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Isaac Bonuedi, Lukas Kornher, and Nicolas Gerber

Making cash crop value chains nutrition-sensitive: Evidence from a quasi-experiment in rural Sierra Leone

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Zentrum für Entwicklungsforschung (ZEF)
Center for Development Research
Genscherallee 3
D – 53113 Bonn
Germany
Phone: +49-228-73-1861
Fax: +49-228-73-1869
E-Mail: zef@uni-bonn.de
www.zef.de

The authors:
Isaac Bonuedi, Center for Development Research (ZEF), University of Bonn.
Contact: s7isbonn@uni-bonn.de
Lukas Kornher, Center for Development Research (ZEF), University of Bonn
Contact: lkornher@uni-bonn.de
Nicolas Gerber, Center for Development Research (ZEF), University of Bonn
Contact: ngerber@uni-bonn.de

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Abstract

With a strong global commitment to ending food insecurity and malnutrition, policymakers are increasingly grappling with how to make smallholder agriculture nutrition-sensitive. While the need to address these problems on multiple fronts is widely recognized, there is limited evidence on the nutritional impacts of integrated interventions in export-oriented sectors in developing countries. This paper aims to bridge this gap by evaluating the nutritional impacts of an innovative nutrition-sensitive value chain intervention, uniquely designed to address food and nutrition insecurity among smallholder cocoa, coffee, and cashew farmers in Sierra Leone. The diversity scores of household, maternal, and child diets are the main dietary outcomes employed in the study. Estimation of programme effects is carried out using the inverse-probability-weighted regression adjustment, which combines the propensity score method with regression adjustments to correct for selection bias and accommodate multiple treatments. We do not find a positive impact of supporting cash crop production on the diversity of household, maternal, and child diets unless it is combined with providing information on nutrition. Specifically, combining both interventions is found to significantly improve dietary diversity and the consumption of nutritious foodstuffs at household and individual levels, in comparison with non-intervention households. We found improvements in nutrition knowledge and women empowerment to be the main pathways linking the combined intervention to better dietary outcomes. The results suggest that nutrition-sensitive investments in cash crop sectors promise to be an effective way to increase dietary diversity and sustainably reduce micronutrient deficiencies among nutritionally vulnerable smallholder families in high-value export crop sectors.

Keywords: nutrition-sensitive agriculture, cash cropping, dietary diversity, Sierra Leone

JEL classification: D12, I15, Q01, Q18

1. Introduction

The production of export-oriented cash crops like cocoa, coffee, and cashew is central to the livelihoods of many smallholder farmers and the prosperity of developing countries. While producing mainly for the nourishment of consumers in high-and-middle income countries, most smallholder cash cropping farmers in Sub-Saharan Africa do not earn enough income or produce sufficient food to feed themselves and their families all year round. Malnutrition is highly prevalent in growing localities, mainly due to the intake of monotonous, unhealthy diets that are deficient in vital micronutrients (De Vries, McClafferty, Van Dorp, & Weiligmann, 2012; Freeman, Reenen, & Weiligmann, 2014). The direct costs of widespread undernourishment in these sectors are enormous, including substantial losses in physical productivity and household incomes due to compromised work capacity from fatigue, ill-health, and substandard human capital formation. Indirectly, these sectors also suffer from malnutrition-induced diversion of household resources away from the farm and non-farm investments towards health care (De Vries et al., 2012; De Vries, McClafferty, Van Dorp, & Weiligmann, 2013b, 2013a). If this situation persists, farmers in these cash crop sectors will also miss out on the opportunity to improve their incomes and well-being on the back of increasing global demand for high-value cash crops. Tackling food insecurity and malnutrition among smallholder farmers remains instrumental in efforts to reverse the downward trend in productivity, bridge world supply gaps, and avert the looming crisis in these sectors.

Agricultural interventions in export crop supply chains have typically focused on addressing such concerns as low productivity/income, poor labor conditions, child labor, and other issues related to the social and environmental sustainability of production methods. Nutrition is rarely prioritized or clearly incorporated in the design, conduct, and appraisal of such agricultural development programmes. Although non-food, export crops inherently offer relatively low nutritional benefits to smallholder households, it is generally assumed that, by boosting productivity and incomes, these interventions will inevitably lead to improved nutritional outcomes. Several studies (Carletto, Corral, & Guelfi, 2017; von Braun & Kennedy, 1995) and systematic reviews of the impacts of commercialization and other agricultural interventions (Herforth, Jones, & Andersen, 2012; Masset, Haddad, Cornelius, & Isaza-Castro, 2012; Webb & Kennedy, 2014; World Bank, 2007) have, however, shown that household food production and income may rise without substantial improvements in food security nor nutritional status. The high rates of hunger and undernutrition in major cocoa, coffee, and tea producing areas, amidst increasing cash crop incomes, attest to this fact (De Vries et al., 2012, 2013a, 2013b). This is because the pathway from income to nutrition is enhanced or attenuated by several individual, household, and community-level factors, including, intra-household control over income and other resources; women's status, education, nutrition knowledge, and decision-making power; caregiving, feeding and hygiene practices; and availability and utilization of health and sanitation services (Herforth & Ahmed, 2015; World

Bank, 2007). For instance, merely facilitating economic access to nutritious foods through higher incomes may not necessarily translate into improved nutrition in settings where caregivers have insufficient knowledge of best feeding and caring practices or are less empowered to influence household spending on nutrition-enhancing goods and services.

Fostering the production of cocoa, coffee, and other non-food cash crops has long been an integral part of rural development strategies to boost incomes, alleviate poverty and ultimately improve food security in these countries (Kuma et al., 2018; Masanjala, 2006; Maxwell & Fernando, 1989). However, given unremittingly high rates of hunger and malnutrition in producing countries and inconclusive evidence on the food security and nutritional impacts of commercialization interventions[1], policymakers are increasingly grappling with how to intervene in agricultural and food systems to make them deliver not only increased economic returns but also act as channels for improved nutrition and well-being for smallholder families. In the light of increasing recognition that hunger and malnutrition need to be fought in multiple fronts (Nisbett et al., 2016; World Bank, 2007), there has been a growing call and support for integrated, nutrition-sensitive interventions by governments, donors, and development practitioners (Bhutta et al., 2013; Ruel & Alderman, 2013; Ruel, Quisumbing, & Balagamwala, 2018). One of such approaches, with significant promise to address these problems in smallholder communities, is the nutrition-sensitive value chain (NSVC) model, which combines agricultural and nutrition-related interventions to promote both good agricultural practices and good nutritional practices along value chains (Allen & de Brauw, 2018; De la Pena & Garrett, 2018; Gelli et al., 2015; Hawkes & Ruel, 2012; Ruel & Alderman, 2013)

A growing body of research has demonstrated that such nutrition-sensitive interventions, mainly in food crop and livestock value chains, have improved production of, access to, and intakes of nutrient-rich foods; enhanced women's status; reduced morbidity and improved some dimensions of nutritional status of household members (Kumar et al., 2018; Leroy et al., 2016; Nisbett et al., 2016; Ogutu et al., 2018; Olney, Pedehombga, Ruel, & Dillon, 2015; Rosenberg et al., 2018). Empirical evidence is, however, lacking on the impacts of these integrated approaches in non-food, cash crop sectors, which are riddled with food insecurity and malnutrition (De Vries et al., 2012, 2013b, 2013a; Freeman et al., 2014). One main reason for this lacuna is that previous interventions in these value chains rarely give explicit nutritional considerations in their design and implementation.

[1] See DeWalt (1993), von Braun and Kennedy (1995) and World Bank (2007) for survey of early literature. Recently, while some recent studies reported positive effects of cash cropping and commercialization on food security and nutritional outcomes (Kuma, Dereje, Hirvonen, & Minten, 2018; Kuma et al., 2015; Ogutu, Gödecke, & Qaim, 2019), Anderman et al. (2014) and Ntakyo and van den Berg (2019) found that cash cropping hurts food security among cocoa producers in Ghana and calorie intake among commercialized rice producers in Uganda respectively.

This paper aims to fill this gap by drawing on the experience from the *Pro-Resilience Action* (PROACT) project implemented in Sierra Leone by Welthungerhilfe and its partners. We do so by exploiting the peculiar design of the PROACT project, which involved the integration of a nutrition component into a tree crop value chain intervention, aimed at improving the food security and nutrition situation of smallholder cocoa, coffee and cashew farmers in Sierra Leone. In addition to evaluating the nutritional impacts of the project, the study aims to identify complementarities or synergies between the individual interventions, the potentials of which have undergird the push for integrated agriculture-nutrition programmes around policy circles (Ruel & Alderman, 2013; Ruel et al., 2018). While tackling key barriers to improved nutrition from different sectoral purviews, there may be interactions between these agricultural and nutrition programmes, such that combining the two can deliver larger nutritional and health benefits than implementing them in isolation. Except for few recent studies (Kumar et al., 2018; Ogutu et al., 2018; Pace et al., 2018; Rosenberg et al., 2018), most existing assessments of integrated agriculture and nutrition programmes tend to focus largely on the stand-alone impacts and give little considerations to the potential synergies between them. The knowledge gap is even more severe for cash crop sectors, where integrated interventions are lacking. The design of PROACT allows us to undertake these analyses.

By addressing the underlying determinants of malnutrition – food, health, and child care – in a holistic fashion, we expect complementarities between the two types of intervention. While the cash crop component is an income-oriented intervention aimed at ultimately enhancing economic access to nutritious foods, the nutrition programme is directed at improving nutrition knowledge and stimulating nutrition-sensitive spending and allocation of other household resources. As mentioned above, improving income alone may not certainly lead to better nutrition outcomes if caregivers (and key decision-makers) lack knowledge of best child feeding and caring practices, or the significance of consuming diverse diets. Similarly, even when they have adequate nutrition knowledge (e.g., through the nutrition intervention alone), they may have insufficient access to resources to purchase or produce the recommended, diverse foods. Jointly targeting the two interventions may ensure that they complement each other in effectively improving food and nutrition security. At the programmatic level, examining the complementarity effects of the interventions is interesting for at least two reasons. First, the presence of such synergistic effects implies that stand-alone programmes reinforce each other in achieving the desired results. This could lead to better allocation of scarce resources, and reduce significantly the costs of implementing separate programmes to realize the same objectives. Further, in case there are high and significant levels of substitutability, this analysis will inform policymakers on which desired outcomes to prioritize to prevent unintentionally crowding out the effects of other interventions (Ogutu et al., 2018; Pace et al., 2018; Ruel & Alderman, 2013).

The rest of the paper is structured as follows. Section 2 gives a succinct overview of the study setting and the PROACT project in Sierra Leone. Section 3 presents the evaluation design, data, and methods employed in the study. The empirical results are presented and discussed in Section 4. Section 5 concludes with key findings and policy implications.

2. Study setting and the PROACT project

2.1 The Sierra Leonean Context

Sierra Leone's economic development has been severely hampered by major shocks (including a decade-long civil war, global financial and commodity crises, the Ebola epidemic, and mudslides). These mishaps have pushed the once-prosperous West African country into a protracted fragile situation, characterized by widespread poverty, food insecurity, and malnutrition. In terms of human development, Sierra Leone is one of the bottommost countries in the world, ranking 179th out of 188 on the 2016 Human Development Index (HDI) (Human Development Report Office, 2016). More than half (52.9 percent) of its 7 million citizens subsist on less than $1.90 a day (World Bank & Statistics Sierra Leone, 2014). 49.8 percent of its households were food insecure in 2015, and undernourishment afflicted 22 percent of the population in 2017(Development Initiatives, 2017; World Food Programme (WFP), 2015). The nutritional status of children is unsettling as 29.5 percent of under-fives are stunted, 14 percent are underweight, and 5 percent are wasted (Statistics Sierra Leone and The DHS Program, 2019). The country continues to battle with deficiencies in micronutrients such as iron, iodine, zinc, and vitamin A (Ministry of Health and Sanitation (Sierra Leone), UNICEF, Helen Keller International, & WHO, 2015). This is mainly due to habitually intake of monotonous diets that mostly consist of rice and other starchy staples, green leafy vegetables, and palm oil. Consumption of fruits, vegetables, and other nutrient-dense food groups is infrequent and largely depends on households' purchasing power (Ministry of Agriculture & Ministry of Health and Sanitation, 2016).

Agriculture is the backbone of the economy, accounting for about two-thirds of its employment and gross domestic output. After diamond and other minerals, cocoa (and to a lesser extent coffee and cashew) is Sierra Leone's main export commodity and foreign exchange earner (World Bank, 2013). With surging global demand, particularly from emerging markets, cocoa, coffee, and cashew sectors hold vast potential for increasing smallholder incomes, improving food security, reducing poverty, and advancing national development. The immense contribution of these sectors to the economies of Cote d'Ivoire and Ghana, Sierra Leone's West African neighbors, attests to this growth potential. However, unlike these major players in the global market, Sierra Leone accounts for a tiny percentage of the global supply of cocoa, coffee, and cashew. Yields remain relatively low, with production stuck below pre-war levels[2]. The majority of the country's tree crop plantations are aged, damaged, and overgrown, due to long periods of desertion, mainly during the decade-long civil unrest. Not

[2] For instance, prior to the war, average cocoa yield was estimated to be 430.8 kg/ha during 1961-1990. During the war (1991-2002), it declined to 350.9 kg/ha and has recovered marginally to 367.3kg/ha (2003-2017) since the ceasefire. (Own calculation based on FAO estimates obtained from http://www.fao.org/faostat/en/#data on 26.04.2019).

only are smallholder incomes susceptible to fluctuations, but they also remain persistently low, as farmers are locked in a vicious cycle of low investments, low yields, and low incomes. This cycle is further perpetuated by low input use, pest and diseases, poor access to markets, credit, and modern productivity-boosting technologies, low knowledge, and adoption of best agronomic practices and aging farmers, as the younger generation is less interested in farming as a viable, sustainable career (Amara, Momoh, & Oladele, 2015; Spencer, 2009).

This study is situated in the rural areas of Eastern and Northern Sierra Leone, where farming households predominantly depend on tree crops production for their sustenance. Besides being prominent for diamond, gold, and other mineral mining activities, the Eastern districts of Kailahun, Kenema, and Kono are also home to the majority of Sierra Leone's cocoa, coffee, and oil palm plantations. For instance, in 2015, it was estimated that about 85% and 92% of areas planted, respectively, with coffee (191,791 ha) and cocoa (235,749 ha) in Sierra Leone were located in the Eastern province (Statistics Sierra Leone, 2017). Kenema district is the provincial headquarter and trade center, whereas Kailahun dominates the cocoa, coffee, and oil palm production at regional and national levels. Kono district, albeit least in tree crops production, is the country's richest in diamond reserves. Most of Sierra Leone's food crops (upland rice, cassava, sweet potato, groundnut, and maize) are grown in the Northern region. The most important tree crops cultivated in its Bombali, Kambia and Port Loko districts are oil palm and cashew. Occupying less than 3% of total land under tree crops plantation in Sierra Leone, cashew is a relatively new tree crop and has been recently introduced in the country for its significant income potential (Statistics Sierra Leone, 2017).

About 8 out of every 10 persons in rural Sierra Leone are multidimensionally poor, deprived of education, healthcare, and a minimum standard of living, compared to 5 out of 10 in urban areas. The incidence of multidimensional poverty is higher in the North (75.7%) and East (67.5%) relative to the rest of the country (Statistics Sierra Leone, 2017). However, hunger is more prevalent in the East, with the rates of food insecurity being 46.8% in Kono, 47% in Kenema, and 50.5% in Kailahun. The food insecurity situation in the Northern districts (Bombali (46.6%), Kambia (42.6%), and Port Loko (30.5)) is comparably better than in the East, possibly because of greater involvement of Northern farming households in food crops production (WFP, 2018). Despite improving over the years, the nutritional status of children in these regions remains a major concern, with 25.3% and 30.9% of under-fives in the Eastern and Northern provinces respectively estimated to be stunted (Statistics Sierra Leone and The DHS Program, 2019). The Ebola epidemic, which devastated the country during 2014-2015, also dealt heavy blows to smallholder households in both regions by exacerbating constraints on labor supply. With an 81.1% death rate, the epidemic infected 13,575 persons nationwide, most of whom were within the working-age (70%) and resident in rural areas (54%). The North was the hardest-hit region, with Port Loko district recording the highest number of cases (3,594) and deaths (3,045) in the country. Kailahun was the epicenter in the East, losing 1,391 out of its 1,727 Ebola patients (Statistics Sierra Leone, 2017).

2.2 The PROACT project and its theory of change

The PROACT project was a four-year tree crop value chain project, launched in January 2017 by Welthungerhilfe (WHH) in partnership with Cooperazione Internationale (COOPI) and Inter Aide. With funding from the European Union, the project aimed to foster smallholder agriculture and improve the food and nutrition security among vulnerable cocoa, coffee, and cashew farmers in Sierra Leone. WHH focused on the development and reinforcement of cocoa and coffee value chains in the Kailahun, Kenema, and Kono districts in the Eastern Province. Both COOPI and Inter Aide worked in the Northern Province. While COOPI supported smallholder cashew farmers in the Bombali, Kambia and Port Loko districts, Inter Aide focused on vegetable production and safe water provisioning in the Bombali district. This study focuses on the smallholder tree crop farmers supported by WHH and COOPI under the project. Figure 1 shows the map of PROACT project districts in Sierra Leone.

The PROACT project was two-pronged, with cash crop and nutrition components. The main inputs of the cash crop intervention were capacity building through training in farmer field schools (FFS), provision of productive inputs, and support for market linkages (e.g., certification and traceability). During the FFS, trained extension workers from WHH, COOPI and implementing partners coach farmers on sustainable tree crop production and quality processing, with topics covering, rehabilitation (rehabilitating old plantations, underbrushing, sanitation, pruning and shade management), nursery establishment, harvesting and primary processing (fermentation, and drying), as well as voluntary sustainability standard certification. In addition to acquiring knowledge on improved farming practices, PROACT beneficiaries were also equipped with some agricultural inputs, including improved cocoa, coffee, and cashew seedlings, watering cans, and poly-bags for nursery establishment and out-planting; pruning saws and shears, cutlasses, and head pans for husbandry of tree crops; and solar plastics for improved drying.

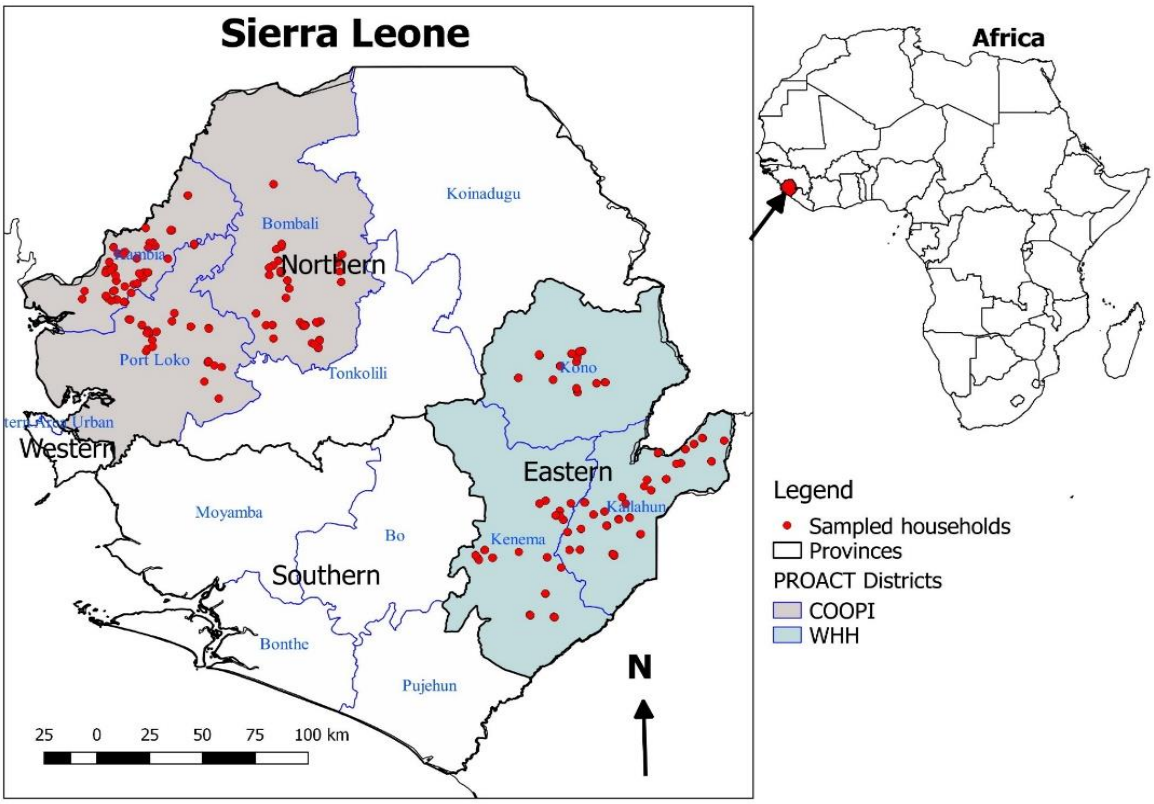

Figure 1: Map of PROACT districts in Sierra Leone

The nutrition component is WHH's flagship nutrition intervention, Linking Agriculture, and Natural Resource Management towards Nutrition Security (LANN). This was incorporated to increase the nutrition-sensitivity of the PROACT project. The LANN component is a participatory community-based approach involving nutrition education, behavioral change communication and awareness creation on the benefits consuming diverse diets, proper child feeding and water, sanitation and hygiene (WASH) practices, and sustainable agriculture and natural resource management in rural areas. As gender-sensitive nutrition intervention, LANN activities also included gender sensitization training, aimed at educating men/couples on the nutritional needs of different household members; advocating for greater participation of women in household financial and nutrition-related decision making; and encouraging men's engagement in domestic tasks, which are stereotyped as "women's works." By educating and engaging men in appropriate nutrition practices, the LANN approach expects to transform norms around women's status, gender roles, and intra-household distribution of nutritious foods in targeted communities, as well as free up women's time to carry out better care and child feeding practices.

To reach a large number of tree crop farmers rapidly and cost-effectively, the project was mainly implemented through contractual arrangements with implementing partners. These partners included cooperatives, community-based organizations (CBOs), farmer-based organizations (FBOs), exporting companies, and other local agencies. About 9,800 cocoa/coffee farmers in the Eastern Province and 1,370 cashew farmers in the Northern Province were supported during the first year of project implementation.

Through certain processes, such as increased knowledge and adoption, these inputs are expected to result in a number of outcomes. Gleaning from the project's logframe matrix, while the cash crop component was envisaged to lead to the rehabilitation of old plantations, establishment/extension of new tree crops, and improved post-harvest practices, the nutrition component was expected to result in the promotion of nutrition-sensitive agriculture, and good nutritional practices. Given these outputs, two specific outcomes/objectives are expected to be realized. Outputs from the cash crop component would lead to reinforced tree crop value chains, which would reflect in increased yields for cocoa, coffee and cashew, increased area planted to new tree crops, reduced average defects of cocoa and coffee exports and increased number of farmers with certified and traceable cocoa, coffee and cashew plantations. Taken together, these outputs were envisaged to lead to increased income for smallholders, which would in turn, facilitate the purchase of diverse nutritious foods and other welfare-enhancing items. The primary outcome of the LANN component is the enhanced consumption of nutritional foods among smallholders. This would be reflected in better nutrition awareness and positive behavioral changes for good health and improved nutrition. With these outcomes, the PROACT project is anticipated to deliver an overall impact of improved food and nutrition security among smallholder cash cropping households, especially for women and children.

3. Evaluation design, data, and methods

This study is the product of an international research partnership between the Centre of Development Research (ZEF) at the University of Bonn, Bonn, Germany, and the implementing organizations, Welthungerhilfe and COOPI. With a specific focus on tree crops, the productivity, profitability and nutritional impacts of which are most likely to materialize in several years (after the project has phased out), the goal of the cooperation is to enable researchers to examine the early impacts of the project interventions to provide information on whether the programme is likely to have its intended impacts.

3.1 Evaluation design

The study design entails three treatment arms and one comparison group. The treatment groups are smallholder households who received only the cash crop intervention (Cash crop only), those who benefited from only on the LANN intervention (LANN only), and those who were supported with both cash crop and LANN interventions (both cash crop & LANN). These treatment arms are mutually exclusive and represent the alternative modalities of the project design. The comparison group consists of non-participating households, that received none of these interventions (non-PROACT). Neither placement of the programme nor assignment to any of these treatment arms was randomized. By virtue of its focus on tree crops, the interventions were purposively targeted at smallholder households in the Eastern and Northern Provinces of Sierra Leone, where the agro-ecological conditions are most suitable for growing the targeted tree crops. This non-random programme placement constitutes one of two sources of endogeneity bias. The second source of bias emerges from voluntary participation. Households, therefore, self-selected into the project by being members of farmer and women's groups registered with the implementing partners of Welthungerhilfe and COOPI. We apply a quasi-experimental method to address these endogeneity problems and credibly estimate the impacts of the cash crop and nutrition interventions relative to the control group.

3.3 Data, sampling design, and attrition

Our analysis is based on two waves of household survey data, which we collected in the project districts using highly-structured questionnaires. The first wave took place between November–December 2017 in the Eastern Province and February–March 2018 in the Northern Province. The second wave, tracking the same households, was conducted in the respective districts 12 months later, between November–December 2018 and February–March 2019. A two-stage cluster sampling method was used, with villages as the primary sampling units and smallholder tree crop farming households as the secondary sampling units. With probability proportional to the size (PPS) of each district, villages (clusters) were randomly sampled in the first stage of the sampling design. In the second stage, we used simple random sampling to select treated cocoa/coffee and cashew farming households from the sampled intervention villages.

We did not have prior information on non-treated households. As with any agricultural intervention that seeks to achieve a local economy-wide impact, the PROACT project intentionally encourages participants to share the new knowledge of better agricultural and nutritional practices with others. While this may increase the potential impact of the project, it complicates the evaluation design by increasing potential spillovers to non-project farm households and making it difficult to identify "uncontaminated" counterfactual. Circumventing this spillover effect – and being able select 'truly' control villages and households – would have meant selecting households from villages that are geographically further away from PROACT villages. Doing so may also render the selected non-treated households less comparable to the treated ones, in terms of livelihoods and other socio-economic characteristics. Poor road networks in Sierra Leone, particularly in rural areas, imply that villages are isolated from one another. The resulting high travel costs (in terms of money and time) may limit social interactions as well as spillovers across villages. . We therefore selected the non-beneficiary households from non-project villages that are sufficiently close geographically to the PROACT villages, to limit the potential spillover effects while maximizing comparability between treated and non-treated groups. We used the lottery method to randomly sampled non-beneficiary cocoa, coffee and cashew farming households from the identified non-project villages who volunteered to participate in the survey. The number of sampled non-treated households is also proportional to the number of volunteering households in the selected non-project villages.

The first wave covered 912 smallholder cash crop farming households and the follow-up 836 households from 6 districts and 129 villages in the Eastern and Northern Provinces of Sierra Leone. The average rate of attrition between the two surveys was 8.6 percent, with some variations across treatment and comparison groups. The probit models in Table A1 analyze how the attrition is associated with household and village characteristics in the baseline sample. The pseudo R-squared from the full sample results in column 5 shows that the control variables explain just 4.1% of the attrition between the two waves. That is, 96% of the attrition is random. With p-values greater than the conventional levels, the Wald tests show that all covariates are jointly not significant predictors of attrition. Hence, we conclude that the balanced panel of 836 households (1672 observations) is representative of the original sample, and attrition may not significantly bias the results. Of the 836 households, 251 are cash crop only, 130 are LANN only, and 193 are both cash and LANN beneficiaries, while 262 are non-PROACT households.

3.3 Empirical strategy

As aforementioned, the primary goal of this paper is to estimate the causal effects of the project, involving multivalued treatments, on household and individual dietary diversity. To do so we assume, for a given population, the treatment variable *T* can take *G*+1 different values, labeled {0, 1, 2,…, *G*}. While zero indicates the control group, 1, 2,…, *G* represents the different treatment options or levels, which are mutually exclusive. For each level of treatment, *t*, let the potential outcomes for randomly sampled household *i,* be $\{Y_{it} : t = 0, 1, 2, \dots, G\}$. Thus, each household *i* has two potential outcomes: Y_{it} if it participates in treatment t and Y_{i0} if it does not participate in the programme. The causal effect of the intervention for household *i* is the difference between Y_{it} and Y_{i0}. Using the expectation operator $\mathbb{E}(.)$, we can define the treatment effects in terms of potential mean outcomes over the entire population as:

$$\mu_t = \mathbb{E}(Y_t), \quad t = 0, 1, 2, \dots, G \tag{1}$$

With $t = 0$ as the control, the average treatment effect (ATE) of treatment level $t \epsilon \{1, 2, \dots, G\}$ is given as

$$\tau_{t,ATE} = \mathbb{E}(Y_t - Y_0) = \mu_t - \mu_0 \tag{2}$$

Restricting the expectation to only those who actually received treatment level *t*, the average treatment effect on the treated (ATET) is obtained as

$$\tau_{t,ATET} = \mathbb{E}(Y_t - Y_0|T = t) = \mathbb{E}(Y_t|T = t) - \mathbb{E}(Y_0|T = t) \tag{3a}$$

The fundamental challenge to estimating the quantities in Equations 2 and 3*a* is the impossibility of observing a household participating in the intervention and not participating at the same time. That is, the expected outcome of the participating households in the absence of participation (μ_0 or $\mathbb{E}(Y_0|T = t)$) cannot be observed once they participated in the programme. However, randomization allows us to replace these expected unobserved counterfactual outcomes with the expected observed outcome of the non-participants, $\mathbb{E}(Y_0|T = 0)$. Hence, due to randomized assignment, the expected non-programme participation outcome is the same whether the household actually participates or does not participate in the intervention: $\mathbb{E}(Y_0|T = t) = \mathbb{E}(Y_0|T = 0)$. Equation 3*a* can therefore be rewritten as

$$\tau_{t,ATET} = \mathbb{E}(Y_t - Y_0|T = t) = \mathbb{E}(Y_t|T = t) - \mathbb{E}(Y_0|T = 0) \tag{3b}$$

Random assignment of treatment ensures that the difference-in-means estimators in Equations (2) and (3*b*), obtainable by an ordinary least squares (OLS) regression, are unbiased, consistent, and asymptomatically normal.

However, as often the case, assignment to the different treatment levels in the PROACT programme was not randomized. Participation was entirely voluntary, and households possibly choose a particular treatment that maximizes their utility (or wellbeing) relative to the utility obtainable from other alternatives. This self-selection into treatment may introduce systematic differences among participating and non-participating households, because the factors determining selection into different treatment groups will also most likely affect the outcome. For instance, the level of education may affect both dietary diversity and selection into nutrition-related treatments, as more educated household heads are more likely to know the benefits of good nutrition and would more likely value information on how to improve the nutritional wellbeing of their members. Consequently, in the absence of randomization, simply taking mean outcome value of non-participating households to be the counterfactual for participating households will be incorrect because $\mathbb{E}(Y_0|T=t) \neq \mathbb{E}(Y_0|T=0)$.

Therefore, estimating the causal effects in our multiple treatments design, using observational data, calls for estimation methods that do not only accommodate multivalued treatment assignments but also account for the problem of self-selection. In this paper, we apply the inverse-probability-weighted regression adjustment (IPWRA) estimator (Cattaneo, 2010; Imbens & Wooldridge, 2009; Wooldridge, 2007). It is a propensity score method which addresses selection bias by estimating both outcome and treatment models, while controlling for all observable confounders associated with both treatment assignment mechanism and potential outcomes. Doing so replicates the randomization process (Linden, Uysal, Ryan, & Adams, 2016). In particular, the IPWRA estimator uses weighted regression coefficients to compute the treatment effects, with the estimated inverse probabilities of treatment as weights (Linden, 2017; Linden et al., 2016; Uysal, 2015). The IPWRA estimator improves the balancing properties of samples across treatment levels by comparing each unit to all others, while attaching higher weights to observations that possess a similar probability of being in the treatment or comparison group and lower weights to those that are unalike (Wooldridge, 2007).

The IPWRA approach proceeds in three steps as follow. The first step involves estimating the treatment model, which relates the probabilities of programme participation to a set of covariates determining selection into a specific treatment. This can be expressed as:

$$p[T_i = t] = h(X_i; \gamma) + \omega_i \qquad (4)$$

where *T* is the treatment variable, taking different values t, which we label {0,1, 2, 3}. Drawn from a large population, each household *i*, $i = 1, \dots, N$, is only observed in one of four treatment groups: Non-PROACT (*t* = 0); Cash crop only (*t* = 1), LANN only (*t* = 2) and both cash crop and LANN (*t* = 3). X_i is a set of observable household, individual, village and district characteristics included as controls. ω_i is the error term. With multivalued treatment, a multinomial logit regression is used to estimate the parameters (γ) of Equation (4) and thus predict the probabilities or generalized propensity scores (Imbens, 2000; Słoczyński & Wooldridge, 2018; Wooldridge, 2007).

In the second step, using the inverse probabilities from Equation (4) as weights, a weighted regression models of the outcome (Y_i) for each treatment level are fitted to derive the treatment-specific predicted outcomes for each household. The conditional mean functions of the potential outcomes can be specified as:

$$\mathbb{E}(Y_{it}|X_i) = \mathbb{E}(Y_i|T_i = t, X_i) = \beta_{0t} + X_i'\beta_{1t} \quad (5)$$

where β_t is the parameter vector. The full specification of the weighted regression for multivalued treatment is derived in Linden et al. (2016) and Uysal (2015). Thirdly, the means of the treatment-specific predicted outcomes are computed. The differences of these averages provide the estimates of the ATEs, while those based on a restricted subset of treated households give the ATETs. Identification of the treatment effect depends on achieving unconfoundedness or covariate balance (which requires the distribution of the covariates to be independent of treatment status). Covariate balance is achieved if the weighted standardized mean difference and variance ratio are close 0 and 1 respectively. Rubin (2001) and Stuart and Rubin (2007) suggest that the variables are out of balance if the weighted standardized variance ratio is greater than 2 or less than 0.5, and the weighted standardized mean difference is above 0.25. A second condition for identification of treatment effects is the overlap assumption. This requires that conditioned on observables, each household has a positive probability of receiving treatment. Strict overlap ensures that for each participating household in the sample, we observe some non-participating households with similar covariates. There is evidence that the overlap assumption is violated when an estimated density has too much mass around 0 or 1 (Busso, DiNardo, & McCrary, 2014).

A key feature that makes IPWRA estimator very attractive (relative to other matching methods) is its double-robustness to misspecifation of either the treatment or outcome model. In contrast, estimates of treatment effects from propensity score matching (PSM) methods will be inconsistent if the treatment model is incorrectly specified. Empirical applications and Monte Carlo simulations (Linden et al., 2016; Uysal, 2015) show that doubly robust estimations of multi-valued treatment effects yield consistent estimates even if either the treatment model or the outcome model (but not both) is misspecified. The parameters of interest are estimated using the '*teffects ipwra*' command (StataCorp, 2013).

Despite its virtues, a major weakness of the IPWRA estimators is that it does not entirely deal with the problem of endogeneity arising from unobserved heterogeneity. Admissibly, unobserved factors, which determine self-selection by households into the project, may also influence dietary diversity and other outcome variables of interest. To purge unobserved heterogeneity and exploit the panel structure of our data, we employed the correlated random effects (CRE) estimator due to Mundlak (1978) and Chamberlain (1984). As a pseudo fixed-effects estimator, the CRE approach includes the mean values of time-varying observable covariates as additional regressors in the estimable model (Wooldridge, 2010). The CRE model can be expressed as:

$$Y_{i\tau} = \beta_0 + \beta_1 cash_{i\tau} + \beta_2 lann_{i\tau} + \beta_3 bcashlann_{i\tau} + \beta_4 X_{i\tau} + \beta_5 \bar{Z}_i + \beta_1 \eta_i + \varepsilon_{i\tau} \quad (6)$$

where $Y_{i\tau}$ is an indicator of dietary outcomes for household i at time τ, $cash,$ $lann$ and $bcashlann$ indicators for households belonging to the cash crop only, LANN only and both cash crop and LANN treatment groups respectively. Their respective impacts are measured by the parameters β_1, β_2, and β_3. X is the vector of individual, household and community-level covariates, $\bar{Z}$ is the vector of the average values of all time-varying controls in *X*. η_i are unobserved time-invariant fixed effects and $\varepsilon_{i\tau}$ is the idiosyncratic error term. The use of the CRE estimator allows us to assess the robustness of our results from the IPWRA estimator.

3.4 Measurement of the outcome variables

The main outcome variables of interest are household dietary diversity score (HDDS) and individual dietary diversity score for reproductive-aged women (WDDS) and children aged 6-59 months (CDDS). We tied our analyses to these dietary diversity measures because they are the main food security and nutrition indicators targeted by the project in achieving its overall objective of improving the food and nutrition security situation of vulnerable groups. The HDDS is measured by summing the number of food groups by a household out of 12 in the last 24 hours prior to the survey (Kennedy, Ballard, & Dop, 2010). The twelve food groups used to calculate HDDS are cereals; white tubers and roots; vegetables; fruits; meat; fish and other seafood; legumes, nuts, and seeds; milk and milk products; oil and fats; sugar and honey; and a miscellaneous group (consisting of spices, condiments, and beverages). The WDDS and CDDS are also measured by counting the number of food groups consumed by reproductive-aged women and under-fives respectively during the last 24 hours, based on the food groups proposed by the Food and Agriculture Organization of the United Nations (FAO) and USAID's Food and Nutrition Technical Assistance III Project (FANTA) (FAO & FHI 360, 2010). The WDDS is made up of ten food groups, while the CDDS is based on seven food groups; both excluding the last three food groups because of their minor contribution to micronutrient intake. The HDDS measures food consumption that reflects household access to diverse foods (hence, food security) at the household level, whereas WDDS and CDDS are proxy measures for nutrient adequacy of the diet of individuals (FAO & FHI 360, 2010; Kennedy et al., 2010). Several studies have validated these associations between dietary diversity, household food security, and nutrient adequacy of individual dietary intakes (Hatløy, Torheim, & Oshaug, 1998; Hoddinott & Yohannes, 2002; Nguyen et al., 2018).

Compared to a national average of 5.3 HDDS in 2017 (Ministry of Health and Sanitation & Action Against Hunger, 2017), our estimated mean of 6.8 suggests higher dietary diversity in rural Sierra Leone (see Table 1). However, such aggregate indicators mask the prevalence of micronutrient deficiencies in the country, which reflect a low intake of micronutrient-rich foods. Typical Sierra Leonean diets are highly undiversified, consisting mainly of rice, cassava, palm oil, and inadequate portions of groundnuts, fish and other seafood, green leafy vegetables, and beans (Ministry of Agriculture & Ministry of Health and Sanitation, 2016). As shown in Figure 2, the consumption of vitamin A and iron-rich foods is limited, partly due to inadequate knowledge of their nutritive values, poverty, and lack of access and availability. Since almost everyone consumes starchy staples, fats, and oil and condiments daily, their inclusion may inflate the dietary diversity scores and overstate access to and intake of micronutrient food groups. To quantify the impacts of the project on micronutrient intake among rural cash cropping households, as well as check the sensitivity of our estimates, we construct micronutrient-sensitive dietary diversity scores for household (MsHDDS) and women (MsWDDS). The modified scores are based on seven vitamin A and haem-iron rich food groups recommended by Kennedy et al. (2010). They include dark green leafy vegetables, vitamin A-rich vegetables or tubers; vitamin A-rich fruits; flesh and organ meat; fish and seafood; eggs; and dairy. Mazunda et al. (2018) have used similar country-specific micronutrient-sensitive dietary diversity indicators to analyze the effects of production diversity on food and nutrition security in Malawi.

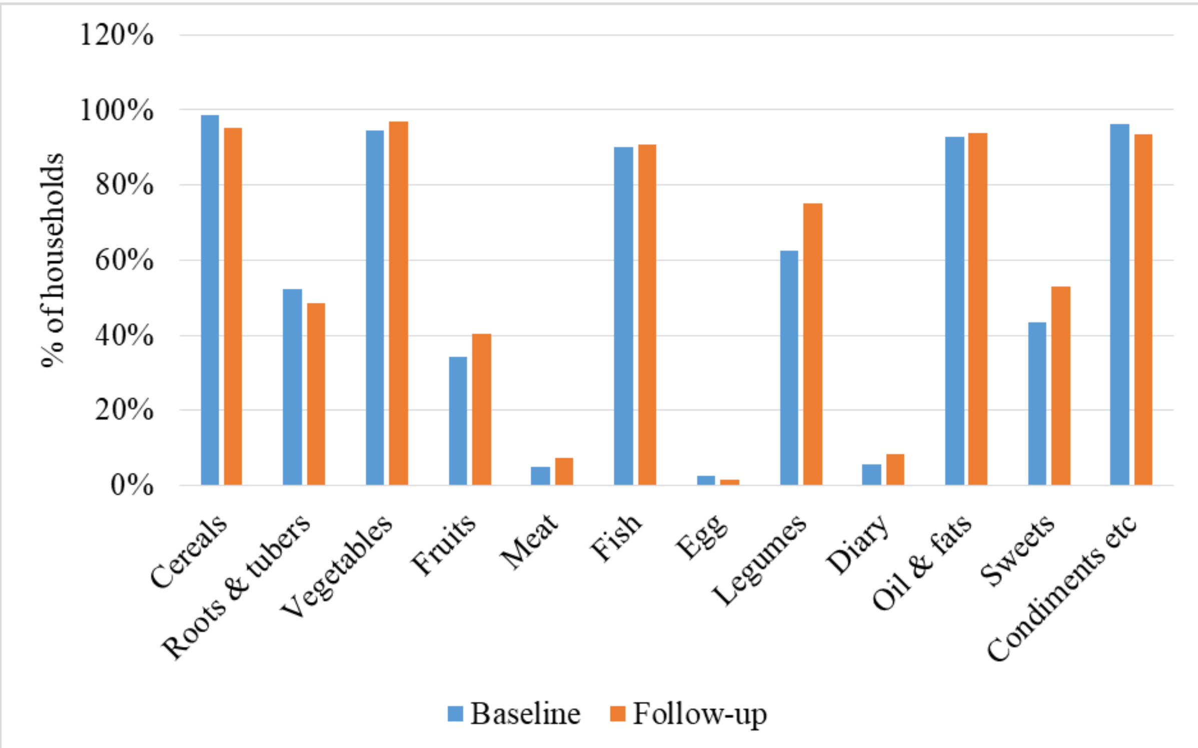

Figure 2: Distribution of HDDS food groups by survey wave

3.5 Measurement of the impact-pathway variables

The targeted cash crops are non-food tree crops that have little or no intrinsic nutritional value to smallholder producers. They are mainly produced for cash, which is then used for food and other purchases. In this study, we examine two broad pathways through which the PROACT project can lead to better dietary outcomes for these cash crop growers: the income-consumption pathway and women empowerment (i.e., women's nutrition awareness, control over the use of income and confidence). The income-consumption pathway is considered the most direct mechanism through which the market-focused, cash crop component of PROACT could lead to improved nutrition. It is expected that increased cash crop revenue (from better yields and prices) could lead to dietary improvements by enabling the market purchase of diverse, nutrient-dense foods, and other welfare-enhancing goods and services. Indirectly, it can also have a spillover effect on food availability from own farms if farming skills and tools obtained from the project are applied in food crop production (Govereh and Jayne, 2003). These project-induced changes may be seen in increased household food consumption expenditure. However, existing evidence suggests that improvements in dietary diversity and nutrition may not automatically follow increased household income (or food production) (World Bank, 2007). Several factors, particularly low nutrition knowledge, and women's lack of social status, participation in decision-making and control over the use of income, can impede increased cash crop income from translating into better diet quality and overall nutrition.

The complementary LANN intervention is expected to tackle these non-income barriers by increasing people's awareness of the nutritional value of different foods and stimulating household spending on and consumption of nutritious foods. As noted previously, the LANN intervention also aimed to improve women's status in targeted communities by engaging both men and women in discussions on gender-related topics (i.e., norms, equality, men's involvement in household chores and childcare, intra-household food allocation, and decision-making). These community-level gender-sensitization activities could also promote women's empowerment more broadly, with women having better control over the use of income and greater participation in decision-making regarding household purchases. Some studies have shown that greater women's control over income and participation in household food-related decisions are significantly associated with improved dietary diversity (Fischer and Qaim, 2012; Amugsi et al. 2016).

To explore these mechanisms, we also analyze the impact of PROACT on food consumption expenditure, and caregiver's nutrition knowledge, control over the use of incomes and confidence. Household food consumption expenditure entails own food production and market purchases. In this study, own food consumption in the 12 months preceding the survey was valued at self-reported producer prices, while purchased food was measured by the total expenditure on foods bought from the market in the last 7 days. As indicators of household welfare all consumption expenditures were annualized and expressed in adult equivalent units. The level of nutrition knowledge is captured by the test score from three nutrition-related questions asking caregivers to state the roles of the three LANN-promoted food groups – energy, growth/body building and health foods – in the human body. It ranges from 0 to 3, with higher values indicating caregivers have better knowledge or awareness of the nutritional values of the foods available to them, which may stimulate consumption. Women's control over income is captured by the degree of input into decisions on the use of income generated different economic activities they have undertaken. A woman is deemed to have adequate control if she participates in the activity and contributes at least some input in decisions about the use of income obtained from it (Alkire et al., 2013). Lastly, we considered women's confidence, a domain of women empowerment – leadership – which relates to public speaking (Alkire et al., 2013). A short description of the control variables employed in the study along with summary statistics from the first wave are reported in Table 1. The summary statistics by treatment groups are presented in appendix Table A2.

Table 1: Description of variables and summary statistics at baseline

Variable	Description	Mean	Std. Dev
Household characteristics			
Household dietary diversity score (HDDS)	Sum of food groups (0–12) consumed by household in last 24 hours based on Kennedy et al (2010)	6.780	1.325
Micronutrient-sensitive HDDS (MsHDDS)	Sum of micronutrient-sensitive food groups (0–7) consumed by household in last 24 hours	2.039	0.859
Age of head	Age of household in years	47.46	14.44
Head is male	Dummy, = 1 if household head is a male and 0 otherwise	0.949	0.221
Head is married	Dummy, = 1 if household head is married and 0 otherwise	0.956	0.206
Head's years of schooling	Years of schooling based on highest level of formal education attained by household	3.611	5.338
Dependency ratio	Ratio of household members aged 0-14 & 65+ to those aged 15-64	1.431	1.283
Household size	Number of household members	6.911	2.657
Farm size	Total cash crops and food crops farm holding in acres	7.999	6.971
Livestock	Dummy, = 1 if household owns chicken and 0 otherwise	0.793	0.405
Off-farm income	Dummy, = 1 if household had at least one off-farm income source	0.459	0.499
Household wealth index	Asset-based wealth index (0 – 100) based on Smits et al. (2015)	50.89	13.17
Head is member of cooperative	Dummy, = 1 if household belongs to any cooperative/farmer group	0.407	0.492
Household experienced any shock	Dummy, = 1 if household experienced any major shock last year	0.695	0.461
Distance to market (miles)	Distance to nearest daily/periodic market by most frequent means of transportation in miles	7.564	9.033
Village has cooperative	Dummy, = 1 if any cooperative or farmer group exists in village	0.694	0.461
Number of households		836	
Caregiver's characteristics			
Women dietary diversity score	Sum of food groups (0–10) consumed by woman in last 24 hrs based on FAO and FHI 360 (2010)	5.459	1.443
Micronutrient-sensitive WDDS (MsWDDS)	Sum of micronutrient-sensitive food groups (0–7) consumed by woman in last 24 hours	2.083	0.937
Caregiver's age	Age of caregiver (woman) in years	37.14	11.94
Caregiver's education	Years of schooling based on highest level of formal education caregiver/woman attained	1.991	3.448
Number of women of reproductive age		636	
Child characteristics			
Child dietary diversity score	Sum of food groups (0–7) consumed by child in last 24 hours based on FAO and FHI 360 (2010)	3.534	1.305
Child's age (months)	Age of child in months	29.31	17.89
Child is a male	Dummy, = 1 if child is male and 0 otherwise	0.482	0.500
Number of children (6-59 months)		575	

4. Results and Discussion

4.1 Descriptive results and diagnostic checks

4.1.1 Descriptive statistics

From the pooled sample at baseline in Table 1, the majority of the sampled households (95%) are headed by males, with very low educational levels (less than 4 years of formal schooling). The average household has about 7 members, with 1.4 dependents per working-age person. In light of the country's low life expectancy (52 years), it is unsettling that the mean age of household heads is about 47.5 years. This poses a significant threat to the productivity and sustainability of these cash crop sectors. The reason is that aged farmers are less productive, have lowered work capacity, and are unable to provide the physical strength required to carry out various labour intensive agronomic practices and post-harvest processing activities. That targeted households are smallholders is shown by the average farm size of about 8 acres (circa 3.6 hectares). The majority of households are shock-prone, with about 70% of them experiencing a major shock in the year preceding the survey. The average wealth index of 50.89 suggests that households possess some durable assets with moderate quality housing and services. Alternative sources of livelihood, aside from farming, are thin, as less than half of them reported to have at least one off-farm source of income. In terms of institutions, close to 70% of the households live in a village where a cooperative or any farmer group exists, and about 41% of them are group members. Households have to travel about 8 miles (about 13 km or one and half hours using the most common means of transportation) to reach the nearest food market, due to generally poor-quality roads and weak transport infrastructure in these rural communities. Out of 12, households consume from 6.78 food groups, suggesting somewhat high dietary diversity in Sierra Leone. At the individual level, while women of reproductive age consume 5.5 out of 10 food groups, and under-5 children receive less diversified diets (3.5), consuming from less than 4 food groups (out of 7).

4.1.2 Specification diagnostics

In observational studies, like ours, the covariates are typically never balanced across treatment groups. Therefore, we utilized an inverse-probability-weighting method that uses a treatment-assignment model to balance the covariates. By this strategy, the covariates are balanced if the weighted distribution of each covariate is similar across treatment groups. We rely on standardized differences and variance ratios for conclusions about covariate balance over treatment groups, and thus correct specification of the treatment-assignment model. As shown in the diagnostic statistics in Table A4, the standardized difference in the means of all treated and non-treated groups for each (weighted) covariate is less than 0.25, and the majority are close to 0. Moreover, the weighted variance ratios are mostly close to 1 or fall within the range (0.5 – 2) proposed by Rubin (2001). These results suggest that the treatment-assignment model is well specified, and the weights constructed from this model balance the covariates. In other words, the counterfactual outcomes are independent of the treatment indicator conditional on these covariates. In addition to conditional independence, non-violation of the overlap assumption is required for estimated treatment effects, using weighting and matching estimators, to be consistent. The overlap assumption asserts that each household has a positive probability of receiving each treatment level, given the covariates. Figure A1 displays the overlap graphs of the estimated densities of the predicted probability of participating in each treatment level. None of the plots have too much probability mass around zero or one, suggesting that there is no evidence that the overlap assumption is violated. In sum, while the covariate balancing tests show successful bias reductions after weighting, the overlap distributions of the generalized propensity scores suggest a satisfaction of the common support conditions. Having verified that these assumptions hold, we now proceed to present and discuss the main results.

4.2 Empirical results

4.2.1 Determinants of programme participation

Table 2 shows the results of the multinomial logit model of programme participation. It reveals the factors associated with the predicted probabilities of participating in the different treatment arms of the PROACT project. The results show that the gender of the household head, farm size, group membership, the presence of a cooperative/farmer group in a village, wealth index, and off-farm income are significantly associated with the probability of participating in any two of the three treatment groups. Male household heads are less likely to participate in nutrition-related treatment groups than their female counterparts. This may be because the LANN approach is purposively designed to reach nutritionally most vulnerable and socially marginalized groups within target communities, particularly women and children below 5 years. Marital status does not significantly affect project participation, suggesting that both married and unmarried household heads are equally likely to participate in any of the interventions. While the age of the household head appears not to play a significant role in participating in the individual treatment groups, older farmers are more likely to decide on the combined intervention than younger farmers. The probability of receiving any intervention, either in isolation or jointly, increases with the farm size of the household, the head's membership of a farmer-based organization, and the presence of these groups in the village. The positive and significant association between farmer groups and the probabilities of program uptake reflects the importance of farmer groups both as social capital and a platform for delivery of development interventions. Households with off-farm sources of income are less likely to participate in the stand-alone cash crop and LANN intervention, perhaps due to the related higher opportunity cost in terms of time and forgone alternative income. While asset-rich households are more likely to decide on the LANN only intervention, they are less likely to adopt the cash crop only intervention. This could be due to the higher valuation of nutrition information and its health-related benefits among asset-rich households, who may already possess the farming tools provided under the cash crop intervention. Finally, livestock ownership seems to lower the probability of project participation, particularly, the uptake of cash crop only intervention.

Table 2: Multinomial logit – determinants of participation

	Cash crop only	LANN only	Both cash crop & LANN
Age of head (years)	-0.007	0.002	0.009*
	(0.005)	(0.006)	(0.005)
Head is male (dummy)	-0.499	-1.673***	-1.385***
	(0.500)	(0.434)	(0.466)
Head is married (dummy)	-0.015	-0.169	0.750
	(0.518)	(0.442)	(0.538)
Head's years of schooling	-0.035**	-0.006	0.002
	(0.014)	(0.015)	(0.014)
Dependency ratio	-0.001	0.125*	-0.053
	(0.063)	(0.064)	(0.065)
Household size	-0.025	-0.156***	0.015
	(0.029)	(0.038)	(0.027)
Farm size (log, acres)	0.545***	0.739***	0.606***
	(0.112)	(0.133)	(0.123)
Livestock (dummy)	-0.475***	-0.269	-0.049
	(0.161)	(0.203)	(0.184)
Off-farm income (dummy)	-0.305*	-0.360*	0.077
	(0.163)	(0.196)	(0.165)
Household wealth index	-0.014**	0.018**	0.011
	(0.007)	(0.008)	(0.007)
Head is member of cooperative	1.463***	0.898***	1.616***
	(0.141)	(0.173)	(0.151)
Household experienced any shock	0.038	0.379**	-0.089
	(0.137)	(0.169)	(0.147)
Distance to market (log, miles)	0.115	-0.826***	-0.138
	(0.098)	(0.119)	(0.100)
Village has cooperative	0.106	0.647***	0.934***
	(0.148)	(0.194)	(0.181)
Constant	0.198	0.181	-2.980***
	(0.582)	(0.657)	(0.664)
District dummies	Yes	Yes	Yes
Observation	251	130	193

Notes: This table reports the treatment equation used for the household level analyses using the first wave sample. The reference group is non-PROACT households with a sample size of 262. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

4.2.2 Impact on household diets

The stand-alone and joint impacts of the PROACT interventions on household diets are presented in Table 3. The results show that the cash crop only intervention is associated with a statistically significant decline in the HDDS, with its recipients consuming 0.28 food groups less than non-PROACT households. LANN only recipients are shown to consume 0.23 food groups more than non-PROACT households, although it is not significant statistically. However, the treatment effects of the combined cash crop and LANN indicate that, relative to the comparison group, HDDS significantly improved by 0.20 food groups (at 10 percent level). This represents almost a 3% increase in HDDS relative to the baseline value of 6.85 for Non-PROACT households. As shown in panel B, these results remain consistent when we consider the ATE instead. The magnitude of the coefficients points to potential synergies in terms of complementarities between cash crop and LANN interventions (statistically significant for ATE estimates) and significant incremental effects of cash crop intervention on LANN only households.

The average treatment effects on MsHDDS are shown in column 2 of Table 3. Though lower for cash crop only households and higher for LANN only households, the results show that there is no significant difference in the consumption of micronutrient-dense foods between each stand-alone intervention group and the comparison group. However, both cash crop and LANN households are found to consume 0.34 micronutrient-rich food groups more than non-participants. The estimated joint impact of both interventions on MsHDDS is statistically significant, suggesting that mainstreaming nutrition in tree crop value chain projects can be an effective strategy to combat micronutrient deficiencies among smallholder households. For non-PROACT households, the estimated average potential-outcome means of HDDS and MsHDDS are respectively 6.98 (out of 12 food groups) and 2.04 (out of 7 food groups).

Reported in columns 3–12 are the estimated treatment effects on the probability of consuming from different food groups. The goal is to identify the sources of change in household dietary diversity attributable to the PROACT project. From the results, while cash crop only households are less likely to consume dark green leafy vegetables, they are more likely to increase the consumption of other vegetables and eggs than non-PROACT households.

Table 3: Impact on household dietary diversity and the likelihood of eating from nutrient-rich food groups

	Household dietary diversity		Food groups consumed by any household member									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	HDDS	Micronutrient -sensitive HDDS	Dark green leafy vegs	Vitamin A rich vegs & tubers	Other vegetables	Vitamin A rich fruits	Other fruits	Meat	Fish	Eggs	Legumes nuts & seeds	Dairy
Panel A: Average treatment effects on treated (ATET)												
Cash crop only	-0.276***	-0.052	-0.07**	0.03	0.06*	-0.00	0.03	0.01	-0.03	0.01*	-0.12***	-0.00
	(0.093)	(0.057)	(0.03)	(0.02)	(0.03)	(0.02)	(0.03)	(0.02)	(0.02)	(0.01)	(0.03)	(0.02)
LANN only	0.226	0.092	0.00	0.01	0.08**	0.07*	0.16***	-0.02	-0.05	0.02**	-0.15***	-0.02
	(0.141)	(0.085)	(0.05)	(0.02)	(0.04)	(0.04)	(0.05)	(0.02)	(0.04)	(0.01)	(0.05)	(0.02)
Both cash crop & LANN	0.203*	0.338***	0.04	0.10***	0.08**	0.11***	0.18***	0.01	-0.01	0.05***	-0.08**	0.06**
	(0.118)	(0.072)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.02)	(0.02)	(0.02)	(0.04)	(0.03)
POM of Non-PROACT	6.932***	2.012***	0.77***	0.08***	0.76***	0.12***	0.24***	0.05***	0.92***	0.00	0.76***	0.06***
	(0.073)	(0.044)	(0.03)	(0.01)	(0.03)	(0.02)	(0.03)	(0.01)	(0.02)	(0.00)	(0.03)	(0.02)
Panel B: Average treatment effects (ATE)												
Cash crop only	-0.288***	-0.062	-0.07**	0.01	0.05*	0.01	0.04	0.02	-0.04*	0.01*	-0.14***	0.01
	(0.088)	(0.056)	(0.03)	(0.02)	(0.03)	(0.02)	(0.03)	(0.02)	(0.02)	(0.01)	(0.03)	(0.02)
LANN only	0.149	0.093	0.03	0.01	0.06*	0.07**	0.13***	-0.01	-0.04	0.02**	-0.17***	-0.01
	(0.115)	(0.071)	(0.04)	(0.02)	(0.03)	(0.03)	(0.04)	(0.02)	(0.03)	(0.01)	(0.04)	(0.02)
Both cash crop & LANN	0.218**	0.345***	0.03	0.11***	0.08***	0.11***	0.15***	0.01	-0.02	0.04***	-0.10***	0.06**
	(0.102)	(0.066)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.02)	(0.02)	(0.01)	(0.03)	(0.02)
POM of Non-PROACT	6.979***	2.041***	0.78***	0.09***	0.77***	0.12***	0.25***	0.06***	0.93***	0.00*	0.78***	0.06***
	(0.060)	(0.037)	(0.02)	(0.01)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(0.00)	(0.02)	(0.02)

Note: All outcome variables are based on 24-hour dietary recall. POM stands for the potential-outcome mean. The outcome models in columns 1 and 2 were estimated using Poisson regression, and those in columns 3-12 were estimated using the probit model. All estimates were conditioned on the covariates in Table A1 and shared similar treatment equations using the IPWRA method. Non-PROACT households are the comparison group for the ATET and ATE estimates.

Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

With respect to LANN only households, the results show that their likelihood of consuming other vegetables, vitamin-A rich fruits, other fruits and eggs is significantly higher than non-PROACT households. Both cash crop and LANN households show significantly higher probability of consuming vitamin A-rich vegetables, other vegetables, vitamin A-rich fruits, other fruits, eggs, and dairy than their non-PROACT counterparts. All treatment groups display a significantly lower propensity to consume legumes, nuts, and seeds. We do not find any significant differences in the likelihood of meat and fish intake among participating and non-participating households. Noticeably, the combined effects of cash crop and LANN interventions on the probabilities of consuming from these food groups are larger than the stand-alone effects, indicating the presence of potential synergistic effects between the components of the project.

4.2.3 Impact on maternal diets

Women of reproductive age (15-49 years) and children below age five (6-59 months) are most vulnerable to nutritional deficiencies, especially in rural areas where entrenched socio-cultural norms strongly tilt intra-household distribution of nutritious foods in favour of men (KIT et al., 2018; Madjdian, 2018). Because of the considerable intergenerational and irreversible consequences of poor maternal and child nutrition, it is vital to go beyond the household to analyze how nutrition-sensitive interventions, like PROACT, might impact on individual dietary diversity (as a proxy indicator of nutrient adequacy). Table 4 reports the stand-alone and joint impacts of the PROACT interventions on women's diets. As shown by the ATET estimates in Panel A, the sole cash crop and LANN interventions are associated with 0.08 decline and 0.22 increase in WDDS, respectively. These effects are, however, not sufficiently large to result in significant differences in the diets of women in these households and those in non-beneficiary households.

The joint impact of both cash crop and LANN interventions on WDDS is estimated to be 0.35 more food groups relative to women in non-PROACT households. This positive effect of the combined treatment on WDDS is statistically significant at 1 percent error level. The estimated effects on our micronutrient-sensitive WDDS (MsWDDS) suggest improvement across all treatment groups compared to non-participants, but only shows significant results for recipients of the nutrition intervention (either singly or in combination with the cash crop component).

Table 4: Impact on women dietary diversity and the likelihood of eating from nutrient-rich food groups

	Maternal dietary diversity		Food groups consumed by a woman aged 15-49 years									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	WDDS	Micronutrient -sensitive WDDS	Dark green leafy vegs	Vitamin A rich vegs & tubers	Other vegetables	Vitamin A-rich fruits	Other fruits	Meat	Fish	Eggs	Legumes nuts & seeds	Dairy
Panel A: Average treatment effects on treated (ATET)												
Cash crop only	-0.08	0.04	0.00	0.02	0.09**	-0.02	0.06**	-0.01	-0.01	0.02***	-0.10***	0.02
	(0.10)	(0.06)	(0.03)	(0.02)	(0.03)	(0.03)	(0.03)	(0.02)	(0.03)	(0.01)	(0.03)	(0.02)
LANN only	0.22	0.22***	0.09**	-0.01	0.03	0.06	0.21***	-0.03	0.08***	0.03**	-0.15***	-0.01
	(0.16)	(0.08)	(0.04)	(0.03)	(0.05)	(0.04)	(0.05)	(0.02)	(0.03)	(0.01)	(0.05)	(0.02)
Both cash crop & LANN	0.35***	0.36***	0.07**	0.14***	0.11***	0.08***	0.19***	-0.01	-0.04	0.04***	-0.07*	0.07***
	(0.13)	(0.08)	(0.04)	(0.03)	(0.04)	(0.03)	(0.04)	(0.02)	(0.03)	(0.01)	(0.04)	(0.03)
POM of Non-PROACT	5.48***	1.97***	0.73***	0.11***	0.75***	0.13***	0.21***	0.07***	0.86***	0.00*	0.77***	0.05***
	(0.07)	(0.05)	(0.03)	(0.02)	(0.03)	(0.02)	(0.02)	(0.01)	(0.02)	(0.00)	(0.03)	(0.02)
Panel B: Average treatment effects (ATE)												
Cash crop only	-0.16*	0.03	-0.02	0.02	0.06*	0.00	0.06**	0.01	-0.04	0.02**	-0.12***	0.03*
	(0.10)	(0.06)	(0.03)	(0.02)	(0.03)	(0.02)	(0.03)	(0.02)	(0.03)	(0.01)	(0.03)	(0.02)
LANN only	0.11	0.17**	0.08**	-0.03	-0.00	0.05	0.18***	-0.01	0.06**	0.03***	-0.17***	-0.00
	(0.13)	(0.07)	(0.04)	(0.03)	(0.04)	(0.03)	(0.04)	(0.02)	(0.03)	(0.01)	(0.04)	(0.02)
Both cash crop & LANN	0.28**	0.36***	0.05	0.14***	0.09***	0.10***	0.16***	0.00	-0.04*	0.04***	-0.09***	0.07***
	(0.11)	(0.07)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.02)	(0.03)	(0.01)	(0.03)	(0.02)
POM of Non-PROACT	5.56***	2.01***	0.75***	0.13***	0.77***	0.13***	0.22***	0.07***	0.87***	0.01**	0.78***	0.05***
	(0.06)	(0.04)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)	(0.02)	(0.00)	(0.02)	(0.01)

Note: All outcome variables are based on 24-hour dietary recall. POM stands for the potential-outcome mean. The outcome models in columns 1 and 2 were estimated using Poisson regression, and those in columns 3-12 were estimated using the probit model. All estimates were conditioned on the covariates in Table A1 and shared similar treatment equations using the IPWRA method. Non-PROACT households are the comparison group for the ATET and ATE estimates. Robust standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Relative to non-beneficiaries, the joint impacts of cash crop and LANN interventions on WDDS and MsWDDS are larger than (the sum of) their isolated impacts. This signifies the presence of potential synergies between the two types of intervention in improving women's diets and tackling maternal micronutrient deficiencies. The estimated potential-outcome means (POM) of WDDS and MsWDDS for non-PROACT women are 5.48 (out 10 foods) for 1.97 (out of 7 food groups), respectively.

The remaining results in columns 3–12 of Table 4 shed more light on the impacts on the likelihood of consuming from individual nutrient-dense food groups. The probabilities of women consuming non-vitamin A-rich vegetables, fruits, and eggs are significantly higher for cash crop only households than non-project households. Women in the LANN only group are estimated to have a significantly higher likelihood of consuming dark green leafy vegetables, fish and seafood, and eggs (which are dense in vitamin A and iron) and other fruits (non-vitamin A-rich) than their counterparts in non-PROACT households.

Similarly, the combined cash crop and LANN treatment is found to significantly increase the likelihood of women consuming dark green leafy vegetables, vitamin A-rich vegetables and fruits, other vegetables and fruits, eggs, and dairy than non-PROACT women. Women in all treatment groups are less likely to consume from the legumes, nuts, and seeds food group compared to those in the comparison group.

4.2.4 Impact on child diets

Table 5 shows the differential impacts of the project on the diets of under-five children, the most nutritionally at-risk individuals. Column 1 presents the estimated average treatment effects on children's dietary diversity, while columns 2–8 unbundle the score and track the effects on the chances of consuming from its constituent food groups. Support for cash crop production alone appears to be significantly associated with a decline in children's dietary diversity (by 0.2 food groups in column 1), relative to receiving no intervention at all. A similar effect is found for children in LANN only households. However, it is not significantly different from the potential-outcome mean of 3.7 for non-PROACT children. In contrast, combining both cash crop and LANN interventions is shown to significantly increase the dietary intake of under-five children by 0.24 food groups more than their peers in non-project households.

Table 5: Impact on child dietary diversity and the likelihood of eating from individual food groups

	Child dietary diversity	Food groups consumed by a child under age 5						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	CDDS	Grains & Tubers	Vitamin A fruits & vegs	Other fruits & vegs	Meat & fish	Eggs	Dairy	Pulses
Panel A: Average treatment effects on treated (ATET)								
Cash crop only	-0.20**	0.02	-0.05	-0.04	-0.02	0.03**	-0.04	-0.10**
	(0.10)	(0.02)	(0.04)	(0.03)	(0.03)	(0.01)	(0.03)	(0.04)
LANN only	-0.05	0.04	-0.03	-0.02	-0.07	0.17**	0.03	-0.12*
	(0.13)	(0.03)	(0.05)	(0.05)	(0.05)	(0.07)	(0.04)	(0.07)
Both cash crop & LANN	0.24**	0.01	0.12***	0.01	0.03	0.09***	0.06*	-0.06
	(0.11)	(0.02)	(0.04)	(0.03)	(0.03)	(0.02)	(0.04)	(0.05)
POM of Non-PROACT	3.67***	0.91***	0.24***	0.89***	0.85***	0.02**	0.10***	0.63***
	(0.08)	(0.02)	(0.03)	(0.02)	(0.03)	(0.01)	(0.03)	(0.03)
Panel B: Average treatment effects (ATE)								
Cash crop only	-0.19*	0.02	-0.04	-0.03	-0.02	0.04**	-0.05*	-0.10**
	(0.10)	(0.02)	(0.03)	(0.03)	(0.03)	(0.02)	(0.03)	(0.04)
LANN only	-0.05	0.05**	-0.04	-0.02	-0.07	0.17**	0.01	-0.10
	(0.12)	(0.02)	(0.04)	(0.05)	(0.05)	(0.07)	(0.04)	(0.07)
Both cash crop & LANN	0.24**	0.01	0.15***	0.01	0.03	0.08***	0.04	-0.08*
	(0.11)	(0.02)	(0.04)	(0.03)	(0.03)	(0.02)	(0.03)	(0.04)
POM of Non-PROACT	3.65***	0.92***	0.23***	0.89***	0.86***	0.02***	0.11***	0.63***
	(0.07)	(0.02)	(0.03)	(0.02)	(0.02)	(0.01)	(0.02)	(0.03)

Note: All outcome variables are based on 24-hour dietary recall. POM stands for the potential-outcome mean. The outcome models in column 1 were estimated using Poisson regression, and those in columns 2-8 were estimated using the probit model. All estimates were conditioned on the covariates in Table A1 and shared similar treatment equations using the IPWRA method. Non-PROACT households are the comparison group for the ATET and ATE estimates.

Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

These child-level results corroborate our findings at household and women's levels: that integrating direct (nutrition-focused) and indirect (livelihood support) interventions promise to be the most instrumental approach to accelerate progress toward improved nutrition among poor smallholder households. The disaggregated results in columns 2–8 reveal that the positive dietary change for children in both cash crop and LANN households is significantly due to improvements in the intake of vitamin A-rich fruits and vegetables, eggs, and dairy products. There are no significant differences in the probabilities of consuming starchy staples, non-vitamin A-rich fruits and vegetables, meat, and fish. As shown by the potential-outcome means of non-PROACT children, the likelihoods of intake of these foods are already high, ranging between 85 and 91 percent.

4.2.5 Possible mechanisms

Investigating which mechanisms are at work behind these results is high relevance to policy. Understanding these impact pathways is essential in identifying promising entry points within the agriculture–nutrition nexus through which nutrition-sensitive value chain interventions, like the PROACT, can achieve maximum nutritional and health benefits. As aforementioned, the cash crop component, by enhancing production and processing of targeted export-oriented cash crops, is envisaged to increase smallholder household incomes – economic access – and indirectly contribute to overall household food and nutrition security. The nutrition-focused (LANN) component is a demand-side intervention aimed at "nudging" or stimulating positive behavior change at household and community levels, particularly, in the areas of dietary diversity, child feeding and hygiene practices, women's status and nutrition-sensitive use of household resources (including cash crop income). We, therefore, consider food consumption expenditure, nutrition knowledge, and women empowerment to be the primary pathways linking the PROACT project to household food and nutrition security.

4.2.5.1 The food consumption pathway

Table 6 reports the estimated impacts on annual household food consumption expenditure per adults equivalent units. The stand-alone impact of the cash crop intervention on total food expenditure per adult equivalent is positive, while that of LANN intervention is negative. However, both stand-alone impacts are not statistically significant, indicating there is no marked difference in the food consumption expenditure of these households and non-PROACT households. The joint impact of both interventions is positive and significant. The results in columns 2 and 3 reveal that this is primarily due to a significant increase in market purchases, which protectively have compensated for the decline in consumption from own production. In terms of magnitudes, the joint impacts of both cash crop and LANN interventions represent a 40.8 percent and 37.9 percent increase in total food consumption expenditure and purchased food per adult equivalent unit, respectively, relative to the non-PROACT households. These correspond to SLL336,661.18 (US$45.59) and SLL236,841.73 (US$32.07) higher annual food consumption and annual food purchases above the respective baseline values of non-PROACT households[3].

Table 6: Impact on household food consumption expenditure

	Total food expenditure per AE (log)	Purchased food per AE (log)	Produced food per AE (log)
	(1)	(2)	(3)
Panel A: Average treatment effects on treated (ATET)			
Cash crop only	0.256	0.222	-0.366
	(0.160)	(0.164)	(0.353)
LANN only	-0.018	-0.007	-0.261
	(0.209)	(0.215)	(0.572)
Both cash crop & LANN	0.342*	0.321*	-0.279
	(0.175)	(0.177)	(0.426)
POM of Non-PROACT	13.622***	13.569***	8.093***
	(0.151)	(0.153)	(0.303)
Panel B: Average treatment effects (ATE)			
Cash crop only	0.226	0.183	-0.472
	(0.146)	(0.150)	(0.295)
LANN only	-0.070	-0.031	-0.502
	(0.171)	(0.175)	(0.436)
Both cash crop & LANN	0.308**	0.303**	-0.602*
	(0.145)	(0.146)	(0.342)
POM of Non-PROACT	13.640***	13.558***	8.031***
	(0.127)	(0.129)	(0.235)

Notes: All food expenditure measures were annualized to facilitate comparison. AE stands for adult equivalent units, with the scale adopted from Haughton and Khandker (2009). POM stands for the potential-outcome mean. All specifications are semi-log models. All estimates were conditioned on the covariates in Table A1 and shared similar treatment equations using the IPWRA method. Non-PROACT households are the comparison group for the ATET and ATE estimates. Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

As the WFP (2018) observed, the fall in own food consumption expenditure across all treated households could be due to erratic rainfall patterns (i.e., delayed onset of the rainy season, unevenly distributed and lower than average precipitation levels, and flooding) in 2018. These rainfall irregularities led to significant reductions in the already extremely low agricultural production and household food stocks (WFP, 2019). More importantly, these adverse weather conditions also resulted in lower than average yields of cocoa and other primary cash crops (reducing household incomes to purchase food) and increased food insecurity (WFP, 2019). Another possible reason for the non-significant consumption effects among cash crop

[3] Given that we estimated semi-logarithmic regressions with dummy regressors (treatment indicator), we calculated the percentage change of each treatment (relative the non-PROACT group) as: $(e^{\beta} - 1) \times 100$, where β is the estimated coefficient of each treatment. See Table A2 for the baseline means of consumption variables by treatment group. The annual average exchange rate in 2017 was US$1: SLL7,384.4.

only households is that the targeted tree crops have long maturation periods, requiring several years to yield harvests at economically profitable levels. At the time of this study, most tree crop plantations in Sierra Leone were overaged, overgrown, and were being rehabilitated and replaced with new seedlings as part of the project. It may, therefore, be too early to witness any significant effects of the cash crop component on yield, cash crop income (which constitutes the lion's share of their incomes), consumption expenditure, and ultimately food and nutrition security. Lastly, the absence of a positive impact of the nutrition intervention on the food consumption expenditure of LANN only households could be explained by the fact that spending and other aspects of dietary behavior modifications occur slowly over time and may be hindered by other factors, including the poor weather conditions mentioned above (WFP, 2018; Kelly and Barker, 2016)

4.2.5.2 The nutrition knowledge and women empowerment pathways

Next, we consider the nutrition knowledge and women empowerment pathways. The average effects on caregiver's nutrition knowledge and empowerment (in terms of control over income and confidence) are reported in Table 7. The results show that, compared to the control group, there is a significant improvement in nutrition knowledge across all treatment groups, with the largest increase occurring among LANN only households, followed by both cash crop and LANN households. The results in columns 2–5 indicate that except for LANN only women involved in food crops farming and livestock rearing, there is no significant change in women's control over the use of income.

Table 7: Impact pathways: nutrition knowledge and women empowerment

		Caregiver has adequate control over income from…				Caregiver is confident in voicing her opinion …		
	Caregiver's nutrition knowledge	Food crop farming	Cash crop farming	Livestock rearing	Off-farm business	Husband/ Partner	Meeting with males & females	Meeting with only women
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Average treatment effects on treated (ATET)								
Cash crop only	0.18**	-0.02	0.01	0.02	0.03	-0.03	-0.04	-0.02
	(0.08)	(0.03)	(0.03)	(0.03)	(0.04)	(0.03)	(0.04)	(0.04)
LANN only	0.71***	0.09***	0.05	0.10**	-0.01	0.13***	0.18***	0.15***
	(0.11)	(0.03)	(0.04)	(0.04)	(0.05)	(0.04)	(0.05)	(0.04)
Both cash crop & LANN	0.55***	0.03	0.03	0.03	0.04	0.08**	0.06	0.02
	(0.10)	(0.03)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
POM of Non-PROACT	1.36***	0.79***	0.68***	0.65***	0.44***	0.72***	0.46***	0.63***
	(0.07)	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Panel B: Average treatment effects (ATE)								
Cash crop only	0.27***	-0.02	0.04	0.01	0.03	-0.03	-0.02	-0.03
	(0.08)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
LANN only	0.74***	0.07**	0.03	0.06	-0.01	0.10***	0.16***	0.12***
	(0.09)	(0.03)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.03)
Both cash crop & LANN	0.55***	0.03	0.05	0.02	0.06	0.06**	0.05	0.02
	(0.08)	(0.03)	(0.03)	(0.03)	(0.04)	(0.03)	(0.04)	(0.03)
POM of Non-PROACT	1.33***	0.79***	0.66***	0.66***	0.46***	0.72***	0.46***	0.62***
	(0.06)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)

Note: POM stands for the potential-outcome mean. The outcome model in column 1 were estimated using Poisson regression and those in columns 2-8 were estimated using the probit model. All estimates were conditioned on the covariates in Table A1 and shared similar treatment equations using the IPWRA method. Non-PROACT households are the comparison group for the ATET and ATE estimates. Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Concerning the project's impact on advancing the agency of women, the results show that LANN women are significantly more likely to be confident in discussing issues around food and management of household resources with their spouses than non-PROACT women. Though insignificant, women in cash crop only households appear to have relatively lower confidence compared to non-project women for being expressive to their husbands on matters related to the allocation of food and other household resources. This could also explain why the reported improvement in nutrition knowledge among women from cash crop only households did not translate into positive changes in the dietary diversity of these households and their women and children. When it comes to public speaking, LANN only women are the only treatment group that demonstrates a significant increase in the probability of being confident in expressing their opinion in the assembly of women or both men and women. Taken together, these results suggest that improving nutrition knowledge as well as bolstering women's confidence can empower them to influence household decisions in ways that prioritize the nutrition and general well-being of their families.

4.2.6 Robustness checks

To check the robustness of the main results (in Tables 3–5), we employed the Mundlak CRE estimator, which addresses the problem of endogeneity resulting from the selection on unobservables. The CRE method does so by including the means of the time-varying regressors as additional covariates in the regression model to allow for the time-invariant unobserved household effects to be correlated with the explanatory variables. The CRE results are reported in Tables A5–A7 (in appendix).

The estimated impacts of the PROACT interventions on household, maternal, and child dietary outcomes are generally consistent with the respective IPWRA results. The CRE results confirm that both household, maternal, and child dietary diversity scores are significantly higher for both cash crop and LANN households relative to non-PROACT households. We do not find any significant impact of the nutrition intervention alone on both household and individual dietary diversity measures. The CRE results also support our previous finding that all LANN households are more likely to consume Vitamin A-rich vegetables, fruits, and tubers. Lastly, they also confirm that solely promoting cash crop production may have adverse impacts on the dietary diversity of households and individuals.

4.2.7 Discussion

This study evaluates a unique integrated export-oriented value chain intervention to explore how to make agricultural and rural development investments nutrition-sensitive, and thus exploit their maximum contributions to improving nutrition. With interesting findings, our analyses demonstrate the differential impacts of the PROACT project on dietary outcomes across different treatment groups. Our results show that implementing only the cash crop intervention, is associated with deterioration in household and individual dietary diversity scores, relative to non-intervention households. Similarly, exclusively implementing the nutrition-focused intervention (LANN only) is found to result in positive but no significant difference in household and individual (women) dietary diversity scores when compared with non-PROACT households. However, delivering both interventions in conjunction appears to significantly improve household and individual (women and children's) dietary diversity, and importantly micronutrient intake, compared to non-project households. The results show that improvement in increased food consumption through market purchases, nutrition knowledge (viz. increased awareness of the nutritional value of foods), and women empowerment (confidence) are potential pathways linking the combined intervention to better dietary outcomes.

This result suggests that, notwithstanding its attraction of higher economic returns to land and labour, singly promoting the production of non-food, export-oriented crops can considerably detract from the food security and nutritional status of smallholder households and their families. Similar findings have been previously reported in the literature. For instance, Andermann et al. (2014) found that cash cropping hurts food security among cocoa producers in Ghana, the world's second-largest producer of cocoa. Caswell et al. (2012) and de Vries et al. (2012, 2013b, 2013a) have also documented a high prevalence of food insecurity and malnutrition (partly owed to poor quality diets) in major cocoa, coffee, and tea growing areas in Africa, Asia, and Latin America, despite huge investments in these sectors. In the same vein, commercialized production of food crops as cash crops, such as rice in Uganda (Ntakyo & van den Berg, 2019), sugarcane in Mexico (Dewey, 1981), and vegetables in Guatemala (Immink & Alarcon, 1993), has been found to be undesirably associated with dietary deterioration and lower food caloric intake.

Several factors could explain this finding in the case of Sierra Leone. Intensified cash crop production may result in an increased work burden on women and take away from the time available for acquiring and preparing nutritious foods for the family. In the rural Sierra Leonean setting, women – the primary caregivers – are also involved in early crop care and post-harvest processing activities related to cocoa and cashew production (including collection, transportation, breaking, fermentation, and drying). With our data collection coinciding with harvesting months in Sierra Leone, it is plausible that women's involvement in these farming activities would likely increase their time-constraints[4] and adversely affect nutrition-related caring practices. Indeed, SPRING's nutrition assessment for Sierra Leone

[4] A 24-hour recall of women's time use reveal that, compared to an average of 9.87 minutes for non-PROACT women, women in cash crop only and both cash crop and LANN households spent more time (26.72 minutes and 18.96 minutes respectively) on activities related to cocoa/coffee and cashew production at the time of our follow-up survey.

reported that competing demands on women's time might also contribute to poor self and infant and young child feeding in the country (SPRING, 2015). Besides, encouraging the expansion of tree crop production may lead to the diversion of land, labour, and other productive resources away from food production, and culminate in a reduced availability of diverse nutritious foods. We found no significant change in the land area(s) under cash crops (and food crops) cultivation after one year of project implementation (because most of the project-supported activities involved gap filling and rehabilitation of old plantations). However, the data showed a dip in food consumption, largely from own production between the two waves because of poor weather conditions, which adversely affected agricultural production (WFP, 2018; WFP, 2019).

The analyses demonstrate that compared to non-intervention households, the project has significantly increased nutrition knowledge across all treatment groups, particularly among LANN households. This result is comparable to findings from several studies that nutrition education programmes that inform households about the nutritional value of foods, as well as the importance of consuming diverse, well-balanced diets, have the potential to increase dietary diversity and avert several micronutrient deficiencies (Berti, Krasevec, & FitzGerald, 2004; Faber & Benadé, 2003; Leroy & Frongillo, 2007; World Bank, 2007). However, merely arming caregivers with information and knowledge about the nutritional importance of the foods they have and consume may not be enough to improve dietary outcomes markedly. As shown by our results, relative to non-intervention households, nutrition knowledge significantly improved among cash crop only and LANN only households with no corresponding enhancement in dietary diversity scores. The pathway analyses reveal that women's confidence – a proxy indicator of women's status or empowerment – is one of many key factors reinforcing the link between nutrition knowledge and positive nutrition outcomes. In cash crop only households, which experienced no significant change in women's confidence relative control households, we do not find the improved nutrition knowledge translating into better household and individual dietary outcomes. However, in all LANN households, where women feel more confident, particularly about making nutritionally vital decisions with their partners, improved nutrition knowledge increased the likelihood of better dietary outcomes.

In highly patriarchal societies like Sierra Leone, where deeply entrenched socio-cultural and religious beliefs marginalize women, women tend to have low status, low self-confidence, and low self-esteem relative to men. Cultural norms preclude women from participation in decision-making processes, as well as accessing and exercising control over resources (Abdullah, Ibrahim, & King, 2016; UNICEF Sierra Leone, 2011). Intra-household distribution of meat, fish, and other nutritious foods favour men at the expense of women and children. Alaofè et al. (2017) and Smith et al. (2003) have shown that the caregiver's level of confidence is a critical factor affecting maternal and child nutritional status. For instance, women with low self-esteem and low status may have good knowledge of appropriate child feeding practices and the significance of consuming healthy diets. However, they may lack the confidence and power to influence the intra-household allocation of food and other nutrition-sensitive decisions. In a recent study, Amugsi et al. (2016) found that women's participation in decision-making concerning household purchases was significantly associated with higher dietary diversity in Ghana. These findings indicate that developmental efforts aimed at improving nutrition in Sierra Leone stand to immensely benefit from empowering women to put nutrition-related knowledge to practice.

The study has some limitations which are worth highlighting. The first one relates to the lack of randomization and the absence of pre-intervention (baseline) data. While the estimation methods employed in the study account for potential selection bias (due to non-random programme placement and self-selection of participants), the absence of baseline data weakens the evaluation design. With our first wave data collection occurring several months after the project start-up, possible initial impacts of some project interventions at the time of the first wave may have resulted in an underestimation of the average treatment effects. The second source of limitation arises from the short time horizon of the study. Agreeably, it takes time for programmes to reach full implementation at the level planned (Leroy et al., 2016). The existence of time lags imply that substantial, detectable impacts cannot be achieved within the first year of project implementation. Although this study investigated the early impacts of the project interventions, the time frame is too short to fully capture the impacts of the interventions, particularly considering the long-maturing period of the targeted tree crops. The long-term impacts, as well as their sustainability, will need to be examined in follow-up studies after sufficient time has elapsed between implementation and evaluation.

5. Conclusion

Fostering smallholder agriculture through cash cropping schemes has long been an integral part of agricultural interventions to boost productivity and alleviate poverty in many developing countries, with seldom explicit nutritional considerations. To accelerate progress towards ending all forms of hunger and malnutrition by 2030, there is a growing recognition and push for nutrition-enhancing agricultural investments targeted toward smallholder farmers. However, there is limited empirical evidence on whether integrating nutrition-related interventions in agricultural development project offers additional nutritional benefits, particularly in export-oriented cash crop sectors. This study bridges this knowledge gap by evaluating the nutritional impacts of an innovative nutrition-sensitive value chain intervention, uniquely designed to address food and nutrition insecurity among smallholder export cropping farmers in Sierra Leone, a country plagued with high rates of food insecurity and malnutrition. In particular, we analysed the programme impacts on household and individual dietary outcomes. Based on a quasi-experimental design involving multiple treatments and two waves of household surveys, we estimated the programme effects using inverse-probability weighted regression adjustment, a doubly robust estimator.

We find that, compared to non-intervention households, isolated promotion of cash crop production is associated with dietary deterioration at household, maternal, and child levels, whereas singly providing nutrition-related information has no significant effect on these dietary outcomes. However, combining both interventions is found to significantly improve the consumption of diverse, nutritious diets at household and individual levels, relative to no intervention. In particular, coupling a cash cropping intervention with a nutrition-related intervention is found to significantly increase the likelihoods of consuming vitamin A and iron-rich foods. We found improvements in food access, nutrition knowledge and women empowerment to be the main pathways linking the combined intervention to better dietary outcomes. The results suggest that nutrition-sensitive investments in cash crop sectors promise to be an effective way to increase dietary diversity and sustainably reduce micronutrient deficiencies among nutritionally vulnerable smallholder families.

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Appendix

Table A1: Attrition Probit Regressions

	Non-PROACT Attrition	Cash Crop only Attrition	LANN only Attrition	Both Cash Crop & LANN Attrition	Full sample Attrition
	(1)	(2)	(3)	(4)	(5)
Cash crop only					-0.27
					(0.17)
LANN only					0.01
					(0.20)
Both cash crop & LANN					-0.23
					(0.18)
Age of head (years)	-0.01	0.01	-0.01	-0.01	-0.00
	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)
Head is male (dummy)	0.00	-0.47	0.00	-1.07*	-0.09
	(0.00)	(0.70)	(0.00)	(0.64)	(0.36)
Head is married (dummy)	0.00	-0.27	0.00	-0.15	-0.50
	(0.00)	(0.72)	(0.00)	(0.75)	(0.37)
Head's years of schooling	-0.03	-0.02	-0.02	-0.00	-0.01
	(0.03)	(0.03)	(0.05)	(0.03)	(0.01)
Dependency ratio	-0.10	0.04	-0.22	0.18*	-0.01
	(0.13)	(0.09)	(0.24)	(0.11)	(0.05)
Household size	0.06	-0.00	-0.02	0.00	-0.00
	(0.05)	(0.05)	(0.09)	(0.05)	(0.03)
Farm size (acres)	0.20	0.01	0.07	-0.04	-0.02
	(0.21)	(0.25)	(0.37)	(0.26)	(0.11)
Livestock (dummy)	0.14	0.20	0.45	0.14	0.19
	(0.41)	(0.31)	(0.52)	(0.39)	(0.17)
Off-farm income (dummy)	0.06	0.13	0.13	0.08	0.11
	(0.25)	(0.30)	(0.39)	(0.31)	(0.13)
Household wealth index	-0.01	0.00	0.01	-0.00	-0.00
	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)
Head is member of cooperative	0.34	0.36	-0.25	0.27	0.17
	(0.28)	(0.32)	(0.43)	(0.32)	(0.14)
Household experienced any shock	-0.58**	0.39	-0.15	-0.01	-0.05
	(0.25)	(0.32)	(0.49)	(0.31)	(0.13)
Distance to market (miles)	0.45***	-0.44**	0.62*	0.16	0.18**
	(0.15)	(0.19)	(0.32)	(0.23)	(0.08)
Village has cooperative	0.78**	-0.19	-0.02	-0.20	0.10
	(0.30)	(0.31)	(0.40)	(0.40)	(0.14)
Constant	-2.10**	-0.99	-1.86	-0.59	-1.01**
	(0.99)	(1.04)	(1.40)	(1.02)	(0.49)
Pseudo R-squared	0.168	0.121	0.138	0.142	0.041
Wald test (*p-value*)	0.215	0.459	0.807	0.357	0.208
Observations	281	268	124	209	912
Attrition rate (%)	10.274	6.343	9.091	7.656	8.333

Notes: The dependent variable is an attrition indicator, assuming the value one for households which drop out of the sample after the first wave and zero otherwise. Coefficient estimates are reported with robust standard errors clustered at village level in parentheses. District dummies were included but not reported to conserve on space. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A2: Baseline summary statistics by treatment group

	Non-PROACT	Cash crop only	LANN only	Both Cash crop and LANN	*F*-test
Household characteristics					
Household dietary diversity score (HDDS)	6.847	6.359	6.977	7.104	14.12***
	(1.039)	(1.332)	(1.486)	(1.414)	
Micronutrient-sensitive HDDS	2.031	1.829	2.146	2.254	10.05***
	(0.683)	(0.804)	(0.881)	(1.047)	
Age of head (years)	47.38	46.30	46.92	49.41	1.78
	(12.58)	(14.72)	(16.58)	(14.78)	
Head is male (dummy)	0.973	0.964	0.862	0.953	8.48***
	(0.162)	(0.186)	(0.347)	(0.211)	
Head is married (dummy)	0.969	0.968	0.885	0.969	5.25***
	(0.172)	(0.176)	(0.321)	(0.174)	
Head's years of schooling	3.844	2.952	3.515	4.218	2.30*
	(5.316)	(4.902)	(4.909)	(6.086)	
Dependency ratio	1.394	1.391	1.725	1.334	2.81**
	(1.223)	(1.331)	(1.492)	(1.121)	
Household size	6.809	6.884	6.208	7.560	7.16***
	(2.351)	(2.827)	(2.112)	(3.003)	
Farm size (acres)	6.904	7.822	8.396	9.451	6.19***
	(5.315)	(5.984)	(7.065)	(9.428)	
Livestock (dummy)	0.859	0.713	0.785	0.813	5.83***
	(0.349)	(0.453)	(0.413)	(0.391)	
Off-farm income (dummy)	0.496	0.363	0.454	0.539	5.35***
	(0.501)	(0.482)	(0.500)	(0.500)	
Household wealth index	50.33	47.29	54.49	53.93	13.67***
	(11.65)	(11.82)	(13.73)	(15.03)	
Head is member of cooperative	0.183	0.550	0.300	0.596	42.15***
	(0.388)	(0.499)	(0.460)	(0.492)	
Household experienced any shock	0.718	0.645	0.792	0.663	3.45**
	(0.451)	(0.479)	(0.407)	(0.474)	
Distance to market (miles)	10.013	7.282	3.577	7.293	26.38***
	(13.493)	(4.539)	(3.306)	(7.355)	
Village has cooperative	0.584	0.689	0.692	0.850	12.84***
	(0.494)	(0.464)	(0.463)	(0.358)	
Number of households	262	251	130	193	
Maternal characteristics					
Women dietary diversity score (WDDS)	5.568	5.158	5.295	5.822	6.89***
	(1.195)	(1.447)	(1.662)	(1.507)	
Micronutrient-sensitive WDDS	2.017	1.951	2.189	2.273	5.12***
	(0.739)	(0.979)	(0.978)	(1.059)	
Caregiver's age (years)	37.51	35.79	38.46	37.49	1.73
	(11.06)	(12.14)	(14.78)	(10.57)	
Caregiver's education (years)	1.695	2.010	2.947	1.737	48.29***
	(3.313)	(3.371)	(3.621)	(3.535)	
Number of women of reproductive age	199	196	95	146	
Child characteristics					
Child dietary diversity score	3.600	3.330	3.476	3.734	2.89**
	(1.172)	(1.258)	(1.363)	(1.428)	
Child's age (months)	30.06	27.85	32.76	28.38	1.65
	(17.36)	(17.45)	(17.04)	(19.22)	
Child is a male	0.463	0.480	0.537	0.474	0.42
	(0.500)	(0.501)	(0.502)	(0.501)	
Number of children (6-59 months)	160	179	82	154	

(Table A2 continued)

	Non-PROACT	Cash crop only	LANN only	Both Cash crop and LANN	*F*-test
Pathway variables					
Purchased food per adult equiv. (annual in real Leones)	625728.5	593847.9	638705.4	675251.5	0.63
	(645224.3)	(586541.6)	(500790.4)	(716148.2)	
Total food consumption per adult equiv. (annual in real Leones)	825635.0	775931.0	812235.2	953118.8	2.24*
	(684320.9)	(658656.0)	(725971.6)	(892938.8)	
Nutrition knowledge (0–3)	1.134	1.430	2.054	1.829	27.39**
	(1.051)	(1.105)	(0.983)	(1.162)	
Caregiver has adequate control over use of income from …..					
Food crops farming	0.714	0.693	0.754	0.705	0.53
	(0.453)	(0.462)	(0.432)	(0.457)	
Cash crops farming	0.653	0.645	0.569	0.585	1.42
	(0.477)	(0.479)	(0.497)	(0.494)	
Livestock rearing	0.603	0.618	0.585	0.596	0.15
	(0.490)	(0.487)	(0.495)	(0.492)	
Off-farm economic activities	0.443	0.422	0.415	0.492	0.91
	(0.498)	(0.495)	(0.495)	(0.501)	
Caregiver has adequate confidence in participating/voicing her opinion …					
Issues around food and resources with husband	0.737	0.653	0.792	0.777	4.13***
	(0.441)	(0.477)	(0.407)	(0.417)	
At community meetings with men & women	0.427	0.363	0.600	0.430	6.74***
	(0.496)	(0.482)	(0.492)	(0.496)	
At Women's group meetings	0.588	0.566	0.638	0.637	1.10
	(0.493)	(0.497)	(0.482)	(0.482)	

Notes: The sample means are reported with standard deviations are in parentheses. The asterisks *, **, *** indicate the means are jointly different from zero at 10%, 5% and 1% significant levels.

Table A4: Covariate balance summary

	Cash crop only				LANN only				Both cash crop & LANN			
	Standardized difference		Variance ratio		Standardized difference		Variance ratio		Standardized difference		Variance ratio	
	Raw	Weighted	Raw	Weighted	Raw	Weighted	Raw	Weighted	Raw	Weighted	Raw	Weighted
Age of head (years)	-0.08	0.02	1.37	1.57	0.02	0.07	1.82	2.19	0.11	0.00	1.33	1.39
Head is male	-0.07	-0.07	1.48	1.47	-0.37	-0.01	4.19	1.05	-0.12	-0.07	1.81	1.46
Head is married	-0.03	-0.03	1.17	1.15	-0.31	0.06	3.29	0.71	0.01	-0.06	0.94	1.34
Head's years of schooling	-0.18	-0.05	0.85	0.97	-0.05	0.07	0.88	0.94	0.06	-0.14	1.29	0.86
Dependency ratio	0.01	-0.01	1.17	1.22	0.18	-0.02	1.41	0.96	-0.05	0.03	0.96	1.10
Household size	-0.03	0.02	1.40	1.73	-0.21	0.09	1.03	1.84	0.19	-0.06	1.62	1.24
Farm size (log, acres)	0.27	-0.09	0.71	0.69	0.37	0.06	0.81	0.68	0.35	-0.05	0.77	0.72
Livestock (dummy)	-0.19	0.00	1.27	1.00	-0.06	-0.03	1.09	1.03	0.02	0.02	0.97	0.98
Off-farm income (dummy)	-0.16	0.06	0.80	1.10	-0.06	-0.09	0.93	0.84	0.05	0.05	1.06	1.09
Household wealth index	-0.19	0.03	1.13	1.42	0.13	0.11	1.53	1.26	0.18	-0.02	1.66	1.18
Head is member of cooperative	0.75	-0.01	1.27	1.01	0.38	-0.03	1.30	1.01	0.89	-0.06	1.20	1.02
Household experienced any shock	-0.03	-0.06	1.01	1.02	0.14	0.09	0.94	0.96	-0.06	-0.02	1.02	1.01
Distance to market (log, miles)	0.13	0.12	0.64	0.66	-0.52	0.07	0.71	0.54	-0.01	-0.07	0.57	0.54
Village has cooperative	0.13	0.10	0.91	0.93	0.26	-0.10	0.81	1.05	0.50	0.02	0.57	0.99

Notes: The control group is non-PROACT households.

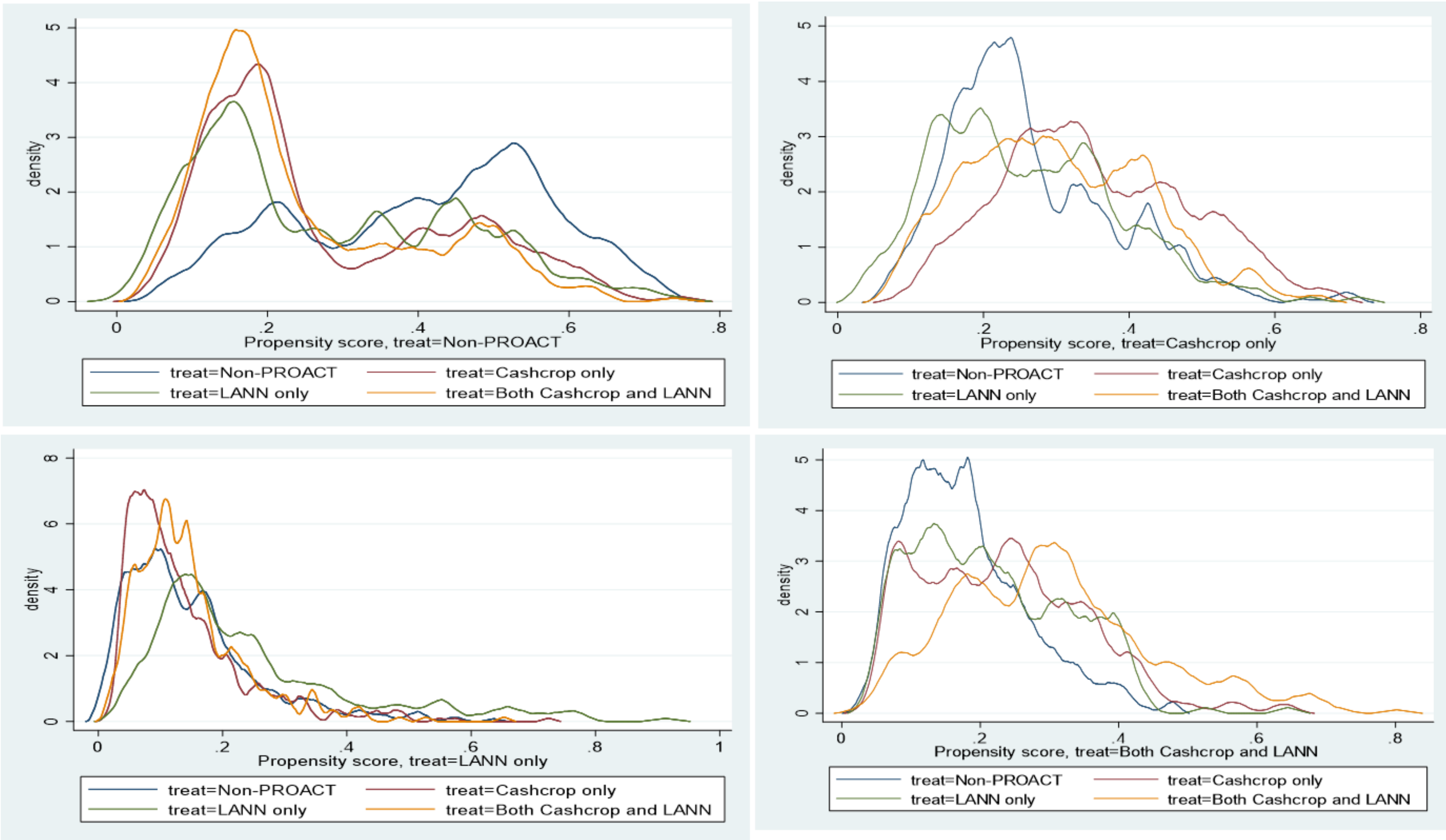

Figure A1: Overlap plots

Table A5: CRE estimates of impacts on household dietary diversity and likelihood of consuming nutrient-rich food groups

	Household dietary diversity scores		Food groups consumed by any household member									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	HDDS	MsHDDS	Dark green leafy veg	Vitamin A-rich veg & tuber	Other vegs	Vitamin A-rich fruits	Other fruits	Fish	Meat	Eggs	Legumes	Dairy
Cash crop only	-0.027**	-0.004	-0.199*	0.146	-0.076	0.208*	0.195*	-0.244*	0.004	0.436	-0.411***	0.104
	(0.013)	(0.027)	(0.113)	(0.130)	(0.115)	(0.114)	(0.104)	(0.130)	(0.170)	(0.402)	(0.096)	(0.173)
LANN only	-0.008	0.022	-0.223	0.270*	-0.182	0.537***	0.127	-0.268*	-0.226	0.681	-0.292**	-0.132
	(0.017)	(0.032)	(0.143)	(0.157)	(0.138)	(0.136)	(0.120)	(0.158)	(0.192)	(0.555)	(0.118)	(0.198)
Both cash crop & LANN	0.025*	0.150***	0.064	0.539***	-0.008	0.602***	0.494***	-0.169	-0.105	0.917	-0.439***	0.429**
	(0.014)	(0.028)	(0.120)	(0.131)	(0.116)	(0.125)	(0.110)	(0.135)	(0.167)	(0.702)	(0.105)	(0.175)
Constant	1.779***	0.286***	6.524*	-4.554	8.834**	17.970***	15.635***	-3.368	16.640***	26.270	-28.099***	13.082**
	(0.480)	(0.099)	(3.685)	(4.482)	(3.960)	(4.222)	(3.871)	(4.695)	(5.627)	(22.919)	(3.821)	(5.508)
Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wave dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mundlak CRE variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1672	1672	1672	1672	1672	1672	1672	1672	1672	1672	1672	1672

Notes: Results in Columns 1–2 are based on Poisson CRE specification and Columns 3–12 from probit CRE specification.
Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A6: CRE estimates of impacts on maternal dietary diversity and likelihood of consuming nutrient-rich food groups

	Maternal dietary diversity		Food groups consumed by woman aged 15-49 years									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	WDDS	Micronutrient -sensitive WDDS	Dark green leafy vegs	Vitamin A rich vegs & tubers	Other vegeta bles	Vitamin A rich fruits	Other fruits	Meat	Fish	Eggs	Legumes nuts & seeds	Dairy
Cash crop only	-0.030	-0.095	-0.037	0.173	-0.017	0.175	0.169*	-0.302**	-0.062	0.356	-0.312***	0.291
	(0.470)	(0.253)	(0.106)	(0.107)	(0.111)	(0.124)	(0.101)	(0.124)	(0.152)	(0.317)	(0.105)	(0.185)
LANN only	-0.102	0.010	-0.159	0.303**	-0.193	0.473***	0.190	-0.204	-0.125	0.372	-0.240*	-0.399*
	(0.140)	(0.081)	(0.139)	(0.128)	(0.132)	(0.142)	(0.117)	(0.164)	(0.194)	(0.332)	(0.123)	(0.237)
Both cash crop & LANN	0.724**	0.522***	0.103	0.630***	0.128	0.572***	0.448***	-0.400***	0.002	0.616**	-0.355***	0.572***
	(0.322)	(0.180)	(0.117)	(0.110)	(0.122)	(0.124)	(0.107)	(0.130)	(0.156)	(0.313)	(0.114)	(0.187)
Constant	2.379	11.128***	0.899	-1.939	1.286	21.392***	16.777***	-7.073*	15.361***	21.045**	-13.869***	19.626***
	(3.729)	(2.180)	(3.628)	(3.566)	(3.810)	(4.175)	(3.654)	(4.225)	(5.393)	(9.283)	(3.856)	(6.158)
Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wave dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mundlak CRE variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1272	1272	1272	1272	1272	1272	1272	1272	1272	1272	1272	1272

Notes: Results in Columns 1–2 are based on Poisson CRE specification and Columns 3–12 from probit CRE specification.
Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A7: CRE estimates of impacts on child dietary diversity and likelihood of consuming from individual food groups

	Child dietary diversity	Food groups consumed by child under age 5						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	CDDS	Grains & Tubers	Vitamin A fruits & vegs	Other fruits & vegs	Meat & fish	Eggs	Dairy	Pulses
Cash crop only	-0.15	0.05*	-0.02	-0.03	-0.03	0.02	-0.05*	-0.08*
	(0.11)	(0.03)	(0.04)	(0.03)	(0.03)	(0.02)	(0.03)	(0.04)
LANN only	-0.03	-0.01	0.04	-0.05	-0.01	0.06**	-0.01	-0.07
	(0.13)	(0.03)	(0.05)	(0.04)	(0.04)	(0.03)	(0.04)	(0.05)
Both cash crop & LANN	0.19*	0.01	0.16***	0.02	0.04	0.05**	0.02	-0.11**
	(0.11)	(0.03)	(0.04)	(0.03)	(0.03)	(0.02)	(0.03)	(0.05)
Constant	3.64***	1.01***	0.00	0.79***	0.85***	-0.15**	0.26***	0.88***
	(0.35)	(0.08)	(0.12)	(0.10)	(0.10)	(0.07)	(0.09)	(0.14)
Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wave dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mundlak CRE variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1027	1027	1027	1027	1027	1027	1027	1027

Notes: Results in Columns 1 are based on Poisson CRE specification and Columns 2–8 from probit CRE specification.
Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$