Relations between Land Tenure Security, Farmland Use and Agricultural Productivity

A Spatio-Temporal Comparative Assessment of Farmland Tenure Arrangements and Agriculture Strategizing in Rwanda (2006-2017)

Singirankabo, U.A.

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Relations between Land Tenure Security, Farmland Use and Agricultural Productivity.
A Spatio-Temporal Comparative Assessment of Farmland Tenure Arrangements and Agriculture Strategizing in Rwanda (2006-2017).

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by

Uwacu Alban SINGIRANKABO

Master of Science degree in Geo-Information Science and Earth Observation (Land administration)
University of Twente – ITC, Enschede, the Netherlands

Born in Kayonza, Rwanda

This dissertation has been approved by the promotors.

Composition of the doctoral committee:

Rector Magnificus	Chairperson
Prof.dr.ir. N.C. van de Giesen	Delft University of Technology, Promotor
Dr.ir. M.W. Ertsen	Delft University of Technology, Copromotor
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Prof. dr. W.T. de Vries	Technical University of Munich
Dr. K. Otsuki	Utrecht University

TU Delft Delft University of Technology

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To my wife Joselyne M. Umunezero and our daughter Jill Aryll Uwacu
for your unconditional support.

Summary

This PhD study aims to assess the relations between land tenure security, farmland use and agricultural productivity. Using a locally-defined research approach, the study explores those relations from a review of the literature to a case study in Rwanda. Therefore, the case study includes four research sites: Gatwe, Nyabubare, Rusebeya and Rutemba, and it follows three research periods within the period 2006-2017.

First, considering land registration as the initial activity that guarantees legal tenure of land, this study carried a review of the scholarly literature on the effect of land registration on these relations. 85 studies were included. The review focused on the regular claim that land registration's facilitation of formal documents-based land dealings leads to investment in a more productive agriculture. I found this claim problematic for three reasons. First, most studies offer no empirical evidence to support this claim. Second, there are suggestions that land registration can actually threaten 'de facto' tenure security or even lead to insecurity of tenure. Third, the gendered realization of land registration and security may lead to uneven distribution of costs and benefits. These effects are however often ignored. Next to suggesting the importance of land information updating and the efficiency of local land management institutions, this review also found that more research with a combined locally-set approach is needed to better understand any relation(s) between land tenure security and agricultural productivity.

In the second part, this study attempted the first and the last problems listed here above by the literature review. I have designed a locally- defined Farmland Tenure Security Index (FLTSI) and applied it to the four case studies in Rwanda. On the basis of a data set collected from four research sites over the course of three agricultural years (2006/2007, 2012/2013, 2016/2017), this study empirically assessed the relations between land tenure security and smallholder farms' crop production in Rwanda. We show that the general assumption that secure land tenure improves farm level harvests, is not found for smallholder farms in Rwanda. My FLTSI is based on plausible threats as conveyed by smallholder farmers at each research site. The findings additionally indicate that the harvest of main crops did neither statistically correlate with this index, nor show differences from the mean at all research sites. Instead, factors mainly related to the ongoing crop intensification program, though threatening tenure security, contributed to the increase of small farm harvests. Lower land tenure security did not affect farmers satisfaction of the crop intensification program Most of them claimed that in the end what matters most is that their harvests continue to increase. The second part concluded that in Rwanda, a new wave of agriculture strategizing contributed to increasing small farms' harvest of prioritized crops and decreasing farmland tenure security simultaneously.

Third, motivated by the previous conclusion in part two, this study assessed the effect of farmland use change on agriculture production. It sought to determine which of the fragmented or

consolidated farmland use earn higher yields for the smallholder farmer in Rwanda. When the agricultural reform started in 2007, the country introduced the Crop Intensification Program (CIP) which promotes farmland Use Consolidation (LUC). Using data collected at the four research sites and considering the three agriculture years, the study confirmed that the CIP/LUC program led to conversion of perennial crops, mainly banana plantations, into seasonal crops prioritized by the program. Overall, this shift in farmland use has created an increase in both harvest and monetary yield of prioritized crops. However, within that general trend, I observed differences: farmers with smaller and/or less farm plots did not realize as much yield increase as those who joined the CIP/LUC program with larger and/or multiple farm plots.

Furthermore, this study made a first attempt to understand the implication of the studied relations on food security. The link between yield and meals per day allowed to demonstrate the farmer's household food access. However, the available data did not allow to extend the analysis to include the nutritious values of the food. Nevertheless, I clearly showed that following the start of the CIP/LUC program, farmers increased their yield and number of meals per day. Future research is need to study the types of food available on the market.

The locally-defined research approach designed for this study combined statistical and qualitative analysis of the information collected from interviews and focus group discussions at a local level. I argue that this approach has contributed to an understanding of those relations that would be overlooked if the research used larger entity setting and econometric methods. This research recommends that a similar approach be applied while studying locally-defined assessment of the relations between land tenure security, farmland use and agricultural productivity. Future research needs to be concentrated on examining these relations from a more operational perspective, taking into account local social-economic and institutional patterns at work. There is a need for a mixed methods approach utilizing experiments as well as randomization, where feasible, in combination with increasing flows of spatial and time-series data from diverse sources. Household-farm panel data collected over long periods of time, combined with simulations, can also provide valuable insights about the relations between land tenure security, farmland use and agricultural productivity.

Samenvatting

Dit promotieonderzoek bespreekt verbanden tussen zekerheid van grondbezit, gebruik van landbouwgrond en landbouwproductiviteit. Deze verbanden worden onderzocht in de lokale context in Rwanda met zowel een literatuuronderzoek als veldonderzoek. Het veldonderzoek omvat vier onderzoeklocaties (Gatwe, Nyabubare, Rusebeya en Rutemba) en is uitgevoerd tijdens drie onderzoeksperioden tussen 2006 en 2017.

Het eerste onderdeel van dit onderzoek bestaat uit een literatuurstudie van 85 wetenschappelijke publicaties over het effect van landregistratie op verbanden tussen de drie bovengenoemde thema's, waarbij landregistratie beschouwd wordt als de primaire activiteit die het wettelijk eigendomsrecht van landbouwgrond garandeert. In deze literatuurstudie wordt de algemeen geaccepteerde veronderstelling dat het faciliteren van formele en gedocumenteerde transacties van grondrechten leidt tot investeringen in een productievere landbouw, besproken. Ik vind deze veronderstelling om drie redenen problematisch. Ten eerste bieden de meeste onderzoeken geen empirisch bewijs die deze veronderstelling ondersteunen. Ten tweede zijn er indicaties dat landregistratie zekerheid van grondbezit kan bedreigen of zelfs tot onzekerheid in grondbezit kan leiden. Ten derde kan landregistratie verschillend effect hebben voor mannen en vrouwen, en zodoende leiden tot een ongelijke verdeling van kosten en baten. Deze effecten worden echter vaak genegeerd. Naast het suggereren van het belang van het actualiseren van gegevens over landregistratie en de efficiëntie van lokale instellingen voor landbeheer, blijkt uit deze literatuurstudie ook dat meer lokaal onderzoek met gecombineerde onderzoeksmethodes nodig is om een beter begrip te krijgen van de relatie(s) tussen zekerheid in grondbezit en landbouwproductiviteit.

Het tweede deel van dit onderzoek is gericht op het eerste en derde probleem genoemd in de literatuurstudie. Ik heb een lokaal gedefinieerde Farmland Tenure Security Index (FLTSI) ontworpen en heb deze toegepast op gegevens uit het veldonderzoek in Rwanda. Mijn FLTSI is gebaseerd op mogelijke bedreigingen voor grondbezit die boeren met kleine landbouwbedrijven noemden. Op basis van een dataset verzameld op vier onderzoeklocaties in de loop van drie landbouwjaren (2006/2007, 2012/2013, 2016/2017), zijn de relaties tussen zekerheid van grondbezit en de gewasproductie van kleine landbouwbedrijven in Rwanda op een empirische wijze geanalyseerd. Het resultaat van deze analyse is dat we geen bewijs zien voor de algemeen geaccepteerde veronderstelling dat zekerheid in grondbezit de oogst van kleine landbouwbedrijven in Rwanda verbetert. Gebaseerd op de bevindingen kan ook gesteld worden dat de oogst van de belangrijkste gewassen niet statistisch correleert met de FLTSI index, noch dat er verschillen zijn tussen de oogst van de belangrijkste gewassen en de gemiddelden op alle onderzoeklocaties. In plaats daarvan zijn het factoren die voornamelijk verband houden met het lopende programma voor gewasintensivering die invloed lijken te hebben op de oogsten, hoewel dit programmade zekerheid van grondbezit vermindert. Deze lagere zekerheid in grondbezit heeft geen invloed op

de tevredenheid van boeren over het programma voor gewasintensivering. De meeste boeren noemen dat uiteindelijk het belangrijkste is dat hun oogsten blijven toenemen. Dit tweede deel concludeert dat in Rwanda een nieuwe golf van landbouwstrategieën heeft bijgedragen aan het verhogen van de oogst van geprioriteerde gewassen voor kleine landbouwbedrijven en tegelijkertijd aan het verminderen van de zekerheid in grondbezit.

Gemotiveerd door de conclusie van het tweede deel van dit onderzoek, gaat het derde deel over het effect van de verandering in landgebruik op de landbouwproductie. Het doel van dit derde deel is om te bepalen hoede gefragmenteerde of geconsolideerde methodes van gebruik van landbouwgrond opbrengsten opleveren voor kleine landbouwbedrijven in Rwanda. Toen de landbouwhervorming in 2007 begon, introduceerde de overheid het Crop Intensification Program (CIP) dat Land Use Consolidation (LUC) voor boeren promootte. Gebruikmakend van gegevens verzameld op de vier onderzoeklocaties en rekening houdend met de drie landbouwjaren, bevestigt dit deel van het onderzoek dat het CIP/LUC-programma leidde tot het vervangen van meerjarige gewassen, voornamelijk bananenplantages, door seizoensgebonden gewassen die door het programma als prioriteit worden beschouwd. Over het algemeen heeft deze verschuiving in het gebruik van landbouwgrond geleid tot een toename van zowel de oogst als de geldopbrengst van deze geprioriteerde gewassen. Binnen die algemene trend zie ik echter verschillen: boeren met kleinere en/of minder percelen ervaren niet zoveel verhoging in opbrengsten als degenen die deelnemen aan het CIP/LUC-programma met grotere en/of meerdere percelen.

Naast het bovengenoemde, is een onderdeel van dit onderzoek ook om de implicaties van de bestudeerde verbanden en voedselzekerheid beter te begrijpen. Het verband tussen de oogst en het aantal maaltijden per dag maakt het mogelijk om de toegang tot voedsel van het huishouden van de boer in kaart te brengen. Op basis van de verzamelde gegevens kan er echter geen analyse gedaan worden wat betreft de voedingswaarden van het voedsel. Desalniettemin heb ik duidelijk aan kunnen tonen dat over het algemeen boeren na de start van het CIP/LUC-programma hun opbrengst en aantal maaltijden per dag hebben verhoogd. Vervolgonderzoek is nodig naar de soorten voedsel die op de markt verkrijgbaar zijn.

De lokaal gedefinieerde onderzoekaanpak die voor dit onderzoek is ontworpen is een combinatie van statistische en kwalitatieve analyse van de gegevens die verzameld zijn uit interviews en discussies van focusgroepen op lokaal niveau. Ik claim dat deze benadering bijdraagt aan het begrijpen van de aan het begin genoemde verbanden, die snel over het hoofd kunnen worden gezien als in het onderzoek grotere entiteiten bekeken worden en econometrische methoden zouden worden gebruikt. Dit onderzoek beveelt aan om een vergelijkbare benadering als de mijne toe te passen bij het bestuderen van lokale verbanden tussen de zekerheid in grondbezit, gebruik van landbouwgrond en landbouwproductiviteit. Toekomstig onderzoek moet gericht worden op het bestuderen van deze verbanden vanuit een meer operationele perspectief, rekening houdend met lokale, sociaal-economische en institutionele patronen. Er is behoefte aan een aanpak met gemengde methoden, waarbij gebruik wordt gemaakt van experimenten en, waar mogelijk, *randomization*, in combinatie met een toename van ruimtelijke en tijdreeksgegevens uit diverse

bronnen. Gegevens van boerenhuishoudens die over een lange periode zijn verzameld, gecombineerd met simulaties, kunnen ook waardevolle inzichten opleveren over de verbanden tussen zekerheid van grondbezit, gebruik van landbouwgrond en landbouwproductiviteit.

Table of content

List of tables

List of figures

1

Introduction

Parts of this chapter are based on:

Singirankabo, U.A., Ertsen, M.W., Relations between Land Tenure Security and Agricultural Productivity: Exploring the Effect of Land Registration. Land 2020, 9, 138. https://doi.org/10.3390/land9050138

Singirankabo, U. A., Ertsen, M. W., & van de Giesen, N. (2022). The relations between farmers' land tenure security and agriculture production. An assessment in the perspective of smallholder farmers in Rwanda. *Land Use Policy, 118*, 106122. doi:https://doi.org/10.1016/j.landusepol.2022.106122

Singirankabo, U.A., Ertsen, M.W., Giesen, N., Securing the Harvest for the Smallholder Farmer in Rwanda: Fragmented or Consolidated Farmland Use? Land 2022, 11, 2023. https://doi.org/10.3390/land11112023

This research looked into the relations between land tenure security, farmland use and farm level agricultural productivity. In particular, it assessed the changes in agriculture production and ascertains their links with land tenure security and farmland use change. To do this, the study developed intensive fieldwork to build a (2006-2017) retrospective study of four research cases. Together with literature on land tenure and agriculture reform programs, the research project could unravel the relations mentioned. From a description of the relations between land tenure security, farmland use and agricultural productivity, this research attempted a locally-defined research approach that assesses those relations using a sample of 400 farmers in Rwanda.

1.1. Rationale and research problem

Securing land tenure has regularly been prioritized by policy-makers to ensure and develop more productive agriculture (Atwood, 1990; Bambio & Bouayad Agha, 2018; Boboya, 2015; Higgins, Balint, Liversage, & Winters, 2018; Holden, Deininger, & Ghebru, 2009; Holden & Ghebru, 2016; Xianlei Ma, Nico Heerink, S. Feng, & Xiaoping Shi, 2017a; Michler & Shively, 2015; Rao, Spoor, Ma, & Shi, 2017). In this journey, land registration has been considered the main intervention and starting point to ensure that tenure is formally recognized and protected against illegal claims of land rights.

The International Federation of Surveyors (FIG) defines land registration as the official recording of legally recognized interests in land (Tahsin & McLaughlin, 2017). The usual proof of formal registration is a legal document ascertaining that the rights held on a plot of land are provided by the law against any third party. Hence, adopting the FAO (2002b) definition, this study considers land tenure security to be the certainty that a person's rights to land is and will be recognized by others and protected in cases of specific challenges. Nonetheless, not all land registration programmes prove to secure land rights, nor instil improvement in agricultural productivity (Ege, 2017; Michler & Shively, 2015; Frank Place & Hazell, 1993). As said in chapter two, the effects of land registration on agricultural productivity are even more unclear.

Land tenure and land titles would have featured prominently in early agricultural economies (Hanstad, 1998; Sjaastad & Bromley, 1997), but traditionally, land tenure security and agricultural productivity have been two separate areas of research. The link between land tenure security and agricultural productivity is therefore a relatively new subject (Holden & Ghebru, 2016; Moor & Nieuwoudt, 1998). Although recent decades have seen many publications research on the subject, the relation between land tenure and production continues to be conceptually described rather than operationally proven (Rockson, Bennett, & Groenendijk, 2013a). Furthermore, the relation itself is still open for debate. Initially, Hanstad (1998) argued that individual and secure land tenure rights are vital components of a productive agricultural sector, which is crucial to poverty alleviation and economic growth. However, Holden and Ghebru (2016) found that, although the links between tenure security and agricultural productivity are of primary interest, the reverse link

can also potentially be important. The authors argue that, given that tenure security is endogenous, a positive correlation between investment and land tenure security could occur, because people invest to become more tenure secure. Empirical evidence to confirm the proposed direct relation, as already noticed early on in the debate (Feder & Noronha, 1987), remains scant.

1.2.The Rwanda case

In many policy programs in sub-Saharan African countries, tenure and use of farmland are seen as constituting fundamental conditions for agriculture production of smallholder farmers. In Rwanda, until the early 2000s, a customary tenure regime prevailed all over the country. The literature emphasizes that the customary systems were ineffective, in the sense that they were dominated by unclear land rights and limited security of tenure (Bizoza & Havugimana, 2013; Musahara, 2006). In addition, due to the growing demographic pressure on land, the agricultural lands in Rwanda were (and are) highly fragmented. Therefore, governmental efforts to improve crop harvest have introduced programs aiming at both land tenure and land use changes. Rwanda introduced two policy programs in 2007. On tenure, the country introduced the Land Tenure Regularization Program (LTRP), aiming to formalize land rights and improve land tenure security. In addition, the Crop Intensification Program (CIP) was launched, with as main goal to increase agricultural productivity of high-potential food crops and to ensure food security and self-sufficiency (GoR, 2011). Hence, the selection of Rwanda as a case study was based on that reform journey.
One of the pillars of the CIP is a Land Use Consolidation approach (LUC) seeking to increase the farmland size and improve farming activities. Bringing individual plots together in terms of land use and agricultural practices, the tenure conditions of these fields does not change for farmers. Individual exploitation, however, is no longer possible. The main reasoning for this policy is that the use of inputs, such as improved seeds and fertilizer, can be translated into profitability for smallholder farmers only if the land fragmentation is overcome. Under the LUC policy, farmers in a given area grow specific food crops in a synchronized fashion with the goal to improve the productivity.

The evolution towards new legal tenure arrangements and consolidated use of farmland has attracted researchers (Bizoza & Havugimana, 2013; Bizoza & Opio-Omoding, 2021; Del Prete, Ghins, Magrini, & Pauw, 2019; Musahara, 2006; Muyombano & Espling, 2020; Ntihinyurwa & Masum, 2017), but little is said on their subsequent relations. This study discusses precisely the relation between tenure arrangements and farmland use consolidation, through the changes in yields that were found at four research sites across Rwanda over the years between 2007 and today. I present the complex relations between land tenure security, land policy (land use consolidation) and agriculture production in this study.

At the time Rwanda launched the LTRP, 80% of Rwanda's land was neither formally demarcated nor registered (Enemark, Bell, Lemmen, & McLaren, 2014). Most of the laws governing land

administration and management in the country had been formulated by the colonial authorities and had remained the same until the 1990s (Mbonigaba & Dusengemungu, 2012). The 2005 Organic Land Law (modified in 2013 (GoR, 2013)) guided the systematic land registration, part of the LTRP program (2007-2013). During the registration period, claims of rights on land were formally recorded, provided that they were adjudicated based on available proof documents held by claimants and in the presence of owners of neighbouring parcels. The LTRP aimed at improving land tenure security; it was believed to play a key role in the facilitation of economic transformation, encourage good land use practices and contribute to land conflict management (GoR, 2009).

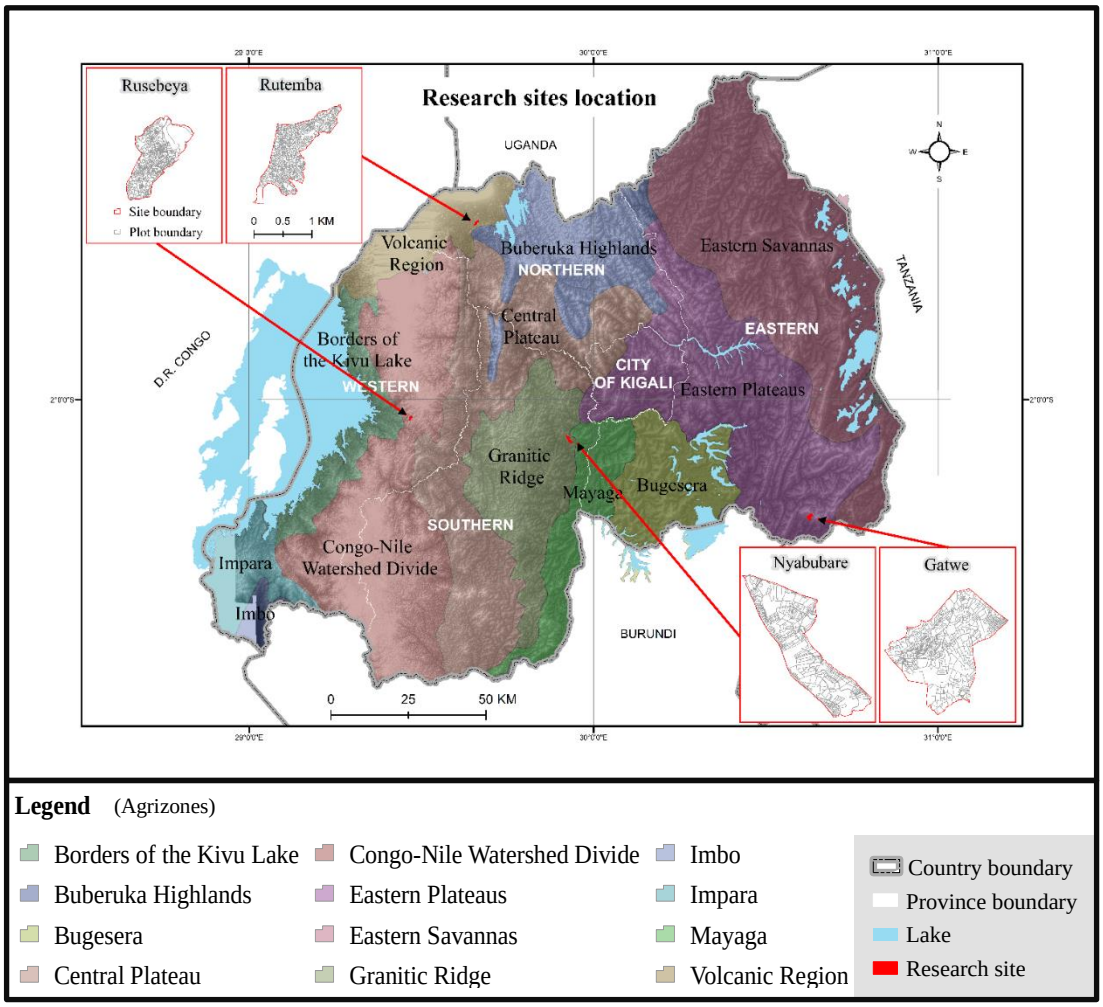

Figure 1. Research sites location

The process of LTR in Rwanda has been hailed as “fit-for-purpose” (Enemark et al., 2014; Milindi Rugema, Birhanu, & Shibeshi, 2021). It systematically registered more than 10 million parcels within 5 years, using local community-based approaches, and established a functional land information system (Enemark et al., 2014; Nishimwe et al., 2020). However, as discussed in

chapter four, research work on the LTR achievement has been contradictory. On one hand, (Santos, Fletschner, Savath, & Peterman, 2014) praised the process and outcome, arguing that local capacity building, awareness-raising campaign, and public dialog events appear to have been particularly effective at increasing (perceived) tenure security. The authors argue that Rwanda's LTRP has had considerable outreach, in line with how LTR was described in the LTRP strategic roadmap (GoR, 2009): "using local capacity to the full". On the other hand, (M. C. Simbizi, 2016) underlines the threats undermining the positive economic outcome and benefits of the LTR. According to the author, these threats included the emergence of new state land use restrictions. In a way, the state might have become a major source of tenure insecurity for the rural poor. Simbizi (2016) highlights the contribution of the LTRP and associated legal and policy reform, in actually weakening existing tenure security. She measures tenure security based on a set of indicators including people, institutions, continuum of land rights and restrictions. Her work triggers to question the impact of the Rwandan state-led systematic land registration, the LTRP and, as a result, to further reflect on the anticipated success of 'land information-based' agricultural reform programs now operating in Rwanda.

Rwanda Vision 2020, published in 2000, acknowledges that the most important issue retarding Rwanda's agricultural development was not land size, but low productivity – which was associated with traditional, peasant-based, subsistence farming (GoR, 2000). In order to change this, several agricultural reform programs were initiated in Rwanda. Within the ongoing agriculture reform, in 2007 the government of Rwanda launched the CIP in all 30 districts of Rwanda, providing at proximity advisory services to farmers, inputs distribution (seeds and fertilizers) and post-harvest technologies (e.g. driers and storage facilities). The CIP is also subsidized by the government through other initiatives, like land-husbandry, irrigation, and mechanization infrastructure development. All these initiatives aimed to bring more land under production, avoid dependency on rain-fed farming system and promote a market-oriented agricultural sector (Mbonigaba & Dusengemungu, 2012).

The component of the CIP that is considered as key for agricultural transformation is land use consolidation (Alphonse Nahayo et al., 2017; Ntihinyurwa & Masum, 2017; USAID Land Project, 2013). Land use consolidation stipulates collective use of neighbouring farming land plots. The Rwanda ministerial order determining the models of land consolidation and its productivity, defines land consolidation as "the unification of land parcels with an estimated easier and productive farming than the fragmented use of farm plots."(GoR, 2010). (Ntihinyurwa & Masum, 2017) define LUC as "a policy in which farmers in a given area with closer parcels grow the same priority crops on a minimum size area of 5 ha in a synchronized manner on the provision of subsidized inputs by the government while the boundaries and rights on parcels remain intact". In Rwanda, therefore, consolidation does not implicate changes in ownership, it is rather the use of land that is changed.

The Government of Rwanda actively promoted the cultivation of a single crop by multiple farmers on a large area in order to increase agricultural production. One of the reasons for this reorganization of agriculture land use was the high growing demographic pressure on land in the past decades, which had resulted in a continued fragmentation of households' plots by inheritance. The 2012 census reported an intercensal (2002-2012) growth rate of 3.2, while the average farmland size was 0.7 Ha (NISR, 2012). However, the process of LUC is not clear when it comes to issues of decision making (Kwabena Obeng Asiama, Voss, Bennett, & Rubanje, 2021). How decisions on farming activities are to be undertaken within consolidated areas, the types of crops to grow, the availability and access to subsidies, when to harvest, and the influence of the individual small farmers on these issues, remains unclear. As such, it remains unclear how the consolidation process possibly affects land tenure security, let alone how it impacts agricultural production.

1.3.Research aim and questions

The study aimed to unravel the complex relations between land tenure security, farmland use and agricultural productivity from field evidence. As such, the study paid a specific attention to the local selection of research area and data collection which appeared in the literature to be a weakness in the current research work on the subject. To achieve the research aim, this study targeted a set of sub-objectives and research questions (table 1).

Table 1. Research sub-objectives and questions

Sub-objectives	Research questions
1 Describing the changes in land tenure security and agricultural productivity operated by land registration programs.	A. What are the effects of land registration on land tenure security and agricultural productivity? B. What is the gap in the literature on the research approach and methods used to study the relations between land tenure security and agricultural productivity?
2 Assessing the link between farmland tenure security and farm level food production in Rwanda.	C. What are the locally-defined elements reflecting the level of farmland tenure security within the smallholder farmers? D. How did the defined farmland tenure security elements contribute to the food production in Rwanda between 2006 and 2017?
3 Assessing the effect of farmland use change on farm level food production in Rwanda.	E. How did farmland use change in the period of 2006 - 2017? F. How did the shift from fragmented farmland use to the consolidated farmland use affect farm level food production?
4 Exploring the future research agenda on the relations between	G. What do locally-defined research approach and methods used in this study mean for future related studies?

	land tenure security, farmland use and agricultural productivity.	H.	What would be future research on the relations between land tenure security, farmland use and agriculture productivity?

1.4.Research outline and thesis structure

The locally-defined research approach being the core of this study, the research area consisted of four localities within the four provinces of Rwanda: namely, Kirehe in the Eastern province; Musanze in the Northern province; Karongi in the Western province and Kamonyi in the Southern province. The four case studies have been selected following a set of criteria defined based on literature review and after the preliminary field visit. The criteria of selection considered the systematic land registration and shifts of tenure regimes; disagreements over land; performance in CIP/LUC; size of farmland; size of farmers' household; and proximity to the market (urban areas, borders). More details of the research methodology can be found in **Chapter 2.** "Research approach and methods". This chapter bundles the methodological steps that were employed in the respective chapters. In **Chapter 3. "**Relations between Land Tenure Security and Agricultural Productivity: Exploring the Effect of Land Registration", a literature study providing an overview of research on the effects of land registration on land tenure security and agricultural productivity is presented. The chapter highlights and synthesizes the current global debates; explains how claims that legal tenure does (not) improve agricultural productivity were made and which data sets are mobilized. From an intensive review of a broad set of literature related to land information recording, land tenure security and agricultural productivity, the chapter provides a new synthesis of those effects.

In **Chapter 4.** "The relations between farmers' land tenure security and agriculture production. An assessment in the perspective of smallholder farmers in Rwanda", the field research data are explored to discuss land tenure security. For the period before, during and after the systematic land registration in Rwanda (2006-2013-2017), the chapter measures land tenure security. It looks at the dynamics of tenure systems, procedures and processes of land registration and information updating, disagreements over land, decisions over land use and rights holders' use of land for investment in agriculture. Then, the chapter elaborates on the changes in agriculture productivity to assess correlations with the measured LTS. It will be shown that the relation between tenure and production in Rwanda is complex. As this complexity is closely linked to Rwanda's agrarian policy, this aspect is discussed in **Chapter 5.** "Securing the harvest for the smallholder farmer in Rwanda: Fragmented or consolidated farmland use?". This chapter analyses in much more detail how agricultural productivity in the four field research areas can (not) be linked to the land use policy programs in Rwanda. The chapter also shows that effects of policies on production are not equally distributed over the farming population.

Finally, **Chapter 6.** "Conclusions and recommendations" summarizes the main findings of the study, focusing on the relations between land tenure security, farmland use and farm level agricultural productivity. After a brief discussion on the related aspect of food security – an

important policy target in Rwanda – the study concludes with methodological suggestions for further research.

2

Research approach and methods

Parts of this chapter are based on:

Singirankabo, U.A., Ertsen, M.W., Relations between Land Tenure Security and Agricultural Productivity: Exploring the Effect of Land Registration. Land 2020, 9, 138. https://doi.org/10.3390/land9050138

Singirankabo, U. A., Ertsen, M. W., & van de Giesen, N. (2022). The relations between farmers' land tenure security and agriculture production. An assessment in the perspective of smallholder farmers in Rwanda. *Land Use Policy, 118*, 106122. doi:https://doi.org/10.1016/j.landusepol.2022.106122

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2.1. Introduction

The research approach is derived from the review of the scholarly literature. The reviewed materials suggested that many studies on the relations between land tenure security and agricultural productivity offer indirect evidences, in terms of secondary data rather than direct field evidence. The review highlighted weaknesses in the methods and techniques used to collect and analyse data, as well as the types of data mobilized to study the relations. The use of representatives' data from local authorities and farmers cooperatives instead of from farmers themselves. Therefore, to overcome those weaknesses, this study used first hand on data collected from farmers. This was done by using a locally-defined research approach. The chapter provides an overview of the research methods of chapters 3, 4 and 5. As such, this chapter overlaps with parts of these chapters. The benefit of this chapter is that the reader has a complete of the methods applied. The research is elaborated in three elements as depicted in figure 2.

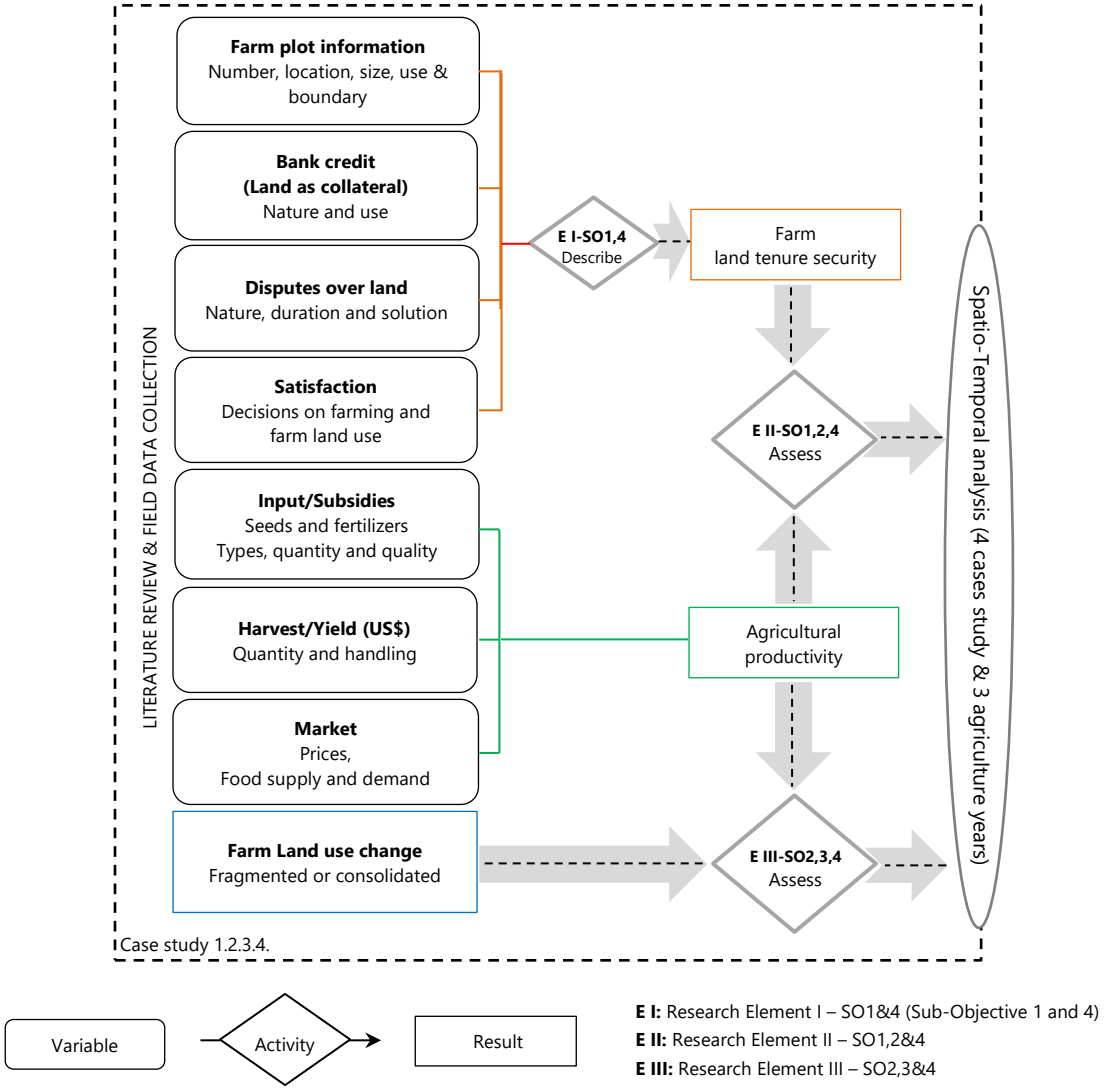


Figure 2. Research approach

Each of these elements focuses on the sub-objectives as described below:

- **Element I (Sub-objective 1 and 4)**

Systematic land registration – Farmland tenure security

Element one consisted of a description of the changes in land tenure security operated by the systematic land registration program and the land information updating in Rwanda. Using the information collected from the local farmers, I designed a locally-defined farmland tenure security index (FLTSI).

- **Element II (Sub-objectives 1, 2 and 4)**

Farmland tenure security - Agricultural productivity

Element two of this research assessed the relations between farmland tenure security and agricultural productivity. The study statistically correlated the designed FLTSI to a set of variables reflecting the agricultural year production. The analysis was conducted on the three research periods and with respect to the four research sites.

- **Element III (Sub-objectives 2, 3 and 4)**

Farmland use forms - Agricultural productivity

The third element assessed the relations between farmland use forms and agricultural productivity. The research sought the difference in terms of agricultural productivity under fragmented or consolidated farmland use. Retrospectively, the research investigated agricultural productivity taking into account farming techniques, inputs that were introduced and resulting agricultural yield in the period 2006-2017.

2.2.Literature review

As stated before figure 2, the research started by reviewing literature to identify the effects of land registration on agricultural productivity and determines any gaps yet to fill in. A systematic search of literature was conducted to highlight current arguments and research findings on those effects. The same literature was subsequently used to determine gaps in the literature on the subject. The methods used to search and review the literature are described in (Cooper, 1998b). The review followed five stages: (1) Problem formulation, (2) literature search, (3) data quality evaluation, (4) analysis and interpretation, and (5) presentation of results.

2.2.1. Search Strategy

The literature search was computer-based. I developed a strategy using a set of key words and other advanced search options such as Boolean operations (and, or) and truncation.

That allowed to formulate the following search query:

> (("land registration" OR "land certification" OR "land tenure regulari*" OR "land reform" OR "land tenure" OR "land tenure security" OR "customary land tenure" OR "land right*" OR "land governance" OR "land information") AND ("agricultur* producti*" OR "agricultur* transform*" OR "investment in agriculture*" OR "Fertilizer*")).

Table 2. Inclusion criteria

Criteria	**Rationale**
Inclusion criteria first screening	
1. Study deals with the relations between land tenure security (LTS) and agricultural productivity with a lean-to the effect of land registration, land certification, land titling, land reform, land tenure regularization, land governance.	▪ This is the scope of our study
2. Study was published between 1980 and 2019, using data collected within this period, and, if the study reviews other research work, that research work should have been conducted within this period.	▪ We found that the year 1980 arguably corresponds to the recent history and development of evolutionary theory of property rights (James E. Krier, 2009; Richard A. Epstein, 1980)
3. Considered for our review are peer reviewed journal articles, books and technical reports.	▪ This ensures a minimum quality level and avoids broadening the search to an unmanageable level.
Inclusion criteria second screening	
4. The study's abstract opens a clear path to explore the effect of land registration on the relations between land tenure security and agricultural productivity. For example, we assess if the study contains sufficient details for methodology to be assessed and results to be properly interpreted.	▪ This ensures a proper assessment of findings.

The search query and a number of other combinations of its composing key words were used on different search databases. The search comprised databases like SCOPUS, Web of Science, Elsevier, GEOBASE, Springer Link, AJOL, JSTOR and libraries to which I are subscribed were used. In addition, I utilized available resources on the World Wide Web.

The preliminary search attempts generated many resources that were not all useful. Then, I set boundaries of this review. Three types of documents were considered for the review: (1) Peer-reviewed journal articles, (2) books, (3) technical reports (grey literature) published by

international organisation. Only resources written in English, addressing the relations between land registration, land tenure security and agricultural productivity, were selected for the review.

A priori methodological quality judgment criteria (Cooper, 1998b) were applied to exclude studies whose methodological quality was difficult to assess in a systematic way (mainly conference papers and national reports).

The review period was set from 1980–2019, bearing in mind that the year 1980 arguably corresponds to the recent history and development of evolutionary theory of property rights (Alston & Mueller, 2015; Krier, 2009; Platteau, 2008). This year marked the start of heated debates on land reform in many countries with developing economies. A data extraction form was used to systematically fill in the following information: (1) Type of document, (2) the title, (3) field of the study, (4) country/sub-region/region, (5) meaning, definition or views of the effects of land registration on agricultural productivity (6) online library where the document had been accessed, (7) reference and (8) search date. A critical descriptive analysis was conducted using the technique of topic mapping (Hart, 2007). After exploring 1940 studies, I considered 85 for this study (see Figure 4 in Chapter 3). Of these 85 studies, 79 are journal articles, 2 technical reports and 4 books.

Of the 85 studies reviewed, 45 discussed issues in 22 countries with developing economies (see Figure 5 in Chapter 3). The other 40 consist of regional and international studies. The distribution of reviewed studies per year of publication illustrates their gradual increase in numbers from 1980's to the recent years (see Figure 6 in Chapter 3).

2.2.2. Assessment of the content of the reviewed studies

The 85 texts discussed in this chapter cover a wide range of topics concerning land registration, land reform, land tenure activities and outcomes, as well as agricultural productivity. The review followed a narrative synthesis approach (Popay et al., 2006). I identified and assessed the main claims made concerning the effect of land registration on the relations between land tenure security and agricultural productivity. This was done by categorizing the evidence found in the studies I reviewed (Table 3).

Table 3. Assessment of the evidence on the effect of land registration on the relations between land tenure security and agricultural productivity

Category	Rationale	Reviewed studies %
Strong evidence	Correlation between land tenure security and agricultural productivity calculated before and after land registration using panel data about: • Cases of conflicts over land • Loans used to invest in agricultural activities (fertilizers, seeds, irrigation) • Investment in agriculture • Farm harvest; • Farm technical efficiency following land registration; • Improvements in legal land (rights) transactions.	54
Weak evidence	The relations between land tenure security and agricultural productivity may exist, but they are difficult to measure given that land registration alone cannot have an effect; The effect exists indirectly through enabling design and implementation of developmental strategies such as taxation, land use plan, land consolidation, agricultural transformation.	34
No evidence	This category contains the studies claiming, on the contrary, that land registration threatens the long-term established de facto tenure security and agricultural productivity.	12

In general, the research work that I reviewed is mostly based on literature review and secondary data sources. When primary data are mobilized, the methodological approaches vary, although they tend to converge to a combination of econometric modelling and statistical analysis. The dominant methods are: (1) Stochastic Production Frontier (SPF) models using data from household panel surveys (Ma et al., 2017a; Michler & Shively, 2015). (2) Conditional Maximum Likelihood (CML) [2]. (3) Two-step conditional maximum likelihood (2SCML) techniques: linear probability regression for the discrete variable and probit regression (Ghebru & Lambrecht, 2017; Rao et al., 2017).

2.3. Case study

To engage with relevant direct primary data, a case study in four areas was set up in Rwanda. How the areas were selected, the approach followed to assess land tenure security, farm yield, farmland use change and the statistical methods used to assess the links between those three variables within and across the research sites are described below.

2.3.1. Study area selection and sampling

The study involved smallholder farmers across four study sites, one in each of the four Provinces in Rwanda: Gatwe in the Eastern Province, Nyabubare in the Southern Province, Rusebeya in the Western Province and Rutemba in the Northern Province (Figure 3).
The study sites have in common that they are located in districts where pilot trials of the land tenure regularizations were conducted. Hence, the sites represent areas where the formalization of land rights started in the country. Other selection criteria were linked with the performance in the CIP/LUC program, including number and size of farmland plots per household, and agriculture zoning (Table 4). Those criteria vary from site to site, offering the possibility of a comparative analysis. Considering the systematic implementation of land tenure registration and CIP/LUC, I assumed that farmers at the research sites shared an awareness of these programs – which was confirmed when visiting the sites.

Table 4. Research sites selection.

Study area	**Selection criteria**
Gatwe Eastern Province	- High performer in the CIP/LUC program - Less populated and grouped settlements (larger farm plots) - Eastern lowlands with a tropical climate
Nyabubare Southern Province	- Respondent farmers have not yet joined the CIP/LUC program - Big size of the farm plots but less number per farmer - Central plateau with granitic ridge alternating hills
Rusebeya Western Province	- CIP/LUC started in 2014 (6 years after Gatwe and Rutemba) - Average size of farm plots - Western mountainous landscape with a rainy climate
Rutemba Northern Province	- High performer of the CIP/LUC program - High number of farm plots but small size plots - Volcanic fertile soil and a rainy climate

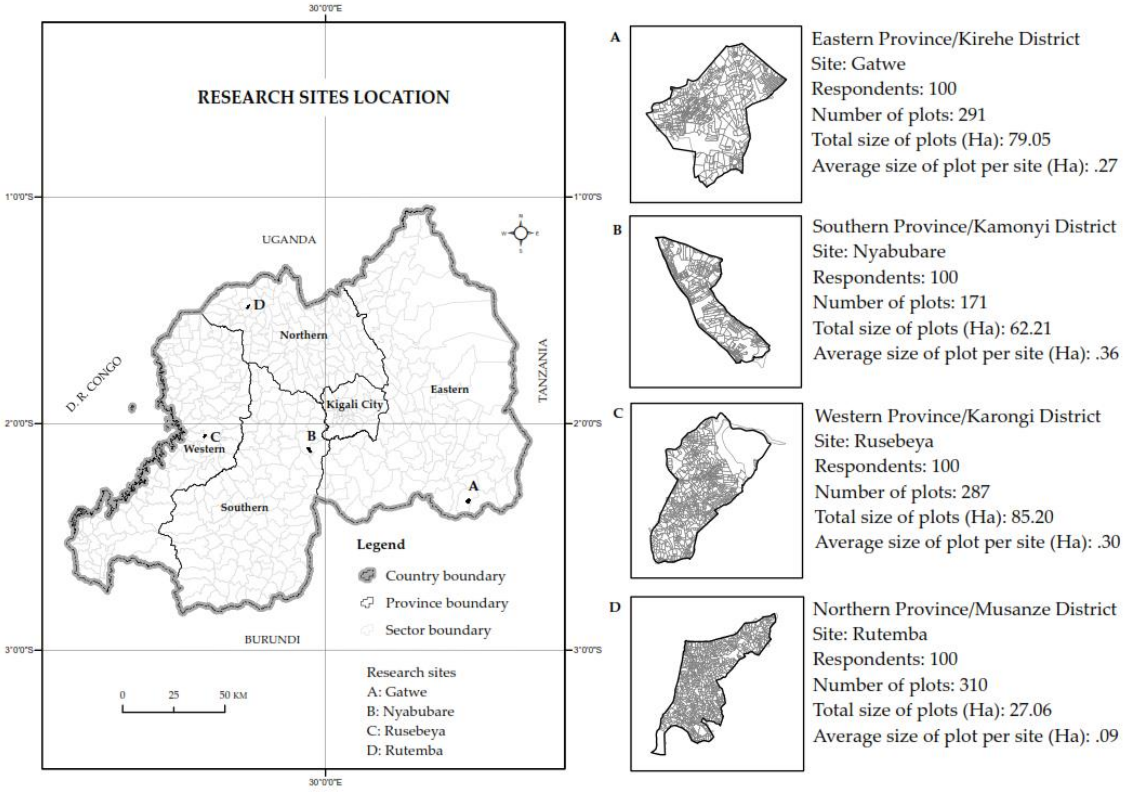


Figure 3. Study sites description

Per site, a questionnaire was administered to the first 100 random farmers who accepted to be part of the study (Table 5). With the help of three enumerators and carrying a written authorisation from local administration, I entered the research site. One household at a time, I sat with the first willing 100 farmers to fill the questionnaire.

Table 5. Sample size

Research site	Province	District	Population	Household	Sample size
Nyabubare	Southern	Kamonyi	501	100	100
Rusebeya	Western	Karongi	450	110	100
Rutemba	Northern	Musanze	887	178	100
Gatwe	Eastern	Kirehe	576	107	100

2.3.2. Research period and primary data collection

The survey was carried in two periods, namely July to September 2018 and July to October 2019. In the process, three techniques of data collection were applied: (1) an appropriate semi-structured questionnaire was designed for the farmers, based on the initial analysis of published materials; (2) semi-structured face-to-face interviews were conducted with officials working in land management and agriculture, including local agronomists and land management officers; (3) focus group discussions were conducted with farmers within their cooperatives (Table 6).

Table 6. Composition of participants in FGDs per research site

Research site	Number of participants in FGD	
	Male	Female
Nyabubare	3	2
Rusebeya	4	4
Rutemba	7	3
Gatwe	5	4

In case I could not collect records either from farmers, their cooperatives or local authorities in charge, I asked the farmers to retrace their tenure and agricultural activities. This allowed to collect retrospective data over three research periods coinciding with three agriculture years/seasons:

1. 2006/2007, when almost all information on land was not formally recorded in rural areas;
2. 2012/2013, the systematic land registration period; and
3. 2016/2017, the period after registration.

The generated dataset covers farmers' plots biography and their agriculture production. In particular, the survey focused on discerning the legal land tenure, agriculture inputs, harvested crops, and the farmer's participation in decision making concerning farming activities.

Table 7. Research period

Research Period	Rationale
2006/2007 Before formal registration of land rights	Insights on land tenure arrangement and the status of land tenure security before registration. In addition, the study looks at the land use change, if land was used for agriculture then, identify farming techniques and production
2012/2013 During the systematic land registration	During this period, the systematic land registration took place. Land rights holders registered their rights for the first time through land demarcation and adjudication. In addition, the country undertook agricultural transformation programs starting with the implementation of the crop intensification program that launched land use consolidation. The research investigates both processes and identifies correlations.
2016/2017 After the systematic land registration	5 years after land registration, the research assesses the effect of (legal) land tenure security brought by the land tenure regularizations program and, in particular, land registration and titling.

The retrospective nature of the dataset used in this study may generate uncertainty and limitations of interpretation. Nevertheless, I believe that the approach followed allowed to collect the most accurate data possible given that in most cases I could cross-check the content with documented records found in the local sector or the district archives.

2.3.3. Secondary data

To complete the dataset, especially to fully retrace the changes in land tenure security and agriculture production within the ten years period of this study, I used documentary evidence from various relevant sources. I collected plot indexes and associated information on land registration, tenure and use from the Ministry of Environment (MoE), the Rwanda Land Management and Use Authority, and the District One-Stop Centres. For information on past harvests and agriculture inputs, I visited the libraries of the Rwanda Ministry of Agriculture and Animal Resources (MINAGRI), agriculture projects on the site, and farmers cooperatives. Finally, secondary data were collected from local government offices at district, sector and cell levels, where data on the use and management of land, as well as information on the implementation of LTRP and CIP/LUC could be found.

2.3.4. Descriptive statistics

The analysis of our data from three periods and four sites, started with descriptive statistics. The description comprised the variables of sex, age, education and marital status of the heads of households, as well as plot-related data (size, number and information on land tenure of the

surveyed farmland plots). I counted frequency and percentile of respondents per variable, and calculated the central tendency mean and standard deviation.

2.3.5. Land Tenure Security Index

The perception of land rights on a continual basis, which summarises the definition of land tenure security, has been often regarded as deriving from ownership rather than being associated with the use of land. This definition was found to have limits, especially when the research setting aims to understand LTS at a local level (Keovilignavong & Suhardiman, 2020). Recent research work emphasized the need for a combined locally-set approach to study the relations between LTS and agriculture production (Rockson, Bennett, & Groenendijk, 2013b). Therefore, this study designed a locally-defined Farmland Tenure Security Index (FLTSI), that not only features the frequently used definition of LTS, but also includes farmer perceptions of LTS at our research sites in Rwanda. The results from three focus group discussions underlined three most threatening variables: (1) Disagreements over land; (2) Decisions on farmland use; (3) Decisions on crops to cultivate.

I added the variable (4) Access to bank credits with farm plots as collateral. Formalising land rights has long been branded as a key element to bring about higher levels of access to credit and investment (De Soto, 2000; Klaus Deininger & Jin, 2006; Higgins et al., 2018; Ngango & Hong, 2021; Rashid, 2021; Vu & Goto, 2020). Indeed, formal (legal) tenure grants the use of land as a collateral. Therefore, provided that other enabling conditions exist, that landholders perceive legal tenure as more useful than alternative strategies and instruments to secure transactions, and that landholders actually register transactions, investments may stimulate agricultural productivity among other economic activities (Barry & Danso, 2014; Rao, Spoor, Ma, & Shi, 2020). In his study carried in North-East Ghana, (Bugri, 2008) claims that access to credit and other agricultural inputs, such as seeds and fertilisers by farmers, is important for enhanced agricultural production.

These four variables were combined into an index to determine the level of farmland tenure security (FLTS). The design of our locally-defined FLTSI was motivated by two elements: (1) the frequently used definition of land tenure security and (2) the theory of change of land tenure security activities. According to the definition of LTS retained for this study, LTS is realized when individual land rights are perceived on a continuous basis, free from imposition or interference from outside sources, as well as ability to reap the benefits of labour and capital invested in that land either in use or upon transfer to another holder (Bruce, 1993; M. C. D. Simbizi, Bennett, & Zevenbergen, 2014). On the other hand, the standard theory of change of LTS activities stipulates that registering land rights improves LTS, and that the gained LTS stimulates rights holders to invest and improve agriculture production (Bizoza & Opio-Omoding, 2021; Higgins et al., 2018). The design and operationalisation of FLTS in this study was an attempt to study the validity of such LTS-related claims. It is a locally-defined set, linked to the agriculture production of the

research sites. As such, it should not automatically be considered as an overall definition of LTS in Rwanda.

The locally-defined FLTSI was preferred over a Principal Component Analysis (PCA) because, through the focus group discussions, information was available as to what farmers themselves find important in this context. A PCA would be less informative because the meaning of the major components would remain somewhat arbitrary.

2.3.6. Total farm yield

To allow a comparison between the different sites and their crops over the research period, the monetary yield was used. The monetary yield was calculated by multiplying each crop harvest by its unit price in the relevant year. The obtained yield was then summed up to calculate the yield per farmer and per plot in each research site with respect to the research period. I calculated the percentage increase of yield between two research periods as

$$PI = (B-A)/A*100$$

And

$$PI = (C-B)/B*100$$

with

PI is the percentage increase between research period B and research period A
A is the first research period (Agriculture year 2006/2007)
B is the second research period (agriculture year 2012/2013)
C is the third research period (agriculture year 2016/2017)

2.3.7. Farmer's responses

Thematic analysis was used to identify and analyse patterns in the qualitative interview data. The interviews were translated from Kinyarwanda to English, transcribed, and thematically coded. Thus, data collected was analysed with the help of the Statistical Package for Social Sciences (SPSS) for the presentation of results. To assess farmer satisfaction over farming activities, I used a Likert scale. The farming activities include decisions over LUC and decisions on the selection and growing of crops. The respondents were requested to rate the degree of satisfaction on a 5-point Likert scale from 1 to 5, where 1 symbolises 'Not at all satisfied' and 5 represents 'Very satisfied'. Consequently, the data was analysed for statistical correlations using SPSS Version 23.0, as explained below.

2.3.8. Statistical correlations between tenure and selected variables

As I was interested in the potential influence of several variables on the actual yields of farmers in the different years and sites, I first applied a standard Pearson correlation computation.

$$r_{xy} = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \sum(x_i - \bar{y})^2}}$$

Where for each crop

r_{xy} the correlation coefficient of the linear relationship between the variables x and the yield
x_i the values of the x-variable per household
$\bar{x}$ the mean of the values of the x-variable per research site
y_i the yield-variable per farmer
$\bar{y}$ the mean of the yield-variable per research site

The difference of the computation is to be found in variable x, which can be:

- Our FLTS index value;
- The satisfaction over decisions on farming;
- The size of farm plots per household;
- The number of farm plots per household; or
- The households receiving subsidies.

As the goal of this study was to assess the relation between land tenure security and agriculture production of farmers in Rwanda, I performed an additional statistical test in the form of the One-way ANOVA test. The independent variable was our FLTSI. The dependent variable was the harvest of the main crops produced over the course of the three research periods. Using these variables, I sought to answer the main research question

Does a statistically robust relationship exist between small holder farmers LTS index and their harvest of the main crops?

I prepared two hypotheses:

H_0: There is no statistically significant relationship between small holder farmers LTS index and their harvest of the main crops.

H_1: There is a statistically significant relationship between small holder farmers LTS index and their harvest of the main crops.

Three one-way ANOVA tests were conducted at each site to evaluate the relationship between FLTS and total yield per size of the farm plots. The independent variable, FLTSI, included five levels: from 0 (low FLTS) to 4 (High FLTS). The dependent variable was the total yield in US$ of identified main crops at each research site.

2.3.9. Farmland use change

To validate and compare the changes as found in primary and secondary data, I used satellite images retrieved from Google Earth on 7th September 2021. I created feature classes containing place marks of the four research sites and exported them as shape files to Google Earth. The images with marked places were imported into ArcGIS 10.5 for further processing. The images were georeferenced using the place marks priori created and marked in Google Earth and projected to WGS_1984 Transverse Mercator. The images used are not of the same period of the years. Hence, I were not able to determine the variability in seasonal crops. Nonetheless, perennial crops like banana and trees could be identified. These can be used as indicators of land use change, as those perennial crops tend to be on separate farm plots and were therefore removed when adopting the land use consolidation approach. A combination of supervised classification using sample signatures and digitization of discrete areas on the images was applied. The classification followed a maximum likelihood technique.

2.3.10. Yield variation per farmland use

To be able to compare the developments of harvests across years and research sites, I converted harvest amounts in monetary value. To measure the variation in monetary yield across the research periods, the year 2007 was taken as baseline. I calculated the farmers ability to buy the same food that they used to harvest before the farmland use consolidation in the other two research periods. For example, for the research period 2013, the harvest of 2013 was subtracted from that of 2007 (calculation: a, c). Then, I multiplied the obtained additional harvest with the crop prices of 2013 (calculation: b. d). With reference to table 1, I was able to calculate the additional yield for crops that are prioritised by the land use consolidation program, and for the remaining crops harvested by the farmer. I repeated the same calculations for the research period 2017, keeping 2007 as reference. Please note that I did not study the nutritional value of harvests or the ability to actually buy the food with the money earned.

Calculation:
Using the example of the Gatwe research site, here I calculated the additional yields for the research period 2013.

LUC crops	(a) $\text{Harvest 2013}_{(\text{maize, beans, rice})} - \text{Harvest 2007}_{(\text{maize, beans, rice})} = \text{AH}_{(\text{maize, beans, rice})}$
	(b) $\text{AH}_{(\text{maize, beans, rice})} * \text{Price 2013}_{(\text{maize, beans, rice})} = \text{AY}_{(\text{maize, beans, rice})}$
Other crops	(c) $\text{Harvest 2013}_{(\text{banana, coffee})} - \text{Harvest 2007}_{(\text{banana, coffee})} = \text{AH}_{(\text{banana, coffee})}$
	(d) $\text{AH}_{(\text{banana, coffee})} * \text{Price 2013}_{(\text{banana, coffee})} = \text{AY}_{(\text{banana, coffee})}$

AH, additional harvest
AY, additional monetary yield

2.3.11. Sign test

I used the sign test to determine if there were increases in the median of the yield between different years. The sign test is a non-parametric test that does not make assumptions about the underlying distribution of the variables. As such, it is more conservative than, say, a t-test, which assumes normality of the underlying distribution. The sign test determines the chance that the median yield from one year is larger than the median yield from another year. I calculate the chance that the number of farms with an increase in yield could be explained by random chance and subtract this chance from one. So, if for a given year, there are 62 out of 100 farms with a yield higher than the median yield of a previous year, I calculate what the chance would be that this is due to random chance. Or, if I would flip a fair coin 100 times, what would be the chance that I have head 62 times. This follows a binomial distribution and the chance would in this case be 0.60% - which means there is a chance of 99.4% this is not due to random chance

3

Relations between land tenure security and agricultural productivity: exploring the effect of land registration

This chapter is based on:

Singirankabo, U. A., & Ertsen, M. W. (2020). Relations between Land Tenure Security and Agricultural Productivity: Exploring the Effect of Land Registration. *Land, 9*(5). doi:10.3390/land9050138

Abstract

This chapter reviews the scholarly literature discussing the effect(s) of land registration on the relations between land tenure security and agricultural productivity. Using 85 studies, the chapter focuses on the regular claim that land registration's facilitation of formal documents-based land dealings leads to investment in a more productive agriculture. The chapter shows that this claim is problematic for three reasons. First, most studies offer no empirical evidence to support the claim on the above-mentioned effect. Second, there are suggestions that land registration can actually threaten 'de facto' tenure security or even lead to insecurity of tenure. Third, the gendered realization of land registration and security may lead to uneven distribution of costs and benefits, but these effects are often ignored. Next to suggesting the importance of land information updating and the efficiency of local land management institutions, this chapter also finds that more research with a combined locally-set approach is needed to better understand any relation(s) between land tenure security and agricultural productivity.

Keywords: land tenure security; agricultural productivity; land registration

3.1. Introduction

Securing land tenure has regularly been prioritized by policy-makers to ensure and develop more productive agriculture (Atwood, 1990; Bambio & Bouayad Agha, 2018; Boboya, 2015; Higgins et al., 2018; Holden et al., 2009; Holden & Ghebru, 2016; Ma et al., 2017a; Michler & Shively, 2015; Rao et al., 2017). In this journey, land registration has been considered the main intervention and starting point to ensure that tenure is formally recognized and protected against illegal claims of land rights. The International Federation of Surveyors (FIG) defines land registration as the official recording of legally recognized interests in land (Tahsin & McLaughlin, 2017). The usual proof of formal registration is a legal document ascertaining that the rights held on a plot of land are provided by the law against any third party. Hence, adopting the FAO (2002b) definition, this chapter considers land tenure security to be the certainty that a person's rights to land is and will be recognized by others and protected in cases of specific challenges. Nonetheless, not all land registration programmes prove to secure land rights, nor instill improvement in agricultural productivity (Ege, 2017; Michler & Shively, 2015; Frank Place & Hazell, 1993). The effects of land registration on agricultural productivity are even more unclear, however, as this chapter will show.

Land tenure and land titles would have featured prominently in early agricultural economies (Hanstad, 1998; Sjaastad & Bromley, 1997), but traditionally, land tenure security and agricultural productivity have been two separate areas of research. The link between land tenure security and agricultural productivity is therefore a relatively new subject (Holden & Ghebru, 2016; Moor & Nieuwoudt, 1998). Although recent decades have seen many publications research on the subject, the relation between land tenure and production continues to be conceptually described rather than operationally proven (Rockson et al., 2013a). Furthermore, the relation itself is still open for

debate. Initially, Hanstad (1998) argued that individual and secure land tenure rights are vital components of a productive agricultural sector, which is crucial to poverty alleviation and economic growth. However, Holden and Ghebru (2016) found that, although the links between tenure security and agricultural productivity are of primary interest, the reverse link can also potentially be important. The authors argue that, given that tenure security is endogenous, a positive correlation between investment and land tenure security could occur, because people invest to become more tenure secure. Empirical evidence to confirm the proposed direct relation, as already noticed early on in the debate (Feder & Noronha, 1987), remains scant.

The purpose of this paper is therefore to assess in considerable detail how the relations between land registration, land tenure security, and agricultural productivity are discussed in the scholarly literature. We identify the extent of and evidence for those relations, and indicate plausible needs for further research on the subject. The chapter discusses the claim, found implicitly or explicitly in most of the literature, that land registration would realize land tenure security, which would allow—envisaging their tenure sustainably—farmers to use their land plots as collateral to get loans from the bank and invest in new farming systems and technology to increase the yield at a lower cost of production. In fact, holding legal proof of land rights is claimed to stimulate farmers' initiative to invest in a more productive agriculture.

We provide three (sets of) remarks that suggest that this major claim is less straightforward than often presented.

1. A reasonable number of research work found quite low effects at most or no evidence at all to prove such relations, especially in the customary tenure regime in Sub-Saharan Africa.
2. Some studies suggest that land registrations can threaten 'de facto' tenure security or even lead to insecurity of tenure which affects agricultural productivity.
3. Whereas women land rights and their role in agriculture production is discussed, the literature is relatively silent on specifying how costs and benefits of land registration are distributed over male and female farmers.

Furthermore, we explore the evolution of research on the relations between land registration and agricultural productivity. Primarily, since the early 1980s, transactions over land have been considered as enabler of any possible effect of formalizing land tenure on agricultural productivity. Apart from the 'legal papers-loan-investment' theory referred to above, the literature argues that land registration's legal outcome facilitates land transactions by supporting the possibility to sell, buy and lease land in a more secure way (Bambio & Bouayad Agha, 2018; Holden & Ghebru, 2016; Smith, 2004). These transactions may or may not reach out to investments in agriculture. As the research amassed, a new aspect emerged: the importance of local settings.

In addition to the economic aspect, recent literature underlines the role of locally formed institutions to strengthen the relations we discuss (Higgins et al., 2018; Keovilignavong & Suhardiman, 2019). However, this new aspect still lacks field evidence, since a number of the

reviewed texts are synthesis and review papers themselves. In general, the documents reviewed for this chapter pay less attention to the process of land registration itself, instead prioritizing the resulting land tenure security in their analysis. We argue that land registration programmes and procedures to implement these programmes are among the major reasons of failure to achieve stronger land tenure security. Thus, land registration and land information updating processes should be part of studies on land tenure and productivity.

Below, we will describe how we selected the 85 studies that we used in our analysis, followed by a discussion on the main claim discussed in this chapter and depicted above. After discussing the three categories of remarks and the importance of the registration process, we conclude with implications of the results.

3.2. Materials and Methods

This study reviews literature to identify the effects of land registration on agricultural productivity and determines any gaps yet to fill in. Given the review nature of this chapter, we adopted the review methods used in the research paper written by M. C. D. Simbizi et al. (2014). A systematic search of literature was conducted to highlight current arguments and research findings on those effects. The same literature was subsequently used to determine gaps in the literature on the subject. The methods used to search and review the literature are described in (Cooper, 1998). The review followed three stages: (1) Problem formulation, (2) literature search, (3) data quality

3.2.1. Search Strategy

The literature search was computer-based. We developed a strategy using a set of key words and other advanced search options such as Boolean operations (and, or) and truncation. That allowed to formulate the following search query:

> (("land registration" OR "land certification" OR "land tenure regulari*" OR "land reform" OR "land tenure" OR "land tenure security" OR "customary land tenure" OR "land right*" OR "land governance" OR "land information") AND ("agricultur* producti*" OR “agricultur* transform*” OR “investment in agriculture*” OR “Fertilizer*”)).

*For inclusion criteria see Table 2.

The search query and a number of other combinations of its composing key words were used on different search databases. The search comprised databases like SCOPUS, Web of Science, Elsevier, GEOBASE, Springer Link, AJOL, JSTOR and libraries to which we are subscribed were used. In addition, we utilised available resources on the World Wide Web.

The preliminary search attempts generated many resources that were not all useful. Then, we set boundaries of this review. Three types of documents were considered for the review: (1) Peer-reviewed journal articles, (2) books, (3) technical reports (grey literature) published by international organisations. Only resources written in English, addressing the relations between

land registration, land tenure security and agricultural productivity, were selected for the review. A priori methodological quality judgment criteria (Cooper, 1998a) were applied to exclude studies whose methodological quality was difficult to assess in a systematic way (mainly conference papers and national reports).

The review period was set from 1980–2019, bearing in mind that the year 1980 arguably corresponds to the recent history and development of evolutionary theory of property rights (Alston & Mueller, 2015; Krier, 2009; Platteau, 2008). This year marked the start of heated debates on land reform in many countries with developing economies. A data extraction form was used to systematically fill in the following information: (1) Type of document, (2) the title, (3) field of the study, (4) country/sub-region/region, (5) meaning, definition or views of the effects of land registration on agricultural productivity (6) online library where the document had been accessed, (7) reference and (8) search date. A critical descriptive analysis was conducted using the technique of topic mapping (Hart, 2007). After exploring 1940 studies, we considered 85 for this chapter (Figure 4). Of these 85 studies, 79 are journal articles, 2 technical reports and 4 books.

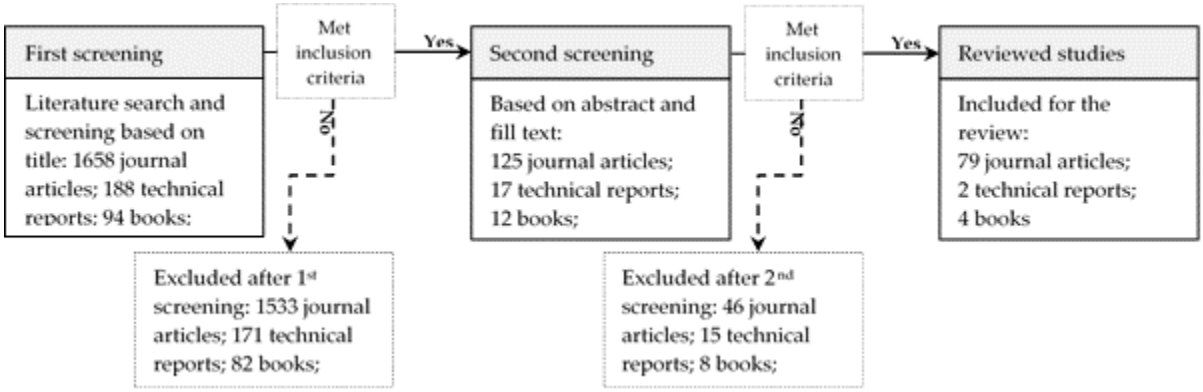


Figure 4. Flow diagram for quantitative search and screening

Of the 85 studies we reviewed, 45 discussed issues in 22 countries with developing economies (Figure 5). The other 40 consist of regional and international studies. The distribution of reviewed studies per year of publication illustrates their gradual increase in numbers from 1980's to the recent years (Figure 6).

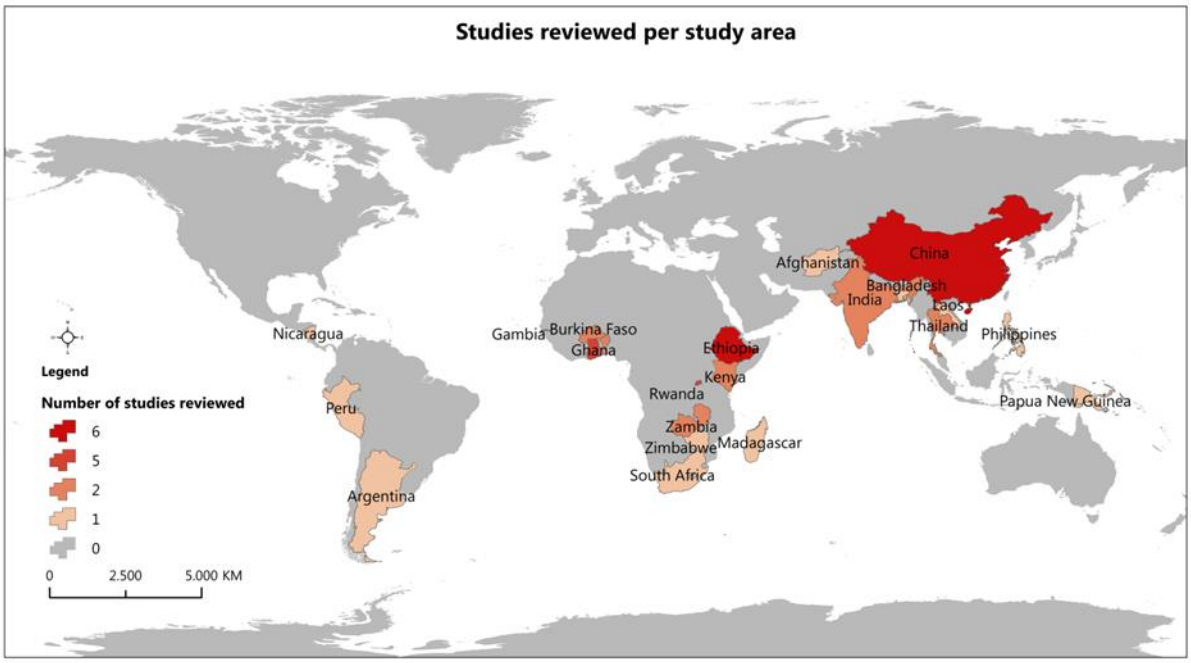


Figure 5. Distribution of studies reviewed per country

2.2.2. Assessment of the Content of the Reviewed Studies

The 85 texts discussed in this chapter cover a wide range of topics concerning land registration, land reform, land tenure activities and outcomes, as well as agricultural productivity. The review followed a narrative synthesis approach (Popay et al., 2006). We identified and assessed the main claims made concerning the effect of land registration on the relations between land tenure security and agricultural productivity. This was done by categorizing the evidence found in the studies we reviewed (Table 8). The evidence with considerable coverage is discussed in detail in Section 3.4.

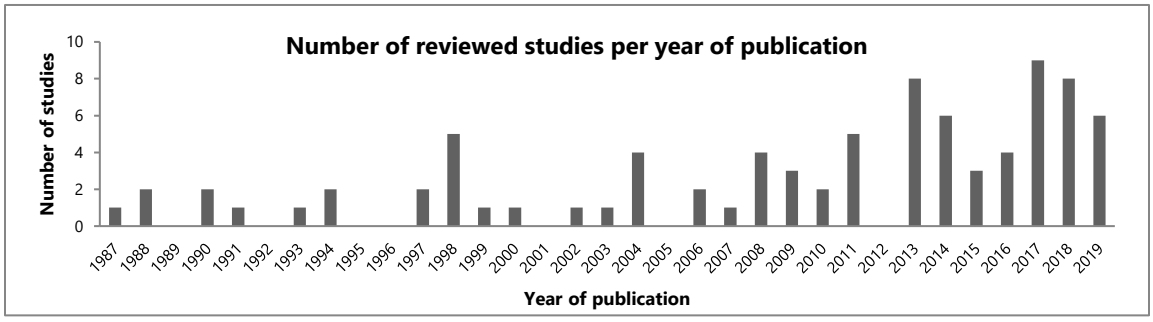


Figure 6. Distribution of reviewed studies by year of publication

Table 8. Assessment of the evidence on the effect of land registration on the relations between land tenure security and agricultural productivity.

Category	Rationale	Reviewed studies %
Strong evidence	Correlation between land tenure security and agricultural productivity calculated before and after land registration using panel data about: • Cases of conflicts over land • Loans used to invest in agricultural activities (fertilizers, seeds, irrigation) • Investment in agriculture • Farm harvest; • Farm technical efficiency following land registration; • Improvements in legal land (rights) transactions.	54
Weak evidence	The relations between land tenure security and agricultural productivity may exist, but they are difficult to measure given that land registration alone cannot have an effect; The effect exists indirectly through enabling design and implementation of developmental strategies such as taxation, land use plan, land consolidation, agricultural transformation.	34
No evidence	This category contains the studies claiming, on the contrary, that land registration threatens the long-term established de facto tenure security and agricultural productivity.	12

In general, the research work that we reviewed is mostly based on literature review and secondary data sources. When primary data are mobilized, the methodological approaches vary, although they tend to converge to a combination of econometric modelling and statistical analysis. The dominant methods are: (1) Stochastic Production Frontier (SPF) models using data from household panel surveys (Ma et al., 2017a; Michler & Shively, 2015). (2) Conditional Maximum Likelihood (CML) (Bambio & Bouayad Agha, 2018). (3) Two-step conditional maximum likelihood (2SCML) techniques: linear probability regression for the discrete variable and probit regression (Ghebru & Lambrecht, 2017; Rao et al., 2017).

3.3. Land Registration, Tenure Security and Investment(s)

In the last four decades, land tenure regularization gained importance in the literature on agricultural productivity. The underlying main claim stipulates that when their land rights are legally protected, farmers invest to make their agricultural system more productive. Overall, 54 per cent of our 85 studies claimed so. However, whether or not legally recognized land tenure has an impact on agricultural productivity, or even to what extent that form of tenure contributes to more productive agriculture, remains uncertain (Abdulai, Owusu, & Goetz, 2011; Chand & Yala,

2009; Gignoux, Macours, & Wren-Lewis, 2013; van Gelder, 2010). Furthermore, research underlines the particularity of growing agrarian economies of developing countries (K. Deininger, Ali, & Alemu, 2011; FAO, 2013). These countries are still working to secure land rights, while pursuing an agriculture transformation phase, transiting from subsistence to market-oriented production.

As the starting point of land tenure regularization, land registration is assumed to support land dealings (Murtazashvili & Murtazashvili, 2016; Tahsin & McLaughlin, 2017). In the first place, the information gathered through registration forms part of a system, that may be open to renters, sellers and buyers of land (rights), and so provide increased transparency on the land market. Second, land registration and the resulting legal framework may guarantee trust when accessing loans from the banks. Given that land and agriculture constitute the main source of income in rural areas of developing economies, the loans may be invested in agricultural activities and associated businesses. Another effect underscored and contested in the literature, is the ability of legal tenure to improve perceived tenure security (Fort, 2008; Törhönen, 2004; van Gelder, 2010).

Early literature suggests that the guarantee assured by a tenure-registration document improves the security of tenure. The effects of secured ownership on both the availability of credit and investment incentives, imply that farmers without secure ownership will have lower investments and land improvements, use of variable inputs, and productivity per unit of land (Feder & Nishio, 1998; Feder et al., 1988; F. Place, Roth, & Hazell, 1994). For example, Feder et al. (1988)'s work in Thailand highlighted first evidence of the link between tenure security and agricultural productivity. They distinguished three effects. First, the greater tenure security increased farmers' demand for improvements by increasing their confidence that they would benefit from such improvements over the long-term. Second, tenure security increased the supply of formal credit through the creation of tradable collaterals. Finally, both effects resulted in higher short-term investments in inputs and long-term investments in productive and land-conservation technologies, leading to higher sustainable (Feder et al., 1988; D. Maxwell & Wiebe, 1999; F. Place et al., 1994).

Several studies have focused on the effect of legal ownership on farm output or income. In a study conducted in Costa Rica, for one province a positive correlation of 0.53 was found between income per unit of land and security of ownership. In another province, however, the correlation was negative, although quite weak (−0.07) (Feder & Nishio, 1998). A study dealing with the Brazilian state of Maranhao concluded that granting full legal ownership to squatters and undocumented occupiers would increase their income by 200 percent. The same study reported that income levels of titled farmers were two times higher than those of untitled farmers, when the amount of land owned was held constant (Feder & Nishio, 1998).

More recent research work explores the benefits of land registration projects on a longer time span, trying to demonstrate the link with land tenure security and agriculture productivity (Rao, Spoor, Ma, & Shi, 2016; Twerefou, Osei - Assibey, & Agyire-tettey, 2011). A study on Benin stressed

that land certification has improved tenure security and stimulated investment in agriculture (Goldstein, Houngbedji, Kondylis, O'Sullivan, & Selod, 2018). The study concluded that increasing tenure security, especially in the initial stages of formalization, can positively affect investment decisions. Hence, according to the authors, 'improved tenure security from program demarcation activities leads households to shift their investment decisions from subsistence crops to long-term and perennial cash crops' (Goldstein et al., 2018). However, the same study suggested that further research was needed to complete the picture and establish the causal effect of a full formalization of property rights, up to the delivery of a transferable title.

Using panel data from rural representative households surveys in Burkina Faso, Bambio and Bouayad Agha (2018) argue that stronger land rights increase land-attached investment. In reverse, land investment has positive and negative effects on stronger and weaker land rights, respectively, in rural Burkina Faso. However, investment in land with unclear rights increases land conflict (Lund, 2000). The authors also found that assets, immigration, and literacy have positive effects on land investment, which suggests that more than land tenure alone is at stake in improving agricultural production. Moreover, the authors imply that a gain of efficiency can be achieved by combining practices in land tenure and investment. Formal land rights is only applicable to 4% of agricultural land in Burkina Faso (Bambio & Bouayad Agha, 2018).

In general, there is widespread belief among development economists, that land registration has a bearing on agricultural productivity in developing countries. Land registration, it is argued, increases credit use through greater incentives for investment in agriculture and reduced incidences of land disputes (Barrows & Roth, 1990; Santos et al., 2014). The resulting legal tenure also would influence investments in fixed inputs such as machinery, which are important for enhancing productivity. Among the studies we reviewed, 34 per cent found weak evidence to claim so. Below, we provide three (sets of) remarks that suggest why the major claim is less straightforward than often presented. First, we discuss the actual evidence provided to prove such relations. Second, we discuss how land registration could threaten 'de facto' tenure security. Third, we show that the literature is relatively silent to specify the gendered nature of land registration and tenure.

3.4. Evidence for Relations between Land Registration and Agricultural Productivity

In the 1990s, a number of studies on African settings have formally tested the nature and strength of the relation between tenure security and agricultural performance (e.g., (Hayes, Roth, & Zepeda, 1997) in Gambia; (F. Place et al., 1994) in Ghana, Kenya and Rwanda; and (Migot-Adholla, Place, & Oluoch-Kosura, 1994) in Kenya). With few exceptions, land rights were not found to be a significant factor in determining whether or not farmers made land-improving investments, used yield-enhancing inputs, accessed credit, or improved the productivity of land. A study that included Ghana, Kenya and Rwanda, found 'no relationship between cross-sectional variations in land rights and productivity' (Migot, Peter, Benoît, & Frank, 1991). The authors argue that the most pronounced relationships were found in Rwanda, where the right to bequeath was a significant determinant of some types of land improvements. Rwandese parcels that could not be

bequeathed, were mostly rented or borrowed under short-term arrangements. As such, the tenant had little incentive to invest. In addition, the use of formal credit did not appear to be related significantly to land rights. In Kenya, no significant relationship between crop yield and land rights was found. The study found, that the presence of land titles did not affect yields in any significant way either. These results are contrary to the widely held notion that security of tenure and titling leads to higher yields. It is notable that the study focused largely on smallholders with an average land parcel of between 0.53 ha to 4.1 ha. These results questioned the need for ambitious land registration and titling programs at that time (Frank Place & Hazell, 1993).

A recent literature review study based on the analysis of 59 studies found strong evidence for positive effects of land tenure security on productive and environmentally beneficial agricultural investments, as well as on female empowerment, but a lack of support for links with productivity, access to credit and income (Higgins et al., 2018). Overall, the review suggests that more evidence still needs to be generated on the land tenure security interventions as there is much learning to be done. The most complete evidence is likely to be generated through a combination of quantitative and qualitative approaches, with quantitative approaches taking the most rigorous approach possible, particularly randomised control trials, to assess impact and qualitative approaches that seek to identify key contextual factors to determine that impact.

Li and Zhang (2017) argued that generally in Africa, land tenure reform has made a great contribution to improving agricultural productivity and can provide an effective long-term solution to food security. However, in sub-Saharan Africa, where land under customary tenure is usually neither registered nor accepted as tradable collateral, the authors hardly detected such contributions. Lawry et al. (2017) argue that most farms in sub-Saharan Africa are held under customary tenure arrangements, which generally provide long-term tenure security to qualified members of land-holding families, groups or communities. Their study underlines the existence of a level of pre-existing tenure security provided by customary tenure without formalization. Therefore, titling may not operate easily in areas where customary tenure exists. This suggests that titling programmes are suitable mainly for households in stable employment, who can afford to service the market-based interest rates for accessing formal credit, along with meeting other terms and conditions, such as collateral and deposits or down-payments (Klaus Deininger & Chamorro, 2004; Payne, Mitchell, Kozumbo, English, & Baldwin, 2015). This has been the case in Uganda, for which Kamusiime, Rugadya, and Obaikol (2005) claim that the transformation of customary tenure embodied in systematic demarcation, was expected to provide an opportunity for farm households to rid themselves of poverty, but actually created more tenure insecurity. The authors conclude that neo-liberal policies, emphasising market-based land reforms, effectively put pressure on customary tenure.

As mentioned above as well, however, many authors found that the key relationship discussed in this chapter is not automatic and other effects need to be taken into account (Ayamga & Dzanku, 2013; Baltissen & Betsema, 2016; Klaus Deininger, Ali, Holden, & Zevenbergen, 2008; Gautam & Ahmed, 2018; Gignoux et al., 2013; Holden & Otsuka, 2014; D. G. Maxwell & Wiebe, 1998;

Nilsson, 2018). A study on agricultural productivity impacts of formal and informal land rights in Madagascar found that tenure insecurity would negatively influence the relation between the right to lease out land and agricultural productivity (Bellemare, 2013). These empirical results suggest that formal land rights (i.e., land titles) have no impact on productivity, but that informal land rights (i.e., landowners' subjective perceptions of what they can and cannot do with their plots) have heterogeneous impacts on productivity. Törhönen (2004) suggests that a successful land reform program supposes a workable land administration, built upon good governance, appropriate resources, cultural sensitivity, equity, quality and commitment. This implies that land tenure structures are secure, corruption-free, flexible and all-inclusive. Lack of transparency of public administration leads to a situation, where farmers are reluctant to use the title deed as collateral, and formal credit institutions do not put much faith in the title deed (Migot-Adholla et al., 1994).

Other studies cast doubt on the existence of a systematic influence of land tenure security on investment. (Brasselle, Gaspart, & Platteau, 2002) conclude that the traditional village order, where it exists, provides the basic land rights required to stimulate small-scale investment. (Klaus Deininger & Chamorro, 2004) suggest that in Nicaragua, titling can have a positive effect, but that the legal validity and official recognition of the titles issued appears to be of great importance. For North-East Ghana, (Bugri, 2008) claims that a policy focus on enhancing tenure security may fail to lead to increased agricultural production, if similar focus is denied to non-tenurial factors, including lack of finance, poor soil fertility, inadequate and unreliable rainfall, pests and diseases, inadequate farmlands, bush burning and excessive tree cutting. The report of the Economic Commission for Africa's Sustainable Development Division (SDD) on Land Tenure Systems and their Impacts on Food Security highlights similar claims (ECA/SDD, 2004).

3.5. Insecurity of Tenure Threatening Productivity

Numerous studies conducted on tenure and how it affects agricultural productivity, suggested tenure's ability to stimulate investment in agriculture. However, increasing numbers of current research work suggest that—at least in Africa—the opposite may prevail. On the one hand, the complexity emanates from the existence of various types of land tenure systems. It is difficult to comprehend the manner in which land tenure issues influence farmer incentives in a mixed group of farmers who hold statutory and/or customary rights on lands (Ncube, 2018). Ege (2017) argues that land registration failed to improve tenure security, land dealings and agricultural productivity in Ethiopia. The author distinguished three different rights in land tenure security: possession, renting and latent rights. Following land registration, rights of possession are believed to have improved, but the evidence remains weak and conflicting. Land rentals were expanding, but farmers were facing high tenure insecurity. The main problem, though, has been the latent rights, with great insecurity and increased conflict levels. The author found that, despite rapid economic development, there was considerable social malaise, a failing agricultural structure, and considerable pressure for land redistribution because of unresolved land tenure issues. In addition, given that purchase restrictions hardly exist, Ncube (2018) argues that international organisations

and governments have embarked on land purchases in Africa, exposing smallholder farmers to arbitrary land acquisitions.

An Indonesian case illustrates the complexity of the relations between land tenure security and agricultural productivity well. Using empirical material from 16 villages in Jambi province in Indonesia, Kunz, Hein, Mardiana, and Faust (2016) show that the outcomes of the state-led land reforms and land tenure formalization processes are imitated and translated into locally feasible actions. The authors refer to these translation processes as 'mimicry of the legal.' The authors found that, even though the government of Indonesia invested massive amounts of money to accelerate national land formalization processes, flexibility in regard to land use continues to be present, allowing for an exploitation of the landscape and accelerating the expansion of small-scale agriculture in the forest frontier areas of rural Indonesia (Kunz et al., 2016; Lund & Rachman, 2016).

A study on the link between land tenure security and technical efficiency in Northwest China and Bangladesh (Ma et al. (2017a) argues that the provision of land certificates to rural households had a negative impact on the technical efficiency of agricultural productivity under the prevailing factor market imperfections in the region. In the Philippines, despite the presence of formalised titles, a study found that the rental market remained ineffective for allocating land. In contrast, non-formalised tenure contracts used by farmers appeared to provide tenure security (Michler & Shively, 2015). For Afghanistan, Murtazashvili and Murtazashvili (2016) argue that the Community-Based Land Adjudication and Registration, or CBLAR, initiative is more appropriate than legal titling. More generally, the authors argue that CBLAR improves household land tenure security in post-conflict settings, when implemented in the appropriate context and with appropriate support from the state and international donors. Despite the promising approach, however, the success of these initiatives in improving household land tenure security is thought to depend on the quality of customary governance and on investment in public goods, such as roads, schools, lending institutions, administrative capacity of local governments, and forums to resolve disputes that overwhelm communities.

3.6.Gender Considerations

Our chapter reviewed scholarly literature on the effect of land registration on the relations between land tenure security and agricultural productivity. Given that 14 of the reviewed studies discuss the particularity of gendered land tenure, we found it relevant to include this issue in our chapter. However, the studies we reviewed rarely discuss how gendered land tenure relates to agricultural productivity. This link needs to be further explored in future research work.

Odhiambo (2006) claims that unless the context is right, formalizing land tenure may exacerbate a given unequal situation in land ownership, while introducing new problems and challenges. When that happens, those who suffer the most are the poor, marginalized and vulnerable in society, including women and children, pastoralists and hunter-gatherers. Women land rights and their role

in agriculture production feature in most of the literature dealing with land registration, land tenure security and agricultural productivity. Land tenure insecurity for women arises from rapid socioeconomic change, disrupting customary institutions, and from excessive government interference in customary tenure systems (ECA/SDD, 2004). However, in the studies on the relations between the three issues central to our chapter, what gendered relations in land tenure and agricultural production actually mean is less discussed, and if so, only very recently. Among the 85 studies we reviewed, only 14 looked into gender implications and particularities of positions and rights of women. This points to a scarcity of empirical evidence to assert how land tenure security of women is affected by land registration or how women tenure security contributes to agricultural productivity, let alone how the relations between their land tenure security and access to credit, technology adoption and agricultural productivity are shaped (Bambio & Bouayad Agha, 2018; Meinzen-Dick, Quisumbing, Doss, & Theis, 2019).

Inclusiveness to ensure access to land to unlock land tenure insecurity issues particularly for women and other underprivileged groups, is discussed more often (U. E. Chigbu, P. D. Ntihinyurwa, W. T. de Vries, & E. I. Ngenzi, 2019), as it enables land users and farmers, who own land, to capture the expected socioeconomic benefits from their land. Formalising land tenure does not always seem to benefit women, however. The social, political and economic context in which formalization is implemented, is the key determinant of whether or not formalization succeeds in benefiting the target group and securing tenure (Odhiambo, 2006).

Looking at the role of women in smallholder agriculture, the World Bank claims that men are usually the formal landowners in both traditional and modern land tenure systems. Less than 2 percent of African women have ownership rights to their land. Lack of official landownership reduces women's ability to access finance and other resources (World Bank, 2018b). Plots held by women in polygamous households are perceived as less tenure secure (Ghebru & Lambrecht, 2017). Formal land titles, when they exist, appear to be usually assigned to men in both traditional and modern land tenure systems, even when women contribute significantly to agricultural production (Meinzen-Dick et al., 2019). Han, Zhang, and Zhang (2019) argue that the land tenure of Chinese rural women is subject to considerable discrimination and is highly insecure because of the greater risks involved compared to those faced by men. The authors call for policies facilitating legal land tenure security through the separation of women's individual tenure from the households in the issue process and ensuring their legal status as the co-owners of household contracted farmland (Han et al., 2019).

Formal registration of women's land rights is claimed to be a key in solving women's land disputes and increasing their empowerment, but being entitled to land ownership does not necessarily mean women's land tenure is secure, an issue that has received little attention to date (Ali, Deininger, Mahofa, & Nyakulama, 2019; Han et al., 2019). During land reform, women and other vulnerable groups encounter more conflicts and evictions than men. For Rwanda, (Ali, Deininger, & Goldstein, 2014) argue that the land tenure regularisation program carried in the period 2007–2013, did improve land access for legally married women (about 76% of married couples) and

prompted better recording of inheritance rights without gender bias. The authors found that the program was associated with a very large impact on investment. They noted this effect particularly to be pronounced for female-headed households, suggesting that this group had suffered from high levels of tenure insecurity, which the program managed to reduce.

1.6.Discussion and Conclusion

The aim of this chapter was to determine and describe the gap in the scholarly literature discussing the effect of land registration on the relations between land tenure security and agricultural productivity. Our review highlights the growing volume of literature on tenure security since the 1980s. However, in many studies, those effects continue to be conceptually described rather than operationally proven. Many studies offer indirect effects, in terms of secondary data rather than direct field evidence. We found weaknesses in the methods and techniques used to collect and analyse data, as well as the types of data mobilised to study the effects. The use of representatives' data from local authorities and farmers cooperatives instead of from farmers themselves, may provide misleading results and hide the households' tenure and productivity realities. In addition, research has been conducted using case studies within countries, but generalising their findings seems difficult given the particularities of different local settings.

Early research work revealed the importance of market settings and other economic processes at work in different countries to determine agricultural inputs and harvests in formal or informal land rights dealings. Later on, social elements like farmers' perceptions and farmers' groups started to gain relevance in studies conducted on land rights formalisation and agricultural productivity. Assessing local realities and locally-set institutions appear as crucial, when seeking to understand the effects of land registration on agricultural productivity. The clear heterogeneity in findings in the literature suggests that policy responses must pay attention to both local contexts and overarching macro and sectoral conditions, within which tenure systems operate. Deeds systems, where the possession of the deed is proof of ownership, may not work in countries with high rate of criminal activities, for example. (Ali et al., 2019; Bugri, 2008; Fenske, 2011; Keovilignavong & Suhardiman, 2019; Kepe & Tessaro, 2014; Kunz et al., 2016; Lawin & Tamini, 2017; Ma, Heerink, van Ierland, Lang, & Shi, 2019; Paltasingh, 2018; Frank Place, 2009; Sitko, Chamberlin, & Hichaambwa, 2014; Teka, Van Rompaey, & Poesen, 2013).

We demonstrated the contradicting arguments found in the literature concerning effects of land registration and updating on agricultural productivity. Land titles or related legal papers may have helped to obtain loans from banks, using land as collateral, to invest in agriculture. On the other hand, land certification may have contributed to increased tenure insecurity, with possible negative consequences for agricultural productivity. Some studies concluded that even when there is effectively a correlation, it is associated with many intervening factors altogether, which makes it difficult to claim that it is the isolated link itself that created favourable conditions. One intermediate and linking element standing out, and most highlighted in the literature, is 'land tenure security': the security of tenure guarantees perceptions of long-term tenure and stimulates

farmers initiatives to sustain their agricultural activities, thus creating the enabling environment. At the same time, literature points at the need to keep the cadastre information updated to avoid future misleading of land information-based dealings and to construct belief in the tenure systems.

The processes and procedures of land registration and land information updating projects appear to play a crucial role. However, the difference between systematic and sporadic registration and the way each affect productivity, is often ignored in the literature. In addition, claims that changes in agricultural productivity are associated with formalising land rights would not be strong enough, if studies do not consider the tenure systems at work and the effectiveness of institutions involved. Land registration has been considered both in cases of first (land information) registration and for the continual land information updating. The main underlying assumption was, that when land is formally registered, farmers use their legal documents to seek loans, using land as collateral and invest in agriculture. It is clear, however, that land registration may affect productivity in more ways than just via the loans-investment process as described in most of the reviewed studies.

8. Suggestions for New Research on Tenure, Security and Productivity

In most literature, land registration is mentioned as affecting land tenure security, but studies that directly deal with the relations between land registration and agricultural productivity are absent. We found that the effect of the land registration process itself on land tenure security and agricultural productivity is an understudied topic. Hence, the process of land registration, including the methods and techniques used to demarcate, adjudicate and record land information, is not considered, while it may have a crucial impact on farmers' decisions and thus agricultural productivity. Some authors stress that before one can validly assert whether land registration will enhance investment and productivity, a more careful definition is needed of the concept of 'tenure security' itself. Factors besides land titles that bear on such security, must be identified (M. C. D. Simbizi et al., 2014). Indeed, land registration is not simply a technical matter; it is a complex social intervention. Therefore, historically evolved social relations and circumstances must be considered to achieve the results of land titling that are desired. Recognizing this would be directly relevant to the design and evaluation of titling programmes (Kunz et al., 2016; Lemel, 1988; Odhiambo, 2006).

Several studies have emphasised the important role of land (tenure) institutions at all levels of the administration to streamline land-based productivity. Such streamlining is not always positive is argued for Rwanda by Pritchard (2013), who concludes that simultaneous and aggressive implementation of registration and crop intensification has significantly reduced land tenure and food security of subsistence households. Land registration records information needs to be managed, using regulatory and institutional frameworks (Lavigne Delville, 2010; Roth & Haase, 1998). The research approaches we found in our review miss two important aspects to deal with registration issues. One is the role of an up-to-date land information registry to realize tenure security and land governance in general (Ali, Deininger, & Duponchel, 2017). Second, especially in rural areas, researchers pay less attention to other factors interfering with tenure security,

including developmental programs such as land taxation and land consolidation, as well as the important role of particular local traditions (Higgins et al., 2018).

The methods that are used in most of the studies in our review cannot tackle the complexity of how land tenure systems affect productivity (W. Odhiambo, 2003). This suggests that there is need for a mixed methods approach utilizing experiments as well as randomisation, where feasible, in combination with increasing flows of spatial and time-series data from diverse sources. Household-farm panel data collected over long periods of time, combined with simulations, can also provide valuable insights about the relations.

This chapter contributes to an understanding of the effect of land registration on the relations between land tenure security and agricultural productivity. From an intensive review of a broad set of literature related to land registration, land information updating and agricultural productivity, the chapter provides a better understanding of those effects. From the literature, we find that formalising land rights appears to contribute to an increase in agricultural productivity only when it is combined with effective land and agriculture policy (among others) and when the implementing institutions are effective (Lavigne Delville, 2010). Future research needs to concentrate on examining these relations from a more operational basis, taking into account local social-economic and institutional patterns at work.

4

The relations between farmers' land tenure security and agriculture production. An assessment in the perspective of smallholder farmers in Rwanda

This chapter is based on:

Singirankabo, U. A., Ertsen, M. W., & van de Giesen, N. (2022). The relations between farmers' land tenure security and agriculture production. An assessment in the perspective of smallholder farmers in Rwanda. *Land Use Policy, 118*, 106122. doi:https://doi.org/10.1016/j.landusepol.2022.106122

Abstract

On the basis of a data set from four research sites over the course of three agricultural years (2006/2007, 2012/2013, 2016/2017), this article empirically assesses the relations between land tenure security and smallholder farms' crop production in Rwanda. We show that the general assumption that secure land tenure improves farm level harvests, is not found for smallholder farms in Rwanda. We defined a farmland tenure security index based on plausible threats as conveyed by smallholder farmers at each research site. Our findings indicate that the harvest of main crops did neither statistically correlate with this index, nor show differences from the mean at all research sites. Instead, factors mainly related to the ongoing crop intensification program, though threatening tenure security, contributed to the increase of small farm harvests. Lower land tenure security did not affect farmers satisfaction of the crop program, most of them claiming that in the end what matters most is that their harvests continue to increase. Therefore, in Rwanda, a new wave of agriculture strategizing contributes to increasing small farms' harvest of prioritised crops and decreasing farmland tenure security simultaneously.

Key notes: *land tenure security, agriculture production, smallholder farmers, Rwanda*

4.1.Introduction

In many policy programs in sub-Saharan African countries, land tenure security is seen as constituting fundamental conditions for the improvement of agriculture production of smallholder farmers (Atwood, 1990; Bambio & Bouayad Agha, 2018; Higgins et al., 2018; Holden & Ghebru, 2016; Xianlei Ma, Nico Heerink, Shuyi Feng, & Xiaoping Shi, 2017b; Michler & Shively, 2015; Rao et al., 2017). However, recent research work, mostly review studies, suggest that this link may not be straightforward (Rockson et al., 2013b). This suggestion underlines the need for a locally defined research approach to assess the relations between land tenure security and agriculture production.

In Rwanda, until the early 2000s, a customary tenure regime prevailed all over the country. The literature emphasizes that the customary systems were ineffective, in the sense that they were dominated by unclear land rights and limited security of tenure (Bizoza & Havugimana, 2013; Musahara, 2006). In addition, due to the growing demographic pressure on land, the agricultural lands in Rwanda were (and are) highly fragmented. Therefore, governmental efforts to improve crop harvest have introduced programs aiming at both land tenure and land use changes. Rwanda introduced two policy programs in 2007. On tenure, the country introduced the Land Tenure Regularisation Program (LTRP), aiming to formalise land rights and improve land tenure security. In addition, the Crop Intensification Program (CIP) was launched, with its main goal to increase agricultural productivity of high-potential food crops and to ensure food security and self-sufficiency (GoR, 2011). One of the pillars of the CIP is a Land Use Consolidation approach (LUC)

seeking to increase the farmland size and improve farming activities. Bringing individual plots together in terms of land use and agricultural practices, the tenure conditions of these fields do not change for farmers. Individual exploitation, however, is no longer possible. The main reasoning for this policy is that the use of inputs, such as improved seeds and fertilizer, can be translated into profitability for smallholder farmers only if the land fragmentation is overcome. Under the LUC policy, farmers in a given area grow specific food crops in a synchronized fashion with the goal to improve the productivity.

The evolution towards new legal tenure arrangements and consolidated use of farmland has attracted researchers (Bizoza & Havugimana, 2013; Bizoza & Opio-Omoding, 2021; Del Prete et al., 2019; Musahara, 2006; Muyombano & Espling, 2020; Ntihinyurwa & Masum, 2017), but little is said on their subsequent relations. This article discusses precisely the relation between tenure arrangements and land consolidation, through the changes in yields that were found at four research sites across Rwanda over the years between 2007 and today. We present the complex relations between land tenure security, land policy (land use consolidation) and agriculture production in this chapter.

At the time Rwanda launched the LTRP, 80% of Rwanda's land was neither formally demarcated nor registered (Enemark et al., 2014). Most of the laws governing land administration and management in the country had been formulated by the colonial authorities and had remained the same until the 1990s (Mbonigaba & Dusengemungu, 2012). The 2005 Organic Land Law (modified in 2013 (GoR, 2013)) guided the systematic land registration, part of the LTRP program (2007-2013). During the registration period, claims of rights on land were formally recorded, provided that they were adjudicated based on available proof documents held by claimants and in the presence of owners of neighbouring parcels. The LTRP aimed at improving land tenure security; it was believed to play a key role in the facilitation of economic transformation, encourage good land use practices and contribute to land conflict management (GoR, 2009).

The process of LTR in Rwanda has been hailed as "fit-for-purpose" (Enemark et al., 2014; Milindi Rugema et al., 2021). It systematically registered more than 10 million parcels within 5 years, using local community-based approaches, and established a functional land information system (Enemark et al., 2014; Nishimwe et al., 2020). However, as said in chapter two, research work on the LTR achievement has been contradictory. On one hand, Santos et al. (2014) praised the process and outcome, arguing that local capacity building, awareness-raising campaign, and public dialog events appear to have been particularly effective at increasing (perceived) tenure security. They argue that Rwanda's LTRP has had considerable outreach, in line with how LTR was described in the LTRP strategic roadmap (GoR, 2009): "using local capacity to the full". On the other hand, (M. C. Simbizi, 2016) underlines the threats undermining the positive economic outcome and benefits of the LTR. These threats included the emergence of new state land use restrictions. In a way, the state might have become a major source of tenure insecurity for the rural poor. M. C.

Simbizi (2016) highlights the contribution of the LTRP and associated legal and policy reform, in actually weakening existing tenure security. She measures tenure security based on a set of indicators including people, institutions, continuum of land rights and restrictions. Her work triggers to question the impact of the Rwandan state-led systematic land registration, the LTRP and, as a result, to further reflect on the anticipated success of 'land information-based' agricultural reform programs now operating in Rwanda.

Rwanda Vision 2020, published in 2000, acknowledges that the most important issue retarding Rwanda's agricultural development was not land size, but low productivity – which was associated with traditional, peasant-based, subsistence farming (GoR, 2000). In order to change this, several agricultural reform programs were initiated in Rwanda. Within the ongoing agriculture reform, in 2007 the government of Rwanda launched the CIP in all 30 districts of Rwanda, providing at proximity advisory services to farmers, inputs distribution (seeds and fertilisers) and post-harvest technologies (e.g. driers and storage facilities). The CIP is also subsidised by the government through other initiatives, like land-husbandry, irrigation, and mechanization infrastructure development. All these initiatives aimed to bring more land under production, avoid dependency on rain-fed farming system and promote a market-oriented agricultural sector (Mbonigaba & Dusengemungu, 2012).

The component of the CIP that is considered as key for agricultural transformation is land use consolidation (Alphonse Nahayo et al., 2017; Ntihinyurwa & Masum, 2017; USAID Land Project, 2013). Land use consolidation stipulates collective use of neighbouring farming land plots. The Rwanda ministerial order determining the models of land consolidation and its productivity, defines land consolidation as "the unification of land parcels with an estimated easier and productive farming than the fragmented use of farm plots."(GoR, 2010). Ntihinyurwa and Masum (2017) define LUC as "a policy in which farmers in a given area with closer parcels grow the same priority crops on a minimum size area of 5 ha in a synchronized manner on the provision of subsidised inputs by the government while the boundaries and rights on parcels remain intact". In Rwanda, therefore, consolidation does not implicate changes in ownership, it is rather the use of land that is changed.

The Government of Rwanda actively promoted the cultivation of a single crop by multiple farmers on a large area in order to increase agricultural production. One of the reasons for this reorganisation of agriculture land use was the high growing demographic pressure on land in the past decades, which had resulted in a continued fragmentation of households' plots by inheritance. The 2012 census reported an intercensal (2002-2012) growth rate of 3.2, while the average farmland size was 0.7 Ha (NISR, 2012). However, the process of LUC is not clear when it comes to issues of decision making (Kwabena Obeng Asiama et al., 2021). How decisions on farming activities are to be undertaken within consolidated areas, the types of crops to grow, the availability and access to subsidies, when to harvest, and the influence of the individual small farmers on these

issues, remains unclear. As such, it remains unclear how the consolidation process possibly affects land tenure security, let alone how it impacts agricultural production and food security. How does consolidation act on farmers' right to use land and how does this relation affect agricultural production?

In its unravelling of these complex relation between land tenure security, crop intensification and land use consolidation, this article continues by discussing the materials and methods used to collect and analyse data. We will describe the study area and research period, discuss the design of our Farmland Tenure Security Index (FLTSI), and the statistical analysis performed to assess the relations between the FLTSI and farm harvest. The third part presents the findings and results, which leads to the concluding part that discusses the key findings of this study.

4.2.Materials and methods

4.2.1. Study area selection and sampling

The study involved smallholder farmers across four study sites, one in each of the four Provinces in Rwanda: Gatwe in the Eastern Province, Nyabubare in the Southern Province, Rusebeya in the Western province and Rutemba in the Northern province (Figure 3). What the study sites have in common is that they are located in districts where pilot trials of the land tenure regularisation were conducted. Hence, the sites represent areas where the formalisation of land rights started in the country. Other selection criteria were linked with the performance in the CIP/LUC program, including number and size of farmland plots per household, and agriculture zoning (Table 4). Those criteria vary from site to site, offering the possibility of a comparative analysis. Considering the systematic implementation of LTRP and CIP/LUC, we assumed that farmers at the research sites shared an awareness of both programs – which was confirmed when visiting the sites. Therefore, as a result of the preliminary visit to the research sites, a questionnaire was administered to the first 100 random farmers who accepted to be part of the study. The study used random sampling techniques because our preliminary field visit indicated a quasi-homogeneity of the farming activities and of the livelihood of smallholders involved in the CIP/LUC program within each of the research sites. The diversity of the answers we received, as will be discussed below, furthermore suggests that this sampling approach managed to cover a diverse set of perspectives within these relatively homogeneous communities.

4.2.2. Research period and primary data collection

The survey was conducted in two periods, namely July to September 2018 and July to October 2019. In the process, three techniques of data collection were applied: (1) an appropriate semi-structured questionnaire was designed for the farmers, based on the initial analysis of published materials; (2) semi-structured face-to-face interviews were conducted with officials working in

land management and agriculture, including local agronomists and land management officers; (3) focus group discussions were conducted with farmers within their cooperatives.

In case we could not collect records either from farmers, their cooperatives or local authorities in charge, we asked the farmers to retrace their tenure and agricultural activities. This allowed to collect retrospective data over three research periods coinciding with three agriculture years/seasons (Table 5):

2006/2007, when almost all information on land was not formally recorded in rural areas;
2012/2013, the systematic land registration period; and
2016/2017, the period after registration.

The generated dataset covers farmers' plots biography and their agriculture production. In particular, the survey focused on discerning the legal land tenure, agriculture inputs, harvested crops, and the farmer's participation in decision making concerning farming activities.

We apprehend the uncertainty that may come with the prospective nature of the dataset used. We nevertheless believe that our technique allowed to have the most accurate data possible given that in most cases we could cross-check the content with documented records found in the local sector or the district archives, thus allowing us to add a semi-quantitative aspect to the answers. Furthermore, the respondents' answers show that variables of interest do not change uniformly between periods. In other words, respondents appear to be able to differentiate between variables, which we see as an indication that respondents are able to show the relational aspects of our findings of changes and similarities over the years.

4.2.3. Secondary data

To complete the dataset, especially to fully retrace the changes in land tenure security and agriculture production within the ten years period of this study, we used documentary evidence from various relevant sources. We collected plot indexes and associated information on land registration, tenure and use from the Ministry of Environment (MoE), the Rwanda Land Management and Use Authority, and the District One-Stop Centres. For information on past harvests and agriculture inputs, we visited the libraries of the Rwanda Ministry of Agriculture and Animal Resources (MINAGRI), agriculture projects on the site, and farmers cooperatives archives. Finally, secondary data were collected from local government offices at district, sector and cell levels, where data on the use and management of land, as well as information on the implementation of LTRP and CIP/LUC could be found.

4.2.4. Descriptive statistics

The analysis of our data from three periods and four sites, started with descriptive statistics. The description comprised the variables of sex, age, education and marital status of the heads of households, as well as plot-related data (size, number and information on land tenure of the surveyed farmland plots). We counted frequency and percentile of respondents per variable, and calculated the central tendency mean and standard deviation.

4.2.5. Farmland Tenure Security Index

The perception of land rights on a continual basis, which summarises the definition of land tenure security, has been often regarded as deriving from ownership rather than being associated with the use of land. This definition was found to have limits, especially when the research setting aims to understand LTS at a local level (Keovilignavong & Suhardiman, 2020). Recent research work emphasized the need for a combined locally-set approach to study the relations between LTS and agriculture production (Rockson et al., 2013b). Therefore, this study designed a locally-defined Farmland Tenure Security Index (FLTSI), that not only features the frequently used definition of LTS, but also includes farmer perceptions of LTS at our research sites in Rwanda.

Using M. C. Simbizi (2016) as a reference when designing the FLTSI, we could not consider all the indicators she developed because our aim was to capture the practical tenure issues in our study areas, not the theoretically possible issues in any setting. As such, our framework is more limited concerning LTS. Nevertheless, in our results section we show that the method followed allows to determine the levels of Farm LTS, that includes aspects that otherwise could be reduced to small threats while farmers reported them as serious attempt to their land tenure security given the importance of farmland use in rural areas. Our research approach may be simpler than existing indexes, but we argue that our index is highly informative in the local level context.

The results from three focus group discussions underlined three most threatening variables: (1) Disputes over land; (2) Decisions on farmland use; (3) Decisions on crops to cultivate. We added the variable (4) Access to bank credits with farm plots as collateral. Formalising land rights has long been branded as a key element to bring about higher levels of access to credit and investment (De Soto, 2000; Klaus Deininger & Jin, 2006; Higgins et al., 2018; Ngango & Hong, 2021; Rashid, 2021; Vu & Goto, 2020). Indeed, formal (legal) tenure grants the use of land as a collateral. Therefore, provided that other enabling conditions exist, that landholders perceive legal tenure as more useful than alternative strategies and instruments to secure transactions, and that landholders actually register transactions, investments may stimulate agricultural productivity among other economic activities (Barry & Danso, 2014; Rao et al., 2020). In his study carried in North-East

Ghana, (Bugri, 2008) claims that access to credit and other agricultural inputs, such as seeds and fertilisers by farmers, is important for enhanced agricultural production.

These four variables were combined into an index to determine the level of farmland tenure security (FLTS). The design of our locally-defined FLTSI was motivated by two elements: (1) the frequently used definition of land tenure security and (2) the theory of change of land tenure security activities. According to the definition of LTS retained for this study, LTS is realized when individual land rights are perceived on a continuous basis, free from imposition or interference from outside sources, as well as ability to reap the benefits of labour and capital invested in that land either in use or upon transfer to another holder (Bruce, 1993; M. C. D. Simbizi et al., 2014). On the other hand, the standard theory of change of LTS activities stipulates that registering land rights improves LTS, and that the gained LTS stimulates rights holders to invest and improve agriculture production (Bizoza & Opio-Omoding, 2021; Higgins et al., 2018). The design and operationalisation of FLTS in this study was an attempt to study the validity of such LTS-related claims. It is a locally-defined set, linked to the agriculture production of the research sites. As such, it should not automatically be considered as an overall definition of LTS in Rwanda.

The locally-defined FLTSI was preferred over a Principal Component Analysis (PCA) because, through the focus group discussions, information was available as to what farmers themselves find important in this context. A PCA would be less informative because the meaning of the major components would remain somewhat arbitrary.

4.2.6. Farm yield

To allow a comparison between the different sites and their crops over the research period, the monetary yield was used. The monetary yield was calculated by multiplying each crop harvest by its unit price in the relevant year. The obtained yield was then summed up to calculate the yield per farmer and per plot in each research site with respect to the research period. We calculated the percentage increase of yield between two research periods as

$$PI = (B-A)/A*100$$

and

$$PI = (C-B)/B*100$$

with

PI is the percentage increase between research period B and research period A
A is the first research period (Agriculture year 2006/2007)
B is the second research period (agriculture year 2012/2013)
C is the third research period (agriculture year 2016/2017)

4.2.7. Farmer's responses

Thematic analysis was used to identify and analyse patterns in the qualitative interview data. The interviews were translated from Kinyarwanda to English, transcribed, and thematically coded. Thus, data collected was analysed with the help of the Statistical Package for Social Sciences (SPSS) for the presentation of results. To assess farmer satisfaction over farming activities, we used a Likert scale. The farming activities include decisions over LUC and decisions on the selection and growing of crops. The respondents were requested to rate the degree of satisfaction on a 5-point Likert scale from 1 to 5, where 1 symbolises 'Not at all satisfied' and 5 represents 'Very satisfied'. Consequently, the data was analysed for statistical correlations using SPSS Version 23.0, as explained below.

4.2.8. Statistical correlation

As we are interested in the potential influence of several variables on the actual yields of farmers in the different years and sites, we first applied a standard Pearson correlation computation.

$$r_{xy} = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \sum(x_i - \bar{y})^2}}$$

Where for each crop

r_{xy} the correlation coefficient of the linear relationship between the variables x and the yield
x_i the values of the x-variable per household
$\bar{x}$ the mean of the values of the x-variable per research site
y_i the yield-variable per farmer
$\bar{y}$ the mean of the yield-variable per research site

The difference of the computation is to be found in variable x, which can be:

- Our FLTS Index value;
- The satisfaction over decisions on farming;
- The size of farm plots per household;
- The number of farm plots per household; or
- The households receiving subsidies.

4.2.9. One-way ANOVA test

As the goal of this study was to assess the relation between land tenure security and agriculture production of farmers in Rwanda, we performed an additional statistical test in the form of the One-way ANOVA test. The independent variable was our FLTSI. The dependent variable was the harvest of the main crops produced over the course of the three research periods. Using these variables, we sought to answer the main research question

Does a statistically robust relationship exist between small holder farmers LTS index and their harvest of the main crops?

We prepared two hypotheses:

H_0: There is no statistically significant relationship between small holder farmers LTS index and their harvest of the main crops.

H_1: There is a statistically significant relationship between small holder farmers LTS index and their harvest of the main crops.

Three one-way ANOVA tests were conducted at each site to evaluate the relationship between FLTS and total yield per size of the farm plots. The independent variable, FLTSI, included five levels: from 0 (low FLTS) to 4 (High FLTS). The dependent variable was the total yield in US$ of identified main crops at each research site.

4.3.Findings and discussion

4.3.1. General profile of respondents

From the four research sites, with 100 respondents each, we included 400 respondents in our study (Table 3). Respondents were heads of smallholder farmers' households. Although the collection of data proceeded randomly, we managed to balance the gender among respondents with a four-sites average of sex ratio of 90 males per 100 females. The composition of our sample corresponds well with the national male-female ratio in Rwanda, which was 92% in 2017 (NISR, 2018). About 85% of respondents were above 35 years of age, with a similar distribution across the four research sites. About the same percentage had at most a primary education, with about half of this group not having been to school at all. Rusebeya reported the smallest average farmland plot size per farmer at 0.17 Ha, while Gatwe had the largest size of 0.79 Ha. The site with the highest number of plots per farmer was Rutemba with 3.1 Ha, against the lowest number per farmer of 1.71 Ha at Nyabubare.

Table 9. General profile of respondents

	Category	Number of respondents				Total
		Rusebeya	Nyabubare	Rutemba	Gatwe	
Sex	Female	51.00	59.00	60.00	41.00	211.00
	Male	49.00	41.00	40.00	59.00	189.00
Age range	25-34	20.00	13.00	15.00	14.00	62.00
	35-44	34.00	27.00	27.00	25.00	113.00
	45-65	29.00	46.00	37.00	43.00	155.00
	Over 65	17.00	14.00	21.00	18.00	70.00
Education	Never been at school	40.00	16.00	60.00	49.00	165.00
	Primary	48.00	69.00	38.00	48.00	203.00
	Secondary	12.00	15.00	2.00	3.00	32.00
Marital Status	Married	78.00	61.00	77.00	68.00	284.00
	Single	2.00	9.00	21.00	8.00	40.00
	Separated	5.00	4.00	.00	4.00	13.00
	Widow/Widower	15.00	26.00	2.00	20.00	63.00
Average number of plots per HH		2.91	1.71	2.87	3.1	
Average size of plot per HH	Ha	.79	.62	.17	.27	

4.3.2. Farm plot biography

Biographical information on farmland plots was used to calculate the FLTSI, agricultural production and the monetary yield per farmer. Such information included plot size and plot number per farmer, the period of acquisition, whether the plot was formally registered, and whether the plot was part of the CIP/LUC site (Table 4). The 400 farmers reported a total of 1059 farmland

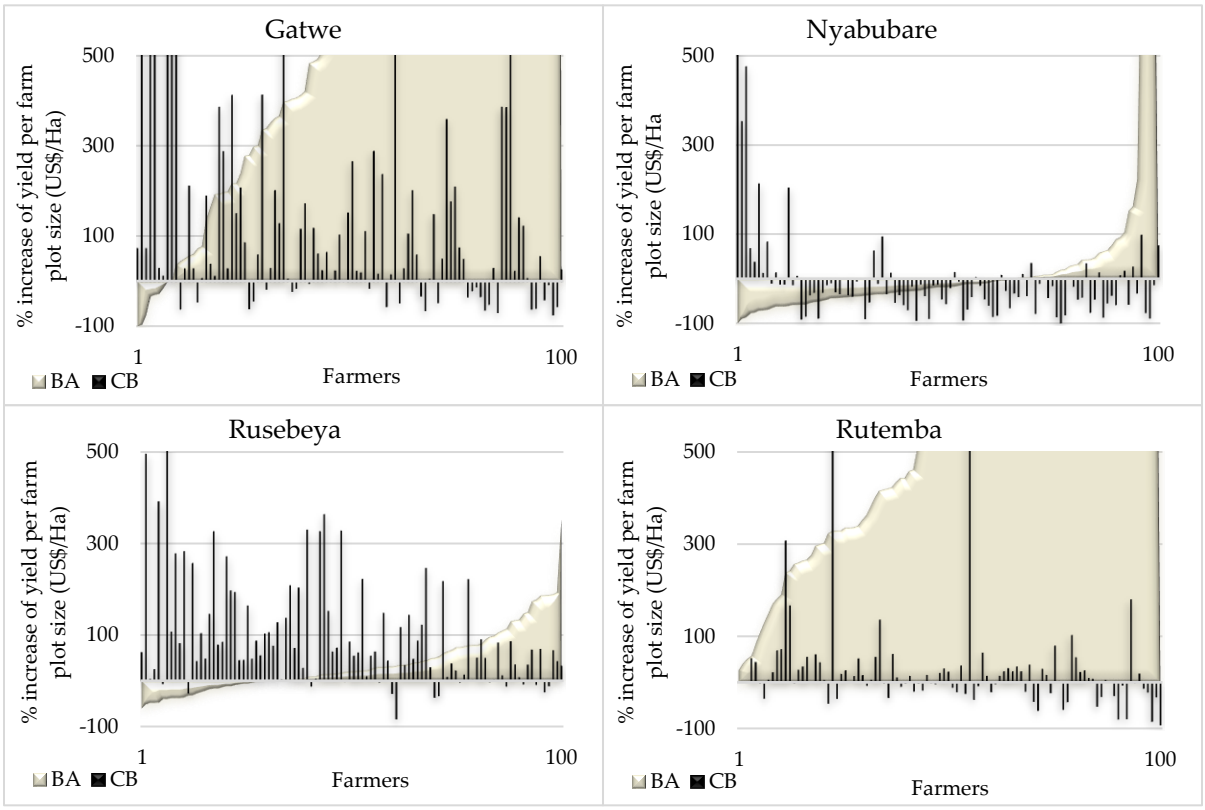
plots. About 77% of these plots have been acquired before 2006. About 64% of them had been registered during the systematic land registration process, so in the period 2007-2012.

Table 10. Farm plot identification

Number of farm plots	**Gatwe**	**Nyabubare**	**Rusebeya**	**Rutemba**	**Mean**
Total number	291	171	287	310	
Formally registered	75.26	81.29	39.37	72.26	67.04
Total size (Ha)	79.05	62.21	85.20	27.06	63.38
Mean size per site (Ha)	0.27	0.36	0.30	0.09	
First research period					
Formally registered	0	0	0	0	0
Acquisition	73.12	68.64	73.58	93.51	77.21
Included in the LUC program	0	0	0	0	0
Second research period					
Formally registered	75.26	78.36	29.97	71.61	63.80
Acquisition	12.90	30.77	16.05	5.19	16.23
Included in the LUC program	100	0	0	78	44.50
Third research period					
Formally registered	0	2.92	9.41	.65	3.24
Acquisition	13.98	0.59	10.37	1.30	6.56
Included in the LUC program	100	0	98	78	69

4.3.3. Variation of yield per research site and research period

Three research sites reported growing yield figures but Nyabubare did not (figure 2). We ordered the percentage increase of yield between the second and first research periods (BA) from low to high. The increase between the third and second research periods (CB) did not follow the same order which indicates that the dynamics of yield increase per farmer changed.



BA: % increase between the second and the first research periods (2012/13 - 2006/07)
CB: % increase between the third and the second research periods (2016/17 - 2012/13)

Figure 7. Percentage increase of farmers yield per research site and research period

In Gatwe and Rutemba, yield increased notably following the introduction of consolidated farming supplemented with government-subsidised seeds and fertilizers. Smallholder farmers testified of the increase of the harvest of selected crops within the CIP/LUC program which allowed them to sell part of their harvest and earn money. In return, the generated money was used to purchase the food they lacked in the household or (rarely) invested in small businesses.

In Nyabubare, the figure shows a persistent decline in total yield across the research periods. In fact, cassava being the main crop produced by farmers, this decline corresponds with the fall of cassava harvest mainly due to the cassava brown streak disease (CBSD) that attacked cassava crops during the agriculture year 2013/2014. CBSD is a devastating disease that causes loss of cassava root (tuber) production and quality. Root rot resulting from the viral disease renders the cassava tuber inedible (Hillocks, Raya, Mtunda, & Kiozia, 2008). The harvest of cassava dropped from 80 tonnes in 2013 to 48 tonnes in 2017.

Rusebeya shows a relatively similar yield percentage increase figure as Nyabubare between the first two research periods (BA); 40% of the farmers saw their yield decrease. However, following the terracing of their farm plots and the start of CIP/LUC program, famers increased their yield with 30% of the farmers reaching 100% or higher increase between the third and second research period (CB).

4.3.4. Farmers satisfaction over decisions on farming

Over the course of the three research periods, we observe a growing satisfaction of smallholder farmers with regard to the decisions on farming (figure 3). This has been the case at the three research sites except for the Nyabubare site, where satisfaction declined.

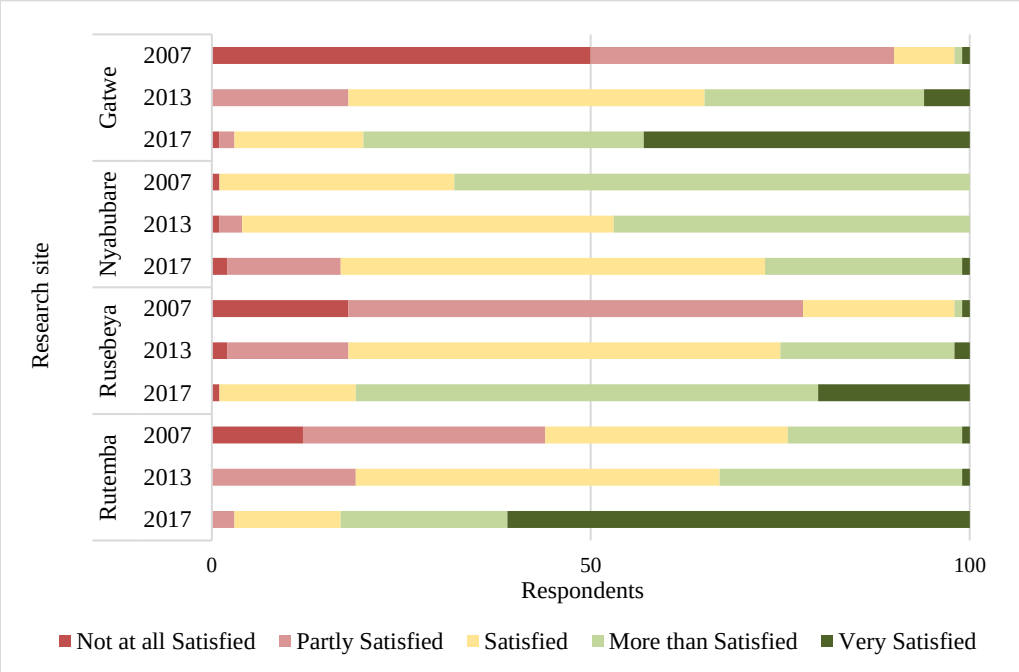


Figure 8. Farmers satisfaction over decisions on farming

A five level Likert scale was used to determine the level of satisfaction of farmer over the decisions on farming. The scale ranges from “not at all satisfied” to “more than satisfied”. With the exception of the Nyabubare site, the other three research sites reported an improving satisfaction over the course of 10-years research period of this study. Later on, we will correlate the farmers satisfaction with the FLTSI and the yield to further explain the noted dynamics.

4.3.5. Farmland tenure security

After 2007, as a result of governmental interventions, farming activities in Rwanda have been gradually regulated and strategized in line with the two leading governmental programs we discuss in this chapter. Land tenure security constitutes one of the crucial targets of the LTRP in Rwanda. It is indeed regarded as an enabler of land development, following the accepted theory of change. Hence, concerning smallholder farmers of the rural Rwanda, a secure land tenure was branded as reducing land disputes and stimulating land rights holders to invest in a productive market-oriented agriculture. Indeed, smallholder farmers at the four research sites perceived that LTRP had improved their land tenure security. They mentioned that the land-lease documents obtained after registering their land plots, certify their rights over the land and guarantee their rights against any possible third party. However, at the same time, respondents mentioned that the new "formal" tenure system has taken their right away to decide on the use of their land plots. This decision has shifted to (representatives of) the government. One example that was repeatedly mentioned during the focus group discussions conducted with the famers in each of the research sites, was that they no longer take part in the decisions over the use of their farmland plots or their farming activities. However, at the same time, most respondents were positive about the CIP program, as reflected in their level of satisfaction about the overall shift in farming activities (Figure 3).

The following quotes from interviews with farmers provide a flavour of the type of remarks that farmers made, and also show the importance of the different aspects of the FLTSI that we developed, based on the four variables (1) Disputes over land; (2) Decisions on farmland use; (3) Decisions on crops to cultivate, and (4) Access to bank credits with farm plots as collateral..

> "I remember when officials sensitised us for the systematic land registration, they branded legal tenure as one that will grant the use of land to obtain bank credits … well, that is not happening: either our pieces of land are too small or the documents they request are well beyond the "land lease" papers alone …"
>
> - Interviewed farmer at Gatwe research site, September 2018

> "Farming is not as it used to be before registration and consolidation, we have to work in cooperatives, plant indicated crops and share our harvest in cooperatives … you can't claim that you have a land when farming is determined by others …"
>
> - Interviewed farmer at Gatwe research site, August 2018

> "I am told land is mine but I am not allowed to decide how to use it … there is a government program that asks us to consolidate the use of our farmland … please understand me well I appreciate this program because it is contributing to the increase of harvest"
>
> - Interviewed farmer at Rutemba research site, September 2019

> "… Of course after registration, land disputes reduced in number and to me, that is a clear indication that security improved as well"
>
> - Interviewed farmer at Rusebeya research site, October 2019

a. Land disputes

Table 5 presents the data on land disputes. The Gatwe research site reported the highest number of cases (18) of land disputes, recorded during the 10 years research period of this study (2006-2017). The responding smallholder farmers reported 1, 9 and 8 land disputes respectively before, during and after the systematic land registration. 11 of those disputes originated from disagreements on boundaries, while the remaining 7 resulted from multiple claimants of land rights over the same land plot. The disputes were initially resolved within two years of occurrence, mainly at the family or community levels. At the time of data collection, 5 cases of disputes were ongoing with one being in court.

Like Gatwe, the Rusebeya site reported 18 land dispute cases as well, spread over the 10 years research period of this study. Of those, 8 were reported to have occurred before 2007, the second and third research periods recorded 5 each. The disputes originated from overlapping boundaries (10) and multiple claims of ownership over the same land plot. 12 disputes were solved within 2 years of occurrence, while 4 were not yet resolved by the year 2017.

Nyabubare reported 12 land dispute cases, of which 11 were raised during the systematic land registration - the second research period of this study. At this research site, the cause of land disputes was generally found in the disagreement over ownership. The Rutemba site reported the lowest number (7) of land dispute cases. The 100 smallholders farmers in Rutemba claim that land rights were clearly known at the time of registration in 2008 which reduced the number of disputes. All 7 disputes occurred during or after the systematic adjudication of land rights. 4 of them were resolved at family or community levels, while 3 were ongoing in the court.

The rising of the number of land dispute cases during and after the systematic land registration finds explanation in the land tenure regularisation process. Across the four research sites, respondents conveyed that the legal recording of land rights signalled an alarm to those having interest in land, especially within families where the fear of losing hands on land instilled members to claim ownership of the same land plot. Originally, the disputes were solved by local mediators, "Abunzi", following the proofs of rights and listening to testimonies within the community.

Table 11. Land disputes

	Gatwe	**Nyabubare**	**Rusebeya**	**Rutemba**	**Total**
Total number of disputes	18	12	7	18	55
Total resolved	13	10	4	14	41
First research period					
Number of disputes	1	0	0	8	9
Disputes over boundary	1	0	0	2	3
Disputes over ownership	0	0	0	6	6

Resolved	1	0	0	7	8
Second research period					
Number of disputes	9	11	3	5	28
Disputes over boundary	4	1	3	4	12
Disputes over ownership	5	10	0	1	16
Resolved	8	10	3	3	24
Third research period					
Number of disputes	8	1	4	5	18
Disputes over boundary	4	0	2	4	10
Disputes over ownership	4	1	2	1	8
Resolved	4	0	1	5	10

b. Decisions on farmland use

The formalisation of land tenure undertaken systematically over the country in 2007 stipulates that, in Rwanda, land is the common heritage of past, present and future generations (GoR, 2013). Article 3 of Rwanda land law stipulates that, notwithstanding the recognised rights of people, only the State has the supreme power of management of all land situated on the national territory, which it exercises in the general interest of all, with a view to ensuring rational economic and social development as defined by law. Therefore, the State is the sole authority to accord rights of occupation and use of land. In line with the legal regulations, and with the exception of Nyabubare, most farmers reported the loss of their decisive power over farmland use at the time they joined the CIP/LUC program. This is more notable at the Gatwe research site, as this site joined the new programs directly at the beginning of them. The Rutemba site followed in 2009, while the program started in 2014 at the Rusebeya site. The LUC/CIP efforts have not started in Nyabubare yet, which would explain the difference with the other three sites (figure 4).

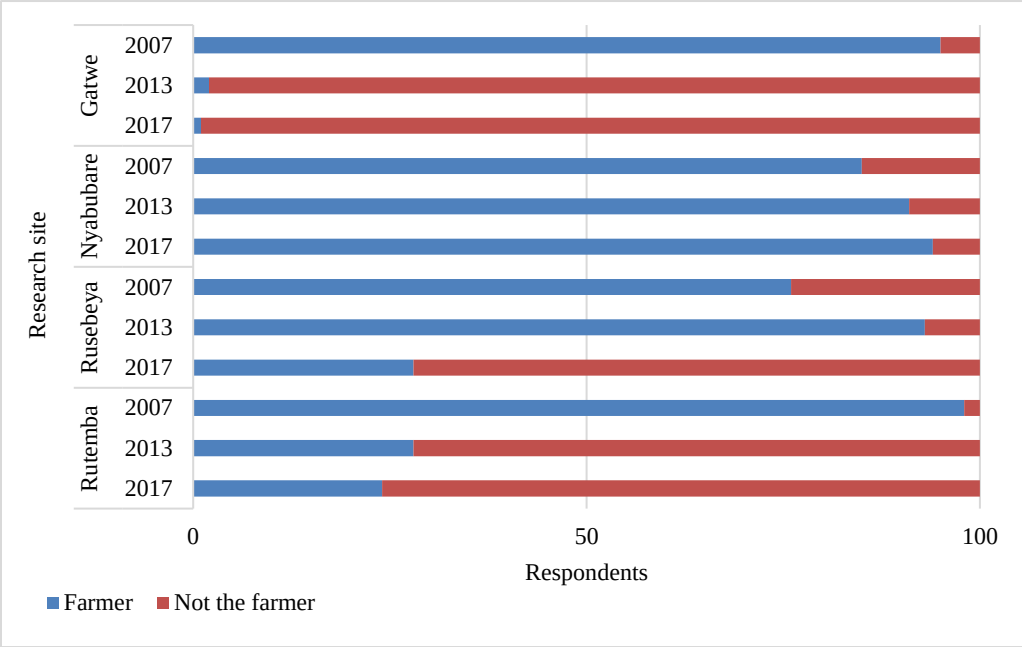


Figure 9. Who decides on farm land use

c. Decisions over farming activities

Unsurprisingly, throughout the three research periods, the overall trend in our findings indicates a coinciding shift in decisions over farming activities compared to land use (Figures 5). In 2007, decisions on farming activities were taken by farmers – which does not mean they were satisfied with the way agricultural fragmented land was used. Our survey indicates they were not. For 2017, the respondents reported that decisions were taken by the government – as already mentioned, they were satisfied with this and the associated consolidated use of agricultural land. At least, this is the case in the Gatwe, Rusebeya and Rutemba study sites. Again, the Nyabubare site registers an exception, with farming activities still being decided by farmers and a slowly decreasing satisfaction with the way agricultural land is being used.

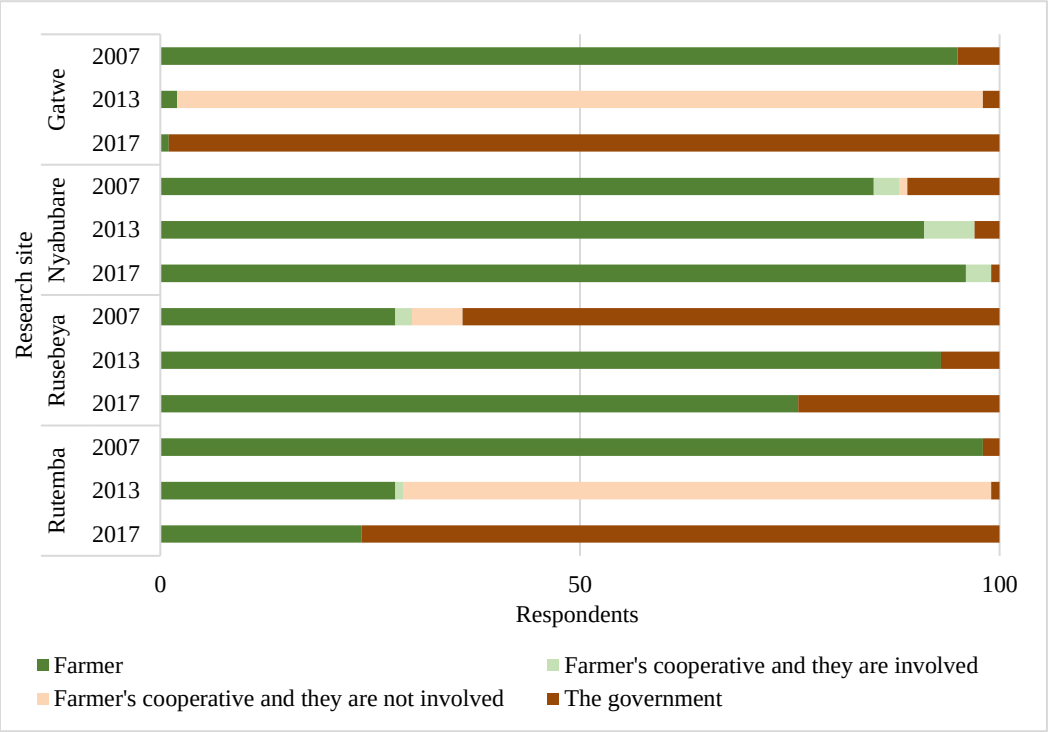


Figure 10. Who decides on farming activities

d. Land used as collateral to access bank credit

In rural areas of Rwanda, smallholders seek credit from microfinance institutions, particularly from Savings and Credit Cooperatives (SACCOs) (Table 6). With banks and other financial institutions more concentrated in urban areas, whilst the majority of the Rwandan population lives in rural areas and are generally excluded from the formal financial institutions (GoR, 2014), the government of Rwanda established the SACCO program in 2008 with the aim to boost up rural savings and provide Rwandans with loans to improve their earnings and enhance their livelihoods. The (World Bank, 2018a) Rwanda Agriculture Finance Diagnostic reported that SACCOs likely finance a large number of farmers in Rwanda. Their credits increased from RWF 8.2 billion in 2012 to 20.0 billion in 2016. To what extent smallholder farmers have easy access to the credits, let alone how they use the obtained credit to invest in their agricultural activities, is less clear, however. Therefore, we asked the heads of households to indicate whether any obtained credit was invested in farming activities.

Table 12. Credits acquired per research site

Study site	Credit offeror	Sector	Number of farmers
Gatwe	Umurunga SACCO	Musaza	8
		Nyamiyaga	9

Nyabubare	SISUNYA SACCO CLECAM Ejoheza Ruyumba		
Rusebeya	SACCO Rubengera COOPEC Inkunga	Rubengera	2
Rutemba	Abamuhoza SACCO, CLECAM-Musanze CLEA-Musanze	Muhoza	9
Total			28

In total, 28 households acquired bank credits, using their land plots as collateral (Table 6 and Figure 6). This type of credit was possible after holders received their Emphyteutic lease documents, which are required by both banks and SACCOs to access credit. Except for Rusebeya with 2 credits, an average of 9 credits were reported per site. Of the 28 credits, 11 were invested in farming activities: 6 to buy materials; 3 to buy seeds and 2 to buy pesticide (figure 6). The other 17 credits helped farmers to build or repair their residential houses. Overall, our results suggest that the necessary enabling conditions that land tenure would bring for obtaining credits are not yet met in Rwanda. Farmers claim to have abandoned the idea of seeking credits, because they were repeatedly refused by the banks. The reasons were either because the smallholders' land plots were assessed to be too small in size to be accepted as collateral, or the farmers' cooperatives were too young and not yet functional enough to be trusted by the credit institutions.

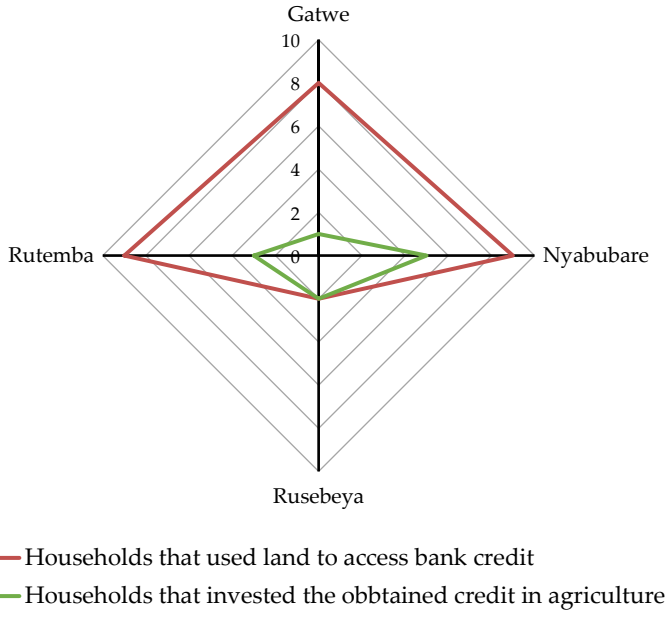


Figure 11. Land used as collateral to access bank credit and invest in agriculture

4.3.6. Results of FLTSI

Security of land tenure cannot be measured directly and, to a large extent, it is what people perceive it to be (Brown & Hughes, 2017; FAO, 2002a; Keovilignavong & Suhardiman, 2020; Rao et al., 2020). The same FAO report argued that the attributes of security of tenure may change from context to context. Considering LTS in the context of smallholder farmers agricultural production, this study designed the FLTSI. Four variables were retained for this study for which we counted occurrences of values (table 7). The resulting table 8 contains the levels of FLTS for each research period and across the four research sites on the basis of a five levels scale from "very low" (0) to "very high" (5).

Overall, FLTS declined (table 8). Farmers claimed that the main threat to their land tenure security was the loss of decision power over their farming activities which occurred when the government of Rwanda launched CIP/LUC program. This was confirmed by the shift from around 96% respondents perceiving to have at least medium FLTS score in 2007 to 12% in 2013 in Gatwe and Rutemba. At these sites, more than 86% of the farmers reported a low level of FLTS in 2013 which remained the same in 2017. The Rusebeya site demonstrated a similar shift when the program started as recorded in 2017. The particular case of Nyabubare site where CIP/LUC program had not started, the level of FLTS only declined from high to medium.

Table 13. FLTSI applied to the selected variables

Variables	Value	Definition	Gatwe			Nyabubare			Rusebeya			Rutemba		
			A	B	C	A	B	C	A	B	C	A	B	C
(1) Households that reported disputes over land	1	No dispute reported	100	97	96	100	89	99	99	91	92	92	95	95
	0	The household reported at least one dispute	0	3	4	0	11	1	1	9	8	8	5	5
(2) Who make decisions on farmland use	1	The household makes decisions on farmland use themselves	100	100	5	82	93	95	99	28	26	98	97	4
	0	Other than the farmer's household make decisions on farmland use	0	0	95	18	7	5	1	72	76	2	3	96
(3) Who make decisions on crops to cultivate	1	The household makes decisions on crops to cultivate themselves	76	93	28	85	91	94	98	28	24	95	2	1
	0	Other than the farmer make decisions on crops to cultivate	24	7	72	15	9	6	2	72	76	5	98	99
(4) Household that accessed bank credits using their farm plots as collateral	1	Household who accessed at least one bank credit was reported	1	2	6	0	4	5	1	4	3	0	0	2
	0	No bank credit was reported	99	98	94	100	96	95	99	96	97	100	100	98

*A: First research period 2006/2007
B: Second research period 2012/2013
C: Third research period 2016/2017

Table 14. The results of FLTSI

FLTS Index	Number of respondents												Level of FLTS
	Gatwe			Nyabubare			Rusebeya			Rutemba			
	A	B	C	A	B	C	A	B	C	A	B	C	
0	1	16	16	5	1	4	0	0	3	0	55	55	Very low FLTS
1	0	74	73	6	6	1	0	0	67	3	33	36	Low
2	21	9	11	14	11	88	30	13	29	73	12	9	Medium
3	71	1	0	70	75	7	69	86	1	23	0	0	High
4	7	0	0	5	7	0	1	1	0	1	0	0	Very high FLTS

4.3.7. FLTS Index versus harvest: no statistically significant correlation

As already mentioned a few times, the respondents in our survey generally acknowledge that their decision making power has diminished. This does not mean that farmers are dissatisfied with the changes that have been brought about since 2007. Smallholder farmers in the Gatwe site, for example, mention that, though they no longer decide on their own farming activities, the government's land use program is bearing fruits. Reporting about 2007, when they decided themselves on farming activities, half of the respondents gave as their perception over the decisions on agricultural land use that they were not at all satisfied by these decisions. Only 40% was partly satisfied. These percentages gradually improved through 2013 (as in becoming lower), to become 3% for 2017. While their satisfaction was improving to 76%, farmers' rights to decide on their farming activities transited first to their cooperative in 2013 and later on to the government in 2017. The increase of satisfaction appears to relate directly to the increase of the harvests of selected crops, namely maize, beans, banana, rice and coffee.

Similar observations can be made for two other sites. In Rusebeya, 97% of smallholder farmers felt the government had a deciding influence from 2013. This percentage remained this high for 2017, and was a large change from 2007, for which the same percentage of farmers reported to decide their farming activities themselves. At the same time, the LUC program in this area is applauded by 99% of the respondents. When the LUC was introduced in the Rutemba area, smallholder farmers could still decide on their farming activities. Farmers in this area were used to a monoculture nature like in the LUC, given that the fertile volcanic soil of this area is favourable to maize and Irish potatoes already. However, according to the Sector Agronomist, the effort of the government to facilitate the distribution of subsidized fertilisers has induced farmers to feel its influence in the decision over farming activities – which we do see in Figure 5 for 2017. Nonetheless, in 2017, 83% of the respondents were more than satisfied by the consolidated land use. Nyabubare represents an exceptional site, where farmers kept and consolidated their decision rights over farming activities. In this area, we observe a marginal falling appreciation of land use.

Across the three research periods, with the exception of the Nyabubare research site, respondents reported an increasing total yield and a decrease in FLTS. In Gatwe, more than 50% of the farmers earned less than 100 $ per Ha from their agriculture production in 2007. The same percentage perceived FLTS to be high with a score of 3 on the index – very similar to Rusebeya and Rutemba. The other two later research periods revealed that not only the yield increased but also that FLTS declined in the three research sites. To support these impressions on issues of land tenure, satisfaction and yields, and further study relations between the harvest or yield per size of the farm plot and the FLTSI, two statistical techniques were used: Pearson correlation and One-way ANOVA.

Concerning the Pearson correlation, our main finding is that the harvest of major crops does not have a statistically significant correlation with FLTS levels at all the four research sites. This suggests that changes in farmland tenure security did not influence higher (or lower) yields. Table 9 shows two Pearson correlation coefficients: (1) the correlation between FLTSI and the harvest of major crops per research site and research period; and (2) the correlation between FLTS and the total monetary yield from harvested crops per size of farm plots. Overall, the table displays a low correlation (below .29) between the studied variables. The rare significant correlation that was found suggests that a decline in FLTS corresponds with an increase in harvest on almost the same magnitude (Figure 7).

Table 15. Pearson correlation between FLTSI and harvest (and yield) per size of the farm plot

Harvested crops	**FLTS index**			
	Gatwe	Nyabubare	Rusebeya	Rutemba
First research period				
Maize	0.087	0.155	0.046	0.032
Beans	-0.049	0.146	0.145	0.047
Sweet potatoes		-0.086	-0.129	
Irish potatoes			-0.084	0.114
Cassava		-0.008		
Sorghum		0.177	0.047	0.039
Banana	-0.043	0.042		
Rice	0.029	-0.163		
Peanuts		-0.022		
Coffee	0.156			
Total yield per size of the plots ($/Ha)	0.053	-0.121	-0.14	-0.06
Second research period				
Maize	-0.202*	-0.106	0.072	-0.144
Beans	-0.141	0.04	0.189	-0.126
Sweet potatoes		0.064	-0.106	
Irish potatoes			-0.249*	-0.083
Cassava		0.013		
Sorghum		0.106	-0.036	0.307**
Banana	0.064	0.028		
Rice	-0.032	-0.287**		
Peanuts		0.019		
Coffee	0.144			
Total yield per size of the plots ($/Ha)	0.023	-0.17	-0.126	-0.104
Third research period				
Maize	-0.132	-0.011	-0.284**	-0.197*
Beans	-0.114	0.035	-0.243*	0
Sweet potatoes		0.031		
Irish potatoes				-0.148
Cassava		0.001		
Sorghum		0.113		0.178
Banana	-0.105	0.024		
Rice	-0.062	-0.320**		
Peanuts		-0.038		
Coffee	0.097			
Total yield per size of the plots ($/Ha)	0.003	-0.171	-0.066	-0.053

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

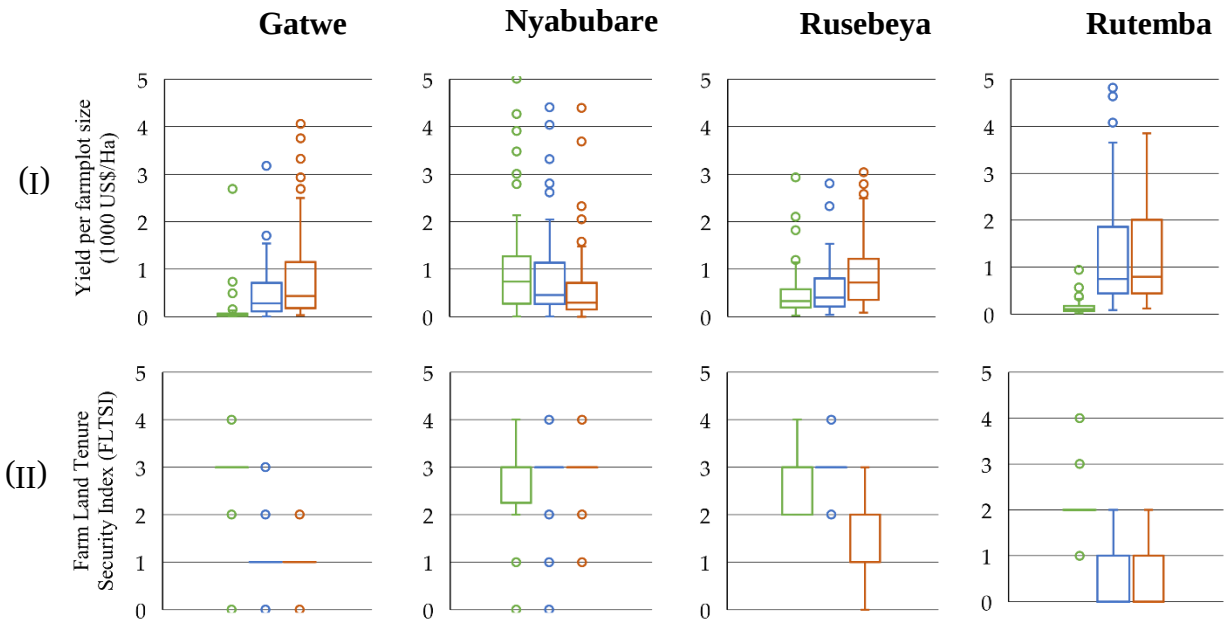


Figure 12. Yield per farm plot size (I); farm land tenure security (II)

In line with the Pearson results, our three ANOVA tests were not significant p=0.05 for all four research sites across the three research periods (table 10). Therefore, the results allowed to reject the null hypothesis H_0 and supporting the conclusion, that there is not a statistically significant positive relation between FLTS and the total yield per size of the farm plot. Because there was no statistically significant relation, there was no need to push the analysis further by differentiating between groups.

Table 16. One way ANOVA: comparison between mean total yield $ per size of the farm plots across the 5 levels of FLTS (df: 4)

	Research site			
	Gatwe	Nyabubare	Rusebeya	Rutemba
First research period				
Sum of Squares	101502062	7665453053	429888638	8804236
Mean Square	33834021	1916363263	214944319	2934745
F	0.42	1.12	1177	0.14
Sig.	0.74	0.35	0.31	0.94
Second research period				
Sum of Squares	813777096	5067503835	662800632	9670567
Mean Square	271259032	1266875959	331400316	4835283645
F	0.88	0.85	1418	0.60
Sig.	0.45	0.50	0.25	0.55
Third research period				
Sum of Squares	2912974	5304636475	963302059	3053960186
Mean Square	1456487205	1768212158	321100686	1526980093

F	1258	1517	0.33	0.16
Sig.	0.29	0.22	0.81	0.86

4.3.8. Increase of small farms harvest and the CIP/LUC program

Looking further to understand what caused the increase of yield, we extended the analysis to other variables: plot size, number of plots, farmers receiving government subsidy, as well as their satisfaction of changes in farming activities. Table 11 allows us to suggest that the ongoing crop intensification program is the main contributor to the increase of small farms harvests.

Table 17. Pearson correlation between total yield per size of the farm plot and selected variables

	Total yield per size of the farm plots ($)			
	Gatwe	Nyabubare	Rusebeya	Rutemba
First research period				
Number of plots	0.202*	0.327**	0.406**	0.486**
Size of the plots	0.496**	0.279**	0.293**	0.525**
Subsidized	n.a.	0.501**	0.224*	n.a.
Satisfaction	0	0.311**	-0.049	0.069
Second research period				
Number of plots	0.136	0.403**	0.428**	0.312**
Size of the plots	0.404**	0.208*	0.190	0.211*
Subsidized	0.417**	0.465**	-0.079	0.476**
Satisfaction	0.340**	0.233*	-0.051	0.051
Third research period				
Number of plots	0.249*	0.331**	0.653**	0.288**
Size of the plots	0.246*	0.115	0.272**	0.195
Subsidized	0.587**	0.605**	0.141	0.461**
Satisfaction	0.236*	0.329**	0.073	0.006

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

n.a. Not applicable. Farmers did not receive subsidies

First, the number and size of the farm plots per farmer correlated with the yield independently of the study site or the research period. Furthermore, farmers with more than one plot increased their yield compared to those with only one plot. The larger the farm plot, the higher the increase of the yield realized. Secondly, farmers who received the government subsidies, either through the CIP/LUC or other programs, increased their yield. For the smallholder farmers, the subsidies comprised mainly fully or half waived prices on fertilizers and seeds. Overall, smallholder farmers said that the consolidation of the use of land came from the government. When their plot fell within the selected LUC site, they were afforded no other choice but to join, willingly or not. Therefore, for most of our respondents, joining the program signified losing their rights to decide over the use of their land plots (table 7). However, after the new 'imposed' use of land, farmers increased their

harvest of major crops per site: maize and beans which are prioritized by the CIP/LUC program. Farmers hail the increase of harvest when they started following the directives of the agronomists on the use of fertilizers.

> "I recall ten years ago, I was not using any sort of fertilizers. I had no cow so not even manure … When I started using the mixed manure-mineral fertilizers, my harvest of maize and beans has tripled and the quality improved".
>
> -Interviewed farmer at Rusebeya research site, September 2019

Finally, the satisfaction of farmers over the changes in farming activities correlate with yields. Farmers indeed conveyed that their satisfaction of the CIP/LUC was purely based on the increase of their yield, which they attributed to the program. It is important to note that seeing and valuing this increase did not take away their perception of the reduced decision power on land use and farming in general.

> "I am told land is mine but I am not allowed to decide how to use it … there is a government program (CIP/LUC) that asks us to consolidate the use of our farmland … please understand me well. I appreciate this program because it is contributing to the increase of harvest"
>
> - Interviewed farmer at Rutemba research site, September 2019

The exception to the general pattern is the Nyabubare site, which displayed the highest correlation coefficient despite respondents not joining the CIP/LUC program. Farmers in Nyabubare have adopted the Crop Regionalization Program, within which agronomists point farmers to the benefits of prioritizing agro-ecological crops and assist them with the implementation. In Nyabubare, this led to an increase in harvest. In addition, the program comprised government subsidies of fertilizers and seeds. For the same reasons as farmers implementing the CIP/LUC program, the increase of harvest led to satisfaction of the farmers. However, the monoculture nature of the regional crop in the area has exacerbated the cassava brown streak disease that attacked cassava plants in 2014. Farmers recall other challenges for their production too, including a long period of drought in 2007, insects in beans, farming plots being far making it hard to transport manure, and low production of rice due to the lack of water for irrigation in marshlands.

Despite not being part of it, farmers have (diverging) opinions on the CIP/LUC program. While some farmers wanted the program to reach their farms, others rejected the idea.

> "Polyculture was not productive. I used to produce little quantity of almost everything but that was not enough to feed my family. At least now, I can gain money from selling the harvest of maize and rice. Though I still cannot afford to feed my family from the harvest, I use the small amount of money I earn from selling the harvest to buy alternative food from the market".

The same farmer added:

> "I also want to join CIP/LUC program but unfortunately, it reaches some farmers while others, like me, are not concerned because their plots fall out of the selected LUC sites!"
>
> -Interviewed farmer at Nyabubare research site, August 2019

> "Here in Nyabubare, we firmly rejected the LUC program. The program favours only a number of selected crops and prohibit others which are good for our meal. For example in my case, I reported a lack of good quality banana seeds back in 2014 but I was told to focus on maize and beans instead! This is a big issue considering that banana used to grow well here and remains one of the main meals on table."
>
> -Interviewed farmer at Nyabubare research site, August 2019

The case of Nyabubare, a site that did not yet join the CIP/LUC program, helps us to see that that the farmers' satisfaction of the farming activities that we find should not be attributed to the CIP/LUC program as such. Rather, in Nyabubare, the government subsidies and assistance to farmers seems to have led to the increase of yield playing a crucial role in their satisfaction.

4.4.Conclusion

This study assessed the relations between farmland tenure security and agriculture production among smallholder farmers in Rwanda. The study used four research sites to collect data retrospectively on farmers' FLTS and agricultural production. We designed the index following our review study presented in chapter two, that underlined the need for a locally-defined mixed approach to depict the link between land tenure security and agriculture production. As such, our FLTSI should not be understood as an overall status of LTS in Rwanda. We connected our locally-defined Farmland Tenure Security Index to a one-way ANOVA test and calculated statistical correlations with the harvest and monetary yield. The analysis was extended to a set of additional variables including plot size, plot number and farmers satisfaction to broaden our understanding of the relations we are interested in. Our results suggest that at least, for the four sites constituting our study area in Rwanda, a new wave of agricultural programs appear to contribute to an increase of small farms' harvests of main crops. These programs aim to intensify the cropping by means of consolidating the farmland use and subsidize the farming activities. These same government programs seem to result in a decrease in actual land tenure security of farmers.

Our FLTSI was based on threats associated with these governmental programs as perceived by smallholder farmers at each research site. The mentioned threats include shrinking participation of farmers on decisions over land use and their farming activities. Our findings indicate that the harvest of main crops did not statistically correlate nor show differences in the mean within the land tenure security index levels in all the four research sites. Instead, factors mainly related to the ongoing crop intensification program which though seemingly threatening tenure security contributed to the increase of small farms' harvest. We pose that the weakened land tenure security did not affect farmers' satisfaction of the crop program with most of them claiming that in the end what matters most is that their harvest of main crops continues to increase.

Our findings confirm how complex the issue of tenure security, and its associated evaluation, actually is. One could argue that increased government interventions (e.g. new restrictions or responsibilities) around land use undermine LTS (compare with (M. C. Simbizi, 2016). Indeed, we show with our four aspects that define our FLTSI, that the decision making aspects are the cause for the Index becoming lower over time. Having said that, we do recognize the complexity of valuing increased governmental influence when it comes to tenure security. Indeed, we show that farmers acknowledge that increased governmental influence did result in higher harvests. We also show that farmers' responses suggest that when these governmental programs started, farmers did not necessarily appreciate these interventions. Over time, given the higher harvests, appreciation changed. What smallholder farmers appreciate is the fact that LUC increase their yield of selected crops.

For three research sites, the harvest and yield value per farm plot size grew particularly for the crops prioritised by the CIP/LUC program (maize and beans). The main exception to the general observation of harvest increase is Nyabubare because cassava, the main crop produced in the

area was attacked by CBSD that considerably reduced the harvest of cassava tubers from the agriculture year 2014. For the research sites where farmers joined the CIP/LUC program and prioritised selected crops, the harvest of other crops reduced to give way to maize and beans. However, the more plots the farmers owned outside the program the more possibilities they had to keep diversifying their harvest. Our findings show that the shift in the types of crops produced and the increase of harvest though not as high as the one achieved with CIP/LUC has been taking place in Nyabubare research site as well. Indeed, other programs promoting crop regionalization and the proximity of agronomists' services to farmers were found to contribute.

To understand the changes related to the tenure and use of farmland, we asked respondents to retrace the biography of their farmland plot as well as their agriculture production activities. This was the only technique possible to collect such data, since we could not find exhaustive archives of data per farm plot. The little information found in the district reports was used as additional source to validate the data. Furthermore, they served as background information to expand on the narrative of our findings. As such, the generalization of the findings and conclusions of this study should be done carefully, given the locally-defined approach pursued to collect and analyse data. However, the research approach designed is applicable and deserves to be taken up by further research work to locally assess the relations between land-tenure security and agricultural production.

Finally, the research approach designed in this study was motivated by our early synthesis review article presented in chapter two , that claimed a lack of studies based on local field evidence when studying the relations between land tenure and agricultural productivity. Rwanda was selected as a case study because of the ongoing systematic reform process to improve LTS and agricultural productivity. In fact, having both reforms operating simultaneously all over the country, and given the diversity of the four corners of the country with regards to the variables considered, this study conducted an empirically relevant spatio-temporal comparative analysis.
This field-data-bound study contributes to the knowledge of the relations between farmland tenure security and agricultural production, relations that are too often discussed without clear local evidence. We went beyond conceptually describing the studied relations. We did engage with the complexity of tenure and governmental intervention, relying on the data collected from rights holders. Our respondents indicated that their tenure is changed by the reduced/loss of rights to decide on the use of land, but also indicated that their satisfaction of the CIP program changed over time. Most importantly, we have mobilized our locally-defined FLTS and a set of variables to represent the reality of local Rwandese smallholder farmers when it comes to their complex tenure situation, their abilities (or not) to exercise decision making power and their satisfaction concerning (increased) yields.

5

Securing the harvest for the smallholder farmer in Rwanda: fragmented or consolidated farmland use?

This chapter is based on:

Singirankabo, U.A., Ertsen, M.W., Giesen, N., Securing the Harvest for the Smallholder Farmer in Rwanda: Fragmented or Consolidated Farmland Use? Land 2022, 11, 2023. https://doi.org/10.3390/land11112023

Abstract

The year 2007 marked the beginning of a journey to secure food in Rwanda. The country introduced the Crop Intensification Program (CIP), which promotes the farmland use consolidation (LUC). This study assesses the effect of farmland use changes on the agriculture production. We collected data at four research sites and considered three agriculture years to assess the effect of the fragmented or consolidated farmland use on the harvest. The study confirms that the CIP/LUC program converted perennial crops, mainly banana plantations, into seasonal crops, which were prioritized by the program. Overall, we conclude that the shift in farmland use has created an increase in both the harvest and monetary yields of the prioritized crops. However, within that general trend, we observe differences: farmers with smaller and/or fewer farm plots did not realize as great a yield increase as those who joined the CIP/LUC program with larger and/or multiple farm plots.

5.1.Introduction

Across Africa, recent decades have seen countries undertaking developmental policy-informed programs with the aim to improve the agriculture harvest for their growing population. Lately, consolidating farmland has been prioritized. In fact, continued land fragmentation reportedly discourages investments in mechanization or the adoption of innovative farming techniques (Del Prete et al., 2019; Nilsson, 2019). This is particularly the case in many sub-Saharan African countries where farming areas are being fragmented due to inheritance. To reverse the effects of land fragmentation, countries proceed with land consolidation. For Rwanda, Muyombano and Espling (2020) found that at first, land fragmentation was often not seen as a problem among the local farmers. This was because fragmented landholdings favoured the traditional agricultural system of shifting cultivation, which provided better risk management for the landholders.

However, over the course of past twenty years, the country registered an increasing population growth (average 2.5% annual increase) and a declining per capita agricultural land size (currently less than 0.5 ha). In addition, studies on Rwandan agriculture enumerate other challenges like inadequate agricultural technology, over-cultivation and low use of agricultural inputs, land fragmentation, and imperfect financial markets (Bizoza & Havugimana, 2013; Byiringiro & Reardon, 1996; GoR, 2021; A. Nahayo et al., 2017). Despite all these problems, the agriculture sector in Rwanda remains the backbone of the economy in terms of employment and income generation for the majority of households (NISR, 2018).

Aiming to sustain food production on farm level and secure food for its growing population, the Rwanda government decided to consolidate the use of (farm) land and improve farming practices. These are the two main pillars of the crop Intensification Program (CIP) that was introduced in 2007 by the Ministry of Agriculture and Animal Resources (MINAGRI) as a solution to land fragmentation, low use of agricultural inputs and low access to extension services (A. Nahayo et al., 2017). CIP aims at improving agricultural productivity, which has

long been a challenge in Rwanda due to land scarcity and agricultural intensification strategies that exhausted the country's natural resources (Bizoza & Havugimana, 2013; Uchendu Eugene Chigbu, Pierre Damien Ntihinyurwa, Walter Timo de Vries, & Edith Ishimwe Ngenzi, 2019; Del Prete et al., 2019; Mbonigaba & Dusengemungu, 2012; Muyombano & Espling, 2020).

In a global perspective, the process of land consolidation dates back to the 18th century. The first consolidation initiatives were carried in Denmark in the 1750s as part of a profound social reform to free people from obligations to noble landlords by establishing privately-owned family farms (FAO, 2002a). Since, as in current rural Africa, this process of consolidation is focused on optimising conditions in the agricultural sector through the re-allocation or exchange of parcels, and the provision of additional lands from land banks (Ekise, Nahayo, Mirukiro, & Mukamugema, 2013). While the consolidation of fragmented holdings did result in improved agricultural productivity in Europe, in Africa, this process is new (K. O. Asiama, Bennett, & Zevenbergen, 2017). Only recently, its diverging outcome in several African settings started to emerge in the scholar literature (Ekise et al., 2013; Jacoby, 1959; Jiang, Tang, Long, & Deng, 2022).

Land Use Consolidation (LUC) emerged as the main pillar of the CIP with the aim to stop the land fragmentation. The Ministerial Order determines the models of land use consolidation in Rwanda. It stipulates that through the LUC program, participating farmers commit to consolidate aspects of their operations while retaining individual ownership of their farm plots (GoR, 2010). This joint cultivation of large areas comprising multiple adjacent smallholder plots over which the farmers retain their individual land rights, is expected to deliver important economies of scale in the production of selected crops (Bizoza & Havugimana, 2013; GoR, 2011; Musahara, 2006; Muyombano & Espling, 2020). Prior to the beginning of the agricultural season, farmers commit to participation in the program and agree to forego traditional intercropping techniques in favour of cultivating a single, government-approved crop in collaboration with neighbouring farmers. By joining the LUC program, farmers gain access to various services under CIP such as: (i) delivery of inputs (improved seeds, fertilizers), (ii) extension services, (iii) post-harvest handling and storage facilities, (iv) irrigation and mechanization by public-and private stakeholders and (v) markets for inputs and outputs (Ekise et al., 2013; GoR, 2010).

The CIP focuses on eight priority staple crops: maize, wheat, rice, Irish potato, beans, cassava, banana and soybean. The crop rotation system is based on crop suitability in a specific agro-ecological zone and its contribution to overall food security (Mbonigaba & Dusengemungu, 2012; A. Nahayo et al., 2017). While credited with increasing yields of select crops, both CIP and LUC have been linked to reduced decision-making authority over land and, in some cases, decreased tenure security for participating smallholder farmers - thus discouraging them to expand their investment in agriculture (Kwabena Obeng Asiama et al., 2021).

This chapter uses four case studies in Rwanda to assess the effect of farmland use change on agricultural production of smallholder farmers in Rwanda. The assessment is based on a dataset retrospectively compiled from three agricultural years: 2006/2007; 2012/2013 and 2016/2017. Our results suggest that crop yields increased statistically with the start of the CIP in 2007 and the beginning of land use consolidation. Total production quantities for CIP priority crops grew by more than 150 per cent between 2007 and 2017 in CIP-supported plots, and yields of all the targeted commodities improved. However, the yield increases did not vary the same way for all farmers - some of them actually lost yields on the change. As we will discuss in the following sections, LUC prioritised a number of crops which conditioned the trend in yield increase. Before doing that, we will explain our research methodology.

5.2.Methodology

5.2.1. Study area selection and sampling

The study involved smallholder farmers across four study sites, one in each of the four Provinces in Rwanda: Gatwe in the Eastern Province, Nyabubare in the Southern Province, Rusebeya in the Western Province and Rutemba in the Northern Province (Figure 1). The study sites have in common that they are located in districts where pilot trials of the land tenure regularisation were conducted. Hence, the sites represent areas where the formalisation of land rights started in the country. Other selection criteria were linked with the performance in the CIP/LUC program, including number and size of farmland plots per household, and agriculture zoning (Table 4). Those criteria vary from site to site, offering the possibility of a comparative analysis. Considering the systematic implementation of land tenure registration (see and CIP/LUC, we assumed that farmers at the research sites shared an awareness of these programs – which was confirmed when visiting the sites. Per site, a questionnaire was administered to the first 100 random farmers who accepted to be part of the study.

5.2.2. Research period and primary data collection

The survey was conducted in two periods, namely July to September 2018 and July to October 2019. In the process, three techniques of data collection were applied: (1) a semi-structured questionnaire was designed for the farmers, based on the initial analysis of published materials; (2) semi-structured face-to-face interviews were conducted with officials working in land management and agriculture, including local agronomists and land management officers; (3) focus group discussions were conducted with farmers within their cooperatives.

In case we could not collect records either from farmers, their cooperatives or local authorities in charge, we asked the farmers to retrace their tenure and agricultural activities. This allowed to collect retrospective data over three research periods coinciding with three agriculture years/seasons (Table 5):

1. 2006/2007, when almost all information on land was not formally recorded in rural areas;
2. 2012/2013, the systematic land registration period; and
3. 2016/2017, the period after registration.

The generated dataset covers farmers' plots biography and their agriculture production. In particular, the survey focused on discerning the legal land tenure, agriculture inputs, harvested crops, and the farmer's participation in decision making concerning farming activities,.

Research period

Research Period	Rationale
2006/2007 Before formal registration of land rights	Insights on land tenure arrangement and the status of land tenure security before registration. In addition, the study looks at the land use change, if land was used for agriculture then, identify farming techniques and production
2012/2013 During the systematic land registration	During this period, the systematic land registration took place. Land rights holders registered their rights for the first time through land demarcation and adjudication. In addition, the country undertook agricultural transformation programs starting with the implementation of the crop intensification program that launched land use consolidation. The research investigates both processes and identifies correlations.
2016/2017 After the systematic land registration	5 years after land registration, the research assesses the effect of (legal) land tenure security brought by the land tenure regularisation program and, in particular, land registration and titling.

5.2.3. Secondary data

To complete the dataset, especially to fully retrace the changes in land tenure security and agriculture production within the ten years period of this study, we used documentary evidence from various relevant sources. We collected plot indexes and associated information on land registration, tenure and use from the Ministry of Environment (MoE), the Rwanda Land Management and Use Authority, and the District One-Stop Centres. For information on past harvests and agriculture inputs, we visited the libraries of the Rwanda Ministry of Agriculture and Animal Resources (MINAGRI), agriculture projects on the site, and farmers cooperatives archives. Finally, secondary data were collected from local government offices at district, sector and cell levels, where data on the use and management of land, as well as information on the implementation of LTRP and CIP/LUC could be found.

5.2.4. Farmland use change

To validate and compare the changes as found in primary and secondary data, we used satellite images retrieved from Google Earth on 7th September 2021. We created feature classes

containing place marks of the four research sites and exported them as shape files to Google Earth. The images with marked places were imported into ArcGIS 10.5 for further processing. The images were georeferenced using the place marks priori created and marked in Google Earth and projected to WGS_1984 Transverse Mercator. The images used are not of the same period of the years. Hence, we were not able to determine the variability in seasonal crops. Nonetheless, perennial crops like banana and trees could be identified. These can be used as indicators of land use change, as those perennial crops tend to be on separate farm plots and were therefore removed when adopting the land use consolidation approach. A combination of supervised classification using sample signatures and digitization of discrete areas on the images was applied. The classification followed a maximum likelihood technique.

Satellite images description

Research site	**Time period**		
Gatwe	07/2006	09/2013	08/2018
Nyabubare	07/2007	06/2013	06/2019
Rusebeya	09/2002	01/2015	08/2018
Rutemba	10/2006	07/2014	01/2020

5.2.5. Yield variation

To be able to compare the developments of harvests across years and research sites, we converted harvest amounts in monetary value. To measure the variation in monetary yield across the research periods, the year 2007 was taken as baseline. We calculated the farmers ability to buy the same food that they used to harvest before the farmland use consolidation in the other two research periods. For example, for the research period 2013, the harvest of 2013 was subtracted from that of 2007 (calculation: a, c). Then, we multiplied the obtained additional harvest with the crop prices of 2013 (calculation: b. d). With reference to table 1, we were able to calculate the additional yield for crops that are prioritised by the land use consolidation program, and for the remaining crops harvested by the farmer. We repeated the same calculations for the research period 2017, keeping 2007 as reference. Please note that we did not study the nutritional value of harvests or the ability to actually buy the food with the money earned.

Calculation:
Using the example of the Gatwe research site, here we calculate the additional yields for the research period 2013.

LUC crops

(e) $\text{Harvest 2013}_{(\text{maize, beans, rice})} - \text{Harvest 2007}_{(\text{maize, beans, rice})} = \text{AH}_{(\text{maize, beans, rice})}$

(f) $\text{AH}_{(\text{maize, beans, rice})} * \text{Price 2013}_{(\text{maize, beans, rice})} = \text{AY}_{(\text{maize, beans, rice})}$

Other crops

(g) $\text{Harvest 2013}_{(\text{banana, coffee})} - \text{Harvest 2007}_{(\text{banana, coffee})} = \text{AH}_{(\text{banana, coffee})}$

(h) $\text{AH}_{(\text{banana, coffee})} * \text{Price 2013}_{(\text{banana, coffee})} = \text{AY}_{(\text{banana, coffee})}$

AH, additional harvest
AY, additional monetary yield

5.2.6. Sign test

We used the sign test to determine if there were increases in the median of the yield between different years. The sign test is a non-parametric test that does not make assumptions about the underlying distribution of the variables. As such, it is more conservative than, say, a t-test, which assumes normality of the underlying distribution. The sign test determines the chance that the median yield from one year is larger than the median yield from another year. We calculate the chance that the number of farms with an increase in yield could be explained by random chance and subtract this chance from one. So, if for a given year, there are 62 out of 100 farms with a yield higher than the median yield of a previous year, we calculate what the chance would be that this is due to random chance. Or, if we would flip a fair coin 100 times, what would be the chance that we have head 62 times. This follows a binomial distribution and the chance would in this case be 0.60% - which means there is a chance of 99.4% this is not due to random chance.

5.3.Findings

5.3.1. Land use

In table 2, we show the shift from fragmented to consolidated land use for each of the research sites. We also show the different years that the research sites joined the LUC program. Land use consolidation has seen the harvest of some crops abandoned or considerably limited, mainly due to the prioritisation of crops that are deemed most suitable for the farming site – as shown in table 16.

Table 18. Types of crops harvested per site and per farmland use type

Research site	Crops prioritised in consolidated farmland use	Crops harvested in fragmented farmland use
Gatwe	maize, beans, rice	banana, coffee
Nyabubare*	n.a.	maize, beans, sweet potatoes, sorghum, banana, rice, peanuts
Rusebeya	maize, beans	sweet potatoes, Irish potatoes, sorghum
Rutemba	maize, beans, Irish potatoes	Sorghum

**Nyabubare research site kept the harvest of the same crops since it has not joined the consolidated farmland use at the time of data collection (September 2019).*

Figures 1 and 2 illustrate these changes with respect to the three research periods of our study. We observe that in the three areas where land consolidation has been important, the areas of permanent crops that are visible (especially banana's) have reduced (Figures 1a, 1b and 1c). At the Gatwe research site (Figure 1a), areas of banana plantation that used to cover half of the farmland on the image of 2006 reduced noticeably on the images of 2013 and 2018. Indeed, our survey revealed that the area that used to grow banana has been converted into seasonal cropping like maize and beans. Land use that expanded is the residential area. Within the research period, more and more houses appear on the images on both sides of the road that crosses the site in the north. This area has been delineated for residential purpose by the Kirehe district land use plan with the aim to prevent housing extension on farmland area.

At the Rusebeya research site, the image of 2002 shows areas covered with banana plantations (Figure 1b). The satellite image of 2015 looks remarkably different, with the disappearance of banana plantations and the emergence of terraces. In fact, the terraces were created by a government sponsored program that was implemented in 2014. The area terracing coupled with the prioritization of maize and beans brought about by the CIP/LUC made banana growing disappear at the Rusebeya site. In line with the other LC-districts, the Rutemba research site denotes the same conversion of banana plantation into farmland with seasonal cropping (Figure 1c) over the period 2006, 2014 and 2020. Banana was found surrounding residential houses on the image of 2006, but it is completely absent on the images of 2014 and 2020. The other class that extended is (again) residential houses. The classified images show more and more houses along the roads as we advance in our research period. The area has been urbanising especially because of the proximity to the centre town of Musanze. The new settlers on the Rutemba site are mainly coming from Musanze, and also from Kigali as reported by the respondents.

Figure 13. Land use changes at the Land Consolidation sites (13a Gatwe / 13b Rutemba / 13c Rusebeya)

Figure 13a

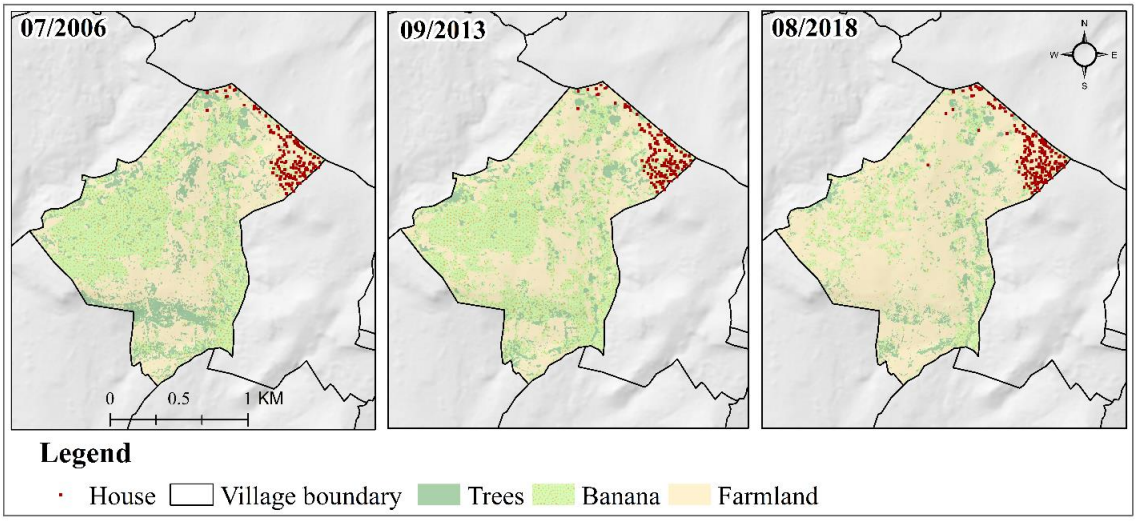


Figure 13b

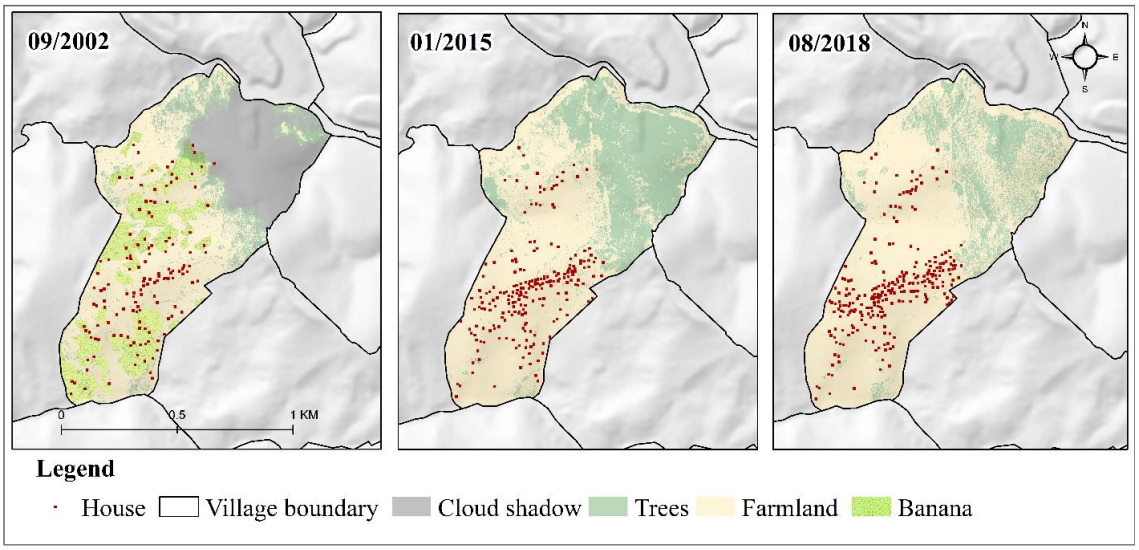
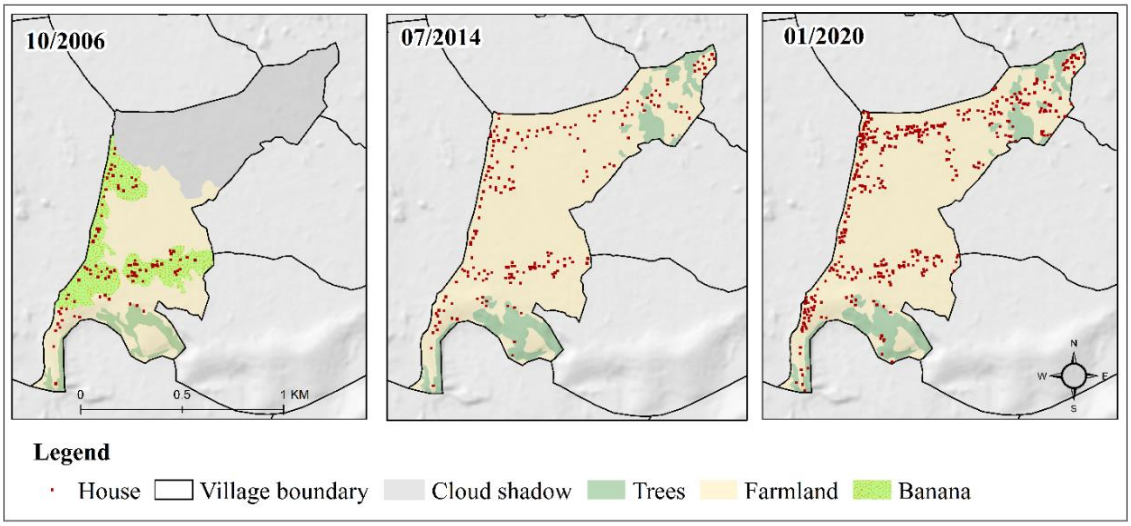
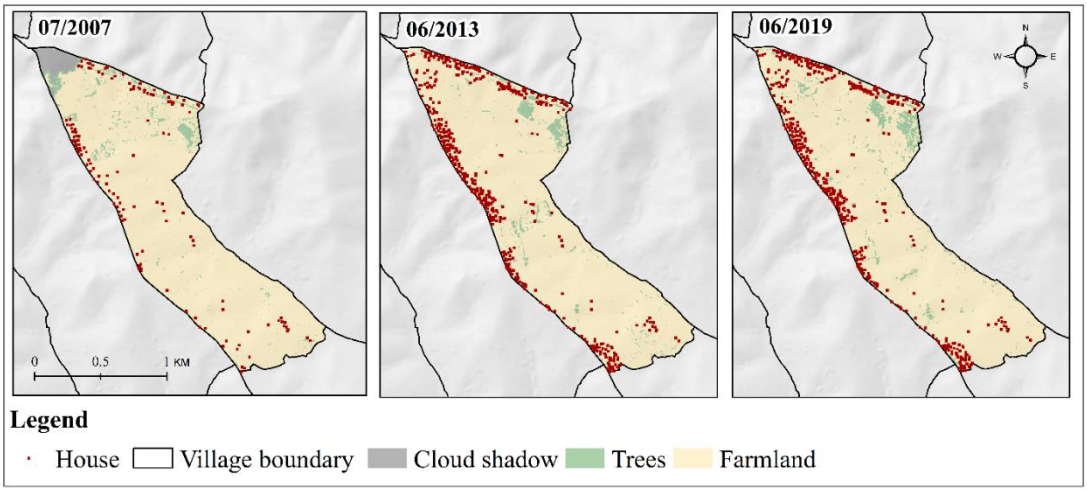


Figure 13c



The satellite images of Nyabubare site show a different change in land use. In fact, only the housing class showed tangible changes over the course of the research period (Figure 2). The image of 2013 shows that residential houses have amassed along the road that constitutes the western boundary of this site. This trend continued as detected on the image of 2019. The farmland extends from the road towards the lower altitudes and the wetlands.

Figure 14. Land use changes at the Nyabubare research site



5.3.2. Overall increase of crop yield per research site

Overall, the three research sites that had joined the LUC program at the research period time, reported an increase of the yield per farmer between the three research periods of this study (Table 6). The Nyabubare research site (that had not started the LUC program just yet) does not show such an increase. However, the overall increases do not happen to all farmers alike. With reference to the harvest of 2007, a decrease of the yield indicates that the farmer produced less harvest in 2013 or 2017. Table 18 shows that some farmers kept a negative additional yield from the crops that were not prioritised by the LUC program even after adding the yield from LUC crops.

Table 19. Chances that the median of a yield in a given year (expressed in USD) is larger than the median of the harvest in the other year for all four research sites.

	P(M2013>M2007)	P(M2017>M2013)	P(M2017>M2007)
Gatwe	1.00	0.93	1.00
Nyabubare[a]	0.31		
Rusebeya	0.99	1.00	1.00
Rutemba	1.00	0.76	1.00

[a] In Nyabubare, the yield in 2017 was lower than the yield in 2013

(P(M2017<M2013=1.00***)), the yield in 2017 was lower than the yield in 2007 (P(M2017<M2007=1.00***)), and the yield in 2013 was lower than the yield in 2007 (P(M2013<M2007=0.76)).

Table 20. Number of farmers with negative (additional) yield with reference to the harvest of 2007

		Farmers having a negative (additional) yield			
	Harvest year	LUC crops	Other crops	Total AY	Other crops in Total AY
Gatwe	2013	15	7	15	**2**
	2017	13	9	15	**6**
Rusebeya	2013	33	45	43	**41**
	2017	6	83	15	**15**
Rutemba	2013	20	64	30	**18**
	2017	11	64	32	**25**

5.3.3. Variation of the monetary yield per farmer

Our four research sites have not joined the LUC program at the same time. Gatwe and Rutemba research sites joined the LUC program at the beginning, from agriculture year 2007/2008. The program started in 2014 at the Rusebeya research site when the government proceeded with the terracing of the farmland on its hilly landscape. The Nyabubare site had not joined the program during the period of this research (2006-2017). Figure 15 displays an almost similar trend in yield variation per farmer for the three sites that joined the LUC. However, in figure 6, a unique display is observed which suggests that at the Nyabubare research site, the additional yield does not follow a trend. The variation of yield observed cannot be related to the LUC program package. Let us explore these yield patterns in more detail.

Figures 15a, 15b and 15c show the variations of the yield between the first research period (2006/2007) and the second (2012/2013) and third (2016/2017) respectively for each of the research sites. The figures display three curves: (1) additional yield per farmer realised from the harvest of the crops prioritised by the LUC program; (2) additional yield per farmer from the crops that are not considered for the LUC program; and (3) total yield per farmer of the later research period. Based on these figures, we can clearly observe that more farmers lost their yield from the additional harvest of crops not prioritised by the LUC program in 2013 and 2017. This is the case in the Rusebeya and Rutemba research sites while in Gatwe, the negative additional yield was found among farmers who joined LUC program.

Figure 15a

Figure 15b

Figure 15c

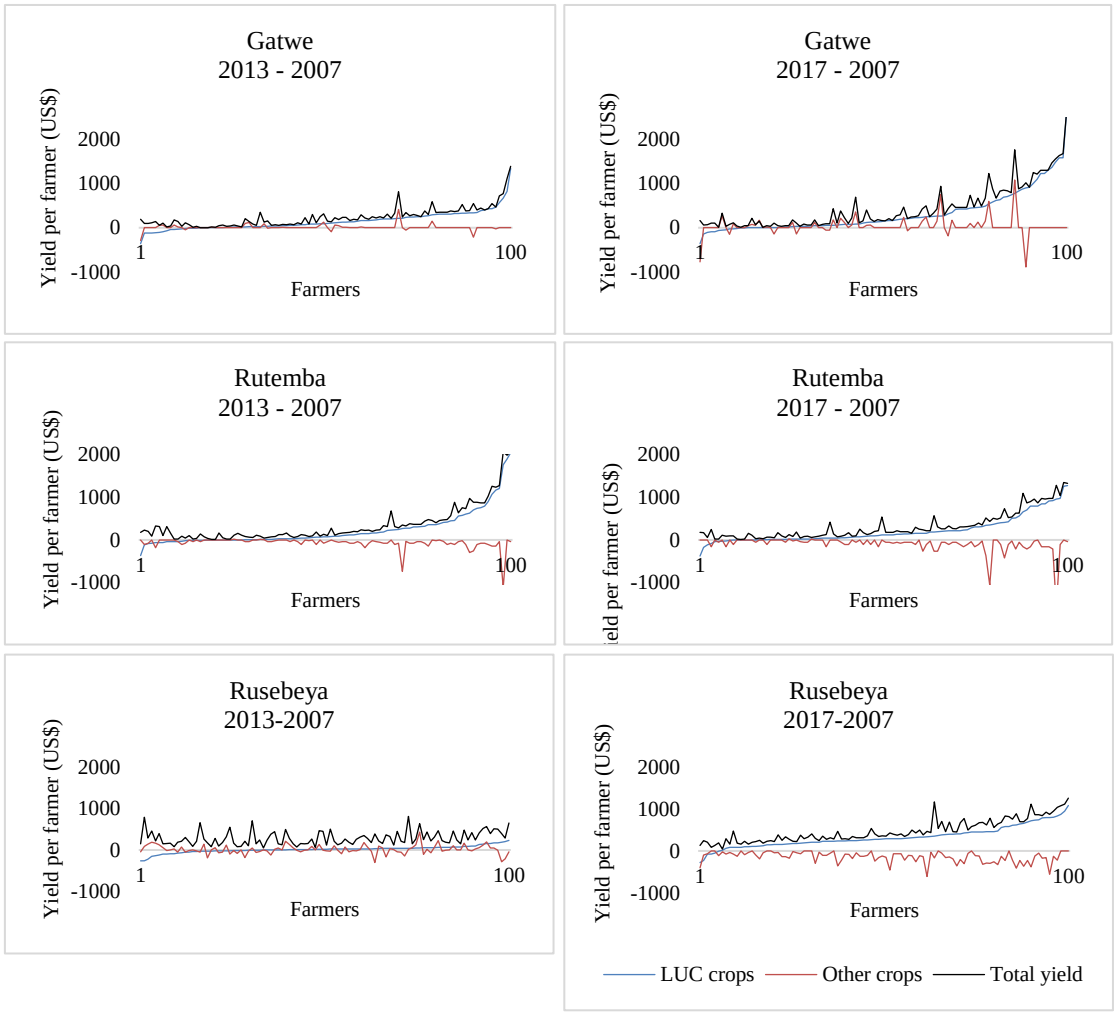


Figure 15. Variation of yield per farmer and per research site

At the Gatwe research site, the crops prioritised by the LUC program include maize and beans. In addition, we added rice production because it is harvested in cooperatives of interviewed farmers in a similar setting concerning plot use as the LUC system. The remaining crops considered as non-LUC for this research are banana and coffee. Most farmers realised a positive additional yield from both LUC and non-LUC crops. The additional yield from LUC crops and the total yield per farmer clearly show a variation trend among the farmers. The trend indicates that the farmers with higher additional yield from LUC crops earned higher total yields as well, which suggests that LUC contributed to the total yield per farmer for most farmers. 15 farmers in 2013 and 13 farmers in 2017 realised a negative additional yield from LUC crops. The

additional yield from the non-LUC crops varied slightly more per farmer in the research period 2017.

Before 2014, farmers at the Rusebeya research site reported that the agriculture production included the harvest of maize, beans, sweet potatoes, Irish potatoes and sorghum. When the LUC program started, maize and beans were selected as priority crops. Moreover, the site introduced the harvest of a variety of vegetables and fruits. Rusebeya research site's farmland is situated on hilly landscape that had been difficult to cultivate. This morphology has seen the site less productive because of the difficulties to cultivate steep slopes. Therefore, the additional yield per farmer is slightly varying and near zero for the harvest of 2013. This has been the case for the crops later selected for the LUC program and the other crops. However, after the terracing of the area, the yield increased considerably for the priority crops while the yield from non-LUC crops dropped to negative for most of the farmers. The same trend observed at the sites where the LUC program started can be seen on the figure 5c of 2017 yield. This is the quasi-alignment of the curve of the yield from LUC crops and the total yield per farmer which suggests that LUC contributed to the increase of the total yield per farmer. Indeed, the yield from the crops that were not selected for the LUC program declined for all farmer respondents of this study.

Farmers at the Rutemba research site reported the harvest of maize, beans, Irish potatoes and sorghum before the LUC program was introduced. The program started in 2008 prioritising maize and beans. This allowed to calculate the additional yield for 2013 and 2017. Both research periods display a similar figure as the one of the Gatwe research site where the additional yield of LUC crops aligns with the curve of the total yield per farmer. This can find explanation in the fact that the LUC program started in the same agriculture year 2007/2008 at both research sites. However, farmers at the Rutemba research site lost the yield that they had earned from the harvest of 2007 as shown on the graph of 2013. More loss was observed in 2017. This decline in the yield concerns the crops that were not selected for the LUC program. Therefore, while farmers joined the LUC program, they reduced or sometimes abandoned the harvest of the crops not selected for the program.

The Nyabubare research site is an exception because the types of crops harvested and the farmland use did not change along our research period. Cassava constitutes the main crop at the site. It is supplemented by the harvest of maize, beans, sweet potatoes, sorghum, banana, rice and peanuts. The harvest of cassava dropped in the agriculture year 2013/2014 mainly due to the cassava brown streak disease (CBSD) that attacked cassava crops. CBSD is a devastating disease that causes loss of cassava root (tuber) production and quality. Root rot resulting from the viral disease renders the cassava tuber inedible (Hillocks et al., 2008). To assess additional yield for the Nyabubare research site, we calculated the additional yield from cassava harvest separately of the other crops. Figure 6 shows that half of the farmers have seen their cassava yield decline in 2013 and in 2017. Furthermore, the other crops' additional yield did not increase for all farmers. Those who succeeded to secure an increase of yield are farmers of rice who realised higher yields following the systematic wetland development by the government

of Rwanda. As such, agricultural policies do explain (partially) the unequal distribution of changing harvests between farmers in this area too.

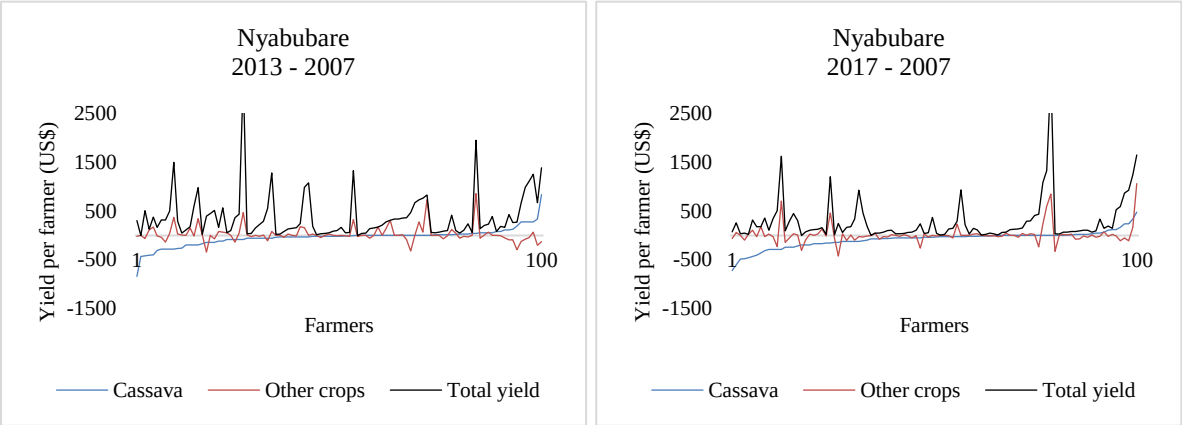


Figure 16. Variation of yield and total yield per farmer at the Nyabubare research site

5.3.4. Correlation between the additional yield and selected variables

Building on these first explorations on the variation of the yield with regard to the LUC program, and to extend the explanation on the causes and effects of the yield variation, we selected variables like the average monthly income, the size of the household, the size(s) of the farmland plot(s), the number of owned plots and the use of subsidized fertilisers. Respectively, the correlations allowed to detect the alignment of the agricultural yield with the farmer's monthly income; to determine whether the yield realised depends on the number and size of farm plots possessed by the farmer; and finally, to find out whether accessing subsidised fertilisers contributed to the increase of the yield. Tables 6 and 7 show that the variation of the additional yield statistically correlates with most of the variables for those crops prioritised by the LUC program at the research sites that joined the program. The additional yield of 2013-2007 from LUC crops statistically correlates significantly with monthly income and the LUC subsidies to production at the Gatwe and Rutemba research sites. This coincides with the fact that among the four research sites, the LUC program had only started at these two sites. Nyabubare and Rusebeya research sites did not show any significant correlation for the LUC crops between these research periods.

The correlations remained significant in the period 2017-2007 for Gatwe and Rutemba, with the Rusebeya research site joining the early LUC adaptors. Again, the correlation coincides with the Rusebeya site joining the LUC program in 2014 after the area was terraced to improve farming activities on its hilly farm plots. The reason for that coincidence finds explanation in the fact that in rural areas of Rwanda, farming constitutes the main source of income. Therefore, after joining the LUC program, and hence introducing the use of government subsidies of

mainly mineral fertilisers, farmers see both their yield and monthly income increase. In most cases, the number and size of farm plots correlate with the additional yield of crops selected for the LUC program. We observe a negative correlation for the crops that are not prioritised by the LUC program. On one hand, this suggests that less plots and smaller size of plots per farmer coincide with a higher yield in crops that are not selected for the LUC program. This relates possibly to the observation that these farmers use home produced organic fertilisers instead of the subsidised mineral fertilisers. On the other hand, farming using mineral fertilizers through the LUC program earn more yield for the farmers that possess more farm plots and/or larger plots

Table 21. Correlation between the additional yield (2013-2007) and selected variables

	Gatwe	Rutemba	Rusebeya	Nyabubare
Selected variables	*Yield of crops selected for LUC (US$)*			
Average monthly income (US$)	0.344**	0.443**	0.07	0.03
Number of owned plots	0.05	0.214*	0.16	0.08
Size of the plots (Ha)	0.233*	0.06	0.08	0.1
Subsidised fertilisers (Kg)	0.460**	0.474**	0.11	-0.05
	Yield of other crops (US$)			
Average monthly income (US$)	0.05	-0.285**	0	-0.02
Number of owned plots	-0.03	-0.303**	-0.13	0.208*
Size of the plots (Ha)	-0.264**	-0.18	-0.08	-0.11
Subsidised fertilisers(Kg)	-0.13	-0.261**	0.03	0.501**

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Table 22. Correlation between the additional yield (2017-2007) and selected variables

	Gatwe	Rutemba	Rusebeya	Nyabubare
Selected variables	*Yield of crops selected for LUC (US$)*			
Average monthly income (US$)	0.402**	0.561**	0.225*	-0.16
Number of owned plots	0.18	0.16	0.514**	-0.241*
Size of the plots (Ha)	0.19	0	0.16	-0.234*
Subsidised fertilisers (Kg)	0.549**	0.427**	0.13	0.06
	Yield of other crops (US$)			
Average monthly income (US$)	-0.04	-0.247*	0.02	-0.01
Number of owned plots	0.03	-0.300**	-0.362**	0.15
Size of the plots (Ha)	-0.332**	-0.18	-0.02	-0.13
Subsidised fertilisers (Kg)	0.16	-0.235*	-0.06	0.583**

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

5.4. Discussions

Our findings demonstrate that in Rwanda, the consolidation of farmland use earned an overall increase of monetary yield among participant farmers. In each of the four research sites, the farming counts on a subsidy package of the CIP program that encompasses inputs like mineral fertilisers and selected seeds. In addition, farmers use the proximity of agronomist guidance. To understand the link between the CIP package and the increase of farm yield, we conducted statistical correlation analysis between yield and a set of variables which confirmed the relation between the increase of yield and the monthly income, the subsidised fertilisers, as well as the size and number of farm plot.

It is evident that the CIP/LUC approach in Rwanda has contributed to the growth of yields per farmer on average. As mentioned, this increase of yield mainly involves the crops that are selected for the program – maize and beans in most cases. Three research sites witnessed the impact of the CIP/LUC program on agricultural yield in particular. The Gatwe and Rutemba research sites have demonstrated an increase in yield per farmer after five years of first implementation of the CIP/LUC program. The program started in 2014 at the Rusebeya research site, which showcases an increase in yield in 2017. Overall, most of the farmers who joined the program realised an increase of yield compared to the yield of the agricultural years before the CIP/LUC program. This increase comes from the crops selected for the program at each site. Farmers reduced or, in most cases, abandoned the harvest of crops neglected by the land use consolidation program. Furthermore, the case of the Nyabubare as the site that had not joined the LUC program, confirmed the impact of the CIP/LUC program on yields. Apart from the harvest of cassava that dealt with a disease, the yield did not increase at the Nyabubare site as it was observed at the other three research sites.

Our previous research article looked into the perception of the farmers on the CIP/LUC program. As presented in chapter four, the article found that farmers are generally positive about LUC and believe it has brought them benefits which in fact translates into the increase of their yield . However, as this study demonstrated, the increase in yield did not happen to all farmers nor did it take a similar trend across our research period. We could not study the implications of a decrease in yields on the availability of food for the farmer's household. What we could observe is that on all four research sites, farmers did not report a clear increase of the number of meals per day over time. This phenomenon needs to be studied in more detail, and is beyond the scope of this chapter. We did not assess the capacity of the farmers to buy what they used to produce either, nor the effects on the farmer's household diet. Although still underexplored, these aspects of the CIP/LUC program have featured in the scholar literature. For example, despite the growth in yield, Del Prete et al. (2019) found that 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. While both

satisfaction and agricultural productivity of land are high, it is important to note that food insecurity, vulnerability to shocks, access to the market and poverty remain serious problems for LUC farmers (USAID, 2014).

5.5. Conclusion

This chapter assessed the effect of farmland use change on agricultural production of smallholder farmers in Rwanda. The study was based on a dataset constituted from four research sites and three research periods. The research periods corresponded with the period before, during and after the systematic land registration as well as the periods when the research sites joined the LUC program. The four research sites, one in each of the provinces of Rwanda, represent the variability in agricultural zone. For each research site, we studied farmland use, harvest and monetary yield per farmer and per research period. The assessment used statistical sign-test and correlations.

When a research site joined the LUC program, farmers adopted the harvest of regionally selected crops. This shift from the harvest of perennial crops like banana, to seasonal crops like maize and beans, is clearly seen on the classified satellite images of the Gatwe, Rusebeya and Rutemba research sites. LUC is also accompanied by the concentration of expanding residential area along the roads. Both processes aim to increase the agricultural land and improve the farming activities. The shift from traditional fragmented land use to the consolidated land use was found to correlate with overall farm-level yields increasing over the course of the considered 10 years span based on the three research periods. This was confirmed by the yields at the three research sites that had joined the LUC program at the time of data collection. The Nyabubare research site, which did not join the LUC, has actually seen yields declining.

Although the yields increased for most farmers, some farmers saw their yields decrease. Such decline in yields correlated with the size and the number of farm plots per farmer at the three LUC sites. In fact, farmers with more and larger farms realised higher yield increases while those who possess only one and smaller farm plot did not. This found explanation in the use of mineral fertilisers that benefited larger farms while farming on smaller plot kept using home produced compost fertiliser instead of the subsidised mineral fertilisers.

Our finding that consumption did not necessarily increase even when crop production did, might suggest that LUC did not necessarily improve overall food security for farmers in Rwanda. Detailed analysis of this phenomenon goes beyond this chapter, but we can speculate that given the monoculture nature of the LUC program, some food types may be(come) less available and more expensive to buy on the market – some crops may even have completely disappeared. Hence, farmers who earn more money from the LUC program may not be able to diversify their everyday meal in the same way as they used to. An extended discussed of the food security can be found in chapter six section d.

Overall, this study showed that the LUC Land Use Consolidation program (and the whole package of government subsidies channelled to the farmer through the CIP Crop Intensification Program) contributed to a general increase of harvests and monetary yields in Rwanda. Our findings suggest important farmland use and agriculture policy implications on three aspects: (1) we observe the clear shift in crops harvested by farmers; (2) we observe that increases of yields did not take the same trend per research sites nor per farmer; (3) we show that some farmers with less number of farm plots and/or smaller holdings registered a decrease of yield. Therefore, we conclude that although consolidated farmland use appears to earn higher yields compared to fragmented land use, the aim to reverse the effect of fragmented use farming is not fully achieved (yet) in Rwanda.

6

Conclusions and recommendations

This study was conducted with the main objective of assessing the relations between land tenure, farmland use and agricultural productivity. The assessment started with a review of the scholarly literature on those relations (a). It proceeded to the link between land tenure security and agricultural production (b), before linking agricultural productivity to the farmland uses at work in Rwanda (c). As I advanced with the assessment of the studied relations, I noticed the need to mention food accessibility (d). Although, I could not extend our analysis further to explain the implications on food security in full.

(a) The relations as they appear in the literature: the role of land registration

I reviewed the gap in the scholarly literature discussing the effect of land registration on the relations between land tenure security and agricultural productivity. Our review highlighted the growing volume of literature on tenure security since the 1980s. However, in many studies, those effects continue to be conceptually described rather than operationally proven. Many studies offer indirect effects, in terms of secondary data rather than direct field evidence. I found weaknesses in the methods and techniques used to collect and analyse data, as well as the types of data mobilised to study the effects. The use of representatives' data from local authorities and farmers cooperatives instead of from farmers themselves, may provide misleading results and hide the households' tenure and productivity realities. In addition, research has been conducted using case studies within countries, but generalising their findings seems difficult given the particularities of different local settings.

The study demonstrated contradicting arguments found in the literature concerning effects of land registration and updating on agricultural productivity. Land titles or related legal papers may have helped to obtain loans from banks, using land as collateral, to invest in agriculture. On the other hand, land certification may have contributed to increased tenure insecurity, with possible negative consequences for agricultural productivity. Some studies concluded that even when there is effectively a correlation, it is associated with many intervening factors altogether, which makes it difficult to claim that it is the isolated link itself that created favourable conditions. One intermediate and linking element standing out, and most highlighted in the literature, is 'land tenure security': the security of tenure guarantees perceptions of long-term tenure and stimulates farmers initiatives to sustain their agricultural activities, thus creating the enabling environment.

In most literature, land registration is mentioned as affecting land tenure security, but studies that directly deal with the relations between land registration and agricultural productivity are absent. I found that the effect of the land registration process itself on land tenure security and agricultural productivity is an understudied topic. Hence, the process of land registration, including the methods and techniques used to demarcate, adjudicate and record land information, is not considered, while it may have a crucial impact on farmers' decisions and thus agricultural productivity. Some authors stress that before one can validly assert whether land registration will enhance investment and productivity, a more careful definition is needed of the concept of 'tenure security' itself. Factors besides land titles that bear on such security,

must be identified (M. C. D. Simbizi et al., 2014). Indeed, land registration is not simply a technical matter; it is a complex social intervention. Therefore, historically evolved social relations and circumstances must be considered to achieve the results of land titling that are desired. Recognizing this would be directly relevant to the design and evaluation of titling programmes (Kunz et al., 2016; Lemel, 1988; Odhiambo, 2006).

The methods that are used in most of the studies in our review cannot tackle the complexity of how land tenure systems affect productivity (W. Odhiambo, 2003). This suggests that there is need for a mixed methods approach utilizing experiments as well as randomisation, where feasible, in combination with increasing flows of spatial and time-series data from diverse sources. Household-farm panel data collected over long periods of time, combined with simulations, can also provide valuable insights about the relations.

This review contributed to the understanding of the effect of land registration on the relations between land tenure security and agricultural productivity. From an intensive review of a broad set of literature related to land registration, land information updating and agricultural productivity, the chapter provided a better understanding of those effects. From the literature, I found that formalising land rights appears to contribute to an increase in agricultural productivity only when it is combined with effective land and agriculture policy (among others) and when the implementing institutions are effective (Lavigne Delville, 2010). I suggested that future research needs to concentrate on examining these relations from a more operational basis, taking into account local social-economic and institutional patterns at work.

(b) Farmland tenure security and agricultural production

The second part of the assessment looked into the relations between farmland tenure security and agriculture production among smallholder farmers in Rwanda. The study used four research sites to collect data retrospectively on farmers' FLTS (Farmland Tenure Security) and agricultural production. I designed the index following the findings of presented in the first chapter, a review study that underlined the need for a locally-defined mixed approach to depict the link between land tenure security and agriculture production. As such, our FLTSI should not be understood as an overall status of LTS in Rwanda. I connected our locally-defined Farmland Tenure Security Index to a one-way ANOVA test and calculated statistical correlations with the harvest and monetary yield. The analysis was extended to a set of additional variables including plot size, plot number and farmers satisfaction to broaden our understanding of the relations I are interested in. Our results suggest that at least, for the four sites constituting our study area in Rwanda, a new wave of agricultural programs appear to contribute to an increase of small farms' harvests of main crops. These programs aim to intensify the cropping by means of consolidating the farmland use and subsidise the farming activities. These same government programs seem to result in a decrease in actual land tenure security of farmers.

Our FLTSI was based on threats associated with these governmental programs as perceived by smallholder farmers at each research site. The mentioned threats included shrinking participation of farmers on decisions over land use and their farming activities. Our findings indicated that the harvest of main crops did not statistically correlate nor show differences in the mean within the land tenure security index levels in all the four research sites. Instead, factors mainly related to the ongoing crop intensification program which though seemingly threatening tenure security contributed to the increase of small farms' harvest. I pose that the weakened land tenure security did not affect farmers' satisfaction of the crop program with most of them claiming that in the end what matters most is that their harvest of main crops continues to increase.

Our findings confirmed how complex the issue of tenure security, and its associated evaluation, actually is. One could argue that increased government interventions (e.g. new restrictions or responsibilities) around land use undermine LTS (compare with Simbizi, 2016). Indeed, I showed with our four aspects that define our FLTSI, that the decision making aspects are the cause for the Index becoming lower over time. Having said that, I did recognize the complexity of valuing increased governmental influence when it comes to tenure security. Indeed, I showed that farmers acknowledge that increased governmental influence did result in higher harvests. I also showed that farmers' responses suggest that when these governmental programs started, farmers did not necessarily appreciate these interventions. Over time, given the higher harvests, appreciation changed. What smallholder farmers appreciate is the fact that LUC increase their yield of selected crops.

For three research sites, the harvest and yield value per farm plot size grew particularly for the crops prioritised by the CIP/LUC program (maize and beans). The main exception to the general observation of harvest increase is Nyabubare because cassava, the main crop produced in the area was attacked by CBSD that considerably reduced the harvest of cassava tubers from the agriculture year 2014. For the research sites where farmers joined the CIP/LUC program and prioritised selected crops, the harvest of other crops reduced to give way to maize and beans. However, the more plots the farmers owned outside the program the more possibilities they had to keep diversifying their harvest. Our findings show that the shift in the types of crops produced and the increase of harvest though not as high as the one achieved with CIP/LUC has been taking place in Nyabubare research site as well. Indeed, other programs promoting crop regionalisation and the proximity of agronomists' services to farmers were found to contribute.

To understand the changes related to the tenure and use of farmland, I asked respondents to retrace the biography of their farmland plot as well as their agriculture production activities. This was the only technique possible to collect such data, since I could not find exhaustive archives of data per farm plot. The little information found in the district reports was used as additional source to validate the data. Furthermore, they served as background information to expand on the narrative of our findings. As such, the generalisation of the findings and conclusions of this study should be done carefully, given the locally-defined approach pursued to collect and analyse data. However, the research approach designed is applicable and deserves

to be taken up by further research work to locally assess the relations between land-tenure security and agricultural production.

The research approach designed in this chapter was motivated by our early synthesis review article presented in the chapter two, that claimed a lack of studies based on local field evidence when studying the relations between land tenure and agricultural productivity. Rwanda was selected as a case study because of the ongoing systematic reform process to improve LTS and agricultural productivity. In fact, having both reforms operating simultaneously all over the country, and given the diversity of the four corners of the country with regards to the variables considered, this study conducted an empirically relevant spatio-temporal comparative analysis.

This field-data-bound study contributes to the knowledge of the relations between farmland tenure security and agricultural production, relations that are too often discussed without clear local evidence. I went beyond conceptually describing the studied relations. I did engage with the complexity of tenure and governmental intervention, relying on the data collected from rights holders. Our respondents indicated that their tenure is changed by the reduced/loss of rights to decide on the use land, but also indicated that their satisfaction of the CIP program changed over time. Most importantly, I have mobilized our locally-defined FLTS and a set of variables to represent the reality of local Rwandese smallholder farmers when it comes to their complex tenure situation, their abilities (or not) to exercise decision making power and their satisfaction concerning (increased) yields.

(c) Farmland use and agricultural productivity

The importance of farmland use change has been briefly discussed in the previous part (b). Here, I extended the assessment on the effect of farmland use change on agricultural production of smallholder farmers in Rwanda. The study was based on a dataset constituted from four research sites and three research periods. The research periods corresponded with the period before, during and after the systematic land registration as well as the periods when the research sites joined the LUC program. The four research sites, one in each of the provinces of Rwanda, represent the variability in agricultural zone. For each research site, I studied farmland use, harvest and monetary yield per farmer and per research period. The assessment used statistical sign-test and correlations.

When a research site joined the LUC program, farmers adopted the harvest of regionally selected crops. This shift from the harvest of perennial crops like banana, to seasonal crops like maize and beans, is clearly seen on the classified satellite images of the Gatwe, Rusebeya and Rutemba research sites. LUC is also accompanied by the concentration of expanding residential area along the roads. Both processes aim to increase the agricultural land and improve the farming activities. The shift from traditional fragmented land use to the consolidated land use was found to correlate with overall farm-level yields increasing over the course of the considered 10 years span based on the three research periods. This was confirmed by the yields

at the three research sites that had joined the LUC program at the time of data collection. The Nyabubare research site, which did not join the LUC, has actually seen yields declining.

Although the yields increased for most farmers, some farmers saw their yields decrease. Such decline in yields correlated with the size and the number of farm plots per farmer at the three LUC sites. In fact, farmers with more and larger farms realised higher yield increases while those who possess only one and smaller farm plot did not. This found explanation in the use of mineral fertilisers that benefited larger farms while farming on smaller plot kept using home produced compost fertiliser instead of the subsidised mineral fertilisers.

Our finding indicated that consumption did not necessarily increase even when crop production did, might suggest that LUC did not necessarily improve overall food security for farmers in Rwanda. Detailed analysis of this phenomenon goes beyond this chapter, but I can speculate that given the monoculture nature of the LUC program, some food types may be(come) less available and more expensive to buy on the market – some crops may even have completely disappeared. Hence, farmers who earn more money from the LUC program may not be able to diversify their everyday meal in the same way as they used to.

Overall, this chapter showed that the Land Use Consolidation program (and the whole package of government subsidies channelled to the farmer through the Crop Intensification Program) contributed to a general increase of harvests and monetary yields in Rwanda. Our findings suggest important farmland use and agriculture policy implications on three aspects: (1) I observed the clear shift in crops harvested by farmers; (2) I observed that increases of yields did not take the same trend per research sites nor per farmer; (3) I showed that some farmers with less number of farm plots and/or smaller holdings registered a decrease of yield. Therefore, I concluded that although consolidated farmland use appears to earn higher yields compared to fragmented land use, the aim to reverse the effect of fragmented use farming is not fully achieved (yet) in Rwanda.

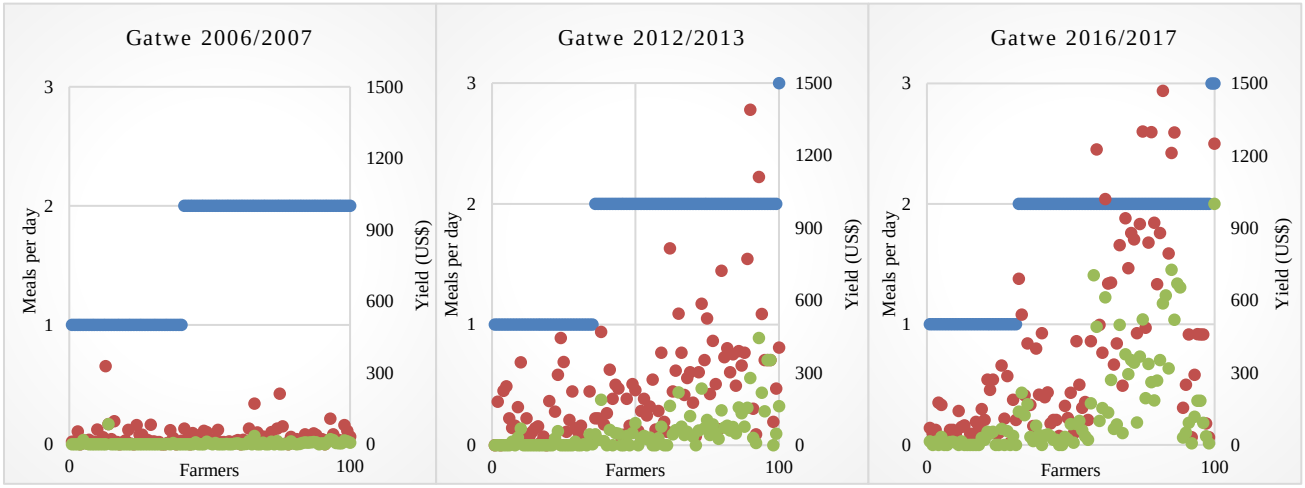
(d) Food accessibility: How does the number of meals per day compare to the harvest and yield per agricultural season?

This study explained the link between farmland tenure security, farmland use and agriculture productivity. One of our findings was that the governmental programs being implemented by the farmer, earned an increase of the crop yields. However, this increase of the yield did not happen for all farmers. In addition, the programs at work mainly the CIP/LUC, prioritized the harvest of a number of regionally selected crops which reduced or suppressed the harvest of a variety of crops that farmers used to grow on a fragmented exploitation (as opposed to the farmland use consolidation). For these two reasons, I explored the farmer's household food accessibility.

The figures below display three variables as follows:

(1) Number of meals per day
(2) Total agricultural year value of the farmer's harvest
(3) Actual yield realized by selling own harvest

All graphs display the three variables. They are sorted ascending the number of meals per day.



Legend

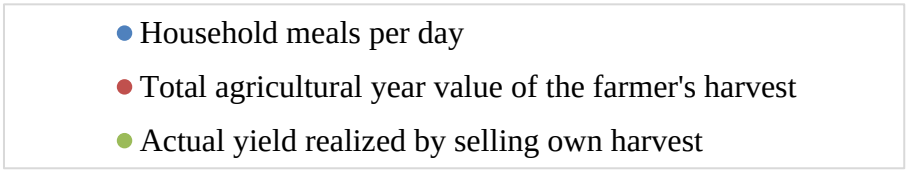
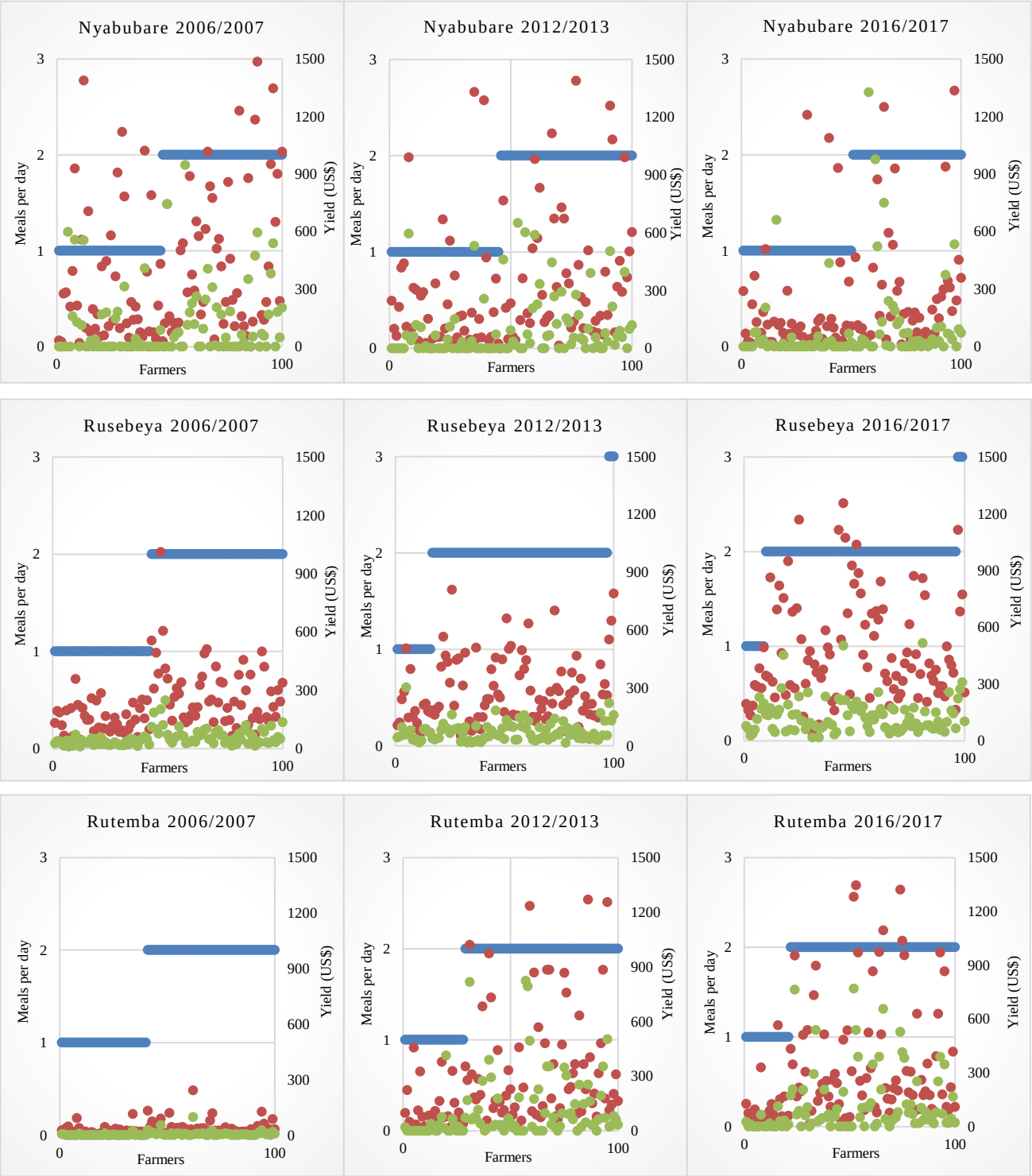


Figure 17. Food accessibility: Yield versus Meals

The overall observation is that except for the Nyabubare research site, the increase of yield coincided with the increase of meals per day. Although, some farmers were having two or more meals per day in 2007, those who attained at least 500 USD per agricultural year, managed to have at least two meals per day in the following research periods 2013 and 2017.

Gatwe and Rutemba research sites reported variation of the yield and meals per day over the course of the research period of this study. In 2007, the yield was low and quite equally distributed among farmers. The following research periods brought about an increase of the yield accompanied with increased number of farmers' households who had two meals per day. The increase of total yield at both Gatwe and Rutemba research sites was reported following the start of the implementation of the CIP/LUC program. The harvest of higher quantities of maize and beans opened the market where farmers looked to sell their produce and buy the food they were not producing.


Nyabubare 2006/2007
Nyabubare 2012/2013
Nyabubare 2016/2017
Rusebeya 2006/2007
Rusebeya 2012/2013
Rusebeya 2016/2017
Rutemba 2006/2007
Rutemba 2012/2013
Rutemba 2016/2017
Meals per day
Yield (US$)
Farmers
0
1
2
3
300
600
900
1200
1500
100

Before 2007, farmers had been participating on the market at Nyabubare and Rusebeya research sites. In fact, farmers in Nyabubare had been producing high quantity of cassava while wheat was also produced and sold on the market in Rusebeya. This is represented on the figures 17 where farmers who realized high yields are clearly visible especially in Nyabubare. I recall that Nyabubare is the research site that had not started a LUC program at the time of field data collection. This site displays the least variation of meals per day across the three research periods compared to the other research sites. In addition, the CBSD disease that attacked cassava crop in 2014 and the drought of 2017 reduced the yield. In 2014, the Rusebeya farmland had been improved with radical terraces to enable secure farming on the steep flanks of its hills. That year marked the launch of the CIP/LUC program which, as I noted for Gatwe and Rutemba research sites, this resulted in higher yield and more meals per day.

The farmers at the three research sites that joined the CIP/LUC program work in cooperatives based on the crops they are producing. Those cooperatives channel fertilizers and selected seeds to the farmer at the planting period. At the harvest period, the cooperatives collect, store and sell the produce. Members share the monetary yield earned based on their stake (information on cooperatives in chapter 3). Although, cooperatives gather farmers to serve their interest, some of them were accused by the farmers to take their total harvest away and later on distribute little money after a long waited selling. This is the case of rice growers at the Gatwe research site.

The link between yield and meals per day allowed to demonstrate the farmer's household food access. Our data did not allow to extend the analysis to the extent of the nutritious values of the food. Nevertheless, I clearly showed that following the start of the CIP/LUC program, farmers increased their yield and number of meals per day. There is need to study the types of food available on the market.

What do locally-defined research approach and methods used in this study mean for future related studies?

The research approach designed and applied by this study derived from the literature review. Most reviewed scholar materials underlined that the relations between land tenure security, farmland use and agricultural productivity continue to be conceptually described rather than operationally proven. They suggested that a mixed methods locally-defined research approach would be used to assess the relations between land tenure security, farmland use and agricultural productivity. That is what this research attempted. In fact, the assessment combined statistical analysis and qualitative analysis of the information collected from interviews and focus group discussions at a local level. I argue that this approach earned an understanding of those relations that would be overlooked if the research used larger entity setting and econometric methods. This research recommends that a similar approach be applied while studying locally-defined assessment of the relations between land tenure security, farmland use and agricultural productivity. Future research needs to concentrate on examining these relations from a more operational basis, taking into account local social-economic and institutional patterns at work.

There is need for a mixed methods approach as well as randomisation, where feasible, in combination with increasing flows of spatial and time-series data from diverse sources. Household-farm panel data collected over long periods of time, combined with simulations, can also provide valuable insights about the relations.

What would be future research on the relations between land tenure security, farmland use and agriculture productivity?

This research has filled a gap in assessing the relations between land tenure security, farmland use and agricultural productivity. The setting of the research approach indicated a clear path the future research would take to assess those relations at the local level. However, this research prioritised criteria that fitted the most the selected study area and as such, did not explore all the variables that could contribute to a broader understanding of the studied phenomena elsewhere. First, in Rwanda, future studies should focus on the link between the studies relations with food security and gender implications. This research found that the smallholder farmer's yield of LUC prioritized crops has increased despite the insecurity of farmland tenure mainly due to the loss of decision power over farming activities. This brought about questions that remain unanswered and could lead future research:

What is the impact of farmland use change on food availability and accessibility?
How about the nutritious value of the limited crop harvested under the LUC program?
How do those relations link to gender?

Second, other similar research should be conducted in countries that have been implementing land tenure and agriculture reform programs. In fact, defining mixed local research approach in different localities would add to the validity of the research approach and contribute to an understanding of the relations between land tenure security, farmland use and agricultural productivity from the local settings to the level of a country, a region. Finally, this research relied on a combination of data collected retrospectively from the farmers and records found in the districts archives. This was due to a lack of enough records of agricultural inputs and harvest at the farmer's level. Future research should attempt to use prospective data collected along the priory-determined research period.

This study contributed to an understanding of the ongoing land tenure and agricultural reform programs in Rwanda. Therefore, its findings can be used to improve that process of reform by integrating the new generated knowledge in policy formulation and strategizing with an intent to the smallholder farmer.

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