Land Consolidation, Specialization, and Household Diets: Evidence from Rwanda

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Abstract:

Since 2007 the Rwandan government has pursued a large-scale Crop Intensification Program entailing land consolidation and a regionalized approach to crop production support. As agricultural development is generally associated with improved food and nutrition security outcomes, the Rwandan development strategy has supported the increased crop specialization by smallholders with the assumption that as incomes improve, households could increasingly rely on markets for maintaining diverse and nutritious diets. Despite its scale, no detailed assessment of the causal relationship between land consolidation under CIP and food and nutrition security outcomes has been carried out. Using recent household survey data and a propensity score matching difference-in-difference method, we find that participation in land consolidation activities had an ambiguous effect. On the one hand it positively impacted on consumption of roots and tubers, while on the other, had negative effect on meat, fish and fruits consumption and potential availability of vitamin B12 in participants' diets. The share of consolidated land, the emphasis on cultivating only certain priority crops, and market access are identified as important explanatory factors . This calls for a review of CIP implementation practices so that its capacity to achieve broad food and nutrition security objectives is further improved.

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1 Introduction

Many governments have aimed at fast-tracking rural transformation by providing incentives to smallholder farmers for an increased commercial orientation or specialisation in marketable crops. Examples of such policies are crop intensification programmes which include promoting crop specialisation and consolidating land. Such programmes are likely to affect food security and nutrition because they are being implemented in contexts where subsistence farming has dominated for decades and has been the key determinant of households' food supplies.

The impact of crop specialisation and land consolidation activities on food security and nutrition is therefore of peculiar interest. Indeed, deciding on which crops to grow is of tremendous importance for farmers, and land is the most fundamental asset they have. Some micro-level researches provide indications on how such interventions may affect food security and nutrition. High levels of land fragmentation (i.e. high number of plots, small average size, and high distance between parcels) reportedly lead to higher production costs. When land size falls below a critical threshold, it discourages heavy investments in mechanization or the adoption of innovative farming techniques. As a result, smallholder performance in terms of output, productivity and profitability is usually lower with respect to larger farmers since smallholders cannot exploit the benefits that economies of scale offer. In this line, crop specialisation and land consolidation would be expected to augment productivity, the availability of self-produced crops and thereby contribute to achieve food security.

Another way in which crop specialisation and land consolidation may have an effect on food security and nutrition is through markets. It is expected that resulting improvements in productivity and profitability will lead to higher incomes. If nutritious food is available and affordable in local markets, improved nutritional intakes would follow. A known caveat of this theory is that food markets in developing countries remain uncertain and weak, with risk averse farm households continuing to adopt a subsistence orientation in terms of both their production and consumption decisions (Fafchamps 1992). For this reason, Huang and Rozelle (2010) underline the importance of investments in market infrastructures in order to strengthen agriculture-nutrition linkages. Related to the market pathway are price changes caused by shifts in the supply of certain agricultural commodities as a consequence of crop specialisation and land consolidation. Price shifts influence affordability of foods or consumption choices. Furthermore, crop specialisation and land consolidation may reduce crop diversity at farm level. Diverse farming systems are not only associated with increased resilience (food supply is smoothed) - they also contribute to dietary diversity, which is a strong indicator of food availability at household level (Hoddinott and Yohannes 2002).

How crop intensification and land consolidation affect food security and nutrition in a context in which rural areas are dominated by smallholders therefore is a complex question. Although the literature has singled out some of these potential land consolidation-nutrition pathways, few studies provide direct measurements of the impact of such interventions on food consumption and nutrition in developing countries (Holden and Ghebru 2016). Producing such measurements is however essential to deepen our understanding of agricultural development processes and for policy design.

This is especially true in the case of Rwanda, a small landlocked country with a population of 12 million growing at around 2.5%per annum. As in many Sub-Saharan African countries there is significant pressure on land (World Bank 2016): about half of households hold less than 0.33 hectares (ha) of land, which is only about one-third of what is deemed necessary to feed a family without having an off-farm job (REMA 2015). Within this context, it is understandable why agricultural intensification through crop specialisation and land use consolidation is emphasized as a policy priority under the Rwanda's Strategic Plan for the Transformation of Agriculture (*Plan Stratégique pour la Transformation de l'Agriculture*), which thus far has comprised three phases (PSTA I–III) spanning 2004–17, with a fourth phase (PSTA IV) currently being developed. Crop specialisation and land consolidation are carried out in the context of a large-scale Crop

Intensification Programme (CIP), in line with the PSTAs. The CIP's main objective is to increasefarm productivity and profitability and, in the long run, to reduce poverty and hunger. In spite of the CIP being one of the government's flagship initiatives for agricultural development, little analysis on its effects on food security and nutrition is currently available. In fact, only a handful of studies have examined agricultural intensification policies in Rwanda within a food security and nutrition context. For example, looking at basic descriptive statistics based on semi-structure interviews of 150 participating households, Cioffo (2014) suggests that severely food insecure households consolidate a much larger share of their land compared to those that are less food insecure. Isaacs et al. (2016) compare monocropping systems as promoted under the CIP with intercropping practices and find that the latter outperform monocroppingon several counts, including yield, market value of production, land-use efficiency, and contribution to diet quality. They argue that the type of practices promoted under the CIP may not be conducive to improvements in food and nutrition security outcomes. More recently, Weatherspoon et al. (2017) demonstrated how—like in the Indian and Malawian examples cited earlier—high price sensitivity and inefficient markets prevented Rwandan rural households from increasing their dietary diversity, suggesting agricultural intensification in itself is no guarantee of food security and nutrition improvements. Despite providing useful insights on the links between intensification and smallholders' welfare, none of these papers has already investigated – using robust econometric techniques – the direct causality between the participation in land consolidation activities and household diets.

In the attempt to fill this gap, the present study uses recent household survey data and a propensity score matching difference-in-difference method (PSM-DiD) to evaluate the impact of crop specialisation and land consolidation carried out within the CIP on food consumption patterns and nutrient availability of participants. In our most robust econometric specification, we find that participation to the programme had a positive effect on roots and tubers consumption, 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 share of households' land that is consolidated, the emphasis on cultivating so-called priority crops, and market access are important explanatory factors for our results.

Our work calls for a review of CIP activities to ensure that the programme can contribute to food security and nutrition objectives, as originally expected.The analysis thus adds up to the nascent yet still limited evidence on the food security and nutrition implications of the CIP andagricultural intensification in Rwanda. It is also relevant for decision-makers and donors working on development policy design in Sub-Saharan Africa. Furthermore, it provides an interesting case study on the linkages between land use policies and food security and nutrition in developing countries, an issue which has not been extensively covered by the literature (Holden and Ghebru 2016).

The remainder of the paper is structured as follows. Section 2 presents crop specialisation and land consolidation in Rwanda in more detail and reviews the recent agricultural performance and food and nutrition security trends in the country; section 3 presents the empirical model; section 4 describes the data; section 5 discusses the results; while 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) 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 fertilisers that are distributed to participants alongside extension services (MINAGRI 2009). The latter primarily focus on agronomic practices, although some resources are also dedicated to advising on post-harvest handling and storage.

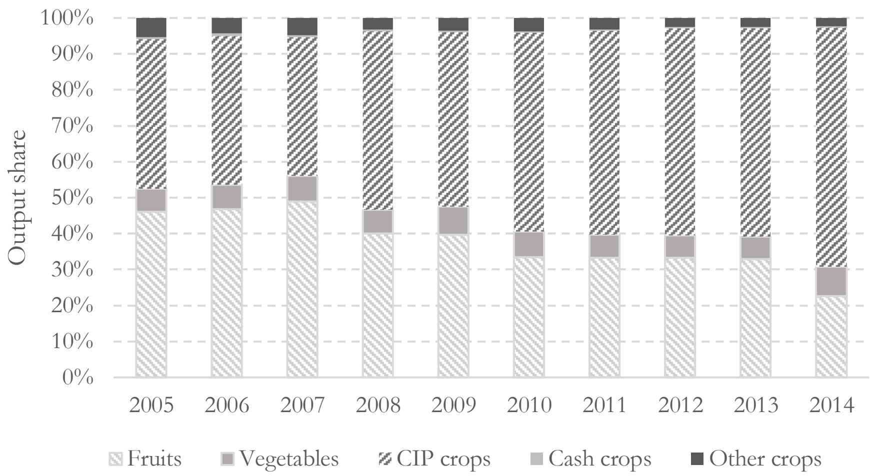
Whereas the main objective of the program is increased crop productivity and profitability of farming, its long-term goal is to reduce poverty and hunger and contribute to rural development, primarily through strengthening markets and developing small businesses (e.g., in processing, trading, and transportation).

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 rationale for this approach is that productivity can be increased by encouraging farmer groups to cultivate the same crops in a synchronised manner. Land consolidation is implemented at *umudugudu* (village) level and typically entails groups of 20–25 farmers "consolidating" land through coordination of land allocation and input use for priority crops. Farmer groups are supervised, also in a coordinated manner, by agronomists, local government authorities and RAB extension workers. Participant farmers retain their property rights and participation is voluntary, but program benefits such as fertilisers, seeds and training are only provided to participants and therefore implicitly encourages participation (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 percent 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 2008–11, while the use of fertilisers, distributed by private sector firms under a government-backed voucher system, increased rapidly from 4 to 30kg/ha in during 2006–13 (MINAGRI 2014a).

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, particularly for CIP priority crops. Figure 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.

Figure 1. Crop production shares in Rwanda, 2005-14



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. Source: FAOSTAT (2016).

Table A1 in Appendix presents detailed crop production statistics for 2008–14. Production of maize, beans, cassava and Irish potatoes increased at steady positive yearly rate across the period. For maize, cassava and Irish potatoes, most of the increase was attributable to yield growth. For beans, higher harvested areas were mostly responsible for output increases. By sharp contrast, and despite its prioritization, paddy rice production stagnated during 2008-14. Rice yields declined between 2010 and 2014, although more up-to-date figures suggest they have been increasing recently (see Ghins et al. 2017). Wheat yields rose over the period, but the decline in harvested areas was too strong to allow for increases in aggregate 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.

Table 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	48	24	28
2009	February-March 2009	79	17	4
2012	March-April 2012	79	17	4
2015	April-May 2015	80	17	3

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

On the nutrition front, Rwanda has performed reasonably well. Although 30% of the population is still undernourished relative to a minimum required caloric availability of 1,710 kilocalories (kcal) per person per day (FAO 2008), the share has declined by around 13 percentage points in the last decade (FAOSTAT 2016). Various Comprehensive Food Security and Vulnerability Analysis(CFSVA) reports carried out by the World Food Programme (WFP) confirm the notable improvements in food security during 2006–09 (Table 1), although since 2009 the shares of "moderately" and "severely" food insecure have remained stable. Stunting among children under five declined marginally from 42 to 37% during 2012–15 (WFP 2016). Although it is difficult to assess how, if at all, food production and supply shifts influenced nutrition indicators, it is evident that the scale of the CIP may have significantly influenced how much and what people eat in Rwanda, whether through encouraging production of specific crops and hence consumption choices of farm households, or through affecting consumption choices of rural and urban consumers indirectly via supply and price effects.

3 Methods: Identification and estimation strategy

We aim to investigate the causal effect between CIP participation through land consolidation and household dietary outcomes, measured in this study as consumption quantities of food items, the availability of several macro- and micronutrients in the diet, and a Diet Diversity Score (DDS). CIP participation is likely driven by several household characteristics, such as household wealth, education, place of residence, and personal motivation, which in turn may also be correlated with ouroutcome 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 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 its 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, while Y^1 and Y^0represent the outcomes of the treated and non-treated units, respectively. The standard approach is to use propensity score matching (PSM) (Rosenbaum and Rubin 1983), with the ATTexpressed as:

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

τ_{ATT}measures the difference between the expected consumption and/or nutritionaloutcomeswith or without land consolidationfor 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 main assumption necessary to identify the effect of the treatment is that there is a set of observable characteristicssuch 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 CIPlikely depends also on some 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 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 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, i.e., 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:

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

where the subscripts denote time periods before (0) and after (1) the 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 the CIP the outcome variable of these households would have the same trend (Abadie 2005; 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 as well. 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 to be followed are: (i) applying a PSM to find non-treated that were like the treated before the program was implemented; (ii) applying the DiD method to estimate a counterfactual for the change in outcomes in each subgroup of matched units; and (iii)averagingthose double-differences out across matched subgroups (Caliendo and Kopeinig 2008). The PSM-DiD estimator is then based on the following identifying assumption:

$$E(Y_1^0 - Y_0^0 | D = 1, P(X)) = E(Y_1^0 - Y_0^0 | D = 0, P(X)) \quad (4)$$

One 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). To respect this support condition, we therefore restrict our sample to the overlapping regionof the estimated propensity score between control and treated observations.The difference-in-differences matching estimator we use in our analysis is then given by:

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

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).In our analysis, we usekernel weights to benefit the major advantage that all the available information is exploited since each participating unit is matched to the whole sample of non-participating units (Heckman, Ichimura, and Todd, 1997 and 1998; Villa, 2016).

Following the bulk of the literature, our empirical application based on the DID identification strategy relies on a standard linear regression specification (Lechner, 2011), i.e.:

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

where Y_{it} is the outcome of household *i*at time *t*; *D* is the binary treatment for 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 $\alpha_{\tau}$is the DID estimator and captures the treatment effect. For the sake of robustness, we run several specifications of equation [6] to show the consistency of our results across multiple estimates.

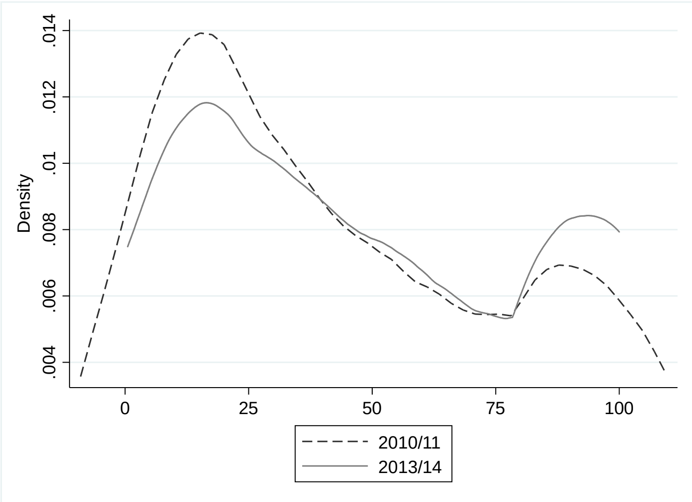
4 Data

For our econometric analysis,we use the latest two waves of the Integrated Household Living Conditions Surveys (*EnquêtesIntégrales sur les Conditions de Vie des Ménages - EICV*)conducted in 2010/11 (EICV3)and 2013/14 (EICV4). The panel structure of these surveys allows us to employ the PSM–DiDmethodology. The merged datasets include a panel sub-sample of 1,259 households with detailed information on land consolidation activities, agricultural practices, and householdconsumption behaviourcollected at two points in time.

To fully identify our treatment and control groups, two decisions need to be made. The first relates to the protocol adopted for identifying participant households in any year. Both survey rounds contain a question on whether each plot of land cultivated by a household had been incorporated into a land consolidation activity under CIP.Since households have around five plots on average, plot-level information is collapsed to construct a household level binary treatment variable. For our "baseline" results we simply classify a household as a participant if at least one field has been consolidated. Two additional definitions of treatment are used as robustness checks where we specifically consider the share of landholdings consolidated to distinguish "low-intensity" (less than 50% of consolidated land) and "high-intensity" consolidators (more than 50% of consolidated land).

Figure 2 plots the kernel densities for the percentage of consolidated land in 2010/11 and 2013/14. 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 helps explain the increase in the average consolidation rate.

Figure 2.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 second issue relates to the 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 groupwe 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 2). The control group consists of those 736 households that were excluded from the program in both periods. Our analysis therefore excludes so-called "quitters", i.e., households that participate 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 2.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.

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 the latter, only the total amount spent is reported; hence we impute quantities based on food prices retrieved from own consumption estimates, for which both the estimated value and quantities are reported by households. Table 3 reports average daily consumption quantities per adult equivalent in grams. We note increases in cereals (5.8%), dairy (8.5%), meat (14.5%) and eggs (38.9%) consumption, as well as a very large increase in fish consumption (194.8%), albeit off a low base. By contrast, consumption of all other food items, including fruits, legumes, vegetables and roots and tubers declined.

Table 3. Descriptive statistics: daily food consumption quantities per adult equivalent in 2010/11 and 2013/14

	Period 1: 2010/11		Period 2: 2013/14		
Variable	Mean (grams)	Std. dev.	Mean (grams)	Std. dev.	Percentage change
Cereals	109.2	124.0	115.5	117.7	5.8
Meat	5.6	12.1	6.4	11.9	14.5
Eggs	0.2	0.7	0.3	0.8	38.9
Fish	1.6	5.5	4.6	7.6	194.8
Dairy	30.7	70.6	33.3	72.5	8.5
Oil	10.4	10.3	9.9	10.1	-5.1
Fruits	193.8	218.8	190.0	201.0	-2.0
Legumes	158.5	102.7	150.1	95.6	-5.3
Vegetables	154.5	121.4	141.9	107.1	-8.2
Roots and tubers	801.1	453.8	699.7	469.3	-12.7

Source: Authors' estimates based on EICV3 and EICV4 data.

Food quantities are converted into macro- and micronutrients, including calories, protein, iron, zinc, and vitamins C, B12 and A, using food conversion tables compiled by Lukmanji et al. (2008) (Table 4).The results show that among the macronutrients,caloric and protein availability increased by 5.7% and 2.4%, respectively. These macronutrients are particularly prevalent in cereals, dairy products, eggs, fish and meat, for which consumption increased. Macronutrients are important for maintaining an active life and repairing body cells.

Table 4. Nutrient availability per adult equivalent and dietary diversity in 2010/11 and 2013/14

	Period 1: 2010/11		Period 2: 2013/14		
Variable	**Mean**	**Std. dev.**	**Mean**	**Std. dev.**	**Percentage change**
Energy (kcal)	2,289	1,122	2,420	1,323	5.7
Protein (g)	62.7	32.0	64.2	32.3	2.4
Iron (mg)	18.6	9.1	18.0	9.0	-3.3
Zinc (mg)	8.8	4.6	9.1	5.1	3.5
Vitamin C (mg)	197.9	111.7	182.9	103.0	-7.6
Vitamin B12 (mcg)	0.35	0.63	0.53	0.65	51.4
Vitamin A (mcg)	566.6	440.1	508.7	468.6	-10.2
Diet Diversity Score	4.9	1.7	5.0	1.7	3.3

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

Among micronutrients, iron availability declined by 3.3%. Iron is available in animal flesh (heme iron), for which consumption increased, or plant foods such as legumes or green leafy vegetables (non-heme), for which consumption declined, and is crucial for combating anaemia. Iron deficiency is said to be one of the most common micronutrient deficiencies in the world; hence the observed decline in iron availability is cause for concern. Zinc availability, on the other hand, increased by 3.5%. Zinc is critical for growth, the immune system, and sexual maturation, and is available in food sources such as beef as well as in whole grains. Zinc contained in whole grains is hardto 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. Consistent with the consumption trends for these foods, vitamin C availability declined by 7.6% over the period. Vitamin B12 availability, by contrast, increased sharply by 51.4%. This micronutrient is contained in fish, beef, poultry and dairy products, and a lack thereof in the diet can lead to anaemia or neurological symptoms. Finally, availability of vitamin A, which is mainly contained in liver, egg yolks, and whole milk, declined by 10.2%, which is concerning as deficiency can lead to night blindness, increased infections, and impaired growth and reproductive functions.

We also calculate a DDS, which is simply the average number of food groups consumed by the household in two days prior to the 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 considered a simple yet very powerful nutrition indicator which is also sensitive to shocks and seasonality (Headey and Ecker 2013). The DDS increased marginally from 4.9 to 5.0 (3.3%), suggesting an improvement in diet quality in Rwanda.

There are some limitations to using consumption surveys to estimate food consumption quantities and macro- or micronutrient availability. First, whereas subsistence producers report the quantity consumed, purchased food quantities are based on amounts expended. Not all purchased food is necessarily ingested, as some is stored, given to people outside of the household, fed to animals, or wasted. Second, as reporting is done at household levelwe do not have information about the allocation of food among members. Third, as mentioned earlier, food quantities associated with purchased foods are imputed based on the perceived value of food items as reported by households rather than actual market prices. Fourth, although quantities of own consumption are reported in standard metric units (i.e., kilograms or litres), these estimates may be biased in instances where respondents have difficulty in converting non-standard units of measurement used in practice (e.g., pail of maize, bunch of bananas, or number of chickens) 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. This relates to metabolic processes and how efficiently the body extracts nutrients from food. These factors may potentially introduce bias in our estimates.

5 Results

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 X which includes 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. Considering the potential effect of wealth on the decision to consolidate or not, we also introduce into our model a measure of household well-being based on asset ownership. Following the standard approach proposed by Filmer and Pritchett (2001), we construct an index of the household assets relying on Principal Components Analysis (PCA)[1].The marginal effects of these variables on the decision to participate are presented in Appendix (Table A2).

Figure 3 shows the kernel density distributions of the treated and control groups before and after the PSM was implemented. It is evident that two distributions are very similar after the matching procedure, suggesting that once we control for these covariatesthe potential outcomes are independent of the treatment status. Table A3 in the Appendix provides some additional information on the balancing property between covariates before and after the matching procedure. In the unmatched sample, we observe that 4 variables report statistically significant differences in means between those who consolidate and those who do not. Specifically, we see that in the baseline period participants were more likely to live in the western province, to own livestock, to be located in rural areas and to have a lower level of total consumption expenditure (per adult equivalent) with respect to non-participants. After the matching procedure all the variables turn out to be balanced and the residual difference between the two groups eliminated.

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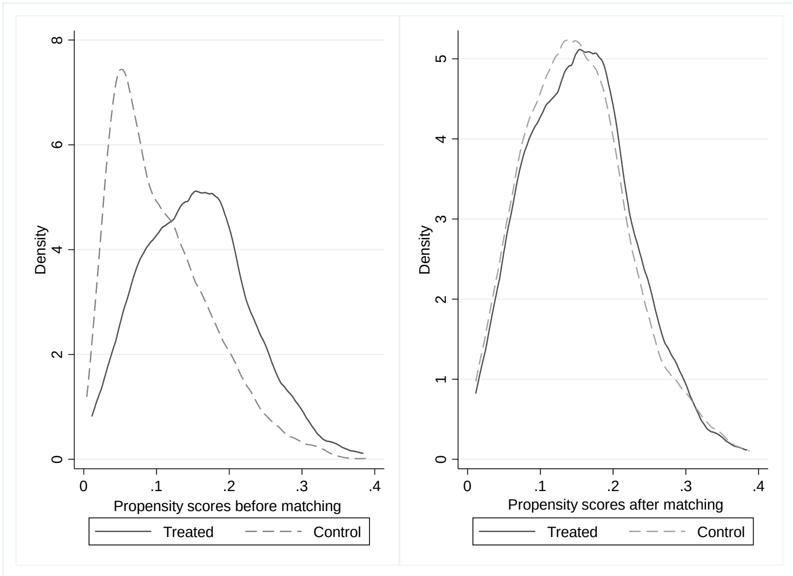
[1] The method consists of aggregating various ownership indicators into one proxy for wealth using the scoring factors of the first principal component as weights to be assigned to the different assets. We included in the index information on the ownership of housing durables (radio, telephone, refrigerator, TV, motorized transport) and housing quality (type of wall materials and type of toilet).

Figure 3. Propensity score matching



Source: Authors' estimates based on EICV3 and EICV4 data.
Note: Kernel matching with bandwidth 0.06

We now turn to the main results of our analysis. In Table 5, **Error! Reference source not found.**we report the DID estimator (i.e. α_τ in equation [6]) using different econometric specifications. In particular, we show the estimates obtained from the basic DID and the PSM-DID, with and without the set of controls X. Our preferred estimate is the last one since it is the wider and it includes both the benefits of the PSM correction and the larger set of information given by demographic, technical and geographical characteristics. The upper pane lof Table 5 reports the impact of land consolidation on daily food consumption quantities per adult equivalent while the lower panel show the effect on nutrient availability. Looking at the upper panel, it is worth noting that we obtain very similar results in magnitude and sign across the different empirical estimates. This suggests that our analysis is stable and not sensitive to the econometric specifications.

Table 5. Differences-in-Difference estimates of the impact of participation in land consolidation

	DID			DID-X			PSM-DID			PSM-DID-X		
Outcome	**AE**		**SE**	**AE**		**SE**	**AE**		**SE**	**AE**		**SE**
Consumption quantity												
Cereals	0.230		0.192	0.056		0.189	0.274		0.201	0.167		0.195
Meat	-0.354	**	0.141	-0.323	**	0.131	-0.403	***	0.140	-0.361	***	0.133
Eggs	0.037		0.037	0.020		0.036	0.020		0.035	0.004		0.034
Fish	-0.360	***	0.104	-0.328	***	0.101	-0.396	***	0.106	-0.302	***	0.102
Dairy	0.218		0.208	0.240		0.199	0.274		0.209	0.291		0.204
Oil	-0.153		0.123	-0.077		0.12	-0.040		0.129	0.042		0.126
Fruits	-0.619	***	0.224	-0.595	***	0.207	-0.548	**	0.231	-0.621	***	0.217
Legumes	0.104		0.104	0.060		0.099	0.167		0.104	0.060		0.099
Vegetables	0.051		0.119	0.016		0.114	0.046		0.121	0.029		0.123
Roots & Tubers	0.380	***	0.109	0.308	***	0.096	0.369	***	0.110	0.274	***	0.105
Nutrient availability												
Energy (kcal)	0.102	*	0.057	0.038		0.050	0.126	**	0.058	0.038		0.054
Protein (g)	0.092		0.057	0.025		0.050	0.114	*	0.059	0.020		0.054
Iron (mg)	0.104	**	0.053	0.040		0.045	0.128	**	0.053	0.037		0.049
Zinc (mg)	0.113	**	0.050	0.044		0.044	0.126	**	0.052	0.038		0.048
Vitamin C (mg)	0.089		0.073	0.099		0.065	0.120		0.074	0.092		0.070
Vitamin B12 (mcg)	-0.102	***	0.038	-0.099	***	0.034	-0.117	***	0.037	-0.112	***	0.035
Vitamin A (mcg)	0.006		0.136	-0.010		0.135	0.015		0.144	0.021		0.146
Diet Diversity Score	-0.081		0.179	-0.050		0.156	-0.118		0.174	-0.027		0.159
Observations	1966			1924			1856			1856		

Source: Authors' estimates based on EICV3 and EICV4 data.

Note: Statisticalsignificance: 1% ***; 5% **; 10% *

Despite a positive coefficient, participating farmers do not have any significant benefits in terms of consumed cereals, eggs, dairy products, oil, legumes and vegetables. Indeed, all the coefficients are not statistically different from zero. It is interesting to note that some of these food groups include CIP priority crops (i.e. maize, wheat, rice for cereals; and beans for legumes). This indicates that the link between consolidation, intensification and increased consumption is not granted, independently from the pathway through which the program is supposed to deliver its benefits. According to the preferred estimate, the only food group where we observe a positive and significant impact of land consolidation is in roots and tubers - which includes cassava and Irish potatoes – where the participation increases consumption by approximately 27.4% with respect to what it would have been if farmers had not participated. More interestingly, we register a significant and negative impact on consumption of meat (-36%), fish (-30%) and fruits (-62%) among participants. None of these food groups include CIP priority crops, suggesting that the intensification process favoured by the land consolidation changes households' behaviour and makes them shifting away from these nutrition-relevant food groups.

The lower panel of Table 5 summarizes the effects of the land consolidation on the availability of selected nutrients. The sign of the coefficients seem to be respected across the different specifications while the magnitude of the treatment effect and its significance turn out to be sensitive to the model choice. In particular, the two specifications without covariates (DID and PSM-DID) report a positive and significant effect on participating farmers for calories, protein, iron, and zincwith an impact in the range of 10-12% in most of the cases. Once we control for the set X using our preferred specification, i.e. PSM-DID-X, the treatment effects halve and become not significant. In other words, all the positive effects of consolidating seem to vanish once we use the most robust estimate suggesting that the participation does not have any substantial and evident effect on nutrition. This is further supported by the negative and not significant treatment effect on the diet diversity score. On the contrary, the only $\alpha_\tau$which is consistent across specifications in terms of magnitude, sign and significance is the negative impact on vitamin B12. In particular, the availability of this nutrient decreased by 10-12% with respect to what it would have been if farmers had not participated in the land consolidation. This is clearly the direct consequence of the reduction in meat and fish consumption observed in the upper panel of Table 5[2].

We can speculate as to some possible reasons for these results. First, the implementation of the land consolidation policy in Rwanda favours mono-cropping to the detriment of diversification (Isaacs et al., 2016). Therefore, it is reasonable assuming that participants will drop out from those activities not prioritized under the CIP programme such as growing fruits and/or farming livestock, with the consequence to reduce their availability for self-consumption. Second, 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. As supply of priority commodities rose substantially — and likely at the expense of meat, fish or fruits supplies — relative prices may have shifted, thus causing a relative increase in consumption of CIP priority crops. Furthermore, despite increased income generally associated with productivity gains, weak market access may be another explanation as to why land consolidation may have had a negative impact on consumption habits. If markets are not capable of absorbing the surplus production, participating farmers may experience a deterioration of their purchasing power due to the worsening of their terms of trade. They may be forced to reduce the purchases of other expensive and not affordable items such as fruits, meat and fish.On top of that, high transport or storage costs may be preventing households from bringing crops to the market at competitive

[2] We also run some robustness checks to control for the heterogeneity of the treatment due to the variability generated by the possibility to consolidate only a share of the smallholders' available land. In particular, we re-run the model and analyze the treatment effect differentiating between those who performed a low-intensity consolidation (less than 50% of consolidated land) from those who achieved a high-intensity consolidation (more than 50% of consolidated land).For sake of brevity, we do not report the results but they are fully aligned to those observed in the baseline exercise. More specifically, results show that the negative effects of the participation in land consolidation on nutrition increase with the intensification of the treatment

prices, thus forcing program participants to auto-consume their produce. Rwandan farmers indeed face high marketing costs (Cambridge Resources International 2017), which together with an underdeveloped retail distribution system (IFAD 2016) suggests that market infrastructure investments are much-needed to fully exploit the possible nutritional benefits of CIP.

6 Conclusions

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 activities, a major component of its development strategy, on food security outcomes. Using panel survey data from the third and fourth rounds of the Integrated Household Living Conditions Surveys, conducted in 2010/11 (EICV3)and 2013/14 (EICV4), we combine propensity score matching (PSM) and difference-in-difference (DiD) methods to evaluate the effect of land consolidation on household consumption patterns, nutrient availability, and diet diversity. The combined PSM-DiD method applied to panel data ensures that we control both for time invariant unobservable characteristics and self-selection bias. The estimated model coefficients measure the impact of treatment—i.e., participation in land consolidation activities under various specifications—on the outcome variable such as food consumption quantities and nutrient availability.

Under a baseline specification in which participation is defined as any household that consolidates at least one plot of land, 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 consolidation on vitamin B12 availability. Despite these consumption shifts, no significant impact on DDS is observed. Several factors may explain why land consolidation seemingly does little to help 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: when public programs encourage crop specialization but neglect market development, households may be forced to auto-consume much of their output.

Our results have important implications for policy. It is evident that land consolidation in Rwanda has had significant impacts on household food consumption trends, and hence macro- and micro-nutrient availability. Despite growth in food production, diets of those participating in the land consolidation program diversified less quickly than those of non-participants. Consumption for some nutrients also declined as a result of participation. It is crucial that the program be complemented by investments in market infrastructure, while in addition to promoting good agronomic practices, extension agents can impart knowledge on good nutritional practices. In recognition of the potential for relative price shifts to contribute to significant and possibly harmful food substitution effects, government should closely monitor price movements of important non-staple foods, such as meat, fish, vegetables and fruits. Finally, government should promote a gradual consolidation which does not entail a complete specialization of the farmers and gives them the incentive to maintain some inter-cropping practises. More generally, as a future area of research, it would be informative to assess how programs such as the CIP are shaping food supply, demand and price trends, and therefore household food consumption behaviour.

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Appendix

Table A1. Production (mt), yield (mt/ha) and harvested area (1000ha) for CIP priority crops, 2005–14 (selected years)

	2008	2009	2010	2011	2012	2013	2014	Avg. annual growth (%)	Yield/area production growth contribution shares (%)
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).

Table A2 - Logit Regression

Variable	(1) Consolidation	(2) Low-intensity consolidation	(3) High-intensity consolidation
Hh size	0.034	0.118	-0.097
	(0.063)	(0.075)	(0.097)
Head age	0.049	0.032	0.072
	(0.031)	(0.038)	(0.046)
N of children	-0.000	-0.000	-0.001
	(0.000)	(0.000)	(0.000)
Married	-0.157*	-0.255**	0.010
	(0.086)	(0.106)	(0.123)
Head sex	-0.145	-0.310	0.101
	(0.229)	(0.278)	(0.341)
Primary educ.	0.303	0.590*	-0.160
	(0.262)	(0.322)	(0.380)
Secondary educ.	0.139	-0.199	0.605**
	(0.182)	(0.223)	(0.266)
prov_2	0.161	-0.035	0.476
	(0.321)	(0.402)	(0.458)
prov_3	1.792***	2.919***	0.872
	(0.545)	(1.034)	(0.646)
prov_4	2.007***	2.652**	1.662***
	(0.544)	(1.037)	(0.636)
prov_5	1.254**	2.195**	0.580
	(0.575)	(1.063)	(0.690)
Urban	1.601***	2.968***	0.356
	(0.575)	(1.058)	(0.710)
Land	-0.444	-0.479	-0.386
	(0.277)	(0.355)	(0.383)
Livestock	0.215	0.177	0.333
	(0.182)	(0.229)	(0.264)
Land size	-0.042	-0.220**	0.174
	(0.076)	(0.099)	(0.109)
Land irrigated (%)	-0.448	-1.451	0.306
	(0.848)	(1.442)	(0.955)
Food consumption (ae)	-0.208**	-0.140	-0.258**
	(0.086)	(0.100)	(0.110)
Proxy index	-0.011	0.001	-0.048
	(0.055)	(0.066)	(0.080)
Constant	-1.506	-2.893	-2.348
	(1.364)	(1.815)	(1.822)
Obs	943	838	807

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table A3 - Balancing Property of the Covariates (baseline period)

		Mean		Bias		t-test	
Variable		**Treated**	**Control**	**%**	**|red|**	**t**	**p>|t|**
Hh size	U	4.73	4.84	-5		-0.67	0.50
	M	4.77	4.74	1.3	73.2	0.15	0.88
Head age	U	47.22	46.28	5.9		0.80	0.42
	M	47.30	47.22	0.5	91.6	0.06	0.96
Head age sq	U	2470.10	2397.50	4.5		0.60	0.55
	M	2476.80	2469.00	0.5	89.3	0.05	0.96
N of children	U	1.92	2.10	-11.8		-1.57	0.12
	M	1.93	1.93	0.1	99.1	0.01	0.99
Married	U	0.55	0.55	0.9		0.12	0.90
	M	0.55	0.55	0.7	21.6	0.08	0.94
Head sex	U	0.70	0.69	1.3		0.18	0.86
	M	0.70	0.70	0.5	65.5	0.05	0.96
Primary educ.	U	0.59	0.56	6.1		0.82	0.41
	M	0.58	0.58	1.7	72.2	0.19	0.85
Secondary educ.	U	0.07	0.09	-7.5		-1.00	0.32
	M	0.07	0.08	-0.5	92.8	-0.06	0.95
Southern Province	U	0.34	0.31	6.4		0.87	0.38
	M	0.35	0.35	-1.6	75.4	-0.17	0.87
Western Province	U	0.36	0.26	21.3		2.96	0.00
	M	0.36	0.35	1.4	93.4	0.15	0.88
Northern Province	U	0.13	0.17	-11.5		-1.52	0.13
	M	0.12	0.11	2.6	77	0.32	0.75
Eastern Province	U	0.16	0.15	3		0.42	0.68
	M	0.16	0.17	-2.5	19.1	-0.27	0.79
Urban	U	0.10	0.18	-24.7		-3.16	0.00
	M	0.09	0.09	0.7	97	0.10	0.92
Livestock Ownership	U	0.71	0.64	15		2.01	0.05
	M	0.72	0.72	1.3	91.2	0.15	0.88
Land Ownership	U	3.39	3.20	14.8		1.97	0.05
	M	3.45	3.47	-1.4	90.7	-0.17	0.86
Land irrigated (%)	U	0.01	0.02	-6.1		-0.76	0.45
	M	0.01	0.01	0.1	98.1	0.01	0.99
Ln Food Expenditure (ae)	U	11.63	11.83	-19.8		-2.62	0.01
	M	11.63	11.71	-7.3	63.4	-0.85	0.39
Wealth Index	U	0.48	0.61	-7.5		-0.99	0.32
	M	0.48	0.51	-1.5	79.8	-0.17	0.86

U=unmatched; M=matched

Figure A1 Common support on Consolidation