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The Effects of a Private-Sector-Driven Smallholder Support Programme on Productivity, Market Participation and Food and Nutrition Security

Evidence of a Nucleus-Outgrower Scheme from Zambia

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Abstract

Nucleus-outgrower schemes (NOSs) are supposed to be a particularly effective private-sector mechanism to support smallholder farmers and contribute towards mitigating the problematic aspects of pure large-scale agricultural investments. This discussion paper uses panel household survey data collected in two rounds in Zambia to analyse some agro-ecological and socio-economic impacts of the outgrower programme of one of the largest agricultural investments in Zambia: Amatheon Agri Zambia (AAZ) Limited. The descriptive results show that the type of participation in the programme varies across participants and components, with most participating in trainings. Econometric results suggest the following key findings. First, although the overall impact of the AAZ outgrower programme on the uptake of conservation agriculture practices is robust and promising, impacts on the adoption of other agricultural technologies is less obvious and the effect depends on the type of support provided. Second, the programme has had a significant impact on maize productivity promoted in the initial phase but not on the other crops – mainly oilseeds – promoted later. Third, the initially less productive farmers seem to benefit slightly more than already better performing ones. Fourth, although the impact on overall household security was insignificant, there is some suggestive evidence (although the effect is weak) that the programme has a positive effect on improving women's uptake of micronutrients. Finally, our findings show that the three components of the programme (trainings, seed loans and output purchases) have different effects on the adoption of sustainable agricultural practices and productivity, and to some extent on food security. Overall, the results suggest that NOSs, with all their risks, can play a role in the adoption of sustainable agricultural practices, improving farm-level agricultural technologies, providing input credit, and thereby improving productivity and smallholder livelihoods. However, this is not automatically the case, as it crucially depends on the design and management of the project; the availability of good policies and institutions governing the rules of operation; the types of crops promoted; the duration of the project; and the political commitment of host countries, among others.

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Abbreviations

AAZ	Amatheon Agri Zambia
ATT	average treatment effect on the treated
CA	conservation agriculture
CFU	Conservation Farming Unit
CR	crop rotation
DDS	dietary diversity score
DID	difference-in-differences
FC	farmer coordinator
ha	hectare
HH	household
IDOS	German Institute of Development and Sustainability
kg	kilogram
LSF	large-scale farm
MSD	minimum soil disturbance
MT	minimum tillage
NGO	non-governmental organisation
NOS	nucleus-outgrower scheme
OPV	open pollinated varieties
pca	principal component analysis
PSM	propensity score matching
RE	random effects
RR	residue retention
SDID	semiparametric difference-in-differences
SLM	sustainable land management
SSA	sub-Saharan Africa
USAID	United States Agency for International Development
ZMW	kwacha (currency of Zambia)

Executive summary

Many countries in sub-Saharan Africa (SSA) have experienced an upsurge in large-scale (foreign) agricultural investments since the mid-2000s. Zambia has been among the major recipients of such investments. Most of these investors not only cultivate large tracts of land themselves, but also engage systematically with smallholders in their periphery. On the one hand, this is to mitigate the possible negative land-concentration effects of the estates and to improve smallholder farmers' productivity, sustainability, incomes, food security, and other socio-economic and agro-ecological impacts, thereby improving the overall impacts of the investments. On the other hand, it is hoped that these activities and impacts will garner social and political support for the investments. Moreover, content and prosperous smallholders act as a "shield" to deflect political campaigns directed against the investors and can support the attraction of additional funding. Typical smallholder-oriented activities include their integration into supply chains, the provision of – or at least ease of access to – inputs, credit and/or training. Such integrated schemes are usually subsumed under the term nucleus-outgrower schemes (NOSs), using the term "outgrower" in a generous way to mean "closely related to" with regard to some of the services mentioned above, and not only the original meaning of "producing under licence for" a central enterprise. An underlying assumption behind the big expectations for such NOSs is that producer-investors can address the critical issues of (smallholder) farming in a comprehensive and realistic way better than other external supporters (e.g. government agencies, non-governmental organisations, traders or input providers).

However, whether this expectation holds true and what the overall effects of such complex investments and programmes are have been widely controversial topics of policy and scholarly debates. On the one hand, it is often argued that foreign commercial investments in agriculture more generally are likely to create rural employment, lead to the transfer of technology and knowledge, and help modernise agricultural value chains. On the other hand, critics have pointed out that large-scale agricultural investments displace local populations and increase the vulnerability of farmers. The debates continue to rage without clear conclusions, not least because the impacts of the smallholder programmes are not yet well-understood and are difficult to determine, which requires trustful but unbiased cooperation in impact research. This discussion paper attempts to contribute towards the debate by unpacking the NOS puzzle and analysing the effects of the outgrower programme of one of the largest agricultural investments in Zambia: Amatheon Agri Zambia Limited (AAZ). Specifically, the paper examines the impacts of the AAZ outgrower programme on the uptake of conservation agriculture (CA) practices, the adoption of agricultural technologies, crop productivity (land productivity), market participation and food security for the phases without contract purchases.

AAZ belongs to a private German agribusiness company that acquired large tracts of land in Zambia in 2012. Besides running commercial operations on the estate, the company also established an "outgrower"[1] scheme to support smallholder farmers in two districts, Mumbwa and Chibombo. Amatheon was confident enough to support the research of the German Institute of Development and Sustainability (IDOS) on the scheme by sharing information on smallholder participants from an early stage of programme implementation onwards. This collaboration decisively contributed towards making it an interesting case study that offers a thorough analysis of the effects of private-sector-driven smallholder support programme on various outcomes. It did this by allowing for more than a simple one-off and random-selection survey design. It also allowed for systematically selecting and interviewing participants and non-participants of the scheme close to the start of the scheme and at a later stage, thus allowing for a high-quality difference-in-differences (DID) approach. Specifically, this discussion paper compares households participating in at least one component of the AAZ outgrower programme (listed below) with similar non-participants on a range of outcomes, grouped into primary and secondary outcomes. The first set of primary outcomes refers to the uptake of the promoted agronomic methods and technologies, mainly CA practices; improved maize and soybean seeds; the uptake of other legumes (cowpeas, sunflower, groundnuts); and the use of inorganic fertilisers. The second set of outcomes refers to crop productivity (specifically maize, soybeans, aggregate and net), agricultural commercialisation (mainly maize, soybeans and overall crop commercialisation, all computed by dividing kg sold by kg harvested), and finally, at the impact level, household and gender-specific food and nutrition security (mainly the household food insecurity score and the minimum dietary diversity score for women of reproductive age). The outcomes in a DID approach are measured by comparing the evolution of the selected indicators between participants and non-participants in between two survey rounds – one in 2018 near the start of the scheme in 2016 (baseline) and the next in 2021.

AAZ's outgrower programme consists of three components: i) agricultural extension services with free trainings on CA and sustainable intensification, fertilisers and seed use, post-harvest handling, marketing and business skills, ii) seed loans and iii) purchase of the harvested staple crops grown by farmers (maize and soybeans). In the early stages, purchases were made without prior contractual agreements; in the last stage (which came too late to have the chance of being included in the first-round survey) contracts were finally granted. Trainings were designed on state-of-the-art knowledge about CA and through a farmer-to-farmer extension approach, whereby lead-farmers ("farmer coordinators") were trained to then train other fellow farmers in self-organised groups. As part of the AAZ input support and output market interventions, community trading depots were set up in the two districts to sell inputs (seeds, fertiliser, herbicides) on a cash or – more rarely – loan basis and to buy crops from farmers. As mentioned, the scheme experienced changes over time due to learning and changes in external

1 The literature, scientific and political debates are not clear in the use of the terms "contract farmer" and "outgrower". Literally, contract farmer simply means that a farmer produces an agricultural product (with specific process and substantive prescribed characteristics) on his/her own account/ own farm /self-chosen technology, with a contract which offers/guarantees the sale to an up-taking enterprise, often at an agreed price or at least a price-finding mechanism, while an outgrower is supposed to be much more closely associated with the uptaker through the provision of advice, inputs, credit, and sometimes even investments and land. In much of the literature, including many UN Food and Agriculture Organization texts, the terms are used interchangeably. Although AAZ's smallholder support programme did not provide in the initial phases binding contracts for purchasing products, they provided services, sold inputs and purchased non-contracted products. In the last phase, which is so young that it was not captured by the first-round survey, the company started to provide contracts. We continue to use the term "outgrower programme" for all of AAZ's smallholder-related packages in all phases, also to be consistent with the company's terminology.

conditions, which can serve to define phases. When the programme commenced in 2016, AAZ focussed mainly on maize and farmers in Mumbwa district. In 2017, the programme expanded to Chibombo district and included the supply of seeds for sunflower, cowpeas and groundnuts. In 2019, AAZ restructured its programme to introduce new, high-value crops for export such as quinoa and chia. For this restructured programme, AAZ started a contract farming approach with farmers in Mumbwa district and scaled-down other components of the programme. The current discussion paper focusses on the enduring effects of the programme interventions in the early phase prior to the shift to quinoa and chia in "real" contract farming.

This paper uses panel household survey data collected in two rounds in the target districts: Mumbwa and Chibombo. The baseline survey in 2018 focussed on the 2016/17 main agricultural season with about 793 households. The follow-up survey took place in 2021 with 690, with the focus on the outcomes of the 2019/20 agricultural season. In addition, qualitative interviews (focus group discussions) were carried out in six villages selected from the two districts where AAZ implements its outgrower programme and where it also operates its own estate. In terms of statistical analyses, the paper uses both descriptive statistics and various econometric techniques such as propensity score matching difference-in-differences (PSM-DID), semiparametric DID and PSM (to account for differences in relevant observable characteristics and remove time-invariant factors).

The descriptive results show that the type of participation in the programme components varies across participants and components, with most participating in trainings. For instance, at the baseline, around 58 per cent of the sample farmers had received trainings or advice from AAZ, and this figure rose to 67 per cent at the follow-up. Similarly, around 24 per cent and 33 per cent of our sample farmers had acquired inputs (in cash or loans) and sold crops to AAZ at the baseline, respectively. At the follow-up, the figures increased only slightly to 28 per cent and 39 per cent, respectively. The main crops purchased by AAZ during the study period were maize, soybeans, groundnuts, sunflower and cowpeas. The proportion of farmers who had received training as well as input support was similar at the baseline (27 per cent) and the follow-up (33 per cent). Except for input support, which was less prevalent in Chibombo district, programme components were evenly distributed across districts. On a series of socio-demographic and economic indicators, there were few significant differences between AAZ outgrower participants and non-participants, except for household size, kinship (household head relationship to the village chief) and landholding size. Participants had larger landholdings and better relationships with village chiefs than non-participants. The observed significant differences increased during the programme.

After accounting for these observable differences using the PSM-DID to single out their estimation bias on the impact indicators, our regression analyses suggest the following key findings. First, we found that participation in the outgrower programme increased the adoption of full-suite CA practices by about 8 percentage points, compared to similar, matched non-participants. However, the impacts of AAZ on the adoption of other technologies, specifically the use of improved seed varieties, is less obvious and depends on the type of interventions and scheme design details such as crops promoted.

Second, our various estimates suggest that the impacts of the programme on productivity and commercialisation indicators are weak. However, impacts on crop productivity and market participation were higher (and significant) during its early phase than in later phases, specifically for maize and before the programme shifted its focus towards oilseed crops. In this regard, the establishment of trading depots during the early phase significantly contributed to that positive impact, which suggests that they would merit further support in order to have a sustainable impact on the livelihoods of smallholder farmers growing cereal crops, but we ignored why these depots have been mostly closed, that is, whether that measure had too high of a cost for the company. In addition, the overall effect of a programme on crop commercialisation suggests that AAZ's strategy of vertically integrating grain producers into the food value chain seems ineffective, although there were some positive effects detected during the early phase of the programme operation. For instance, in terms of maize and soybean sales to AAZ, we found no significant difference between participants and non-participants. Moreover, although we did not find an overall robust effect of the programme on improving crop productivity, further analysis suggests that the programme increased crop productivity by inducing the uptake of CA practices and use of improved agricultural technologies. As an example, we found that increased adoption of CA practices and improved agricultural technologies during the project period have positive and significant effects on productivity. These results provide evidence about private-sector-driven support programmes as an indirect channel, through which their interventions can increase farmers' productivity.

Third, there is some suggestive evidence (although the effect is weak) that the programme has a positive effect on improving the dietary diversity of women in participating households, but no effect on general household food security. This is partly because of the fact that the level of food insecurity does not seem high, at least in the study areas observed during the research period. Our qualitative data suggests that the nutritional education programmes of AAZ, increased off-farm employment of participating households and improved joint decision-making in the households regarding land allocation are some of the pathways through which the programme affects nutrition outcomes. However, further research would be necessary to explore how exactly these effects occur.

Fourth, our findings show that the magnitude and significance of the estimates depend on the type of interventions (or components) that participants are involved in. The three components of the programme (trainings, input support and output purchases) have heterogeneous effects (both in terms of sign and magnitude) on primary and secondary outcomes. For instance, on average, training improved the uptake of CA practices as well as the adequacy of micronutrient levels in women; input support and the purchase of harvested crops enhanced the adoption of agricultural technologies and crop productivity. Hence, if the policy focus is to improve productivity, it is important to strengthen components that provide input support and the guaranteed off-take of crops produced by farmers. With regard to improving women's micronutrient consumption, complementing input and output market interventions with nutrition education (training) can yield additional positive results.

Fifth, the effects of AAZ interventions are heterogeneous for different types of farms: The effects are larger for participating households that are in the lower end of the (maize and soybeans) productivity distribution (e.g. 10th or 25th percentile) than in the upper end of productivity distribution (e.g. 90th percentile). This implies that such interventions would also play a role in reducing productivity inequality. Similarly, the analysis suggests that the largest effects materialise for the extremely food-insecure among the participating households. However, the results of this distributional impact of programme participation should be interpreted with caution, as the estimates might be biased by a lack of adequate statistical power and measurement errors.

In sum, there is some evidence of positive impacts of AAZ outgrower programmes that points to the potential role of private-sector actors in improving agricultural services for farmers and the adoption of new technologies and practices, which contribute towards improving smallholder livelihoods. However, the effects are not overwhelming and less clear for some of the components of the programme than one would have expected. In addition, not all participants profit at the same rate. Poorer and less productive farmers seem to profit more, but again the effects are not very strong. However, partial and unequal positive impacts may partly explain why the participation rate was relatively low. The fact that Amatheon itself changed the scheme design (change of crops, depots, credit, contracts) indicates that the package is not yet stable or fully performing. One should remember that the company was a start-up and adopted the package based on recommended information in the local innovation system. It is, however, documented that these elements (for instance improved seeds with all components) are not working as well as sometimes insinuated by the research and by stakeholders – it is possible that they relied more on experimental than real-farm data. Some of the selected crops, in particular maize, are highly politicised, which makes interventions even more vulnerable to policy interventions in addition to the "usual" variability of production and markets. In addition, the quick turnover of Amatheon elements also makes it more difficult and less likely that large impacts can be found, since farmers tend to adopt such innovations and spend money on them only piecewise. Moreover, it is important to note that the 2016/17 and following seasons were characterised as dry agricultural seasons, which made AAZ's operations and those of smallholders more difficult. In addition, the decision by the Zambian government to not issue export licences or restrict exports of maize further contributed to the challenges faced by Amatheon to access markets for their produce and that of smallholder outgrower participants. All these factors have implications on yields and incomes, and thus on the impacts of interventions. Furthermore, AAZ indicated that price volatilities for staple crops forced the company to shift its focus to high-value crops such as quinoa. It would be interesting to examine the potential impacts of such a shift on smallholder farmers.

As a more general conclusion, thus, the impacts of complex packages of support to smallholders depend on a wide variety of factors, some of which are in the hands of private-sector outgrower scheme organisers, while others are not. The selection of scheme design (crops, components and types of intervention, details of delivery) have to be carefully selected and – ideally – tested before being applied on a mass scale. Once started, schemes should be adaptive but stable in the broader lines of intervention since – poorer more than richer – smallholders are reluctant to take risks; they can and should adopt proposed innovations only gradually while learning and adjusting. Smallholder supporters should do the same. It is possible – and should be followed up on – that the technological packages for CA and the improved seeds are less sound than they should be. Investors reaching out to smallholders assume high levels of responsibility, particularly if they offer them loans and "drag" them into debt, so the utmost care has to be given to the design of the schemes. Design obviously depends on context, and variability and (particularly unexpected) changes of contexts will influence the appropriateness of a scheme. This also means that no per se positive impact can be expected from NOSs – the devil is in the details.

1 Introduction

There has been growing foreign commercial interest to invest in agricultural land in developing countries since the mid-2000s (Anseeuw et al., 2013; Deininger et al., 2011). Among other factors, this trend was sparked by the biofuel boom of the mid-2000s (Brüntrup, Anders, Herrmann, Schmitz, & Kaup, 2010; Hirschl et al., 2014) and the 2007/08 food price crisis (Anseeuw et al., 2013; Baumgartner, von Braun, Abebaw, & Müller, 2015). Many countries in sub-Saharan Africa (SSA), where productive agricultural land has been often perceived as abundant and low cost (Deininger et al., 2011; Schoneveld, 2014), have experienced an upsurge in large-scale foreign farmland acquisitions. Zambia has been among the major recipients in SSA. Similar to many other countries in the region, the Zambian government has attempted to attract foreign commercial investments in agriculture by facilitating farmland acquisitions, for instance through the farm block programme targeting 1 million hectares (ha) in all of Zambia’s 10 provinces (Matenga & Hichaambwa, 2017).

Large-scale foreign farmland acquisitions have been highly controversial in policy and scholarly debates (Borras & Franco, 2012; Deininger et al., 2011; White, Borras Jr, Hall, Scoones, & Wolford, 2012), raising questions of potentials and risks. On the one hand, it has been often argued that foreign commercial investments in agriculture more generally are likely to create rural employment, transfer of technology and knowledge, and modernise agricultural value chains (Deininger et al., 2011; Deininger & Xia, 2016; Robertson & Pinstrup-Andersen, 2010; Songwe & Deininger, 2009). On the other hand, critics have pointed out that large-scale land acquisitions specifically may displace local populations and increase resource conflicts, jeopardising an inclusive rural development strategy (e.g. Cotula, Vermeulen, Leonard, & Keeley, 2009; De Schutter, 2011; White et al., 2012). The empirical evidence on the effects for SSA, generated with both qualitative (Bluwstein et al., 2018; Bruna, 2019; Engström & Hajdu, 2019; Hall, Scoones, & Tsikata, 2017; Nolte & Subakanya, 2016; Nolte & Väth, 2015; Sulle, 2017) and quantitative methods (Bottazzi, Crespo, Bangura, & Rist, 2018; Deininger & Xia, 2016; Herrmann, 2017; Herrmann & Grote, 2015; Khadjavi, Sipangule, & Thiele, 2020; Lay, Nolte, & Sipangule, 2020; Osabuohien, Efobi, Herrmann, & Gitau, 2019), so far suggests that potential effects for local communities are very context-specific and influenced by how the investment is implemented.

By integrating outgrower schemes in their supply chains, large-scale commercial investments can provide market opportunities for small-scale farmers and address production constraints regarding access to national and international output markets, high-quality inputs, information, credits and/or technology (Barrett et al., 2012; Biggeri, Burchi, Ciani, & Herrmann, 2018; Deininger et al., 2011; Deininger & Xia, 2016; Herrmann & Grote, 2015). Others have been less optimistic and stress the potential negative effects from the exploitation of farmers due to monopsonic market structures (Little & Watts, 1994; Sivramkrishna & Jyotishi, 2008) or negative distributional effects, for example when land- and resource-poor farmers are excluded (Goldsmith, 1985; Key & Runsten, 1999; White et al., 2012). To attenuate critics, but also for other reasons such as efficiency gains, cost reduction, search for political allies or simply lack of sufficient land, some large-scale investments have engaged smallholder farmers as suppliers (outgrower or more loose cooperation agreements). Such arrangements that aim at increasing the market participation of smallholder farmers and often try to increase their productivity are often seen as win-win-win solutions for investors, smallholder farmers and rural development. The impacts of such programmes, however, are complex and still not well understood, not least because the external and internal conditions of cooperation vary from case to case. Moreover, the empirical evidence on the impact of outgrower models for staple crops in SSA is still relatively limited and offers mixed results (Bellemare & Novak, 2017; Herrmann, Jumbe, Brüntrup, & Osabuohien, 2018; Maertens & Vande Velde, 2017; Negash & Swinnen, 2013; Ragasa, Lambrecht, & Kufoalor, 2018).

This discussion paper attempts to contribute towards filling this knowledge gap by analysing the ex-post effects of a foreign (private) commercial investment in farmland in Zambia – the Amatheon Agri Zambia (AAZ) "outgrower" programme – on various welfare outcomes. Specifically, the paper compares households participating in at least one of the AAZ outgrower activities with non-participants in terms of adoption of agricultural technology (seed and fertiliser), CA practices, crop productivity, food and nutrition security (of women of reproductive age), and commercialisation. To expand its trading volume and as part of its corporate social responsibility, AAZ has developed an outgrower programme with farmers, first in Mumbwa district in 2013/14 and then expanded to Chibombo district in 2017. The first phase of AAZ's outgrower programme (season 2013/14 to season 2015/16) was comprised of three components: i) free trainings on conservation agriculture (CA) and sustainable intensification, input use, post-harvest crop handling, marketing and business skills; ii) input support in the form of seed loans, specifically improved maize and soybean seeds; iii) purchase of maize and soybeans without prior contracts with farmers. Establishing trading depots (about 30) to sell inputs and buy grains was also part of the market support. The second phase (season 2016/17 to season 2018/19) of the programme expanded its activities in phase one (both in terms of geographic coverage and crop focus) to include additional crops for sunflower, cowpeas and groundnuts as part of its input support programme as well as the purchase of these promoted crops. Consequently, the purchase of promoted crops – initially limited to maize and soybeans – was expanded to include sunflower and legumes, supported through input loans. During the second phase, the programme also incorporated different public–private and non-governmental organisation (NGO)–private partnership arrangements. For instance, the programme received support from the United States Agency for International Development (USAID), the German Investment Corporation (DEG) and Musika (a Zambian non-profit company involved in the promotion of agricultural markets) to expand the construction of depots in Chibombo district. After 2019 (the third phase), AAZ re-designed its outgrower programme to focus on high-value export crops such as quinoa and chia with a contract-farming approach in Mumbwa district, while scaling-down or stopping some of its other activities, specifically the provision of input support and the purchase of cereals. In contrast to other contract-farming schemes, the first and second phases of AAZ outgrower programmes, which are the focus of this paper, did not involve contractual obligations on either AAZ or farmers at the time of the surveys. In fact, although AAZ's outgrower programme can best be described as a "nucleus-outgrower" scheme (NOS), we prefer to use the term "outgrower" programme to remain consistent with the company's term.2 In this paper, all farmers who participated in one or more of the components of the programme (training, input support and purchase of grain from farmers) are subsumed under the term "outgrowers".

This discussion paper makes a number of contributions to scholarly and policy debates. First, it contributes to a growing literature on the socio-economic effects of the different business models for large-scale land-based agricultural investments (e.g. Brüntrup et al., 2018; Nolte & Ostermeier, 2017) by shedding light on the potentials and limitations of smallholder outgrower

2 "The nucleus is a large farm unit, in this case AAZ, which guarantees a certain minimum provision of raw material for a large-scale processing plant or other downstream aggregation use, while the other part of the raw material is procured from smallholder farmers who are linked through contractual arrangements to the nucleus" (Brüntrup et al., 2018, p. 1).

programmes to complement an investor's large-scale commercial farming operation. Second, the paper contributes to the emerging literature on the socio-economic effects of outgrower farming in staple crop sub-sectors of SSA (Maertens & Vande Velde, 2017; Ragasa et al., 2018), specifically to the NOSs (Brüntrup et al., 2018; Herrmann & Grote, 2015). Third, the paper aims to contribute towards the debate on the sustainable intensification of small-scale agricultural systems in SSA through CA (Giller et al., 2015; Rodenburg, Büchi, & Haggar, 2020) and the potential role of the private-sector as a driver for CA adoption (Westengen, Nyanga, Chibamba, Guillen-Royo, & Banik, 2018). Zambia is one of the countries in which CA was promoted early in SSA, yet in spite of more than two decades of promotion, adoption rates in Zambia and other SSA countries have been limited, and its potential for smallholder agriculture is controversially debated (Corbeels, Naudin, Whitbread, Kühne, & Letourmy, 2020; Rodenburg et al., 2020). Lastly, the paper will add to the literature on the role of private-sector outreach programmes in improving the adoption of smallholder farm-level agricultural technologies, productivity and market participation in the developing world.

The analysis of this paper relies on a panel dataset from two waves of household surveys covering about 800 farming households conducted in 2018 and in 2021 with farmers who had participated in the first two phases of the outgrower programme and non-participants. To complement the quantitative analyses, qualitative interviews (focus group discussions) were carried out in the six villages – three from each district – where AAZ operates its investment as well as implemented its outgrower programme. The paper uses both descriptive as well as various econometric techniques, such as propensity score matching difference-in-differences (PSM-DID) and semiparametric DID (to account for differences in relevant observable characteristics) in comparing households participating in the AAZ programme with non-participant households both before (in an early phase) and after the programme intervention. Furthermore, we ran various robustness checks to examine whether our results are sensitive to various definitions of outgrower participation, estimation techniques and changes in programme focus. Moreover, a quantile treatment effect in DID has been carried out to examine the heterogeneous effects of programme participation at different levels of outcomes of interest.

The discussion paper is structured as follows: Section 2 presents background information on AAZ's commercial investment and the AAZ outgrower programme. Section 3 discusses the theory of change. Section 4 contains all information on the sampling strategy, the methodology for our analysis and a description of the AAZ outgrower programme based on the sample information. Thereafter, Section 5 provides the results of the descriptive and econometric analyses of the outcome comparisons between programme participants and non-participants as of the 2016/17 agricultural season. Section 6 provides conclusions and policy implications relevant for programme design and further research.

2 Amatheon Agri Zambia and the outgrower programme

Amatheon Agri Holding N.V. is a German agribusiness company founded in 2011. It operates in SSA, where it established a subsidiary in Zambia in 2012, Amatheon Agri Zambia (Amatheon Agri, 2013), and later subsidiaries in Uganda and Zimbabwe. Amatheon Agri's headquarters is located in Berlin, Germany. In Zambia, it acquired a 99-year land lease of initially 32,000 ha in Mumbwa district (Amatheon Agri, 2013), which was increased to 38,760 ha in 2014 (Amatheon Agri, 2015). According to the Land Matrix website, the privatised and titled farm block was originally designated in 1973-1974 and previously used for large-scale planting by various owners (Land Matrix Global Observatory – LMGO, 2019). AAZ implemented a system of large-scale commercial farming in 2013, focussing on maize, soybean and wheat on both irrigated and rainfed fields. At the end of 2014, the company reported 1,430 ha under cropping as well as approval for an expansion of 4,000 ha (Amatheon Agri, 2015). By 2016, AAZ reported to have 2,988 ha under cropping (Amatheon Agri, 2017). AAZ increasingly expanded its own crop portfolio towards high-value and horticulture products (Amatheon Agri, 2018, 2019), eventually focussing on "natural healthy foods" such as chia seeds and quinoa for export (Amatheon Agri, 2019; personal communication with AAZ). In addition to crop farming, AAZ operates a cattle-ranching component.

Alongside its large-scale farming operations, AAZ started trading with farmers in its project area in 2013 by purchasing crops, selling inputs and offering extension services (Amatheon Agri, 2014). The smallholder engagement started with AAZ initiating a small extension project for surrounding farmers with a Zambian NGO called Musika. In addition, it established a retail/farm shop for farmers to buy maize and soybean inputs, receive advice on input use, and to sell maize and soybean outputs to AAZ (Amatheon Agri, 2015, p. 27). By integrating the trading component into its general business operations (Amatheon Agri, 2014, 2016), AAZ aimed at increasing its trading volume while "achieving significant social impact", fostering entrepreneurship, stimulating local productivity and diversifying sources of income (Amatheon Agri, 2016, p. 35). AAZ referred to itself as an "anchor investor in rural areas to uplift neighbouring communities economically, socially and environmentally" (Amatheon Agri, 2016, p. 32), with its commercial farm to serve as a "hub" for surrounding communities by providing infrastructure and market access (Amatheon Agri, 2016).

Its outgrower programme has undergone significant changes since its start. The extension component aimed at increasing the productivity of small-scale farmers through CA and business-skills training (Amatheon Agri, 2014, 2015). According to the Food and Agriculture Organization (Food and Agriculture Organization [FAO], 2014a), CA is an approach for resource-efficient agricultural production involving three main components: minimum tillage, mulching and crop rotation (CR) with legumes.

Training was provided free of charge and also covered the issues of lime, fertiliser and herbicide application, post-harvest handling, marketing and accounting ("farming as a business"). Training was implemented in collaboration with two NGOs: the Conservation Farming Unit (CFU) and World Vision. CFU has implemented CA training in Zambia since the 1990s. Training is based on a lead-farmer-extension or train-the-trainer model, that is, experienced farmers were selected as farmer coordinators (FCs) and trained by CFU and World Vision, after which they trained 60-100 farmers in self-organised groups. FCs were not employed by AAZ but received inputs as incentives (personal communication with AAZ staff). By 2016, AAZ reported to have a network of 8,000 farmers who participated in training (Amatheon Agri, 2017, p. 9).

As part of the trading component, AAZ established rural trading depots in close proximity to communities for farmers to buy inputs and sell their crops. Although maize and soybeans comprised the majority of crops traded during the initial phase of the programme, in 2017, the company started promoting cowpeas, groundnuts and sunflower (Amatheon Agri, 2017, p. 17). AAZ had a partnership with the UN World Food Programme to operate as the buyer of smallholder cowpeas to supply them to the World Food Programme for their national school feeding programme (Amatheon Agri, 2017, p. 9), but the partnership had stopped before the follow-up survey was conducted. At some point, AAZ also operated a livestock purchase and service component (Amatheon Agri, 2017).

AAZ also negotiated an input financing scheme with Zanaco Bank (Amatheon Agri, 2015, p. 18), with AAZ acting as co-guarantor for the loans in a tripartite agreement (personal communication with AAZ staff). In the loan agreement, farmers were to pay 50 per cent of the loan up front and the remaining amount plus interest after harvest, with loan recipients receiving a crop purchase guarantee from AAZ (personal communication with AAZ staff). About 140 farmers overall participated in the initial loan trial (Amatheon Agri, 2016), expanding to 285 farmers in 2017/18, with AAZ guaranteeing purchasing the harvest (personal communication with AAZ staff).

In 2017, AAZ established a partnership with USAID to expand the outgrower programme to Chibombo district and “to support an additional 6,000 farmers with access to inputs, credit, trainings and markets” (Amatheon Agri, 2018, p. 9; personal communication). Along with its expansion, AAZ additionally focussed more on cowpeas, sunflower and groundnuts (Amatheon Agri, 2019, p. 1). To improve seed access for these crops, a seed bank was established (Amatheon Agri, 2018, p. 9; 2019, p. 9). By 2018, the outgrower programme had reached around 15,000 smallholder farmers in Mumbwa and Chibombo districts (Amatheon Agri, 2019, p. 9).

Around 2019, AAZ restructured the programme by introducing quinoa to farmers in the vicinity of its farm in Mumbwa, with 1,000 smallholder farmers joining the trial and more than 100 farmers being officially certified by an internationally recognised certification body as organic (quinoa) farmers (Amatheon Agri, 2021). Although AAZ did not have purchase agreements with farmers in the other trading components – with neither side obliged to purchase or sell – AAZ acts as a “guaranteed offtaker” in the quinoa project with guaranteed prices beforehand (Amatheon Agri, 2021; personal communication). In order to develop the quinoa contract farming and with USAID’s funding ending, the company decided to reduce other programme activities, especially in Chibombo, with plans to expand later once the quinoa scheme has been fully established (personal communication).

This overview suggests that the Amatheon outgrower programme has been changing over time and is still developing, capturing different projects that focus on trading with and supporting farmers in Mumbwa and Chibombo. During the first years, when operating mainly in Mumbwa (the first phase of the outgrower programme), the focus was on maize and soybean production, mainly involving training and trading activities, with a small credit component. With its expansion to Chibombo (the second phase), AAZ had increasingly integrated higher-value crops, using loan schemes to support access to the seeds for these crops.

3 Framework: Potential economic effects of the AAZ outgrower programme

Along its large-scale farming operations, Amatheon uses its commercial farms as a nucleus to support and trade with smallholder farmers. In addition, it uses its newly constructed processing and storage facility to collect produce grown by farmers. Unlike a typical outgrower scheme, which provides inputs to farmers and guarantees the purchase of the entire or part of their harvest, AAZ outgrower programmes envisage incorporating smallholder farmers into the rural value chain, build outgrower networks, foster entrepreneurship, stimulate local productivity and diversify sources of income through three core interventions (channels): technical assistance, provision of input support (seed and fertiliser) and the purchase of the harvested crops (Figure 1). Although some of the interventions may need more years to establish and produce long-term impacts, AAZ interventions affect outcomes through various channels.

The first channel is technical assistance. Of the various technical assistance activities, training is the component in which most farmers participate. Although training covers a range of agricultural and non-agricultural topics, including the adequate use of agricultural technologies (e.g. fertiliser and herbicides), the project focusses on CA and related agricultural extension services. CA is a sustainable agricultural-intensification approach and is often defined by its three main practices: (1) minimum mechanical soil disturbance (minimum tillage); (2) retaining sufficient crop residues to permanently cover the soil, for example mulching (residue retention – RR)[3]; and (3) CR with nitrogen-fixing crops (FAO, 2014b; Kassam, Friedrich, Shaxson, & Pretty, 2009). Although trainings on CA and improved technologies (such as seeds or fertiliser) may enhance farmers' know-how and knowledge, it might not be enough for adopting CA or any other technologies if there are constraining trade-offs or farmers lack access to capital (Arslan, McCarthy, Lipper, Asfaw, & Cattaneo, 2014; Giller et al., 2015). CA practices may improve yields by increasing soil fertility, reducing erosion, or conserving and improving soil moisture (Arslan et al., 2014; Giller et al., 2015; Ngwira, Thierfelder, Eash, & Lambert, 2013) as well as reducing labour demand (e.g. by stopping weed growth) (Giller et al., 2015). Although some studies have confirmed the positive yield and/or income effects of adopting CA (Ngoma, Mason, & Sitko, 2015; Tambo & Mockshell, 2018), estimated effects vary considerably (Corbeels et al., 2020; Rodenburg et al., 2020). Since experimentation with, and adoption of, new practices and technologies can be a rather longer-term process, it might be more realistic to observe the differences in intermediate outcomes in the short term, such as the adoption of promoted practices and technologies rather than yield effects, which may be expected only in the medium term (Giller, Witter, Corbeels, & Tittonell, 2009).

The second channel is the provision of input support (improved seed and fertiliser) in the form of loans and agricultural input credit. The advantage of outgrower farming may not only come from enabling smallholders to access commercial value chains, but also by addressing input market failures, thereby increasing access to inputs, and eventually crop yields and incomes (Barrett et al., 2012). Input market access can be improved, for example, when contracts are used as collateral, when credit schemes are part of the agreements (e.g. tri-partite arrangements with commercial banks) or when earnings are sufficient to purchase inputs (Govereh & Jayne, 2003; Grosh, 1994; Herrmann, 2017). Another advantage for farmers' investments and input use is the potential risk-reduction effect for farmers of having a guaranteed market. In the case of the AAZ outgrower programme, input supply components may improve input access via

3 It is often stated that at least 30 per cent of the soil has to be covered (Giller et al., 2009).

increased community-level input availability due to the input depots or the loan programme, and because of improved grain and legume market opportunities that may raise the profitability of using external inputs.

Having access to the input market might also address technology adoption constraints, for example constraints to access legume seeds, sell legumes and access fertiliser and/or herbicides. CA projects therefore often involve the additional promotion of external inputs such as fertiliser, herbicides and/or improved seeds as part of a full CA package (Arslan et al., 2014; Giller et al., 2009). However, poorer farmers may lack the resources to purchase inputs. Although the programme's loan component may address financial constraints for resource-poor farmers, the risks associated with taking up credits may prevent them from taking them up, and creditors may also favour larger, more solvent commercial farmers rather than smallholders.

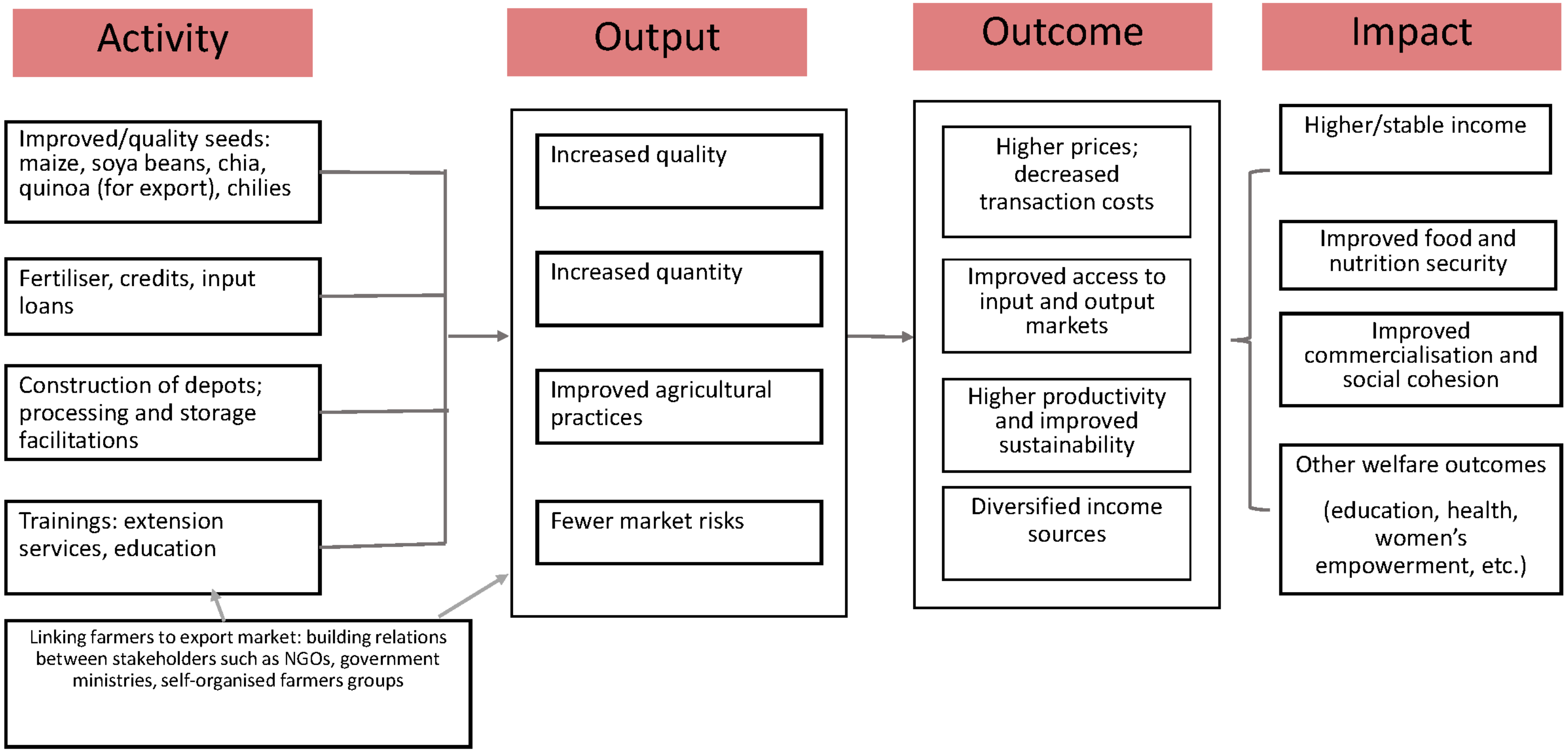
The third channel is the output purchases (with or without prior guarantee). Through AAZ's grain purchases, farmers may improve the sales of crops already part of their portfolio (e.g. maize and soybean) or of the new crops purchased by AAZ (groundnuts, sunflower and/or cowpeas), thereby raising or stabilising revenues and incomes. Especially for crops with markets and buyers that are based in urban centres, proximity to AAZ's input and output aggregation depots located close to communities help farmers overcome barriers to market access by reducing the distance to markets, which helps to decrease transaction costs. Positive price effects for farmers, however, are likely to be stronger for high-value crops and limited for staple crops, such as maize or soybeans, which are commonly traded on local markets.

The fact that AAZ did not have purchase agreements at the time of the survey may allow farmers to sell to the buyer who offers the highest price. But the lack of purchase guarantees can also expose them to more risks, especially when adopting crops that were newly introduced by AAZ to the region. For instance, if contracts are reliable, more stable effects can be observed. A drop in maize prices in 2017, for example, which led AAZ to reduce crop purchases, could have made farmers worse off if they had initially increased production because of AAZ's presence but could not find alternative markets available. Yet, since the major crops of the first phase of the AAZ outgrower programme in 2016/17 (maize and soybean) are also commonly traded locally, such market risks could be less relevant, as farmers would be more likely to find other buyers. Although the impacts remain to be seen, the introduction of a pre-fixed price off-take contract (with quinoa and chia for export) in the third phase of the programme can be a positive adaptation strategy.

Overall, the benefits from participating in the AAZ outgrower programme are likely to be greater when households have access to more or all three components (training, inputs and crop sale). Training is likely to be accessible to most farmers, as it is free of charge and only involves the opportunity costs of time. However, production effects might be lower than when combined with other components. Access to inputs, which could be the most important factor for improving yields, may be limited to better-off households, at least at an initial stage, when the credit system is not yet fully developed. Linking farmers to the export markets, particularly through outgrower schemes, is expected to increase the bargaining power of farmers. The purchase of produce at the farm gate creates market access and decreases transaction costs, and hence can increase income and reduce poverty and food insecurity. Through increased income, production diversification and/or commercialisation, as well as improved access to input and output markets, the project might then improve other dimensions of households' wellbeing, such as the food and nutrition security of household members and their health. The generated changes in production and marketing systems as well as interactions between different approaches can be beneficial to society at large, for example by increasing social cohesion.

However, how effectively these programmes work depends on several factors: project design and management; availability of good policies and institutions that govern interactions among stakeholders, including clarifying the rules of operation; the types of crops promoted (cereals or oilseeds; staple or cash crops); the duration of the project; the types of support provided; the political commitment by host countries, among others. Figure 1 summarises the potential socio-economic channels and effects of the AAZ programme.

Figure 1: AAZ impact framework



Source: Authors

4 Data and empirical approach

4.1 Sample design and data collection

In order to assess the impact of interventions, two rounds of survey data were collected in two districts: Mumbwa and Chibombo (see Figure 2 for a timeline of treatment and survey implementation). A baseline survey was conducted in 2018 focussing on the 2016/17 agricultural season. The follow-up survey took place in 2021, with the focus on the 2019/20 main agricultural season. In addition, qualitative interviews (focus group discussions) were carried out in the two districts, which is where AAZ operates its investment as well as implemented its outgrower programme. During the data collection, tablet-based face-to-face interviews with household heads or their spouses were used, using a structured questionnaire. One of the challenges during the data collection was the difficulty in locating the same households interviewed during the baseline. As a result, the attrition rate was remarkably high, since about 206 (about 25 per cent) of the 793 baseline sample households could not be re-interviewed during the follow-up survey. Hence, we ended up with a balanced panel of 590 households that were re-interviewed during the follow-up. The main reasons reported for this high attrition rate were migration (household moved away – about 127 households), non-contact (56) and death (10 households), among others. Although migration was high among treated households (also stated during the focus group discussion), it was evenly distributed between both districts and not necessarily concentrated in Mumbwa district, where AAZ operates its investment. Since such a high attrition rate could bias our estimates, we checked the patterns of attrition in this. Results show that there were no systematic differences between the attrited and balanced panel households in most of the socio-demographic and economic characteristics, except for the size of the land cultivation for maize, soya and agricultural assets as well as kinship ties with a chief or headman (see Table 1). This was a desirable outcome, as this lends credence to our analysis. Furthermore, 100 additional households engaged in quinoa production in 2021 were surveyed during the follow-up, although we excluded them from the main analysis.

Table 1: Difference in characteristics of attrited vs panel households (HHs) at the time of the baseline

Variables	No. of attrited HHs	Mean 1	No. of panel HHs	Mean 2	Mean diff. (1-2)
HH characteristics					
HH age	206	43.58	582	44.61	-1.03
Female-headed HH	206	0.17	582	0.17	-0.01
HH education (head)	206	7.40	582	7.41	-0.01
HH size	206	6.46	582	7.11	-0.655*
Edu. max (within HH)	206	9.15	582	9.20	-0.05
Dummy=1 if head is married	206	0.81	582	0.83	-0.02
Programme components (treatment status)					
Received training/advice from AAZ (T1)	206	0.55	582	0.58	-0.03
Acquired input or loan (T2)	206	0.32	582	0.33	-0.01
Sold grain to AAZ (T3)	206	0.21	582	0.24	-0.02
Either T1, T2 or T3 (T)	206	0.66	582	0.66	0.00
Received both T1 and T2	206	0.23	582	0.27	-0.04
Production and food security					
HH food insecurity score	206	5.73	582	5.67	0.058
Total cultivated crop, ha	206	3.39	581	3.75	-0.365
Cultivated maize, ha	195	2.17	571	2.66	-0.487*
Cultivated soya, ha	160	1.28	465	1.52	-0.239*
Wealth indices					
Agricultural asset index (pca), incl. tractor/oxen	206	-0.317	582	0.103	-0.420**
Agricultural asset index, only tractor/oxen/plough (pca)	206	-0.196	582	0.063	-0.260*
Agricultural asset index (pca), w/o tractor/oxen	206	-0.239	582	0.078	-0.317*
HH wealth index (pca), incl. motorbike/cars	206	-0.226	582	0.083	-0.309*
HH wealth index (pca), w/o motorbike/cars	206	-0.228	582	0.087	-0.315*
HH experienced a shock	206	0.67	587	0.73	-0.0558
HH irrigated a field	206	0.00	586	0.00	-0.00171
HH accessed a loan other than from AAZ	206	0.27	587	0.28	-0.00413
Land variables					
Per capita farm size	190	0.79	527	0.76	0.0236
HH rented at least one field	206	0.06	587	0.03	0.0293
Land access per capita	199	0.79	548	0.76	0.0221
Kinship ties					
Head or spouse is related to the chief	206	0.04	582	0.09	-0.0488**
Head or spouse is related to the headman	206	0.38	582	0.47	-0.0870*
Head or spouse is related to the farmer coordinator	206	0.32	582	0.38	-0.0642
Head or spouse is related to the chief or headman	206	0.39	582	0.48	-0.0910*

Note: A household is treated if it received advice/training from AAZ or acquired an AAZ input loan/ input purchase or sold grain to AAZ. *** p<0.01, ** p<0.05, * p<0.1.

Source: Authors

The surveys collected detailed data on household socio-demographic characteristics; plot- and crop-level production (i.e. crop management); and adoption of various technologies and agricultural practices, with a special focus on those promoted through the outgrower programme, such as CA, sustainable land management practices, fertiliser use as well as pesticide and herbicide applications. Households were also asked about crop sales, assets, nutrition and food security, labour and land access and use, as well as shocks faced. The surveys have also collected detailed data on household participation in the outgrower programme's components (loan, input purchase, crop sale, training, livestock sale or service access, and employment) since its inception. Moreover, separate modules were designed to collect information about households' access to finance (credit, loan, savings) and social cohesion. Since data was elicited retrospectively for the past 12 months, the agricultural and consumption datasets cover the preceding agricultural seasons. This means that although the baseline survey in 2018 refers to the main agricultural season of 2016/17, the follow-up survey in 2021 refers to the agricultural/cropping season of 2019/20. However, it should be noted that the baseline survey was collected after the programme had already been in operation for about two years in part of the area, and the follow-up was also collected while some interventions were still ongoing or were in their final year (2019/20 was the final season of the main outgrower programme, excluding the quinoa component, which had just started). Thus, the impact assessment measures primary outcomes (such as technology adoption, sustainable land management (SLM) and CA, land markets) and secondary outcomes (productivity, profit, food security) of interest in the 2016/17 and 2019/20 agricultural seasons while AAZ activities (training, input loans/purchase, and purchase of grains) were either ongoing or began after participants had been exposed to at least one of the AAZ activities since the intervention started around 2013/14.

For the data collection, 12 experienced enumerators were recruited and intensively trained to implement the survey. Prior to the formal survey, questionnaire contents were pre-tested in two villages. Enumerators also administered community questionnaires to key informants (FCs, outgrowers and other community members) at the district and ward levels so as to collect data on infrastructure, depot availability, rainfall, temperature, context-specific information as well as to understand stakeholders' views on the AAZ outgrower programme.

The survey employed a multi-stage sampling technique to establish the baseline in 2018. FCs were used as primary sampling units who operated in a given area and managed the lists of farmers participating in the programme. In a second step, the research team selected participant households based on the FC lists and non-participant households from lists created with the FCs and village authorities. From an initial list of 80 active FCs in both districts, the team randomly selected 28 FCs who operated in a total of 103 villages. Up to three villages per FC were selected (largest, smallest and a medium-sized village in terms of the number of participants), resulting in 53 villages with 1,369 registered farmers (1,284 households).

In Mumbwa, we drew a simple random sample of around 250 households from the FC lists among those farmers who stated to have participated in training or to have received a loan.[4]

4 There were some farmers who were on the FC registries – but never or only once participated in a training session – who were excluded from the population. Although we had no prior information on those who sold crops to AAZ or purchased inputs, we expected most of them to also be part of these lists, given the central role of FCs for training others and running input/aggregation depots.

In Chibombo, the FC lists showed much larger shares of seedbank or input loan recipients (31 per cent and 7 per cent of all registered farmer), which is in line with our prior information that, with the programme's expansion to Chibombo, the seedbank component was established to promote cowpeas, groundnuts and sunflower production. In order to reflect all different components of the outgrower scheme, including the relatively new seedbank loans, we stratified the Chibombo sample. We selected all input loan recipients (n=64), 81 out of the 156 seedbank loan farmers and 100 training participants. The final number of loan recipients in the sample, however, differed slightly, as some farmers who registered only as training participants had also obtained seedbank loans. In each district, 150 non-participants were sampled from population lists in the same villages proportionally to village and broad farm size classifications (large, medium, small) to have comparable non-participants.

The slightly higher population share of Chibombo and smaller distance to Lusaka seems to also contribute towards differences in agricultural activity and commercialisation, with more large-scale farms and traders active in Chibombo compared to Mumbwa. In 2015, Sipangule and Lay (2015), for example, identified 12 large-scale land acquisitions in Chibombo over a total of 54,000 ha, compared to only one in Mumbwa with 30,000 ha, but with Mumbwa having nearly twice the total district area (more than 2 million ha). However, Mumbwa hosts a relatively high number of emerging farmers, those cultivating between 5 and 20 ha, compared to other districts in Zambia (Sitko & Jayne, 2014).

Treatment (outgrower programme) participation

Table 2 presents the distribution of households by participation status (referred to as programme participants) and non-participants (those who did not participate in any of the AAZ programme activities) in each district. Individuals are considered participants if: i) they received advice/training from AAZ (T1), ii) they received input support (T2), iii) they sold any of their crops to AAZ (T3) or iv) any of the three treatment arms (T). Households in the first treatment group (T1) had received free training from AAZ in at least one season between 2013/14 and 2020/21 in the areas of crop cultivation, postharvest handling, CA and other sustainable land management practices, input use, marketing and book-keeping, including business skills. Households in the second treatment group (T2) acquired seed loans or purchased seeds from AAZ in at least one season between 2013/14 and 2020/21. We call this input support. Similarly, households in the third treatment group (T3) were those households that sold grain to AAZ under the AAZ's guaranteed off-take of the harvested crops in at least one season between 2013/14 and 2020/21. A general treatment arm (T) refers to households that have taken part in any (one) of the three treatment arms, i.e. T1, T2 or T3. Our main comparison group (C) refers to those households that never participated in any of the AAZ programme activities from the 2013/14 agricultural season (AAZ's initial phase) to the 2019/20 agricultural season.

Apart from participation in one of the AAZ smallholder programmes, some households, mostly from nearby villages, also reported working as casual labourers for AAZ prior to the survey period, although they had all stopped working by the time of the survey reference periods. In addition, only 24 farmers in the sample reported that they had participated in the livestock component. As mentioned previously, since the AAZ smallholder programme was mainly focussed on crop production, our analysis centres on this aspect of the intervention.

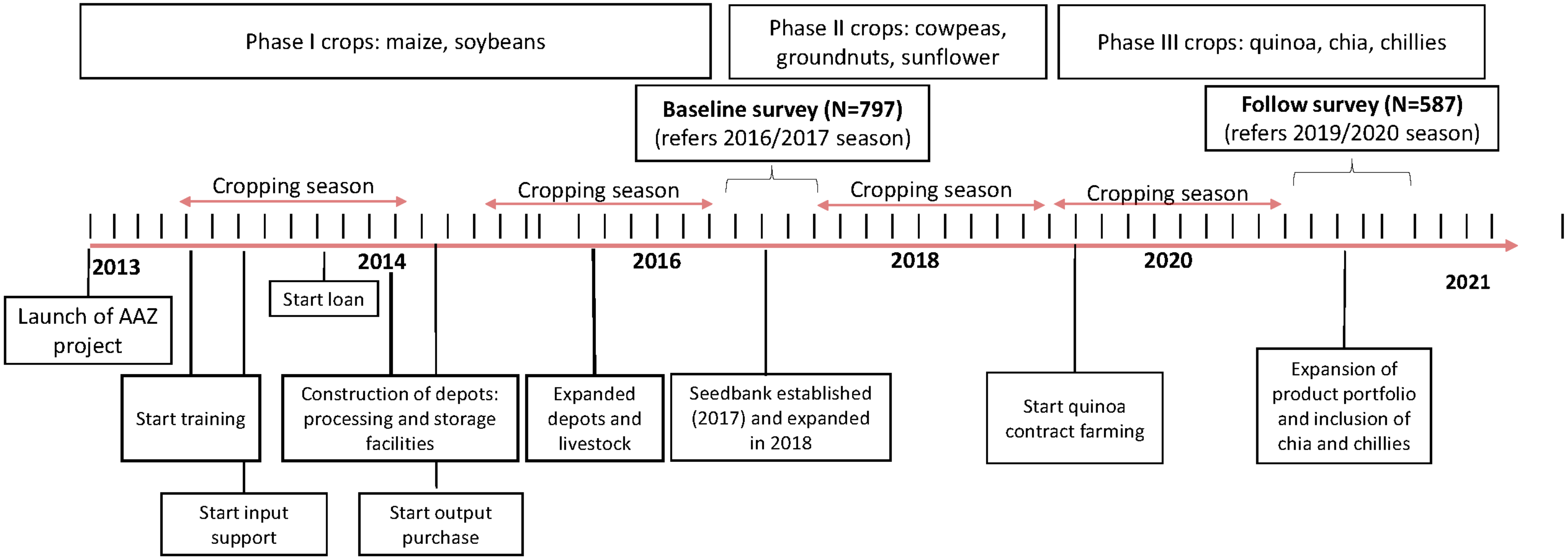
As shown in the first and second columns of Table 2, around 66 per cent and 74 per cent of the households in the sample have received at least one of the three treatment arms at the baseline and the follow-up, respectively. Our data also indicates that, at the baseline, around 58 per cent of the sample farmers had received training or advice from AAZ, and this figure rose to 67 per cent at the follow-up. Similarly, around 24 per cent and 33 per cent of the sample farmers had acquired inputs (either on the bases of loan or cash) and sold crops to AAZ at the baseline, respectively. Moreover, our data suggests that farmers also sell more often to small traders than to AAZ; hence farmers have different options to sell their produce. AAZ was more important in cowpea and sunflower trade (accounting for 28 per cent and 19 per cent of all transactions, respectively), although few reported selling these crops. Groundnuts were mainly sold to small traders or other households and retailers, and hardly any to AAZ. In addition, the share of farmers who have received both T1 and T2 was not high at either the baseline (27 per cent) or the follow-up (33 per cent).

Across the districts, treatment arms are distributed evenly with the exception of T2 (input loan acquisitions or purchases), which, as mentioned above, was more prominent in Chibombo.[5] Most loans were seedbank loans for cowpeas and sunflower, and most loan disbursements in Chibombo only started in the 2017/18 season, later than in Mumbwa. In addition to AAZ, there are also other private loan providers through cotton outgrower schemes in the study areas.

Moreover, as indicated in Appendix A, which summarises the distribution of the assignment of households to different treatment groups over the intervention periods, very few participants received their first training in 2013 (only 2 per cent), but the number steadily increased to 25 per cent and 27 per cent in 2014 and 2015, respectively (see Table A2 in Appendix A). Furthermore, around 38 per cent of the participants had received their first training in 2016, and most of the participants had participated in the programme since 2017 (at the time of the baseline). Overall, there had been substantial changes in participation prior to the 2016/17 agricultural season. Figure 2 depicts a timeline of the intervention implementation, the survey data collection and focus crops of the project.

5 The programme started its first operation in Mumba, where AAZ farm investment is located and was later expanded to Chibombo district.

Figure 2: Timeline of project intervention and survey implementation



Source: Authors

Table 2: Summary of the distribution of participants by districts, balanced panel

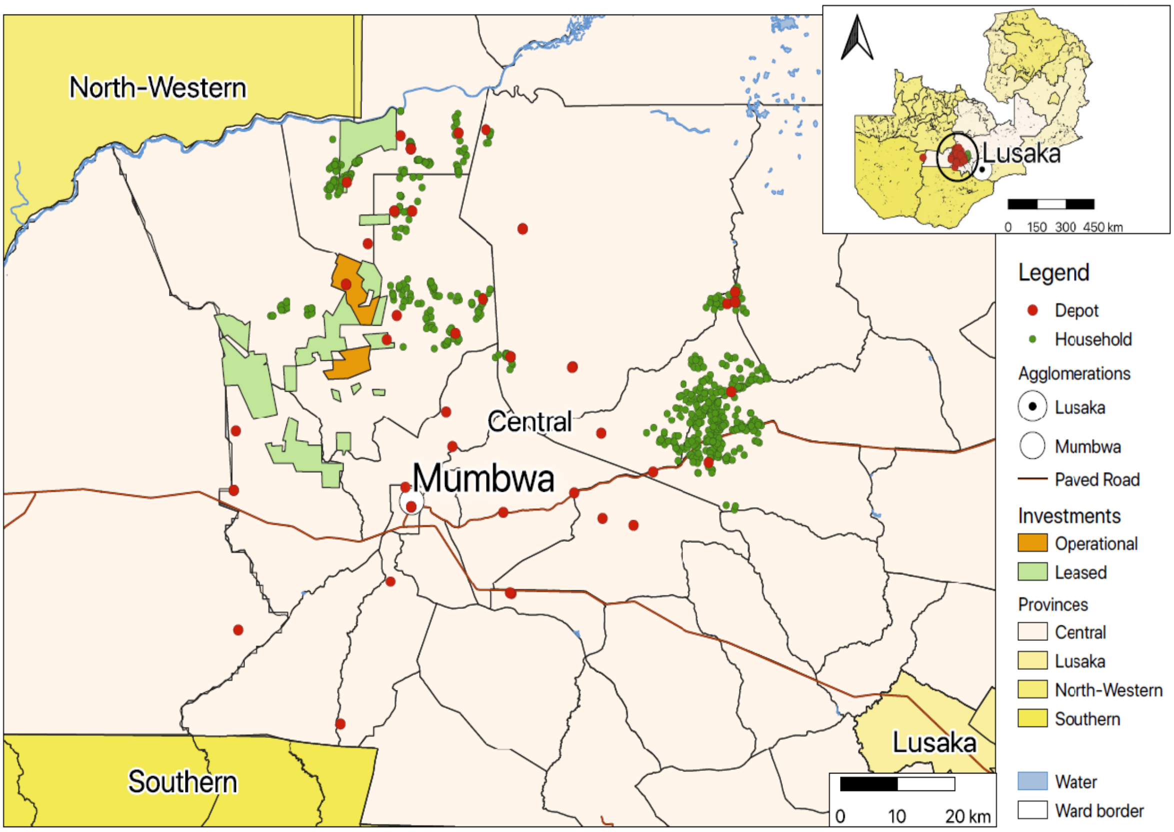
Treatment indicators	All		Chibombo		Mumbwa	
	Baseline	Follow-up	Baseline	Follow-up	Baseline	Follow-up
Received advice/training from AAZ (T1)	58%	67%	53%	61%	64%	73%
Acquired an AAZ input loan or purchased inputs from AAZ (T2)	24%	28%	9%	13%	39%	44%
Sold grain to AAZ (T3)	33%	39%	38%	39%	27%	38%
Participation in at least one project component (T)	66%	74%	62%	69%	70%	80%
No. of HHs	582	587	294	298	288	289

Note: Apart from the AAZ smallholder programme, some households in the sample also reported having worked as seasonal or casual labourers for AAZ before, mainly from the villages located close to AAZ. Yet, most no longer worked at AAZ during the 2016/17 season. Very few farmers in the sample reported having participated ONLY in the livestock component (n=24). We excluded these households from further analysis, as there were only a few and these components are not part of the main smallholder programme that focusses on crop production. Our main comparison group is comprised of those not involved in any AAZ intervention (including AAZ farm labour or participants in the livestock component) nor receiving trainings from CFU.

Source: Authors

Figure 3 summarises the distribution and location of sample households, depot location and AAZ farm blocks.

Figure 3: Study site – Mumbwa and Chibombo districts



Source: German Institute of Development and Sustainability (IDOS) (designed by Kevin Brendlerx)

4.2 Outcome variables of interest

Outcome variables

Since the objectives of the outgrower programme were to provide learning opportunities for farmers to diversify their crop portfolios, increase productivity, reduce post-harvest losses and increase average annual household incomes, hence overall food security, we identified two broad categories of outcomes, namely primary and secondary outcomes.

Our primary outcomes of interest are adoption of CA/SLM practices and the use of improved agricultural technologies. In line with the literature (e.g. Kunzekweguta, Rich, & Lyne, 2017; Ngwira et al., 2013), we measured CA/SLM uptake by focussing on three main practices: minimum tillage (MT), residue retention (RR) and crop rotation (CR). Drawing on Zambia's Rural Agricultural Livelihood Survey – which asked farmers whether they had prepared planting basins, performed zero tillage or ripping on a given plot – we defined MT as a dummy variable taking a value of 1 when at least one plot was treated with planting basins (when using hand hoes), zero tillage or ripping (when using mechanisation) (e.g. Ng'ombe, Kalinda, & Tembo, 2017). CFU additionally recommends till during the dry season, which is argued to reduce labour requirements (Arslan et al., 2014). We therefore also collected information on the timing of the main tillage method.

RR was measured by asking farmers for each plot about the crop/field residue use during the 2016/17 and 2019/20 agricultural seasons, that is, one year before the reference seasons. Accordingly, farmers who left crop residues on the field (e.g. as mulch) and did not plough it back into the soil nor let livestock graze it were defined as RR adopters. To measure CR with legumes or other nitrogen-fixing crops, farmers were asked whether legumes were planted on a given plot, and in which combination they rotate crops on a given plot (e.g. by rotating cereals with legumes/nitrogen-fixing crops). CR is also a binary outcome. CFU also recommends erosion control practices, such as contour farming (contour bunds, grass hedges, contour ploughing, etc.), as part of the CA package, which we also asked about (Arslan et al., 2014).

As to the adoption of agricultural technologies, we focussed on those mainly promoted through the outgrower programme such as improved seeds for maize, soybean, groundnuts, sunflower, cowpeas; and chemical fertiliser use, herbicides, pesticides and weedicides.[6] For each technology, a dummy variable taking a value of 1 indicates if the household has used or applied the respective technology during the agricultural reference period; and 0 otherwise. In addition, technology adoption is also measured in terms of use intensity. As side information, we also documented the effect of the programme on land use and acquisition (methods of land acquisition and tenure status) as another result in the primary outcome.

Our secondary outcome variables are productivity, profits (crop revenue), household food and nutrition security indicators, all of which are considered to be directly related to household welfare outcomes, as well as commercialisation indices. Productivity is measured as maize yield in kg/ha, soya yield in kg/ha or overall cropland productivity. Since AAZ was engaged in the construction of community trading depots to purchase crops from farmers, such intervention

6 We used two different definitions of improved seeds. The first defined the sources of the seeds, which was improved if the seeds came from outside the community (not own harvest/ recycled seed, no other farmer, nor friends/relatives). The second directly asked for the name of the seed, or named them unimproved if farmers referred to them as local or recycled hybrids.

would potentially affect farmers' marketing performance. To capture such an effect, we computed commercialisation indices for maize, soya and the overall crop commercialisation. In particular, the construction of depots can make it easier for outgrowers to reach markets, which may in turn affect farm gate prices. Profits from crop production are measured as total crop revenue minus the cost of fertiliser and seeds.[7] Subsistence production was valued by market prices. Whenever a household did not report crop sales during the 2016/17 and 2019/20 seasons, median prices in the village, ward or district were used. Food security indicators used in this impact evaluation include the household food insecurity access score, the availability of adequate micronutrients in the household for women of reproductive age and the minimum dietary diversity score for women of reproductive age. As a robustness check, we also considered household per capita consumption expenditure – including the values of home production, purchased commodities and gifts – as another indicator of household welfare. We have excluded observations that had clearly inconsistent production and sales data, and we have trimmed income figures at the 1 per cent and 99 per cent levels to account for unrealistic outliers.

Finally, we constructed three commercialisation indices to proxy households' market participation: maize, soybean and the overall crop commercialisation index. All three indices are computed by dividing kg sold by kg harvested. Hence, it also measures the intensity of market participation. For instance, the maize commercialisation index is computed as maize revenue (the price of maize per kg multiplied by kg sold) divided by the maize value of production (price of maize per kg multiplied by kg of maize harvested). A similar procedure is followed to construct the soybean and overall crop commercialisation index. By construction, the indices are continuous variables. Table 3 summarises the various outcomes of interest considered in our study.

7 The cost of fertiliser is computed using the average price of urea and nitrogen-phosphate plus sulphur per kilogram in each district.

Table 3: Outcome indicators

Outcome indicator	Description
***Primary outcomes (outcome related to CA and technology adoption*)**	
Minimum tillage (MT)	=1 if a household is using MT on at least one plot in the 2016/17 and/or 2018/19 agricultural season
Retaining crop residues (RR)	=1 if using RR on at least one plot in 2016/17 and/or 2018/19
Crop rotation (CR)	=1 if using CR on at least one plot in 2016/17 and 2018/19
At least two CA measures	=1 if using at least two CA measures in 2016/17, dummy
All three CA measures	=1 if using all CA measures in 2016/17 and 2018/19
Improved seeds	Seed is not local nor recycled hybrid, dummy
External seeds	=1 if seeds are not from own harvest/recycled seed, no other farmer, nor friends/relatives in 2016/17 and 2018/19 agricultural season
HH produced grounduts	=1 if HH cultivated groundnuts on at least one plot in 2016/17 and 2018/19
HH produced sunflower	=1 if cultivated sunflower on at least one plot in 2016/17 and 2018/19
HH produced cowpeas	=1 if cultivated cowpeas on at least one plot in 2016/17 and 2018/19
HH acquired herbicides	=1 if used herbicides in 2016/17 and 2018/19 on at least one plot
HH acquired fertiliser	=1 if used fertiliser in 2016/17 and 2018/19 on at least one plot, dummy
Use of fertiliser (kg/ha)	Amount of fertiliser used per ha in kg in 2016/17 and 2018/19
Secondary outcomes	
Outcomes related to productivity	
Maize yield in kg/ha	Maize yield in kg per ha (in log form), a continuous variable
Soybean yield in kg/ha	Maize yield in kg per ha (in log form), a continuous variable
Crop value in ZMW/ha	Total value of all crops (cereals, vegetables and fruits) in ZMW per ha
Net productivity per ha	Value of crop production minus variable costs (seed and fertiliser), continuous variable
Crop diversificaiton	Total number of crops grown by a household, discrete variable
Outcomes related to food and nutrition outcomes	
HFIS	Household food insecurity score (0=not food-insecure, 21=often)
MDDW	Minimum dietary diversity score for women of reproductive age
Micro_adequate	Dummy=1 if women's diets in households are adequate in micronutrients
Outcomes related to commercialisation indicators	
Maize commercialisation index	Maize revenue (the price of maize per kg multiplied by kg sold) divided by maize value of production (price of maize per kg multiplied by kg of maize harvested), hence continuous variable
Soybean commercialisation index	Computed the same way as maize commercialisation, a continuous variable
Crop commercialisation index	Computed the same way as maize commercialisation, a continuous variable

Source: Authors

We have also carefully constructed various additional covariates that are indicators of socio-demographic and economic indicators and which need to be considered in the outcome estimation framework. Table 1 shows these selected additional covariates used in the regression analyses, while Table A1 in Appendix A presents the full list of variables and their description.

4.3 Empirical approach

AAZ activities (training, awareness-creation, construction of depots, input loans) are expected to ease several constraints limiting the adoption of profitable agricultural technologies, sustainable agricultural practices and marketing strategies and/or investment decisions faced by farmers. For instance, training by AAZ increases awareness as well as the adoption of CA and improved agricultural technologies, which can be considered as an investment decision to enhance agricultural productivity if adopted. In order to evaluate the impact of the programme, we employed a DID estimation strategy, in which households in the outgrower programme and non-outgrower farmers are compared before and after the programme intervention. Here, we focussed on evaluating the impact of AAZ programme participation on the adoption of CA, agricultural technologies, productivity and household food security outcomes. The decision to adopt new agricultural practices or improved agricultural technologies can be understood as a dichotomous outcome whereby household i participates in one of the AAZ activities. This could then inspire behavioural changes for the household to adopt CA practices and/or agricultural technologies (mainly seed and fertiliser). This in turn increases productivity or food security when a household anticipates a higher than expected utility due to participation in the AAZ programme as compared to if it had not. The main specification is given as follows:

$$Y_{it} = \beta_1 wave_t + \beta_2 Treat_{it} + \beta_3 (wave_{it} * Treat_{it}) + X'_{it}\alpha + Z_i\eta + u_{it} \quad (1)$$

where Y_{it} are the outcome variables of interest (CA practices, technology adoption, productivity, food security indicators) for household i at the time of each survey t; $Wave_t$ is a binary variable that denotes the survey round/year and takes the value "1" if the survey year is 2021, and 0 otherwise; $Treat_{it}$ is a dummy variable that equals 1 for households that participated in one of the AAZ activities at the time of each survey t and 0 otherwise; X'_{it} is a vector representing all time-varying household and community characteristics observed at the time of survey t; Z_i are household and community time-invariant factors; u_{it} is a normal stochastic term. The main parameter of interest, β_3, captures the average treatment effect on the treated (ATT), that is, participation effect for the AAZ outgrower programme participants.

The main identification challenge in our settings is that participation in AAZ is not random, since farmers self-select themselves for the programme, hence participation in the programme is endogenous (Khandker, Koolwal, & Samad, 2010). In other words, since AAZ participation is not randomised, the estimation strategy needs to consider that AAZ participants and non-participants were likely to be systematically different at the baseline. It should be noted that the interpretation of these effects as causal depends on the identifying assumption: the parallel trend assumption. The assumption states that households with and without AAZ participation during the programme operation would have had the same time trend in the impacts on the outcome variables without the AAZ interventions.

Although our difference-in-differences (DID) setting could allow us to remove time-invariant characteristics driving participation, still time-variant characteristics could be the main source of endogeneity, which biases our estimates. To address also this potential endogeneity problem and to exploit the panel structure of our datasets, we employed a propensity score matching (PSM) in combination with DID (PSM-DID) estimators to measure the true effects of AAZ participation (treatment) on the various outcome variables of interest discussed earlier (Abadie & Imbens, 2011; Villa, 2016). One of the main advantages of this approach is that it can consistently estimate the effect of programme participation on our outcome variables of interest, given that our outcome model is specified correctly (Furno & Caracciolo, 2020). PSM helps to reduce potential bias resulting from self-selection into AAZ activities. Using panel data, this method estimates the ATT. Analytically:

$$ATT^{DiD-PSM} = \frac{1}{N_{Tp}} \sum_{i \in T_p \cap S} \left[\left(Y^{p}_{i,t+1} - Y^{np}_{i,t}\right) - \sum_{j \in T_{np} \cap S} W_{ij} \left(Y^{p}_{j,t+1} - Y^{np}_{j,t}\right) \right] \quad (2)$$

Where T_p (T_{np}) represents a treated (non-treated) group, W_{ij} is the nearest neighbour matching weights and S is the area of common support for the covariates. The PSM creates statistically comparable groups based on observable characteristics before performing the DID estimator. This approach has three main advantages (Gebel & Voßemer, 2014). First, it is more robust in minimising misspecification errors. Second, the method ensures a more suitable weighting of covariates. Third, a classical linear regression would extrapolate outside of the area of common support, making comparisons of non-comparable households. A probit model with the following specification is estimated to predict AAZ participation:

$$Treat_{it} = \mu_i + X'_{it}\beta \quad + u_{it} \quad (3)$$

where X denotes vectors of household time-variant characteristics assumed to influence household i’s participation in the programme, μ_i controls for all household and community time-invariant fixed effects such as initial socio-economic conditions of communities and relationship to the FC that are possibly determining participation. The choice of covariates is based on considerations of the relevant literature and the availability of data that explain participation and outcomes: household socio-demographic and economic characteristics (age, gender and highest level of education in the household, household size, farm size, livestock ownership household assets, housing conditions); institutional and other access- and community-related factors believed to affect participation in AAZ activities); and institutional and access-related factors (credit access, non-farm income source and distance to district capital, extension access, membership in organisation). Based on this estimation, a propensity score is calculated, which is then used to match real AAZ participants in the treatment group with their most similar counterfactual from the comparison group (i.e. the matched controls) via one-to-one nearest-neighbour matching without replacement. Since matching results can also be sensitive to variable selection and choice of the matching algorithm, we also carried out some robustness checks.

We also conducted additional robustness checks using a semiparametric DID, “a reweighting technique that addresses the imbalance of characteristics between treated and untreated groups” (Abadie, Drukker, Herr, & Imbens, 2004), and by restricting the sample of households that had benefited from the programme in both waves. In the latter case, households are considered as treated if they meet at least one of the following criteria: received AAZ training/advice in both waves; sold to AAZ in wave one and two; or received or acquired a loan or input purchase in both waves. This means that if household *i* did not participate in the first wave, it is not considered to be part of the treated group. This estimation can also provide some insights about the medium/long-term impacts of the programme. Finally, we conducted additional robustness checks by analysing the impacts of programme participation on outcomes of interest by survey round, that is, separately for the first round and the follow-up using PSM techniques.

Heterogeneous treatment effects

Although the average treatment effect is interesting in determining the effect of programme participation on outcomes of interest, it fails to unravel the heterogeneous and/or distributional effects of the treatment (programme participation) at different levels of outcomes. In other words, it helps to address the question: What is the distribution of productivity across the treated household groups if the treatment had not been offered? In addition, policy-makers may be more interested in knowing the effects of programme participation, say on the productivity of farmers at the tail end of the productivity distribution. Thus, as a final analysis, we employed the quantile DID treatment effect on the treated (QTT) framework following Callaway and Li (2019) to estimate the effects of programme participation on quantiles of productivity, mainly maize productivity (kg/ha), soybean productivity (kg/ha), net productivity (ZMW/ha) as well as commercialisation (soybean), as they are the only continuous variable to run quantile regressions.

5 Results

5.1 Descriptive results

In presenting the main descriptive results, we used the general treatment indicator (T), that is, participation in one of the three treatment categories. As stated earlier, an individual is considered a participant if: i) they received advice/training from AAZ prior to the survey (free trainings on cultivation, handling of high-value crops, on conservation farming and business skills), ii) if they received input support in the form of seed or purchased seed in cash, iii) if they sold any of their crops to AAZ under AAZ's guaranteed off-take of the harvested crops, or iv) a combination of the three categories. In our regression analyses, however, we also provided results of the individual treatment (programme) components to gain additional insight. For instance, the effects of training are likely to differ from access to loan input or other aspects of the programme interventions. As a result, analysing each component enables us to uncover the potential benefits of each programme activity. In addition, given the low number of households that participated in the input loans and guaranteed off-take of the harvested crop components of the programme, the overall potential effect of the programme could be obscured by the low level of participation in some potentially more rewarding components. Expanding smaller but more rewarding components in the future may increase the overall average effects. Moreover, the results of these various treatment arms would serve as robustness checks.

5.1.1 Household characteristics

Table 4 reports the summary statistics of household characteristics for AAZ programme participants and non-participants from the balanced panel of 582 households, including tests for covariate balancing between the different treatment groups to check the validity of our empirical strategy presented in Section 5.2. Columns 5 to 8 present the summary statistics for households in the different treatment groups at the baseline, and column 6 presents summary statistics for households in the control group at the baseline. Finally, columns 7 to 9 show the mean difference between households in the control group (C) and the various treatment arms (T1-T4). As stated earlier, our baseline data is not ideal since data was collected two years after the programme had started (however, although the programme had started in 2013/14, many sampled treated households only joined in 2015, the year the baseline refers to). For instance, about 57 per cent (339 households out of the 587 outgrower participants) and 32 per cent (192 households out of the 228) of the outgrower participants had already received training and acquired/purchased inputs from AAZ, respectively. Interestingly, however, there are no significant differences on a series of socio-demographic and economic indicators (age and sex of head, years of education, household size) between the AAZ participants and non-participants, except for a few variables such as kinship ties (head relationship to village chief), cropland and household size. We found that most AAZ participants have closer relationships to the village chief or FCs tend to have more cropland and have a larger family size compared to non-participants. For instance, more than 50 per cent of programme participants are related to village headmen, but only around one-third of non-participants are related to the chiefs or headmen. Such differences might affect programme participation, specifically access to loans. Although participants' mean area of land owned at the baseline (about 5.42 ha) is slightly larger than for non-participants (4.42 ha), the cropped area is almost equal at around 4 ha. Similarly, households in the AAZ programme have higher agricultural asset scores and durable consumer goods (e.g. TV, radio, mobile phone) indices than households in the non-outgrower programme group at the baseline.

Table 4: Mean difference between outgrower participants and non-participants

Variables	(1) Overall	(2) T: either T1, T2 or T3	(3) T1: training	(4) T2: input support	(5) T3: crop purchase	(6) C	(7) T1-C	(8) T2-C	(9) T3-C
	Mean					Mean	Mean difference		
Female-headed household, 1=Yes	0.17	0.16	0.17	0.15	0.16	0.19	-0.02	-0.04	-0.03
Dummy=1 if married heads	0.83	0.83	0.84	0.84	0.86	0.81	0.03	0.03	0.05
Age of HH head, years	44.61	44.89	44.82	45.38	43.14	44.05	0.77	1.33	-0.91
HH size	7.11	7.31	7.23	7.65	7.65	6.72	0.51	0.93	0.93
Head’s education, years	7.41	7.40	7.45	7.82	7.49	7.42	0.03	0.4	0.07
Maximum education for any HH member, years	9.20	9.23	9.27	9.57	9.33	9.14	0.13	0.43	0.19
Agricultural index (pca), incl. tractor/oxen	0.10	0.15	0.12	0.60	0.24	0.02	0.1	0.58	0.22
Agricultural index, only tractor/oxen/plough (pca)	0.06	0.08	0.06	0.30	0.12	0.03	0.03	0.27	0.09
Agricultural index (pca), w/o tractor/oxen	0.08	0.12	0.10	0.50	0.22	0	0.1	0.5	0.22
HH wealth index (pca), incl. motorbike/cars	0.08	0.15	0.15	0.42	0.30	-0.05	0.2	0.47	0.35
HH wealth index (pca), w/o motorbike/cars	0.09	0.17	0.16	0.39	0.25	-0.07	0.23	0.46	0.32
Dummy=1 if main tillage done before the rains on any plot	0.09	0.12	0.13	0.13	0.19	0.02	0.11	0.11	0.17
Total cultivated land, ha	3.75	3.96	3.93	4.44	4.36	3.34	0.59	1.1	1.02
Cost of crop inputs per hectare seed+fertiliser, ZMW	983.65	988.40	984.20	1112.00	1084.38	974.17	10.03	137.83	110.21
Dummy=1 if HH rents land	0.03	0.03	0.04	0.03	0.03	0.02	0.02	0.01	0.01
Per capita farm size, ha	0.76	0.79	0.80	0.84	0.79	0.7	0.1	0.14	0.09
Land access per capita, ha	0.76	0.79	0.80	0.85	0.79	0.71	0.09	0.14	0.08
Dummy=1 if HH accessed loan from sources other than from AAZ	0.28	0.30	0.29	0.24	0.34	0.24	0.05	0	0.1
Dummy=1 if HH irrigated any field	0.00	0.00	0.00	0.01	0.00	0	0	0.01	0
Dummy=1 if HH experienced a shock in past five years	0.73	0.74	0.73	0.75	0.72	0.72	0.01	0.03	0
Chief related to head or spouse of HH, 1=Yes	0.09	0.10	0.09	0.11	0.07	0.07	0.02	0.04	0
Headman related to head or spouse of HH, 1=Yes	0.47	0.52	0.53	0.45	0.52	0.36	0.17	0.09	0.16
Farmer coordinator related to head or spouse of HH, 1=Yes	0.38	0.49	0.51	0.51	0.49	0.17	-0.02	-0.04	-0.03
Chief or headman related to head or spouse of HH, 1=Yes	0.48	0.54	0.55	0.47	0.54	0.36	0.03	0.03	0.05
No. of HHs	587	386	339	192	138	196			

Note: All data is from the 2017/18 survey dataset. Columns 7 to 9 show the mean difference between treatment arm one and control group [T1-C], treatment arm two and the control group [T2-C], and treatment arm three and control group [T3-C]. HH is household; AAZ=Amatheon Agri Zambia; pca=principal component analysis; C=non-AAZ participants.

Source: Authors

5.1.2 Primary (intermediate) outcomes of interest

By comparing the means at the baseline (2016/17 agricultural season) and the follow-up (2019/20 agricultural season) for each group separately, we present below the main descriptive results for the different primary and secondary outcome variables of interest we discussed earlier.

Adoption of agricultural technologies

One of the mechanisms through which AAZ interventions are expected to improve productivity, household income or food security is through the promotion and adoption of improved farming techniques. Conceptually, the presence of a large-scale farm (LSF) operation could facilitate improved technology adoption among farmers in nearby communities through learning effects and cost effects (Liverpool-Tasie et al., 2020). Essentially, the cost effects refer to the transaction cost reductions for the smallholder farmers that come with purchasing inputs from LSFs. The learning effect results from training or extension messaging from medium and large-scale farms that increases the productivity of smallholder farms (Liverpool-Tasie et al., 2020). As we show later in our regression analysis, the evidence does indeed suggest that AAZ interventions impact productivity and food security via these mechanisms.

Transaction cost reductions result from the pooling of purchases between LSFs and neighbouring small farms in cases where the two grow similar crops, given that LSFs enjoy economies of scale in transport (Deininger & Xia, 2016). If the location of an LSF is accompanied with investments in public infrastructure such as roads, transport costs may decrease; however, this is not always the case, as investments may locate to areas with already developed infrastructures (Lay et al., 2020). There are also transaction cost reductions that may arise because of the location of input suppliers closer to the community due to the presence of an LSF. From the learning aspect, the location of LSFs near smaller farms creates an enabling environment for smallholder farmers' access to better extension services provided by LSFs. This result has been demonstrated for Tanzania, where Wineman et al. (2021) associate the presence of large farms in an area with improved extension access, an increased likelihood of the cultivation of cropland and increased usage of improved seed for the neighbouring farms.

As mentioned earlier, AAZ has a range of interventions, including providing input support to farmers in the form of seed loans and improving access to improved seeds so that they can buy inputs. In addition, free training on crop cultivation, handling and post-harvest loss could improve the adoption of these technologies. Hence, the interventions could have a positive effect on the adoption of agricultural technologies. In Table 5, the trends in the adoption of technologies among farmers in the participating and non-participating groups are presented. For the key crops promoted during the first two phases of the outgrower programme (soybeans, groundnuts, cowpeas and sunflower), results show a significantly higher adoption of groundnuts, sunflower and cowpeas among the outgrower participants during the first wave of data collection. Yet, the follow-up results show a statistically significant decline in the share of hybrid or open pollinated varieties of the same crops used by households, suggesting that many initial adopters did not continue after the end of the programme. Among non-treated, sunflower and cowpea adoption was low, both at the baseline and the follow-up.

There are significant increases in the fertiliser application rates and share of households using fertiliser on their soybean fields in both the treatment and control groups. Yet, a significant share of respondents in both groups reported applying fertiliser on any fields they cultivated, about 82 per cent for participating groups and 68 per cent for non-participating groups; although we observed a decline in the share of households applying fertilisers. However, for farmers applying fertiliser, the change in the soybean fertiliser application rate is higher among AAZ programme participants than non-participants. The opposite was observed for maize production, with fertiliser-use intensity declining by almost 96 kg in the treatment group and about 75 kg in the control group. An important side note here is that maize fertiliser also comes from the government's subsidy programme, and the result may reflect the programme implementation or a shift of fertiliser towards soybeans. Although not statistically significant, the use of non-recycled seed declined for both groups. A similar trend is observed for seeds acquired from friends/family or other farmers. This suggests that sources of seeds other than family or friends became more important for farmers.

Table 5: Adoption of improved agricultural technologies by treatment categories and survey round

		A		B		C	C-B		D		E		F	F-E
	Treatment (outgrower participants)							Control (non-participants)						
	N	Overall	N	Baseline	N	Follow-up	Difference	N	Overall	N	Baseline	N	Follow-up	Difference
Dummy=1 if source of seed is not recycled	820	0.77	386	0.75	434	0.78	0.04	337	0.7	196	0.68	141	0.74	0.06
Dummy=1 if seed not recycled/not from friends/family	820	0.74	386	0.73	434	0.75	0.02	337	0.66	196	0.66	141	0.67	0
Dummy=1 if maize seed is OPV, hybrid	811	0.74	386	0.73	425	0.74	0.01	329	0.67	191	0.69	138	0.66	-0.03
Dummy=1 if soya bean seed is OPV, hybrid	757	0.23	386	0.37	371	0.08	-0.29***	307	0.24	196	0.33	111	0.07	-0.26***
Dummy=1 if used OPV/hybrid groundnut seed	377	0.11	172	0.22	205	0.02	-0.19***	145	0.07	81	0.11	64	0.02	-0.1**
Dummy=1 if used OPV/hybrid sunflower seed	104	0.21	42	0.43	62	0.06	-0.36***	33	0.0	14	0.0	19	0.0	0.0
Dummy=1 if used OPV/hybrid cowpeas seed	55	0.38	37	0.43	18	0.28	-0.15	5	0.0	2	0.0	3	0.0	0.0
Average no. of crops grown	820	2.71	386	2.74	434	2.68	-0.07	337	2.48	196	2.42	141	2.56	0.14
Dummy=1 if applied fertiliser on any field	822	0.82	386	0.82	436	0.81	-0.01	347	0.68	196	0.7	151	0.65	-0.06
Dummy=1 if applied fertiliser on any maize field	822	0.79	386	0.8	436	0.78	-0.02	347	0.64	196	0.66	151	0.62	-0.04
Maize fertiliser-use intensity, kg/ha	818	131.11	386	181.48	432	86.11	-95.37***	337	116.75	196	147.69	141	73.74	-73.95***
Dummy=1 if applied fertiliser on any soya field	822	0.03	386	0.01	436	0.04	0.03***	347	0.03	196	0.02	151	0.04	0.02
Soybeans fertiliser use intensity, kg/ha	757	1.71	386	0.05	371	3.43	3.37***	307	1.57	196	1.16	111	2.31	1.15
Dummy=1 if HH applied herbicide/weedicide	822	0.63	386	0.64	436	0.62	-0.02	347	0.5	196	0.48	151	0.54	0.06
Dummy=1 if HH applied insecticide	822	0.44	386	0.78	436	0.14	-0.64***	347	0.41	196	0.64	151	0.13	-0.51***
Dummy=1 if HH purchased seeds in community	751	0.45	317	0.56	434	0.37	-0.2***	291	0.45	150	0.51	141	0.38	-0.12**
Time (minutes) to reach point of input access (seeds)	647	112.28	313	117.01	334	107.84	-9.18	249	116.54	148	132.79	101	92.74	-40.05
Time (minutes) to reach point of input access (other inputs)	738	113.91	349	115.31	389	112.65	-2.65	273	131.73	155	144.57	118	114.87	-29.7

Note: A household is treated if it received advice/training from AAZ or acquired an AAZ input loan/ input purchase or sold grain to AAZ. *** p<0.01, ** p<0.05, * p<0.1.

Source: Authors' calculations using the AAZ baseline and follow-up surveys

As was expected regarding the location of LSFs, travel time to points of input access for both seeds and other inputs decreased, despite being statistically insignificant. The decrease was higher for the non-participant than the participant group and for seeds than for other inputs. Furthermore, the number of crops grown decreased in the participant group, whereas an increase is observed for the non-participant group. However, the changes are not statistically significant. This may suggest that participation in the AAZ programme may have had no effect on the diversification of crop portfolios.

Overall, the descriptive results suggest a higher degree of technology adoption among participants during the first wave, but the adoption rate declined during the follow-up for some of the technologies, such as for improved seed for soybeans, sunflower, groundnuts and the use of insecticide. However, it is important to explore further the impact of programme participation on technology adoption using robust impact evaluation techniques, an issue we examine in Section 5.2.

Adoption of sustainable land management practices

Conservation agriculture (CA) has been promoted for close to three decades in Zambia as a way of improving crop productivity by improving soil fertility and mitigating the effects of reduced rainfall levels on crop production. The main promoter has been Zambia's Conservation Farming Unit, among other governmental and non-governmental organisations. CA consists of three main principles, including minimum soil disturbance (MSD), permanent soil organic cover through the retention of crop residues (RR) on fields and cereal/legume crop rotation (CR) (Haggblade & Tembo, 2003). Of the three principles, MSD is a key component of CA, as such, the definition for partial CA adoption has MSD as a requirement alongside either CR or RR (Zulu-Mbata & Chapoto, 2016). MSD is achieved through tillage practices such as ripping, zero tillage and the use of planting basins or potholes.

AAZ, alongside CFU, promoted the adoption of conservation farming in Mumbwa and Chibombo districts. Tables 6 and 7 show the results of the adoption rates of the individual CA components and composite CA practices for participants and non-participants at the baseline and the follow-up. The results are consistent irrespective of which treatment indicator (general or individual) is used in mean difference comparisons. As such, we discuss the results of Table 5 based on a general treatment indicator in generating the mean differences.

Table 6: Adoption of sustainable land management practices by treatment indicator

	A Overall	B Baseline	C Follow-up	C-B Difference	E Overall	F Baseline	G Follow-up	G-F Difference
	Treatment (outgrower participants)				Control (non-participants)			
Conservation agriculture practices								
Share of HHs that practiced crop rotation (CR) cereals to legumes or cereals to fallow	0.88	0.93	0.84	-0.09***	0.83	0.87	0.77	-0.09**
Share of HHs that practiced residue retention (RR)	0.4	0.05	0.7	0.64***	0.31	0.06	0.67	0.61***
Share of HHs practicing minimum soil disturbance (MSD)	0.25	0.3	0.21	-0.09***	0.09	0.07	0.11	0.04
Share of HHs practicing CR and RR	0.34	0.05	0.6	0.54***	0.26	0.05	0.56	0.51***
Share of HHs practicing MSD and RR	0.09	0.03	0.15	0.12***	0.03	0.01	0.06	0.05**
Share of HHs practicing MSD and CR	0.22	0.28	0.17	-0.11***	0.05	0.05	0.06	0.02
Share of HHs practicing full-suite CA, MSD+CR+RESID	0.08	0.03	0.13	0.1***	0.02	0.01	0.03	0.03*
Share of HHs practicing partial CA, MSD+CR or MSD+RR	0.23	0.28	0.19	-0.1***	0.06	0.05	0.08	0.03
No. of HHs	**820**	**386**	**434**		**338**	**196**	**142**	

Note: A household is treated if it received advice/training from AAZ or acquired an AAZ input loan/ input purchase or sold grain to AAZ. *** p<0.01, ** p<0.05, * p<0.1.

Source: Authors

Results show a statistically significant increase in the share of households adopting the full-suite CA technology for both the treated and control groups over the two survey periods. However, the increase was greater in the treated group compared to the control group, that is, 10 per cent vs 3 per cent. The sharp increase seems to be due to the large share of farmers reporting RR in the follow-up.

The partial adoption rate of CA decreased in the treated group by 10 per cent, whereas an insignificant but positive increase can be seen for the control group. For the treated group, this result appears to have been driven by a decrease in the number of households practising CR of cereals and legumes, given that the number of seed loans also decreased towards the follow-up survey. Also, the observed decline in the treated group could be driven by a drop in the share of households that practised MSD.

Of interest also are the changes in the share of households that practised tillage methods that offer MSD. For both the treatment and control groups, the use of animal draught power and ploughing is very high. For instance, the proportion of households in both the treated and control groups that were using animal draught power at the follow-up was above 95 per cent and 93 per cent, respectively. This is despite the fact that the share of households that used animal draught power declined in both groups, that is, 0.05 for the treatment group and 0.07 for the control group. Given the high share of households using ploughs, it is unclear whether the promotion of CA was done with minimum tillage implements available for sale to farmers or through tillage service providers. There is a statistically significant drop in the number of households that used planting basins in the treated group, that is, an 0.08 drop over the two waves (note that, on average, the percentage of households using this technique is quite low: 6

per cent in the treatment group vs 3 per cent in the control group). A drop in the number of households that used ripping, though statistically insignificant, was also observed

Table 7: Adoption of tillage power sources and tillage methods by participation status

	Treatment (outgrower participants)				Control (non-participants)			
	A	B	C	C-B	D	E	F	F-E
Variables	Overall	Baseline	Follow-up	Difference	Overall	Baseline	Follow-up	Difference
Sources of power for tillage								
Share of HHs that used manual power	0.12	0.15	0.1	-0.06**	0.07	0.06	0.07	0.01
Share of HHs that used animal draught power	0.97	1.00	0.95	-0.05***	0.97	1.00	0.93	-0.07***
Share of HHs that used a hand hoe	0.15	0.12	0.17	0.05**	0.07	0.06	0.09	0.04
Other tillage methods used								
Share of HHs that ploughed their fields	0.82	0.8	0.84	0.04	0.89	0.91	0.87	-0.03
Share of HHs that used ridging	0.02	0.02	0.02	0.00	0.01	0	0.02	0.02*
Share of HHs that used bunding	0.02	0.04	0.01	-0.04***	0.03	0.04	0.02	-0.01
Tillage methods that promote MSD								
Share of HHs that used planting basins	0.06	0.1	0.02	-0.08***	0.03	0.03	0.03	0
Share of HHs that used ripping	0.2	0.22	0.19	-0.03	0.06	0.05	0.08	0.04
No. of HHs	**820**	**386**	**434**		**338**	**196**	**142**	

Note: A household is treated if it received advice/training from AAZ or acquired an AAZ input loan/ input purchase or sold grain to AAZ. *** p<0.01, ** p<0.05, * p<0.1.

Source: Authors

5.1.3 Secondary outcomes of interest (final outcomes)

Although AAZ recently decided to shift its outgrower programme to high-value crops such as quinoa rather than continue working on staple crops, we analyse below the mean comparisons at the baseline and the follow-up for the respective treatment and control groups for secondary outcomes of interest discussed earlier: productivity (both land and labour); profits/gross revenues; commercialisation patterns (for maize, soybean and aggregate) as well as food and nutrition security status. We used these outcomes to explore the mechanisms through which the adoption of improved seed varieties, use of fertilisers as well as adoption of sustainable land management is achieved. Table 8 provides summary statistics for these outcomes. The variables in monetary value are adjusted for inflation and expressed in real terms, where the base year is set as 2017/18.

Maize production

As maize is one of the dominant staple crops in the country, almost all households in both the treatment and control groups are maize producers. On average, about 98 per cent and 97 per cent of farmers in the treatment group were involved in maize production at the baseline and the follow-up, respectively, although the difference is statistically insignificant. We observed a similar trend for households in the control group, but the drop was statistically significant (dropped from 97 per cent to 91 per cent). In terms of land allocation for different crops (measured in terms of areas planted), however, we observed an increasing trend in land allocation for maize production for both the treated and control groups, although statistically insignificant.

In terms of maize productivity, measured in kilograms per hectare, on average, farmers in the treatment group reported around 2,326 kg/ha of maize yield at the baseline. These figures decreased to 1,829 kg/ha of maize at the follow-up. These differences within groups across rounds are statistically significant. Moreover, although we observed a steep decline in yields per hectare planted for both maize and soybeans, there was a significant increase in farm gate prices for both crops across the two groups. Interestingly, the control group reported a higher farm gate price increase than the treatment group.

Across all crops, transactions with AAZ involved, on average, lower transport costs (as reflected in cost per kg of sold crop vs other transactions). Similarly, input costs (mainly fertiliser and seed), showed a significant decrease for both the treatment and control groups. Outgrowers also receive relatively higher farm gate prices than market prices. The construction of community trading depots might have contributed to increased farm gate prices and decreased transport costs.

Soybean production

Soybeans are another widely cultivated crop in the study area and one of the focus crops of AAZ interventions in the early phase of its programme. Whereas the share of households involved in the production of soybeans had increased from 81 per cent at the baseline to 85 per cent at the follow-up for the treatment group, the number of households involved in soybean production in the control group had decreased between the two survey periods (from 77 per cent to 74 per cent), although the difference is statistically insignificant. Unlike maize cultivation and compared with the baseline, we observed an increase in land allocated to soybean production for both the treatment and control groups at the follow-up, although the difference is statistically significant only for the treatment group. In terms of yield, on average, there was a sharp decline in yield per hectare planted over the two survey periods for both the treated and control groups (about 1,500 kg/ha at the baseline and 550 kg/ha at the follow-up for both groups; this needs further verification).

In addition to the two primary crops, cowpeas, groundnuts, sunflowers, as well as vegetables and fruits are also grown in the study areas. The proportion of farmers in the treatment group producing groundnuts and sunflowers increased between the baseline and follow-up surveys, except for cowpeas. For instance, about 45 per cent, 11 per cent and 10 per cent of the farmers in the AAZ programme produced groundnuts, sunflowers and cowpeas at the baseline, compared with 47 per cent, 14 per cent and 4 per cent at the follow-up, respectively. The share of households producing fruits and vegetables has increased considerably, and more so in the treatment group.

Commercialisation

One of the objectives of the AAZ programme is to incorporate smallholders into the rural value chain by increasing its trading volumes, that is, through its grain purchases from smallholders. AAZ used its constructed processing and storage facilities (rural depots) to purchase staple crops such as maize and soybeans from farmers. In this regard, we compared the (intensity of) market participation of treated (participants in outgrower programme) and control groups at the baseline and the follow-up.

Looking at the two groups separately, we observed an overall significant increase in market participation (commercialisation) for both the treatment and control groups over the two survey periods. Disaggregating market participation based on crops sold, we found that farmers in both the treated and control groups had increased their maize sales. Additionally, the descriptive results suggest that most soybeans harvested are for sale. For instance, for treatment groups, about 90 per cent of soybeans harvested were sold at the baseline, compared with 72 per cent at the follow-up. We found that this difference is statistically significant. We observed a similar trend for the control group over the two survey periods. About 91 per cent of soybeans harvested were sold at the baseline, compared with 75 per cent at the follow-up, and the difference is statistically significant. At least two factors may have contributed to such a decline. First, as stated previously, yields decreased significantly compared with the baseline. Second, AAZ's grain purchases from farmers were more intense in the initial phase of its outgrower programme than at the time of the follow-up. In fact, since 2019, AAZ has reshaped its outgrower programme with a strong focus on high-value crops such as quinoa.

Productivity (gross and net per hectare)

We also looked at differences in land productivity (gross and net per hectare) at the baseline and the follow-up for both the treated and control groups, separately. Overall productivity – measured in terms of total production value or cropland productivity (in ZMW/ha) – significantly increased over the survey periods for both the treatment and control groups, yet more so for the treatment group. We explore further in the next section if this is suggestive evidence of the impact of the programme. If we compared net productivity per ZMW/ha (or net margins), which is the value of crop production per hectare minus seed costs and fertiliser costs at the baseline and the follow-up, we observed a significant increase for both the treatment and control groups. On average, the increase is higher in the treatment than in the control group. For instance, on average, net productivity per hectare (ZWM/ha) has increased by about 1,722 ZMW/ha for farmers in the treatment group, whereas the corresponding figure is about 1,211 ZMW/ha in the control group. It is interesting to note also that, on average, input costs (mainly seeds and fertiliser costs, excluding transport costs) for farmers in both groups (participants and non-participants) decreased at the follow-up compared with the baseline, but more so for the treatment group. The differences between the baseline and the follow-up for each group are statistically significant.

Table 8: Mean differences for secondary outcomes of interest between the baseline and the follow-up

	A	B	C	C-B	D	E	F	F-E
	Treatment (outgrower participants)				Control (non-participants)			
Variables	**Overall**	**Baseline**	**Follow-up**	**Difference**	**Overall**	**Baseline**	**Follow-up**	**Difference**
Participation in crop production								
Dummy=1 if HH produces maize, 0 otherwise	0.98	0.98	0.97	-0.01	0.95	0.97	0.91	-0.06**
Dummy=1 if HH produces soya beans, 0 otherwise	0.83	0.81	0.85	0.04	0.76	0.77	0.74	-0.04
Dummy=1 if HH produces cowpeas	0.07	0.1	0.04	-0.06***	0.02	0.02	0.02	0
Dummy=1 if HH produces groundnuts	0.46	0.45	0.47	0.02	0.44	0.43	0.45	0.03
Dummy=1 if HH produces sunflower	0.13	0.11	0.14	0.03	0.1	0.08	0.13	0.04
Secondary outcomes								
Maize hectares planted	2.13	2.07	2.19	0.12	1.95	1.89	2.03	0.14
Maize yield, kg/ha planted	2,063.3	2,326	1,829	-496.87***	2,014	2,246	1,692	-554.78***
Maize price per kg (farm gate), ZMW	1.76	1.18	2.30	1.13***	1.61	1.13	2.35	1.21***
Value of maize sales, ZMW	5,145	3,686	6,969	3,282.32***	4,968	3,692	7,869	4,176.28***
Soybean hectares planted	1.52	1.34	1.67	0.33***	1.43	1.34	1.55	0.21
Soybean yield, kg/ha planted	1,053	1,591	597	-993.7***	1,089	1,491	543	-947.5***
Soya price per kg (farm gate), ZMW	3.68	3.05	4.38	1.33***	3.5	2.9	4.7	1.72***
Value of soybean sales, ZMW	6,356	5,783.27	7,002.03	1,218.76**	5,608	5,527	5,757	229.6
Value of fruit/vegetable sales, ZMW	2,133	10,709	535	-10,173.76***	6,338	30,335	431	-29,903.77***
Crop total production value, ZMW	20,890	15,964.02	25,619.72	9,655.71***	17,879	13,902	24,135	10,233.13***
Crop land productivity (in ZMW/ha)	4,388	3,671	5,076	1,405.5***	4,093	3,731	4,663	931.75***
Value of crop sales, ZMW	15,765	12,197	19,191	6,994.7***	12,820	9,879	17,445	7,566.28***
Crop and fruit sales value, ZMW	16,065	12,627	19,286	6,658.76***	13,250	10,621	17,154	6,532.75***
Total production value (crops, fruits/vegetables), ZMW	21,229	16,693	25,478	8,784.55***	18,470	15,405	23,020	7,614.91***
Net productivity per ZMW/ha	3,561	2,682	4,404	1,721.98***	3,227	2,757	3,968	1,211.3***
Commercialisation								
Maize commercialisation index	1	0.46	0.65	0.2***	0	0	1	0.19***
Soybean commercialisation index	0.82	0.90	0.73	-0.16***	0.85	0.91	0.75	-0.16***
Crop commercialisation index	0.72	0.66	0.77	0.11***	0.67	0.61	0.77	0.15***
No. of HHs	822	386	436		347	196	151	

Note: After the first wave, most of the activities of AAZ shifted to the promotion of cash crops such as quinoa. Net productivity per ZMW/ha is the difference between the value of crop production per ha minus seed costs and fertiliser costs. *** p<0.01, ** p<0.05, * p<0.1.

Source: Authors

Household food insecurity and women's nutritional outcomes

We also examined if there are mean differences in food insecurity status between the baseline and the follow-up for the participant and non-participant groups. As discussed earlier, food and nutrition security is measured in terms of the share of the household food insecurity access score and the minimum dietary diversity score (DDS) for women of reproductive age. As indicated in Table 9, on average, the food insecurity access score for households in the general treatment group was about 5.67 at the baseline. This figure had increased at the follow-up (5.75). Conversely, the average household food access insecurity score for farmers who had never participated in any of the three components was about 5.67 at the baseline and 5.19 at the follow-up. The differences for the two groups over the two study periods are not statistically significant. As to the number of households with adequate micronutrients for women of reproductive age, we found a slight decrease at the follow-up compared with the baseline for both treatment and control groups, more so in the control group. However, the difference between the baseline and the follow-up is statistically significant only for the control group.

Table 9: Mean differences for food security indicators by participation status and survey round

	Outgrower participants							Non-outgrower participants						
		A		B		C	C-B		E		F		G	G-F
Variables	N	Overall	N	Baseline	N	Follow-up	Difference	N	Overall	N	Baseline	N	Follow-up	Difference
HHs with adequate micronutrients for women of reproductive age	611	36%	290	39%	321	33%	-6%	244	31%	145	35%	99	24%	-11*
HH food access insecurity score	822	5.71	386	5.67	436	5.75	0.09	347	5.46	196	5.67	151	5.19	-0.48
Minimum DDS for women of reproductive age	611	4.19	290	4.26	321	4.13	-0.12	244	4.11	145	4.16	99	4.03	-0.13

Note: A household is treated if it received advice/training from AAZ or acquired an AAZ input loan/ input purchase or sold grain to AAZ. *** p<0.01, ** p<0.05, * p<0.1.

Source: Authors

In summary, the simple means comparisons suggest that participants in the AAZ programme performed on average slightly better than non-participants in terms of technology adoption, CA practices, productivity, and food and nutrition security, except for the household food access insecurity score. However, since mean comparisons presented earlier do not take into account the socio-economic and institutional differences of households (e.g. differences in terms of access to relevant resources, assets, transport costs and other household characteristics) as well as communities, it is important to account for these factors, as done in the next section, to draw intuitive conclusions. In addition, mean comparisons do not help to quantify the relative effect of the programme on participants compared to non-participants and why. Now we present the regression results.

5.2 Empirical results

In the following section, we discuss the regression results for the main outcome variables of interest grouped along the themes discussed earlier: technology adoption, sustainable land management practices, land productivity (for maize and soybeans, net and aggregate), commercialisation, and household food and nutrition security. In most of our analyses, we used propensity score matching difference-in-differences (PSM-DID) discussed earlier to estimate the average treatment effect on the treated (ATT). The main discussions are based on the general treatment indicator discussed earlier – that is, participation in one of the three activities/programmes of AAZ trainings offered, input loan provision and purchase of cereals (off-take of the harvested crops) – by comparing change over the time of the outcomes of interest across the treatment groups. We adjusted for differences between the treatment and control groups on the observable characteristics at the baseline that are correlated to the propensity score.

5.2.1 Effects on primary outcomes

Effect on the adoption of improved technologies

Table 10 reports the estimation results from the main specification (1) using PSM-DID for the adoption of improved agricultural technologies, mainly improved seed (OPV, hybrid seed varieties) for maize and soybeans and inorganic fertiliser use on maize and soybean fields. Overall, our analysis shows that participating in at least one of the AAZ programmes does not significantly affect the adoption of improved seeds compared to non-participation, but it does affect the use of inorganic fertilisers. In terms of household fertiliser use on maize fields, the programme has an adverse and statistically significant effect; however, it has a positive and statistically significant effect on household fertiliser use on soybean fields. For instance, participation in at least one of the programmes decreased households' use of chemical fertilisers on maize fields by 20 percentage points (a relative decrease of 28 per cent compared to the control group), but raised households' use of chemical fertilisers on soybean fields by 3 percentage points. Interestingly, even if the programme led to the increased use of fertilisers on soybean fields, it did not result in significant changes with regard to the adoption of OPV soybean seeds. The same is true with fertiliser application on maize fields, where no impact on OPV maize seeds was found. To determine whether the impact of each intervention on the adoption of improved seeds is also insignificant, we examined further the effects of the three types of intervention (training, seed loans, crop sales to AAZ) on the adoption of these technologies. By doing so, we found that input support in the form of seed loans increased the use of non-recycled seeds, particularly OPV maize seeds, whereas the purchase of cereals from farmers (treatment T3) increased the adoption of improved soybean seeds. The provision of training (on conservation farming, business skills, production and processing) had no effects on the adoption of these technologies (see Table R1-B in Appendix B for the detailed results).

Since AAZ interventions had already begun at the time of the baseline survey and some project activities had changed over the course of the project, evaluating the impact of programme participation separately for the baseline (in its early phase) and the follow-up (four years after the start of the operation) is useful. For that, we examined the effects of outgrower participation separately at the baseline and the follow-up using the PSM estimation techniques. Our estimation results suggest that the programme had greater effects on the adoption of improved maize seeds and fertiliser application on soybean fields at the time of the baseline survey than at the time of the follow-up survey (see Tables R13B1-R13B2, Appendix B).

In its early operation, AAZ, with the support of USAID, had engaged in the construction of community trading depots, which are accessible to farmers. This may bias our ATT estimates. In order to reduce the bias, we controlled for proximity to community trading depots (proxied by household distance to the nearest depot centre) and AAZ farm blocks (measured by the distance between AAZ farm blocks and location of household residence). We found that households' distance to the nearest depot or AAZ farm block is negatively and statistically significantly associated with most of the indicators of agricultural technologies (except for the adoption of OPV soybeans) (Table 10). This means that households closer to trading depots were more likely to adopt these improved technologies compared to those located farther away. For instance, a 1 per cent increase in household distance to the nearest depots reduces the likelihood of using improved seeds and/or fertiliser applications on fields by about 4 per cent to 6 per cent, depending on the type of improved seeds.

Table 10: Effect of AAZ participation on the adoption of technology components, PSM-DID estimates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Adopted OPV/hybrid soybean seed	Adopted non-recycled seed, not from relatives	Adopted non-recycled seed	Purchased seeds in community	Adopted OPV/hybrid maize seed	Applied fertiliser on any maize field	Applied fertiliser on any soya field	Log (fertiliser on maize field, kg/a)	Log (fertiliser on soybeans field, kg/a)
$ATT\_{PSM\text{-}DID}$	-0.0370	-0.0529	-0.0627	0.0260	-0.0673	-0.196***	0.0249*	-1.226***	0.121*
	(0.0516)	(0.0531)	(0.0514)	(0.0631)	(0.0543)	(0.0521)	(0.0177)	(0.276)	(0.0715)
Observations	1,061	1,154	1,154	1,008	1,129	1,162	1,162	1,139	1,061
R-squared	0.104	0.004	0.008	0.045	0.006	0.041	0.009	0.040	0.016
Log (distance to nearest depot)	0.000 (0.098)	-0.279** (0.105)	-0.273* (0.106)	-0.246** (0.094)	-0.269* (0.110)	-0.222 (0.116)	-0.072 (0.175)	-	-
Log (distance to AAZ)	-0.016 (0.011)	-0.008 (0.012)	-0.011 (0.012)	0.007 (0.011)	-0.018 (0.013)	-0.038** (0.014)	0.017 (0.019)	-	-

Note: A household is treated if it received advice/training from AAZ or acquired an AAZ input loan/ input purchase or sold grain to AAZ. If we did not control for the presence of depots and distance to AAZ farm blocks, the use of non-recycled seed turns positive and statistically significant, further supporting the positive effects of depots and AAZ farm blocks. We also found that herbicide and insecticide application was significantly reduced. ATT_PSM_DID denotes the average treatment effect on the treated estimated using Kernel PSM-DID. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Source: Authors

Effect on the adoption of sustainable land management practices

As discussed earlier, AAZ – along with the Conservation Farming Unit (CFU) – has promoted the adoption of SLM practices in both districts. Irrespective of the estimation techniques used (conventional PSM-DID, FE or semiparametric difference-in-differences) and in line with the descriptive results, we found a strong and consistent significant effect of AAZ programme participation on the adoption of various SLM practices, except for the adoption of minimum soil disturbance (MSD) and crop rotation (CR) (Table 11). For instance, our estimates suggest that participation in AAZ increases the adoption of full-suite CA practices (MSD + CR cereals to legumes or cereals to fallow + residue retention (RR)) by 8 percentage points, compared to non-participants. Considering the overall mean of the treatment/sample group is 0.049, households in the programme are 63 per cent more likely to adopt SLM practices than those not in the programme. Moreover, proximity to community trading depots and AAZ farm blocks increases the adoption of SLM/CA practices. In addition, although the programme had a positive effect on most of the SLM practices considered in this discussion paper, there were cases in which the programme had also negatively affected the adoption of some of the SLM practices, such as MSD in combination with CR or RR. These results, however, should be interpreted with caution and not attributed as causal effects, as they might be driven by unobservable time-variant factors. It would also be interesting to explore further how the construction of trading depots by AAZ (to sell inputs and buy grains) and proximity to AAZ farm blocks have contributed to the adoption of SLM practices.

Table 11: The effects of AAZ participation on the adoption of SLM practices, PSM-DID estimates

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	Adopted CR and RR practices	Adopted MSD and RR practises	Adopted MSD and CR practises	Adopted full suite CA practises (MSD+CR+RESID)	Adopted MSD+CR or MSD+RR	Main tillage done before the rains on any plot
$ATT_{PSM\text{-}DID}$	0.0699	0.0799***	-0.103**	0.0779***	-0.0978**	0.644**
	(0.0490)	(0.0308)	(0.0454)	(0.0287)	(0.0460)	(0.207)
Log (distance to nearest depot)	-0.00396	-0.00944	-0.0688***	-0.00829	-0.0699***	-0.003
	(0.0243)	(0.0165)	(0.0229)	(0.0159)	(0.0232)	(0.122)
Log (distance to AAZ)	-0.00103	-0.00354*	-0.0118***	-0.00336*	-0.0119***	-0.028
	(0.00279)	(0.00190)	(0.00263)	(0.00182)	(0.00267)	(0.015)
Observations	1,064	1,064	1,064	1,070	1,070	
R-squared	0.041	0.057	0.061	0.050	0.057	

Note: A household is treated if it received advice/training from AAZ or acquired an AAZ input loan/ input purchase or sold grain to AAZ. $ATT_{PSM\text{-}DID}$ denotes the average treatment effect on the treated estimated using PSM-DID. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Source: Authors

5.2.2 Effects on secondary outcomes

Effect on productivity, returns (net and gross) and crop diversification

In the previous sections, we showed that households participating in the AAZ programme are more likely to use improved seeds, apply chemical fertilisers (though for soybean production) and adopt SLM practices than non-participating households. If so, one can expect positive effects of these technologies and improved SLM practices on productivity, returns as well as crop diversification. The next question then is to explore whether the adoption of improved seeds, adjustments to fertiliser use and use of improved SLM practices led to improved yields, productivity (net as well as gross) and crop diversification. In Table 12, we examine the impact of AAZ participation on maize productivity (measured in kg/ha and monetary values (ZMW/ha)), Soybean productivity (in kg/ha and ZMW/ha), aggregate crop productivity (sum of cereals, fruits and vegetables in ZMW/ha), net productivity (in ZMW/ha) and crop diversification (number of crops grown). Descriptive analysis suggests mixed results in the sense that participating households have higher farm productivity (net returns per hectare) when monetary values are used instead of yield harvested and grow more crops than non-participating households. To make it comparable with crop net returns, we also used monetary values per ha for the analysis of maize and soybean productivity.

The regression results suggest no statistically significant causal effect of AAZ interventions on various indicators of productivity and returns (despite a positive trend in net productivity), except for maize productivity. Interestingly, participating households would have reduced the maize yield/ha by 12 percentage points had they not participated in the programme, a relative loss of 7 per cent (Table R3). Earlier we showed that the programme increased the use of improved maize seed and decreased fertiliser use on maize fields. The weak or lack of a significant effect of the programme on productivity could be due to various interrelated factors. First, although AAZ interventions may not have a direct significant effect on improving farmers' productivity or net returns, they do encourage the adoption of CA and improved technologies, as shown below (Table R3-B, Appendix B). We found that the adoption of these technologies and SLM practices have a strong positive impact on productivity. It could also be possible that adoption of improved agricultural technologies and CA practices may not improve yields in the short run. Second, the focus and activities of the AAZ programme had changed between the baseline and follow-up surveys from maize and soybeans (as well as groundnuts, sunflower and cowpeas) to cash crops such as quinoa and chia.[8] Third, estimation techniques based on pooled panel data for the baseline and the follow-up might obscure the heterogeneous effects of the programme on productivity. To verify if this was the case, we re-ran our analysis separately for the two survey periods, that is, at the time of the first wave and the second wave. To minimise the bias influencing programme participation due to observable covariates, we used the PSM approach. Our estimation results suggest that there is no statistically significant effect for most of the productivity indicators. However, we observed that the magnitude of our estimates are larger at the follow-up period. This could be suggestive evidence of some longer-term effects of the programme. In addition, we found that AAZ programme participation has a positive and more significant effect (at 10 per cent) on aggregate productivity (crop, fruit and vegetables) at the time of the follow-up than at the baseline period. The results are presented in Table R13B3 in Appendix B. Fourth, given the nature and design of the programme, spillovers/contamination with non-participating households is highly likely, which could underestimate the true effect of the programme. Finally, the attrition rate was high among participating households.

As to the effect of the interventions on crop diversification – one important strategy to diversify the risk of crop failure – our estimates suggest that participation in one of the AAZ components increases crop diversification, although we did not find a statistically significant difference. Separately analysing by survey rounds suggests, however, that programme participation has a strong and statistically significant positive effect on crop diversification at the baseline survey, about 32 percentage points (Table R13B3). It is also interesting to note that exposure to AAZ farm blocks (being closer to AAZ farm blocks) is positively associated with soybeans and aggregate productivity, but proximity to trading depots is not statistically significant.

Examining the adoption of agricultural technologies and SLM practices as potential mechanisms, we found that both the adoption of agricultural technologies (seed and fertiliser) and SLM practices had a positive effect on soybean productivity, maize productivity (improved

8 Focus group discussion participants indicated that most of the AAZ activities decreased since 2017, including late delivery of inputs and late payment for the crops purchased, and significant decrease in purchase of maize by AAZ in 2017.

technologies only), aggregate productivity (total value of crop and fruits per ha) and crop diversification (see Table R5-B, Appendix B). In addition, the adoption of improved technologies seems to have a stronger effect on productivity than SLM practices. All in all, the findings suggest that the programme affects productivity and nutrition security, especially that of women, by driving the adoption of SLM practices and improved agricultural technologies, such as the use of improved seed and fertiliser.

Table 12: Effect of AAZ participation on productivity, profits and crop diversification, PSM-DID estimates

	(1) Log maize yield in kg/ha	(2) Log soybean yield in kg/ha	(3) Log of crop and fruits/vegetables value in ZMW per ha	(4) Log of crop land productivity in ZMW/ha	(5) Log of net productivity per ZMW/ha	(6) No. of crops grown
$ATT_{\_PSM\text{-}DID}$	0.127**	-0.0954	0.0971	-0.101	0.00272	0.0855
	(0.0613)	(0.127)	(0.168)	(0.104)	(0.133)	(0.123)
Observations	1,044	876	1,035	1,020	990	1,064
Log (distance to nearest depot)	-0.0131	5.84e-05	-0.0749	-0.0329	0.0507	0.0112
	(0.0242)	(0.0628)	(0.0666)	(0.0497)	(0.0634)	(0.0606)
Log (distance to AAZ)	0.00165	-0.0199***	-0.0131*	-0.0140**	-0.00976	0.00336
	(0.00277)	(0.00711)	(0.00757)	(0.00562)	(0.00717)	(0.00697)
R-squared	0.009	0.0263	0.040	0.034	0.054	0.005

Note: A household is treated if it received advice/training from AAZ or acquired an AAZ input loan/ input purchase or sold grain to AAZ. $ATT_{\_PSM\text{-}DID}$ denotes the average treatment effect on the treated estimated using PSM-DID. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Source: Authors

Effect on commercialisation (cereal market participation)

Since one of the main project activities of AAZ is to support farmers market participation and trade with farmers through direct purchases using constructed rural trading depots as well as by providing free training on business skills, we also examined whether the programme has improved commercialisation patterns (maize, soybeans and aggregate crop commercialisation). Table 13 presents the results of this econometric analysis. We found that participation in AAZ programmes decreased farmers' commercialisation of maize, soybeans and overall crop commercialisation, though this effect is statistically significant only for the latter outcome. If one looks at the aggregate measure of crop commercialisation patterns, it seems that participating households tend to have lower market participation levels than non-participating households, by about 6.5 percentage points. This is not surprising, given that AAZ's grain purchases from smallholders (through its guaranteed off-take of the harvested crops) were intense only during the initial phase of its "outgrower" programme. Later, the focus of AAZ had shifted to high-value crops such as quinoa purchases. This is further substantiated by the fact that programme participation has a positive and statistically significant effect on the crop commercialisation index during the baseline but not during the follow-up (see Table R13B4, Appendix B). In fact, we observed a decreasing trend of commercialisation patterns during the follow-up survey. It is also interesting to note that households that live farther away from depots showed lower market participation levels, more so regarding soybeans sales (Table R4-B). For instance, a 1 per cent increase in households' distance to the nearest depots is associated with a 2 percentage point reduction in sales of soybeans.

Table 13: Impact of AAZ participation on crop commercialisation, PSM-DID estimates

	(1) Maize commercialisation index	(2) Soybean commercialisation index	(3) Crop commercialisation index
$ATT_{PSM-DID}$	-0.0680	-0.000183	-0.0649**
	(0.0435)	(0.0278)	(0.0279)
Log (distance to nearest depot)	-0.000642	-0.0246*	-0.00398
	(0.0180)	(0.0147)	(0.0121)
Log (distance to AAZ)	0.0150	-0.0167	-0.00795
	(0.0431)	(0.0359)	(0.0314)
Observations	925	798	1,073
R-squared	0.119	0.180	0.093

Note: A household is treated if it received advice/training from AAZ or acquired an AAZ input loan/ input purchase or sold grain to AAZ. $ATT\_{PSM-DID}$ denotes the average treatment effect on the treated estimated using PSM-DID. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Source: Authors

Effect on household food and nutrition security

Hunger and malnutrition are still major challenges in SSA, and smallholders are among many of the food-insecure households (Sibhatu, Arslan, & Zucchini, 2022). The situation is no different in Zambia. Thus, it is important to examine the impact of the programme on household food and nutrition security. One would expect that agricultural training, input support in the form of seed and extension services, and output market interventions (such as a guaranteed off-take of the harvested crops) help to alleviate the food and nutrition insecurity of smallholder farmers and improve household dietary diversity through increased productivity, diversification of crop portfolios and market participation. In this regard, the study investigated whether programme participation has any effect on household food and nutrition security and/or dietary diversity measured using the household food insecurity access score and the minimum DDS for women of reproductive age. We observed that participation in AAZ programmes (training, input loans/purchase, selling grains to AAZ) did not significantly reduce household food insecurity conditions and/or improve women's dietary diversity in participating households. Interestingly, however, we found suggestive evidence of the programme's effects on improving the likelihood of women meeting their micronutrient adequacy in beneficiary households. For instance, our estimates suggest that participating households had a 17 percentage point (about 48 per cent) higher likelihood of having adequate diets for women in the household compared to non-participants if the programme had not been offered (Table 14). This suggests that the programme has a positive effect on improving women's nutrition in the household. A detailed analysis by survey round and intervention type did not alter our main conclusions (see Table R13B5, Appendix B). However, the use of quantile regression analysis suggests that the programme had stronger effects on those who were extremely food-insecure, that is, the programme benefited mostly those households with the highest food insecurity score (results not reported here).

The introduction of new nutritious crops (or crop diversification) and extension services – including training and/or participation in off-farm employment – are some of the potential mechanisms through which the programme could contribute to such improvements. For instance, we examined the effect of programme participation on households' participation in off-farm employment, which is the most common livelihood diversification strategy among poor households in developing countries. In this regard, our analysis suggests that there is an increasing upward trend in off-farm employment for both groups, but the programme increases participation in off-farm employment of participating households by about 8 percentage points, and this effect is statistically significant (a relative increase of 50 per cent compared to sample average) (see Table R13B5, Appendix B).[9] In addition, we observed that the programme increased productivity through the adoption of technologies and CA practices. Increased productivity would contribute to such improved nutritional outcomes.

Table 14: Effect of AAZ programme participation on household and women's food and nutrition security, PSM-DID estimates

	(1) Household food insecurity score	(2) Minimum DDS for women of reproductive age	(3) Dummy=1 if women's diets in households are adequate in micronutrients
$ATT_{PSM\text{-}DID}$	0.184	0.197	0.171**
	(0.565)	(0.157)	(0.0676)
Observations	1,162	828	828
R-squared	0.010	0.013	0.030

Note: Training has a positive and significant effect on the DDS of women, suggesting the importance of the training/education component of the intervention in improving women's nutritional outcomes. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Source: Authors

Effect on the production of oilseed crops

As explained above, with the programme's expansion from Mumbwa to Chibombo, the programme's focus increasingly shifted around 2017 towards supporting the adoption of sunflower, cowpeas and groundnuts through the provision of seeds and by purchasing the crops from farmers. This component, however, was abandoned when the programme switched towards quinoa and chia. Table 15 shows the estimation results for the PSM-DID, that is, after the follow-up survey. The results do not suggest significant effects on crop adoption after the programme has ended.

9 However, further analysis is required if the increase in off-farm employment is due to the loss of land as a result of the expansion of AAZ, or if it is because of the search for alternative livelihoods.

Table 15: Effect of AAZ participation on the production of other crops, PSM-DID

	(1) Produced legumes	(2) Produced sunflower	(3) Produced cowpeas	(4) Produced groundnuts
$ATT_{PSM-DID}$	0.0699	0.0620*	-0.0759***	-0.00916
	(0.0490)	(0.0407)	(0.0268)	(0.0634)
Observations	1,064	1,070	1,070	1,064
R-squared	0.315	0.004	0.027	0.001

Note: A household is treated if it received advice/training from AAZ or acquired an AAZ input loan/ input purchase or sold grain to AAZ. $ATT\_{PSM-DID}$ denotes the average treatment effect on the treated estimated using PSM-DID. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Source: Authors

5.2.3 Individual treatment components: Intervention types matter?

So far, our analyses focussed on whether households benefiting from (or participating in) any of the AAZ interventions – such as advice/training (T1), input support (in the form of loan or access) (T2), or a guaranteed off-take of the harvested crops (purchase of cereals/grains (T3)) – are different from non-beneficiary households. Nonetheless, it is plausible to assume that the effects of each of the interventions on those outcomes differ. For instance, the effect of training on productivity could be different from that of input support or output market guarantee. As a result, the general treatment indicator (T) we used earlier could potentially conceal (or underestimate) the effects of each of the treatments on the various outcomes of interest discussed earlier. To explore this, we examined the effects of each of the three treatments (T1, T2, T3) on the relevant outcome variables of interest.

Results from the various specifications of equation (1) are presented in Table 16. In order to save space, we focussed on selected technologies, SLM practices, productivity and food security. Our results suggest the following: In terms of the impact on the adoption of agricultural technologies (specifically the adoption of improved maize seed varieties and fertiliser use), input support in the form of seed loans and output purchases were more effective (positive and statistically significant effects) than training (Table 17, columns 1-3). As to the effect on the adoption of various combinations of SLM practices, all three types of intervention had positive and significant effects (Table 16, columns 5-8). As to the impacts on land productivity (both on aggregate and individual crops), we found no clear evidence of impacts on maize or soybean productivity, but input loans and grain purchases had positive effects on the aggregate productivity of beneficiary households (Table 17, columns 9-11). Interestingly, only training had a consistently positive and statistically significant effect in improving the dietary diversity of women and the micronutrient adequacy of women’s diets in beneficiary households (Table 17, columns 13-14). Output market interventions seem to reduce household food insecurity, though statistically insignificant (Table 17, column 12). In addition, farmers who received input support or sold grain to AAZ diversified their crop production portfolios more than those who did not receive this support (not reported here).

In sum, the results suggest that AAZ interventions affect outcomes of interest differently: Whereas training on CA and business skills appears to be more effective in improving women’s nutrition outcomes as well as enhancing SLM practices, input support and output market interventions were more effective in improving technology adoption, enhancing SLM practices and productivity. In other words, despite consistently positive effects, we found little evidence to show that training improves technology adoption and productivity, except for improving the adequacy of micronutrients in women's diets in the household and the adoption of SLM practices. In addition, the sign and significance level of the estimated ATT varies for some of the outcomes, depending on the types of treatment, for instance training vs the purchase of grains. Although we controlled for various household and community characteristics and removed time-invariant effects, it should be noted that these are correlations, and they should not be interpreted as the causal effects of the interventions (due to the presence of self-selection into the programme with regard to time-variant factors).

Table 16: Impact of AAZ interventions on selected outcomes of interest, RE estimates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	Agri technologies					SLM practices			Land productivity			Food security		
	Adopted OPV/hybrid soybean seed	Adopted OPV/hybrid maize seed	Applied fertiliser on any maize field	Applied fertiliser on any soya field	Adopted MSD and CR practices	Adopted full-suite CA practices (MSD+CR+RESID)	Adopted MSD+CR or MSD+RR	Main tillage done before the rains on any plot	Log maize yield in kg/ha	Log soybean yield in kg/ha	Log of crop and fruits/vegetables value in ZMW per ha)	HH food insecurity score	Minimum DDS for women of reproductive age	Women's diet in HH is micronutrient adequate
Advice/ training (T1)	-0.009 (0.112)	-0.136 (0.130)	0.230 (0.140)	0.179 (0.148)	0.320* (0.128)	0.363 (0.203)	0.311** (0.121)	0.456* (0.182)	-0.006 (0.027)	-0.009 (0.073)	0.036 (0.078)	0.404 (0.320)	0.172* (0.092)	0.089** (0.038)
Input support (T2)	0.074 (0.108)	0.525*** (0.136)	0.178 (0.146)	0.156 (0.155)	0.319** (0.117)	0.312* (0.169)	0.308** (0.111)	0.253 (0.153)	0.052* (0.027)	0.036 (0.071)	0.224** (0.078)	0.037 (0.320)	-0.050 (0.090)	-0.028 (0.038)
Grain purchase (T3)	0.161 (0.125)	0.042 (0.149)	0.317 (0.165)	0.249 (0.174)	0.288* (0.123)	0.198 (0.178)	0.261* (0.117)	0.158 (0.163)	0.013 (0.032)	0.103 (0.082)	0.293*** (0.089)	-0.323 (0.366)	0.102 (0.102)	0.043 (0.043)
Log (distance to the nearest depot)	0.010 (0.094)	-0.332** (0.115)	-0.326** (0.124)	-0.513*** (0.134)	-0.344*** (0.100)	-0.201 (0.146)	-0.314*** (0.095)	-0.010 (0.131)	-0.013 (0.024)	-0.023 (0.064)	-0.070 (0.068)	0.005 (0.273)	0.071 (0.078)	0.016 (0.032)
Log (distance to Amatheon)	-0.277 (0.251)	-0.606* (0.289)	-0.856** (0.329)	-1.129** (0.347)	-1.105*** (0.249)	-0.607 (0.355)	-1.037*** (0.236)	-0.563 (0.315)	0.138* (0.062)	-0.227 (0.165)	0.025 (0.177)	0.534 (0.709)	0.146 (0.191)	0.014 (0.079)
Observations	1057	1126	1152	1142	1152	1122	1152	1152	1126	941	1117	1152	851	851

Note: The use of robust treatment indicators produces similar results. Using these treatment indicators, it seems that training leads more to the adoption of SLM practices than market interventions, although it is difficult to claim causality. We also found a positive significant effect of T2 on the fertiliser application on soybeans. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Source: Authors

5.2.4 Heterogeneity impact of the programme: Quantile DID

As a final analysis, moving beyond the average effects and in the interest of understanding heterogeneous effects, we employed the quantile treatment effect on the treated (QTT) following Callaway and Li (2019) to estimate the effects of programme participation on quantiles of maize productivity (kg/ha), soybean productivity (kg/ha), net productivity (ZMW/ha) and soybean commercialisation. The QTT helps to examine how the effect of programme participation varies at different levels of outcomes of interest. In other words, it helps to address the question: What would have been the distribution of productivity across the treated household groups if the treatment had not been offered? Table 17 reports the estimation results from the quantile PSM-DID estimation, controlling for various covariates used to estimate the propensity score. Overall, distributional analysis reveals that participation in the programme indeed has heterogeneous effects on the productivity of participating households, compared to non-participating households. Specifically, if there is any impact, the most significant positive gains are observed for those at the bottom (in the lower quantiles) compared to those at the higher productivity levels. For instance, at the 10th percentile and 25th percentile, the productivity of maize is estimated to be 18 and 29 percentage points higher for participating households than non-participating households, respectively. However, in the upper end of maize productivity distribution, programme participation appears to have no significant effect on maize productivity. Similarly, we found suggestive evidence that, at the lower end of soybean productivity distribution, the effect of programme participation on soybean productivity appears to be positive and significant. For example, at the 25th percentile, soybean productivity is estimated to be 19 percentage points higher as a result of programme participation than it would have been without programme participation. However, in the upper end of soybean productivity distribution, programme participation appears to decrease (75th percentile) or increase (90th percentile) soybean productivity, though the effect is statistically insignificant. In sum, the quantile DID estimates suggest that, compared to non-participation, programme participation has a positive and significant effect on those at the lower end of distribution of maize and soybean productivity than for those at the upper end of distribution. This again suggests that targeting those at the lower end increases the impact of the programme and may improve productivity, and hence overall welfare. On the contrary, the programme seems to benefit those households on the upper end of distribution, while reducing the level of commercialisation for those at the bottom end of distribution.

Table 17: The quantile treatment effect on the treated (QTT) estimates of the effect of AAZ participation on productivity

	(1)	(2)	(3)	(4)	(5)
	0.10	0.25	0.50	0.75	0.90
$QTT_{PSM\text{-}DID:}$ maize productivity (log kg/ha)	0.182**	0.288***	0.164***	0.154***	-0.182
	(0.0889)	(0.002)	(0.00123)	(0.0105)	(0.302)
Observations	887	887	887	887	887
$QTT_{PSM\text{-}DID:}$ soybean productivity (log kg/ha)	0.363	0.189**	0.0643	-0.100	0.250
	(0.525)	(0.0834)	(0.338)	(0.107)	(0.205)
Observations	922	922	922	922	922
$QTT_{PSM\text{-}DID:}$ gross productivity (log ZMW/ha)	-0.278	-0.214	-0.0705	-0.136	0.149
	(0.455)	(0.197)	(0.523)	(0.337)	(0.199)
Observations	1065	1065	1065	1065	1065
$QTT_{PSM\text{-}DID:}$ soybean commercialisation	-0.110	-0.0836***	-0.0333***	0.0843***	0.0131***
	(0.0933)	(0.0323)	(0)	(0.00998)	(0.00197)
Observations	804	804	804	804	804

Note: If soybean value per ha is used, the 25th percentile turns significant. The effect of the programme is also stronger (positive) on the lower end of distribution of crop diversification. Whereas input support benefits those at the top of the productivity distribution, it hurts those at the lower end of distribution. The programme enhanced the commercialisation of farmers at the top end while reducing it for those at the bottom end of distribution. In general, most of the statistical significance is around the lower end of productivity distribution. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Source: Authors

5.2.5 Robustness checks

We ran various robustness checks to examine whether our results are robust to various definitions of treatment, estimation techniques and year-by-year analysis due to changes in programme focus such as a shift to highly commercial crops. As a first robustness check, we reconstructed our treatment and control groups by restricting households into those that benefited from the programme during both the baseline and the follow-up, and those that did not participate at all. The PSM (kernel) was conducted by using the same covariates (individual, household and community characteristics) described earlier, except that the treatment indicator is now restricted to those that participated both at the baseline and the follow-up. Results from these analyses are presented in Table 18. The estimates of our variables of interest remain qualitatively similar, suggesting that our previous results are robust to a measurement and/or definition of the treatment and control groups. That is, participation in one of the AAZ activities increased the adoption of SLM practices and the use of chemical fertilisers for soybean production, but it decreased the adoption of maize production, improved maize and aggregate productivity (though it was significant only for the later), and improved nutritional outcomes for women in the beneficiary households. As an additional insight, we found suggestive evidence that participation in the programme during the project period increased both the use and intensity of inorganic fertilisers on soybean fields. Moreover, participation in the programme increased the production of groundnuts (Table R13B6).

Table 18: The effects of AAZ programme participation on outcomes of interest, using robust treatment indicator

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	Agri technologies				CA practices				Crop productivity			Food and nutrition security		
	Adopted OPV/hybrid soybean seed	Applied fertiliser on any soya field	Adopted OPV/hybrid maize seed	Applied fertiliser on any maize field	Adopted min. MSD and CR practices	Adopted full-suite CA practices	Adopted MSD+CR or MSD+RR	Main tillage done before the rains on any plot	Log maize yield in kg/ha	Log soybean yield in kg/ha	Log of crop and fruits/vegetables value in ZMW per ha	HH food insecurity score	Minimum DDS for women of reproductive age	Women's diet in HH is micronutrient adequate
$QTT_{PSM\text{-}DID}$	-0.0281	0.0385**	-0.0452	-0.200***	-0.0862*	0.0878***	-0.0750	0.006	0.103*	-0.0819	0.0111	-0.0444	0.210*	0.205***
	(0.0581)	(0.0182)	(0.0589)	(0.0564)	(0.0456)	(0.0265)	(0.0460)	(0.0360)	(0.0606)	(0.126)	(0.168)	(0.602)	(0.167)	(0.0723)
Observations	924	996	969	996	989	996	996	996	969	793	970	996	716	716
R-squared	0.084	0.012	0.008	0.047	0.070	0.058	0.069	0.069	0.012	0.262	0.049	0.000	0.013	0.036

Note: Robust treatment indicator refers to those households that benefited from the programme both during the baseline and the follow-up; that is why there is a drop in the sample size. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Source: Authors

As an additional analysis of robustness, we re-estimated our specification in (1) using semiparametric DID techniques. Results from these analyses are presented in Tables R1-B to R4-B in Appendix B. Again these analyses do not alter our main conclusions, though we observed improvements in the magnitude of our ATT estimates and significance levels of some outcome variables of interest.

The last check of robustness extends the analysis by analysing the impacts of the programme for the baseline and follow-up periods separately. This is done using propensity score matching (nearest neighbours). Doing so helps to capture some of the effects of the programme that might be obscured due to changes in focus or operations. Again the results remain similar to the original treatment categorisation (see Tables R13B1-R13B6 in Appendix B). With this analysis, we observed the following interesting additional insights. First, we confirmed our earlier findings of the strong positive effect of the programme on the adoption of SLM practices; the magnitude and significance level of the estimates for most of the SLM indicators are greater at the follow-up than at the baseline. This could be due to the fact that the adoption of SLM practices takes time to materialise. Second, the programme has a positive and significant effect (at 10 per cent) on the use of improved non-recycled seed varieties (including maize and soybeans) at the baseline rather than at the follow-up. Third, although we found suggestive evidence (even if weak, at a 10 per cent level) that the programme has a positive impact on maize, soybeans and the gross productivity of participating households at the baseline, the effects fade at the follow-up. Fourth, interestingly, the programme enhanced market participation among participating households during its early operation, especially among maize producers. This is mainly due to the fact that most of the early interventions of the AAZ programme focussed on input support in the form of seed and grain purchases. AAZ’s trading depots served as conduits for bulk purchases from farmers during those periods. Finally, the nutritional effects of the programme (mainly that of women in beneficiary households) were more significant at the follow-up than at the baseline. According to our analysis, improved nutrition outcomes for women in beneficiary households can be attributed to the increased production of sunflower, groundnuts and cowpeas as well as increased off-farm employment generated by the programme.

Finally, it should be noted that, although we controlled for various household and community characteristics, exposure to trading depots and AAZ farm blocks (to account for some spillovers or contamination with control groups) in our specifications – while also implementing a method that can remove the effects of time-invariant covariates driving self-selection – the effects should be interpreted with caution and may not necessarily imply causal effects.

6 Conclusions and policy implications

Many countries in SSA have experienced an upsurge in large-scale, mostly foreign, agricultural investments since the mid-2000s. Zambia has been among the major recipients of such investments in the region. The effects of these investments on smallholder farmers have been widely controversial in policy and scholarly debates. To attenuate critics – but also for other reasons such as efficiency gains, cost reduction, search for political allies or simply a lack of sufficient land – some large-scale investments have engaged smallholder farmers as suppliers (outgrower or more loose cooperation agreements). Such arrangements aim at securing supplies for the investors without having to make their own investments in land and inputs, while at the same time increasing the market participation and productivity of smallholder farmers. Hence, they are often seen as win-win-win solutions for the investors, the smallholder farmers and rural development. The impacts of such programmes, however, are complex and still not well understood, not least because the external and internal conditions of cooperation vary from case to case. For instance, the absence of institutional and/or proper contracts between farmers and the company for product delivery (inputs and outputs) and extension services could undermine the effectiveness of such interventions. In our case, qualitative findings suggest that product delivery (of harvested crops) contracts are given without price guarantee mechanisms for all the crops grown by farmers.

This discussion paper attempts to contribute to filling this knowledge gap by analysing the ex-post effects of a foreign commercial investment in farmland in Zambia – the AAZ "outgrower" programme – on various household outcomes: the adoption of CA, improved agricultural technologies, crop productivity, food and nutrition security, and market participation. AAZ had made several adjustments during its operation. In the initial phase (phase 1), the programme focussed mainly on maize and soybeans as part of its strategy to vertically integrate grain producers into the food value chain. During phase 2, the programme expanded to Chibombo district and included the supply of seeds for cowpeas, groundnuts and sunflower, as well as the purchase of these promoted crops. In phase 3 (after 2019), AAZ re-focussed to quinoa and chia. As a result, input support for maize and oilseeds as well as the purchase of these crops as part of the company's outgrower programme dropped significantly after 2019. Although the programme activities changed over the course of the project, free training remained the focus of the programme. This paper focusses on the impacts of the first and second phases of the AAZ outgrower programme. It uses two rounds of household survey data: a baseline survey in 2018 focussing on the 2016/17 main agricultural season, and the follow-up survey, which took place in 2021, with the focus on the 2019/20 main agricultural season. The paper uses both descriptive analyses as well as various econometric techniques that compare households participating in the AAZ programme with non-participant households before (in an early phase) and after the programme intervention.

Descriptive results illustrate that AAZ programme participants performed, on average, slightly better than non-participants in terms of technology adoption (mainly uptake of promoted crops, except cowpeas/groundnuts), uptake of CA practices, productivity, market participation (mainly maize marketing) and nutritional outcomes of women. We found that programme participants scored higher in adopting at least one or two CA practices, in the number of agricultural technologies adopted, crop diversification, the dietary diversity of women in the household as well as market participation (specifically maize).

Econometric results demonstrate that, although the overall impact of the AAZ outgrower programme on the uptake of CA practices is robust and promising, impacts on other aspects of technology adoption – specifically improved seed varieties – depend on the types of crops promoted. For instance, we found that AAZ outgrower participants are more likely to use at least one or a combination of CA practices, but less likely to apply fertiliser on maize fields (used less per hectare). We also observed that the focus on cereals and oilseeds in an early phase of the programme yielded more impact. Besides, the duration of the intervention matters and should not be overlooked in interventions that necessitate gaining experience and learning. As to the AAZ programme components, we found that types of intervention (or support given) matter to enhance technology adoption. For instance, training was effective in enhancing the uptake of CA practices and more so during the second round survey; however, input support in the form of seeds and guaranteed off-take of harvested crops were more effective in increasing the adoption of agricultural technologies.

As to the impacts of outgrower programme participation on crop productivity, we found weaker effects during the first phase, except on maize productivity. In addition, the impacts on crop productivity were more significant during its early phase than in later phases, that is before the programme shifted its focus towards commercial crops. One explanation could lie in the way the programme increased both productivity and market participation through the purchase of selected crops during the early phase of its programme operation than in later phases. As to the programme's integrated value chain strategy, the overall effects of the programme on crop commercialisation suggest that AAZ's strategy of integrating smallholder farmers into their primary production of staple crops seems to be ineffective, although there were some positive effects detected during the early phase of the programme operation.[10] Furthermore, our results suggest that the effects of the programme on productivity and commercialisation vary by project focus (whether the focus was on cereals or oilseeds) and duration (in an early phase or after some years). Moreover, our results indicate that the programme could increase household productivity (and nutritional outcomes) by enhancing the adoption of agricultural technologies and uptake of CA practices.[11] Of the various interventions, training was found to be the most useful tool to enhance the adoption of sustainable land management practices that to have long-term impacts on productivity. However, seed loans and output purchases from farmers seem the most promising in terms of improving crop productivity. In this regard, the positive impact of the construction of trading depots during the early phase of the project or purchase of staple crops would need further support in order to have a sustainable impact on the livelihoods of smallholder farmers. That, however, contradicts the reorientation of the project towards cash crops. This also implies that such interventions would play an important role in enhancing productivity and closing productivity gaps. Moreover, AAZ programme participation has heterogeneous effects on participants: Programme participation benefited more those with low productivity levels than those with higher productivity. Further consultation with Amatheon is necessary to find out whether supporting the least productive is financially beneficial and if there are fewer benefits to working with larger farmers.

Recent emerging empirical evidence suggests that large-scale agricultural intervention programmes that integrate smallholders in their value chain have the potential to help alleviate hunger and malnutrition among smallholder farmers by improving productivity and market participation simultaneously. Our paper indicates that, although the effects are not very strong, there is some suggestive evidence of the programme's effect on improving the nutritional outcomes of women in participating households. However, further research would be necessary to confirm the pathways through which these effects occur exactly, for example nutritional education programmes, production diversification or local employment effects. Our analysis of the inter-household distributional impacts of participation in the programme suggests that the programme had the largest effects on those who were extremely food-insecure. As highlighted in the results section, the introduction of new nutritious crops (or crop diversification during phase two), nutrition-related extension services, off-farm employment (better rural-urban

10 The qualitative interview suggests that a change or shift in project focus (from cereals to oilseeds); a deterioration or malfunctioning of the constructed trading depots during the follow-up period; a continued change in the design of the project; and a lack of an institutional/proper contract between farmers and the company are some of the factors that might have contributed to such a low effect or none at all. Since the lack of a proper contract between farmers and AAZ is mentioned as one reason for the constraints limiting commercialisation, exploring the effects of the recent shift to quinoa contract farming would be interesting.

11 We analysed potential pathways through which AAZ interventions affect productivity and nutritional outcomes. Two such pathways we considered are adoption of improved agricultural technologies and the uptake of CA practices.

linkages), the improved productivity of low productive groups and increased joint decision-making in the household regarding the allocation of land for crops grown are some of the potential mechanisms (qualitative interviews pointed to these factors). Analysis of AAZ programme components also suggests that complementing input and output market interventions with nutrition education in the training package could yield significant impacts on improving household food security in general, and women's consumption of micronutrients in particular.

General remarks: Our analyses confirm that large-scale agricultural investments that integrate smallholders, with all their risks, can offer opportunities for the farmers or communities that they are operating in. They would be appropriate for enhancing the production of important crops and improving sustainability via enhancing the adoption of sustainable agricultural practices and providing input credit, as well as establishing processing facilities in rural areas where such infrastructure is often lacking, thus improving the welfare of households. However, for their benefits to outweigh their drawbacks, the appropriate policies and institutions (for instance, in the areas of land policies, contract enforcement, the monitoring and evaluation of project implementation, clarifying the rules) that shape such investments in a development-friendly way are vital. In addition, a strong political commitment from the hosting government is needed, not only to protect the vulnerable farmers, but also to attract and promote more development-friendly, foreign-based, large-scale agricultural investments. Moreover, support should be provided to farmers and local communities where such investments are operating to negotiate for win-win outcomes.

Finally, it is important to acknowledge some of the limitations of this paper. The first is related to the caveat of the analysis: the missing plausible test of the parallel trends assumption in using DID. The results might be due to diverging trends in the outcome variables of interest between the AAZ outgrower programme participants and non-participants prior to AAZ intervention. As such, our results should be interpreted with caution and may not necessarily imply causality. Second, although our employed methods enable us to control for various household and community characteristics and remove time-invariant effects, it should be noted that unobserved time-variant factors might bias the estimates. Third, although we included exposure to depots and proximity to AAZ farm blocks, spillover effects from the programme or contamination to non-participating households are highly likely. This would, in turn, underestimate the true effects of the programme. Future research that analyses the extent of such spillovers would be important to understand the complete benefits of such programmes. Fourth, although a high attrition rate is expected in panel surveys such as this, it is higher in our dataset (we failed to track about 20 per cent of the baseline participants) than in the standard panel surveys. As highlighted in the data section, we conducted attrition-bias tests and carefully included variables that explain the attrition rate in our regression analyses to reduce the potential biases. Finally, future interventions interested in scaling out of such intervention models should take into account the external validity of this paper. And future studies considering wider geographic coverage (ours is only two districts) and agro-ecological conditions would give a clearer picture of the effects of private outreach programmes (or nucleus-outgrower schemes) on the welfare of smallholder farmers. In this regard, an interesting hypothesis to be tested by widening the scope of future studies would be if interventions of nucleus large farms would likely be better targeting the needs of smallholders (they may be better able to understand them than pure large processors or traders).

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Appendices*

Appendix A

Table A1: Definition of variables used in the regression analyses

Variables	Description
HH characteristics	
HH age	Age of the HH head (years)
Female-headed HH	=1 if HH head is female
HH education (head)	Education of the HH head (years of formal education)
HH size	No. of HH members (size)
Edu. max (within HH)	Maximum education for any HH member (years of formal education)
Head is married	=1 if HH head is married
Total cultivated crop, ha	Total cultivated land for crop production (ha)
Cultivated maize, ha	Total cultivated land for maize production (ha)
Cultivated soya, ha	Total cultivated land for soybeans (ha)
Wealth indices	
Agricultural asset index (pca), incl. tractor/oxen	Agricultural asset index computed using pca, including tractor/oxen
Agricultural asset index, only tractor/oxen/plough (pca)	Agricultural asset index, only tractor/oxen plough (using pca)
Agricultural asset index (pca), w/o tractor/oxen	Agricultural asset index, without tractor/oxen
HH wealth index (pca), incl. motorbike/cars	HH wealth index (pca), including motorbikes or cars
HH wealth index (pca), w/o motorbike/cars	HH wealth index (pca), without motorbikes or cars
HH experienced a shock	=1 if a HH experienced a shock in the past five years
HH irrigated a field	=1 if a HH irrigated a field
HH accessed a loan other than from AAZ	=1 if a HH has accessed a loan other than from AAZ
Land variables	
Per capita farm size	Per capita farm size (ha)
HH rented at least one field	=1 if a HH rented land for at least one field
Kinship ties	
Head or spouse is related to the chief	=1 if a HH or spouse is related to the chief
Head or spouse is related to the headman	=1 if a HH or spouse is related to the headman
Head or spouse is related to the farmer coordinator	=1 if a HH or spouse is related to the farmer coordinator
Head or spouse is related to the chief or headman	=1 if a HH or spouse is related to the chief or headman

* Authors are the source for all tables in Appendices A and B, unless otherwise indicated.

Table A2: AAZ programme participation dynamics, unbalanced panel HHs

	All districts		Mumbwa		Chibombo	
Variables	**N**	**%**	**N**	**%**	**N**	**%**
Households with a member that has received training/advice from AAZ (baseline), N=239	239	100%				
Share of HHs that received training from AAZ in 2014	239	31%				
Share of HHs that received training from AAZ in 2015	239	32%				
Share of HHs that received training from AAZ in 2016	239	41%				
Share of HHs that received training from AAZ in 2017	239	11%				
Share of HHs that received training from AAZ in 2018	239	1%				
No. of years HH has been trained by AAZ	239	1.17				
Households with a member that has received training or advice from AAZ (follow-up)	395	100%	212	100%	183	100%
Share of HHs that received training or advice from AAZ in 2016	244	16%	148	24%	96	4%
Share of HHs that received training or advice from AAZ in 2017	244	24%	148	26%	96	20%
Share of HHs that received training or advice from AAZ in 2018	244	59%	148	50%	96	73%
Share of HHs that received training or advice from AAZ in 2019	244	29%	148	34%	96	21%
Share of HHs that received training or advice from AAZ in 2020	244	14%	148	23%	96	0%
Share of HHs that received training or advice from AAZ in 2021	244	8%	148	14%	96	0%
Average no. of years HH has been trained/advised by AAZ	244	1.5	148	1.7	96	1.18
Household bought inputs from AAZ (baseline), N=75	75	100%	66	100%	9	100%
Purchased inputs from AAZ in 2013/14, baseline	75	8%	66	9%	9	0%
Purchased inputs from AAZ in 2014/15, baseline	75	21%	66	24%	9	0%
Purchased inputs from AAZ in 2015/16, baseline	75	52%	66	58%	9	11%
Purchased inputs from AAZ in 2016/17, baseline	75	28%	66	29%	9	22%
Purchased inputs from AAZ in 2017/18, baseline	75	23%	66	15%	9	78%
No. of years purchased inputs from AAZ, 2014-18	75	1.32	66	1.35	9	1.11
Household bought inputs from AAZ (follow-up), N=87	87	100%	64	100%	23	100%
Dummy=1 if purchased AAZ inputs in 2016/17	87	51%	64	59%	23	26%
Dummy=1 if purchased AAZ inputs in 2017/18	87	24%	64	17%	23	43%
Dummy=1 if purchased AAZ inputs in 2018/19	87	15%	64	9%	23	30%
Dummy=1 if purchased AAZ inputs in 2019/20	87	15%	64	17%	23	9%
Dummy=1 if purchased AAZ inputs in 2020/21	87	17%	64	22%	23	4%
Number of years HH has purchased inputs from AAZ	81	1.31	59	1.36	22	1.18

	All districts		Mumbwa		Chibombo	
Variables	**N**	**%**	**N**	**%**	**N**	**%**
Household acquired a seed loan from AAZ (baseline) (N=77) 2014-17	77	100%				
Share of HHs that received a seed loan from AAZ in 2014	77	8%				
Share of HHs that received a seed loan from AAZ in 2015	77	21%				
Share of HHs that received a seed loan from AAZ in 2016	77	13%				
Share of HHs that received a seed loan from AAZ in 2017	77	62%				
No. of years HH received seed loan from AAZ	77	1.04				
Household acquired a seed loan from AAZ (follow-up), N=66	66	100%	22	100%	44	100%
Share of HHs that received a seed loan from AAZ in 2016/17	66	23%	22	36%	44	16%
Share of HHs that received a seed loan from AAZ in 2017/18	66	45%	22	36%	44	50%
Share of HHs that received a seed loan from AAZ in 2018/19	66	26%	22	23%	44	27%
Share of HHs that received a seed loan from AAZ in 2019/20	66	6%	22	0%	44	9%
No. of years HH has acquired seed loans from AAZ	61	1.08	20	1.05	41	1.1
Households selling crops to AAZ (baseline), N=184	184	100%				
Share of HHs that sold to AAZ in 2014	184	14%				
Share of HHs that sold to AAZ in 2015	184	27%				
Share of HHs that sold to AAZ in 2016	184	44%				
Share of HHs that sold to AAZ in 2017	184	43%				
Share of HHs that sold to AAZ in 2018	184	6%				
No. of years HH sold crops to AAZ	184	1.34				
Households selling crops to AAZ (follow-up), N=87	87	100%	64	100%	23	100%
Share of HHs that sold to AAZ in 2017	87	51%	64	59%	23	26%
Share of HHs that sold to AAZ in 2018	87	24%	64	17%	23	43%
Share of HHs that sold to AAZ in 2019	87	15%	64	9%	23	30%
Share of HHs that sold to AAZ in 2020	87	15%	64	17%	23	9%
Share of HHs that sold to AAZ in 2021	87	17%	64	22%	23	4%
No. of years HH sold crops to AAZ	81	1.31	59	1.36	22	1.18

Appendix B

Abadie's semiparametric DID (SDID) estimates for robustness checks

Table R1-B: The effects of AAZ programme participation on individual technology adoption: Improved seed and fertiliser use, semiparametric DID estimates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Change in the use of improved soybeans (OPV)	Change in the use of improved seed not from friends/family	Change in the use of non-recycled seed	Change in the use of community seed	Change in the use of maize seed (OPV/hybrid)	Change in the use of fertiliser on maize field	Change in the use of fertiliser, on any field	Change in the use of fertiliser on soybeans field
ATT_DID_absd	-0.081 (0.061)	-0.019 (0.078)	-0.034 (0.076)	-0.056 (0.075)	-0.022 (0.071)	-0.001 (0.052)	0.020 (0.047)	0.026 (0.029)
No. of HHs	464	561	561	447	542	564	564	564

Note: A household is treated if it received advice/training from AAZ or acquired an AAZ input loan/ input purchase or sold grain to AAZ. Number of households shows the number of observations in common support used for the estimation of ATT, that is, the observations (after balanced) for which the estimated propensity score is bigger than 0 and smaller than 1.ATT_DID_absd refers to ATT estimated using the semiparametric difference-in-differences (SDID) estimator of Abadie et al. (2004). Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table R2-B: The effect of AAZ participation on the adoption of SLM practices, semiparametric DID estimates

	(1)	(2)	(3)	(4)	(5)
	Change in the practice of CR and RR	Change in the practice of RR and MSD	Change in the practice of CR and MSD	Change in full-suite CA practiced, MSD+CR+RESID	Change in MSD+CR or MSD+RR
ATT_DID_absd	0.081 (0.072)	0.073^{*} (0.033)	-0.092^{*} (0.041)	0.080^{**} (0.029)	-0.100^{*} (0.043)
No. of HHs	422	422	422	422	422

Note: A household is treated if it received advice/training from AAZ or acquired an AAZ input loan/ input purchase or sold grain to AAZ. Number of households shows the number of observations in common support used for the estimation of ATT, that is, the observations (after balanced) for which the estimated propensity score is bigger than 0 and smaller than 1.ATT_DID_absd refers to ATT estimated using the SDID estimator of Abadie et al. (2004). Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table R3-B: Effects of AAZ participation on productivity, profits and crop diversification, semiparametric DID estimates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	The change of log maize yield in kg/ha between baseline and follow-up	The change of log maize value in ZMW/ha between baseline and follow-up	The change of soybean yield in kg/ha between baseline and follow-up	The change of soybean yield in ZMW/ha between baseline and follow-up	The change of log of crop and fruits/ vegetables value in ZMW per ha	The change of log crop land productivity in ZMW/ha between baseline and follow-up	The change of log net productivity per ZMW/ha	The change in no. of crops grown
ATT_DID_absd	-0.020 (0.054)	0.154 (0.246)	-0.222 (0.305)	0.263 (0.417)	0.018 (0.258)	0.019 (0.132)	0.030 (0.158)	0.241 (0.190)
No. of HHs	407	351	318	332	400	390	374	862

Note: A household is treated if it received advice/training from AAZ or acquired an AAZ input loan/ input purchase or sold grain to AAZ. Number of households shows the number of observations in common support used for the estimation of ATT, that is, the observations (after balanced) for which the estimated propensity score is bigger than 0 and smaller than 1.ATT_DID_absd refers to ATT estimated using the SDID estimator of Abadie et al. (2004). Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table R4-B: AAZ interventions on commercialisation, semiparametric DID estimates

	(1)	(2)	(3)
	The change of maize commercialisation index between baseline and follow-up	The change of soybean commercialisation index between baseline and follow-up	The change of crop commercialisation index between baseline and follow-up
ATT_DID_absd	0.075 (0.153)	0.017 (0.057)	-0.004 (0.067)
No. of HHs (balanced)	284	231	389

Note: A household is treated if it received advice/training from AAZ or acquired an AAZ input loan/ input purchase or sold grain to AAZ. Number of households shows the number of observations in common support used for the estimation of ATT, that is, the observations (after balanced) for which the estimated propensity score is bigger than 0 and smaller than 1.ATT_DID_absd refers to ATT estimated using the SDID estimator of Abadie et al. (2004). Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table R5-B: Impact of SLM practices and technology adoption on agricultural productivity: Test of mechanisms, RE estimates

	(1)	(2)	(3)	(4)	(5)	(6)
	Log maize yield in kg/ha between baseline and follow-up	Log soybean yield in kg/ha	Log of crop and fruits/ vegetables value in ZMW per ha	Log of crop land productivity in ZMW/ha	Log net productivity per ZMW/ha	No. of crops grown
No. of CA practices adopted	-0.009	0.069^{**}	0.031	0.012	0.017	0.052^{*}
	(0.009)	(0.023)	(0.026)	(0.019)	(0.024)	(0.022)
No. of agri. technologies adopted	0.015^{*}	0.012	0.148^{***}	0.044^{**}	0.029	0.133^{***}
	(0.008)	(0.019)	(0.021)	(0.016)	(0.021)	(0.018)
Log (distance to nearest depot)	-0.010	-0.013	-0.043	-0.043	0.013	0.066
	(0.024)	(0.062)	(0.076)	(0.052)	(0.066)	(0.057)
dist_Amatheon	0.005	-0.017^{*}	-0.003	-0.013^{*}	-0.010	0.011
	(0.003)	(0.007)	(0.009)	(0.006)	(0.007)	(0.006)
Observations	964	819	948	931	908	979

Note: Insecticide has a positive and significant effect on gross productivity and net productivity.

Table R6-B: Impact of AAZ components on production of oil crops, RE estimates

	(1)	(2)	(3)	(4)
	Produced legumes	Produced sunflower	Produced cowpeas	Produced groundnuts
Received advice/training from AAZ	-0.069	0.036	0.496^{**}	0.055
	(0.195)	(0.150)	(0.183)	(0.128)
Acquired AAZ input loan/ input purchase	-0.057	0.497^{***}	0.360^{*}	0.076
	(0.208)	(0.151)	(0.158)	(0.128)
Sold grain to AAZ	0.877	-0.520^{**}	-0.222	-0.068
	(0.688)	(0.190)	(0.192)	(0.148)
Observations	1126	1129	1129	1123

Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Using propensity score matching (PSM), by survey rounds

Table R13B1: Effects of AAZ participation on the adoption of SLM practices, PSM estimates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Practiced CR	Practiced CR cereals to legumes or fallow	Practiced RR	Practiced MSD	Adopted CR and RR practices	Adopted MSD and RR practices	Adopted MSD and CR practices	Adopted full-suite CA practiced, MSD+CR+RESID	Adopted MSD+CR or MSD+RR	Main tillage done before the rains on any plot
$ATT_{\_PSM1}$	0.078**	0.066**	-0.002	0.228***	0.003	0.021	0.238***	0.021	0.238***	0.099***
	(0.027)	(0.025)	(0.020)	(0.035)	(0.020)	(0.012)	(0.034)	(0.012)	(0.034)	(0.024)
Observations	579	579	579	579	579	579	579	579	579	579
$ATT_{\_PSM2}$	0.064	0.066	0.030	0.096*	0.044	0.095**	0.109**	0.097**	0.106**	0.086**
	(0.037)	(0.037)	(0.045)	(0.038)	(0.048)	(0.032)	(0.034)	(0.030)	(0.036)	(0.029)
Observations	570	570	570	570	570	570	570	570	570	570

Note: $ATT_{\_PSM1}$ and $ATT_{\_PSM2}$ refer to ATT estimated using PSM based on wave 1 and wave 2, respectively. Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Nearest neighbours matching is used to calculate the ATT. In all the cases, the number of neighbours used to calculate the matched outcome is 4. Also common support is imposed. In both rounds, herbicide and insecticide use is higher among AAZ participants and significant during wave 1.

Table R13B2: Effects of AAZ participation on technology adoption, using k-nearest neighbours matching

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Adopted OPV/ hybrid soybean seed	Adopted non-recycled seed, not from relatives	Adopted non-recycled seed	Purchased seeds in community	Adopted OPV/ hybrid maize seed	Applied fertiliser on any maize field	Applied fertiliser on any field	Applied fertiliser on any soya field
$ATT_{\_PSM1}$	0.042	0.070*	0.068*	0.055	0.046	0.135***	0.115**	-0.005
	(0.042)	(0.040)	(0.039)	(0.049)	(0.040)	(0.038)	(0.036)	(0.010)
Observations	579	579	579	467	568	579	579	579
$ATT_{\_PSM2}$	0.004	0.079	0.042	-0.017	0.080	0.128**	0.128**	-0.001
	(0.029)	(0.043)	(0.041)	(0.047)	(0.044)	(0.042)	(0.040)	(0.020)
Observations	476	567	567	567	555	570	570	570

Note: $ATT_{\_PSM1}$ and $ATT_{\_PSM2}$ refers to ATT estimated using PSM based on wave 1 and wave 2, respectively. Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table R13B3: Effects of AAZ participation on agricultural productivity, using k-nearest neighbours matching

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Log maize yield in kg/ha	Log maize value per ha	Log soybean yield in kg/ha	Log soya value per ha	Log of crop and fruits/ vegetables value in ZMW per ha	Log of crop land productivity in ZMW/ha	Log net productivity per ZMW/ha	No. of crops grown
ATT_{PSM1}	0.054 (0.041)	0.247* (0.120)	0.115* (0.057)	0.463 (0.304)	0.200* (0.112)	0.018 (0.067)	0.058 (0.100)	0.324*** (0.087)
Observations	568	579	464	579	579	578	555	579
ATT_{PSM2}	0.056 (0.049)	0.043 (0.163)	0.100 (0.114)	0.224 (0.183)	0.293* (0.141)	0.077 (0.095)	0.145 (0.109)	0.105 (0.096)
Observations	555	378	476	355	535	518	508	567

Note: ATT_{PSM1} and ATT_{PSM2} refers to ATT estimated using PSM based on wave 1 and wave 2, respectively. Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table R13B4: Effects of AAZ participation on commercialisation, using k-nearest neighbours matching

	(1)	(2)	(3)
	Maize commercialisation index	Soybean commercialisation index	Crop commercialisation index
ATT_{PSM1}	0.021 (0.029)	-0.014 (0.015)	0.051* (0.022)
Observations	567	463	578
ATT_{PSM2}	0.028 (0.028)	-0.020 (0.030)	0.005 (0.018)
Observations	377	353	518

Note: ATT_{PSM1} and ATT_{PSM2} refers to ATT estimated using PSM based on wave 1 and wave 2, respectively. Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Loan and training seems to concentrate around those near to the depot's location. Also the results suggest that exposure to depots increase soya productivity and commercialisation during the baseline and maize productivity during the follow-up.

Table R13B5: Effects of AAZ participation on food and nutrition security and off-farm employment, using k-nearest neighbours matching

	(1) HH food insecurity score	(2) Minimum dietary diversity score for women of reproductive age	(3) Dummy=1 if women's diet in HH is micronutrient adequate	(4) Number of HHs participating in off-farm employment	(5) 1 if HH member works for pay between 1 May to 30 April
ATT_{PSM1}	0.005 (0.406)	0.089 (0.109)	0.040 (0.050)	0.149** (0.045)	0.081*** (0.021)
Observations	579	433	433	579	579
ATT_{PSM2}	0.322 (0.490)	0.093 (0.135)	0.080* (0.053)	0.028 (0.048)	0.016 (0.036)
Observations	570	415	415	570	570

Note: ATT_{PSM1} and ATT_{PSM2} refers to ATT estimated using PSM based on wave 1 and wave 2, respectively. Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table R13B6: Effects of AAZ participation on the adoption of other crops, using k-nearest neighbours matching

	(1) Produced legumes	(2) Produced sunflower	(3) Produced cowpeas	(4) Produced groundnuts	(5) Used OPV/hybrid groundnut seed
ATT_{PSM1}	0.050* (0.030)	0.027 (0.026)	0.086*** (0.023)	0.025 (0.044)	0.104* (0.052)
constant	0.836*** (0.024)	0.082*** (0.022)	0.015 (0.018)	0.431*** (0.036)	0.111** (0.043)
Observations	579	579	579	579	253
ATT_{PSM2}	-0.000 (0.008)	0.003 (0.033)	0.018 (0.018)	0.016 (0.049)	0.009 (0.022)
constant	0.007 (0.007)	0.135*** (0.029)	0.021 (0.016)	0.453*** (0.042)	0.016 (0.019)
Observations	570	570	570	567	264

Note: ATT_{PSM1} and ATT_{PSM2} refers to ATT estimated using PSM based on wave 1 and wave 2, respectively. Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$