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Land consolidation, specialization and household diets: Evidence from Rwanda

Davide del Prete

Leopold Ghins

Emiliano Magrini

Karl Pauw

Development Strategy and Governance Division

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

AUTHORS

Davide Del Prete (Davide.DelPrete@fao.org) is an economist in the Monitoring and Analyzing Food and Agricultural Policies (MAFAP) program of the Food and Agriculture Organization (FAO), Rome, Italy.

Leopold Ghins (Leopold.Ghins@fao.org) is a policy analyst in the Monitoring and Analyzing Food and Agricultural Policies (MAFAP) program of the Food and Agriculture Organization (FAO), Rome, Italy.

Emiliano Magrini (Emiliano.Magrini@fao.org) is an economist in the Monitoring and Analyzing Food and Agricultural Policies (MAFAP) program of the Food and Agriculture Organization (FAO), Rome, Italy.

Karl Pauw (k.pauw@cgiar.org) is a senior research fellow in the Ghana Strategy Support Program (GSSP), International Food Policy Research Program (IFPRI), Accra, Ghana.

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ABSTRACT

Despite rapid population growth, increasing land pressure and urbanization, farmers in Sub-Saharan Africa have not intensified their production in a sustainable manner and farming systems remain predominantly subsistence-oriented. Unsurprisingly, developing countries are directing large shares of their agricultural budgets to programs that actively promote crop intensification and the development of more commercially-oriented agricultural systems. Rwanda's Crop Intensification Program (CIP), launched in 2007, is one such example. However, despite its apparent success in raising production of several priority crops, there are legitimate concerns about the food and nutrition security implications for households that are encouraged to consolidate their land, specialize in their production, and increasingly rely on markets for their food needs. Using recent household survey data and a propensity score matching difference-in-differences method, we find that participation in land consolidation activities had ambiguous consumption effects: it positively impacted on consumption of roots and tubers, but had a negative effect on meat, fish and fruits consumption and the potential availability of vitamin B12 in participants' diets. This calls for a review of CIP implementation practices to enhance the program's food and nutrition security outcomes, with improvements in market functioning and market access being potential starting points.

Keywords: Crop intensification; food security; nutrition, impact evaluation; Rwanda

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ACRONYMS

ATT	Average Treatment Effect on the Treated
CFVVA	Comprehensive Food Security and Vulnerability Analysis
CIA	Conditional Independence Assumption
CIP	Crop Intensification Programme (CIP)
DDS	Diet Diversity Score
EICV	Integrated Household Living Conditions Surveys (*Enquête Intégrale sur les Conditions de Vie des ménages*)
FAO	Food and Agriculture Organization
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
MINAGRI	Ministry of Agriculture and Animal Resources (Rwanda)
NISR	National Institute of Statistics in Rwanda
PSM-DiD	Propensity score matching difference-in-difference
PSTA	Strategic Plan for the Transformation of Agriculture (*Plan Stratégique pour la Transformation de l'Agriculture*)
RAB	Rwanda Agricultural Board
REMA	Rwanda Environment Management Authority
SSA	Sub-Saharan Africa
WFP	World Food Programme

1 INTRODUCTION

Agricultural transformation is broadly understood as the process whereby rising agricultural productivity per worker leads to an increase in the marketable surplus of agricultural commodities and a gradual integration of agricultural and non-agricultural product and factor markets (Timmer 1988). The initial stage of transformation typically entails shifting from diversified and subsistence-oriented production systems towards more specialized and market-oriented production. Terms such as specialization, (sustainable) intensification and commercialization are often used interchangeably in this context.

Globally, as populations grow and become more urbanized, raising the agricultural production surplus becomes imperative. In short, this requires adoption of sustainable intensification practices in the face of growing land constraints and an increased market orientation for farmers. However, two alarming trends appear to be emerging in SSA. First, while rapid (rural) population growth is associated with declining farm sizes and reduced fallow, especially in land constrained countries (Jayne et al. 2014), sustainable agricultural intensification practices have not been adopted at the pace required to maintain soil fertility (Binswanger-Mkhize and Savastano 2017). Low-productivity, subsistence-oriented smallholder farming systems therefore continue to dominate. Second, even though rapid urbanization and economic growth provide new potential market opportunities for the rural farm sector, urban food needs are increasingly met through imports (FAO 2012). Some see this not only as a missed opportunity for Africa's rural farm sector to modernize and expand, but importing food is also a drain on scarce foreign exchange reserves.

These trends provide a clear rationale for the adoption of what could be termed "agricultural commercialization" policies. However, as governments increasingly push agricultural commercialization agendas, many are raising concern over the food and nutrition security outcomes associated with commercialization of traditional smallholder farming systems, particularly as it often entails on-farm specialization in only a few crops. Proponents of commercialization argue that increased farm incomes from the sale of cash crops would allow farmers to buy farm inputs and nutritious foods, while sceptics maintain that production and consumption decisions are inseparable because of structural constraints and output market failures. Fafchamps (1992) posited that in the face of weak and uncertain markets, risk averse farmers adopt a subsistence approach to their production and consumption decisions. Indeed, much of the evidence suggests household production continues to have strong links with household dietary patterns of its members (Carletto et al. 2015). Unsurprisingly, therefore, Radchenko and Corral (2018) find that Malawian households are less likely to grow cash crops when food access is uncertain or when they are faced with marketing barriers for their outputs. Weak and underdeveloped markets seemingly provide one explanation for the slow pace of agricultural transformation in SSA.

Against this background, we examine the commercialization debate further in the context of Rwanda. As a small landlocked country with a population of 12 million people, Rwanda faces significant land pressure. Average land holdings are declining (Jayne et al. 2014) and smallholders find it increasingly difficult to feed their families without off-farm income (REMA 2015). Rwanda also imports significant quantities of food, including rice, a commodity in which it supposedly has a comparative advantage (Ghins et al. 2017). Policymakers are blaming the traditional subsistence farming system rather than small land holdings for low productivity and the country's failure to be self-sufficient (Diao et al. 2010). Therefore, the vision for agricultural transformation is not necessarily to increase the size of plots, but to encourage commercial behaviour by smallholders and promote better coordination of farmers' activities at village-level. More specifically, Rwanda's Strategic Plan for the Transformation of Agriculture (*Plan Stratégique pour la Transformation de l'Agriculture*) (PSTA) prioritizes sustainable agricultural intensification through crop specialisation, increased fertilizer use, and land use consolidation among farmers to raise productivity, promote more efficient service delivery to farmers, and better coordination of farmers' activities. The large-scale Crop Intensification Programme (CIP) is the main policy vehicle for achieving these goals. In addition to increased productivity and profitability, CIP also aims to reduce poverty and improve food and nutrition security outcomes (MINAGRI 2018).

Despite its scale and prominence, analysis on the effect of CIP on food and nutrition security is scant. Descriptive statistics from a small survey suggest that severely food insecure households consolidate a much larger share of their land under CIP than those that are less food insecure (Cioffo 2014). Isaacs et al. (2016) compare monocropping systems (such as those promoted under CIP) with intercropping practices and find that the latter outperform the former on several counts, including productivity and contribution to diet quality. They conclude that agricultural practices promoted under CIP may not be conducive to improvements in food and nutrition security outcomes. More recently, Weatherspoon et al. (2017) demonstrate how sensitivity to prices and inefficient markets prevent Rwandan rural households from diversifying their diets, which is suggestive that agricultural intensification may not necessarily improve food and nutrition security outcomes. Despite providing some relevant insights, none of these studies provides robust quantitative results on the direct causal links between participation in land consolidation activities and household consumption behaviour.

In addressing this shortcoming in the literature, our study uses recent household panel data and a propensity score matching difference-in-differences (PSM-DiD) method to evaluate the impact of crop specialisation and land consolidation carried out through Rwanda's CIP on food consumption patterns and nutrient availability of participants. In our most conservative econometric specification, we find that participation in the programme had a positive effect on roots and tubers consumption, which are among the so-called CIP priority crops, but a negative impact on meat, fish and fruits consumption. Crop specialisation and land consolidation did not have a significant impact on caloric availability or dietary diversity, but negatively impacted the availability of vitamin B12 in participants' diets. The adverse nutrition effects obsereved are enhanced when a greater share of a household's land is consolidated.

Our results suggest a need to review CIP activities to ensure that it contributes rather than detracts from food security and nutrition objectives. This could include measures that encourage households to improve their nutritional status through kitchen gardening or the poultry farming. Furthermore, the kind of evidence presented by Radchenko and Corral (2018) suggests that improvements in market functioning and access could be a necessary precondition for success of a commercialization strategy. While our analysis contributes to the limited evidence on the food security and nutrition implications of CIP in Rwanda, our results also have implications for SSA countries more broadly, where policies designed to fast-track agricultural commercialization continue to emphasize the production side but tend to fall short on addressing market rigidities or adopting mitigation measures for potential adverse nutritional outcomes.

The remainder of the paper is structured as follows. Section 2 provides contextual information on Rwanda's CIP, recent agricultural performance, and food and nutrition security outcomes. Section 3 presents the empirical model and section 4 introduces the data. Section 5 presents and discusses the results, and, finally, section 6 concludes and makes policy recommendations.

2 LAND CONSOLIDATION, AGRICULTURAL PERFORMANCE AND NUTRITION OUTCOMES IN RWANDA

Rwanda's CIP was launched in September 2007. It comprises four components: (i) distribution of improved inputs; (ii) consolidation of land use; (iii) coordinated provision of extension services; and (iv) support to post-harvest handling and storage. CIP targets six priority crops, namely: maize, beans, cassava, rice, wheat, and Irish potato (MINAGRI 2011). The bulk of CIP spending is dedicated to purchasing seeds and fertilizers that are distributed to participants who also receive extension services (MINAGRI 2009). Extension messages focus on agronomic practices, although some resources are also dedicated to advising on post-harvest handling and storage. Whereas the immediate objective of the program is increased crop productivity and profitability of farming, its long-term goal is to reduce poverty and hunger and contribute to rural development by strengthening markets and developing small businesses (e.g., in processing, trading, and transportation).

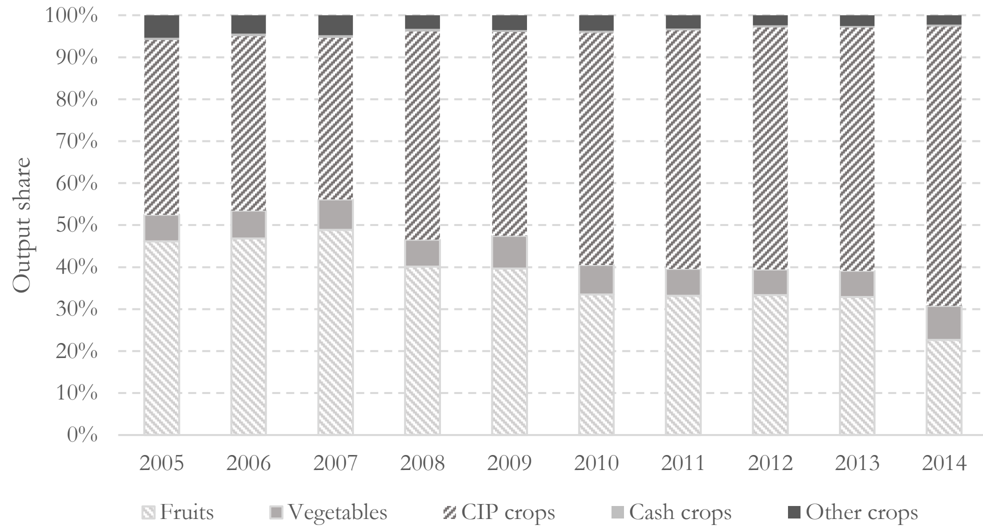
The Rwanda Agricultural Board (RAB), an agency of the Ministry of Agriculture and Animal Resources (MINAGRI), is responsible for implementing the CIP. Through consultations with agronomists, RAB identifies CIP target areas and priority crops—grown on a two-crop rotation basis—as well as land consolidation targets across the country's agroecological zones. The idea behind CIP is to provide inputs and services to groups of farmers who cultivate the same crops in a synchronised manner. This, the architects of CIP believe, will increase cost-efficiency of the program in terms of extension service delivery and input distribution, and yield comparatively better results in terms of crop productivity.

Land consolidation is implemented at *umudugudu* (village) level, and typically involves groups of 20–25 farmers (MINAGRI 2012). Participating farmers would effectively operate as a collective through planting the same crops, coordinating the timing of planting and harvesting, and collectively marketing their crops. Beneficiary groups also receive inputs alongside coordinated extension advice from agronomists, local government authorities and RAB extension workers. Farmers retain their individual property rights and participation is voluntary, but since program benefits such as fertilisers, seeds and training are only available to participants, participation is implicitly encouraged (Cioffo 2014; MINAGRI 2012).

Land consolidation under the CIP started in 2008 when about 28,000ha (or 5% of total harvested land in the country) were incorporated into the program. The consolidated land area expanded rapidly in the following years, reaching 600,000ha by 2016 (40% of total harvested land) (RAB 2017). Although the program initially targeted mostly maize, beans became more prominent from 2011 onwards and represented 55% of consolidated land by 2016. The CIP had a significant impact on input use. The proportion of CIP farmers using improved seeds increased from 3% to 40% during 2008–2011, while the use of fertilizers, distributed by private sector firms under a government-backed voucher system, increased from 4 to 30kg/ha in during 2006–2013 (MINAGRI 2014). Measured in terms of output shares, the composition of Rwanda's agricultural sector has shifted significantly during the CIP implementation period. These production shifts were brought about both by changes in land allocation and differential yield growth rates across crops, with CIP priority crops performing relatively better.

Figure 2.1 depicts the broader production shifts, measured in terms of crop-specific outputs (physical quantities) as a share of total output, by CIP and non-CIP crops, while Table 8.1 in the appendix presents detailed crop production statistics for 2008–2014. As shown in the latter, production of maize, cassava and Irish potatoes increased steadily over the period, mostly because of yield growth, while much of the output growth in beans was a result of land expansion. By sharp contrast, paddy rice production stagnated during 2008-2014. Although wheat yields rose over the period, a decline in harvested areas led to a decline in output. In general, though, rapid output growth, brought about mostly by yield increases, means CIP crops now account for almost 70% of total crop output, compared to less than 50% in 2005 (see Figure 2.1).

Figure 2.1 Crop production shares in Rwanda, 2005-14



Source: FAOSTAT (2016). Note: Output share is the metric tons (mt) produced as a share of total production. CIP priority crops include maize, beans, cassava, rice, wheat, and Irish potato.

Although poor nutrition remains a concern in Rwanda, progress has been made since the early 2000s. The share of the population that is undernourished (measured in terms of the calories available to them) declined by 13.8 percentage points between 2000 and 2015, although at around 40%, undernourishment rates remain high. Furthermore, the undernourishment rate increased between 2012 and 2015, rising from about 34 to 40%. The series of Comprehensive Food Security and Vulnerability Analyses (CFSVAs) by the World Food Programme (WFP) in Rwanda confirm that food security generally improved over the course of the last decade, although a slight deterioration is observed for more recent years. As shown in Table 2.1, the shares of “moderately” and “severely” food insecure remained stable between 2009 and 2012, but increased in 2015. Observed trends however need to be taken with caution because survey data collection timeframes may differ across CFSVAs. Nevertheless, the WFP (2016) notes that household consumption did not increase between 2012 and 2015 because of high prices.

Table 2.1 Food security status of Rwandan households, national estimates, 2006–15

Year	Data collection period	Food secure (%)	Moderately food insecure (%)	Severely food insecure (%)
2006	March-April 2006	65.4	27.9	6.7
2009	February-March 2009	78.5	17.3	4.2
2012	March-April 2012	79.0	17.0	4.0
2015	April-May 2015	74.0	19.0	7.0

Source: WFP (2016). Note: The methodology used to classify households across food security profiles varies between the CFSVAs. The authors reconstructed an indicative mapping.

Stunting among children under five declined marginally from 42% to 37% during 2012–2015 (WFP 2016). While it is difficult to attribute national-level nutrition outcomes to food production and supply shifts, it is evident that the scale of the CIP may have significantly influenced how much and what people eat in Rwanda, both through encouraging production of specific crops over others, or through affecting consumption choices of rural and urban consumers via supply and price effects.

3 IDENTIFICATION AND ESTIMATION STRATEGY

There is much interest among policymakers in understanding how the promotion of crop specialization or agricultural commercialization in traditional rural societies impacts on food consumption and nutritional outcomes. Hence the objective of our study is to investigate the causal effect between engaging in land consolidation through CIP participation and household dietary outcomes. The latter is measured in terms of consumption quantities of various food items, the availability of key macro- and micronutrients in the diet, and a Dietary Diversity Score (DDS).

CIP participation is likely driven by several household characteristics, such as household wealth, education, place of residence, and personal motivation. These may, in turn, also be correlated with our outcome indicators. We deal with this potential selection bias by comparing participants and non-participants who are similar per a set of observable covariates (see Mendola 2007; Kassie et al. 2011; Amare et al. 2012; Magrini and Vigani 2016). The main challenge in observational studies is constructing a credible counterfactual group to capture what would have happened to participating units had they not participated. Since the counterfactual of each individual household can neither be observed nor estimated, impact evaluation techniques focus on the so-called Average Treatment Effect on the Treated (ATT) instead of the effect on individual units.

Formally, we define D as a binary variable equal to one if the farmer participates in the land consolidation activities under CIP and zero otherwise, while Y^1 and Y^0 represent the outcomes of the treated and non-treated units, respectively. The standard approach is to use propensity score matching (PSM), with the ATT expressed as:

$$\tau_{ATT} = E(Y^1 - Y^0 | \, D = 1) = E[Y^1 | \, D = 1] - E[Y^0 | D = 1] \qquad (1)$$

τ_{ATT} measures the difference between the expected consumption and/or nutritional outcomes with or without land consolidation for those who have access to the program. We can observe the outcome for participants ($E[Y^1|D = 1]$), but not for those participating had they not been treated ($E[Y^0|D = 1]$); thus, the assumption required to identify the effect of the treatment is that there is a set of observable characteristics, such that, after controlling for these covariates, the potential outcomes are independent of the treatment status. This is referred to as the Conditional Independence Assumption (CIA).

The PSM method then identifies a control group—i.e., non-participants that are like participants—using information on observable characteristics (X). The procedure involves two steps: first, estimating the probability of participation in the program (or the propensity score); and, second, comparing non-adopters and adopters with similar probabilities of participating in the program. The PSM estimator can be written as:

$$\tau_{PSM}(X) = E[Y^1|D = 1, P(X)] - E[Y^0|D = 1, P(X)] \quad (2)$$

where $P(X)$ is the propensity score, and the outcomes of the treated households are compared to the outcomes of the nearest non-treated households.

Given that the selection into CIP likely also depends on unobservable characteristics, the CIA may be too strong. For example, if farmers' ability or motivation for participation, neither of which are observed, are key determinants of the participation into the program, it is not possible to fully control for self-selection using PSM. More generally, the approach cannot control for time-invariant and time-variant unobserved heterogeneity. If, however, pre-treatment data are available, and if unobservable factors driving the selection are time-invariant, the CIA assumption can be relaxed. In this case, the effect of the unobservable characteristics can be cancelled out by taking the difference in outcomes before and after the treatment. The difference-in-differences (DiD) approach relies on a less strict assumption, namely that in the absence of treatment the unobserved differences between treatment and control groups are the same over time.

Counterfactual levels for treated and non-treated units can therefore be different, but their time variation is similar, i.e.:

$$E(Y_1^0 - Y_0^0 \middle| D = 1) = E(Y_1^0 - Y_0^0 \middle| D = 0) \quad (3)$$

where the subscripts denote time periods before (0) and after (1) consolidation. In equation (3) the right-hand term represents the control group; thus, in the absence of treatment, the change in the outcome of treated units is the same as the change in the outcome of non-treated units. While PSM only controls for the bias associated with observable characteristics, DiD controls for the bias associated with observable and unobservable time-invariant characteristics.

Still, one limitation remains, namely that when there is a high degree of heterogeneity between treated and non-treated units, it is difficult to assume that without CIP the outcome variable of these households would have the same trend (Imbens and Wooldridge 2009). More precisely, farmers that are less similar at the beginning of the period are likely to follow different paths over time. By combining the two methodologies (PSM–DiD) we can overcome both limitations. Smith and Todd (2005) find that estimators based on such a combination are more robust than traditional cross-section matching estimators. The steps are: (i) apply a PSM to find non-treated observations that were like the treated observations before the program was implemented; (ii) apply the DiD method to estimate a counterfactual for the change in outcomes in each subgroup of matched units; and (iii) average those double-differences across matched subgroups (Caliendo and Kopeinig 2008). The PSM-DiD estimator is then based on the following identifying assumption:

$$E(Y_1^0 - Y_0^0 \big| D = 1, P(X)) = E(Y_1^0 - Y_0^0 \big| D = 0, P(X)) \tag{4}$$

An important underlying condition required by equation (4) is the existence of a "common support" for the propensity score between participants and non-participants in both periods (Smith and Todd 2005). We restrict our sample to the overlapping region of the estimated propensity scores between control and treated observations to respect this support condition. The DiD matching estimator we use in our analysis is then given by:

$$\hat{\tau}_{PSM-DID} = \frac{1}{n_1} \sum_{i \in I_1 \cap S_p} \left\{ \left(Y_{i1}^1 - Y_{i0}^0 \right) - \sum_{i \in I_0 \cap S_p} W(i,j)(Y_{i1}^0 - Y_{i0}^0) \right\} \tag{5}$$

where I_1 and I_0 indicate the set of participants and non-participants, respectively, S_p the region of common support, n_1 the number of treated farmers in the space $I_1 \cap S_p$, and $W(i,j)$ a weighting function depending on the matching estimator employed (Smith and Todd 2005). We use kernel weights to ensure that all available information is exploited as each participating unit is matched to the whole sample of non-participating units (see Heckman et al. 1998). Alternative matching algorithms were also tested and results are available upon request.

In line with most empirical applications of the DiD identification strategy, we adopt a standard linear regression specification:

$$Y_{it} = \beta_0 + \beta_1 \mathrm{D}_i + \beta_2 Post_t + \alpha_\tau D_i * Post_t + \lambda X_{it} + \mu_{it} \quad (6)$$

where Y_{it} is the outcome variable of interest (e.g., food consumption, nutrient availability, or dietary diversity) for household *i* at time *t*; *D* is the binary treatment (i.e., participation in land consolidation); *Post* is a binary variable that takes the value 0 or 1 if the household is observed in pre- or post-consolidation, respectively; and *X* identifies the set of control variables. The coefficient α_τ is the DiD estimator and captures the treatment effect. As explained further below, we run several specifications of equation (6) to test the robustness of our results.

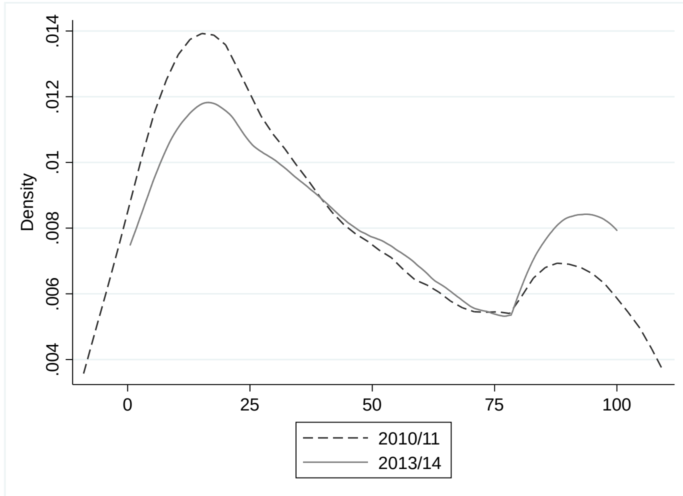
4 DATA

Our analysis is based on the two latest waves of the nationally representative Integrated Household Living Conditions Surveys (*Enquête Intégrale sur les Conditions de Vie des ménages*) conducted in 2010/11 (EICV3) and 2013/14 (EICV4) (NISR 2012; 2015). The surveys have a panel structure as required by the PSM–DiD method. The merged datasets include a panel sub-sample of 1,259 households with detailed information on land consolidation activities, agricultural practices, and household consumption behaviour collected at two points in time. Since households have around five plots on average, plot-level information is collapsed to form household-level indicators on agricultural production activities.

Treatment and control group identification is based on survey responses to questions on whether individual plots of land cultivated by respondents had been incorporated into a land consolidation activity under CIP. In our benchmark estimation, a household is included in the treatment group if at least one of its plots is committed to the land consolidation program. We also run robustness checks which explore possible differences within the treatment group relating to the share of land consolidated. For these tests, we define treatments groups respectively as "low-intensity consolidators" when less than 50% of a household's land (in terms of area) is consolidated, or "high-intensity consolidators" when more than 50% of land is committed to the program.

Figure 4.1 plots the kernel densities for the percentage of consolidated land in 2010/11 and 2013/14. Households' responses are plotted independently for each year, and the figure only includes households who consolidated at least one plot in a survey year. The average consolidation share among CIP participants increased from 43% to 48% over the period. In both years, the largest share of CIP participants consolidated around 15% of their land (i.e., the mode of the distribution). A secondary mode can be observed close to 100%, and it appears as if a greater percentage of participants consolidate almost all their land in 2013/14 compared to 2010/11. This partially explains the increase in the average consolidation share.

Figure 4.1. Kernel density plots: percentage of consolidated land in 2010/11 and 2013/14



Source: Authors' estimates based on EICV3 and EICV4 data. Note: household responses for different years are plotted independently.

The estimation strategy also requires a decision about which two groups to compare across the two periods. In both periods, we can identify CIP participants and non-participants. However, for our treated group we are particularly interested in the so-called "switchers", i.e., households who were non-participants in 2010/11 but joined the program in 2013/14. There are 247 such observations in our panel (see Table 4.1). The control group consists of those 736 households that were excluded from the program (or chose not to participate) in both periods. Our analysis therefore excludes "quitters", i.e., households that participated in 2010/11 but not in 2013/14 (195), as well as the "always treated", i.e., households that participated in both periods (81).

Table 4.1. Number of sample observations in treated and control groups

		Period 2: 2013/14		Total
		Non-participants (0)	Participants (1)	
Period 1: 2010/11	Non-participants (0)	736 "never treated" (control group)	247 "switchers" (*treated group*)	983
	Participants (1)	195 "quitters" (excluded)	81 "always treated" (excluded)	276
Total		931	328	1,259

Source: Authors' estimates based on EICV3 and EICV4 data. Note: Under the high-intensity definition of participants there are 109 observations in the treated group, while the control group stays unchanged.

Consumption quantities, macro- and micronutrient availability, and a DDS serve as outcome variables. Consumption quantities are reported for both home-produced and purchased foods in the EICV datasets. For purchased foods, only the total amount spent is reported; hence we impute quantities based on food prices retrieved from own consumption estimates. Consumption quantities are reported at the household level in the survey, but for our purposes these are converted into grams per capita per day, using an adult equivalent household size measure.

Macro- and micronutrients are derived from food consumption quantities using food conversion tables produced by Lukmanji et al. (2008) for neighboring Tanzania. As such, reported food quantities directly determine the availability of nutrients in the diet. Macronutrients such as calories and protein are particularly prevalent in cereals, dairy products, eggs, fish and meat, and are important for maintaining an active life and repairing body cells.

Among micronutrients, iron is available in animal flesh (heme iron) or plant foods such as legumes or green leafy vegetables (non-heme). Iron is crucial for combating anaemia, and iron deficiency is highly prevalent globally. Zinc is critical for growth, the immune system, and sexual maturation, and is available in food sources such as beef and whole grains. However, zinc contained in whole grains is harder to absorb, hence deficiencies are common among populations with cereals-based diets. Vitamin C is obtained from fruits and vegetables and its deficiency can lead to scurvy. Vitamin B12 is available in fish, beef, poultry and dairy products, and a lack thereof in the diet can lead to anaemia or neurological symptoms. Finally, vitamin A is mainly contained in liver, egg yolk, and whole milk. Vitamin A deficiency can lead to night blindness, increased infections, and impaired growth and reproductive functions.

The DDS is computed as the average number of food groups consumed by the household in the two days prior to the survey interview. A higher score is indicative of a higher quality diet and is strongly correlated with anthropometric measures such as wasting and stunting among children; as such, it is a simple yet very powerful nutrition indicator which is also sensitive to shocks and seasonality (Headey and Ecker 2013).

There are several sources of potential error when using consumption surveys to estimate food consumption quantities and macro- or micronutrient availability. First, whereas consumption from own sources is reported both in quantity and value terms, purchased food quantities are imputed, with some error, from amounts expended as well as implicit prices derived from own consumption estimates. Second, not all available food is necessarily ingested by household members during the recall period, as some may be stored, given to people outside of the household, fed to animals, or wasted. Third, as reporting is done at household level we do not have information about the allocation of food among members. An age-weighted uniform distribution of food is assumed, but this may not necessarily be accurate due to skewed intra-household power relations. Fourth, although quantities of own consumption are reported in standard metric units in the survey, it can be expected that some respondents have difficulty in converting non-standard units of measurement used in practice (e.g., a pail of maize or bunch of bananas) into metric units. Finally, when computing macro- or micronutrients available in the diet, we cannot make any statements about the bioavailability of the food consumed, as this depends on metabolic processes and how efficiently the body extracts nutrients from food.

Table 4.2 reports consumption and nutrient-availability measures in daily units (grams or otherwise) per adult equivalent as well as the DDS. Mean estimates are reported for the combined (treated and untreated) sample as well as separately for the two subsamples. We use *t*-tests to compare differences in means over time for the whole sample, as well as differences in means between treated and untreated groups within each survey period. For the whole sample, and measured against a 0.05 *p*-value, we note statistically significant increases in mean consumption levels of cereals, meat, eggs, fish and fruits, and a significant decline in roots and tubers. We further note small but significant declines in vitamins C and A availability, and a large and statistically significant increase in vitamin B12 availability. The DDS also improve significantly over the period, from 4.85 to 5.01.

Table 4.2. Descriptive statistics and t-tests: daily food consumption quantities and nutrient availability per adult equivalent per day, and dietary diversity 2010/11 and 2013/14

	Whole sample (treated and untreated)			Period 1: 2010/11			Period 2: 2013/14		
	Period 1: 2010/11	Period 2: 2013/14	Equality of means over time (*p*-values)	Treated	Untreated	Equality of means across groups (*p*-values)	Treated	Untreated	Equality of means across groups (*p*-values)
Food consumption (g)									
Cereals	3.58	3.95	0.00	3.60	3.52	0.59	3.92	4.07	0.22
Meat	0.69	0.86	0.01	0.68	0.73	0.65	0.94	0.63	0.00
Eggs	0.09	0.12	0.02	0.10	0.05	0.06	0.12	0.12	0.79
Fish	0.26	0.96	0.00	0.24	0.30	0.29	1.03	0.74	0.00
Dairy	1.07	1.19	0.17	1.13	0.87	0.06	1.20	1.15	0.74
Oil	1.90	1.83	0.19	1.90	1.91	0.86	1.86	1.73	0.12
Fruits	3.97	4.17	0.04	3.87	4.26	0.02	4.23	3.99	0.12
Legumes	4.74	4.75	0.83	4.72	4.78	0.50	4.71	4.86	0.02
Vegetables	4.61	4.58	0.63	4.62	4.58	0.70	4.58	4.60	0.83
Roots & Tubers	6.43	6.21	0.00	6.46	6.34	0.08	6.14	6.40	0.00
Nutrient availability									
Energy (kcal)	7.61	7.64	0.14	7.60	7.62	0.63	7.61	7.73	0.00
Protein (g)	4.01	4.05	0.19	4.01	4.02	0.81	4.02	4.12	0.01
Iron (mg)	2.86	2.82	0.14	2.85	2.87	0.71	2.79	2.91	0.00
Zinc (mg)	2.18	2.19	0.50	2.17	2.19	0.73	2.16	2.29	0.00
Vitamin C (mg)	5.09	5.03	0.04	5.10	5.09	0.94	5.01	5.09	0.08
Vitamin B12 (mcg)	0.22	0.35	0.00	0.22	0.22	0.96	0.37	0.27	0.00
Vitamin A (mcg)	5.84	5.72	0.04	5.83	5.86	0.79	5.71	5.74	0.71
Diet Diversity Score	4.85	5.01	0.04	4.85	4.86	0.90	5.03	4.97	0.61

Source: Authors' estimates based on EICV3 and EICV4 data. Note: kcal = kilocalories; g = grams; mg = milligrams; mcg = micrograms (= 0.001mg).

The treated and untreated samples display very similar dietary patterns in the first period prior to the intervention, with the only significant difference observed for fruit consumption. In the second period, however, we note significantly higher levels of consumption of meat and fish and lower consumption of legumes and roots and tubers among the treated as compared to the untreated. Treated households also have less calories, protein, iron and zinc available in their diets, but more vitamin B12. These results suggest some mixed outcomes over time and when comparing our treated and untreated households over time; however, these simple *t*-tests do not control for possible selection bias; hence, we turn to our econometric estimates in the next section.

5 RESULTS, ROBUSTNESS CHECKS AND DISCUSSION

5.1 CIP Impact on Consumption, Nutrient Availability and Dietary Diversity

The first step of our empirical strategy is to estimate the propensity scores. We use a logit model and control for a set of covariates, namely household size, education, age and gender of the household head, number of children, marital status, household location, livestock ownership, land size, share of land irrigated, and per capita food consumption expenditure (in adult equivalent terms) and province dummies. We further include a household asset index using principal component analysis (PCA) following Filmer and Pritchett (2001). The marginal effects of these variables on the decision to participate are presented in Table 8.2 in the appendix.

Figure 8.1 in the appendix shows the kernel density distributions of the treated and control groups before and after the PSM was implemented. The similarity between the two distributions after matching suggests that once we control for these covariates the potential outcomes are independent of the treatment status. Table 8.3 in the appendix provides additional information on the balancing property between covariates before and after the matching procedure. In the unmatched sample, we observe statistically significant differences in means between treated and untreated subsets for four variables (the western province, livestock ownership, rural areas, and consumption expenditure). After the matching procedure, all variables are balanced.

Turning now to the main results of our analysis, Table 5.1 reports the DiD estimator (i.e. α_τ in equation (6)) under four different econometric specifications, namely the basic DiD, the PSM-DiD, and for both these, with and without the set of controls, *X*. The final specification, labelled PSM-DiD-*X* in Table 5.1, is our preferred specification, for reasons explained in section 3. With respect to consumption (see upper part of Table 5.1), a key observation is that our estimated effects on consumption are not sensitive to the econometric specification, i.e., the estimators are consistent in magnitude, sign and statistical significance across the specifications. However, this is not the case for the nutrient availability effects (lower part of Table 5.1), where results are more sensitive to the econometric specification, at least in terms of the size and significance of estimators.

Focusing on results from our preferred specification (PSM-DiD-*X*), we notice positive consumption effects for cereals (which includes CIP priority crops maize, rice and wheat), eggs, dairy products, oil, legumes (which includes CIP priority crop beans), vegetables, and roots and tubers (which includes CIP priority crops cassava and Irish potato). However, among these it is only the increase in roots and tubers (27.4%) that is statistically significant. We also observe statistically significant and negative impacts on consumption of meat (-36.1%), fish (-30.2%) and fruits (-62.1%) among participants. None of these food groups are prioritized under CIP. Overall, the results suggest that CIP participation encourages increased consumption of CIP priority crops (especially roots and tubers) at the expense of nutritionally-important foods such as meat and fish.

With respect to nutrient availability, treatment effects are much lower and, for the most part, statistically insignificant in our preferred specification as compared to the other econometric specifications. The only significant effect is an 11.2% decline in vitamin B12 availability, which we can relate directly to the decline in meat and fish consumption. The effect on the DDS, although negative, indicating a decline in average number of food groups consumed, is also not statistically significant.

5.2 Robustness Checks

The validity of our identification strategy and the casual interpretation of the results rely on the assumption that the control group is a valid counterfactual for what would have happened to the treated farmers in the absence of the consolidation programme. Specifically, the so-called common trends assumption, implies parallel trends between groups in the outcome variables. Testing for this requires at least two pre-treatment serial observations of the outcome variables, while in our dataset we only have one. However, some features of our baseline specification and the results of two additional placebo tests minimize the concerns on the validity of our estimates.

Thus, while we cannot correct for the time-variant unobservable pre-treatment characteristics, which are associated with the dynamics of the outcome variables and, at the same time, are unbalanced between treated and control group, the adoption of a PSM-DiD specification allows us to control for both observed time-variant and unobserved time-invariant heterogeneity between groups and to correct for any observable pre-existing difference by using only the matched sample with similar characteristics. This is confirmed in Table 8.3 in the appendix where observed pre-treatment variables are all balanced after the propensity score adjustment.

Considering the top-down approach followed by RAB in selecting the CIP target areas and crops, it is difficult picturing additional pre-treatment characteristics, beyond the set of covariates X, capable of driving our results. These confounders should simultaneously influence the probability of participating in CIP—which is mostly determined by the RAB—and the trends of the consumption habits and nutritional status of the farmers. One possible factor we can think of is the case of authorities targeting CIP areas not only according to their agroecological characteristics, but also according to (say) poverty rates in an effort to achieve certain socioeconomic objectives as stated in CIP policy documents. In that case poor farmers would have higher chance to be treated and simultaneously show different pre-treatment outcome trends since they tend to rely more on staple crops. Nevertheless, the treated and control groups' poverty rates in our data in the pre-treatment period are, respectively, 44.1% and 44.8%, and a t-test on the mean does not reject the null hypothesis of zero differences between groups (i.e. p-value = 0.862), suggesting that the level of poverty before consolidation is not biasing our results.

As an additional check for the presence of unobserved time-varying heterogeneity, we run a placebo test using a fake treatment group (Gertler et al. 2016). We randomly assign the treatment status to a subset of households in the control group and then rerun the PSM-DiD model comparing the fake treatment against the remaining control group. We replicate the simulation 5,000 times for each outcome variable. The expectation here is that there will be no impact of the fake land consolidation participation on consumption behavior; a significant result would indicate the existence of omitted pre-treatment factors that drive the outcome variables and cast doubt on our baseline specification. Figure 8.2 shows that the probability densities of the estimated 5,000 placebo effects are centered around zero while the true treatment effects estimated in Table 5.1 always lies at the extreme of the distribution tails. This suggests, once again, that the analysis is not driven by unobserved heterogeneity raised by omitted pre-existing factors in our baseline specification.

Finally, we look at the heterogeneous effects of land consolidation. Thus far we have defined the treatment group as all household that participate in land consolidation activities. An additional set of estimates test the robustness of our results to alternative treatment groups. These include (i) low-intensity consolidation (less than 50% of the household's land has been consolidated) and (ii) high-intensity consolidation (50% or more of the household's land has been consolidated), i.e., we essentially divide our benchmark treatment group into two subgroups and evaluate the effects of the program separately. In these models, we still have 736 control households, but the treatment groups now consist of 138 and 109 units in the low- and high-intensity cases, respectively (see Table 4.1; also note Table 8.2 in the appendix reports the propensity score estimation results for these robustness tests). The results from the robustness tests are presented in Table 5.2.

Results are broadly consistent in terms of the direction of treatment effects. However, effects differ in terms of size and statistical significance. In line with the benchmark case, we note that meat and fish consumption declines for high-intensity consolidators, but not for low-intensity consolidators, while fruit consumption declines for both treatment subgroups. We only observe the significant increase in consumption of roots and tubers for the low-intensity consolidators. The negative effect on vitamin B12 availability is significant only in households who consolidated more than 50% of their land.

A possible explanation for these results is that when consolidation activities regard only a small portion of available land, farmers may still have the possibility to diversify production on the remaining plots. Once the consolidated land is above a certain threshold, farmers may not have the incentive to differentiate anymore and the initial benefits of participating in the programme in terms of food and nutrition security outcomes may be more than offset by the effects of excessive specialization.

Table 5.1. Impact of participation in land consolidation on consumption, nutrient availability and dietary diversity under alternative specifications

	Alternative specifications							
	DiD		DiD-*X*		PSM-DiD		PSM-DiD-*X*	
Outcome	Estimator (α_τ)	Std. err.	Estimator (α_τ)	Std. err.	Estimator (α_τ)	Std. err.	Estimator (α_τ)	Std. err.
Food consumption								
Cereals	0.23	0.19	0.06	0.19	0.27	0.20	0.17	0.20
Meat	-0.35 **	0.14	-0.32 **	0.13	-0.40 ***	0.14	-0.36 ***	0.13
Eggs	0.04	0.04	0.02	0.04	0.02	0.04	0.00	0.03
Fish	-0.36 ***	0.10	-0.33 ***	0.10	-0.40 ***	0.11	-0.30 ***	0.10
Dairy	0.22	0.21	0.24	0.20	0.27	0.21	0.29	0.20
Oil	-0.15	0.12	-0.08	0.12	-0.04	0.13	0.04	0.13
Fruits	-0.62 ***	0.22	-0.60 ***	0.21	-0.55 **	0.23	-0.62 ***	0.22
Legumes	0.10	0.10	0.06	0.10	0.17	0.10	0.06	0.10
Vegetables	0.05	0.12	0.02	0.11	0.05	0.12	0.03	0.12
Roots & Tubers	0.38 ***	0.11	0.31 ***	0.10	0.37 ***	0.11	0.27 ***	0.11
Nutrient availability								
Energy	0.10 *	0.06	0.04	0.05	0.13 **	0.06	0.04	0.05
Protein	0.09	0.06	0.03	0.05	0.11 *	0.06	0.02	0.05
Iron	0.10 **	0.05	0.04	0.05	0.13 **	0.05	0.04	0.05
Zinc	0.11 **	0.05	0.04	0.04	0.13 **	0.05	0.04	0.05
Vitamin C	0.09	0.07	0.10	0.07	0.12	0.07	0.09	0.07
Vitamin B12	-0.10 ***	0.04	-0.10 ***	0.03	-0.12 ***	0.04	-0.11 ***	0.04
Vitamin A	0.01	0.14	-0.01	0.14	0.02	0.14	0.02	0.15
Diet Diversity Score	-0.08	0.18	-0.05	0.16	-0.12	0.17	-0.03	0.16

Source: Authors' estimates based on EICV3 and EICV4 data. Note: Statistical significance: 1% ***; 5% **; 10% *

Table 5.2. Robustness tests on impact of participation in land consolidation on consumption, nutrient availability and dietary diversity

	Benchmark specification: all participants included in treatment group (*from Table 4*)		Robustness checks on treatment identification			
			Low-intensity consolidation (*< 50% land consolidated*)		(ii) High-intensity consolidation (*≥ 50% land consolidated*)	
Outcome	Estimator (α_τ)	Std. err.	Estimator (α_τ)	Std. err.	Estimator (α_τ)	Std. err.
Food consumption						
Cereals	0.17	0.20	0.29	0.24	-0.07	0.28
Meat	-0.36 ***	0.13	-0.17	0.17	-0.58 ***	0.18
Eggs	0.00	0.03	0.01	0.04	-0.02	0.05
Fish	-0.30 ***	0.10	-0.10	0.12	-0.54 ***	0.14
Dairy	0.29	0.20	0.18	0.25	0.39	0.31
Oil	0.04	0.13	0.11	0.15	0.04	0.18
Fruits	-0.62 ***	0.22	-0.48 *	0.26	-0.82 ***	0.31
Legumes	0.06	0.10	0.04	0.12	0.05	0.14
Vegetables	0.03	0.12	0.05	0.15	-0.11	0.19
Roots & Tubers	0.27 ***	0.11	0.31 ***	0.12	0.18	0.17
Nutrient availability						
Energy	0.04	0.05	0.01	0.06	0.03	0.08
Protein	0.02	0.05	0.00	0.06	-0.02	0.08
Iron	0.04	0.05	-0.01	0.05	0.03	0.08
Zinc	0.04	0.05	-0.01	0.05	0.04	0.07
Vitamin C	0.09	0.07	0.11	0.09	0.04	0.10
Vitamin B12	-0.11 ***	0.04	-0.07	0.04	-0.18 ***	0.05
Vitamin A	0.02	0.15	0.10	0.17	-0.10	0.22
Diet Diversity Score	-0.03	0.16	0.06	0.19	-0.13	0.23

Source: Authors' estimates based on EICV3 and EICV4 data. Note: Statistical significance: 1% ***; 5% **; 10% *

5.3 Summary of Results

In summary, our results are not very encouraging as far as the impact of land consolidation on consumption patterns and nutrient availability is concerned. Consumption of nutritionally important foods such as meat, fish and fruits decline in the benchmark treatment group, and the effect is amplified the more engaged households are in land consolidation activities. In contrast, consumption of roots and tubers increases, on average, but not for high-intensity consolidators. The availability of key macro- and micronutrients as well as the DDS is largely unaffected although we note a significant decline in vitamin B12 availability, which is more pronounced among high-intensity consolidators.

We can speculate as to the possible reasons for these results. First, the land consolidation policy in Rwanda favours mono-cropping over crop diversification (Isaacs et al. 2016). Therefore, it is reasonable that participants will switch out of those activities not prioritized under the CIP such as growing fruits and/or rearing animals, with the consequence that availability of these foods for auto-consumption declines. One possible way to counter these adverse effects is to afford greater attention to the production of legumes, fruits and animal proteins at household level, e.g., through kitchen gardening initiatives or poultry farming.

Although agricultural productivity gains are generally associated with rising farm incomes, weak market access may either constrain income growth or prevent farmers from supplementing their diets through marketed consumption. Put differently, if markets cannot absorb surplus production, participating farmers' terms of trade worsens, and they may be forced to auto-consume their produce and/or limit purchases of items they might not (or no longer) produce themselves, such as fruits and meat. There is some evidence that high marketing costs and an underdeveloped retail distribution system (IFAD 2016) constrain Rwandan farmers' ability to access markets, whether for selling or buying (Weatherspoon et al. 2017).

Although further analysis is warranted, well-functioning markets appear to be critical to the success of the program as far as nutritional outcomes are concerned. Investing in market and transport infrastructure and reducing domestic trade and processing costs are important complementary policies for enhancing the nutritional benefits of CIP. This will not only benefit participants, but also non-participants. The fact that adverse consumption and nutritional effects worsen with the intensification of treatment suggests that policymakers should refrain from fast-tracking the program without complementary investments in markets.

A final issue worth mentioning is the effects of the program on relative prices. Land consolidation under CIP appears to have contributed to higher yields and an increase in the share of arable land allocated to CIP priority crops (Table 8.1 in the appendix). As supply of priority commodities rises—and likely at the expense of meat, fish or fruit supplies—relative prices of CIP crops can be expected to decline, which will in turn prompt an increase in demand for CIP priority crops from consumers. Given the evaluation framework developed here, we are not able to test these general equilibrium price effects or assess the implications for non-participant farmers or consumers; however, understanding the potential spill-over effects of CIP for the rest of the market is an important topic for further analysis.

6 CONCLUSIONS

Despite rapid population growth, increasing land pressure, and urbanization, farmers in Sub-Saharan Africa have not intensified their production systems in a sustainable manner and at the pace required to maintain soil fertility, raise productivity and production, and substitute food imports. Instead, farming systems remain predominantly subsistence-oriented, and agricultural transformation is not playing out in the way theory predicted it would. Unsurprisingly, many countries are investing large shares of their agricultural budgets in programs that promote sustainable crop intensification and encourage the development of more commercially-oriented agricultural systems.

Rwanda's Crop Intensification Program (CIP), which promotes land consolidation, crop specialization, and increased fertilizer use, is one such example. Since its launch in 2007 Rwanda has experienced impressive agricultural growth. Total production of CIP priority crops—including maize, beans, cassava, rice, wheat and Irish potato—expanded around 160% during 2007–2014, driven largely by yield growth, and has displaced non-prioritized crops. However, following an initial improvement in reported food security levels during 2006–2009, food security indicators remained unchanged thereafter, with around one-fifth of the population reportedly being food insecure during 2009–2015.

Using panel survey data, we combine propensity score matching (PSM) and difference-in-differences (DiD) methods to evaluate the effect of land consolidation on household consumption patterns, nutrient availability, and dietary diversity. Under the benchmark specification, results suggest significant growth in consumption of roots and tubers among participants. By contrast, a negative impact on the consumption of meat, fish and fruits is observed, which is also reflected in a significant negative impact of land consolidation on vitamin B12 availability. Despite these consumption shifts, no significant impact on a Dietary Diversity Score (DDS) is observed. Results are robust to different treatment specifications: when differentiating between low-intensity consolidators (less than 50% of household cropland is consolidated) and high-intensity consolidators (50% or more of household cropland is consolidated), we no longer detect the positive effect on roots and tubers consumption in the high-intensity case. Also, the negative effects on meat, fish and fruits consumption as well as vitamin B12 availability is amplified for high-intensity consolidators.

Several factors may explain why land consolidation seemingly does little to help farm households improve and diversify their diets. First, as has been the experience in many countries, a rapid increase in supply of calorie-dense staple crops tends to be associated with increases in the relative prices of meat, fish, vegetables and fruits, which gives rise to the kind of substitution effects observed. Second, weak markets and limited market access may prevent farmers from selling produce and/or purchasing foods to diversify their diets: households may thereby be forced to auto-consume much of their output.

Our results have important implications for policy in Rwanda and in developing countries more generally. As Rwanda winds up activities under its third Strategic Plan for the Transformation of Agriculture (PSTA III), it is timely to consider the impact of land consolidation, a major element of its development strategy, on food consumption outcomes, to better design future interventions over the next years. So far, it is evident that land consolidation in the Rwandan context has had significant impacts on household food consumption trends, and hence macro- and micronutrient availability. Despite growth in food production, diets of those participating in the land consolidation program diversified less quickly than those of non-participants. Availability of some nutrients also declined due to participation. It is therefore crucial that programs that promote specialization and intensification be complemented by interventions aimed at improving nutritional intakes at household level, such as the promotion of kitchen gardening or animal protein production such as poultry. Moreover, in addition to promoting good agronomic practices, extension agents could be trained to impart knowledge on nutritional literacy at home. Lastly, investmenting in market infrastructure is crucial to allow improved market access not only for selling crops but also for acquiring nutritious foods.

In recognition of the fact that relative food price changes associated with investment in cash or staple crop production may contribute to harmful food substitution effects, governments should closely monitor price movements of key non-staple foods, such as meat, fish, vegetables and fruits. Additionally, governments should favour a gradual consolidation process rather than rapid and complete specialization within a short space of time. This will allow farmers to maintain some level of diversification while markets gradually develop. An area of future research is to assess how programs such as the CIP—which are bound to have important economywide effects—are shaping food supply, demand and price trends, also for non-participants and consumers.

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8 APPENDIX

Table 8.1 Production, yield and harvested area for CIP priority crops, 2005–14 (selected years)

	2008	2009	2010	2011	2012	2013	2014	Avg. annual growth (%)	Contribution to growth (%)
Maize									
Production	166,853	286,946	432,404	525,679	573,038	667,833	480,000	23.6	
Yield	1.2	2.0	2.3	2.4	2.3	2.3	1.9	11.8	53.3
Area harvested	144,901	147,129	184,662	223,417	253,703	292,332	250,000	10.4	46.7
Beans									
Production	308,000	326,532	327,497	331,166	432,857	438,236	422,590	6.0	
Yield	0.9	0.9	1.0	1.0	0.9	0.9	0.9	0.4	6.3
Area harvested	336,575	345,866	319,260	341,831	479,886	479,996	454,251	6.2	93.7
Cassava									
Production	1,681,823	2,019,741	2,377,213	2,579,000	2,716,421	2,948,121	3,161,470	11.2	
Yield	10.3	11.2	12.0	12.3	14.9	15.8	16.1	7.9	69.8
Area harvested	163,099	180,210	197,394	210,076	182,278	186,996	195,910	3.4	30.2
Paddy rice									
Production	82,025	81,076	93,902	81,365	84,079	95,906	72,723	-0.9	
Yield	4.4	5.6	7.2	5.6	5.7	5.5	4.5	2.3	62.6
Area harvested	18,455	14,433	12,975	14,592	14,701	17,568	16,000	-1.4	37.4
Wheat									
Production	67,869	72,479	77,193	90,684	75,913	70,129	67,730	0.6	
Yield	1.3	1.7	1.6	2.0	2.2	2.0	2.2	10.3	57.7
Area harvested	52,336	42,437	49,385	44,284	35,015	35,198	30,991	-7.5	42.3
Irish potato									
Production	1,161,943	1,289,623	1,789,404	2,171,518	2,337,706	2,240,715	2,225,080	12.3	
Yield	9.1	10.2	11.9	12.8	14.2	13.6	13.4	6.8	58.3
Area harvested	127,226	126,166	150,777	169,494	164,779	164,691	166,350	4.9	41.7

Source: FAOSTAT (2016).

Note: Production is reported in metric tons (mt); area harvested in thousands of hectares (ha); and yields are reported as metric tons per hectare (mt/ha). The final column shows the contribution of yield and area expansion, respectively, to overall production growth over the period.

Table 8.2 Propensity score estimation (logit model): baseline and robustness checks

	Baseline specification		Robustness checks			
			Low-intensity consolidation		High-intensity consolidation	
Variable	**Coeff.**	**Std. err.**	**Coeff.**	**Std. err.**	**Coeff.**	**Std. err.**
Household size	0.03	-0.06	0.12	-0.08	-0.10	-0.10
Head age	0.05	-0.03	0.03	-0.04	0.07	-0.05
No. of children	0.00	0.00	0.00	0.00	0.00	0.00
Married	-0.16 *	-0.09	-0.26 **	-0.11	0.01	-0.12
Head sex	-0.15	-0.23	-0.31	-0.28	0.10	-0.34
Primary educ.	0.30	-0.26	0.59 *	-0.32	-0.16	-0.38
Secondary educ.	0.14	-0.18	-0.20	-0.22	0.61 **	-0.27
Southern prov.	0.16	-0.32	-0.04	-0.40	0.48	-0.46
Western prov.	1.79 ***	-0.55	2.92 ***	-1.03	0.87	-0.65
Northern prov.	2.01 ***	-0.54	2.65 **	-1.04	1.66 ***	-0.64
Eastern prov.	1.25 **	-0.58	2.20 **	-1.06	0.58	-0.69
Urban	1.60 ***	-0.58	2.97 ***	-1.06	0.36	-0.71
Land ownership	-0.44	-0.28	-0.48	-0.36	-0.39	-0.38
Livestock ownership	0.22	-0.18	0.18	-0.23	0.33	-0.26
Land size	-0.04	-0.08	-0.22 **	-0.10	0.17	-0.11
Share land irrigated	-0.45	-0.85	-1.45	-1.44	0.31	-0.96
Food consumption	-0.21 **	-0.09	-0.14	-0.10	-0.23 **	-0.11
Asset index	-0.01	-0.06	0.00	-0.07	-0.05	-0.08
Constant	-1.51	-1.36	-2.89	-1.82	-2.35	-1.82

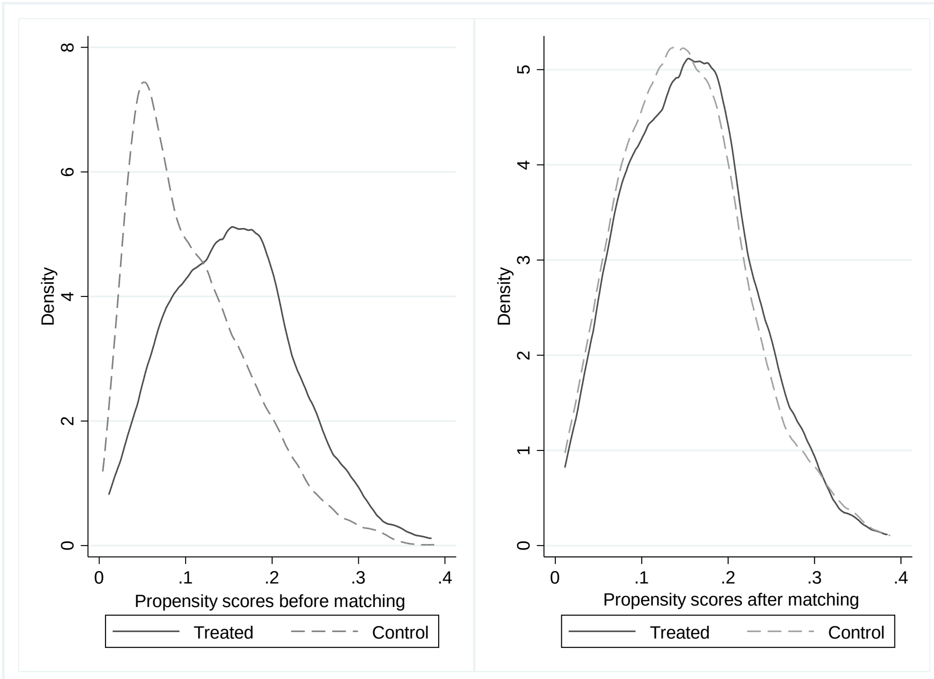
Note: Statistical significance: 1% ***; 5% **; 10% *.

Table 8.3 Balancing property of the covariates (baseline period)

Variable	Sub-samples	Mean		Bias		t-test	
		Treated	Control	%	|red|	t	p>|t|
Household size	U	4.7	4.8	-5.0		-0.7	0.5
	M	4.8	4.7	1.3	73.2	0.2	0.9
Head age	U	47.2	46.3	5.9		0.8	0.4
	M	47.3	47.2	0.5	91.6	0.1	1.0
Head age squared	U	2470.1	2397.5	4.5		0.6	0.6
	M	2476.8	2469.0	0.5	89.3	0.1	1.0
No. of children	U	1.9	2.1	-11.8		-1.6	0.1
	M	1.9	1.9	0.1	99.1	0.0	1.0
Married	U	0.6	0.6	0.9		0.1	0.9
	M	0.6	0.6	0.7	21.6	0.1	0.9
Head sex	U	0.7	0.7	1.3		0.2	0.9
	M	0.7	0.7	0.5	65.5	0.1	1.0
Primary educ.	U	0.6	0.6	6.1		0.8	0.4
	M	0.6	0.6	1.7	72.2	0.2	0.9
Secondary educ.	U	0.1	0.1	-7.5		-1.0	0.3
	M	0.1	0.1	-0.5	92.8	-0.1	1.0
Southern Province	U	0.3	0.3	6.4		0.9	0.4
	M	0.4	0.4	-1.6	75.4	-0.2	0.9
Western Province	U	0.4	0.3	21.3		3.0	0.0
	M	0.4	0.4	1.4	93.4	0.2	0.9
Northern Province	U	0.1	0.2	-11.5		-1.5	0.1
	M	0.1	0.1	2.6	77.0	0.3	0.8
Eastern Province	U	0.2	0.2	3.0		0.4	0.7
	M	0.2	0.2	-2.5	19.1	-0.3	0.8
Urban	U	0.1	0.2	-24.7		-3.2	0.0
	M	0.1	0.1	0.7	97.0	0.1	0.9
Livestock Ownership	U	0.7	0.6	15.0		2.0	0.1
	M	0.7	0.7	1.3	91.2	0.2	0.9
Land Ownership	U	3.4	3.2	14.8		2.0	0.1
	M	3.5	3.5	-1.4	90.7	-0.2	0.9
Share land irrigated	U	0.0	0.0	-6.1		-0.8	0.5
	M	0.0	0.0	0.1	98.1	0.0	1.0
Food consumption	U	11.6	11.8	-19.8		-2.6	0.0
	M	11.6	11.7	-7.3	63.4	-0.9	0.4
Asset index	U	0.5	0.6	-7.5		-1.0	0.3
	M	0.5	0.5	-1.5	79.8	-0.2	0.9

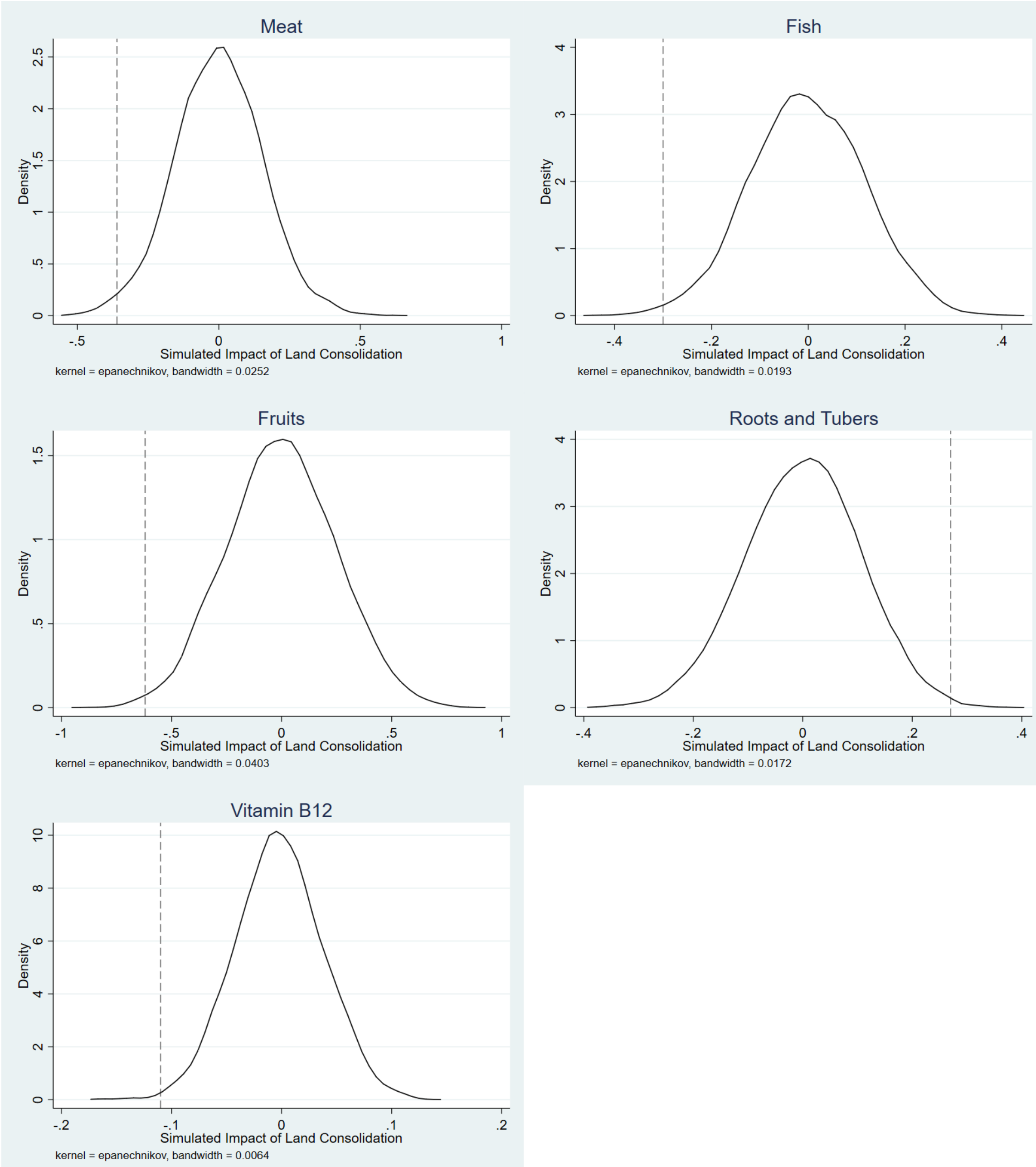
Note: U = unmatched; M = matched. T test differences for baseline equation

Figure 8.1 Propensity score matching of treated and control groups



Source: Authors' estimates based on EICV3 and EICV4 data. Note: kernel density distributions with bandwidth 0.06 of the treated and control groups before and after the PSM was implemented..

Figure 8.2 Probability density of the simulated impact of consolidation



Source: Authors' estimates based on EICV3 and EICV4 data. Note: For sake of brevity, we only report the probability densities with respect to those outcome variables that turn out to be significantly influenced by the treatment in our baseline specification. The tests for the remaining outcomes are available upon request.

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IFPRI HEADQUARTERS
1201 Eye Street, NW
Washington, DC 20005 USA
Tel.: +1-202-862-5600
Fax: +1-202-862-5606
Email: ifpri@cgiar.org