.



The targeting strategy within the agricultural camps followed an inclusive principle, determined by the farmers' potential and willingness to participate. To deliver extension services, S3P used a public-private partnership strategy between MoA (public provider) and COMACO and TLC (private providers), which is considered an innovative approach in Zambia as it was the first time that a programme under MoA used this approach. The Programme Completion Report (PCR) (IFAD, 2021) states that as a result of this public-private partnership, the Programme reached a higher number of beneficiaries. Each implementing partner operated in one of the 150 agricultural camps, of which 60 per cent was supported by MoA, 17 per cent by COMACO and 23 per cent by TLC. While MoA operated in all three provinces, TLC operated in Luapula and Northern provinces and COMACO in Muchinga province. The Programme developed harmonised guidelines and approaches to improve the collaboration between the three implementing partners.

The crops targeted by the S3P were cassava, groundnut, beans, rice and nutrient-dense crops such as orange-fleshed sweet potatoes, orange maize, bean varieties rich in zinc and iron, and soybeans. Among them, cassava, groundnuts and mixed beans were the main crops supported by the Programme, as, following maize, they are the main crops in the targeted area. Rice was also included in limited areas to support crop diversification and in response to market opportunities.[21] Following the mid-term review of the Programme, support for nutrient-dense crops was included to increase the impacts on nutrition.

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[19] The province of Muchinga was officially created in 2011, which was after the S3P was designed. Its land area used to be part of the Northern province with the exception of Chama district, which was part of the Eastern province.

[20] The objective was to develop lessons of experience and use them to guide implementation (IFAD, 2021).

[21] The S3P implemented trials of System for Rice Intensification (IFAD, 2021).

2.3. Research questions

The primary objective of this IA study is to report on the Tier II development impact indicators as defined in IFAD's Results Management Framework. These are the Economic goal (EG) of increasing incomes and the three Strategic Objectives (SO) of improving productive capacities (SO1), market access (SO2) and strengthening environmental sustainability and climate resilience (SO3); as well as the mainstreaming themes (MTs) of food and nutrition security, and women's empowerment. We present the list of research questions related to each of these indicators in Table 1.

We assess each strategic objective by analysing a number of aspects, which are linked to the intended S3P impacts and impact pathways outlined in the ToC. The EG assesses the impact of S3P on economic mobility as measured by household income and asset ownership. The SO1 includes all indicators related to increasing agricultural production and productivity, such as the value of agricultural production and agricultural yields, as well as the adoption of good agricultural practices and improved planting materials as pathways. In particular, the S3P aspired to increase the crop yields and quantities produced by 30 and 20 per cent, respectively. The SO2 indicators include the probability of selling agricultural products in the market, the share of crops sold over the production and revenues from crop sales. The SO3 assess the ability to recover from climatic and non-climatic shocks and factors that can increase household resilience, such as income and crop diversification. Specifically, the S3P aspired to reduce the vulnerability of small-scale farmers' crop production to climatic variability. For the mainstreaming themes, we measure the food and nutrition security using the standard indices recognized in the literature. Finally, women's empowerment is assessed by women's contribution to and control over household income and asset ownership. We report the full list of indicators in Section 3.2.

Table 1: Matrix of research questions and IFAD's goal, strategic objectives (SOs) and mainstreaming themes (MTs).

Research questions	EG	SO1	SO2	SO3	MT
Has the S3P increased household-level asset ownership and income?	X				
Has the S3P increased the adoption of good agricultural practices and improved planting materials?		X		X	
Has S3P increased the production and productivity of the targeted crops?		X			
Has S3P increased market participation and crop revenues?			X		
Has S3P increased household resilience?				X	
Has S3P improved the food and nutrition security?					X
Has S3P increased women's empowerment (i.e. contribution to and control over income and asset ownership)?					X

Note: EG: Economic Goal; SO1: Productive capacities; SO2: Market access; SO3 Resilience; MT: Food and nutrition security: and Women's empowerment. Source: Authors' elaboration.

3. Impact assessment design: Data and methodology

3.1. Sample design

This study applies the RIA standard approach to IA and employs a multi-stage sampling strategy using both available secondary data and survey data. First, we have restricted the study area to the three provinces selected by the Programme. This allows limiting the sample to the highest administrative unit ensuring comparability of environmental and institutional backgrounds of households in the sample. Second, we have identified treated and control communities using the PSM technique (Rosenbaum and Rubin, 1983), and eventually identified matched pairs of treated and control households using the same technique. These two stages of PSM allow to construct a robust counterfactual to overcome the non-random assignment of the programme by creating a comparison group (i.e. control group) that has a very similar probability of being selected by the programme based on observable characteristics at both the community and household levels (Dehejia and Wahba, 1999). At each stage of PSM, we estimate a propensity score, which represents the probability that communities or households receive the treatment conditional on observable characteristics. Formally:

$$p(X) \equiv \Pr(t = 1|X) = E(t|X) \quad (1)$$

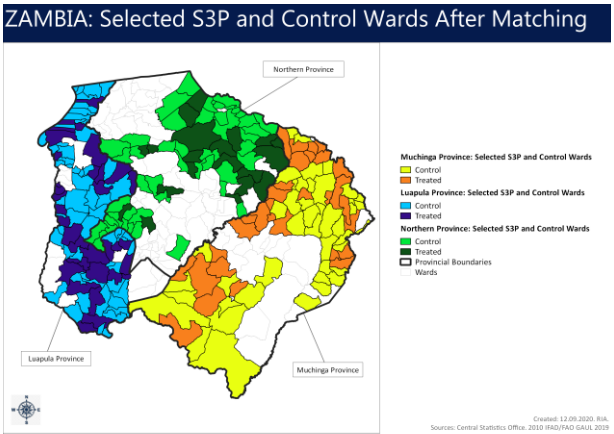
Where $p(X)$ is the estimated propensity score, t is the treatment indicator, which equals one if the community or household is treated and zero otherwise, X is a matrix of observable characteristics. The propensity score is predicted using the maximum likelihood estimation of the probit model, where the dependent variable is the treatment status and the independent variables are the relevant matching characteristics (Caliendo and Kopeinig, 2008). The treated and untreated communities/households are matched using the nearest neighbour with caliper width, which is set at 0.2 times the standard deviation of the estimated predicted probability (Austin, 2009, 2011). The sample is finally trimmed to the common support by excluding communities/households with no match (Heckman et al., 1998). Treated communities/households with a propensity score greater than the maximum propensity score of the untreated communities/households are removed. Similarly, untreated communities/households with a propensity score less than the minimum propensity score of treated communities/households are also removed from the sample to increase comparability.

a) Treated and control communities

The sample is designed to be representative of the 150 agricultural camps benefiting from the S3P. As they are almost equally distributed among the three targeted provinces and no stratification strategy has been used in the selection, the number of agricultural camps selected for the IA study is equally distributed among the three provinces without stratification. Since there is no secondary data available to be used in PSM at the agricultural camp level, we use the administrative unit called "ward" (Agricultural Census data contain ward level information) to create a sample of treated and control communities. Note that the geographical boundaries of agricultural camps do not correspond exactly to those of wards. An agricultural camp may cross ward boundaries, and a ward may include more than one agricultural camp. Therefore, to identify the treated and untreated wards, we mapped the treated camps to the wards using official ward boundaries provided by the MoA. For each of the treated agricultural camps, we obtained GPS coordinates from the PMU and constructed a buffer zone of 10 kilometres around the centroid point (GPS coordinates). When at least 60 per cent of a ward's area overlaps with the area of a treated camp, the ward is classified as "treated". Wards that are located beyond the buffer area of 10 kilometres from the nearest beneficiary agricultural camp are classified as "control." Finally, using the PSM technique, treated and untreated wards are matched based on ward-level data from the 2010 national census (CSO, 2010) and geospatial data.[22]

The number of control wards is higher than the number of treated wards in the matched sample (140 control versus 102 treated). To ensure an equal number of treated and control wards, 102 control wards are randomly selected from the 140 matched control wards. Figure 3 shows the treated and control wards selected for the final sample. Successively, we randomly selected a treated agricultural camp in each treated ward and a Standard Enumeration Area (SEA)[23] in each control ward. Two villages are randomly selected within each camp/SEA, and treated households are randomly selected using the list of beneficiaries provided by the S3P, while control households are randomly selected after listing all households in each control village (around five households per village were interviewed).

Figure 3: Geographic distribution of treated and control wards after matching.



b) Treated and control households

The sample size for the household survey is calculated using the standard statistical power calculations based on data from the 2012 Rural Agricultural Livelihood Survey (RALS) (See Arslan et al., 2020 for the details of the sample size calculations). In total, 2,052 households have been interviewed almost equally divided between treated and control groups. Once the data have been cleaned and outliers removed,[24] we matched beneficiary and non-beneficiary households using PSM using data on observable characteristics before the implementation of the S3P.[25] The matching variables include household composition, household head characteristics, household wealth, short- and long-run climate characteristics, population density in the area, and community characteristics (Appendix I provides the full list of matching variables). Matching diagnostics in Appendix I indicate that treated and control households are well balanced after the matching. The remaining differences between control and treatment households are not statistically significant and the standardised mean differences are always less than 0.1 as recommended by Austin (2009).[26]

3.2. Questionnaire and impact indicators

Data at the community and household levels have been collected using Computer Assisted Personal Interviews (CAPI) through Survey Solutions software.[27] Data collection has been carried out by

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[22] National census data include the following ward level variables: average household characteristics, average household ownership (goods and housing characteristics), percentegate of households that grow cassava, beans and groudnunuts, and percentage of households accessing to electricity and drinking water. Geospatial data include long-run averages of rainfall and temperature, and population density at the ward level. For more details on the PSM of treated and control communities see Arslan et al. (2020).

[23] The list of SEA and corresponding villages has been provided the Zambia Statistical Agency in collaboration with IAPRI.

[24] The survey has collected 198 community questionnaires (103 treated and 95 control wards) and 2,052 household questionnaires (1,055 treated and 997 control households). After removing outlier observations and trimming the top and bottom one per cent of the gross income distribution, the final unmatched sample consists of 1,999 households divided between 1,054 treated households and 945 control households.

[25] Treated and control households are matched using 3 nearest neighbours with caliper width of 0.04.

[26] Although, the matching method cannot take into account unobserved characteristics that might affect programme participation (e.g. behavioural attitudes such as risk aversion, learning ability, or willingness to apply new technologies), to the extent that observed variables used act as proxies of such characteristics, their effect is minimal.

[27] Fieldwork activities were allowed in the country in line with government regulations to prevent the spread of COVID-19 and all the necessary measures have been taken by field teams during the data collection.

IAPRI[28] between October and November 2020[29] with eight teams of five enumerators, each coordinated by a supervisor. The reference period of both surveys is the previous 12 months (i.e. from October 2019 to September 2020), which overlap perfectly with the cropping season in the country.

The community survey covers a range of topics to capture the availability of infrastructure and public services, prices of key products and wages in the area. It has been administered to a group of respondents based on their leadership role in the community.[30] The household survey includes questions on household demographic characteristics, income-generating activities, food consumption, housing quality and asset ownership before and after the interventions, access to credit and financial inclusion, extension and training services received, participation in group association and exposure to shocks. The section on agricultural production is extensively expanded to take into account S3P-related aspects such as farming practices and use of inputs (including planting material). Given the timing of the surveys, specific questions related to the COVID-19 outbreak have been added to the questionnaire. The main set of impact indicators to answer the research questions listed above are constructed using the household data. Table 2 shows the full list of impact indicators and their descriptions. All impact indicators represent annual values per household, unless otherwise indicated, and refer to the 2019/2020 agricultural season.

Table 2: Description of outcome and impact indicators.

Indicator	Description
Economic Goal (EG)	
Total gross income per capita	The total gross income is based on the method developed by the team of Rural Income Generating Activities (RIGA) project, which aggregates the value of production and cash income to make rural household incomes comparable across countries. The sources of income are crop, livestock and fisheries production, self-employment activities, agricultural and non-agricultural wage employment, transfers (private and public) and other income sources (Davis et al., 2010; Carletto et al., 2007). The total is divided by the number of household members to obtain per capita values.
Cropping gross income per capita	The cropping gross income includes the value of crop production minus the value of losses and processed crops (Davis et al., 2010; Carletto et al., 2007).
Durable assets index	Index of durable assets calculated using Principal Component Analysis (PCA) and normalized from 0 to 1. Durable assets include the number of owned cell phones, radio, bicycles, solar panels, pickups/van/cars/trucks/ lorries, car batteries, TV, boats/canoe, sewing machine, motorcycle and generator (Smits and Steendijk, 2015; Kolenikov and Angeles, 2009; Booysen et al., 2008; Filmer and Pritchett, 2001).

[28] IAPRI is a research institute based in Zambia, which has strong experience in collecting data in the country and the region. https://www.iapri.org.zm/

[29] The entire process, from data collection to data analysis, lasted from October 2020 to July 2021, namely data collection between October and November 2020; data cleaning between December 2020 and February 2021; data cleaning and processing between March and April 2021 and analysis between May and July 2021.

[30] Eligible respondents were Headman/Woman (18 per cent of respondents), Community leaders (28 per cent of respondents), Cooperative/farmers secretary (14 per cent of respondents), Cooperative/farmers chair person (13 per cent of respondents), Village secretary (9 per cent of respondents), Head teacher/teachers (3 per cent of respondents), Pastor/Bishop (2 per cent of respondents), Councilor (6 per cent of respondents), Ward chairman (5 per cent of respondents), Cooperative leaders (5 per cent of respondents), Youth leader (4 per cent of respondents), Lead farmer (3 per cent of respondents), Camp officier (4 per cent of respondents), DACO (less than 1 per cent of respondents), Health officers (1 per cent of respondents) and Parent teachers association chiarman/woman (1 per cent of respondents).

Indicator	Description
Productive assets index	Index of durable assets calculated using PCA and normalized from 0 to 1. Productive assets include the number of owned trained oxen/cows, ox-drawn plough, wheel barrow, hammer mill, knapsack sprayer (Smits and Steendijk, 2015; Kolenikov and Angeles, 2009; Booysen et al., 2008; Filmer and Pritchett, 2001).
Housing assets index	Index of housing characteristics quality using Multiple Correspondence Analysis (MCA) and normalized from 0 to 1. Housing characteristics include the quality of walls, roof, floor, toilet facility, lighting, cooking fuel, source of drinking water and number of rooms (Smits and Steendijk, 2015; Kolenikov and Angeles, 2009; Booysen et al., 2008; Filmer and Pritchett, 2001).
Tropical Livestock Unit (TLU) index	Index of livestock ownership created by multiplying the number of animals in each category by internationally comparable tropical livestock unit coefficients (FAO, 2011)
Productive capacities (SO1)	
Total value of crop production	The total value of the harvested quantity of each cultivated crop (valued at the market price). Per hectare value is obtained by dividing this value by the total hectares of harvested land.
Quantity harvested and crop yield.	Total kilogrammes harvested for the main crops (i.e. cassava, groundnut, mixed beans and maize). The yield for each are obtained by dividing total harvest by harvested area.
Adoption of agricultural practices	A set of indicators capturing whether or not the farmer has used a certain practice in the 2019/2020 agricultural season (the variable assumes the value of one if the farmer has practiced it and zero otherwise). The agricultural practices assessed are zero tillage, minimum tillage (zero tillage, planting basins and ripping), soil cover (growing cover crops or leaving crop residues), crop rotation (with and without legumes), fallowing, agro-forestry and erosion control.
Use of improved planting material	A set of indicators capturing whether or not the farmer has used improved planting materials in the 2019/2020 agricultural season (the variable assumes the value of one if the farmer has practiced it and zero otherwise). The improved planting materials (i.e. improved, hybrid and recycled) are considered for all crops and separated for maize, cassava, groundnut and mixed beans.
Market access (SO2)	
Crop sales	A set of indicators capturing whether or not the farmer has sold any crops in the 2019/2020 agricultural season. Also calculated separately for cassava, groundnut, mixed beans and maize.
Share of sales value	A set of indicators capturing the share of sales value in the total value of all crops produced in the 2019/2020 agricultural season. Also calculated separately for cassava, groundnut, mixed beans and maize.
Revenues from sales	A set of indicators capturing the total revenues from sales of all crops in the 2019/2020 agricultural season. Also calculated for cassava, groundnut, mixed beans and maize.
Participation in farmer groups	A variable that assumes the value of one (or zero otherwise) if any person within the household is a member of a farmer organization.
Resilience (SO3)	
Income diversification	Gini-Simpson Index of income diversification (from 0 no diversification to 1 full diversification). $GSI = 1 - \sum a_i^2$ where a_i is the gross income share from the ith income source.

Indicator	Description
Crop diversification	Gini-Simpson Index of crop diversification (from 0 no diversification to 1 full diversification). $GSI = 1 - \sum a_i^2$ where a_i is the land share from the ith cultivated crop.
Recovery from shocks	Self-reported ability to recover (to the same level or better off) from the most severe climate and non-climate shocks during the programme implementation (in the past six years). Ability to recover from climate and non-climate shocks during the last year corrected by RIA method.
Food and nutrition security (MT)	
Food security	Food Insecurity Experience Scale (FIES): A 0-8 scale index (from 0 full food secure to 8 full food insecure) based on eight questions regarding food insecurity, also adopted by SDGs (2.1.2) (Cafiero et al., 2018; Ballard et al., 2013). Months of Adequate Household Food Provisioning (MAHFP): A 0-12 scale index (from 0 full food insecure to 12 full food secure) based on the number of months during which the household has an adequate food provisioning (Bilinsky and Swindale, 2010). Food Consumption Score (FCS): index score based on dietary diversity, food frequency and relative nutritional importance of good groups consumed in the past week (WFP, 2008).
Dietary diversity	Household Dietary Diversity Score (HDDS): A 0-12 scale index (from 0 low dietary diversity to 12 high dietary diversity) based on the consumption of 12 food groups in the past week (FAO, 2010; Swindale and Bilinsky, 2006).
Women's empowerment (MT)	
Female control of household income	Probabiltiy of women working in wage employment. Probability of women controlling at least one source of household income (alone or jointly with men) Probability of women controlling revenues from crop sales for at least one crop (alone or jointly with men)
Female asset ownership	A set of indicators capturing whether or not, women within the households own (alone or jointly with men) a given asset. The assets considered are land, livestock, durable assets and productive assets.
Female participation in farmer organizations	Probability of women being a member of a farmer organization (alone or jointly with men)

Source: Authors' elaboration.

3.3 Impact estimation

We estimate the impact attributable to the S3P using non-experimental ex-post methodologies. The main challenge of this type of design is that we cannot observe what would have happened to households if they had not participated in the programme, nor what would have happened to those who did not participate if they had participated. Both beneficiary and non-beneficiary households are only observed at the end of the programme. In such cases, the literature has widely acknowledged the potential outcome framework (Rubin, 1974) by estimating the Average Treatment Effect on the

Treated (ATET) as a cornerstone method (Imbens and Wooldrige, 2009). ATET is formally defined as:

$$ATET = E(y_1 - y_0|t = 1) \quad (2)$$

Where E is the expectation operator, y is the outcome variable that would be obtained if the household is treated (y_1) or not treated (y_0) conditional on $t = 1$, which is the treatment exposure indicator. We estimate ATET using the Inverse-Probability-Weighted Regression Adjustment (IPWRA) model, and conduct robustness checks using Nearest-Neighbour Matching (NNM) model.[31]

The IPWRA is a doubly robust estimation approach that models both the outcome and selection equations (Wooldridge, 2007, 2010). Although there is no indisputable way in the literature to select one of the estimation models, doubly robust estimators are the most consistent in representing both selection and outcome equations (Imbens and Wooldridge, 2009). The IPWRA uses the inverse-probability weights (IPW) from the estimation of the predicted probability of receiving treatment to account for the missing data problem arising from the fact that each household is only observed in one of the potential outcomes (Hirano et al., 2003). In the case of ATET, the IPW is computed as follows:

$$IPW_{ATET} = t + \frac{p(X)(1-t)}{1-p(X)} \quad (3)$$

Where t and $p(X)$ are defined as in equation (1). All treatment households are assigned a weight of one, while control households are weighted by the inverse of this score, meaning that households that are more similar to a treatment household are assigned a higher weight. Using the computed IPW, a weighted regression model is then used to estimate the predicted value of the outcome for the treatment and the control group. The regression model is specified as follows:

$$y_i = \alpha + \beta t_i + \gamma X_i + \delta(X_i - E[X_i|t_i = 1)t_i + \varepsilon_i \quad (4)$$

Where y_i is the outcome for household i, t_i is the treatment status for household i, X_i is the matrix of control variables, X1bar is their average values for the treated sample and γ and sigma are the respective vector of coefficients to be estimated, β is the coefficient of the treatment indicator, α is the constant and ε_i is the error term. The model is estimated using ordinary least squares and standard errors are clustered at the ward level. The control variables in the matrix X_i are factors that are expected to influence the outcome variable, while not having been affected by the programme. The full list of variables in the selection and outcome equations are presented in Appendix II. The ATET is then calculated as the difference between the predicted values for the treatment and control groups, as follows:

$$ATET = \hat{y}_1 - \hat{y}_0 \quad (5)$$

Where $\hat{y}_1$ is the average expected outcome for the treatment households, and $\hat{y}_0$ is the average expected outcome for control households obtained from Equation 4.

[31] NNM results are available upon request.

4. Profile of the project area and sample

4.1 Selected characteristics of sample communities

The community survey includes data from 197 wards, corresponding to 184 agricultural camps in 26 districts of the three provinces, divided between 52 per cent treated and 48 per cent control wards. Overall, Luapula, Muchinga and Northern provinces account for 28.7 per cent of country's area (CSO, 2010), and are mainly located in Agro-Ecological Region (AER) III, which is characterised by an average annual rainfall exceeding 1,000 millimetres and a cropping season that varies from 120 to 150 days. The southern parts of Mpika and Chama districts in Muchinga are in AER IIb, which is characterised by an average annual rainfall between 800 and 1,000 millimetres and the cropping season varies from 120 to 160 days. The soil quality in the sampled areas is generally favourable for agriculture and the main crops are maize, cassava, beans, rice, groundnuts, millet and sorghum.

Table 3 shows selected characteristics of sample communities based on the community survey. The sample wards have an average population of 6,090 people and 1,331 households, on an average area of 358,946 ha. The treated wards are on average more densely populated than the control wards. Around 60 per cent of the land is considered arable and agriculture is the primary source of livelihood in all communities, accounting for around 75-78 per cent of household livelihoods. All other livelihood activities are localized in only a few communities including livestock that is reported as main livelihood source for around 15 per cent of households in both groups. Trade is reported to be the main income source for only 13 per cent of households.

The number of wards that have received infrastructure investments since 2014 is low. The main investments have been in transport infrastructure (roads and bridges) and hammer mills (generally used for cassava processing), but less than 30 per cent of communities have received them. As expected, a higher percentage of treated wards have received infrastructure investments than control wards. The availability of services and infrastructure is limited overall, with the exception of primary schools and mobile phone networks. For instance, only 3 per cent of communities have banks or credit unions; around 66 per cent of communities do not have electricity; and only 8 per cent of communities have a private fertiliser retailer. The last column in Table 3 shows that the difference between treated and control wards is not statistically significant for most of these variables. Nevertheless, we include a set of community variables in estimating the ATETs to control for potential differences that may remain after household level matching (see Appendix II for the full list of variables included in the model).

Table 3: Selected characteristics of sampled communities.

Variable	Treated		Control		Difference (T-C)
	Mean	Obs.	Mean	Obs.	
Total population in the community	7,123	103	4,970	95	2,153**
Number of households in the community	1,531	103	1,114	95	417*
Total community area (ha)	214,294	89	517,885	81	-303,591
Proportion of arable land	0.59	88	0.61	77	-0.02
Source of livelihood – percentage of households that rely on:					
- Crop production	78.57	103	75.19	95	3.38

Variable	Treated		Control		Difference (T-C)
	Mean	Obs.	Mean	Obs.	
- Livestock	14.22	49	15.54	59	-1.32
- Processing and transformation of animal and fisheries	20.00	6	10.00	1	10.00
- Trade	13.13	60	11.96	48	1.18
If since 2014 the community received investment in (%)					
- Storage sheds	17	100	05	93	12**
- Bridge	25	101	28	93	-03
- Weirs	06	99	02	92	04
- Hammer mills	36	100	23	93	13**
- Local roads	33	102	20	92	14**
- Farmer training centre	01	100	03	92	-02
- Housing of field officer	14	100	13	92	01
- Solar panels	14	100	15	92	-01
- Others	22	101	28	93	-06
Percentage of communities with:					
- Electricity	42	103	26	95	15**
- Mobile phone network	97	103	94	95	03
- Tarmac road	28	103	22	95	06
- Borehole/piped water	74	103	77	95	-03
- Primary school	94	103	91	95	04
- Secondary school	50	103	39	95	11
- Health centre	72	103	72	95	00
- Bank/credit union	03	103	04	95	-01
- Resident extension service	75	103	69	95	05
- FRA point	62	103	48	95	14*
- FISP point	39	103	38	95	01
- Private fertiliser retailer	06	103	12	95	-06
- Agricultural market	26	103	19	95	07
- Hammer mill	90	103	78	95	12**

Note: Columns (2) and (4) report the mean in the sample dividing by treated and control households, columns (3) and (5) report the number of observations for each variable, and column (4) reports the results of statistical tests to assess whether the difference between treated and control communities' averages is significant. No weights are applied. Asterisks indicate the level of statistical significance from t-test: * < 0.10; ** < 0.05; *** < 0.01.

4.2 Selected characteristics of sample households

The households in the sample are extremely poor: 75 per cent have gross incomes below the threshold of US$1.90 daily gross income per capita.[32] The average annual gross income per capita of the households is US$608[33] (equivalent to 3,020 Zambian Kwacha (ZK)), composed mainly of income from crop production and self-employment (Figure 4). Treated households show a slightly higher annual gross income per capita, but the difference between the treated and control groups is

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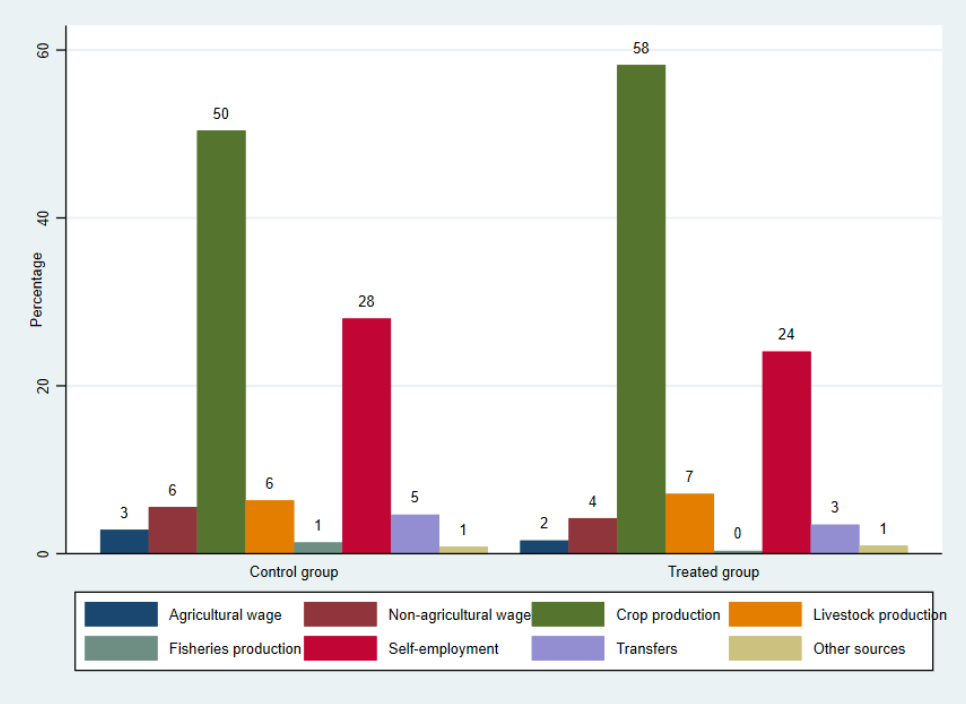
[32] This is the international poverty line defined as less than US$ 1.90 in purchasing parity power in 2011.

[33] The value is expressed in real intertional 2015 dollars. The local currency unit is first deflated to the 2015 value using the consumer price index and then converted to international dollars using the purchasing power parity GDP conversion factor.

not statistically significant. Treated households have also a higher average annual gross crop income per capita (US$289 in the treated group versus US$208 in the control group) as well as a higher share of crop income in total income (58 versus 50 per cent).

Figure 4: Shares of gross income by source for treated and control households.



Asset ownership, especially of productive assets, is very low and concentrated in a few households. Considering the normalized indices ranging from 0 to 1,[34] beneficiary households have an average score of 0.15 (against 0.11 of the control group) for durable assets, of 0.02 (same as the control group) for productive assets, of 0.33 (against 0.26 of the control group) for the quality of housing. Finally, the average Tropical Livestock Units of treated households is 0.53 (against 0.49 of the control group).

Food security indicators show that sampled households have 9.6 months of adequate food provisions on average and 71 per cent did not have adequate food for at least one month. According to IAPRI (2020b), more than 40 per cent of rural households in Zambia (in a nationally representative sample) do not have adequate food provisions for at least one month, indicating that households in our sample are generally more food insecure. Around 27 per cent of households have experienced a whole day without eating and 48 per cent have run out of food during the year. Household dietary diversity, measured by the weekly Household Dietary Diversity Score (HDDS), is 8.3 on a scale of 0 to 12, and around 80 per cent of households have a score above 6. The average weekly Food Consumption Score (FCS) indicates that 85 per cent of sampled households are classified as having “acceptable” levels of FCS according to the classification developed by WFP (2008). The tests of the difference between treated and control households show that the former do better than the latter in all food and nutrition security indicators.

Crop production is the main activity and source of livelihood. Given the sample construction for this IA, farmers in the sample have mainly cultivated the crops targeted by S3P: cassava (71 per cent), groundnut (55 per cent) and mixed beans (31 per cent) in the 2019/20 agricultural season, even

[34] The asset index (durable, productive and housing) refers to the PCA and MCA index presented in Table 2.

though maize is the main crop (88 per cent).[35] All other crops are cultivated by less than 20 per cent of farmers. On average, farmers cultivated 3.3 crops and treated farmers show a greater crop diversification than control farmers. According to the Gini-Simpson index, constructed on the basis of land allocated to different crops, the treated farmers diversify their crops more (0.53 vs. 0.43).

The total value of crop production for the 2019/20 agricultural season averages US$2,107 (10,466 ZK) for treated farmers and US$1,481 (7,356 ZK) for control farmers. It is mainly composed of maize and cassava, which constitute 59 and 40 per cent of the total value on average, respectively. Rice also accounts for a large share of crop production among rice growers, around 38 per cent of the total value, but only 9 per cent of our sample households cultivated rice.

The farming system is subsistence agriculture, mostly rain-fed and characterised by low levels of input use. On average, farmers have cultivated 2 ha out of 5 ha of total land they have access to (owned and rented). This is to be expected given that the Programme has targeted small-scale farmers that cultivate up to 5 ha. Twenty-three per cent of the sample has a farm size less than 1 ha, 40 per cent between 1 and 2 ha and 36 per cent more than 2 ha. We use these categories later to assess potential heterogeneity in S3P impact by land size.

The majority of sampled farmers reported to use improved, hybrid or recycled planting materials (88 per cent for treated, 63 per cent for control) for at least one crop, out of which the majority are hybrid planting material (79 per cent of treated and 52 per cent of control). In Zambia, the adoption of improved seed among small-scale farmers has increased over the past 15 years due to the integration of the private sector in the seed market, including research, breeding, production, marketing and extension services (IAPRI, 2020a). In the 2019/20 agricultural season, around 70 per cent of small-scale farmers (in a nationally representative sample) in Zambia have used improved seeds (IAPRI, 2020a). The percentage of treated farmers using hybrid varieties in our sample is slightly higher, suggesting widespread use of improved planting material among S3P beneficiaries. The use of non-traditional (improved, hybrid and recycled) planting material is highest for maize (89 per cent for treated and 70 per cent for control) followed by beans (16 per cent treated and 17 per cent control), cassava (15 per cent treated and 5 per cent control) and groundnuts (14 per cent treated and 13 per cent control).

The percentage of fertiliser users within the treated group is greater than the national average of 64 per cent reported by IAPRI (2020a) for the 2019/20 agricultural season. Around 89 per cent of treated farmers have applied inorganic fertilisers on at least one plot/crop compared to 66 per cent of control farmers. However, the use of organic fertilisers is almost non-existent, only 3 per cent have used them in both treated and control group. Fertilisers are mostly applied to maize and horticultural crops, while few farmers use them for crops supported by the Programme. The percentage of farmers that have used fertilisers for cassava, groundnut and mixed beans are 5, 4 and 19 per cent, respectively. Considering all inputs (seeds, fertilisers, labour, pesticides, herbicides, insecticides, fungicides, machinery), treated households have used more agricultural inputs than control households. In particular, the value of input per ha used by treated households is US$876 (equivalent to 4,351 ZK) while it is US$807 (equivalent to 4,009 ZK) for control households.

S3P aimed to increase the use of certain farming practices, specifically the components of conservation farming (reduced tillage, soil cover and crop associations). Among sampled households, only 2-5 per cent of households use all three components, though more than 90 per cent use at least one component. Reduced tillage is the least used component; around 3 percent use zero tillage and 4-9 per cent use minimum tillage (planting basins or ripping). Around 64 per cent of farmers use soil cover on at least one plot, mainly by leaving crop residues on the field and then incorporating them into the soil. Yet, around 48 per cent of farmers also report burning crop residues

[35] Cassava, groundnut, mixed beans and maize have been cultivated by 78, 60, 36 and 94 per cent of treated farmers, respectively, while the same crops have been cultivated by 64, 49, 27 and 82per cent of control farmers, respectively.

on at least one field in both treated and control groups. Crop associations (crop rotation or intercropping) is practiced by more than 80 per cent of households. Rotation with legumes is the most common version practiced by 65 and 51 per cent of treated and control households, respectively, while intercropping with legumes is used less (13 and 14 per cent in the treated and control groups, respectively). Agroforestry is sometimes associated with conservation farming, and around 26 per cent of sampled farmers have practiced agroforestry.

The 2019/20 agricultural season has experienced an overall favourable rainfall season in Zambia with few dry spells that have mostly affected central and southern Zambia from February to late March (IAPRI, 2020a; FEWSNET, 2020). However, parts of the S3P provinces, have experienced flooding in early 2020, causing damage to crops, infrastructure and housing (IAPRI, 2020b). Nonetheless, given the rain-fed nature of the farming system, the favourable rainfall has led to prospects of high yields especially for cereals such as maize, wheat and sorghum across the country (IAPRI, 2020a; FAO, 2020). Farmers in the sample have experienced an average total seasonal rainfall of 1,140 millimetres, and 3 dekads (i.e. 10-daily periods) of dry spells on average. The average daily temperature during the rainy season was 22.4℃ and the average maximum temperature was 26.9℃.

The combination of the use of multiple inputs, farming practices and climatic conditions seem to have resulted in relatively good yields during the 2019/20 season. For instance, the average yields are 2.7 tons per ha for maize, 5.5 tons per ha for cassava, 0.6 tons per ha for groundnuts and 0.4 tons per ha for mixed beans (average yields are higher for treated group for each of these crops). These values are similar to or better than those reported by IAPRI (2020a) for the 2019/20 agricultural season in a nationally representative sample (2.28 tons per ha for maize, 0.65 ton per ha for groundnut, 0.56 ton per ha for mixed beans).

One of the main goals of S3P was to increase sales of household production. Around 90 and 78 per cent of treated and control farmers, respectively, have sold at least one of their crops in the market. As expected, horticultural and cash crops are the most marketed, while staple crops such as cassava are less so. Around half of the value of all crops produced is marketed on average. The average revenue from the sale of crops is US$1,350 (equivalent to 6,706 ZK) in the treated group and US$911 (equivalent to 4,525 ZK) in the control group, composed mostly of maize sales (around 70 per cent), and this income is an important source of livelihood for households.

Table 4: Selected characteristics of sampled households.

Variable	Treated		Control		Difference (T-C)
	Mean	Obs	Mean	Obs	
If any household member has a disability (1=yes)	0.28	1,052	0.29	891	-0.01
Average years of education of household members above the age of 15	6.69	1,052	6.50	891	0.20*
Female household head (1=yes)	0.15	1,052	0.18	891	-0.03*
Age of household head	49.41	1,052	46.94	891	2.68***
Hectares of land owned	4.97	1,052	3.92	891	1.29***
Total seasonal rainfall 2019/20	1,174	1,052	1,102	891	75***
Average seasonal mean temperature 2019/20	22.24	1,052	22.51	891	-0.27***
Average seasonal max temperature 2019/20	26.85	1 052	26.95	891	-0.10**

Variable	Treated		Control		Difference (T-C)
	Mean	Obs	Mean	Obs	
Travel time to the next 5-10k city in minutes	75.95	1,052	80.67	891	-4.93*
If a portion of land is irrigated (1=yes)	0.10	1,052	0.05	891	0.05***
Economic Goal (EG)					
Total gross income per capita (US$)	621	1,052	594	891	26
Gross cropping income per capita (US$)	289	1,046	208	874	81***
Durable assets index	0.15	1,052	0.11	891	0.03***
Productive assets index	0.02	1,052	0.02	891	-0.00
Productive capacity (SO1)					
Total value of crop production (US$)	2,107	1,046	1,481	874	626***
Total value of crop production per ha (US$)	1,083	1,046	1,043	874	40
Quantity harvested for cassava (kg)	2,950	591	2,561	443	389*
Crop yield for cassava (kg/ha)	5,682	591	5,278	443	404
Quantity harvested for maize (kg)	3,161	985	2,138	703	1,023***
Crop yield for maize (kg/ha)	2,877	985	2,411	703	466***
Adoption of all three CA techniques (reduced tillage, soil cover, crop diversification) (%)	02	1,052	05	891	-03***
Adoption of at least one CA technique (reduced tillage, soil cover, crop diversification) (%)	95	1,052	93	891	02*
Adoption of non-traditional planting material (improved, hybrid and recycled) for all crops (%)	88	1,050	63	882	24***
Market access (S02)					
Probability of selling crops (%)	90	1 048	78	877	13***
Share of sales value in total value of production (%)	56	946	48	678	08***
Revenues from crop sales (US$)	1,350	948	911	678	440***
Resilience (S03)					
Crop diversification index (Gini-Simpson index)	0.53	1 052	0.43	891	0.09***
Probability to recover from the most severe climate shock during the programme (%)	48	714	46	551	02
Probability to recover from the most severe non-climate shock during the programme (%)	62	951	55	756	07***
Food security (MT)					
Months of Adequate Household Food Provisions (MAHFP)	9.83	1 052	9.41	891	0.42***

Variable	Treated		Control		Difference (T-C)
	Mean	Obs	Mean	Obs	
Household Dietary Diversity Score (HDDS)	8.59	1 052	8.09	891	0.51***
Food Insecurity Experience Scale (FIES)	4.53	1 052	5.18	891	-0.66***
Food Consumption Score (FCS)	54.44	1 052	51.48	891	2.96***

Note: Columns (2) and (4) report the mean in the sample dividing by treated and control households, columns (3) and (5) report the number of observations for each variable, and column (4) reports the difference between treated and control households' averages. The sample is weighted using IPW analytical weights. Asterisks indicate the level of statistical significance from the t-test of mean differences: * < 0.10; ** < 0.05; *** < 0.01.

4.3 COVID-19 outbreak

A particularly important aspect of conducting this IA study for the 2019/20 agricultural season relates to the COVID-19 outbreak and consequent measures to contain its spread, such as movement restrictions and social distancing. In Zambia, the first cases of COVID-19 infection have been reported in March 2020 with a peak in the number of cases recorded in August 2020. Public gatherings, including schools, have been restricted and non-essential workers have been encouraged to work from home (GRZ, 2020). The 2019/20 agricultural season had already advanced, therefore crop production was not expected to be significantly affected. Many businesses have closed or downsized, which directly and indirectly affected household incomes and disrupted food supply chains (Kabisa et al., 2020; Finn and Zadel, 2020; Mofya-Mukuka et al., 2020; Mulenga et al., 2020).

An early study by Mulenga et al. (2020) identified some potentially negative impacts such as limited access to food for low-income groups, reduced or no access to informal markets and price gouging due to food supply disruptions. Other studies (e.g. Kabisa et al., 2020; Mofya-Mukuka et al., 2020) suggest that the negative impacts of the pandemic might be observed more in urban than in rural areas of Zambia, with the main effects being related to increased food prices and reduced business activities.

Our survey tool included several questions to capture exposure to and effects of COVID-19. A selected set of descriptive statistics of these variables is presented in Table 5. One in three households reported that input access has decreased and around 90 per cent reported that input prices have increased due to the pandemic. Only about half as many reported that output prices have increased. Around 60 per cent reported that their agricultural marketing activities have been affected somewhat or a lot. Thirty-five per cent reported that their income from self-employment has been affected by COVID-19 restrictions, and around 12 per cent said that other sources of income were negatively affected. Regarding coping strategies, only a small percentage of households reported to have sold any asset to deal with COVID-19 impacts. Around 12 per cent have received a transfer as a response to the COVID-19 outbreak. The differences between treated and control households are not statistically significant for most of these variables. Even when it is statistically significant, the magnitude of the difference is very low. The questionnaire also asked about subjective assessments of well-being before and after the pandemic. While both groups reported a decrease in subjective well-being, the magnitude of the decrease is the same for both groups. We argue that the careful sample design and matching have addressed any potential systematic differences in exposure to COVID-19. Nonetheless, we also create a composite COVID-19 index in impact analysis to control for any remaining differences between groups and to ensure that the reported findings are not influenced by any systematic differences in COVID-19 exposure or impact.[36]

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[36] To control for the intensity of the COVID-19 effect, we construct an index using the standard Principal Component Analysis (PCA) approach. The index includes six dummy variables that indicate: (i) Whether access to inputs have decreased due to the COVID-19 outbreak; (ii) Whether marketing activities have been affected by the COVID-19 outbreak; (iii) Whether household has

Table 5: COVID-19 exposure and impacts.

Variable	Treated		Control		Difference (T-C)
	Mean	Obs.	Mean	Obs.	
Crop production and sales					
Input access decreased (%)	33	1,052	35	891	-03
Input prices increased (%):	93	343	89	305	04*
Marketing activities have been affected somewhat/a lot (%):	58	935	61	665	-00
Output price increased (%):	47	934	40	664	07***
Self-employment and household business					
COVID-19 restrictions affected the regular business performance (%)	34	470	38	403	-04
Other sources of income and transfers					
Other sources of income and transfers were negatively affected (%)	12	624	13	488	-01
Sales of assets					
Sold livestock to cope with effects (%)	06	1,052	07	891	-02
Sold durable assets to cope with effects (%)	06	1,052	08	891	-02*
Sold productive assets to cope with effects (%)	03	351	03	280	-00
Transfers as COVID-19 response					
Received any transfer as COVID-19 response (%)	12	1,052	13	891	-01
Total transfers received as COVID-19 response (US$)	54.26	121	91.11	94	-36.85
Subjective assessment of well-being					
Well-being (step on ladder) before COVID-19 outbreak (0-10)	4.62	1,052	4.15	891	0.48***
Well-being (step on ladder) today (0-10)	4.39	1,052	3.87	891	0.52***
Difference of well-being before and after COVID-19 outbreak (0-10)	-0.24	1,052	-0.28	891	0.04

Note: Columns (2) and (4) report the mean in the sample dividing by treated and control households, columns (3) and (5) report the number of observations for each variable, and column (4) reports the difference between treated and control households' averages. The sample is weighted using IPW analytical weights. Asterisks indicate the level of statistical significance from t-test: * < 0.10; ** < 0.05; *** < 0.01.

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sold any livestock to cope with the negative economic effect of the COVID-19 outbreak; (iv) Whether the COVID-19 restrictions have affected the regular performance of crop processing; (v) Whether the househod has sold any durable goods to cope with the negative economic effect of the COVID-19 outbreak; (vi) Whether the source of other income and/or transfers have been negatively affected by the COVID-19 outbreak. The PCA index is then normalized to an index between 0 and 1. In the estimation of the S3P's impact, the normalized index is interacted with the variable indicating whether the household has received any transfers as a response to COVID-19 outbreak.

5. Results

In section 5, we discuss the estimated impacts of S3P on indicators presented in Table 2, as well as additional outcome indicators that help us understand the channels through which impact may have been realized. We also present the results of heterogeneity analyses to assess whether impact has varied by service provider (public and private extension services), farm size (smallest, small and medium/large) and gender of the household head to gain further insights for future programme design.

To facilitate interpretation, we report the magnitude of the impact in per cent or percentage point change[37] and the potential outcome mean (POM),[38] while we present the full estimates of IPWRA in Appendix IV.[39] When not explicitly stated, the results are robust across different estimation methods. Each table includes four columns: the first column shows the outcome indicator, the second column the estimated impact of the Programme, the third column the POM and the fourth column the number of observations. All variables refer to the 2019/20 agricultural season and are annual values from September 2019 to October 2020 (after six years of interventions). We convert local currency values (ZK) into international real 2015 US$ by deflating the ZK to the year 2015 and then converting to international US$ at purchasing power parity,[40] and report values also in ZK for the main variables in the text. Note that ATET captures the average impact on the whole beneficiary population, therefore, the impact of activities provided to a small group of households may not be captured. Finally, non-beneficiary households are the comparison group (i.e. a control group) representing what beneficiary households would have looked like if they had not benefited from the Programme.

5.1 Overall impacts of S3P

a) Economic goal: Household income and assets

One of the ultimate goals of the S3P was to increase household income and asset ownership. According to the Programme Completion Report (PCR) (IFAD, 2021), beneficiary households have increased asset ownership by 90 per cent compared to the baseline. We assess the impact on the economic goal through the total annual gross income per capita and annual gross crop income per capita (value of crop sales and home consumption), ownership of durable and productive assets, housing quality, and livestock ownership. We present the impact for these indicators in Table 6.

The S3P increased the gross crop income per capita of beneficiary households by 40 per cent compared to the control group.[41] This means an increase by approximately US$52 per person

[37] The interpretation of the ATET coefficient has to take into account the different construction of the impact variable. When the impact variable is the logarithmic transformation of a continuous variable (e.g. monetary value or kilogrammes of production), the ATET coefficient is interpreted as per cent change of $[\exp(ATET) - 1] * 100$. When the impact variable is a binary variable that assumes the value of one or zero (e.g. one if the household used an input and zero otherwise), the ATET coefficient is interpreted as the change in percentage points, i.e. the percentage difference between the treated group and the control group. When the impact variable is a score or index value, the ATET coefficient is divided over the potential outcome mean to convert the impact into per cent change.

[38] Potential outcome mean is what the treated household would have had if they had not benefited from the programme. The value might be slighly different from the weighted means of both treated and control groups because the variable on which POM is calculated can be logarithmic transformed and POM is estimated by considering a set of control variables that might affect the outcome.

[39] In Appendix IV, we report ATET coefficient and standard errors, the potential outcome mean and standard errors, and number of observations divided between treated and control groups.

[40] Values in ZK are deflated to the year 2015 using the consumer price index and then converted to 2015 international dollars using the purchasing power parity GDP conversion factor. Both informations are retrieved from the World Bank Development Indicators (World Bank, 2021).

[41] There is no difference between the impact on total and per capita values. Therefore, we only report per capita impact.

(equivalent to 258 ZK). Although the estimated impact on the total gross income per capita is not statistically significant, we note that crop income is the source of income targeted by the S3P and the largest share of the total income, around 50-60 per cent.

The S3P has also an impact on the ownership of durable goods and the quality of housing. Both indicators combine several assets and housing characteristics that are expressed as an index between zero and one. The average score of the beneficiary households has increased by 17 and 6 per cent compared to the control group in durable asset ownership and housing quality, respectively. Increased asset ownership is also reported during the focus group discussion and stakeholder interviews conducted in the Final Programme Evaluation by MoA (MoA, 2021) as a result of increased agricultural production and productivity.

In contrast, ownership of productive agricultural assets remains considerably low, even though the S3P has sought to finance their purchase.[42] Some assets such as improved cook stoves,[43] water pumps, ox carts and harrows are almost non-existent in the sample (i.e. owned by less than one per cent of the sample households). Other assets, such as trained oxen/cows, ox-drawn ploughs, wheel barrows, hammer mills and knapsack sprayers are instead concentrated in a few households. Indeed, according to the PCR (IFAD, 2021), only five farmers' cooperatives have accessed funding to purchase of labour-saving/productivity-enhancing equipment.

The S3P has also supported ownership of small livestock through the pass-on scheme (IFAD, 2021).[44] However, there is no impact on livestock ownership. Indeed, the PCR (IFAD, 2021) reports that a total number of 578 households (about 1 per cent of total beneficiaries) have benefited from the pass-on scheme, which is a small number of households to generate an average impact in the beneficiary population. In addition, both the treated and control groups report higher livestock ownership at the time of programme implementation rather than in 2019/20. Note that few households (around 5 per cent) have sold livestock to cope with the COVID-19 effect.

Table 6: S3P impacts on Economic Goal (EG).

Impact indicator	Impact	POM	N
Total gross income per capita (US$)[(a)]	1	372	1,943
Gross cropping income per capita (US$)[(a)]	40 ***	129	1,920
Durable assets index (0-1)	17 ***	0.12	1,943
Productive assets index (0-1)	0	0.02	1,943
Housing characteristics index (0-1)	6 *	0.31	1,943
Tropical Livestock Unit index	6	0.51	1,943

Note: Impacts are reported in per cent change and are estimated using IPWRA regressions with standard errors clustered at ward level, including covariates as described in Appendix II. (a) Indicates that a logarithmic transformation was used. POM indicates the potential outcome beneficiary households would have had if they had not benefited from the programme and it is expressed in the outcome's original unit. Monetary values are expressed in 2015 PPP US$. Asterisks indicate the level of statistical significance: * at 10 per cent; ** at 5 percent; *** at 1 per cent.

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[42] According to the PCR (IFAD, 2021), through the subcomponent of local agricultural investmens, the Programme financed the purchase of labour-saving equipment, such as hammer mills, hand tractors and four-wheel tractors. With these investments, the Programme has sought to improve market access, increase labour productivity, reduce post-harvest losses, and improve land and water management (IFAD, 2021).

[43] The S3P promoted improved cooking stoves to reduce wood consumption relative to cooking on a traditional 3-stone stove. Among other benefits, the use of improved cooking stoves reduces the time and effort of women and girls to find, cut and transport wood from distant locations and health risks associated with using of traditional stoves. A total number of 6,652 households (around 12 per cent of the total beneficiaries) were trained in the construction and use of improved cooking stoves (IFAD, 2021).

[44] The integration of the small livestock pass-on scheme was intended to contribute to increase animal protein in the diet, the use of manure and agricultural diversification in case of crop failure due to effects of climate change. The pass-on scheme was implemented by TLC (IFAD, 2021).

b) Strategic objective one (SO1): Productive capacities

We assess the impact on SO1 through (i) agricultural production and crop yields, and we discuss potential impact channels using three categories of indicators (ii) adoption of good agricultural practices; (iii) adoption of improved planting material; and (iv) the use of fertilisers and labour. For each of these indicators, we discuss results both for all crops grown during the agricultural season, and separately for cassava, groundnuts, mixed beans and maize. The first three are the crops targeted by the Programme, which was expected to have spillover impacts on maize (the main staple crop).[45]

(i) Crop production and productivity

The final objective of the S3P was to increase production by 20 per cent and productivity by 30 per cent of targeted crops as a result of the adoption of good agricultural practices, the use of improved planting material, and more efficient use of agricultural inputs. We present the impact for crop production and productivity in Table 7.

The total value of crop production of beneficiary households has increased by 14 per cent compared to the control group, which is equivalent to US$166 (825 ZK). However, the impact for the total value of crop production per ha is not statistically significant. On average, beneficiary households have cultivated more land (2.4 ha treated group and 1.8 ha control group) and the effect on cultivated land size is 11 per cent. Looking at individual crops, the S3P shows a positive impact on the two main crops. Treated households have increased (compared to the control group) production and yield of cassava by 27 and 25 per cent, respectively, and of maize by 23 and 10 per cent, respectively. Using the POMs in the table, we can convert these impacts into comparisons with the counterfactual "without-S3P scenario" for the beneficiaries for ease of interpretation. The average cassava yield of treated households is 4,244 kg/ha compared to an average yield of 3,395 kg/ha they would have had without the Programme. Regarding maize yields, the average of treated households is 2,381 kg/ha compared to an average of 2,165 kg/ha they would have had without the Programme.

These findings indicate that, the S3P has achieved the overall objective of increasing cassava production by 20 per cent and almost reached the objective of increasing productivity by 30 per cent. Although maize has not been targeted by S3P, the significant spillover effects on increased maize production and productivity are notable, because maize accounts for a large share of crop income. In contrast, there is no impact attributable to the Programme in increasing production and productivity of groundnut and mixed beans. However, the results of cassava and maize are sensitive to the estimation method as the ATETs estimated using NNM are not statistically significant. The spillover impact on total maize harvest is robust using all estimation methods, while the impact on maize yield is not statistically significant using NNM. Both impacts on cassava harvest quantity and yield are not statistically significant using NNM, but are statistically significant using Inverse-Probability Weighting (IPW).[46]

Table 7: S3P impacts on production and productivity (SO1).

Impact indicator	Impact	POM	N
Total value of crop production (US$)[(a)]	14 **	1,188	1,920
Total value of crop production per ha (US$)[(a)]	4	898	1,920
Cassava:			

[45] Although the S3P has also supported other crops (see Section 2), the number of farmers in the sample growing these other crops is too small to allow for a robust analysis. Rice is grown by 9 per cent of treated sample (7 per cent of control sample) despite the fact that 24 per cent of treated households (15 per cent of control households) self-report to have received extension services or participated in training on System of Rice Intensification. Soybean is grown by 12 per cent of treated sample (6 per cent of control sample) and or orange-flesh sweet potatote is grown by less than 1 per cent of treated and control samples.

[46] Since cassava is the main crop targeted by the S3P, we used an additional estimation method, i.e. IPW, to check the robustness of the results.

Impact indicator		Impact	POM	N
-	Quantity harvested (kg)[(a)]	27 **	1,480	1,034
-	Crop yield (kg/ha)[(a)]	25 **	3,395	1,034
Groundnut:				
-	Quantity harvested (kg)[(a)]	9	81	1,037
-	Crop yield (kg/ha)[(a)]	3	369	1,037
Mixed beans:				
-	Quantity harvested (kg)[(a)]	- 5	99	599
-	Crop yield (kg/ha)[(a)]	- 16	330	599
Maize:				
-	Quantity harvested (kg)[(a)]	23 ***	1,495	1,688
-	Crop yield (kg/ha)[(a)]	10 **	2,165	1,688

Note: Impacts are reported in per cent change and are estimated using IPWRA regressions with standard errors clustered at ward level, including covariates as described in Appendix II. (a) Indicates that a logarithmic transformation was used. POM indicates the potential outcome beneficiary households would have had if they had not benefited from the programme, and it is expressed in the outcome's original unit. Monetary values are expressed in 2015 PPP US$. Asterisks indicate the level of statistical significance: * at 10 per cent; ** at 5 per cent; *** at 1 per cent.

(ii) Impact Channels: Adoption of good agricultural practices

The impacts on production have been facilitated through the promotion of a set of good agricultural practices. We assess the impact on the adoption of these practices by evaluating the probability that treated households have practiced a particular technique during the 2019/20 agricultural season (Table 8).

Although the promotion of good agricultural practices was one of the most important activities of the Programme, the attributable impact on their adoption is limited to a few practices. We find a positive impact on the adoption of some of the CA components. The probability that treated households practice crop rotation (with legumes) is 5 (7) percentage points higher than in the control group. This may have facilitated the significant productivity impacts. For example, an agronomic study by Thierfelder et al. (2013a) finds a positive impact of crop rotation (with or without legumes) on crop productivity through improved water infiltration and soil fertility. Similarly, the probability that beneficiary households leave crop residues in the field to subsequently incorporate them into the soil, is 12 percentage points greater than control households. In general, in areas of limited crop-livestock competition (livestock income provides only 7 per cent of income on average in our sample), farmers are more likely to retain crop residues in the field. There is, however, no impact on the rate of full or partial (at least one of the three practices) adoption of CA (minimum/zero tillage,[47] soil cover, crop rotation or intercropping), and the adoption of fallowing, agroforestry and erosion control.[48]

What emerges in particular are the very low adoption rates of some agricultural practices, such as zero or minimum tillage and cultivation of cover crops for soil cover (fundamental in CA), and agroforestry using nitrogen fixing trees (Grilicidia Sepium).[49] For instance, zero tillage is practiced by 3 per cent of treated households (4 per cent of control households), while minimum tillage (zero, planting basins and ripping) is practiced by 4 per cent of treated households (9 per cent of control

[47] The practices considered as minimum tillage are zero-tillage, planting basins and ripping. Zero tillage is based on handlheld or mechanized riect planters. Planting basins are made with hand-hoes. Rip lines are made with ox- or tractocr-drawn rippers (Haggblade and Tembo, 2003).

[48] Even if we analyse the different erosion control practices separately, the S3P has no significant impact. The erosion control practices included in the survey are terraces, drainage ditches, trees, bushes, grass strips and bunds.

[49] The S3P distributed 1,000 kg of Grilicidia seeds and transplanted 3.32 million seedlings across the Programme area (IFAD, 2021).

households).[50] Similarly, cover crops and Grilicidia Sepium are cultivated by less than 1 per cent of the sample.

A low adoption rate of zero or minimum tillage is also the main reason for not fully adopting CA, as the other components of CA are used much more extensively. For instance, soil cover through crop residue management[51] and crop diversification through rotation/intercropping are practiced by 68 and 87 per cent of treated households, respectively (60 and 81 per cent of control households, respectively). Intercropping and intercropping with legumes are adopted to a slightly lower extent: 27 and 13 per cent of treated households, respectively (25 and 14 per cent of control households, respectively).

Other good agricultural practices such as fallowing, agroforestry and erosion control measures, for which there is no significant impact, are largely used to a similar extent by both the treated and control groups. For instance, 52 and 42 per cent of households leave a portion of land fallow among treated and control households, respectively; 26 and 27 per cent of households practice agroforestry among treated and control households; and 39 and 36 per cent of households use erosion control measures among treated and control households, respectively.

The above mentioned impacts on adoption are for all cultivated crops. No substantial difference is observed when the analysis is restricted to individual crops (e.g. cassava or maize), suggesting that there is no crop-specific effect on the adoption of these practices. Therefore, we do not report impacts disaggregated by crop to avoid increasing the length of the analysis without adding value.

Although these findings show a limited impact of the Programme, a large number of treated households in the sample have received extension services or participated in training on these topics. In particular, 40 per cent of treated households report to have been supported in reduced tillage practices (38 per cent of control households), 65 per cent in crop residue management (56 per cent of control households), 77 per cent in crop rotation and intercropping (72 per cent of control households), and 42 per cent in agroforestry practices (34 per cent of control households). This suggests that *attributable* impact on adoption is not estimable with our sample, although the S3P may have *contributed* to adoption as reported in the PCR indicating that 47 per cent of FFS participants adopted the promoted practices (IFAD, 2021). Nevertheless, it is important to note that the PCR reports that the number of farmers who adopted CA is 2,055, which corresponds to approximately 4 per cent of the total beneficiaries, supporting the very low levels of overall adoption in our sample.[52] Notably, this highlights the difference between attribution analysis that isolates all other factors and the contribution analysis.

Table 8: S3P impacts on adoption of good agricultural practices.

Impact indicator	Impact	POM	N
Conservation agriculture (reduced tillage; soil cover, crop diversification)			
Full adoption (all three techniques) (%)	-2	4	1,943
Partial adoption (at least one technique) (%)	1	94	1,943
Tillage methods			
Zero tillage (%)	1	2	1,943
Minimum/reduced tillage (zero till, planting basins and ripping) (%)	- 3	7	1,943

[50] As presented in Section 4, the main tillage methods in the sample households are ridging and hand hoeing.

[51] Crop residue management for soil cover includes crop residue left on the field and then incorporated into field, crop residue cut and spread on the field and crop residue left on the field, adopted by 51, 4 and 24 per cent of treated households respectively compared to 35, 3 and 28 per cent of control households.

[52] The percentage of farmers adopting practices promoted in FFSs and the number of farmers adopting conservation agriculture are reported in the Logical Framework of the PCR (IFAD, 2021).

Impact indicator	Impact	POM	N
- Planting basins (%)	- 1	2	1,943
- Ripping (%)	0	0	1,943
Soil cover practices			
Soil cover (growing cover crops or residue management) (%)	2	67	1,943
Growing cover crops (%)	- 1	1	1,943
Residue management (%)	3	65	1,943
- Crop residues left in the field and then incorporated (%)	12 ***	38	1,943
- Crop residues cut and spread on the field (%)	- 3	7	1,943
- Crop residues left in the field (%)	- 6	30	1,943
Crop diversification			
Crop diversification (crop rotation and/or intercropping) (%)	2	84	1,943
Crop rotation with or without legumes (%)	5 **	76	1,943
Crop rotation with legumes (%)	7 **	58	1,943
Crop rotation with fallow land (%)	2	35	1,897
Intercropping with or without legumes (%)	2	25	1,943
Intercropping with legumes (%)	- 1	14	1,943
Other good agricultural practices			
Fallow land during the season (%)	- 1	52	1,943
Agroforestry (%)	0	26	1,943
Erosion control measures (%)	1	38	1,943

Note: Impacts are reported in percentage point change and are estimated using IPWRA regressions with standard errors clustered at ward level, including covariates as described in Appendix II. POM indicates potential outcome beneficiary households would have had if they had not benefited from the programme and it is expressed in per cent. Asterisks indicate the level of statistical significance: * at 10 per cent; ** at 5 per cent; *** at 1 per cent.

The low adoption rates and limited impact on good agricultural practices is not surprising. The literature extensively raises the issue of low adoption rates of some CA-related agricultural practices. Ngoma et al. (2014) emphasize the low adoption rate of zero or minimum tillage in the AER III (the S3P area). Ngoma et al. (2014) highlight that farmers initially adopt these techniques as a response to drought and low soil moisture conditions in the past season without continuing their use in subsequent seasons. Similarly, Arslan et al. (2014) document low adoption and high dis-adoption rates for CA practices in Zambia.

Low adoption rates are usually explained by the long time period that needs to pass before CA can bring yield gains (Giller et al. 2009) or no yield gains under good/normal rainfall conditions (although yield gains are more likely under low rainfall – Michler et al. 2019). Corbeels et al. (2020) find through a meta-analysis of 79 studies in 16 different countries in Sub-Saharan Africa that average yields in CA are only slightly higher than those in conventional tillage systems, while larger yield responses occur from mulching and crop rotations/intercropping. In addition, the liquidity constraint faced by farmers in those areas limits the opportunity to grow more crops with negative effects on legume intercropping or cultivation of cover crops.

Similarly, the high labour requirements for minimum tillage reduce the adoption of such techniques (Ngoma et al., 2014) making labour availability (measured as the number of people working per ha) another critical constraint for CA adoption. In Zambia Kalinda et al. (2017) find that CA adoption increases with labour availability, though Nyanga (2012) and Ngoma et al. (2016) find no link between the two. This could be due to the fact that land is abundant but the population density is low, which might limit labour availability in CA adoption (Ngoma et al., 2021).

Overall, Ngoma et al. (2021) suggest that capital-intensive CA is more likely to be adopted in areas of economic dynamism, where capital is cheap relative to labour. In contrast, labour-intensive CA practices are more likely to be adopted in regions of economic stagnation where capital is expensive and labour is abundant and cheap. Thus, access to credit might not be the most limiting factor for CA adoption in areas where both land and labour are abundant (Ngoma et al., 2021).

Nonetheless, non-financial factors might also limit CA adoption. Farmers may be reluctant to adopt CA due to lack of technical know-how, because of culture and traditions, limited linkages to output and input markets or the labour burden of some technologies (Ngoma et al., 2016; Zulu-Mbata et al., 2016). Similarly, Ndah et al. (2018) suggest that management of weed infestation related to CA, improvement of market access conditions and involvement of young farmers are critical aspects in CA adoption. Ngoma (2018) emphasises the behavioural aspects and finds that risk aversion, impatience, and farmers' subjective perceptions of the riskiness of CA significantly reduce the probability of adoption. Risk-averse farmers may not adopt it because they may be unwilling to take on unfamiliar farming practices or because they do not understand the risk-reducing capabilities of CA.

Therefore, the adoption of good agricultural practices is not straightforward and multiple factors might affect its adoption or dis-adoption. If a programme does not take into account these potential factors in the area during the design and implementation phases, the success of promoting good agricultural practices could be reduced. We discuss some related recommendations in Section 6.

(iii) Impact Channels: Adoption of improved planting material

Another key activity of the S3P was the dissemination and promotion of improved planting material. Around 66 per cent of treated households in the sample self-report that they have been supported through extension services or training in new crop varieties (47 per cent of control households). According to the PCR (IFAD, 2021), approximately 24,975 beneficiary households adopted improved crop varieties (around 44 per cent of total beneficiaries). We assess the adoption of improved planting material by evaluating the probability that treated households use improved, hybrid or recycled planting material in the agricultural season. We report the impact for the adoption of improved planting material in Table 9.

In contrast to the adoption of good agricultural practices, we observe a positive impact of the Programme on the adoption of improved, hybrid or recycled planting material (hereafter called non-traditional planting material). The probability of using non-traditional varieties (for any crop) is 15 percentage points higher in the treated group than in the control group. The probability of using drought-resilient varieties (99 per cent of which are non-traditional) is 12 percentage points higher in the treated group than in the control group. In particular, the S3P has increased the probability to use hybrid varieties by 17 percentage points and recycled varieties by 6 percentage points. Although there is no significant impact on the adoption of improved varieties, it should be kept in mind that farmers usually use the words hybrid and improved interchangeably.

As reported in Section 4, the use of non-traditional planting material by treated farmers is relatively high (88 per cent in the treated and 63 per cent in the control group). The majority in this category is hybrid varieties (79 per cent in the treated and 52 per cent in the control group), while the use of improved varieties is much lower (10 per cent in the treated and 7 per cent in the control group). When examined at the crop level, we find that the use of non-traditional planting material is highest for maize (89 per cent of the treated and 70 per cent of the control group), soybeans (57 per cent of the treated and 45 per cent of the control group) or horticultural crops (around 88 per cent of the treated and 68 per cent of the control groups).

We find that the probability of using non-traditional varieties in cassava cultivation is 7 percentage points higher in the treated compared to the control group. This impact is driven by the use of improved varieties (4 percentage points higher than the control group), and especially for the adoption of Chila and Mweru varieties (1 and 5 percentage points higher than the control group, respectively) (results are available in Appendix IV). These are two high-yielding varieties developed in Zambia since 2000 (Chiona, 2016). However, the overall adoption rate is still low, the Chila variety is used by 1 per cent of treated households (no control household uses it) and Mweru variety by 6 per cent of treated households (1 per cent of control households).

Although the overall impact on non-traditional variety adoption for groundnuts and mixed-beans is not significant, further analysis shows that treated households have increased the probability of using improved groundnut varieties by 1 percentage point and hybrid mixed-beans varieties by 5 percentage points (results are available in Appendix IV). In terms of specific varieties, the Programme has increased the probability of beneficiary households using MGV5 groundnut variety by 2 percentage points, Mbereshi and Lukupa bean varieties by 1 percentage point each.

In summary, the Programme has positively affected the adoption of improved planting material, contributing to the steady increase in Zambia over the years. The overall adoption rate in the treated households is indeed in line with or higher than the national averages of the 2019/20 agricultural season reported by IAPRI (2020a). The significant increase in the adoption of improved planting material suggests that it is one the impact channels through which the productivity increases identified above are achieved (Manda et al. 2017; Khonje et al., 2015). However, the greatest impact is observed for maize, while the adoption rate in directly supported crops (i.e. cassava, groundnut and mixed beans) remains low.

Table 9: S3P impacts on improved planting material adoption.

Impact indicator	Impact	POM	N
All cultivated crops:			
Non-traditional planting material (Improved, Hybrid and Recycled) (%)	15 ***	73	1,932
- Improved (%)	1	8	1,932
- Hybrid (%)	17 ***	62	1,932
- Recycled (%)	6 ***	10	1,932
Drought resilient (%)	12 ***	49	1,899
Cassava:			
Non-traditional planting material (%)	7 **	8	1,167
Drought resilient planting material (%)	4	9	1,145
Groundnut:			
Non-traditional planting material (%)	3	11	1,064
Drought resilient planting material (%)	2	6	1,034
Mixed beans:			
Non-traditional planting material (%)	2	14	623
Drought resilient planting material (%)	1	8	609
Maize:			
Non-traditional planting material (%)	9 ***	81	1,697
Drought resilient planting material (%)	9 **	59	1,428

Note: Impacts are reported in percentage point change and are estimated using IPWRA regressions with standard errors clustered at ward level, including covariates as describe in Appendix II. POM indicates potential outcome beneficiary households would have had if they had not benefited from the programme and it is expressed in per cent. Asterisks indicate the level of statistical significance: * at 10 per cent; ** < at 5 per cent; *** at 1 per cent.

(iv) Impact Channels: Use of fertilisers and labour inputs

Another important impact channel to achieve increased productivity is the use of inputs such as fertilisers and labour, which are also complementary to improved planting material. We report the impacts on these variables in Table 10. The Programme increased the probability of using fertilisers (organic and inorganic) by 16 percentage points for beneficiary households compared to the control households. Yet, there is no impact on the use of organic fertilisers, which is almost non-existent, even though some implementing agencies of the Programme have promoted organic farming. Around 60 per cent of treated households in the sample report to have received extension services or training on the use of agricultural inputs such as organic fertilisers (54 per cent of the control farmers). However, as reported in Section 4, only 3 per cent of treated households (3 per cent of control) apply organic fertilisers. Therefore, the impact is driven by the use of inorganic fertilisers, with an increase of 16 percentage points compared to the control group (for both basal and top dressing). The Programme has also affected the amount of fertiliser applied among users. The treated group has increased both the total and per ha amounts used (both measured as the value of fertilisers at market price) by 36 and 23 per cent compared to the control group (equivalent to an increase of US$88 (437 ZK) and US$31 (154 ZK), respectively.

Looking at crop specific results, we, once again, find that the impact is mostly driven by a higher use of fertilizers in maize cultivation. The probability of the treated group using fertilisers (organic and inorganic) is 6 percentage points greater than the control group for maize. Similarly, treated households have increased the amount of fertiliser per ha used for maize by 15 per cent. Nonetheless, the use of fertilizers for the targeted crops remains low and no impact is observed.

We find that the S3P has also increased the use of labour even though the PCR (IFAD, 2021) indicates that programme contributed to a reduction in agricultural workload through the use of labour saving technologies.[53] Beneficiary households are 7 percentage points more likely to hire workers. Additionally, both the total and per ha value of labour (hired and family) used by beneficiary farmers have increased by 26 and 13 per cent, respectively, which is equivalent to an increase of US$163 (810 ZK) and US$50 (248 ZK). Increased labour use is observed for all analysed crops. Specifically, the probability of hiring workers by treated households has increased by 6 percentage points for cassava, 6 percentage points for groundnuts, 7 percentage points for mixed beans and 8 percentage points for maize. In contrast, the total value of labour per ha has only increased in maize cultivation (by 10 per cent).

Overall, treated households use more agricultural inputs than control households.[54] Total and per ha expenditure increased by 46 and 31 per cent, and the total and per ha value of inputs increased by 32 and 18 per cent, respectively. We find, once again, that these estimated impacts are driven by maize in crop specific results.

As reported in Section 4, the use of fertilisers for the three target crops is generally low compared to maize, while the use of hired labour is similar between the crops, although maize always shows slightly higher input use. Similarly, the total value of all agricultural inputs is slightly higher in maize. These heterogeneous effects across crops can be interpreted in two ways. First, favourable weather conditions during the 2019/20 agricultural season may have led farmers to invest more in maize, since it is the primary crop, rather than in other crops. Second, other crops, especially

[53] The S3P promoted 14 labor-saving techniques that are the cono weeders, rice threshers, modified bicycles, row markers, sickles, chaka hoes, heap pumps, treadle pumps, sprayers, cook stoves, half-walk kitchens, dibble sticks, two wheel and four wheel tractors (IFAD, 2021). According to the PCR (IFAD, 2021), 1,251 farmers adopted labor-saving equipment out of 56,708 total beneficiaries.

[54] Agricultural inputs are planting material, fertilisers (organic and inorganic), labour (hired and family), phytonsanitary products, land rental and other inputs (e.g. transport costs, expenditure on storage, animal equipment rental cots etc.).

cassava, generally have a lower demand for fertiliser and inputs, so farmers may prefer to invest more inputs in crops with higher input demands, such as maize.

Table 10: S3P impacts on input use.

Impact indicator	Impact	POM	N
All cultivated crops:			
Use of fertilisers(b)	16 ***	74	1,943
Total value of fertilisers used (US$)(a)	36 ***	245	1,523
Total value of fertilisers used per ha (US$)(a)	23 ***	136	1,523
Use of hired labour(b)	7 **	53	1,943
Total value of labour (US$)(a)	26 ***	626	1,943
Total value of labour per ha (US$)(a)	13 **	388	1,943
Total value of input (US$)(a)§	32 ***	1,033	1,943
Total value of input per ha (US$)(a)§	18 ***	633	1,943
Cassava:			
Use of fertilisers(b)	2	3	1,451
Use of hired labour(b)	6 *	32	1,446
Total value of labour (US$)(a)	- 4	276	1,446
Total value of labour per ha (US$)(a)	3	391	1,446
Total value of input (US$)(a)§	- 10	317	1,451
Total value of input per ha (US$)(a)§	- 5	450	1,451
Groundnut:			
Use of fertilisers(b)	- 1	6	1,064
Use of hired labour(b)	6 *	25	1,064
Total value of labour (US$)(a)	20 **	112	1,064
Total value of labour per ha (US$)(a)	12	513	1,064
Total value of input (US$)(a)§	20 ***	147	1,064
Total value of input per ha (US$)(a)§	10	665	1,064
Mixed beans:			
Use of fertilisers(b)	3	20	623
Use of hired labour(b)	7 *	28	623
Total value of labour (US$)(a)	- 15	140	623
Total value of labour per ha (US$)(a)	- 29 **	498	622
Total value of input (US$)(a)§	- 8	191	623
Total value of input per ha (US$)(a)§	- 23 **	685	623
Maize:			
Use of fertilisers(b)	6 ***	92	1,697
Total value of fertilisers used (US$)(a)	35 ***	233	1,502
Total value of fertilisers used per ha (US$)(a)	15 ***	337	1,502
Use of hired labour(b)	8 **	47	1,697
Total value of labour (US$)(a)	31 ***	242	1,697
Total value of labour per ha (US$)(a)	10 *	376	1,697
Total value of input (US$)(a)§	40 ***	545	1,697

Impact indicator	Impact	POM	N
Total value of input per ha (US$)[(a)§]	17 ***	846	1,697

Note: Impacts are reported in per cent or percentage point change and are estimated using IPWRA regressions with standard errors clustered at ward level, including covariates as described in Appendix II. (a) Indicates that a logarithmic transformation was used and the impact is reported in per cent change; (b) indicates that the variable assumes the value of one or zero and the impact is reported in percentage point change. POM indicates potential outcome beneficiary households would have had if they had not benefited from the programme and it is expressed in the outcome's original unit. Monetary values are expressed in 2015 PPP US$. Fertiliser indicators include both organic and inorganic. Labour indicators include both hired and family unless otherwise specified. § Agricultural inputs include planting material, fertilisers, phytosanitary products, labour, land rental and other inputs (e.g. transport costs, expenditure on storage, animal or equipment rental cost, etc.). Asterisks indicate the level of statistical significance: * at 10 per cent; ** at 5 per cent; *** at 1 per cent.

c) Strategic objective two (SO2): Access to markets

Improving market access was one of the main goals of S3P. About 24 per cent of treated households report being supported through extension services or training on market access (16 per cent of control households) and 83 per cent report being a member of a farmer organization (51 per cent of control households). As discussed in Section 2.1, participating in farmer organisations increases access to information and bargaining power, which in turn can lead to higher market integration and revenues. Among treated households that are members of farmer organizations, 85 per cent are members of an organization supported by the S3P. We assess the impact on access to markets using a set of indicators: the probability of selling crops, the share of crop value sold over the total value of production, the revenues from crop sales and farmer group membership (Table 11).

The probability of selling crops is 8 percentage points greater in the treated compared to the control group. This result is observed for cassava, groundnut, mixed beans and maize, where the probability of beneficiary households to sell these crops has increased by 15, 8, 11 and 11 percentage points, respectively. The increase in cassava sales is driven by the sale of processed cassava as chips, the probability of which is 13 percentage points higher in the treated group (results are reported in Appendix IV).

The most frequently reported sales channels are direct consumers (63 per cent), small retailers (41 per cent) and the government's Food Reserve Agency (FRA) (42 per cent). While there is no difference between the treated and the control groups in selling through the former two channels, the treated group sells more to the FRA than the control group (52 vs. 30 per cent). However, sales to the FRA mainly concern maize,[55] while targeted crops are not sold to the FRA. Separating private from public sales channels, we find that among those who sold crops, the probability of selling through private channels[56] increased by 6 per cent for the treated households, while the probability of selling through FRA increased by 8 per cent – driven by maize (results are reported in Appendix IV).

Among households that have sold crops, beneficiary households have also increased the share of crops sold by 10 per cent and the revenues from sales by 48 per cent (equivalent to an increase of US$234/1,162 ZK). Yet, disaggregating the impact by crop, only the revenues from maize have increased (by 23 per cent). The estimated impacts on revenues from sales of cassava, groundnut and mixed beans are not statistically significant.

The positive impact on access and integration to the market can be due to two major drivers. First, the linkages created with farmer organizations could have increased farmer bargaining power and reduced transaction costs as largely found in the literature (Bachke, 2019; Verhofstadt and Maertens, 2015; Fischer and Qaim, 2012; Shiferaw et al., 2011; Markelova et al., 2009; Barrett 2010). The probability of beneficiary households to be members of farmer organizations is 20 percentage points higher than in the control group. Second, beneficiary households might have benefited from the synergies created between the S3P and the SAPP focused on increasing commercial opportunities for

[55] The other crop sold at FRA is soybean (2 per cent of soybean sellers).

[56] Private channels include direct consumers, small retailers, other buyers, other private companies, local processor, COMACO, whole seller, institution, cooperative, aggregator, Good Nature, supermarkets, Afri seed, restaurant. Excluding direct consumers and small retailers, all the other channels are used by less than 7 per cent of beneficiaries.

small-scale farmers.[57] The S3P was expected to provide the agricultural production needed to support the SAPP, hence the beneficiaries benefited from the potential market linkages created by the SAPP.

Table 11: S3P impacts on market access (SO2).

Impact indicator	Impact	POM	N
Participation in farmer organizations[(b)]	20 ***	63	1,943
All cultivated crops:			
Probability of selling crops[(b)]	8 ***	83	1,943
Share of sales value in total value of production (%)[(c)]	5 ***	51	1,624
Revenues from crop sales (US$)[(a)]	48 ***	488	1,626
Cassava:			
Probability of selling cassava in all forms[(b)]	15 ***	31	1,033
Share of sales value in total value of production (%) [(c)]	9	42	415
Revenues from cassava sales (US$)[(a)]	26	129	415
Groundnut:			
Probability of selling groundnut[(b)]	8 *	51	1,037
Share of sales value in total value of production (%)[(c)]	- 2	60	593
Revenues from groundnut sales (US$)[(a)]	8	97	593
Mixed beans:			
Probability of selling mixed beans[(b)]	11 *	54	599
Share of sales value in total value of production (%)[(c)]	0	63	398
Revenues from sales (US$)[(a)]	9	140	398
Maize:			
Probability of selling crop[(b)]	11 ***	73	1,688
Share of sales value in total value of production (%)[(c)]	3	62	1,311
Revenues from crop sales (US$)[(a)]	23 **	469	1,311

Note: Impacts are reported in per cent or percentage point change and are estimated using IPWRA regressions with standard errors clustered at ward level, including covariates as described in Appendix II. (a) Indicates that a logarithmic transformation was used and the impact is reported in per cent change; (b) indicates that the variable assumes the value of one or zero and the impact is reported in percentage point change; (c) indicates that the impact is reported in percentage point change. POM indicates potential outcome beneficiary households would have had if they had not benefited from the programme and it is expressed in the outcome's original unit. Monetary values are expressed in 2015 PPP US$. Asterisks indicate the level of statistical significance: * at 10 per cent; ** at 5 per cent; *** at 1 per cent.

d) Strategic objective three (SO3): Resilience

The S3P aimed at improving the resilience capacity of beneficiary households to climate and non-climate shocks. In particular, greater resilience to climate shocks was expected as a result of adopting good agricultural practices (minimum tillage, retention of crop residue, crop rotation, intercropping and agroforestry) and drought-resilient crop verities, both of which enable farmers to adapt to climate change. Yet, as discussed in the SO1 assessment, the impact on the adoption of good agricultural practices is limited to crop residue management and crop rotation, while other techniques are rarely adopted.

However, other factors can affect the resilience capacity of farmers. In the absence of formal markets for risk management, diversification strategies are for instance one of the adaptation measures to

[57] Impact estimates control for the fact that wards have benefited from the SAPP (see Appendix II for the full list of control variables).

cope with shocks. In particular, crop diversification increases the resilience capacity of farmers in several ways. From an agronomic perspective, crop diversification increases the probability of growing the best-adapted crops for a given environment, adapting to climatic conditions, to mitigate the effect of pest prevalence, and using available resources more efficiently as each crop has different agronomic needs (Altieri and Nicholls, 2017; Altieri et al., 2015; Lin, 2011). From an economic perspective, crop diversification reduces the temporal and physical requirement of labour, the exposure of farmers to price volatility affecting individual crops, and input expenditure through economies of scale (Arslan et al., 2018; Di Falco and Perrings, 2005). In the same way, income diversification enables rural households to cope with adverse shocks (Alfani et al. 2021; Arslan et al., 2018).

We present the impact on our resilience indicators in Table 12. In measuring both income and crop diversification, the literature has extensively used the Gini-Simpson Index, which ranges from a zero, meaning no diversification, to one, meaning complete diversification.[58] There is no impact on income diversification while the crop diversification score of the beneficiary households is 11 per cent higher than that of the control households. Overall, beneficiary households cultivate more crops than control households (3.5 crops for beneficiary households versus 2.9 crops for control group) and distribute the allocated land to each crop more equally.

A further indicator to assess household resilience is the self-reported ability of households to recover from climate and non-climate shocks during the programme.[59] Among households reporting having experienced a shock, beneficiary households are 9 percentage points more likely than control households to recover from the most severe shock. This result is driven by the ability to recover from non-climate shocks, while there is no impact on the ability to recover from climate shocks.[60] By contrast, we do not observe an impact if we analyse the impact using the corrected indicators.[61]

Table 12: S3P impacts on resilience (SO3).

Impact indicator	Impact	POM	N
Income diversification (Gini-Simpson index)[(a)]	0	0.39	1,943
Crop diversification (Gini-Simpson index)[(a)]	11 ***	0.47	1,943
Ability to recover from the most severe shock (climate and non-climate) experienced during the programme[(b)]	9 ***	62	1,798
• Climate shocks[(b)]	0	49	1,238
• Non-climate shocks[(b)]	9 ***	54	1,698
Exposure corrected ability to recover from the most severe shock (climate and non-climate) experienced in the last 12 months[(a)]	- 2	2.34	1,594
• Climate shocks[(a)]	- 2	2.68	1,449
• Non-climate shocks[(a)]	- 1	2.16	853

Note: Impacts are reported in percentage or percentage point change and are estimated using IPWRA regressions with standard errors clustered at ward level, including covariates as describe in Appendix II. (a) Indicates that the impact is reported in per cent change; (b) Indicate that the variable assumes the value of one or zero and the impact is reported in percentage point change. POM indicates potential outcome beneficiary households would have had if they had not benefited

[58] We calculate income diversification according to the shares of income sources, and crop diversification according to the land allocated to different crops.

[59] It should be noted that both exposure to shocks and ability to recover from shocks are self-reported by the respondent.

[60] If we consider only the shocks in the previous 12 months, the magnitude of the impact on the ability to recover from climate and non-climate shocks is reduced from 9 to 6 percentage points, while the impact on the abiltiy to recover from non-climate shocks is no loger statistically significant.

[61] These indicators are based on the self-reported information on exposure to shocks and ability to recover from shocks, but they are corrected for the potential subectivity of the response and differences in exposure intensities (methodological note available upon request).

from the programme and it is expressed in the outcome's original unit. Asterisks indicate the level of statistical significance: * at 10 per cent; ** at 5 per cent; *** at 1 per cent.

e) Food and nutrition security (MT)

Increasing food and nutrition security of beneficiary households was the ultimate goal of the S3P along with income and asset ownership. The PCR (IFAD, 2021) reports that beneficiary households have reduced food insecurity by 63 per cent compared to the baseline. Similarly the results of the focus group discussions presented in the Final Evaluation Programme (MoA, 2021) also report a positive effect of S3P on the food and nutrition security of beneficiary households. Noting that these findings are related to the S3Ps contribution to change in these indicators, we assess attributable impacts on food and nutrition security using four main indicators widely recognized in the literature, i.e. MAHFP, HDDS, FIES and FCS[62] (Table 13).

The MAHFP score of beneficiary households has increased by 5 per cent compared to control group score. This means an increase of 0.44 months of adequate household food provision. The dietary diversity has also improved, with beneficiary households having 3 per cent higher HDDS than control households. Considering that HDDS is the sum of food groups consumed, this corresponds to an increase of 0.27 food groups on average. The FCS score of beneficiary households has also increased by 4 per cent, meaning an increase of the score by 2.02 points. Consequently, beneficiary households are 3 percentage points more likely to be in the acceptable FCS category. In contrast, no statistically significant impact is observed for food insecurity, measured by the aggregate FIES score as well as individual FIES questions.

These results suggest a positive impact of S3P on food and nutrition security even though the number of specific S3P activities in this domain were limited. Specifically, the Programme provided training on nutritional and cooking practices, which have been received by 25 per cent of beneficiary households in the sample (18 per cent of control group report having received similar trainings from other sources).[63] Nonetheless, positive linkages between agriculture and nutrition are demonstrated in the literature, indicating other S3P activities (e.g. improvements in agricultural production, crop diversification, crop incomes and crop sales) have potentially positive impacts on food and nutrition security (for a review of the nutrition impacts of agricultural programmes see for example Bernstein et al., 2019; Ruel et al., 2018). The positive impacts of agricultural interventions on food and nutrition security are also shown by Garbero and Jäckering (2021), who investigate the impact of 14 IFAD-funded programmes similar to S3P. Furthermore, a recent study by Mulenga et al. (2021) demonstrate that market participation and household production diversity enhance household dietary diversity in Zambia. In addition, Sibhatu et al. (2015) show that market participation tends to have a greater effect on food security than production diversification. Both of these indicators are positively affected by the Programme as described in the previous sections, suggesting they may act as indirect channels through which food and nutrition security of beneficiaries can improve.

Table 13: S3P impacts on food and nutrition security (MT).

Impact indicator	Impact	POM	N
Months of Adequate Household Food Provisions (MAHFP)[(a)]	5 ***	9.39	1,943
Household Dietary Diversity Score (HDDS)[(a)]	3 ***	8.33	1,943
Food Insecurity Experience Scale (FIES)[(a)]	- 4	4.70	1,943

[62] Table 2 presents the details of the construction of each indicator.

[63] According to the PCR (IFAD, 2021), the Programme established 243 Food and Nutrition Groups with a total membership of 3,649 beneficiaries of which 66 per cent are women. Through these groups, the S3P provided nutrition training and cooking demonstrations, promoted consumption of bio-fortified seed available, promoted cooking stoves, rearing and consumption of small livestock, and dissemination of planting materials such as orange fleshed sweet potatoes, orange maize, iron and zinc rich beans.

Impact indicator	Impact	POM	N
Food Consumption Score (FCS)[(a)]	4 **	52.43	1,943
- FCS – Poor[(b)]	- 1	2	1,943
- FCS – Borderline[(b)]	- 2	13	1,943
- FCS – Acceptable[(b)]	3 *	85	1,943

Note: Impacts are reported in percentage or percentage point change and are estimated using IPWRA regressions with standard errors clustered at ward level, including covariates as described in Appendix II. (a) Indicates that the impact is reported in per cent change; (b) Indicates that the variable assumes the value of one or zero and the impact is reported in percentage point change. POM indicates the potential outcome beneficiary households would have had if they had not benefited from the programme and it is expressed in the outcome's original unit. Asterisks indicate the level of statistical significance: * at 10 per cent; ** at 5 per cent; *** at 1 per cent.

f) Women's empowerment (MT)

One of the key objectives of IFAD is promoting gender equality and women's empowerment in rural areas.[64] The S3P did not have any gender-transformative activity, however, the PCR (IFAD, 2021) emphasises the use of gender strategy in targeting beneficiaries. It reports that approximately 49 per cent of beneficiaries that accessed advisory services, such as training, demonstrations, seed multiplication and market services, were women. Furthermore, approximately 32 per cent of leadership positions in farmer organizations supported by the Programme are held by women. In addition, some interventions such as energy-saving cook stoves and small livestock (goat and chicken) pass-on schemes specifically targeted women (though these were very small components only implemented by TLC accounting for 1 per cent of total beneficiaries). Around 46 per cent of livestock beneficiaries (264 out of a total of 578) were female-headed households ((IFAD, 2021).

Accessing advisory services is expected to increase women's contribution to household income, asset ownership and control over crop production and financial resources of the household. Holding a leadership position in a farmer organization is expected to contribute to empowering women through improved entrepreneurship and business understanding to recognize and benefit from market dynamics as well.

We present the estimated impacts on women's empowerment in Table 14 by evaluating the probability of women's participation into wage employment, female contribution to/control over household income, ownership of land, livestock, durable and productive assets, and participation in farmer organizations. All indicators (except female participation in wage employment) are created based on questions on whether control/decision/ownership is solely by female members of the household or jointly with men. We, therefore, present impacts for both sets of indicators.

There is no impact on the probability of women's participation in wage employment. In terms of decision making on income sources and control of revenues from crop sales, the impacts are not statistically significant when estimated for only females. In contrast, these impacts are significant using joint decision making/control indicators. Beneficiary households are about 5 and 6 percentage points more likely to include women in household decisions jointly with men compared to control households.

Regarding asset ownership, the probability that females in beneficiary households own land by themselves has increased by 4 percentage points compared to the control group. No other indicator of sole asset ownership by women is significant. However, impacts on probability of joint ownership of livestock and durable assets are significant, at 11 and 7 percentage points, respectively.

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[64] IFAD gender equality and women's empowerment policy comprises three dimensions: economic empowerment to enable both rural women and men to participate in and benefit from profitable economic activities (economic empowerment); both women and men have equal voice and influence in rural institutions and organizations, including decision making processes at the household, community, or local level (voice and decision-making); and a more equatable balance workloads and in the sharing of economic and social benefits between women and men (equitable workloads). IFAD policy on gender equality and women's empowerment is available at https://www.ifad.org/en/-/document/ifad-policy-on-gender-equality-and-women-s-empowerment-new.

The joint male-female participation in farmer organizations has also increased by 12 percentage points compared to the control households. This results is expected because the S3P promoted farmer organization membership of both males and females.

The estimated impacts on women's empowerment are overall somewhat weak. These results suggest that targeting women for programme activities is not sufficient because other social and cultural factors may continue constraining women's empowerment. Although women are major contributors to agriculture and rural economies, they face numerous challenges and gender equality is still lagging behind in many areas. Therefore, if these multiple factors that constrain women's empowerment in the economy and society are not specifically addressed, as they are in gender-transformative programmes, achieving women's empowerment could be very challenging (Egger et al., 2021).

Table 14: S3P impacts on women's empowerment (MT).

Impact indicator	Impact	POM	N
Probability of women working in wage employment	-2	14	1,943
Decision making on income sources: at least one income source by			
- Only female	- 4	55	1,943
- Jointly with men	5 *	68	1,943
Control of revenues from crop sales: at least one crop by			
- Only female	0	20	1,626
- Jointly with men	6 **	56	1,626
Land ownership: at least one plot by			
- Only female	4 ***	20	1,852
- Jointly with men	3	34	1,852
Livestock ownership: at least one category by			
- Only female	1	29	1,560
- Jointly with men	11 ***	41	1,560
Durable goods ownership: majority by			
- Only female	0	15	1,837
- Jointly with men	6 ***	32	1,837
Productive goods ownership: majority by			
- Only female	1	5	631
- Jointly with men	3	31	631
Participation in farmer organizations			
- Only female	0	26	1,342
- Jointly with men	11 ***	27	1,342

Note: Impacts are reported in percentage point change and are estimated using IPWRA regressions with standard errors clustered at ward level, including covariates as described in Appendix II. POM indicates potential outcome beneficiary households would have had if they had not benefited from the programme and it is expressed in per cent. Decision making on/control over income/revenue sources is measured by using the answers to the question of "who makes the decision on…" or "who control revenues from…" for each parcel/income-generating activity/sale. Asterisks indicate the level of statistical significance: * at 10 per cent; ** at 5 per cent; *** at 1 per cent.

5.2 Heterogeneous impacts of S3P

We present the results of the heterogeneity analyses that disaggregate the impact of S3P by selected sample characteristics. The overall sample is divided into subsamples for which the ATET is estimated and compared across subsamples. For the purpose of this analysis, we report only statistically significant impacts.

First, we assess impacts disaggregated by implementing agencies. As mentioned earlier, extension services were implemented by public (MoA) and private (COMACO and TLC) service providers. The S3P was the first programme implemented by MoA to use public-private partnership in providing extension services and therefore considered an innovative approach in the Zambian context (IFAD, 2021). For this reason, it is relevant to disaggregate the overall impact by these two types of providers in order to produce evidence to inform policy makers on the effectiveness of this approach.

Second, we assess the potential differences in impact by farm size. Access to land has strong policy implications for poverty reduction strategies (Jayne et al., 2003), and Zambia is undergoing a process of transformation in land distribution. In addition, farm size is generally associated with different levels of productivity (Kimhi, 2006) and CA adoption (Ngoma et al., 2021). Land size categories commonly used in Zambia define small, medium and large farms as those with less than 5 ha, between 5 and 20 ha, and greater than 20 ha, respectively (Sitko and Chamberlin, 2015).[65] However, based on S3P targeting criteria, the sampled farmers almost entirely cultivate less than 5 ha, falling into the general small-scale farmer category. To assess heterogeneity in our sample, we classify households into three categories: smallest (less than one ha), small (between one and two ha) and medium/large (more than two ha) based on the land cultivated in the 2019/20 agricultural season.

The last heterogeneity analysis focuses on the gender of the household head. Female-headed households are generally disadvantaged due to the existence of socio-economic inequalities and gender specific barriers. For example, Ndiritu et al. (2014) find that female plot managers in Kenya are less likely to adopt minimum tillage and animal manure than male farmers. Furthermore, IFAD's priority groups in targeting beneficiaries explicitly include female-headed households. However, the number of female-headed households in the sample is low (16 per cent) to allow for robust analysis, therefore we only conduct separate analysis for male-headed households. The estimated ATETs for the male-headed households are then compared with those in the overall sample to deduce the impact for female-headed households. A higher ATET coefficient in the subsample of male-headed households than the overall ATET coefficient suggests a greater impact on male-headed households. Conversely, a lower ATET coefficient in the subsample of male-headed households than the ATET coefficient in the overall sample suggests a greater impact on female-headed households.

a) Extension service provider (public vs. private)

Households treated by the public provider show an improvement in several domains (Table 15). Compared to the control group, they have significantly higher: gross crop income per capita (US$68/ 338 ZK); asset ownership (durable assets by 7 per cent and housing assets by 10 per cent); total value of crop production (US$221/1,098 ZK); use of agricultural inputs (seed adoption by 21 percentage points, fertiliser use by 23 percentage points and use of hired labour by 10 percentage points); probability of selling crops (9 percentage points); revenues from crop sales (US$291/1,445 ZK); resilience (crop diversification by 13 per cent and ability to recover from non-climate shocks by 13 percentage points); and food and nutrition security (MAHFP by 6 per cent, HDDS by 3 per cent, and FIES by -7 per cent). In contrast, there is no statistically significant impact on these domains for households treated by the private provider.

Households treated by private providers show greater improvements in the adoption of good agricultural practices and input intensification. Compared to the control group, they have increased the probability of adopting minimum/reduced tillage (4 percentage points) and the probability of

[65] Sitko and Chamberlin (2015) use five categories to classify farm size (0-2 ha; 2-5 ha; 5-10 ha; 10-20 ha; more than 20 ha) and consider farms above 5 ha as medium- and large-scale farmers.

using improved, hybrid and recycled cassava planting material (11 percentage points). Similarly, the values per ha of fertilisers and total input expenditure of these households are 46 per cent (US$51/ 253 ZK) and 65 per cent (US$40/199 ZK) higher than those of the control group. The estimated impacts for the same variables in the subsample of public provider beneficiaries are lower and/or insignificant.

Although focus group discussions in the Final Evaluation Programme (MoA, 2021) report a greater contribution to economic goal and food security indicators for households treated by a private provider, we observe a greater attributable impact on economic goal for households treated by the public provider. These results suggest that while beneficiaries of the public provider experience higher improvements in terms of economic goal, crop production, market access, resilience, and food and nutrition security, beneficiaries of the private providers show higher impacts on the adoption of agricultural practices promoted by the Programme. There also seems to be difference in the crop-specific impacts, with public provider having greater impacts on maize, and private provider more on cassava (for example in the adoption of non-traditional planting material). These findings provide evidence that the two types of service providers are complementary to each other in delivering results.

Table 15: Heterogeneous impact by the extension service provider (public and private).

Impact indicator	Public provider			Private provider		
	Impact	POM	N	Impact	POM	N
Economic Goal:						
Gross crop income per capita (US$)[(a)]	51 ***	133	1,292	26	118	755
Durable assets index[(c)]	7 **	0.14	1,305	8	0.13	761
Housing characteristics index[(c)]	10 **	0.30	1,305	0	0.32	761
S01 – Productive capacities:						
Total value of crop production (US$) [(a)]	17 **	1,300	1,292	6	992	755
Minimum /reduced tillage (zero tillage, planting basins and ripping)[(b)]	2 *	1	1,305	4 *	2	761
Crop rotation with legumes[(b)]	5 *	79	1,305	6	71	761
Non-traditional planting material (Improved/Hybrid/Recycled)[(b)]	21 ***	71	1,297	9	71	754
Non-traditional planting material for cassava (Improved/Hybrid/Recycled)[(b)]	5	8	840	11 *	9	468
Non-traditional planting material for maize (Improved/Hybrid/Recycled)[(b)]	17 ***	76	1,146	3	79	635
Use of fertilisers[(b)]	23 ***	72	1,305	1	79	761
Total value of fertilisers per ha (US$) [(a)]	22 ***	140	1,053	46 **	110	567
Use of hired labour [(b)]	10 ***	55	1,305	0	49	761
Total input expenditure per ha (US$)[(a)§]	27 **	83	1,078	65 **	62	595

Impact indicator	Public provider			Private provider		
	Impact	POM	N	Impact	POM	N
Total input value per ha (US$)[(a)§]	15 ***	658	1,305	8	672	761
S02 – Market access:						
Probability of selling crops[(b)]	9 ***	84	1,292	5	81	757
Share of sales value in total value of production (%)[(c)]	5 **	51	1,107	9	48	617
Revenues from crop sales (US$)[(a)]	62 ***	469	1,109	45 *	441	617
Participation in farmer organizations[(b)]	25 ***	62	1,305	9	66	761
S03 – Resilience:						
Crop diversification index (Gini-Simpson index)[(c)]	13 ***	0.46	1,305	- 5	0.56	761
Ability to recover from the most severe non-climate shock during the programme[(b)]	13 ***	52	1,142	0	58	658
MT – Food security and nutrition:						
Months of Adequate Household Food Provisions (MAHFP)[(c)]	6 ***	9.33	1,305	0	9.74	761
Household Dietary Diversity Score (HDDS)[(c)]	3 *	8.44	1,305	3	8.20	761
Food Insecurity Experience Scale (FIES)[(c)]	- 7 **	4.79	1,305	6	4.44	761
MT - Women's empowerment:						
Probability of women to own majority of durable goods[(b)]	1	15	1,238	4 **	11	709

Note: Impacts are reported in per cent or percentage point change and are estimated using IPWRA regressions with standard errors clustered at ward level, including covariates as described in Appendix II. (a) Indicates that a logarithmic transformation was used and the impact is reported in per cent change; (b) indicates that the variable assumes the value of one or zero and the impact is reported in percentage point change; (c) indicates that the impact is reported in per cent change. POM indicates potential outcome beneficiary households would have had if they had not benefited from the programme and it is expressed in the outcome's original unit. Fertiliser indicators include both organic and inorganic. § Agricultural inputs include planting material, fertilisers, phytosanitary products, labour (hired and family), land rental and other inputs (e.g. transport costs, expenditure on storage, animal or equipment rental cost, etc.). Monetary values are expressed in 2015 PPP US$. Asterisks indicate the level of statistical significance: * at 10 per cent; ** < at 5 per cent; *** at 1 per cent.

b) Farm size (smallest, small, medium/large)

Classifying the sample into three categories explained above (i.e. smallest, small, medium/large), we find that the impact on agricultural production is generally higher in the subsample of small farms, while the impact on economic indicators is generally higher in the subsample of medium/large farms (Table 16). For example, the total value of crop production and maize yields have increased by 14 per cent (US$132/656 ZK) among small treated farms compared with the small farms in the control group, while the estimated impacts are not statistically significant in the subsamples of smallest and medium/large farms. In contrast, the estimated impact on gross crop income per capita is 23 per cent (US$28/139 ZK) for small farms, and 49 per cent (US$104/517 ZK) for medium/large farms.

In contrast, the impacts on the adoption of good agricultural practices are generally higher in smallest and small farm categories. The probability that beneficiaries with small farms adopt CA partially (at least one component) and soil cover practices is 5 and 9 percentage points higher, respectively, than the control group with small farms, while it is not significantly different in the other sub-samples. Conversely, the impacts on the probability of adopting crop rotation with or without legumes is significantly higher in the medium/large category only. The impacts on the adoption of non-traditional planting material are significant for all farm size categories, with the largest coefficient observed for the smallest farm size (17 percentage points). When estimated separately for cassava and maize, we find that the main impact on smallest farms is observed through non-traditional cassava variety adoption (18 percentage points), while it is driven by maize (9 percentage points) for the small farms.

Regarding the impact on the use of fertilisers and labour, medium and large farms show the highest impact. Beneficiaries' probability of using fertilisers has increased by 13 and 14 percentage points respectively in small and medium/large farm categories. The value of labour per ha has significantly increased only among small farms (by 16 per cent), while the value of fertilisers per ha has increased only among medium/large farms (by 20 per cent). Although the total input value per ha has increased for all three farm size categories, the largest impact is observed among the medium/large group: impact is around 15 per cent for smallest and small farms, and 30 per cent for medium/large farms.

The increasing input use among beneficiaries in the medium/large farm category is not surprising, as they might have fewer financial and operational constraints, facilitating a greater impact of S3P among these farmers (Mulwa et al., 2021). The positive impact of S3P on the adoption of non-traditional planting materials among farmers cultivating less than one ha is more notable, as this is an important finding considering the critical role of cassava for these farmers.

The impacts on market access indicators are higher among small and medium/large farms. Compared to the control group, the probability of selling any crop is 13 percentage points higher among small farms, and 7 percentage points higher among medium/large farms. The share of production value that is marketed is higher only among beneficiaries in the medium/large category. The revenues from crop sales have increased by 32 per cent (US$118/586 ZK) among small farms and by 51 per cent (US$472/2,345 ZK) among medium/large farms. None of these significantly differ from the control group in the smallest farm category. The beneficiaries in the smallest category are 23 percentage points more likely to participate in farmer organizations compared to the control group, which is higher than the impact for small and medium/large farms (11 and 19 percentage points, respectively). This suggests that although S3P interventions on market access have not been felt by beneficiaries with smallest farms, those related to social capital have been inclusive of this category.

Table 16: Heterogenous impact by farm size (smallest, small and medium/large).

Impact indicator	Smallest (< 1 ha)			Small (1-2 ha)			Medium/Large (>2 ha)		
	Impact	POM	N	Impact	POM	N	Impact	POM	N
Economic Goal:									
Gross crop income per capita (US$)[(a)]	3	57	438	23 ***	121	776	49 ***	213	706
Durable assets index[(c)]	0	0.08	458	9 *	0.11	777	25 ***	0.16	708
S01 – Agricultural production and productivity:									
Total value of crop production (US$)[(a)]	- 12	416	438	14 *	944	776	10	2,368	706
Yield of maize (kg/ha)[(a)]	23	1,636	297	14 **	2,122	708	6	2,368	683
Partial adoption of CA (at least one technique)[(b)]	3	89	458	5 *	90	777	4	91	708
Soil cover (growing cover crops or residue management)[(b)]	- 9	60	458	9 **	59	777	2	73	708
Crop rotation with or without legumes[(b)]	6	75	458	3	83	777	8 *	81	708
Non-traditional planting material (Improved/Hybrid/Recycled)[(b)]	17 **	53	449	11 ***	77	777	16 ***	78	706
Non-traditional planting material for cassava (Improved/Hybrid/Recycled)[(b)]	18 ***	0	240	7 *	7	469	8	8	457
Non-traditional planting material for maize (Improved/Hybrid/Recycled)[(b)]	10	66	300	9 **	79	711	6	88	686
Use of fertilisers [(b)]	10	54	458	13 ***	80	777	14 ***	82	708
Total value of fertilisers per ha (US$)[(a)]	27	192	233	5	167	641	20 *	121	649
Total value of labour per ha (US$)[(a)]	15	503	458	16 **	428	777	17	296	708
Total input value per ha (US$)[(a)§]	15 **	780	458	16 ***	713	777	30 ***	493	708
S02 – Market access:									
Probability of selling crops[(b)]	0	63	441	13 ***	81	776	7 **	91	708
Share of sales value in total value of production (%)[(c)]	2	40	257	2	50	683	9 ***	53	684

Impact indicator	Smallest (< 1 ha)			Small (1-2 ha)			Medium/Large (>2 ha)		
	Impact	POM	N	Impact	POM	N	Impact	POM	N
Revenues from crop sales (US$)[(a)]	12	154	258	32 ***	369	684	51 ***	925	684
Probability of participating in farmer organizations[(b)]	23 ***	44	458	11 **	71	777	19 ***	71	708
S03 – Resilience:									
Crop diversification index (Gini-Simpson index)[(c)]	8	0.37	458	8 **	0.49	777	10 **	0.51	708
Ability to recover from the most severe non-climate shock during the programme[(b)]	3	52	394	2	58	681	8 *	59	632
MT – Food security and nutrition:									
Months of Adequate Household Food Provisions (MAHFP)[(c)]	7	8.21	458	2	9.46	777	4 **	9.96	708
Household Dietary Diversity Score (HDDS)[(c)]	- 2	7.63	458	1	8.49	777	6 **	8.55	708
MT - Women's empowerment:									
Women's control of revenues from crop sales[(b)]	5	30	258	- 1	27	684	3 *	8	684
Probability of women to own land[(b)]	- 2	34	411	5 **	24	747	7 ***	9	694
Probability of women to own livestock[(b)]	14 *	36	279	1	34	645	- 2	21	636

Note: Impacts are reported in per cent or percentage point change and are estimated using IPWRA regressions with standard errors clustered at ward level, including covariates as described in Appendix II. (a) Indicates that a logarithmic transformation was used ant the impact is reported in per cent change; (b) indicates that the variable assumes the value of one or zero and the impact is reported in percentage point change; (c) indicates that the impact is reported in per cent change. POM indicates potential outcome beneficiary households would have had if they had not benefited from the programme and it is expressed in the outcome's original unit. Fertiliser indicators include both organic and inorganic. Labour indicators include both hired and family unless otherwise specified. § Agricultural inputs include planting material, fertilisers, phytosanitary products, labour, land rental and other inputs (e.g. transport costs, expenditure on storage, animal or equipment rental cost, etc.). Monetary values are expressed in 2015 PPP US$. Asterisks indicate the level of statistical significance: * at 10 per cent; ** at 5 per cent; *** at 1 per cent.

The impact on resilience and food security is mainly observed in medium/large farms. In particular, crop diversification index is 10 per cent higher, MAHFP and HDDS are 6 per cent and 4 per cent higher for the beneficiaries in this group. Finally, the impact on women's empowerment is significant only for a couple of indicators and mostly in the subsamples of small and medium/large farms. In the subsample of smallest farms, the only significant impact on women's empowerment is on female ownership of livestock (14 percentage points).

Overall, these results indicate that the impact of S3P is greater in households that have cultivated more than one ha of land. Except for a few indicators (adoption of non-traditional planting materials, participation in farmer organizations and female livestock ownership), the impact on households farming less than one ha is not statistically significant. These findings suggest that further analyses are needed to identify the structural constraints that limit the full achievement of planned goals by smallest farms.

c) Household head's gender

Table 17 shows the estimated impacts for the subsample of male-headed households and the overall sample (recall that the female headed sample was too small to allow separate analysis). We find that the impacts for the male-headed households are generally very close (within a couple of points) to those in the overall sample, suggesting similar impact for female-headed households. Nevertheless, there are a number of slight differences suggesting heterogeneous impacts based on household head's gender.

For example, the impact on the gross crop income per capita of male-headed households is 43 per cent (US$58/288 ZK) compared to 40 per cent in the overall sample. Similarly, the impacts on total value of fertilisers and other inputs are higher in the subsample of male-headed households (26 and 20 per cent compared to 23 and 18 per cent in the overall sample). Impact on maize yield is also slightly higher for male-headed households.

At the same time, for some indicators the impacts are lower in the subsample of male-headed households, suggesting female-headed households have observed a slightly higher impact. These variables include cassava yield, durable assets, and probability of using fertilisers. The impact on food and nutrition security shows mixed results. The impact for male-headed households on HDDS is higher, while it is lower on MAHFP score. These findings suggest that while female-headed beneficiary households are slightly less likely to have food shortages, male-headed beneficiary households have slightly greater dietary diversity. Overall, the small magnitude of differences by household head's gender suggest that female headed households, when involved, benefited mostly to similar extent from S3P as male headed households.

Table 17: Heterogeneous impact by household head's gender.

Impact indicator	Male-headed household			Overall sample		
	Impact	POM	N	Impact	POM	N
Economic Goal:						
Gross crop income per capita (US$)[a]	43 ***	134	1,609	41 ***	129	1,920
Durable assets index[c]	14 ***	0.14	1,624	17 ***	0.12	1,943
Housing characteristics index[c]	6 *	0.31	1,624	6 *	0.31	1,943
S01 – Agricultural production and productivity:						

Impact indicator	Male-headed household			Overall sample		
	Impact	POM	N	Impact	POM	N
Total value of crop production (US$)(a)	15 **	1,300	1,609	14 **	1,188	1,920
Yield of cassava (kg/ha)(a)	21 *	3,498	898	25 **	3,395	1,034
Yield of maize (kg/ha)(a)	12 **	2,230	1,426	10 **	2,165	1,688
Crop rotation with legumes(b)	6 **	76	1,624	7 **	58	1,943
Non-traditional planting material (Improved, Hybrid and Recycled)(b)	14 ***	74	1,617	15 ***	73	1,932
Non-traditional planting material for cassava (Improved/Hybrid/Recycled)(b)	6 *	9	991	7 **	8	1,167
Non-traditional planting material for maize (Improved/Hybrid/Recycled)(b)	8 ***	82	1,434	9 ***	81	1,697
Use of fertilisers (b)	14 ***	76	1,624	16 ***	74	1,943
Total value of fertilisers per ha (US$)(a)	26 ***	132	1,299	23 ***	136	1,523
Use of hired labour(b)	7 **	52	1,624	7 **	53	1,943
Total value of labour per ha (US$)(a)	14 **	372	1,624	13 **	296	1,943
Total input value per ha (US$)(a)§	20 ***	614	1,624	18 ***	633	1,943
S02 – Market access:						
Probability of selling crops(b)	10 ***	82	1,613	8 ***	83	1,943
Share of sales value in total value of production (%)(c)	5 ***	52	1,384	5 ***	51	1,624
Revenues from crop sales (US$)(a)	48 ***	539	1,386	48 ***	488	1,626
Probability of participating in farmer organizations(b)	19 ***	65	1,624	20 ***	63	1,943
S03 – Resilience:						
Crop diversification index (Gini-Simpson index)(c)	13 ***	0.47	1,624	11 ***	0.47	1,943
Ability to recover from the most severe non-climate shock during the programme(b)	8 ***	55	1,417	9 ***	54	1,707

Impact indicator	Male-headed household			Overall sample		
	Impact	POM	N	Impact	POM	N
MT – Food security and nutrition:						
Months of Adequate Household Food Provisions (MAHFP)(c)	3 **	9.57	1,624	5 ***	9.39	1,943
Household Dietary Diversity Score (HDDS)(c)	4 ***	8.33	1,624	3 ***	8.33	1,943
MT - Women's empowerment:						
Probability of women to own land(b)	5 **	6	1,551	4 ***	20	1,852

Note: Impacts are reported in per cent or percentage point change and are estimated using IPWRA regressions with standard errors clustered at ward level, including covariates as described in Appendix II. (a) Indicates that a logarithmic transformation was used and the impact is reported in per cent change; (b) indicates that the variable assumes the value of one or zero and the impact is reported in percentage point change; (c) indicates that the impact is reported in per cent change. POM indicates potential outcome beneficiary households would have had if they had not benefited from the programme and it is expressed in the outcome's original unit. Fertiliser indicators include both organic and inorganic. Labour indicators include both hired and family unless otherwise specified. § Agricultural inputs include planting material, fertilisers, phytosanitary products, labour, land rental and other inputs (e.g. transport costs, expenditure on storage, animal or equipment rental cost, etc.). Monetary values are expressed in 2015 PPP US$. Asterisks indicate the level of statistical significance: * at 10 per cent; ** at 5 per cent; *** at 1 per cent.

6. Conclusions and recommendations

The S3P aimed to increase incomes, food and nutrition security of small-scale farmers by boosting agricultural production, productivity and sales in Luapula, Muchinga and Northern provinces of Zambia. It aimed to reduce rural poverty and achieve food and nutrition security by increasing production, productivity and sales of agricultural products of small scale producers cultivating cassava, groundnuts and mixed beans.

This IA study was conducted as part of IFAD11 IA agenda using data that cover 198 communities and 2,052 households (both beneficiaries and non-beneficiaries) collected in October-November 2020. We analysed S3P impacts on IFAD's goal, strategic objectives and mainstreaming themes using non-experimental impact analysis methods that allow us to attribute impacts to the interventions.

Regarding economic mobility, we find that the S3P had a positive impact on cropping income, ownership of durable assets and housing quality of its beneficiaries. Although it did not have an attributable impact on total income, cropping income makes up 50-60 per cent of beneficiary incomes and is the income source targeted by the programme. We find no attributable impact on productive assets and livestock ownership even though it may have contributed to improvements in these indicators (PCR, 2021).

Regarding the objective of increasing agricultural production, the S3P had a positive impact on beneficiaries' total value of crop production, especially for cassava. It has also increased total production and the yields of cassava of beneficiary households. We find positive spillover impacts on maize, with significant increases in total production comparable to that of cassava. We find no attributable impact on production and yields of groundnuts and mixed beans.

The channels through which production impacts have been realized include increased adoption of crop rotation and crop residue management, which are a subset of practices promoted. There is no attributable impact on the adoption of several other practices, including full adoption of CA. It needs to be noted that the adoption rates of zero and minimum tillage components of CA are remarkably low (around 4 per cent) to allow a robust analysis. By contrast, the S3P has positively affected the adoption of improved planting material, though adoption rates of improved planting material for cassava, groundnut and mixed beans remain low (around 14-17 per cent). The Programme has also increased the use of agricultural inputs, especially of inorganic fertilisers and labour, although it aimed to decrease the use of inorganic fertilisers in favour of organic fertilisers and to reduce the use of agricultural labour. However, the increase in input use is mainly observed for maize, while there is no difference between the treated and control groups for cassava cultivation.

The impact on market access is relatively high compared to the impact on agricultural production. Beneficiary households are significantly more likely to sell crops, and among those that sell, the share of marketed crops and the revenues from it are higher compared to the control group. Potential drivers could be greater participation in farmer organizations by beneficiary households and the linkages created with IFAD-funded programmes that aimed to strengthen the market linkages for small-scale farmers.

The attributable impact on increasing the resilience of beneficiary households in the face of climate and non-climate shocks appears weak. The self-reported ability to recover from shocks (climate and non-climate combined) is higher for beneficiaries, though when analysed separately for climate shocks we find no impact. Nevertheless, the S3P has positively affected crop diversification of beneficiary households, which is an important factor to decrease vulnerability to various shocks.

Regarding IFAD's mainstreaming themes; we find that the S3P had a small yet robust positive impact on multiple indicators of food and nutrition security. Although we find no significant impact for women's empowerment indicators capturing women's sole control of/decision making over resources, we find small yet robust impacts on joint decision making and asset ownership. Noting that S3P was not a gender transformative project, these findings indicate that targeting and including women in programme activities alone are is not sufficient to achieve full empowerment, because other socio-economic factors may remain as barriers.

This study also investigated potentially heterogeneous programme impacts along three dimensions: extension service provider, farm size, and gender of the household head. Findings suggest that public and private service providers are complementary to each other, as the former had a broader impact on several objectives and the latter had impacts focused on immediate extension service outcomes. In terms of farm size, the impacts are more heterogeneous. The impact on the economic goal, revenues from crop sales, input use, and food and nutrition security is higher among the largest landholding category in our sample (i.e. more than two ha), while farms between one and two ha show higher impacts on agricultural production. Finally, the smallest farm category (i.e. less than one ha) has a higher impact on the adoption of improved planting material. Further investments are needed to reduce the structural constraints, which seem to limit impacts for farmers with the smallest farm size. Finally, although some impacts are slightly higher for male-headed households, there are no significant differences between male and female headed households for most indicators.

We present below a list of key lessons learned from the IA findings and recommendations to inform future design and implementation.

Economic mobility is a long term goal. S3P had a positive impact on most of the indicators of production, market access, resilience and food security, though it did not have an attributable impact on total income of beneficiaries. Given that households' resources are scarce and limited, its significant and robust impact on cropping income seem to have come at the expense of income from other activities. Programmes that primarily focus on activities related to cropping income (or other sector specific income), such as S3P, can only expect to achieve the overall economic mobility goal of increasing total income in the longer run in similar resource constrained environments.

Adoption of improved planting material. Although the S3P has increased the adoption of improved planting material for the targeted crops among beneficiary farmers, the adoption rate remains low (around 14-17 per cent). Therefore, the multiplication and diffusion of improved varieties should be continued over time to ensure sustained adoption levels. The related need to invest in developing a comprehensive seed multiplication and distribution system is also recommended by the PCR (IFAD, 2021).

Adoption of good agricultural practices. Good agricultural practices, especially CA, have long been promoted aggressively in Zambia. Our findings indicate that the S3P impact on their adoption is mostly limited to a few practices (crop rotation and crop residue management), and the rate of adoption of some practices (zero and minimum tillage, as well as the full CA package) is almost inexistent. There is a very rich literature to understand the drivers and barriers to the adoption of these practices in SSA and specifically in Zambia. These range from socio-economic factors, to risk aversion, missing markets, climate change and time lags between investment and returns, among others. Therefore, future programme design must take careful stock of locally relevant factors and address them as needed to ensure the sustainable adoption of truly beneficial practices by beneficiaries. Although some factors such as the educational level of farmers or the labour market constraints might be beyond the scope of some development programmes, they should be considered in the design and targeting strategy.

Market access, farmer organizations and synergies with other programmes. Promoting membership of farmer organizations and synergies with complementary programmes is a good practice that should also be implemented in future programmes. This IA study has established that, market access and integrated design has proved to be an important lever for achieving food and nutrition security objectives.

Spillover effects on maize and crop-specific targeting. Although the S3P has not targeted maize, it had significant spillover impacts on this crop, indicating that farmers tend to invest in their main crop even if it is not targeted by the programme. Interventions that target specific crops may be more effective if they incorporate farmers' tendency to use the knowledge for and increase investment in their main crop. In this context, future crop-specific interventions should be complemented with broadly applicable components to address constraints in access to credit, inputs, information, markets and diversification.

The impact of agricultural interventions on food and nutrition security. The results of this IA study show that improvements in agricultural production, crop incomes and crop sales contribute to achieving improved food and nutrition security. However, this result cannot be generalised, as other analyses of nutrition-sensitive agricultural interventions (some specifically in Zambia) find that dietary diversity does not necessarily increase even if diversity in agricultural production does, and market access has been shown to exert a more important impact on food security and nutrition. S3P activities related to nutrition included providing training and information to lead mothers/fathers, who further disseminated it within selected villages, were implemented at a very small scale. The small yet robust impact on nutrition and food security, combined with positive impacts on market participation, suggest that future programmes should scale up the nutrition component jointly with market access component.

Women's empowerment. The findings of the IA study suggest that ensuring women's participation in programme activities is not sufficient to generate a process of women's empowerment, because other social and cultural factors may continue to act as limiting factors. Achieving women's empowerment requires the implementation of specific activities to address the multiple factors (at different levels including awareness raising at the community level), which limit women's empowerment (e.g. gender-transformative programmes).

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Appendix I: Balance diagnostics and tests of matching

Table 18: T-test of matching variables: unmatched vs. matched sample.

Variables	Unmatched sample			Matched sample		
	Treated group	Control group	Standardized difference	Treated group	Control group	Standardized difference
No. of children (<=5) at the beginning of the programme	1.38	1.28	0.09*	1.37	1.41	-0.03
No. of household members in school age (6-14) at the beginning of the programme	1.81	1.57	0.18***	1.79	1.75	0.03
No. of household members in working age (15-64) at the beginning of the programme	2.36	2.17	0.19***	2.34	2.31	0.03
No. of women (>=15) at the beginning of the programme	1.28	1.20	0.12***	1.27	1.27	-0.00
Dependency ratio (no-working age over working age) the beginning of the programme	1.59	1.52	0.06	1.58	1.57	0.01
If any household member has a disability (1=yes)	0.28	0.23	0.11**	0.28	0.24	0.07
Average years of education of household members (>15) at the beginning of the programme	6.45	6.28	0.06	6.44	6.41	0.01
Female household head (1=yes)	0.15	0.18	-0.08*	0.15	0.16	-0.03
Age of household head in years at the beginning of the programme	42.66	39.47	0.24***	42.41	42.41	-0.00
Age of household head in years squared at the beginning of the programme	1,981	1,756	0.19***	1,960	1,951	0.01
Household head is married (1=yes)	0.85	0.81	0.11**	0.85	0.84	0.03
Tropical Livestock Unit at the beginning of the programme	0.73	0.60	0.10**	0.71	0.63	0.05
MCA index of housing characteristics at the beginning of the programme (normalized 0 to 1)	0.18	0.16	0.14***	0.18	0.17	0.04
PCA index of durable assets at the beginning of the programme (normalized 0 to 1)	0.13	0.11	0.13***	0.13	0.13	0.00
PCA index of productive assets at the beginning of the programme (normalized 0 to 1)	0.01	0.01	-0.07	0.01	0.01	0.00
Hectares of land owned by the household	5.52	3.62	0.24***	4.97	4.60	0.06

Variables	Unmatched sample			Matched sample		
	Treated group	Control group	Standardized difference	Treated group	Control group	Standardized difference
Long-run average total seasonal rainfall (1981/2019)	1,102	1,066	0.27***	1,100	1,100	-0.00
Long-run CoV of total seasonal rainfall (1981/2019)	0.12	0.12	-0.20***	0.12	0.12	0.01
Long-run average of seasonal mean temperature (1981/2019)	21.70	21.91	-0.18***	21.71	21.68	0.03
Short-run ratio of CoV of total seasonal rainfall 3 years before the beginning of the programme (2011/13) over the previous 10 years (2001/10)	1.42	1.24	0.32***	1.41	1.39	0.03
Short-run ratio of CoV of average seasonal mean temperature 3 years before the beginning of the programme (2011/13) over the previous 10 years (2001/10)	1.33	1.25	0.18***	1.32	1.33	-0.01
Short-run ratio of CoV of average seasonal max temperature 3 years before the beginning of the programme (2011/13) over the previous 10 years (2001/10)	0.96	0.90	0.14***	0.95	0.97	-0.03
Short-run ratio of CoV of average EVI 3 years before the beginning of the programme (2011/13) over the previous 10 years (2001/10)	0.86	0.76	0.23***	0.85	0.82	0.07
Population density in 2013 (100m grid cells from WorldPop data)	0.32	0.44	-0.20***	0.32	0.30	0.04
Growth rate of population density 10 years before the beginning of the programme	0.49	0.53	-0.04	0.50	0.52	-0.02
Percentage of households engaged in agriculture in the ward (CSO 2010)	0.89	0.88	0.11**	0.89	0.89	-0.01
Percentage of households growing maize in the ward (CS0 2010)	0.64	0.66	-0.10**	0.63	0.63	0.01
Percentage of households growing cassava in the ward (CSO 2010)	0.80	0.72	0.43***	0.80	0.81	-0.07
Percentage of households growing beans in the ward (CS0 2010)	0.43	0.39	0.16***	0.43	0.43	-0.01
Percentage of households growing groundnuts in the ward (CS0 2010)	0.23	0.26	-0.23***	0.23	0.22	0.02
No. of observations	1,054	945	1,999	1,052	891	1,943

Note: Columns (2), (3), (5), and (6) reports mean of the respective group and sample. Columns (4) and (7) named reports the standardized difference. Matched sample is weighted using sample weights generated by PSM. Asterisks indicate the level of statistical significance from t-test: * < 0.10; ** < 0.05; *** < 0.01.

Figure 5: Reduction of bias in matching variables in standardized percentage.

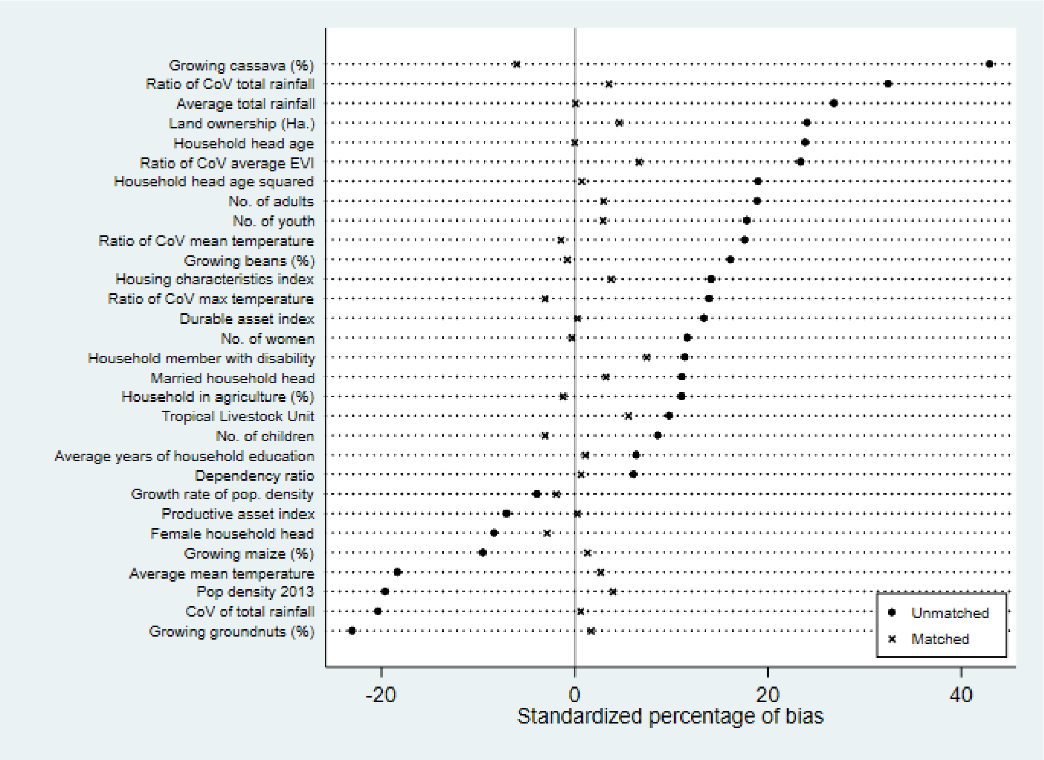
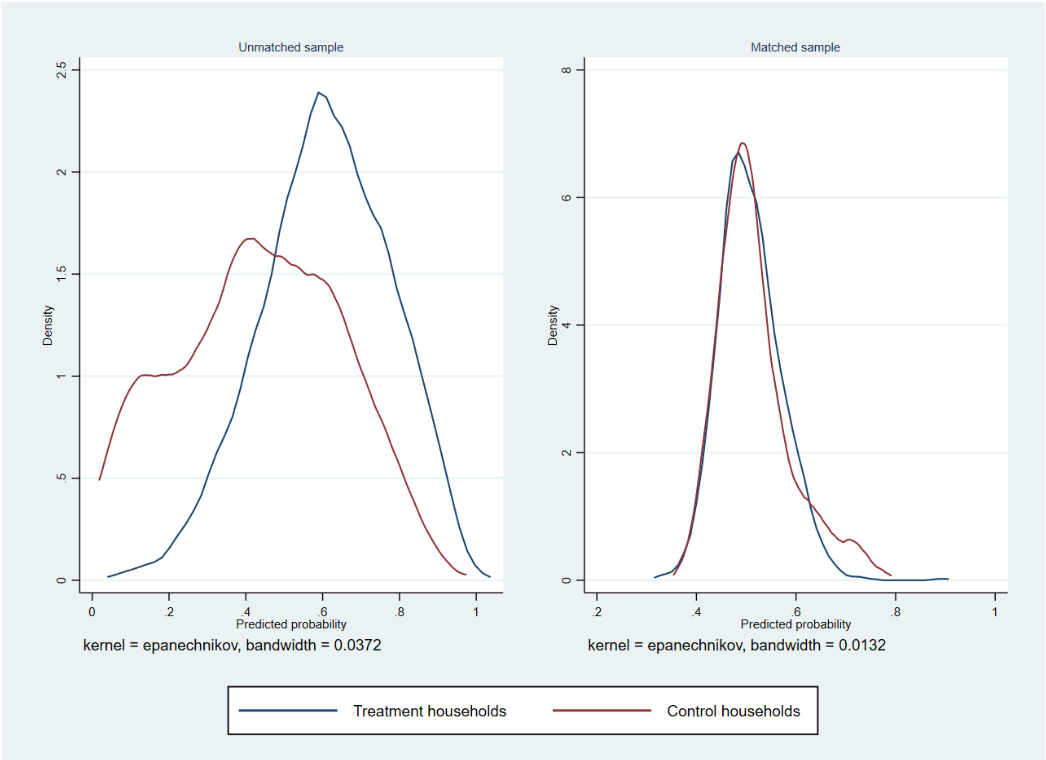


Figure 6: Kernel density of the predicted probability of being selected in the unmatched and matched sample.



Appendix II: List of control variables used in the estimation of the impact

Table 19: List of control variables used in the outcome equation of IPWRA.

Name of variable	Gross income	Assets ownership	Crop production and yields	Agricultural practices and seed adoption	Crop market access	Crop diversification	Ability to recover from shocks	Food and nutrition security	Women's empowerment
No. of children (<=5)	x	x	x	x	x	x	x	x	x
No. of household members in school age (6-14)	x	x	x	x	x	x	x	x	x
No. of household members in working age (15-64)	x	x	x	x	x	x	x	x	x
No. of women (>=15)	x	x	x	x	x	x	x	x	x
Dependency ratio	x	x	x	x	x	x	x	x	x
If any household member has a disability (1=yes)	x	x	x	x	x	x	x	x	x
Average years of education of household members (>=15)	x	x	x	x	x	x	x	x	x
Female household head (1=yes)	x	x	x	x	x	x	x	x	x
Age of household head in years	x	x	x	x	x	x	x	x	x
Age of household head in years squared	x	x	x	x	x	x	x	x	x
If household head is married (1=yes)	x	x	x	x	x	x	x	x	x
TLU at the beginning of the programme	x	x	x	x	x	x	x	x	x
MCA index of housing assets at the beginning of the programme (normalized 0 to 1)	x	x	x	x	x	x	x	x	x

Name of variable	Gross income	Assets ownership	Crop production and yields	Agricultural practices and seed adoption	Crop market access	Crop diversification	Ability to recover from shocks	Food and nutrition security	Women's empowerment
PCA index of durable assets at the beginning of the programme (normalized 0 to 1)	x	x	x	x	x	x	x	x	x
PCA index of productive assets at the beginning of the programme (normalized 0 to 1)	x	x	x	x	x	x	x	x	x
Hectares of land owned by the household	x	x	x	x	x	x	x	x	x
No. of dry dekads within the season 2019/20	x	x	x	x	x	x	x	x	x
Total seasonal rainfall 2019/20	x	x	x	x	x	x	x	x	x
CoV dekadal rainfall within season 2019/20	x	x	x	x	x	x	x	x	x
Avg seasonal mean temperature 2019/20	x	x	x	x	x	x	x	x	x
No. of dekads with a max temp >= 28 within season 2019/20[a]	x	x	x	x	x	x	x	x	x
Population density in 2019 (100m grid cells from WorlPop data)	x	x	x	x	x	x	x	x	x
Density of roads in the 20 Km neighbourhood	x	x	x	x	x	x	x	x	x
Travel time to the next 5-10k city in minutes	x	x	x	x	x	x	x	x	x
If household experienced any non-climate shock in the last 12 months (1=yes)	x	x	x	x	x	x		x	x
If household received any transfer as COVID response (1=yes)	x	x	x	x	x	x	x	x	x
COVID intensity (PCA index normalized 0-1)	x	x	x	x	x	x	x	x	x

Name of variable	Gross income	Assets ownership	Crop production and yields	Agricultural practices and seed adoption	Crop market access	Crop diversification	Ability to recover from shocks	Food and nutrition security	Women's empowerment
If household received any transfer as COVID response interacted with COVID intensity	x	x	x	x	x	x	x	x	x
Province: Luapula; Muchinga; Northern	x	x	x	x	x	x	x	x	x
If SAPP operated in the ward	x	x	x	x	x	x	x	x	x
If CASU operated in the ward	x	x	x	x	x	x	x	x	x
If other sustainable agriculture programmes operated in the ward	x	x	x	x	x	x	x	x	x
Land availability: small; medium; large	x		x	x	x	x			
If FISP depot is available in the ward	x		x	x					
If private fertiliser retailer is available in the ward	x		x	x					
If FRA depot is available in the ward	x				x				
If market place for agricultural products is available in the ward	x				x				
If some portion of land is very/moderately fertile (1=yes)			x						
If some portion of land is irrigated (1=yes)			x						
If any organic or chemical fertiliser is applied (1=yes)			x						
If any phytosanitary product is applied (1=yes)			x						
If any paid labour is used (1=yes)			x						

Note: (a) Estimations of cassava outcomes use the number of dekads with a maximum temperature greater than 31 degrees calculated for the whole year.

Appendix III: Descriptive statistics of sample households

Table 20: List of control variables in IPWRA outcome equation.

Variable	Treated		Control		Difference (T-C)
	Mean	Obs	Mean	Obs	
No. of children (<=5)	0.92	1,052	1.04	891	-0.13***
No. of household members in school age (6-14)	2.03	1,052	1.87	891	0.16***
No. of household members in working age (15-64)	3.56	1,052	3.35	891	0.26***
No. of women (>=15)	1.88	1,052	1.80	891	0.10**
Dependency ratio (no-working age over working age)	1.12	1,052	1.13	891	-0.03
If any household member has a disability (1=yes)	0.28	1,052	0.29	891	-0.01
Average years of education of household members (>=15)	6.69	1,052	6.50	891	0.20*
Female household head (1=yes)	0.15	1,052	0.18	891	-0.03*
Age of household head in years	49.41	1,052	46.94	891	2.68***
Age of household head in years squared	2,603	1,052	2,409	891	215***
If household head is married (1=yes)	0.85	1,052	0.81	891	0.03**
TLU at the beginning of S3P	0.71	1,052	0.72	891	0.02
MCA index of housing assets at the beginning of S3P (normalized 0 to 1)	0.18	1,052	0.16	891	0.02**
PCA index of durable assets at the beginning of S3P (normalized 0 to 1)	0.13	1,052	0.12	891	0.01**
PCA index of productive assets at the beginning of S3P (normalized 0 to 1)	0.01	1,052	0.01	891	-0.00
Hectares of land owned by the household	4.97	1,052	3.92	891	1.29***
No. of dry dekads within the season 2019/20	2.58	1,052	2.97	891	-0.40***
Total seasonal rainfall 2019/20	1,174	1,052	1,102	891	75***
CoV dekadal rainfall within season 2019/20	0.54	1,052	0.57	891	-0.03***
Avg seasonal mean temperature 2019/20	22.24	1,052	22.51	891	-0.27***
No. of dekads with a max temp >= 28 within season 2019/20	2.95	1,052	4.20	891	-1.26***
No. of dekads with a max temp >= 31 from October 2019 to September 2020	8.57	1,052	8.40	891	0.18*
Population density in 2019 (100m grid cells from WorlPop data)	0.41	1,052	0.71	891	-0.30***
Density of roads in the 20 Km neighbourhood	0.06	1,052	0.06	891	-0.00
Travel time to the next 5-10k city in minutes	75.95	1,052	80.67	891	-4.93*
If household experienced any non-climate shock in the last 12 months (1=yes)	0.77	1,052	0.74	891	0.02
If household received any transfer as COVID response (1=yes)	0.11	1,052	0.13	891	-0.01

Variable	Treated		Control		Difference (T-C)
	Mean	Obs	Mean	Obs	
COVID intensity (PCA index normalized 0-1)	0.21	1,052	0.22	891	-0.00
Provice of Luapula	0.35	1,052	0.31	891	0.05**
Provice of Muchinga	0.29	1,052	0.34	891	-0.05**
Provice of Northern	0.36	1,052	0.36	891	0.00
If SAPP operated in the ward (1=yes)	0.40	1,052	0.39	891	0.01
If CASU operated in the ward (1=yes)	0.19	1,052	0.16	891	0.03
If other sustainable agriculture programmes (1=yes)	0.35	1,052	0.22	891	0.13***
If FISP distribution depot is available in the ward (1=yes)	0.05	1,052	0.11	891	-0.06***
If Private fertiliser retailer is available in the ward (1=yes)	0.39	1,052	0.36	891	0.03
If FRA depot is available in the ward (1=yes)	0.63	1,052	0.46	891	0.17***
If market place for agricultural products is available in the ward (1=yes)	0.25	1,052	0.17	891	0.08***
Land availability (< 1 ha)	0.26	1,052	0.42	891	-0.16***
Land availability (1-2 ha)	0.38	1,052	0.34	891	0.04*
Land availability (> 2 ha)	0.37	1,052	0.24	891	0.13***
If a portion of land is very or moderately fertile (1=yes)	0.92	1,052	0.81	891	0.11***
If a portion of cassava land is very or moderately fertile (1=yes) (only in crop analysis)	0.89	824	0.78	627	0.11***
If a portion of groundnut land is very or moderately fertile (1=yes) (only in crop analysis)	0.84	634	0.78	430	0.07***
If a portion of mixed bean land is very or moderately fertile (1=yes) (only in crop analysis)	0.84	380	0.79	243	0.05*
If a portion of maize land is very or moderately fertile (1=yes) (only in crop analysis)	0.83	987	0.72	710	0.11***
If a portion of land is irrigated (1=yes)	0.10	1,052	0.05	891	0.05***
If a portion of cassava land is irrigated (1=yes) (only in crop analysis)	0.01	824	0.01	627	0.01
If a portion of groundnut land is irrigated (1=yes) (only in crop analysis)	0.00	634	0.00	430	0.00
If a portion of mixed bean land is irrigated (1=yes) (only in crop analysis)	0.00	380	0.01	243	-0.00
If a portion of maize land is irrigated (1=yes) (only in crop analysis)	0.01	987	0.01	710	0.00
If farmer used phytosanitary products (1=yes)	0.08	1,052	0.08	891	0.00
If farmer used phytosanitary products for cassava (1=yes) (only in crop analysis)	0.00	824	0.00	627	0.00
If farmer used phytosanitary products for groundnut (1=yes) (only in crop analysis)	0.00	634	0.00	430	0.00

Variable	Treated		Control		Difference (T-C)
	Mean	Obs	Mean	Obs	
If farmer used phytosanitary products for mixed bean (1=yes) (only in crop analysis)	0.03	380	0.07	243	-0.03*
If farmer used phytosanitary products for maize (1=yes) (only in crop analysis)	0.03	987	0.04	710	-0.01
If any fertilizer is applied (1=yes)	0.89	1,052	0.66	891	0.23***
If any fertilizer is applied to cassava (1=yes) (only in crop analysis)	0.05	824	0.05	627	-0.00
If any fertilizer is applied to groundnut (1=yes) (only in crop analysis)	0.05	634	0.03	430	0.03**
If any fertilizer is applied to mixed beans (1=yes) (only in crop analysis)	0.23	380	0.13	243	0.10***
If any fertilizer is applied to maize (1=yes) (only in crop analysis)	0.94	987	0.79	710	0.16***
If any type of paid labour is used (1=yes)	0.59	1,052	0.44	891	0.15***
If any type of paid labour is used for cassava (1=yes) (only crop analysis)	0.38	820	0.29	626	0.09***
If any type of paid labour is used for groundnut (1=yes) (only crop analysis)	0.31	634	0.26	430	0.05*
If any type of paid labour is used for mixed beans (1=yes) (only crop analysis)	0.36	380	0.35	243	0.00
If any type of paid labour is used for maize (1=yes) (only crop analysis)	0.55	987	0.41	710	0.14***

Note: Columns (2) and (4) report the mean in the sample dividing by treated and control households, columns (3) and (5) report the number of observations for each variable, and column (4) reports the difference between treated and control households' averages. The sample is weighted using IPW analytical weights. Asterisks indicate the level of statistical significance from t-test: * < 0.10; ** < 0.05; *** < 0.01.

Table 21: Impact indicators.

Variable	Treated		Control		Difference (T-C)
	Mean	Obs	Mean	Obs	
Economic goal (EG)					
Total gross income per capita (US$)	621	1,052	594	891	26
Gross cropping income per capita (US$)	289	1,046	208	874	81***
Durable assets index (0-1 scale)	0.15	1,052	0.11	891	0.03***
Productive assets index (0-1 scale)	0.02	1,052	0.02	891	-0.00
Housing characteristics index (0-1 scale)	0.33	1,052	0.26	891	0.07***
Tropical Livestock Unit (score)	0.53	1,052	0.49	891	0.04
Productive capacity (SO1)					
Production and productivity					
Total value of crop production (US$)	2,107	1,046	1,481	874	626***
Total value of crop production per ha (US$)	1,083	1,046	1,043	874	40
Quantity harvested for cassava (kg)	2,950	591	2,561	443	389*
Crop yield for cassava (kg/ha)	5,682	591	5,278	443	404
Quantity harvested for groundnut (kg)	136	615	143	422	-7
Crop yield for groundnut (kg/ha)	518	615	625	422	-107***

Variable	Treated		Control		Difference (T-C)
	Mean	Obs	Mean	Obs	
Quantity harvested for mixed beans (kg)	197	364	182	235	15
Crop yield for mixed beans (kg/ha)	404.41	364	440.65	235	-36.24
Quantity harvested for maize (kg)	3,161	985	2,138	703	1,023***
Crop yield for maize (kg/ha)	2,877	985	2,411	703	466***
Conservation agriculture (reduced tillage; soil cover, crop diversification)					
Full adoption (all three techniques) (%)	02	1,052	05	891	-03***
Partial adoption (at least one technique) (%)	95	1,052	93	891	02*
Tillage methods					
Zero tillage (%)	03	1,052	04	891	-01
Minimum/reduced tillage (zero tillage, planting basins and ripping) (%)	04	1,052	09	891	-05***
- Planting basins (%)	01	1,052	05	891	-04***
- Ripping (%)	00	1,052	01	891	-00
Soil cover practices					
Soil cover (growing cover crops or residue management) (%)	68	1,052	60	891	08***
Growing cover crops (%)	01	1,052	01	891	-00
Crop residue management (%)	68	1,052	60	891	08***
- residues left in the field and then incorporated (%)	51	1,052	35	891	15***
- residues cut and spread on the field (%)	04	1,052	03	891	01
- residues left in the field (%)	24	1,052	28	891	-04*
Crop diversification					
Crop diversification (crop rotation and/or intercropping with or without legumes) (%)	87	1,052	81	891	06***
Crop rotation with or without legumes (%)	81	1,052	73	891	08***
Crop rotation with legumes (%)	65	1,052	51	891	14***
Crop rotation with fallow land (%)	37	1,040	32	857	04*
Intercropping with or without legumes (%)	27	1,052	25	891	01
Intercropping with legumes (%)	13	1,052	14	891	-01
Other good agricultural practices					
Fallow land during the season (%)	52	1,052	42	891	09***
Agroforestry (%)	26	1,052	27	891	-01
Erosion control measures (%)	39	1,052	36	891	03
Adoption of planting material for all cultivated crops					
Non-traditional planting material (improved, hybrid and recycled (%)	88	1,050	63	882	24***
- Improved (%)	10	1,050	07	882	03**
- Hybrid (%)	79	1,050	52	882	27***
- Recycled (%)	16	1,050	13	882	03*
Drought resilient (%)	61	1,033	43	866	18***

Variable	Treated		Control		Difference (T-C)
	Mean	Obs	Mean	Obs	
Adoption of planting material for cassava					
Non-traditional planting material (improved, hybrid and recycled (%)	15	669	05	498	10***
- Improved (%)	06	669	02	498	04***
- Hybrid (%)	02	669	01	498	01*
- Recycled (%)	07	669	03	498	04***
Drought resilient (%)	13	652	05	493	08***
Chila variety (%)	01	669	00	498	01**
Mweru variety (%)	06	669	01	498	05***
Adoption of planting material for groundnut					
Non-traditional planting material (improved, hybrid and recycled (%)	14	634	13	430	01
- Improved (%)	01	634	00	430	01**
- Hybrid (%)	08	634	05	430	03**
- Recycled (%)	05	634	08	430	-03**
Drought resilient (%)	08	615	07	419	01
MGV5 variety (%)	02	634	00	430	01**
Adoption of planting material for mixed beans					
Non-traditional planting material (improved, hybrid and recycled (%)	16	380	17	243	-01
- Improved (%)	01	380	01	243	00
- Hybrid (%)	06	380	02	243	05***
- Recycled (%)	09	380	14	243	-06**
Drought resilient (%)	09	372	07	237	02
Mbereshi variety (%)	02	380	00	243	01
Lukupa variety (%)	01	380	00	243	00
Adoption of planting material for maize					
Non-traditional planting material (improved, hybrid and recycled (%)	89	987	70	710	19***
- Improved (%)	04	987	06	710	-02
- Hybrid (%)	82	987	59	710	23***
- Recycled (%)	04	987	06	710	-02
Drought resilient (%)	68	813	50	615	18***
Use of inputs for all cultivated crops					
Use of fertilisers (organic and inorganic) (%)	89	1,052	66	891	23***
Use of organic fertilisers (%)	03	1,052	03	891	-01
Use of basal fertilisers (%)	89	1,052	65	891	24***
Use of topdressing fertilisers (%)	89	1,052	64	891	25***
Total value of fertilisers used (US$)	476	940	375	583	101***
Total value of fertilisers used per ha (US$)	213	940	206	583	6
Hired labour (%)	59	1,052	44	891	15***

Variable	Treated		Control		Difference (T-C)
	Mean	Obs	Mean	Obs	
Total value of labour (hired and family) (US$)	1,098	1,052	832	891	266***
Total value of labour (hired and family) per ha (US$)	568	1,052	552	891	15
Total input expenditure (US$)	479	913	377	668	101***
Total input expenditure per ha (US$)	177	913	194	668	-17
Total value of input (US$)	1,800	1,052	1,267	891	533***
Total value of input per ha (US$)	876	1,052	807	891	70***
Use of inputs for cassava:					
Use of fertilisers (organic and inorganic) (%)	05	824	05	627	-00
Use of organic fertilisers (%)	00	824	00	627	-00
Use of basal fertilisers (%)	05	824	05	627	00
Use of topdressing fertilisers (%)	04	824	04	627	00
Total value of fertilisers used (US$)	121	39	68	29	53 **
Total value of fertilisers used per ha (US$)	152	39	154	29	-2
Hired labour (%)	38	820	29	626	09***
Total value of labour (hired and family) (US$)	419	820	381	626	38
Total value of labour (hired and family) per ha (US$)	595	820	557	626	38
Total input expenditure (US$)	106	379	105	228	1
Total input expenditure per ha (US$)	103	379	118	228	-15
Total value of input (US$)	469	824	431	627	37
Total value of input per ha (US$)	656	824	637	627	19
Use of inputs for groundnut:					
Use of fertilisers (organic and inorganic) (%)	05	634	03	430	03**
Use of organic fertilisers (%)	00	634	00	430	00
Use of basal fertilisers (%)	05	634	03	430	02**
Use of topdressing fertilisers (%)	02	634	03	430	-00
Total value of fertilisers used (US$)	50	34	49	13	1
Total value of fertilisers used per ha (US$)	223	34	322	13	-99*
Hired labour (%)	31	634	26	430	05*
Total value of labour (hired and family) (US$)	198	634	172	430	26**
Total value of labour (hired and family) per ha (US$)	813	634	834	430	-20
Total input expenditure (US$)	50	352	45	225	4
Total input expenditure per ha (US$)	169	352	201	225	-32*
Total value of input (US$)	237	634	208	430	29**
Total value of input per ha (US$)	970	634	1,015	430	-46
Use of inputs for mixed beans:					
Use of fertilisers (organic and inorganic) (%)	23	380	13	243	10***
Use of organic fertilisers (%)	01	380	00	243	00
Use of basal fertilisers (%)	22	380	12	243	10***

Variable	Treated		Control		Difference (T-C)
	Mean	Obs	Mean	Obs	
Use of topdressing fertilisers (%)	19	380	12	243	08***
Total value of fertilisers used (US$)	100	88	93	31	7
Total value of fertilisers used per ha (US$)	264	88	291	31	-27
Hired labour (%)	36	380	35	243	00
Total value of labour (hired and family) (US$)	187	380	197	243	-10
Total value of labour (hired and family) per ha (US$)	547	379	532	243	14
Total input expenditure (US$)	94	243	90	156	4
Total input expenditure per ha (US$)	272	243	190	156	82
Total value of input (US$)	272	380	259	243	13
Total value of input per ha (US$)	746	379	680	243	66
Use of inputs for maize:					
Use of fertilisers (organic and inorganic) (%)	94	987	79	710	16***
Use of organic fertilisers (%)	00	987	01	710	-01*
Use of basal fertilisers (%)	94	987	78	710	16***
Use of topdressing fertilisers (%)	94	987	78	710	16***
Total value of fertilisers used (US$)	449	932	364	570	85***
Total value of fertilisers used per ha (US$)	432	932	388	570	44***
Hired labour (%)	55	987	41	710	14***
Total value of labour (hired and family) (US$)	447	987	359	710	88***
Total value of labour (hired and family) per ha (US$)	569	987	530	710	39
Total input expenditure (US$)	391	820	336.62	541	54*
Total input expenditure per ha (US$)	305	820	331.68	541	-27
Total value of input (US$)	1,056	987	781	710	274***
Total value of input per ha (US$)	1,148	987	990	710	158***
Market access (S02)					
All cultivated crops					
Probability of selling crops (%)	90	1,048	78	877	13***
Share of sales value in total value of production (%)	56	946	48	678	08***
Revenues from crop sales (US$)	1,350	948	911	678	440***
Participation in farmer group (%)	83	1,052	51	891	33***
Cassava					
Probability of selling crops in all forms (%)	46	591	33	442	13***
Probability of selling raw cassava (%)	08	591	07	443	01
Probability of selling cassava chips (%)	34	591	25	443	09***
Probability of selling cassava flour (%)	05	591	03	443	02*
Share of sales value in total value of production (%)	46	271	43	144	02
Revenues from crop sales (US$)	290	271	370	144	-80

Variable	Treated		Control		Difference (T-C)
	Mean	Obs	Mean	Obs	
Groundnut					
Probability of selling crops (%)	59	615	56	422	02
Share of sales value in total value of production (%)	58	361	58	232	-00
Revenues from crop sales (US$)	182	361	197	232	-15
Mixed beans					
Probability of selling crops (%)	63	239	66	159	-03
Share of sales value in total value of production (%)	62	239	63	159	-00
Revenues from crop sales (US$)	355	239	421	159	-66
Maize					
Probability of selling crops (%)	84	985	66	703	18***
Share of sales value in total value of production (%)	65	823	58	488	07***
Revenues from crop sales (US$)	1,085	823	777	488	308***
Resilience (S03)					
Income diversification (Gini-Simpson index) (0-1 scale)	0.39	1,052	0.38	891	0.00
Crop diversification (Gini-Simpson index) (0-1 scale)	0.53	1,052	0.43	891	0.09***
Ability to recover from the most sever shock (climate and non-climate) during the programme	71	991	63	807	09***
Ability to recover from the most severe climate shock during the programme (%)	49	702	48	536	01
Ability to recover from the most severe non-climate shock during the programme (%)	63	948	55	750	07***
Exposure corrected ability to recover from the most severe shock (climate and non-climate) experienced in the last 12 months	2.30	878	2.40	716	-0.10
Exposure corrected ability to recover from the most severe climate shock (last 12 months)	2.62	479	2.69	374	-0.07
Exposure corrected ability to recover from the most severe non-climate shock (last 12 mo.)	2.15	799	2.23	650	-0.08
Food security (MT)					
Months of Adequate Household Food Provisions (MAHFP) (0-12 scale)	9.83	1,052	9.41	891	0.42***
Household Dietary Diversity Score (HDDS) (0-12 scale)	8.59	1,052	8.09	891	0.51***
Food Insecurity Experience Scale (FIES) (0-8 scale)	4.53	1,052	5.18	891	-0.66***
- FIES – Worried to not have enough food (%)	73	1,052	80	891	-07***
- FIES – Unable to eat healthy and nutritional food (%)	72	1,050	80	882	-07***
- FIES – Ate only a few kinds of foods (%)	72	1,051	81	887	-09***

Variable	Treated		Control		Difference (T-C)
	Mean	Obs	Mean	Obs	
- FIES – Skip a meal (%)	58	1,048	66	891	-08***
- FIES – Ate less than thought (%)	65	1,051	74	882	-09***
- FIES – Ran out of food (%)	43	1,051	53	891	-10***
- FIES – Hungry but did not eat (%)	47	1,050	56	890	-10***
- FIES – Without eating for a whole day (%)	24	1,050	30	890	-06***
Food Consumption Score (FCS) (score)	54.44	1,052	51.48	891	2.96***
- FCS – Poor (%)	01	1,052	02	891	-00
- FCS – Borderline (%)	11	1,052	16	891	-05***
- FCS – Acceptable (%)	88	1,052	83	891	05***
Women's empowerment (MT)					
Probability of women working in wage employment	0.13	1,052	0.13	891	0.00
Decision-making on income sources: at least one income source by					
- Only female (%)	51	1,052	50	891	01
- Jointly with men (%)	73	1,052	62	891	10***
Control of revenues from crop sales: at least one crop by					
- Only female (%)	20	948	20	678	-00
- Jointly with men (%)	61	948	49	678	12***
Land ownership: at least one plot by					
- Only female (%)	23	1,022	22	830	01
- Jointly with men (%)	38	1,022	32	830	06***
Livestock ownership: at least one category by					
- Only female (%)	29	891	30	669	-00
- Jointly with men (%)	52	891	38	669	14***
Durable goods ownership: majority by					
- Only female (%)	16	1,014	17	823	-02
- Jointly with men (%)	38	1,014	25	823	12***
Productive goods ownership: majority by					
- Only female (%)	06	351	11	280	-05**
- Jointly with men (%)	34	351	20	280	14***
Participation in farmer groups					
- Only female (%)	26	877	28	465	-02
- Jointly with men (%)	38	877	28	465	10***

Note: Columns (2) and (4) report the mean in the sample dividing by treated and control households, columns (3) and (5) report the number of observations for each variable, and column (4) reports the difference between treated and control households' averages. The sample is weighted using IPW analytical weights. Asterisks indicate the level of statistical significance from t-test: * < 0.10; ** < 0.05; *** < 0.01.

Appendix IV: Inverse-Probability-Weighted Regression Adjustment results

Table 22: S3P impacts on Economic Goal (EG).

Impact indicator	ATET	POM	Observations
Total gross income per capita (US$)[a]	0.01 (0.06)	5.92*** (0.06)	1,943 [T 1,052; C 891]
Gross cropping income per capita (US$)[a]	0.34*** (0.08)	4.86*** (0.08)	1,920 [T 1,046; C 874]
Durable assets index (0-1)	0.02*** (0.01)	0.12*** (0.01)	1,943 [T 1,052; C 891]
Productive assets index (0-1)	0.00 (0.00)	0.02*** (0.00)	1,943 [T 1,052; C 891]
Housing characteristics index (0-1)	0.02* (0.01)	0.31*** (0.01)	1,943 [T 1,052; C 891]
Tropical Livestock Unit	0.03 (0.09)	0.51*** (0.08)	1,943 [T 1,052; C 891]

Note: ATET is estimated using IPWRA with standard errors clustered at ward level, including covariates as described in Appendix II. (a) Indicates that a logarithmic transformation was used. POM indicates the potential outcome mean. Standard errors are in parentheses. The number of observations divided between the treatment (T) and control (C) groups are in square brackets. Asterisks indicate the level of statistical significance: * < 0.10; ** < 0.05; *** < 0.01.

Table 23: S3P impacts on production and productivity (SO1).

Impact indicator	ATET	POM	Observations
Total value of crop production (US$)[a]	0.13** (0.06)	7.08*** (0.06)	1,920 [T 1,046; C 874]
Total value of crop production per ha (US$)[a]	0.04 (0.05)	6.80*** (0.04)	1,920 [T 1,046; C 874]
Cassava:			
- Quantity harvested (kg)[a]	0.24** (0.11)	7.30*** (0.11)	1,034 [T 591; C 443]
- Crop yield (kg/ha)[a]	0.22** (0.10)	8.13*** (0.09)	1,034 [T 591; C 443]
Groundnut:			
- Quantity harvested (kg)[a]	0.09 (0.08)	4.40*** (0.07)	1,037 [T 615; C 422]
- Crop yield (kg/ha)[a]	0.03 (0.08)	5.91*** (0.06)	1,037 [T 615; C 422]
Mixed beans:			
- Quantity harvested (kg)[a]	-0.05 (0.21)	4.60*** (0.19)	599 [T 364; C 235]
- Crop yield (kg/ha)[a]	-0.17 (0.16)	5.80*** (0.15)	599 [T 364; C 235]
Maize:			
- Quantity harvested (kg)[a]	0.21*** (0.07)	7.31*** (0.06)	1,688 [T 985; C 703]

Impact indicator	ATET	POM	Observations
- Crop yield (kg/ha)[(a)]	0.10** (0.05)	7.68*** (0.04)	1,688 [T 985; C 703]

Note: ATET is estimated using IPWRA with standard errors clustered at ward level, including covariates as described in Appendix II. (a) Indicates that a logarithmic transformation was used. POM indicates the potential outcome mean. Standard errors are in parentheses. The number of observations divided between the treatment (T) and control (C) groups are in square brackets. Asterisks indicate the level of statistical significance: * < 0.10; ** < 0.05; *** < 0.01.

Table 24: S3P impacts on the adoption of good agricultural practices adoption (SO1).

Impact indicator	ATET	POM	Observations
Conservation agriculture (reduced tillage; soil cover, crop diversification)			
Full adoption (all three techniques)	-0.02 (0.02)	0.04** (0.02)	1,943 [T 1,052; C 891]
Partial adoption (at least one technique)	0.01 (0.02)	0.94*** (0.01)	1,943 [T 1,052; C 891]
Tillage methods			
Zero tillage	0.01 (0.01)	0.02*** (0.01)	1,943 [T 1,052; C 891]
Minimum /reduced tillage (zero tillage, planting basins and ripping)	-0.03 (0.02)	0.07*** (0.02)	1,943 [T 1,052; C 891]
- Planting basins	-0.01 (0.01)	0.02*** (0.01)	1,943 [T 1,052; C 891]
- Ripping	0.00 (0.00)	0.00 (0.00)	1,943 [T 1,052; C 891]
Soil cover practices			
Soil cover (growing cover crops or residue management)	0.02 (0.03)	0.67*** (0.02)	1,943 [T 1,052; C 891]
Growing cover crops	-0.01 (0.01)	0.01** (0.01)	1,943 [T 1,052; C 891]
Residue management	0.03 (0.03)	0.65*** (0.02)	1,943 [T 1,052; C 891]
- Crop residue left in the field and then incorporated	0.12*** (0.04)	0.38*** (0.04)	1,943 [T 1,052; C 891]
- Crop residue cut and spread on the field	-0.03 (0.02)	0.07*** (0.02)	1,943 [T 1,052; C 891]
- Crop residue left in the field	-0.06 (0.04)	0.30*** (0.03)	1,943 [T 1,052; C 891]
Crop diversification			
Crop diversification (crop rotation and/or intercropping)	0.02 (0.02)	0.84*** (0.02)	1,943 [T 1,052; C 891]
Crop rotation with or without legumes	0.05** (0.02)	0.76*** (0.02)	1,943 [T 1,052; C 891]
Crop rotation with legumes	0.07** (0.03)	0.58*** (0.03)	1,943 [T 1,052; C 891]
Crop rotation with fallow land	0.02 (0.03)	0.35*** (0.02)	1,897 [T 1,040; C 857]

Impact indicator	ATET	POM	Observations
Intercropping with or without legumes	0.02 (0.03)	0.25*** (0.03)	1,943 [T 1,052; C 891]
Intercropping with legumes	-0.01 (0.02)	0.14*** (0.02)	1,943 [T 1,052; C 891]
Other good agricultural practices			
Fallow land during the season	-0.01 (0.03)	0.52*** (0.03)	1,943 [T 1,052; C 891]
Agroforestry	0.00 (0.03)	0.26*** (0.03)	1,943 [T 1,052; C 891]
Erosion control measures	0.01 (0.03)	0.38*** (0.03)	1,943 [T 1,052; C 891]

Note: ATET is estimated using IPWRA with standard errors clustered at ward level, including covariates as described in Appendix II. Impact indicators assume the value of one if farmer has adopted a given practice in the 2019/2020 agricultural season and zero otherwise. POM indicates the potential outcome mean. Standard errors are in parentheses. The number of observations divided between the treatment (T) and control (C) groups are in square brackets. Asterisks indicate the level of statistical significance: * < 0.10; ** < 0.05; *** < 0.01.

Table 25: S3P impacts on improved planting material adoption (SO1).

Impact indicator	ATET	POM	Observations
Non-traditional planting material (Improved, Hybrid and Recycled)	0.15*** (0.03)	0.73*** (0.03)	1,932 [T 1,050; C 882]
- Improved	0.01 (0.02)	0.08*** (0.02)	1,932 [T 1,050; C 882]
- Hybrid	0.17*** (0.03)	0.62*** (0.03)	1,932 [T 1,050; C 882]
- Recycled	0.06*** (0.02)	0.10*** (0.02)	1,932 [T 1,050; C 882]
Drought resilient	0.12*** (0.04)	0.49*** (0.03)	1,899 [T 1,033; C 866]
Cassava:			
Non-traditional planting material (Improved, Hybrid and Recycled)	0.07** (0.03)	0.08*** (0.02)	1,167 [T 669; C 498]
- Improved	0.04*** (0.01)	0.02** (0.01)	1,167 [T 669; C 498]
- Hybrid	0.01 (0.01)	0.01* (0.01)	1,167 [T 669; C 498]
- Recycled	0.02 (0.02)	0.05*** (0.02)	1,167 [T 669; C 498]
Drought resilient	0.04 (0.03)	0.09*** (0.02)	1,145 [T 652; C 493]
Chila variety	0.01** (0.01)	0.00 (0.00)	1,167 [T 669; C 498]
Mweru variety	0.05*** (0.02)	0.00 (0.00)	1,167 [T 669; C 498]
Groundnut:			
Non-traditional planting material (Improved, Hybrid and Recycled)	0.03 (0.03)	0.11*** (0.02)	1,064 [T 634; C 430]
- Improved	0.01*** (0.00)	0.00 (0.00)	1,064 [T 634; C 430]

Impact indicator	ATET	POM	Observations
- Hybrid	-0.02 (0.03)	0.10*** (0.03)	1,064 [T 634; C 430]
- Recycled	-0.04 (0.02)	0.08*** (0.02)	1,064 [T 634; C 430]
Drought resilient	0.02 (0.03)	0.06** (0.03)	1,034 [T 615; C 419]
MGV5 variety	0.02*** (0.01)	0.00 (0.00)	1,064 [T 634; C 430]
Mixed beans:			
Non-traditional planting material (Improved, Hybrid and Recycled)	0.02 (0.04)	0.14*** (0.03)	623 [T 380; C 243]
- Improved	0.01 (0.02)	0.00 (0.02)	623 [T 380; C 243]
- Hybrid	0.05*** (0.02)	0.01 (0.01)	623 [T 380; C 243]
- Recycled	-0.01 (0.03)	0.10*** (0.02)	623 [T 380; C 243]
Drought resilient	0.01 (0.03)	0.08*** (0.02)	609 [T 372; C 237]
Mbereshi variety	0.01** (0.01)	0.00 (0.00)	623 [T 380; C 243]
Lukupa variety	0.01* (0.00)	0.00 (0.00)	623 [T 380; C 243]
Maize:			
Non-traditional planting material (Improved, Hybrid and Recycled)	0.09*** (0.03)	0.81*** (0.02)	1,697 [T 987; C 710]
- Improved	-0.02 (0.02)	0.07*** (0.02)	1,697 [T 987; C 710]
- Hybrid	0.13*** (0.03)	0.68*** (0.03)	1,697 [T 987; C 710]
- Recycled	-0.03 (0.02)	0.07*** (0.02)	1,697 [T 987; C 710]
Drought resilient	0.09** (0.04)	0.59*** (0.03)	1,428 [T 813; C 615]

Note: ATET is estimated using IPWRA with standard errors clustered at ward level, including covariates as described in Appendix II. Impact indicators assume the value of one if farmer has adopted a given practice in the 2019/2020 agricultural season and zero otherwise. POM indicates the potential outcome mean. Standard errors are in parentheses. The number of observations divided between the treatment (T) and control (C) groups are in square brackets. Asterisks indicate the level of statistical significance: * < 0.10; ** < 0.05; *** < 0.01.

Table 26: S3P impacts on fertilisers and labour use (SO1).

Impact indicator	ATET	POM	Observations
All cultivated crops:			
Use of fertilisers (organic and inorganic)(b)	0.16*** (0.03)	0.74*** (0.03)	1,943 [T 1,052; C 891]
Use of organic fertilisers(b)	-0.01 (0.01)	0.04*** (0.01)	1,943 [T 1,052; C 891]
Use of basal fertilisers(b)	0.16*** (0.03)	0.73*** (0.03)	1,943 [T 1,052; C 891]
Use of topdressing fertilisers(b)	0.16***	0.73***	1,943

Impact indicator	ATET	POM	Observations
	(0.03)	(0.03)	[T 1,052; C 891]
Total value of fertilisers (organic and inorganic) used (US$)(a)	0.31*** (0.08)	5.50*** (0.07)	1,523 [T 940; C 583]
Total value of fertilisers (organic and inorganic) used per ha (US$) (a)	0.21*** (0.07)	4.91*** (0.07)	1,523 [T 940; C 583]
Use of hired labour(b)	0.07** (0.03)	0.53*** (0.03)	1,943 [T 1,052; C 891]
Total value of labour (hired and family) (US$) (a)	0.23*** (0.06)	6.44*** (0.05)	1,943 [T 1,052; C 891]
Total value of labour (hired and family) per ha (US$) (a)	0.12** (0.05)	5.96*** (0.04)	1,943 [T 1,052; C 891]
Total input expenditure (US$) (a)§	0.38*** (0.10)	4.96*** (0.09)	1,581 [T 913; C 668]
Total input expenditure per ha (US$) (a)§	0.27*** (0.09)	4.38*** (0.09)	1,581 [T 913; C 668]
Total value of input (US$) (a)§	0.28*** (0.06)	6.94*** (0.05)	1,943 [T 1,052; C 891]
Total value of input per ha (US$) (a)§	0.17*** (0.04)	6.45*** (0.04)	1,943 [T 1,052; C 891]
Cassava:			
Use of fertilisers (organic and inorganic)(b)	0.02 (0.01)	0.03*** (0.01)	1,451 [T 824; C 627]
Use of organic fertilisers(b)	0.00 (0.00)	0.00 (0.00)	1,451 [T 824; C 627]
Use of basal fertilisers(b)	0.02** (0.01)	0.02*** (0.01)	1,451 [T 824; C 627]
Use of topdressing fertilisers(b)	0.02 (0.01)	0.02*** (0.01)	1,451 [T 824; C 627]
Use of hired labour(b)	0.06* (0.03)	0.32*** (0.03)	1,446 [T 820; C 626]
Total value of labour (hired and family) (US$) (a)	-0.04 (0.09)	5.62*** (0.09)	1,446 [T 820; C 626]
Total value of labour (hired and family) per ha (US$) (a)	0.03 (0.07)	5.97*** (0.06)	1,446 [T 820; C 626]
Total input expenditure (US$) (a)§	-0.04 (0.10)	4.07*** (0.12)	607 [T 379; C 228]
Total input expenditure per ha (US$) (a)§	-0.11 (0.11)	4.30*** (0.10)	607 [T 379; C 228]
Total value of input (US$) (a)§	-0.11 (0.10)	5.76*** (0.08)	1,451 [T 824; C 627]
Total value of input per ha (US$) (a)§	-0.05 (0.09)	6.11*** (0.06)	1,451 [T 824; C 627]
Groundnut:			
Use of fertilisers (organic and inorganic)(b)	-0.01 (0.02)	0.06*** (0.02)	1,064 [T 634; C 430]
Use of organic fertilisers(b)			
Use of basal fertilisers(b)	-0.01 (0.02)	0.06*** (0.02)	1,064 [T 634; C 430]
Use of topdressing fertilisers(b)	-0.02	0.04***	1,064

Impact indicator	ATET	POM	Observations
	(0.01)	(0.01)	[T 634; C 430]
Use of hired labour[(b)]	0.06* (0.04)	0.25*** (0.03)	1,064 [T 634; C 430]
Total value of labour (hired and family) (US$) [(a)]	0.18** (0.08)	4.72*** (0.06)	1,064 [T 634; C 430]
Total value of labour (hired and family) per ha (US$) [(a)]	0.11 (0.09)	6.24*** (0.07)	1,064 [T 634; C 430]
Total input expenditure (US$) [(a)§]	0.04 (0.12)	3.29*** (0.11)	577 [T 352; C 225]
Total input expenditure per ha (US$) [(a)§]	-0.10 (0.12)	4.79*** (0.11)	577 [T 352; C 225]
Total value of input (US$) [(a)§]	0.18*** (0.06)	4.99*** (0.05)	1,064 [T 634; C 430]
Total value of input per ha (US$) [(a)§]	0.10 (0.07)	6.50*** (0.06)	1,064 [T 634; C 430]
Mixed beans:			
Use of fertilisers (organic and inorganic)[(b)]	0.03 (0.04)	0.20*** (0.04)	623 [T 380; C 243]
Use of organic fertilisers[(b)]	0.00 (0.01)	0.01 (0.01)	623 [T 380; C 243]
Use of basal fertilisers[(b)]	0.03 (0.05)	0.19*** (0.04)	623 [T 380; C 243]
Use of topdressing fertilisers[(b)]	0.00 (0.04)	0.19*** (0.04)	623 [T 380; C 243]
Use of hired labour[(b)]	0.07* (0.04)	0.28*** (0.04)	623 [T 380; C 243]
Total value of labour (hired and family) (US$) [(a)]	-0.16 (0.13)	4.94*** (0.12)	623 [T 380; C 243]
Total value of labour (hired and family) per ha (US$) [(a)]	-0.34** (0.14)	6.21*** (0.13)	622 [T 379; C 243]
Total input expenditure (US$) [(a)§]	-0.09 (0.19)	3.83*** (0.18)	399 [T 243; C 156]
Total input expenditure per ha (US$) [(a)§]	0.04 (0.17)	4.76*** (0.16)	399 [T 243; C 156]
Total value of input (US$) [(a)§]	-0.08 (0.12)	5.25*** (0.10)	623 [T 380; C 243]
Total value of input per ha (US$) [(a)§]	-0.26** (0.11)	6.53*** (0.11)	622 [T 379; C 243]
Maize:			
Use of fertilisers (organic and inorganic)[(b)]	0.06*** (0.02)	0.92*** (0.02)	1,697 [T 987; C 710]
Use of organic fertilisers[(b)]	-0.01 (0.01)	0.01** (0.00)	1,697 [T 987; C 710]
Use of basal fertilisers[(b)]	0.08*** (0.02)	0.86*** (0.02)	1,697 [T 987; C 710]
Use of topdressing fertilisers[(b)]	0.09*** (0.03)	0.85*** (0.03)	1,697 [T 987; C 710]
Total value of fertilisers (organic and inorganic) used (US$) [(a)]	0.30*** (0.08)	5.45*** (0.07)	1,502 [T 932; C 570]

Impact indicator	ATET	POM	Observations
Total value of fertilisers (organic and inorganic) used per ha (US$) (a)	0.14*** (0.05)	5.82*** (0.05)	1,502 [T 932; C 570]
Use of hired labour(b)	0.08** (0.03)	0.47*** (0.03)	1,697 [T 987; C 710]
Total value of labour (hired and family) (US$) (a)	0.27*** (0.07)	5.49*** (0.05)	1,697 [T 987; C 710]
Total value of labour (hired and family) per ha (US$) (a)	0.10* (0.06)	5.93*** (0.04)	1,697 [T 987; C 710]
Total input expenditure (US$) (a)§	0.30*** (0.11)	4.82*** (0.10)	1,361 [T 820; C 541]
Total input expenditure per ha (US$) (a)§	0.11 (0.08)	5.19*** (0.07)	1,361 [T 820; C 541]
Total value of input (US$) (a)§	0.34*** (0.07)	6.30*** (0.06)	1,697 [T 987; C 710]
Total value of input per ha (US$) (a)§	0.16*** (0.04)	6.74*** (0.03)	1,697 [T 987; C 710]

Note: ATET is estimated using IPWRA with standard errors clustered at ward level, including covariates as described in Appendix II. (a) Indicates that a logarithmic transformation was used; (b) the variable assumes the value of one or zero. § The agricultural inputs include planting material, organic fertilisers, inorganic fertilisers (basal and top dressing), phytosanitary products, labour (hired and family), land rental and other inputs (e.g. transport costs, expenditure on storage, animal or equipment rental cost, etc.). POM indicates the potential outcome mean. Standard errors are in parentheses. The number of observations divided between the treatment (T) and control (C) groups are in square brackets. Asterisks indicate the level of statistical significance: * < 0.10; ** < 0.05; *** < 0.01.

Table 27: S3P impacts on market access (SO2).

Impact indicator	ATET	POM	Observations
Participation in farmer organizations(b)	0.20*** (0.04)	0.63*** (0.03)	1,943 [T 1,052; C 891]
All cultivated crops:			
Probability of selling crops(b)	0.08*** (0.02)	0.83*** (0.02)	1,943 [T 1,052; C 891]
Share of sales value in total value of production (0-1)	0.05*** (0.02)	0.51*** (0.01)	1,624 [T 946; C 678]
Revenues from crop sales (US$)(a)	0.39*** (0.08)	6.19*** (0.07)	1,626 [T 948; C 678]
Cassava:			
Probability of selling of crops in all forms(b)	0.15*** (0.04)	0.31*** (0.04)	1,033 [T 591; C 442]
Probability of selling of raw cassava(b)	-0.01 (0.03)	0.09*** (0.02)	1,033 [T 591; C 442]
Probability of selling of cassava chips(b)	0.13*** (0.04)	0.21*** (0.03)	1,033 [T 591; C 442]
Probability of selling cassava flour(b)	0.02 (0.02)	0.04*** (0.01)	1,033 [T 591; C 442]
Share of sales value in total value of production (0-1)	0.04 (0.04)	0.42*** (0.03)	415 [T 271; C 144]
Revenues from crop sales (US$) (a)	0.23 (0.21)	4.86*** (0.20)	415 [T 271; C 144]
Groundnut:			
Probability of selling of crops(b)	0.08* (0.04)	0.51*** (0.04)	1,037 [T 615; C 422]

Impact indicator	ATET	POM	Observations
Share of sales value in total value of production (0-1)	-0.02 (0.03)	0.60*** (0.02)	593 [T 361; C 232]
Revenues from crop sales (US$) [(a)]	0.08 (0.12)	4.58*** (0.11)	593 [T 361; C 232]
Mixed beans:			
Probability of selling of crops[(b)]	0.11* (0.07)	0.54*** (0.06)	599 [T 364; C 235]
Share of sales value in total value of production (0-1)	0.00 (0.03)	0.63*** (0.02)	398 [T 239; C 159]
Revenues from crop sales (US$) [(a)]	0.09 (0.19)	4.94*** (0.16)	398 [T 239; C 159]
Maize:			
Probability of selling of crops[(b)]	0.11*** (0.03)	0.73*** (0.03)	1,688 [T 985; C 703]
Share of sales value in total value of production (0-1)	0.02 (0.02)	0.62*** (0.01)	1,311 [T 823; C 488]
Revenues from crop sales (US$) [(a)]	0.21** (0.09)	6.15*** (0.08)	1,311 [T 823; C 488]

Note: ATET is estimated using IPWRA with standard errors clustered at ward level, including covariates as described in Appendix II. (a) Indicates that a logarithmic transformation was used; (b) the variable assumes the value of one or zero. POM indicates the potential outcome mean. Standard errors are in parentheses. The number of observations divided between the treatment (T) and control (C) groups are in square brackets. Asterisks indicate the level of statistical significance: * < 0.10; ** < 0.05; *** < 0.01.

Table 28: S3P impacts on resilience (SO3).

Impact indicator	ATET	POM	Observations
Income diversification (Gini-Simpson index)	-0.00 (0.01)	0.39*** (0.01)	1,943 [T 1,052; C 891]
Crop diversification (Gini-Simpson index)	0.05*** (0.01)	0.47*** (0.01)	1,943 [T 1,052; C 891]
Ability to recover from the most severe shock (climate and non-climate) during the programme[(a)]	0.09*** (0.03)	0.62*** (0.03)	1,798 [T 991; C 807]
Ability to recover from the most severe climate shock during the programme[(a)]	0.00 (0.04)	0.49*** (0.03)	1,238 [T 702; C 536]
Ability to recover from the most severe non-climate shock during the programme[(a)]	0.09*** (0.03)	0.54*** (0.03)	1,698 [T 948; C 750]
Exposure corrected ability to recover from the most severe shock (climate and non-climate) in the last 12 months	-0.04 (0.07)	2.34*** (0.06)	1,594 [T 878; C 716]
Exposure corrected ability to recover from the most severe climate shock (last 12 months)	-0.06 (0.12)	2.68*** (0.11)	853 [T 479; C 374]
Exposure corrected ability to recover from the most severe non-climate shock (last 12 mo.)	-0.01 (0.07)	2.16*** (0.06)	1,449 [T 799; C 650]

Note: ATET is estimated using IPWRA with standard errors clustered at ward level, including covariates as described in Appendix II. (a) The variable assumes the value of one or zero. POM is the potential outcome mean. Standard errors are in parentheses. The number of observations divided between the treatment (T) and control (C) groups are in square brackets. Asterisks indicate the level of statistical significance: * < 0.10; ** < 0.05; *** < 0.01.

Table 29: S3P impacts on food and nutrition security (MT).

Impact indicator	ATET	POM	Observations
Months of Adequate Household Food Provisions (MAHFP)	0.44*** (0.14)	9.39*** (0.14)	1,943 [T 1,052; C 891]
Household Dietary Diversity Score (HDDS)[)]	0.27*** (0.10)	8.33*** (0.10)	1,943 [T 1,052; C 891]
Food Insecurity Experience Scale (FIES)	-0.17 (0.14)	4.70*** (0.13)	1,943 [T 1,052; C 891]
- FIES – Worried to not have enough food[(a)]	-0.01 (0.03)	0.74*** (0.02)	1,943 [T 1,052; C 891]
- FIES – Unable to eat healthy and nutritional food[(a)]	-0.02 (0.02)	0.74*** (0.02)	1,932 [T 1,050; C 882]
- FIES – Ate only a few kinds of foods[(a)]	-0.03 (0.03)	0.75*** (0.02)	1,938 [T 1,051; C 887]
- FIES – Skip a meal[(a)]	-0.02 (0.03)	0.60*** (0.02)	1,939 [T 1,048; C 891]
- FIES – Ate less than thought[(a)]	-0.03 (0.02)	0.68*** (0.02)	1,933 [T 1,051; C 882]
- FIES – Ran out of food[(a)]	-0.02 (0.03)	0.45*** (0.02)	1,942 [T 1,051; C 891]
- FIES – Hungry but did not eat[(a)]	0.00 (0.03)	0.46*** (0.02)	1,940 [T 1,050; C 890]
- FIES – Without eating for a whole day[(a)]	-0.02 (0.03)	0.26*** (0.03)	1,940 [T 1,050; C 890]
Food Consumption Score (FCS)	2.02** (0.89)	52.43*** (0.79)	1,943 [T 1,052; C 891]
- FCS – Poor[(a)]	-0.01 (0.01)	0.02*** (0.01)	1,943 [T 1,052; C 891]
- FCS – Borderline[(a)]	-0.02 (0.02)	0.13*** (0.02)	1,943 [T 1,052; C 891]
- FCS – Acceptable[(a)]	0.03* (0.02)	0.85*** (0.02)	1,943 [T 1,052; C 891]

Note: ATET is estimated using IPWRA with standard errors clustered at ward level, including covariates as described in Appendix II. (a) The variable assumes the value of one or zero. POM indicates the potential outcome mean. Standard errors are in parentheses. The number of observations divided between the treatment (T) and control (C) groups are in square brackets. Asterisks indicate the level of statistical significance: * < 0.10; ** < 0.05; *** < 0.01.

Table 30: S3P impacts on women's empowerment (MT).

Impact indicator	ATET	POM	Observations
Probability of women working in wage employment	-0.02 (0.02)	0.14 (0.02)	1,943 [T 1,052; C 891]
Decision-making on income sources: at least one income source by…			
- Only female	-0.04 (0.03)	0.55*** (0.03)	1,943 [T 1,052; C 891]
- Jointly with men	0.05* (0.03)	0.68*** (0.03)	1,943 [T 1,052; C 891]
Control over revenues from crop sales: at least one crop by…			
- Only female	0.00	0.20***	1,626

Impact indicator	ATET	POM	Observations
	(0.02)	(0.02)	[T 948; C 678]
- Jointly with men	0.06** (0.03)	0.56*** (0.03)	1,626 [T 948; C 678]
Land ownership: at least one plot by…			
- Only female	0.04*** (0.01)	0.20*** (0.01)	1,852 [T 1,022; C 830]
- Jointly with men	0.03 (0.03)	0.34*** (0.03)	1,852 [T 1,022; C 830]
Livestock ownership: at least one category by…			
- Only female	0.01 (0.02)	0.29*** (0.02)	1,560 [T 891; C 669]
- Jointly with men	0.11*** (0.03)	0.41*** (0.03)	1,560 [T 891; C 669]
Durable goods ownership: majority by…			
- Only female	0.00 (0.01)	0.15*** (0.02)	1,837 [T 1,014; C 823]
- Jointly with men	0.06*** (0.02)	0.32*** (0.02)	1,837 [T 1,014; C 823]
Productive goods ownership: majority by…			
- Only female	0.01 (0.01)	0.05*** (0.01)	631 [T 351; C 280]
- Jointly with men	0.03 (0.05)	0.31*** (0.05)	631 [T 351; C 280]
Participation in farmer organizations			
- Only female	0.00 (0.03)	0.26*** (0.03)	1,342 [T 877; C 465]
- Jointly with men	0.11*** (0.03)	0.27*** (0.03)	1,342 [T 877; C 465]

Note: ATET is estimated using IPWRA with standard errors clustered at ward level, including covariates as described in Appendix II. Indicators assume the value of one or zero otherwise. Decision making on/control over income/revenue sources is measured by using the answers to the question of "which makes the decision on…" or "who control revenues from…" for each parcel/income-generating activity/sale. POM indicates the potential outcome mean. Standard errors are in parentheses. The number of observations divided between the treatment (T) and control (C) groups are in square brackets. Asterisks indicate the level of statistical significance: * < 0.10; ** < 0.05; *** < 0.01.

Table 31: Heterogeneous impact by the extension service provider (public vs. private).

Impact indicator	Public provider			Private provider		
	ATET	POM	Observations	ATET	POM	Observations
Economic Goal:						
Gross crop income per capita (US$)(a)	0.41*** (0.08)	4.89*** (0.09)	1,292 [T 696; C 596]	0.23 (0.19)	4.77*** (0.19)	755 [T 350; C 405]
Durable assets index (0-1)	0.01** (0.01)	0.14*** (0.01)	1,305 [T 700; C 605]	0.01 (0.01)	0.13*** (0.01)	761 [T 352; C 409]
Housing characteristics index (0-1)	0.03** (0.01)	0.30*** (0.01)	1,305 [T 700; C 605]	0.00 (0.03)	0.32*** (0.03)	761 [T 352; C 409]
S01 – Productive capacities:						
Total value of crop production (US$)(a)	0.16** (0.07)	7.17*** (0.06)	1,292 [T 696; C 596]	0.06 (0.15)	6.90*** (0.14)	755 [T 350; C 405]
Minimum /reduced tillage (zero tillage, planting basins and ripping)(b)	0.02* (0.01)	0.01** (0.01)	1,305 [T 700; C 605]	0.04* (0.02)	0.02 (0.02)	761 [T 352; C 409]
Crop rotation with legumes(b)	0.05* (0.02)	0.79*** (0.03)	1,305 [T 700; C 605]	0.06 (0.09)	0.71*** (0.08)	761 [T 352; C 409]
Non-traditional planting material (Improved/Hybrid/Recycled)(b)	0.21*** (0.03)	0.71*** (0.03)	1,297 [T 700; C 597]	0.09 (0.06)	0.71*** (0.05)	754 [T 350; C 404]
Non-traditional planting material for cassava(b)	0.05 (0.03)	0.08*** (0.03)	840 [T 459; C 381]	0.11* (0.06)	0.09* (0.05)	468 [T 210; C 258]
Non-traditional planting material for maize(b)	0.17*** (0.03)	0.76*** (0.03)	1,146 [T 678; C 468]	0.03 (0.06)	0.79*** (0.05)	635 [T 309; C 326]
Use of fertilisers (organic and inorganic)(b)	0.23*** (0.03)	0.72*** (0.03)	1,305 [T 700; C 605]	0.01 (0.05)	0.79*** (0.05)	761 [T 352; C 409]
Total value of fertilisers (organic and inorganic) per ha(a)	0.20*** (0.07)	4.94*** (0.07)	1,053 [T 660; C 393]	0.38** (0.19)	4.70*** (0.17)	567 [T 280; C 287]
Use of hired labour(b)	0.10*** (0.03)	0.55*** (0.03)	1,305 [T 700; C 605]	0.00 (0.07)	0.49*** (0.06)	761 [T 352; C 409]

Impact indicator	Public provider			Private provider		
	ATET	POM	Observations	ATET	POM	Observations
Total input expenditure per ha (US$)(a)§	0.24** (0.11)	4.42*** (0.10)	1,078 [T 629; C449]	0.50** (0.22)	4.13*** (0.20)	595 [T 284; C 311]
Total input value per ha (US$)(a)§	0.14*** (0.05)	6.49*** (0.04)	1,305 [T 700; C 605]	0.08 (0.10)	6.51*** (0.09)	761 [T 352; C 409]
S02 – Market access:						
Probability of selling crops(b)	0.09*** (0.03)	0.84*** (0.02)	1,292 [T 696; C 596]	0.05 (0.05)	0.81*** (0.05)	757 [T 352; C 405]
Share of sales value in total value of production (0-1)	0.05** (0.02)	0.51*** (0.02)	1,107 [T 644; C 463]	0.09 (0.06)	0.48*** (0.05)	617 [T 302; C 315]
Revenues from crop sales (US$)(a)	0.48*** (0.08)	6.15*** (0.09)	1,109 [T 646; C 463]	0.37* (0.22)	6.09*** (0.19)	617 [T 302; C 315]
Participation in farmer organizations(b)	0.25*** (0.04)	0.62*** (0.04)	1,305 [T 700; C 605]	0.09 (0.10)	0.66*** (0.09)	761 [T 352; C 409]
S03 – Resilience:						
Crop diversification (Gini-Simpson index)	0.06*** (0.01)	0.46*** (0.01)	1,305 [T 700; C 605]	-0.03 (0.06)	0.56*** (0.06)	761 [T 352; C 409]
Ability to recover from the most severe non-climate shock (b)	0.13*** (0.03)	0.52*** (0.03)	1,142 [T 638; C 504]	0.00 (0.07)	0.58*** (0.07)	658 [T 312; C 346]
MT – Food security and nutrition:						
Months of Adequate Household Food Provisions (MAHFP)	0.52*** (0.15)	9.33*** (0.14)	1,305 [T 700; C 605]	0.04 (0.37)	9.74*** (0.39)	761 [T 352; C 409]
Household Dietary Diversity Score (HDDS)	0.23* (0.12)	8.44*** (0.12)	1,305 [T 700; C 605]	0.25 (0.24)	8.20*** (0.22)	761 [T 352; C 409]
Food Insecurity Experience Scale (FIES)	-0.36** (0.17)	4.79*** (0.14)	1,305 [T 700; C 605]	0.27 (0.45)	4.44*** (0.49)	761 [T 352; C 409]
MT - Women's empowerment:						
Female ownership of durable goods(b)	0.01 (0.01)	0.15*** (0.02)	1,238 [T 682; C 556]	0.04** (0.01)	0.11*** (0.03)	709 [T 332; C 377]

Note: ATET is estimated using IPWRA with standard errors clustered at ward level, including covariates as described in Appendix II. (a) Indicates that a logarithmic transformation was used; (b) the variable assumes the value of one or zero. § The agricultural inputs include planting material, organic fertilisers, inorganic fertilisers (basal and top dressing), phytosanitary products, labour (hired and family), land rental and other inputs (e.g. transport costs, expenditure on storage, animal or equipment rental cost, etc.). Decision making on/control over income/revenue sources is measured by using the answers to the question of "which makes the decision on…" or "who control revenues from…" for each parcel/income-generating activity/sale. POM indicates the potential outcome mean. Standard errors are in parentheses. The number of observations divided between the treatment (T) and control (C) groups are in square brackets. Asterisks indicate the level of statistical significance: * < 0.10; ** < 0.05; *** < 0.01.

Table 32: Heterogenous impact by farm size (smallest, small and medium and large).

Impact indicator	Smallest (< 1 ha)			Small (1-2 ha)			Medium and Large (>2 ha)		
	ATET	POM	Observations	ATET	POM	Observations	ATET	POM	Observations
Economic Goal:									
Gross crop income per capita (US$)(a)	0.03 (0.12)	4.05*** (0.13)	438 [T 166; C 272]	0.21*** (0.08)	4.80*** (0.08)	776 [T 417; C 359]	0.40*** (0.11)	5.36*** (0.11)	706 [T 463; C 243]
Durable assets index (0-1)	0.00 (0.01)	0.08*** (0.01)	458 [T 170; C 288]	0.01* (0.01)	0.11*** (0.01)	777 [T 418; C 359]	0.04*** (0.01)	0.16*** (0.01)	708 [T 464; C 244]
S01 – Agricultural production and productivity:									
Total value of crop production (US$)(a)	-0.13 (0.11)	6.03*** (0.10)	438 [T 166; C 272]	0.13* (0.07)	6.85*** (0.06)	776 [T 417; C 359]	0.10 (0.07)	7.77*** (0.06)	706 [T 463; C 243]
Yield of maize (kg/ha)(a)	0.21 (0.14)	7.40*** (0.11)	297 [T 132; C 165]	0.13** (0.06)	7.66*** (0.04)	708 [T 397; C 311]	0.06 (0.07)	7.77*** (0.06)	683 [T 456; C 227]
Partial adoption of CA (at least one technique)(b)	0.03 (0.03)	0.89*** (0.03)	458 [T 170; C 288]	0.05* (0.03)	0.90*** (0.03)	777 [T 418; C 359]	0.04 (0.04)	0.91*** (0.04)	708 [T 464; C 244]
Soil cover (growing cover crops or residue management)(b)	-0.09 (0.06)	0.60*** (0.05)	458 [T 170; C 288]	0.09** (0.05)	0.59*** (0.04)	777 [T 418; C 359]	0.02 (0.05)	0.73*** (0.04)	708 [T 464; C 244]
Crop rotation with or without legumes(b)	0.06 (0.05)	0.75*** (0.05)	458 [T 170; C 288]	0.03 (0.03)	0.83*** (0.03)	777 [T 418; C 359]	0.08* (0.04)	0.81*** (0.04)	708 [T 464; C 244]

Impact indicator	Smallest (< 1 ha)			Small (1-2 ha)			Medium and Large (>2 ha)		
	ATET	POM	Observations	ATET	POM	Observations	ATET	POM	Observations
Non-traditional planting material (Improved/Hybrid/Recycled)[b]	0.17** (0.07)	0.53*** (0.06)	449 [T 168; C 281]	0.11*** (0.04)	0.77*** (0.04)	777 [T 418; C 359]	0.16*** (0.05)	0.78*** (0.05)	706 [T 464; C 242]
Non-traditional planting material for cassava[b]	0.18*** (0.06)	0.00 (0.05)	240 [T 89; C 151]	0.07* (0.04)	0.07*** (0.03)	469 [T 250; C 219]	0.08 (0.05)	0.08* (0.04)	457 [T 329; C 128]
Non-traditional planting material for maize[b]	0.10 (0.08)	0.66*** (0.07)	300 [T 133; C 167]	0.09** (0.04)	0.79*** (0.04)	711 [T 397; C 314]	0.06 (0.04)	0.88*** (0.04)	686 [T 457; C 229]
Use of fertilisers (organic and inorganic)[b]	0.10 (0.06)	0.54*** (0.06)	458 [T 170; C 288]	0.13*** (0.04)	0.80*** (0.04)	777 [T 418; C 359]	0.14*** (0.05)	0.82*** (0.05)	708 [T 464; C 244]
Total value of fertilisers (organic and inorganic) per ha (US$)[a]	0.26 (0.16)	5.26*** (0.17)	233 [T 108; C 125]	0.05 (0.09)	5.12*** (0.08)	641 [T 387; C 254]	0.18* (0.11)	4.80*** (0.11)	649 [T 445; C 204]
Total value of labour (family and hired) per ha (US$)[a]	0.14 (0.09)	6.22*** (0.06)	458 [T 170; C 288]	0.15** (0.07)	6.06*** (0.05)	777 [T 418; C 359]	0.16 (0.11)	5.69*** (0.10)	708 [T 464; C 244]
Total input expenditure per ha (US$)[a]§	-0.10 (0.26)	4.48*** (0.24)	277 [T 111; C 166]	0.19 (0.13)	4.37*** (0.13)	639 [T 359; C 280]	0.42*** (0.15)	4.37*** (0.15)	665 [T 443; C 222]
Total input value per ha (US$)[a]§	0.14** (0.07)	6.66*** (0.05)	458 [T 170; C 288]	0.15*** (0.05)	6.57*** (0.04)	777 [T 418; C 359]	0.26*** (0.10)	6.20*** (0.10)	708 [T 464; C 244]
S02 – Market access:									
Probability of selling crops[b]	0.00 (0.08)	0.63*** (0.06)	441 [T 167; C 274]	0.13*** (0.04)	0.81*** (0.03)	776 [T 417; C 359]	0.07** (0.03)	0.91*** (0.03)	708 [T 464; C 244]
Share of sales value in total value of production (0-1)	0.02 (0.04)	0.40*** (0.03)	257 [T 104; C 153]	0.02 (0.02)	0.50*** (0.02)	683 [T 388; C 295]	0.09*** (0.02)	0.53*** (0.02)	684 [T 454; C 230]
Revenues from crop sales (US$)[a]	0.11 (0.23)	5.04*** (0.19)	258 [T 105;	0.28*** (0.09)	5.91*** (0.08)	684 [T 389;	0.41*** (0.10)	6.83*** (0.09)	684 [T 454;

Impact indicator	Smallest (< 1 ha)			Small (1-2 ha)			Medium and Large (>2 ha)		
	ATET	POM	Observations	ATET	POM	Observations	ATET	POM	Observations
			C 153]			C 295]			C 230]
Participation in farmer organizations(b)	0.23*** (0.06)	0.44*** (0.05)	458 [T 170; C 288]	0.11** (0.04)	0.71*** (0.03)	777 [T 418; C 359]	0.19*** (0.05)	0.71*** (0.05)	708 [T 464; C 244]
S03 – Resilience:									
Crop diversification (Gini-Simpson index)	0.03 (0.03)	0.37*** (0.03)	458 [T 170; C 288]	0.04** (0.02)	0.49*** (0.02)	777 [T 418; C 359]	0.05** (0.02)	0.51*** (0.02)	708 [T 464; C 244]
Ability to recover from the most severe non-climate shock (b)	0.03 (0.07)	0.52*** (0.06)	394 [T 153; C 241]	0.02 (0.05)	0.58*** (0.04)	681 [T 377; C 304]	0.08* (0.05)	0.59*** (0.04)	632 [T 421; C 211]
MT – Food security and nutrition:									
Months of Adequate Household Food Provisions (MAHFP)	0.54 (0.37)	8.21*** (0.34)	458 [T 170; C 288]	0.18 (0.22)	9.46*** (0.20)	777 [T 418; C 359]	0.43** (0.19)	9.96*** (0.18)	708 [T 464; C 244]
Household Dietary Diversity Score (HDDS)	-0.17 (0.26)	7.63*** (0.22)	458 [T 170; C 288]	0.08 (0.16)	8.49*** (0.15)	777 [T 418; C 359]	0.49** (0.19)	8.55*** (0.19)	708 [T 464; C 244]
MT - Women's empowerment:									
Female participation in revenues from crop sales(b)	0.05 (0.04)	0.30*** (0.05)	258 [T 105; C 153]	-0.01 (0.03)	0.27*** (0.03)	684 [T 389; C 295]	0.03* (0.02)	0.08*** (0.02)	684 [T 454; C 230]
Female ownership of land(b)	-0.02 (0.03)	0.34*** (0.04)	411 [T 159; C 252]	0.05** (0.02)	0.24*** (0.02)	747 [T 405; C 342]	0.07*** (0.02)	0.09*** (0.02)	694 [T 458; C 236]
Female ownership of livestock(b)	0.14* (0.08)	0.36*** (0.06)	279 [T 115; C 164]	0.01 (0.04)	0.34*** (0.03)	645 [T 357; C 288]	-0.02 (0.05)	0.21*** (0.04)	636 [T 419; C 217]

Note: ATET is estimated using IPWRA with standard errors clustered at ward level, including covariates as described in Appendix II. (a) Indicates that a logarithmic transformation was used; (b) the variable assumes the value of one or zero. § The agricultural inputs include planting material, organic fertilisers, inorganic fertilisers (basal and top dressing), phytosanitary products, labour (hired and family), land rental and other inputs (e.g. transport costs, expenditure on storage, animal or equipment rental cost, etc.). Decision making on/control over income/revenue sources is measured by using the answers to the question of "which makes the decision on…" or "who control revenues from…" for each parcel/income-generating activity/sale. POM indicates the potential outcome mean. Standard errors are in parentheses. The number of observations divided between the treatment (T) and control (C) groups are in square brackets. Asterisks indicate the level of statistical significance: * < 0.10; ** < 0.05; *** < 0.01.

Table 33: Heterogeneous impact by household head's gender.

Impact indicator	Male-headed household			Overall sample		
	ATET	POM	Observations	ATET	POM	Observations
Economic Goal:						
Gross crop income per capita (US$)[(a)]	0.36*** (0.09)	4.90*** (0.09)	1,609 [T 893; C 716]	0.34*** (0.08)	4.86*** (0.08)	1,920 [T 1,046; C 874]
Durable assets index (0-1)	0.02*** (0.01)	0.14*** (0.01)	1,624 [T 896; C 728]	0.02*** (0.01)	0.12*** (0.01)	1,943 [T 1,052; C 891]
Housing characteristics index (0-1)	0.02* (0.01)	0.31*** (0.01)	1,624 [T 896; C 728]	0.02* (0.01)	0.31*** (0.01)	1,943 [T 1,052; C 891]
S01 – Agricultural production and productivity:						
Total value of crop prod. (US$)[(a)]	0.14** (0.06)	7.17*** (0.06)	1,609 [T 893; C 716]	0.13** (0.06)	7.08*** (0.06)	1,920 [T 1,046; C 874]
Yield of cassava (kg/ha)[(a)]	0.19* (0.11)	8.16*** (0.10)	898 [T 519; C 379]	0.22** (0.10)	8.13*** (0.09)	1,034 [T 591; C 443]
Yield of maize (kg/ha)[(a)]	0.11** (0.05)	7.71*** (0.04)	1,426 [T 843; C 583]	0.10** (0.05)	7.68*** (0.04)	1,688 [T 985; C 703]
Crop rotation with legumes[(b)]	0.06** (0.03)	0.76*** (0.02)	1,624 [T 896; C 728]	0.07** (0.03)	0.58*** (0.03)	1,943 [T 1,052; C 891]
Non-traditional planting material (Improved, Hybrid and Recycled)[(b)]	0.14*** (0.03)	0.74*** (0.03)	1,617 [T 896; C 721]	0.15*** (0.03)	0.73*** (0.03)	1,932 [T 1,050; C 882]
Non-trad. planting material for cassava[(b)]	0.06* (0.03)	0.09*** (0.03)	991 [T 582; C 409]	0.07** (0.03)	0.08*** (0.02)	1,167 [T 669; C 498]
Non-trad. planting material for maize[(b)]	0.08*** (0.03)	0.82*** (0.03)	1,434 [T 845; C 589]	0.09*** (0.03)	0.81*** (0.02)	1,697 [T 987; C 710]
Use of fertilisers (organic and inorganic)[(b)]	0.14*** (0.03)	0.76*** (0.03)	1,624 [T 896; C 728]	0.16*** (0.03)	0.74*** (0.03)	1,943 [T 1,052; C 891]

Impact indicator	Male-headed household			Overall sample		
	ATET	POM	Observations	ATET	POM	Observations
Total value of fertilisers (organic and inorganic) per ha (US$)[(a)]	0.23*** (0.07)	4.88*** (0.07)	1,299 [T 807; C 492]	0.21*** (0.07)	4.91*** (0.07)	1,523 [T 940; C 583]
Use of hired labour[(b)]	0.07** (0.03)	0.52*** (0.03)	1,624 [T 896; C 728]	0.07** (0.03)	0.53*** (0.03)	1,943 [T 1,052; C 891]
Total value of labour (family and hired) per ha (US$)[(a)]	0.13** (0.06)	5.92*** (0.05)	1,624 [T 896; C 728]	0.12** (0.05)	5.96*** (0.04)	1,943 [T 1,052; C 891]
Total input expenditure per ha (US$)[(a)§]	0.29*** (0.10)	4.37*** (0.10)	1,326 [T 777; C 549]	0.27*** (0.09)	4.38*** (0.09)	1,581 [T 913; C 668]
Total input value per ha (US$)[(a)§]	0.18*** (0.05)	6.42*** (0.04)	1,624 [T 896; C 728]	0.17*** (0.04)	6.45*** (0.04)	1,943 [T 1,052; C 891]
S02 – Market access:						
Probability of selling crops[(b)]	0.10*** (0.03)	0.82*** (0.03)	1,613 [T 895; C 718]	0.08*** (0.02)	0.83*** (0.02)	1,943 [T 1,052; C 891]
Share of sales value in total value of production (0-1)	0.05*** (0.02)	0.52*** (0.01)	1,384 [T 819; C 565]	0.05*** (0.02)	0.51*** (0.01)	1,624 [T 946; C 678]
Revenues from crop sales (US$)[(a)]	0.39*** (0.09)	6.29*** (0.08)	1,386 [T 821; C 565]	0.39*** (0.08)	6.19*** (0.07)	1,626 [T 948; C 678]
Participation in farmer organizations[(b)]	0.19*** (0.04)	0.65*** (0.04)	1,624 [T 896; C 728]	0.20*** (0.04)	0.63*** (0.03)	1,943 [T 1,052; C 891]
S03 – Resilience:						
Crop diversification (Gini-Simpson index)	0.06*** (0.01)	0.47*** (0.01)	1,624 [T 896; C 728]	0.05*** (0.01)	0.47*** (0.01)	1,943 [T 1,052; C 891]
Ability to recover from the most severe non-climate shock [(b)]	0.08*** (0.03)	0.55*** (0.03)	1,417 [T 804; C 613]	0.09*** (0.03)	0.54*** (0.03)	1,707 [T 951; C 756]
MT – Food security and nutrition:						
Months of Adequate Household Food Provisions (MAHFP)	0.34** (0.14)	9.57*** (0.14)	1,624 [T 896; C 728]	0.44*** (0.14)	9.39*** (0.14)	1,943 [T 1,052; C 891]
Household Dietary Diversity Score (HDDS)	0.35*** (0.11)	8.33*** (0.10)	1,624 [T 896; C 728]	0.27*** (0.10)	8.33*** (0.10)	1,943 [T 1,052; C 891]
MT - Women's empowerment:						

Impact indicator	Male-headed household			Overall sample		
	ATET	POM	Observations	ATET	POM	Observations
Female ownership of land[(b)]	0.05** (0.02)	0.06*** (0.02)	1,551 [T 871; C 680]	0.04*** (0.01)	0.20*** (0.01)	1,852 [T 1,022; C 830]

Note: ATET is estimated using IPWRA with standard errors clustered at ward level, including covariates as described in Appendix II. (a) Indicates that a logarithmic transformation was used; (b) the variable assumes the value of one or zero. § The agricultural inputs include planting material, organic fertilisers, inorganic fertilisers (basal and top dressing), phytosanitary products, labour (hired and family), land rental and other inputs (e.g. transport costs, expenditure on storage, animal or equipment rental cost, etc.). Decision making on/control over income/revenue sources is measured by using the answers to the question of "which makes the decision on…" or "who control revenues from…" for each parcel/income-generating activity/sale. POM indicates the potential outcome mean. Standard errors are in parentheses. The number of observations divided between the treatment (T) and control (C) groups are in square brackets. Asterisks indicate the level of statistical significance: * < 0.10; ** < 0.05; *** < 0.01.

Investing in rural people

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