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

Singirankabo, Uwacu Alban; Ertsen, Maurits Willem; van de Giesen, Nick

DOI
10.1016/j.landusepol.2022.106122

Publication date
2022

Document Version
Final published version

Published in
Land Use Policy

Land Use Policy 118 (2022) 106122

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

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

Uwacu Alban Singirankabo [a,b,*], Maurits Willem Ertsen [a], Nick van de Giesen [a]

[a] Delft University of technology, Faculty of Civil Engineering and Geosciences, Department of Water Management, The Netherlands
[b] University of Rwanda, College of Science and Technology, School of Architecture and the Built Environment, Department of Geography and Urban Planning, Rwanda

ARTICLE INFO

Keynotes:
Land tenure security
Agriculture production
Smallholder farmers
Rwanda

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 prioritized crops and decreasing farm land tenure security simultaneously.

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 and Bouayad Agha, 2018; Higgins et al., 2018; Holden and Ghebru, 2016; Ma et al., 2017; Michler and Shively, 2015; Rao et al., 2017). However, recent research work, mostly review studies, suggest that this link may not be straightforward (Rockson et al., 2013; Singirankabo and Ertsen, 2020). 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 and 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 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 farm land 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 and Havugimana, 2013; Bizoza and Opio-Omoding, 2021; Del Prete et al., 2019; Musahara, 2006; Muyombano and Espling, 2020; Ntihinyurwa and

* Correspondence to: Delft University of Technology, Mekelweg 5, 2628 CD Delft, Delft, The Netherlands.
E-mail addresses: albanuwacu@gmail.com, u.a.singirankabo@tudelft.nl (U.A. Singirankabo).

https://doi.org/10.1016/j.landusepol.2022.106122
Received 23 July 2021; Received in revised form 17 March 2022; Accepted 24 March 2022
Available online 8 April 2022

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 paper.

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 and Dusengemungu, 2012). The 2005 Organic Land Law (modified in 2013 (Anon, 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 neighboring 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, research work on the LTR achievement has been contradictory (Singirankabo and Ertsen, 2020). On one hand, Santos, Fletschner, Savath, and Peterman (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, 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. 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 and Dusengemungu, 2012).

The component of the CIP that is considered as key for agricultural transformation is land use consolidation (Nahayo et al., 2017; Ntihinyurwa and Masum, 2017; USAID Land Project, 2013). Land use consolidation stipulates collective use of neighboring 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 (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 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 farm land size was 0.7 Ha (NISR, 2012). However, the process of LUC is not clear when it comes to issues of decision making (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 unraveling 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 Farm Land 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.

2. Materials and methods

2.1. Data collection

2.1.1. 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 (Fig. 1). What the study sites have in common is that they are located in districts where pilot trials of the land tenure regularization 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 farm land plots per household, and agriculture zoning (Table 1). 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.

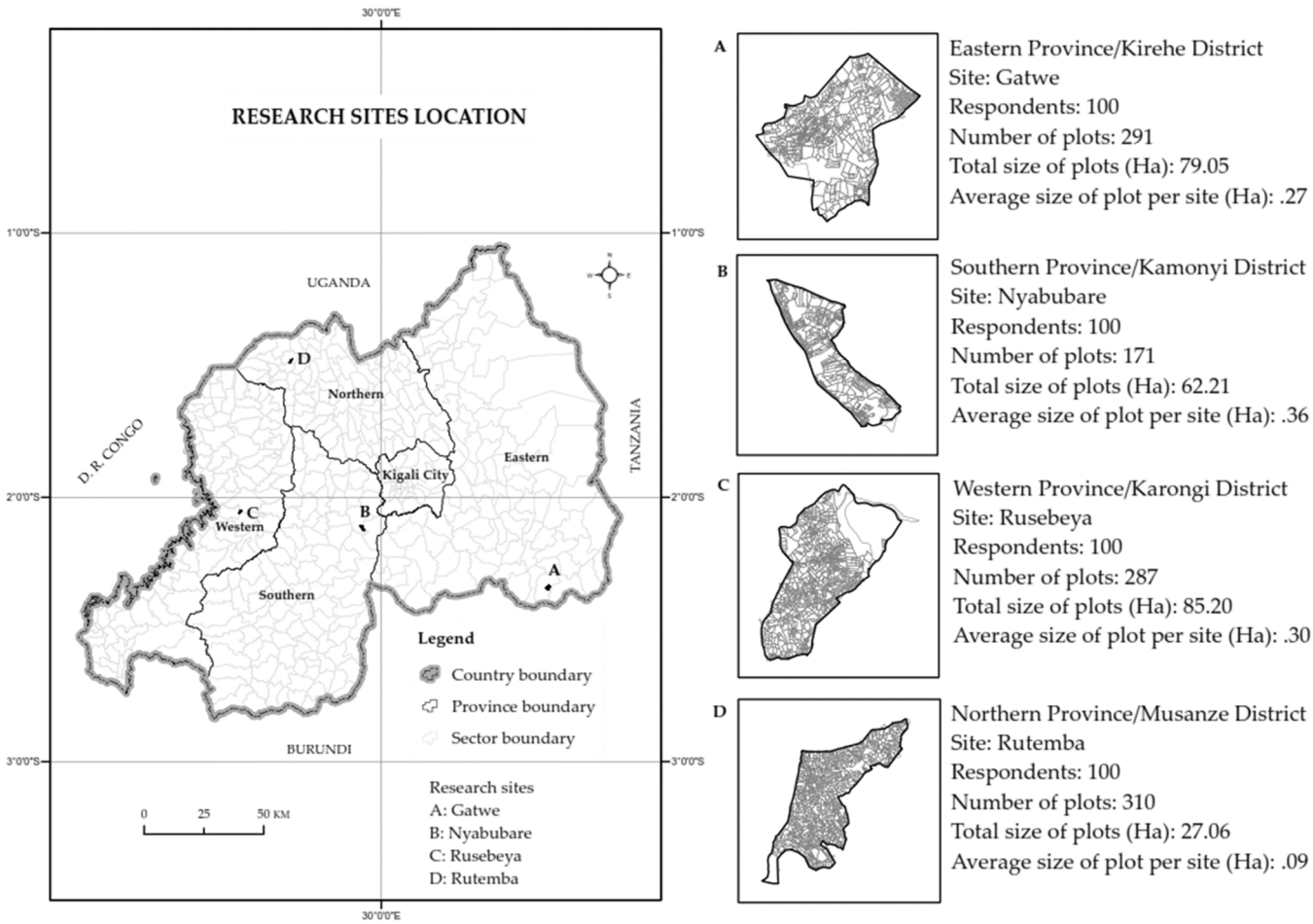

Fig. 1. Research sites location.

Table 1
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

2.1.2. 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 and 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 2):

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

Table 2
Research period.

Research period	Rationale
2006/2007Before 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
2012/2013During 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.
2016/2017After the systematic land registration	5 years after land registration, the research assesses the effect of (legal) land tenure security brought by the land tenure regularization program and, in particular, land registration and titling.

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.

2.1.3. 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 Centers. 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.

2.2. Data analysis

2.2.1. 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 farm land plots). We counted frequency and percentile of respondents per variable, and calculated the central tendency mean and standard deviation.

2.2.2. Farmland tenure security index

The perception of land rights on a continual basis, which summarizes 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 and Suhardiman, 2020; Singirankabo and Ertsen, 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., 2013; Singirankabo and Ertsen, 2020). Therefore, this study designed a locally-defined Farm Land 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 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. Formalizing land rights has long been branded as a key element to bring about higher levels of access to credit and investment (De Soto, 2000; Deininger and Jin, 2006; Higgins et al., 2018; Ngango and Hong, 2021; Rashid, 2021; Vu and 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 and 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 fertilizers by farmers, is important for enhanced agricultural production.

These four variables were combined into an index to determine the level of farm land 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 labor and capital invested in that land either in use or upon transfer to another holder (Bruce and Migot-Adholla, 1993); (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 and Opio-Omoding, 2021; Higgins et al., 2018). The design and operationalization 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.

2.2.3. 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.

$$PI = (B\text{-}A)/A*100$$

and.

$$PI = (C\text{-}B)/B*100$$

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).

2.2.4. 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 symbolizes '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.

2.2.5. Statistical relations

a. **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.

a. **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.

3. Findings and discussion

3.1. Descriptive statistics

3.1.1. 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 farm land 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.

3.1.2. Farm plot biography

Biographical information on farm land 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 farm land 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.

3.1.3. Variation of yield per research site and research period

Three research sites reported growing yield figures but Nyabubare did not (Fig. 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

Table 3
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	

Table 4
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

same order which indicates that the dynamics of yield increase per farmer changed.

In Gatwe and Rutemba, yield increased notably following the introduction of consolidated farming supplemented with government-subsidized 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 et al., 2008). The harvest of cassava dropped from 80 tonnes in 2013–48 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).

3.1.4. 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 (Fig. 3). This has been the case at the three research sites except for the Nyabubare site, where satisfaction declined.

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.

3.2. 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 paper. 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

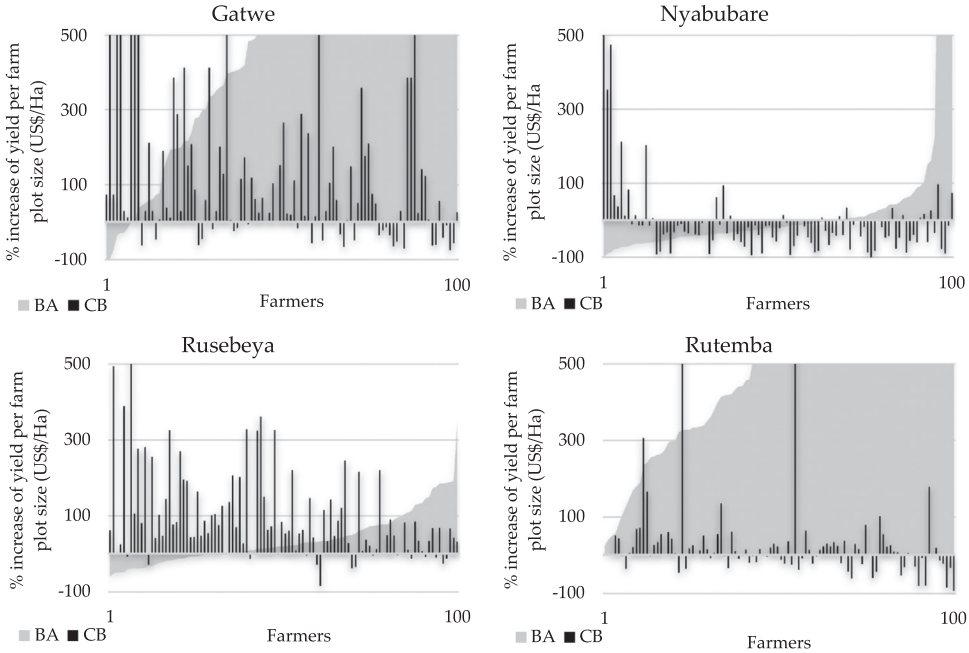

Fig. 2. Percentage increase of farmers yield per research site and research period. BA: % increase between the second and the first research periods (2012/13–2006/07). CB: % increase between the third and the second research periods (2016/17–2012/13).

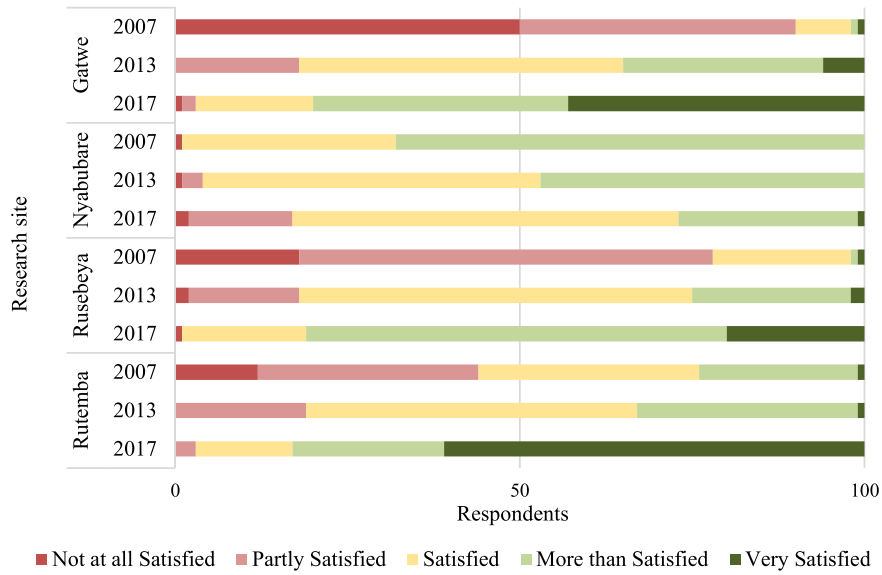

Fig. 3. Farmers satisfaction over decisions on farming.

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 farm land 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 (Fig. 3).

The following quotes from interviews with farmers provide a flavor 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 farm land use; (3) Decisions on crops to cultivate, and (4) Access to bank credits with farm plots as collateral.

> "I remember when officials sensitized 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 farm land … 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.

3.2.1. *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.

Table 5
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

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 regularization process. Across the four research sites, respondents conveyed that the legal recording of land rights signaled 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.

3.2.2. Decisions on farmland use

The formalization 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 recognized 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 farm land 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 (Fig. 4).

3.2.3. 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 (Fig. 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.

3.2.4. 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, 2018) 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 2012–20.0 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.

In total, 28 households acquired bank credits, using their land plots as collateral (Table 6 and Fig. 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 (Fig. 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.

3.2.5. 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 and Hughes, 2017; FAO, 2002; Keovilignavong and 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).

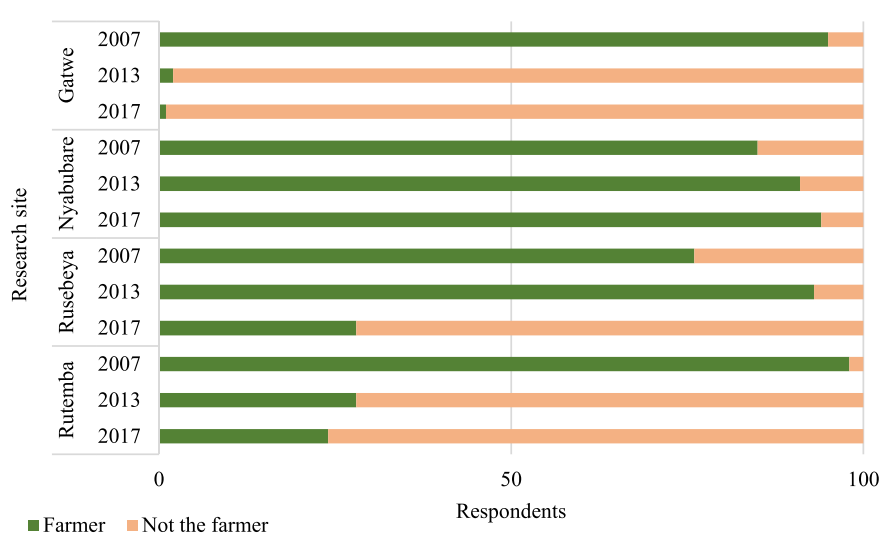

Fig. 4. Who decides on farm land use.

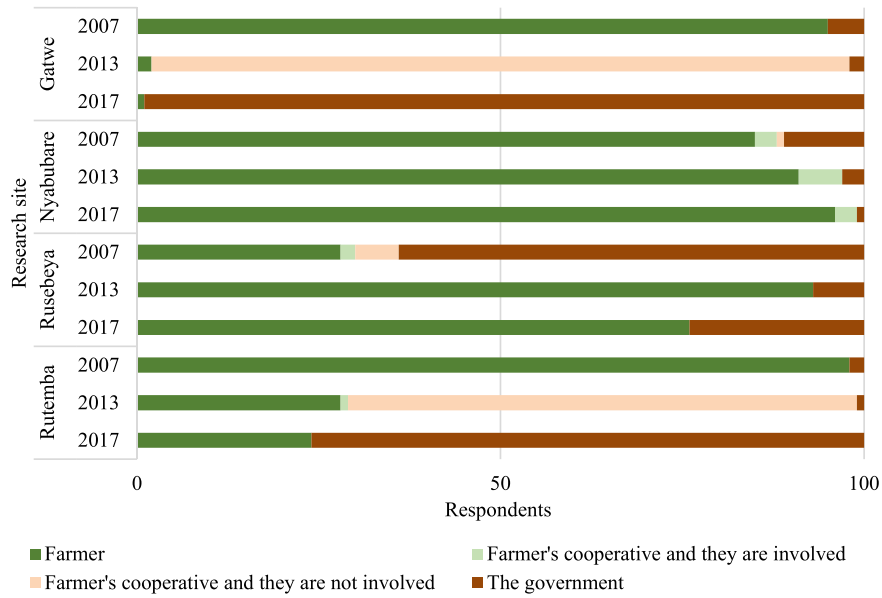

Fig. 5. Who decides on farming activities.

Table 6
Credits acquired per site.

Study site	Credit offeror	Sector	Number of farmers
Gatwe	Umurunga SACCO	Musaza	8
Nyabubare	SISUNYA SACCOCLECAM Ejoheza Ruyumba	Nyamiyaga	9
Rusebeya	SACCO RubengeraCOOPEC Inkunga	Rubengera	2
Rutemba	Abamuhoza SACCO,CLECAM-MusanzeCLEA-Musanze	Muhoza	9
Total			28

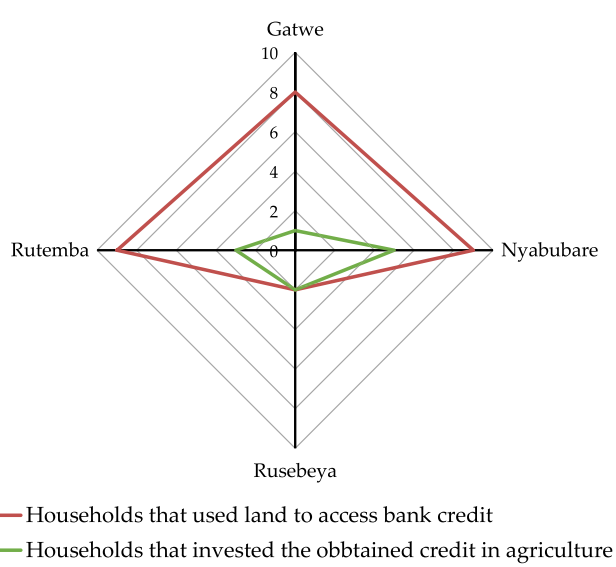

Fig. 6. Land used as collateral to access bank credit and invest in agriculture.

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 2007–12% 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.

3.3. *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 favorable to maize and Irish potatoes already. However, according to the Sector Agronomist, the effort of the government to facilitate the distribution of subsidized fertilizers has induced farmers to feel its influence in the decision over farming activities – which we do see in Fig. 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,

Table 7
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 farm land use	1	The household makes decisions on farm land use themselves	100	100	5	82	93	95	99	28	26	98	97	4
	0	Other than the farmer's household make decisions on farm land 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 8
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

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 farm land 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 (Fig. 7).

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.

3.4. 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.

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-

Table 9
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).

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 farm land … 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".

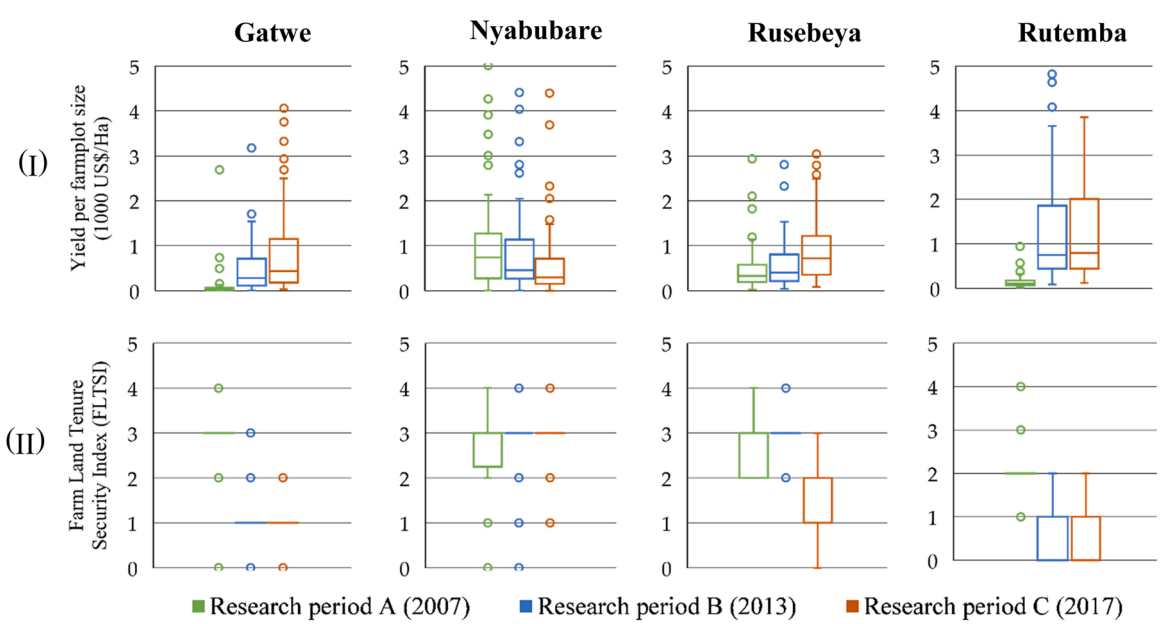

Fig. 7. Yield per farm plot size (I); farm land tenure security (II).

Table 10
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	101,502,062	7,665,453,053	429,888,638	8,804,236
Mean Square	33,834,021	1,916,363,263	214,944,319	2,934,745
F	0.42	1.12	1177	0.14
Sig.	0.74	0.35	0.31	0.94
Second research period				
Sum of Squares	813,777,096	5,067,503,835	662,800,632	9,670,567
Mean Square	271,259,032	1,266,875,959	331,400,316	4,835,283,645
F	0.88	0.85	1418	0.60
Sig.	0.45	0.50	0.25	0.55
Third research period				
Sum of Squares	2,912,974	5,304,636,475	963,302,059	3,053,960,186
Mean Square	1,456,487,205	1,768,212,158	321,100,686	1,526,980,093
F	1258	1517	0.33	0.16
Sig.	0.29	0.22	0.81	0.86

Table 11
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

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 favors 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. Conclusion

This study assessed the relations between farm land 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 Singirankabo and Ertsen (Singirankabo and Ertsen, 2020), 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. We connected our locally-defined Farm Land 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 (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 prioritized 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 prioritized 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 farm land, we asked respondents to retrace the biography of their farm land 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 (Singirankabo and Ertsen, 2020), 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 farm land 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 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.

Funding

This research received an external funding from the Netherlands Organization for International Cooperation in Higher Education (NUFFIC) through SEAD project, which stands for 'Strengthening Education for Agricultural Development' in Rwanda. We acknowledge the NUFFIC/SEAD project.

References

Asiama, K.O., Voss, W., Bennett, R., Rubanje, I., 2021. Land consolidation activities in Sub-Saharan Africa towards the agenda 2030: a tale of three countries. Land Use Policy 101, 105140. https://doi.org/10.1016/j.landusepol.2020.105140.

Atwood, D.A., 1990. Land registration in Africa: the impact on agricultural production. World Dev. 18 (5), 659–671. https://doi.org/10.1016/0305-750X(90)90016-Q.

Bambio, Y., Bouayad Agha, S., 2018. Land tenure security and investment: does strength of land right really matter in rural Burkina Faso? World Dev. 111, 130–147. https://doi.org/10.1016/j.worlddev.2018.06.026.

Barry, M., Danso, E.K., 2014. Tenure security, land registration and customary tenure in a peri-urban Accra community. Land Use Policy 39 (0), 358–365. https://doi.org/10.1016/j.landusepol.2014.01.017.

Bizoza, A.R., Havugimana, J.M., 2013. Land Use Consolidation in Rwanda: A Case Study of Nyanza District, Southern Province. Int. J. Sustain. Land Use Urban Plan. 1, 64–75.

Bizoza, A.R., Opio-Omoding, J., 2021. Assessing the impacts of land tenure regularization: evidence from Rwanda and Ethiopia. Land Use Policy 100, 104904. https://doi.org/10.1016/j.landusepol.2020.104904.

Rao, F., Spoor, M., Ma, X., Shi, X., 2020. Perceived land tenure security in rural Xinjiang, China: the role of official land documents and trust. China Econ. Rev. 60, 101038 https://doi.org/10.1016/j.chieco.2017.03.009.

Rashid, F.N., 2021. Achieving SDGs in Tanzania: is there a nexus between land tenure security, agricultural credits and rice productivity? Resour. Conserv. Recycl. 164, 105216 https://doi.org/10.1016/j.resconrec.2020.105216.

Brown, M. , Hughes, A.K. , 2017. Is land tenure "secure enough" in rural Rwanda? Paper presented at the Annual World Bank Conference on land and Poverty, Washington DC.

Bruce, J.W. , Migot-Adholla, S.E. , 1993. Searching for land tenure security in Africa. Kendall - Hunt Dubuque.

Bugri, J.T., 2008. The dynamics of tenure security, agricultural production and environmental degradation in Africa: evidence from stakeholders in north-east Ghana. Land Use Policy 25 (2), 271–285. https://doi.org/10.1016/j.landusepol.2007.08.002.

Deininger, K., Jin, S., 2006. Tenure security and land-related investment: evidence from Ethiopia. Eur. Econ. Rev. 50 (5), 1245–1277. https://doi.org/10.1016/j.euroecorev.2005.02.001.

Del Prete, D., Ghins, L., Magrini, E., Pauw, K., 2019. Land consolidation, specialization and household diets: evidence from Rwanda. Food Policy 83, 139–149. https://doi.org/10.1016/j.foodpol.2018.12.007.

GoR, 2000. Rwanda Vision 2020. Retrieved from Kigali, Rwanda:

GoR, 2010. Ministerial Order determines the models of land consolidation and its productivity. Retrieved from Kigali, Rwanda:

Higgins, D., Balint, T., Liversage, H., Winters, P., 2018. Investigating the impacts of increased rural land tenure security: a systematic review of the evidence. J. Rural Stud. 61, 34–62. https://doi.org/10.1016/j.jrurstud.2018.05.001.

Hillocks, R., Raya, M., Mtunda, K., Kiozia, H., 2008. Effects of brown streak virus disease on yield and quality of Cassava in Tanzania. J. Phytopathol. 149, 389–394. https://doi.org/10.1111/j.1439-0434.2001.tb03868.x.

Holden, S.T., Ghebru, H., 2016. Land tenure reforms, tenure security and food security in poor agrarian economies: causal linkages and research gaps. Glob. Food Secur. 10, 21–28. https://doi.org/10.1016/j.gfs.2016.07.002.

Keovilignavong, O., Suhardiman, D., 2020. Linking land tenure security with food security: Unpacking farm households' perceptions and strategies in the rural uplands of Laos. Land Use Policy 90, 104260. https://doi.org/10.1016/j.landusepol.2019.104260.

Ma, X., Heerink, N., Feng, S., Shi, X., 2017. Land tenure security and technical efficiency: new insights from a case study in Northwest China. Environ. Dev. Econ. 22 (3), 305–327. https://doi.org/10.1017/S1355770×1600036X.

Mbonigaba, J.J. , Dusengemungu, L. , 2012. Farm Land Use Consolidation- a Home Grown Solution for Food Security in Rwanda.

Michler, J.D., Shively, G.E., 2015. Land tenure, tenure security and farm efficiency: panel evidence from the Philippines. J. Agric. Econ. 66, 155–169. https://doi.org/10.1111/1477-9552.12082.

Milindi Rugema, D., Birhanu, T.A., Shibeshi, G.B., 2021. Spatial aspect of fit-for-purpose land administration for emerging land administration systems: a conceptual framework for evaluation approach. Surv. Rev. 1–14. https://doi.org/10.1080/00396265.2021.1881230.

Musahara, H. , 2006. Improving tenure security for the rural poor in Rwanda. Food and Agriculture Organization of the United Nations (FAO), Commission on Legal Empowerment of the Poor (CLEP).

Muyombano, E., Espling, M., 2020. Land use consolidation in Rwanda: the experiences of small-scale farmers in Musanze District, Northern Province. Land Use Policy 99, 105060. https://doi.org/10.1016/j.landusepol.2020.105060.

Nahayo, A., Omondi, M.O., Zhang, X.-h, Li, L.-q, Pan, G.-x, Joseph, S., 2017. Factors influencing farmers' participation in crop intensification program in Rwanda. J. Integr. Agric. 16 (6), 1406–1416. https://doi.org/10.1016/S2095-3119(16)61555-1.

Ngango, J., Hong, S., 2021. Impacts of land tenure security on yield and technical efficiency of maize farmers in Rwanda. Land Use Policy 107, 105488. https://doi.org/10.1016/j.landusepol.2021.105488.

Nishimwe, G., Milindi Rugema, D., Uwera, C., Graveland, C., Stage, J., Munyawera, S., Ngabirame, G., 2020. Natural capital accounting for land in Rwanda. Sustainability 12, 5070. https://doi.org/10.3390/su12125070.

De Soto, H., 2000. The mystery of capital: why capitalism succeeds in the West and fails everywhere else. New York.

Enemark, S. , Bell, K.C. , Lemmen, C. , McLaren, R. , 2014. Fit-For-Purpose Land Administration. The World Bank and the International Federation of Surveyors (FIG) Publication, 60.
FAO, 2002. Land tenure and rural development. Retrieved from Rome:
GoR, 2009. Strategic Road Map for Land Tenure Reform. Retrieved from Kigali, Rwanda:
GoR, 2011. More information about crop intensification program. Retrieved from Kigali:
GoR, 2013. Law N° 43/2013 of 16/06/2013 Governing Land in Rwanda. Retrieved from Kigali, Rwanda:
GoR, 2014. Umurenge SACCOs Strategy. Retrieved from Kigali:
NISR, 2012. Rwanda Fourth Population and Housing Census. Thematic Report: Population size, structure and distribution. Retrieved from Kigali, Rwanda:
NISR, 2018. Integrated Household Living Conditions Survey 2016/2017 2018 National Institute of Statistics of Rwanda Kigali, Rwanda.
Ntihinyurwa, P.D. , Masum, F. , 2017. Participatory land use consolidation in Rwanda: from principles to practice. Paper presented at the FIG Working Week 2017. Surveying the World of Tomorrow - From Digitalisation to Augmented Reality, Helsinki, Finland.
Rao, F., Spoor, M., Ma, X., Shi, X., 2017. Perceived land tenure security in rural Xinjiang, China: the role of official land documents and trust. China Econ. Rev. https://doi.org/10.1016/j.chieco.2017.03.009.
Rockson, G., Bennett, R., Groenendijk, L., 2013. Land administration for food security: a research synthesis. Land Use Policy 32 (0), 337–342. https://doi.org/10.1016/j.landusepol.2012.11.005.
Santos, F., Fletschner, D., Savath, V., Peterman, A., 2014. Can government-allocated land contribute to food security? Intrahousehold analysis of west bengal's microplot allocation program. World Dev. 64, 860–872. https://doi.org/10.1016/j.worlddev.2014.07.017.
Simbizi, M.C., 2016. Measuring Land Tenure Security: A Pro - Poor Perspective. University of Twente, Faculty of Geo-Information Science and Earth Observation (ITC),, Enschede.
Simbizi, M.C.D., Bennett, R.M., Zevenbergen, J., 2014. Land tenure security: revisiting and refining the concept for Sub-Saharan Africa's rural poor. Land Use Policy 36 (0), 231–238. https://doi.org/10.1016/j.landusepol.2013.08.006.
Singirankabo, U.A., Ertsen, M.W., 2020. Relations between land tenure security and agricultural productivity: exploring the effect of land registration. Land 9 (5). https://doi.org/10.3390/land9050138.
USAID Land Project, 2013. Literature review for land use consolidation and crop intensification in Rwanda. Retrieved from.
Vu, H.T., Goto, D., 2020. Does awareness about land tenure security (LTS) increase investments in agriculture? Evidence from rural households in Vietnam. Land Use Policy 97, 104721. https://doi.org/10.1016/j.landusepol.2020.104721.
World Bank, 2018. Rwanda Agriculture Finance Diagnostic: World Bank.