Endline Report

Impact Evaluation of the PFR

Benin

CENTER FOR EVALUATION AND DEVELOPMENT (C4ED)

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ACRONYM LIST

ADC	Attestation de Détention Coutumière
ADECOB	Association pour le Développement des Communes du Borgou
AFD	Agence Française de Développement
ANDF	Agence Nationale du Domaine et du Foncier (national agency of estate and land)
ATT	Average Treatment Effect on the Treated
BMZ	Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung (German Federal Ministry for Economic Cooperation and Development)
C4ED	Center for Evaluation and Development
CAPI	Computer-Assisted Personal Inteviews
CFD	Code Foncier et Domaniale (land code)
CFR	Certificat Foncier Rural
DiD	Difference in Differences
DRDID	Doubly Robust Difference in Differences
EVI	Enhanced Vegetation Index
FCFA	Franc de la Communauté Financière Africaine
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GLLM	Global Land Logic Model
GPS	Global Positioning System
GTZ	Gesellschaft für technische Zusammenarbeit
HH	Household
IGN	Institut Géographique National
INSAE	Institut National de la Statistique et de l'Analyse Économique
INStaD	Institut National de la Statistique et de la Démographie
IPWRA	Inverse Probability Weighted Regression Adjustment
KfW	Kreditanstalt für Wiederaufbau
MCC	Millennium Challenge Corporation
NDVI	Normalized Difference Vegetation Index
PFR	Plan Foncier Rural (Rural Land Plan)
PPS	Probability Proportional to Size
ProPFR	Promotion d'une Politique Foncière Responsable
RQ	Research Question
SAVI	Soil Adjusted Vegetation Index
SCA	Systematic Cluster Approach
SD	Standard Deviation
SEWOH	Sonderinitiative: Eine Welt ohne Hunger (Special initiative: one world without hunger)
SVGF	Section Villageoise de Gestion Foncière (village land council)
TF	Titre Foncier
ToC	Theory of Change

EXECUTIVE SUMMARY

ENGLISH VERSION

This report presents the endline results of the impact evaluation (IE) of the "*Promotion d'une Politique Foncière Responsable*" (ProPFR) program implemented by the Deutsche Gesellschaft für International Zusammenarbeit (GIZ) in the Borgou region of northern Benin from 2018-21. ProPFR aims to improve access to land and reduce land conflict through the formalization of customary rights. This should reduce poverty and food insecurity by encouraging agricultural investment and a commitment to long term land use planning.

The IE focuses on the implementation of 27 village-level rural land plans (PFRs) across four communes. The PFR is a participatory process to facilitate the recognition of customary land rights through the identification and mapping of local land tenure rights. Endline data was collected 2-3 years after the implementation of the PFRs, with registration of land parcels completed by May 2020 after delays to the process. At the time of writing no formal land titles have been issued on the basis of the GIZ implemented PFRs in Borgou, meaning that only the public registration and demarcation of land form the basis of the treatment for which we seek to measure impacts.

We employ propensity weights to find a valid counterfactual to estimate the impacts using two estimation techniques: Inverse Probability Weighted Regression Adjustment (IPWRA) for variables captured only at endline, and Doubly Robust Difference in Differences (DRDID) for data available at both baseline and endline.

Changes in perceptions of security are considered key in the literature to enable further changes in investment behavior for parcel managers. At baseline, perceptions of tenure security were already high (with only 13% of respondents for parcels stating they feel it is either rather likely or very likely to lose rights over a parcel). We find no strong evidence of overall improvements in perceived tenure security due to the implementation of a PFR, though poorer households do respond positively to the PFR. It should be noted that administrative data show that land was often demarcated in the name of the clan or family, and not at the household level, possibly indicating a strategy to prevent fragmentation and individualization, but which also means that the effect of demarcation may not have been noticed at the level of our unit of analysis, which is the individual household.

In spite of the apparent lack of impact on perceptions, we nonetheless find that households in PFR villages are more likely to invest in measures to improve soil and water conservation. This was particularly true of parcels managed by migrants allochtones to Borgou, who also increased spending on these measures. We also find evidence that this impact was stronger where villages were a priority village for a complementary program implemented by the GIZ focusing on soil rehabilitation (ProSOL).

While investment decisions of migrants allochtones may suggest that they felt their land was more secure due to the PFR, our subgroup analysis on perceptions of security actually suggests the opposite, namely that perceptions were negatively affected among migrants allochtones in general. Among other marginalized groups, we find that females appear to have lost some independence in the management of land. Parcels are less likely to be managed only by females where a PFR has been implemented, with results suggesting that parcels are now co-managed alongside males. This may be a reaction to the formal recording of land rights, with male household members seeking to affirm control of land.

We find no significant impacts on the activity of land markets, agricultural productivity, nor household income. This is in line with the Global Land Logic Model, which suggests that more time is required for such effects to transpire. These null results extend to food security as well as the demand for credit.

Prior to collecting data, it was not clear whether we should expect an increase in reported conflicts, due to disagreements over boundaries during the PFR process, or whether the PFR would help to reduce conflicts. Our results indicate that there is a decrease in self-reported new conflicts since baseline, as well as a reduction in unresolved conflicts, though this latter result is only significant for men, non-migrants, and poor households.

In spite of little change in perceptions of tenure security, we do indeed find positive impacts on investment in water and soil conservation, labor inputs, and reduced conflict from public demarcation of land and recognition of customary rights at the community level. This already has a positive effect on investment in soil and water conservation, particularly when follow up support is available, even without formal titling. It should be noted that no *Titre Foncier* has been issued for PFR parcels, contrary to what was expected when the program was designed.

Finally, as it takes time before impact on land use, productivity and food security are measurable, encouraging longer term evaluation of the results, for example by involving local universities and remote sensing experts.

VERSION FRANÇAISE

Ce rapport présente les résultats finaux de l'évaluation de l'impact (EI) du programme « Promotion d'une Politique Foncière Responsable » (ProPFR) mis en œuvre par la Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) dans la région de Borgou, au nord du Bénin, de 2018 à 2021. ProPFR vise à améliorer l'accès à la terre et à réduire les conflits fonciers grâce à la formalisation des droits coutumiers. Cela devrait réduire la pauvreté et l'insécurité alimentaire en encourageant l'investissement agricole et l'engagement dans une planification des terres à long terme.

L'EI se concentre sur la mise en œuvre de 27 plans fonciers ruraux (PFR) au niveau des villages, répartis dans quatre communes. Le PFR est un processus participatif visant à faciliter la reconnaissance des droits fonciers coutumiers par l'identification et la cartographie des droits fonciers locaux. Les données finales ont été collectées 2 à 3 ans après la mise en œuvre des PFR, avec l'enregistrement des parcelles de terre complétée d'ici mai 2020 après des retards dans le processus. Au moment de la rédaction du rapport, aucun titre foncier formel n'a été délivré sur la base des PFR mis en œuvre par la GIZ à Borgou, ce qui signifie que seulement l'enregistrement public et le bornage des terres constituent le fondement du traitement pour lequel nous cherchons à mesurer les impacts.

Nous utilisons des pondérations de propension pour trouver un contrefactuel valide afin d'estimer les impacts à l'aide de deux techniques d'estimation : l'ajustement de régression pondérée par la probabilité inverse (IPWRA) pour les variables capturées uniquement à la fin de l'étude, et la différence dans la différence doublement robuste (DRDID) pour les données disponibles à la fois au début et à la fin de l'étude.

Les changements de perception de la sécurité sont considérés comme essentiels dans la littérature pour permettre d'autres changements dans le comportement d'investissement des gestionnaires de parcelles. Au départ, les perceptions de la sécurité des droits fonciers étaient déjà élevées (avec 70 % des personnes interrogées déclarant qu'il n'y avait aucun risque de perte de droits sur une parcelle). Nous ne trouvons pas de preuves solides d'améliorations globales de la sécurité des droits

fonciers perçue suite à la mise en œuvre d'un PFR, bien que les ménages les plus pauvres réagissent positivement au PFR. Il convient de noter que les données administratives montrent que les terres étaient souvent délimitées au nom du clan ou de la famille, et non au niveau du ménage, ce qui indique peut-être une stratégie visant à prévenir la fragmentation et l'individualisation, mais ce qui signifie également que l'effet de la délimitation peut ne pas avoir été remarqué au niveau de notre unité d'analyse, qui est le ménage individuel.

Malgré le manque apparent d'impact sur les perceptions, nous constatons néanmoins que les ménages des villages où les PFR ont été mis en œuvre sont plus susceptibles d'investir dans des mesures visant à améliorer la conservation des sols et de l'eau. Cela est particulièrement vrai pour les parcelles gérées par des migrants allochtones à Borgou, qui ont également augmenté leurs dépenses dans ces domaines. Nous constatons également des indications selon lesquelles cet impact était plus fort dans les villages prioritaires pour un programme complémentaire mis en œuvre par la GIZ et axé sur la réhabilitation des sols (ProSOL).

Alors que les décisions d'investissement des migrants allochtones pourraient laisser penser qu'ils estimaient que leurs terres étaient plus sécurisées grâce au PFR, notre analyse par sous-groupe sur les perceptions de sécurité suggère en réalité le contraire, à savoir que les perceptions étaient affectées négativement chez les migrants allochtones. Parmi les autres groupes marginalisés, nous constatons que les femmes semblent avoir perdu une certaine indépendance dans la gestion des terres. Les parcelles sont moins susceptibles d'être gérées uniquement par des femmes lorsque des PFR ont été mis en œuvre, et les résultats suggèrent que les parcelles sont maintenant gérées conjointement avec les hommes. Il s'agit peut-être d'une réaction à l'enregistrement formel des droits fonciers, les membres masculins du ménage cherchant à affirmer le contrôle des terres.

Nous ne trouvons pas d'impact significatif sur l'activité des marchés fonciers, la productivité agricole ni le revenu des ménages. Cela est conforme au Modèle logique mondial des terres, qui suggère que davantage de temps est nécessaire pour que de tels effets se produisent. Ces résultats nuls s'étendent également à la sécurité alimentaire ainsi qu'à la demande de crédit.

Avant la collecte des données, il n'était pas clair si nous devions nous attendre à une augmentation des conflits signalés, en raison de désaccords sur les limites pendant le processus de PFR, ou si le PFR contribuerait à réduire les conflits. Nos résultats indiquent qu'il y a une diminution des nouveaux conflits signalés depuis le début de l'étude, ainsi qu'une réduction des conflits non résolus, bien que ce dernier résultat ne soit significatif que pour les hommes, les non-migrants et les ménages pauvres.

Malgré peu de changement dans les perceptions de sécurité, nous constatons effectivement des impacts positifs sur l'investissement dans la conservation de l'eau et des sols, les efforts de main-d'œuvre et la réduction des conflits grâce à la démarcation publique des terres et à la reconnaissance des droits coutumiers au niveau communautaire. Cela a déjà un effet positif sur l'investissement dans la conservation des sols et de l'eau, en particulier lorsqu'un soutien de suivi est disponible, même en l'absence de titre de propriété formel. Il faut noter que les parcelles des PFR du projet GIZ n'ont pas donné naissance à des demandes de Titre Foncier (TF), contrairement à ce qui était attendu lors de la conception du projet.

Enfin, comme il faut du temps avant que l'impact sur l'utilisation des terres, la productivité et la sécurité alimentaire soit mesurable, il convient d'encourager l'évaluation à plus long terme des résultats, par exemple en impliquant les universités locales et les experts en télédétection.

1. INTRODUCTION

Benin figures among the world's least developed countries, ranking 158 out of 189 by its Human Development Index in 2019[1]. While the country is dependent on trade, agriculture constitutes a significant pillar in Benin's economy, with cotton being the most important export crop[2]. Although the country is making efforts to attract foreign investors, investments towards food security, sustainable farming and livestock systems may require improved tenure security for land under customary systems, the principal tenure system for most communities and smallholders.

Land tenure security is seen as crucial in ensuring poverty reduction and food security in the long run (Higgins, Balint, Liversage, & Winters, 2018). Land is an economic asset that serves multiple important purposes: residential (building housing units), agricultural (subsistence and commercial agriculture, pastoralism), and communal (public infrastructure, national forests). Farmers who lack secure land rights are less likely to carry out essential yield-improving investments in their land as the insecurity prevents them from committing to long-term plans, as their expected returns are lower (Meinzen-Dick, 2009; Higgins, Balint, Liversage, & Winters, 2018). Ensuring tenure security is hoped to reduce conflict, help activate land and credit markets, improve productivity, and thereby reduce poverty and improve food security. Theory predicts that more secure land tenure will result in improved economic outcomes. Besley (1995) summarizes this proposed link via three arguments: 1) if investments will be seized by others, then there is no incentive to invest, 2) secure rights can enable the use of land as collateral which removes constraints on funding investments, and 3) if rights make it easier to rent land, where higher rental prices can be charged for land which has been invested on. An increased incentive to invest may transpire if land users perceive a de facto shift in the tenure security of the land they are working. This would mean that individual documentation of ownership or user rights may not be necessary for land users to benefit. Furthermore, if the prevalence and risk of conflict decrease, the incentive to invest could increase.

To help overcome the barriers faced in improving land tenure security, the German Federal Ministry for Economic Cooperation and Development (BMZ) funded the implementation of the *"Promotion d'une Politique Foncière Responsable"* (Promotion of responsible land policy, ProPFR) program by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) as part of the "One World – No Hunger" program (SEWOH). As part of the program, 27 *"Plans Fonciers Ruraux"* (rural land plans, PFRs) were implemented in the Borgou region of northern Benin from 2018-21.

This report presents an impact evaluation of these PFRs, in the process explaining the project background in more depth in section 2, explaining the impact evaluation design – including a theory of change and the derived research questions - in section 3 as well as the survey methodology and data used. A panel of data was collected with baseline occurring in May-June 2018 and endline in March-April 2022. Section 4 provides some descriptive statistics on the sample and the implementation of the program before the results are provided in section 5, beginning with direct impacts followed by further analysis according to subgroups.

[1] Human Development Index: http://hdr.undp.org/en/content/latest-human-development-index-ranking.

[2] Benin: Situation and Cooperation.
https://www.bmz.de/en/countries_regions/subsahara/benin/zusammenarbeit/index.html.

2. CONTEXT

2.1 BACKGROUND ON LAND REFORM IN BENIN

Historically in Benin, customary land rights have been inherited through the male lineage. This relied on local institutions to uphold a household's claim to use a parcel of land. In this setting, land was passed down from one male family member to another and any conflict was dealt with locally. With the increasing demand for access to land, as the population grows, alongside a changing set of institutions in the country as a whole, it was unclear whether the existing institutions were suited to deal with the new situation. In this context, PFRs presented a community based collective approach to demarcating and recording land use rights. A PFR entails a participative demarcation and mapping procedure, culminating in a village-wide rural land plan being produced as well as installing new institutions. During the process conflicts are recorded and resolved prior to recording, and thereby recognizing, the rights holder of the land. These rights may be recorded either at an individual or collective level (e.g., for a family/clan). Further documentation based on the existence of a PFR is possible on a parcel level, though is not automatic and the documents which can be applied for have changed as the legal framework has developed.

Following the implementation of PFRs in Côte d'Ivoire at the end of the 1980s, the World Bank and the French Caisse Centrale de Cooperation Economique (which became the AFD) promoted their implementation in Benin (Lavigne Delville, 2020). PFRs were offered as an instrument for securing producers and supporting adoption of soil fertility management technologies through the adaptation of existing land rights being formally recognized. Starting in 1993, PFRs were piloted and implanted by several agencies including the German Gesellschaft für Technische Zusammenarbeit (GTZ, which has since become part of the GIZ), the Kreditanstallt für Wiederaufbau (KfW), and the Agence Française de Développement (AFD) while the legal framework was under development. A new Rural Land Act was passed in 2007 providing the legal framework for the PFR, but which was subsequently superseded by a new legal and institutional framework (the Code Foncier et Domaniale, CFD)[3] introduced in 2013 which includes different provisions for the registration of undocumented land currently under customary tenure. The Millennium Challenge Corporation (MCC) funded the Access to Land Project from 2006-2011, which included the development and registration of PFRs in 294 villages across Benin. The village level PFRs under the 2007 legislation intended to provide the information on location and rights as required for the delivery of a *"Certificat Foncier Rural"* (CFR) to register each land parcel included in the PFR in the name of families or individuals, though in practice PFR certification proved to be difficult and CFRs were seldom delivered. Several evaluations were carried out on Benin's PFRs from this period including Goldstein et al. (2018) who found that PFRs led to increased levels of demarcation alongside a shift to long-term investments and perennial cash crops, as well as a reduced gender gap in in fallowing. Yemadje et al. (2014) found evidence of reduced conflict and agricultural intensification on the Adja Plateau, where old palm growing is prevalent. Fabbri (2021) found evidence of increased cooperation and trust in areas which can easily access institutions and government services, while isolated communities suffered a reduction in prosocial behavior. PFRs were also found to have further positive impacts, with Wren-Lewis et al. (2020) finding that forest loss reduced in PFR villages

[3] The 2013 "*Code Foncier et Domanial*" (CFD - Loi N°2013-01) and subsequent amendments. The CFD introduced a single and unified land ownership certificate, the "*Titres Fonciers*" (TFs), delivered by a newly created agency (*Agence Nationale du Domaine et du Foncier*; ANDF), Ministry of Finance and Land.

CFR issuance has been discontinued since 2013 and replaced by land titles in the new land code. Since 2013 the law also allows for the recognition of customary land rights through the introduction of the *"Attestation de Détention Coutoumière"* (ADC), which is delivered by the local government. In 2017 the CFD was amended[4] such that ADC holders can apply for full land titles, which are delivered by the state through the Agence Nationale du Domain et Foncier (ANDF).

2.2 PROPFR IN BORGOU

The program ProPFR was established in 2016 as part of the BMZ's special initiative "One World – No Hunger". ProPFR works in the communes of Bembéréké, Kalalé, Sinendé and Tchaourou in the department of Borgou in northern Benin. These communes are highlighted in green in the overview map of Figure 2.

The overarching goal of ProPFR is to improve access to land and reduce land conflict through the formalization of customary rights (based on the new CFD of 2013) and improvement of the institutional framework. This should happen through three main fields of activity:

1) Improving the institutional framework and process for securing land use and ownership rights.
2) Increasing the involvement of civil society in formulating and implementing a responsible land policy.
3) Raising the awareness of private agricultural investors of the implementation of a responsible land policy

These fields of activity are made up of various activities with different target groups, all in a rural setting.

The impact evaluation focuses only on the first activity, and one major component in particular, namely the establishment of PFRs alongside the reinforcement of institutions. The second activity is key to the development of land policy in Benin, which remains a fluid environment, while the third focuses on a relatively small group of entrepreneurs. The rights of these entrepreneurs and how different types of documentation protects their rights are explored in Akowedaho et al. (2022), who conclude that entrepreneurs would do well to protect their investments with full title.

Following the introduction of further changes to the CFD related to customary tenure in 2017, alongside the PFRs, the promotion of ADCs was trialed by ProPFR as a separate approach and by implementing a systematic cluster approach (SCA) to bundle requests for ADCs, see Guinin Asso et al. (2022). The SCA was implemented in the same four communes but in separate villages from those selected for the PFR and the control villages for this study.

The PFR is a participatory process to facilitate the recognition of customary land rights through the identification and mapping of local land tenure rights. PFRs are a comprehensive village level intervention including information campaigns on land law, assisting communes and villages establish land related institutions such as committees, and most importantly the production of land use and tenure maps. These serve as a basis for obtaining documentation for a land parcel.

[4] This was part of "loi 2017-15" introduced on 10th August 2017.

Villages were selected by the GIZ's ProPFR team together with the local mayors' association (ADECOB) according to the following characteristics: their proximity to classified forests, an identified high risk of land grabbing, the presence of other SEWOH projects, and agropastoral areas (the presence of herders). Additionally, they should not be in close proximity to the border with Nigeria for security reasons, have been involved in an MCC PFR intervention, nor have suffered serious conflict which could block the realization of a PFR. 27 villages were selected to receive a PFR which were organized into 11 geographical clusters.

PFR implementation includes four stages: preparation, starting, execution, and control and validation and also includes the establishment of the Section Villageoise de Gestion Foncière (SVGF) or village land council, which is charged particularly with conflict resolution and prevention. The last two phases were initially envisioned for a duration of six to nine months with execution aimed for completion in 2019, while their actual implementation took around two years (from February 2019 to March 2021). During the preparatory and starting phases all necessary personnel and resources were mobilized and awareness campaigns were conducted. Information sessions were conducted from November 2017 to the end of 2019, while training of SVGF members started in November 2018. During the execution phase (from February 2019 to August 2020), the survey markers were installed, parcel boundaries were identified, a topographic survey was conducted, and land rights were registered. Notably, two types of private rights were recorded: individual private rights (single owner of the property) and collective private rights (group of households, usually belonging to one family). Also, provisional PFR documents were established, and the provisional parcel plans were publicly posted in the villages. Next, any contestations were resolved, which allowed for the correction of the provisional PFR documents and the establishment of the final PFR documents. Finally, during the control and validation stage, the Institut Géographique National (IGN) then proceeded to control (in August 2020) and certification (in September and November 2020) and the final PFR documents were validated. Upon closing of operations, the validated PFR documents were published and transmitted to the relevant bodies, which then proceeded to archive these documents (in March 2021). Following this validation, households should be able to apply for further documented proof of their rights over a parcel, though the definition of this process had not been finalized at the time of PFR validation nor at endline data collection, meaning that households had not yet been able to request full title for their land.

Implementation of the PFRs was carried out by two separate organizations, ATLAS-GIS in Kalalé and Tchaourou, and APIC-ONG/SETI-C in Bembéréké and Sinendé. Some differences in approach are apparent in the information collected by the two firms, e.g. in the land diagnosis of the preparation phase and dates when survey markers were laid. During the land diagnosis, one village (Sui-Gourou in Tchaourou) was determined unsuitable for the implementation of a PFR since two thirds of the surface area belonged to the public domain of the State, as well as facing opposition from residents of the village. This was replaced by the village Bouay, for which we did not have baseline data and so was not included in endline data collection. Although PFR is supposed to include systematic registration of all parcels (or fields), 40% of the households in the treatment villages reported not having any parcel that is demarcated as part of the PFR program. This may be due to parcels reported in our survey belonging to a larger family parcel (which may indeed have been registered) and stands

in contrast to the 80 percent of surface area which was covered by the PFR on average according to administrative data[5].

3. IMPACT EVALUATION DESIGN

3.1 THEORY OF CHANGE AND RESEARCH QUESTIONS

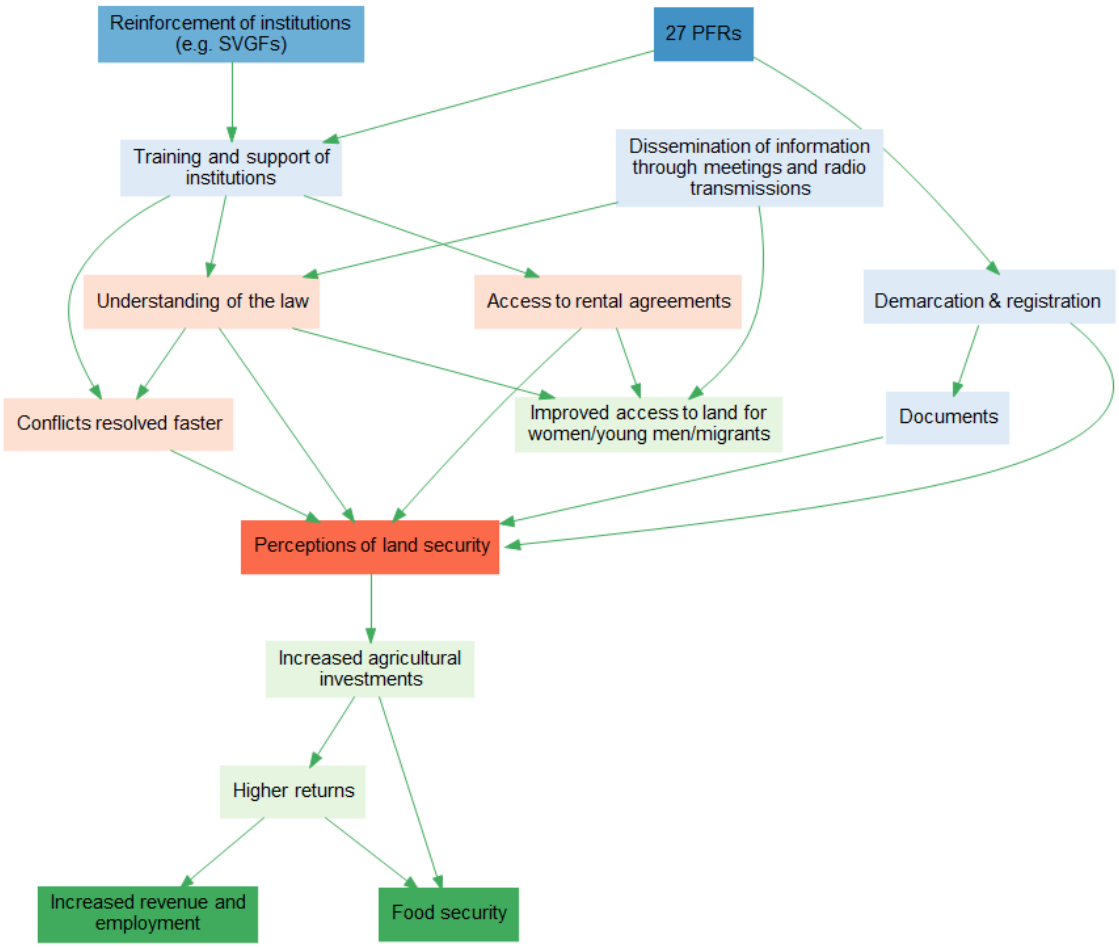
Together with GIZ before the development of the baseline survey, a theory of change (ToC) was developed to clarify the research questions and understand how the PFRs may impact beneficiaries. As other evaluations found a direct linkage between demarcation and perceptions of land security, this was incorporated into the theory of change. The 27 selected villages for the PFR also benefited from the reinforcement of institutions worked on by the project team, as part of the PFR process. The ToC can be seen in Figure 1 and defines the inputs (dark blue), activities (light blue), main expected outputs (red), outcomes (light green), and impacts (dark green) of the PFR and shows the linkages between these stages.

The preparation phase for a PFR intervention started with establishment of an SVGF and dissemination of information about the new land code aimed to help households understand the law and the potential benefits of registering land, and also to reduce land conflict. This was followed by a tenure diagnostic first, followed by (high-precision) surveying of boundaries in the presence of neighbors. The evidence of tenure provided in the PFR, and the public process being used with community members confirming these rights and boundaries, in combination with a better understanding of the law, including the benefits of the PFR, should result in higher perceived land tenure security. This in turn aims to spur increased investment in agriculture and ultimately lead to increased harvests and income, as well as to improve food security.

Through the implementation of the PFR, parcels were demarcated and registered in the documented land plan, providing evidence of rights holders allowing households to subsequently pursue full land title if they chose to do so. We note however that by the time of the endline survey still no regulations had been adopted to provide instruction on how titles can be issued on the basis of the PFRs, thus preventing households from obtaining full title as a result of the PFR in this study.

[5] This figure varies between the two implementing organization, with APIC-ONG/SETI-C including around 95 percent in each of their communes, while ATLAS-GIS covered 79 percent in Kalalé and 61 percent in Tchaourou, which was heavily influenced by issues faced in Oloungbe.

Figure 1 - Theory of Change



In line with the theory of change, the following research questions (RQs) were developed:

1. Do PFRs contribute to a perception of greater land tenure security?
2. Does improved tenure security lead to a growth in agricultural investment and/or changes to management of land?
3. Do PFRs improve access to land and rights over land among marginalized groups (women, youth and migrants *allochtones*)?
4. Do PFRs lead to an increased number of land transactions?
5. Does increased land security address existing constraints on land markets and lead to more efficient allocation of land resources and thereby an increase in productivity?
6. Do property rights and improved user rights result in better access to credit, possibly allowing for income diversification and thus increasing household welfare?
7. Do the new arrangements put in place during the implementation of the PFRs facilitate the resolution of land conflicts, or even prevent the emergence of these land conflicts?

Indicators were defined to assess each of the research questions above, which guided the development of the questionnaire. Given that the PFRs work through the registration of parcels of land, we define indicators both on the parcel level and the household level. With regards to RQ3 on marginalized groups, household level indicators are defined according to the characteristics of the household head, while for parcel level data we use the parcel manager. For gender and age these characteristics are easily defined, while for migrant status we follow the definition of migrant agreed upon during the baseline analysis. “Migrants” are defined as individuals who originate from outside

the department of Borgou, which is in line with the concept of *allochthonous individuals (or "migrants allochtones*»). Results for the effects of the PFR on each indicator are presented in Section 5.2.

It is important to account for the timeline of the impact evaluation alongside the PFR implementation when considering for which indicators we are likely to observe effects. Given that at the time of the endline survey no land titles had been distributed on the basis of the PFR, any impact measured is likely on the basis of the measurement and recording of land parcels through improved perceptions of tenure, as was the case in Goldstein et al. (2018) in their evaluation of the MCC PFRs in Benin. The process took much longer than anticipated, with the topographic survey of land parcels was mostly completed by May 2020, with a small number of parcels recorded later and the first demarcations occurring in April 2019. If this is indeed the salient event in the process of a PFR for land users, then this would mean that for most parcels at least 2 years have passed since demarcation. It should be noted that unfortunately, it was not possible to match the parcels in the survey data to the administrative data and so we could not consider the length of time since demarcation in our analysis.[6]

According to Lisher (2019) in the Global Land Logic Model (GLLM), in the short term after 0-2 years we may be able to find impacts on perceived tenure security (RQ1), bargaining power for women and vulnerable groups (RQ3), renting/selling of land (RQ5) and access to credit where documented proof of tenure is provided (RQ6). In our case the overall level of land market transfers is very low, and no individual documents had been provided to rights holders of parcels registered under a PFR and of these, we would only expect effects on RQ1 and RQ3. Lisher (2019) considers the medium term as 3-4 years and suggests that conflicts and associated costs may be reduced in this period (RQ7) but these effects seem to already occur in the short-term, as we will discuss later. Medium term effects are predicted for productive investments such as tree planting, irrigation and infrastructure development (RQ2), so are not yet expected. Higher productivity, improved food security, better employment opportunities and overall poverty reduction (RQ5 and RQ6) are likely to take longer to transpire.

3.2 SURVEY METHODOLOGY

3.2.1 QUESTIONNAIRE DESIGN

At baseline and endline there were two main survey tools used for data collection, a household questionnaire and a community questionnaire. Data were collected using the World Bank's Survey Solutions software. Some adjustments were made to the questionnaire between baseline and endline to improve the quality of data collected but they followed the same structure. These changes were based on qualitative interviews which took place several months before endline, as well as lessons learned from baseline.

The endline household questionnaire is composed of 11 modules including a household roster, income generation, wealth, housing, a census of non-agricultural land, a census of agricultural land (covering access to land, rental, investment, fallowing, conflicts, rights, demarcation, and land tenure security), agricultural production, land transfers, general land tenure perceptions, credit, food security, a young men's module, and a women's module. The young men's module was aimed at an

[6] Furthermore, the two different consortiums implementing the PFRs recorded dates for slightly different events throughout the process of the PFR.

unmarried man aged 18-35. The women's module was targeted at the wife of the household head (or one selected at random in case of polygamy) or the female household head.

Data were collected from the same selected households at baseline and endline to allow for a panel analysis. In addition to collecting a panel of households, we also sought to create a panel of land parcels as well as finding the same women and young men at baseline and endline. Information was pre-loaded in the CAPI form to aid in the identification of the respective observed unit from baseline.

The community questionnaire was administered to each village in the form of small group interviews to collect information on the socio-economic characteristics of these villages, local land tenure structures and practices, and local prices on agricultural inputs and production. The questionnaire is organized in 9 modules: characteristics of the survey participants, land tenure, land use, land market, land conflicts, other village structures and interventions, agriculture, PFR, and village chief. The characteristics of the participants were recorded in a separate roster.

3.2.2 SURVEY SAMPLING

For any impact evaluation it is key to find a suitable counterfactual, which best represents what would have happened to the treated units (households or land parcels in our case) in the absence of the treatment. Selecting a sample for this purpose entailed two steps for this impact evaluation, namely selecting villages and then households. The same villages and households were surveyed at baseline and endline.

VILLAGE SELECTION

As described in Section 2.2, treated villages were selected by the ProPFR team with the local mayors' association. We attempted to find villages which appeared as similar as possible to those selected for the implementation of a PFR. This task was made more complicated by the redefinition of villages in Benin in 2013, often referred to as the "nouveau découpage"[7], meaning that very little data was available on the village level to select control villages. The GIZ's ProPFR team provided guidance on this selection process. After obtaining GPS coordinates for the new villages, one control village was selected for each of the treated villages based on the following geographic characteristics:

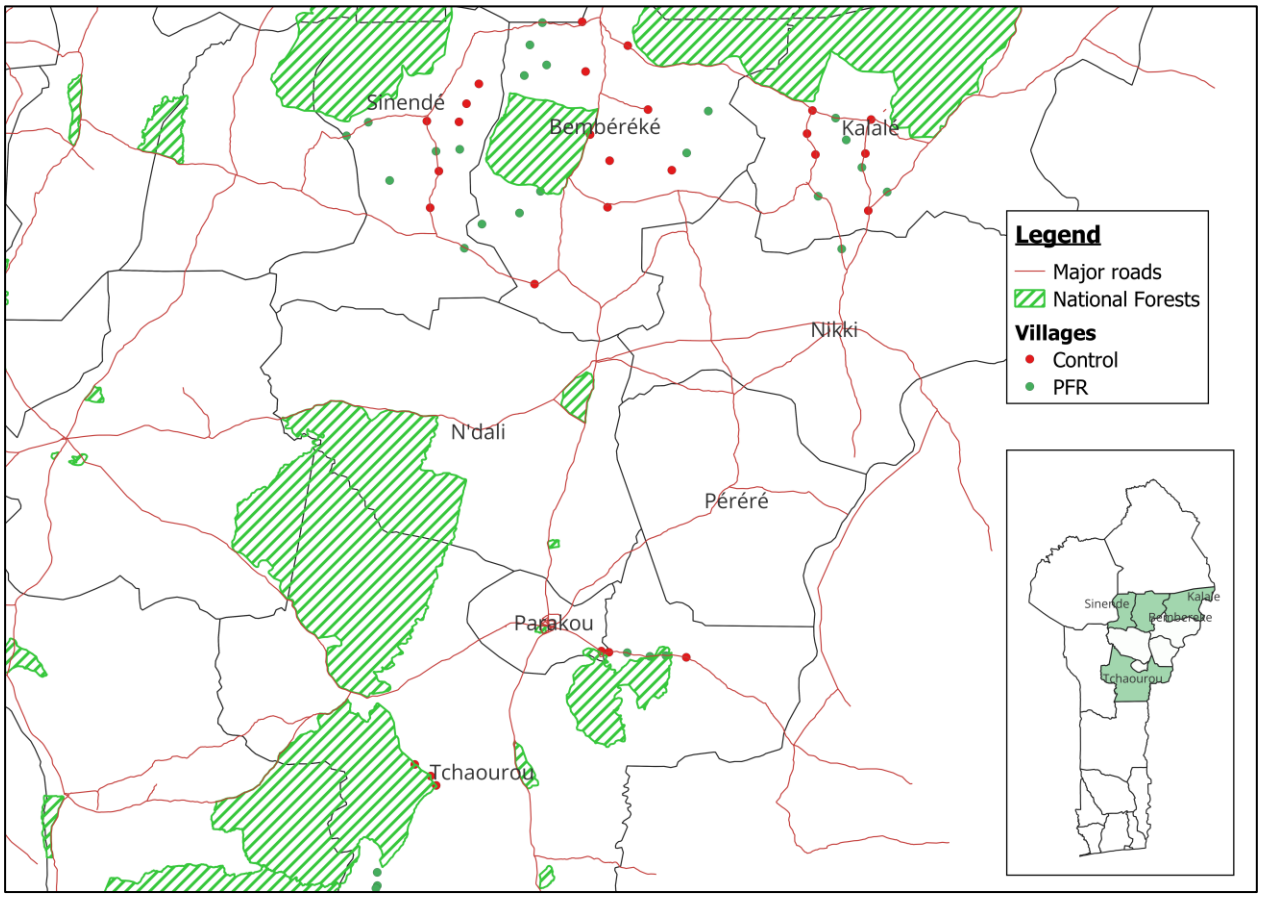
- Proximity to selected PFR villages (within a 20km buffer where possible), to maximize the likelihood of cultural similarity.
- Proximity to national forests (within a 5km buffer), which may lead to added pressure on land demand and was a selection criterion for PFR implementation.
- Proximity to main roads (within 1km of the central point according to Open Street Map), as a proxy for access to markets.
- A similar number of buildings at the village center (within 1km of the central point according to a shapefile extracted from satellite imagery by Digital Globe).

As was the case in selecting villages for a PFR, we also exclude villages in which a PFR was implemented by the MCC. In the case of the southernmost cluster in Tchaourou, no villages were available within a 20km buffer and so the area of search was extended to include the other side of the nearby national forest (as can be seen in the South-West in Figure 2). In some cases, villages were

[7] During this process the official number of villages changed from 3758 to 5290.

chosen from across the commune border as these appeared a better match than any villages within the commune. Villages are balanced according to these characteristics as can be seen in Table A 2.

Figure 2 - Map of Borgou



During data collection at baseline, one treated village in Bémbéréké (Sombouan 2) refused to be surveyed, citing existing conflicts so was excluded from the sample. As mentioned in Section 2.2, one village selected for PFR implementation was replaced by the ProPFR team after the baseline survey had taken place. This meant no replacement could be made in our sample and so our sample for analysis suffers the reduction of two treated villages, leaving us with 25 instead of 27 PFR villages.

HOUSEHOLD SELECTION

No sample frame of households exists for the villages selected to be part of the study. We therefore employed GIS data to sample among buildings within estimated village boundaries as proxy for households within each village.

We randomly selected 56 buildings from each village with the aim was to provide a sample of 3024 households for analysis. Given we select from a list of buildings, this implicitly applies probability proportional to size (PPS) random sampling, where the measure of size is the number of buildings held by a household. We adjust for this sampling by weighting according to the self-reported number of buildings held by a household, to avoid richer households with more buildings playing a disproportionate role. Replacement buildings were required in cases where the building did not belong to a household (e.g. a school or not a building at all) or when multiple buildings belonging to

the same household were drawn[8]. The coordinates of the selected buildings were provided to enumerators in the CAPI application.

3.3 EVALUATION DESIGN

3.3.1 IMPACT EVALUATION STRATEGY

Our impact evaluation follows a quasi-experimental design, seeking to establish a suitable counterfactual by combining the use of propensity scores with a difference-in-differences (DiD) setup where data is available at both baseline and endline. For outcome variables of interest only available at endline, we employ inverse probability weighted regression adjustment (IPWRA). Details are included in Appendix A.6.

Since the PFRs were targeted to villages with specific characteristics, we could not guarantee ex ante that we should expect treatment and control villages to be balanced on our indicators of interest at baseline. If the trends for PFR and control villages would be parallel in the absence of treatment, then a canonical DiD estimator would be appropriate to estimate the causal effects of a PFR. By subtracting the difference in outcomes between treated and control at baseline from the difference at endline, we would be able to calculate what part of the difference at endline is attributable to the PFR program. This would ensure we rule out any trends in the data present among households in both PFR and control villages and provide us with a counterfactual for what would have happened to the treatment villages in the absence of the PFRs. However, the assumption of parallel trends is impossible to test in our setup since we do not have data at multiple points in time from before PFR implementation. Furthermore, since this is a targeted intervention there is reason to believe that the PFR villages and control villages would differ.

We therefore choose to relax this assumption such that we require only parallel trends conditional on observables. While specifying control variables within a DiD estimation may suffice to establish parallel trends conditional on observables, this is sensitive to the specification used. Another alternative would be to combine DiD with propensity score weighting, which would also be sensitive to the specification used. Through the combination of both propensity score weighting as well as the inclusion of control variables our estimator will be doubly robust to misspecification. For DiD in the two periods and two groups setting, one such estimator has been proposed by Sant'Anna and Zhao (2020) while for cross sectional analysis we use IPWRA, as derived in Wooldridge (2007) and explained in Wooldridge (2010), using Stata's *teffects ipwra* command. We estimate the Sant'Anna and Zhao (2020) estimator in Stata using the *drdid* command prepared by Rios-Avila et al. (2021). In the results section we present the average treatment effect on the treated (ATT), which is an estimate of the effect experienced by those households in villages treated under the PFR[9], comparing actual outcomes with a generated counterfactual for what would have happened to the same units in the absence of treatment. Using propensity scores and controlling for other variables we construct the counterfactual $E(Y^0|D = 1)$ to inform us about the expected value of the outcome for the treated

[8] In the field 179 buildings were identified as empty or non-residential, 80 as derelict, 62 unable to find the building, 23 where no person could be found at the building, and 112 marked as "other" which include the household already being surveyed.

[9] In a sense, this also makes our estimate reflect the intention to treat, since not all households have land parcels which were demarcated and registered into the PFR.

units ($D = 1$) in the case they were not treated (indexed 0). This is compared to the observed mean among the treatment group $E(Y^1|D = 1)$ to estimate our ATT.

$$ATT = E(Y^1 - Y^0|D = 1) = E(Y^1|D = 1) - E(Y^0|D = 1) = \eta_1^1 - \eta_1^0$$

While an assessment of agricultural productivity would be unlikely to find results due to the relatively short time span between PFR implementation and the endline survey, the use of remote sensing data would enable a later estimation of the impacts (though is beyond the scope of this report). Since village boundaries were defined during the PFR process, this allows for a geographical discontinuity approach, which was not feasible prior to the definition of village boundaries, as were produced by the ProPFR team. Around the village boundary, a buffer could be established within which the land is likely to have similar characteristics, except for the implementation of the PFR within the treated villages. This would allow the comparison of vegetation indices (NDVI, SAVI and EVI) on the pixel level which could be generated through the use of Google Earth Engine. Such an analysis would necessitate dropping any household information since we do not have any data on the land users beyond the village boundary.

3.3.2 DATA SOURCES

We exploit seven sources of data in our approach to evaluating the impact of the PFR in Borgou, Benin: (i) pre-implementation administrative data on village characteristics and other GIZ project implementation guided the selection of counterfactual villages; (ii) shapefiles produced by digital globe identified buildings as a proxy for households for sampling purposes; community level surveys were carried out at (iii) baseline and (iv) endline providing village level information about land and financial institutions accessed in the village as well as local crop prices, used where individual information was missing; household surveys at (v) baseline and (vi) endline provide the key data for analysis to estimate impact; (vii) PFR administrative parcel data (including shapefiles) were shared along with the pre-implementation village diagnostic survey and were used in considering the implementation of the program.

As part of the household survey a roster of parcels of land was collected, including GPS coordinates for the parcels. These were intended to be collected by remotely inputting the parcel corners on satellite images of the parcel as a map. Most respondents were unable to identify their parcel and so a first step was visiting the parcel to provide a point of reference on the map using the GPS unit of the tablet (showing a blue dot on the map for the current location). Many of the tablets used had faulty GPS units, meaning that an alternative device had to be used to identify coordinates which were then manually entered. This process led to poor quality shapefiles, despite attempts to provide feedback during baseline and subsequently clean the data. In this context, traversing the plot with more precise GPS measurement would provide more accurate data. As a result of the poor-quality shapefiles, it is difficult to match the parcels from the survey data to the administrative data since the parcel shapefiles do not overlap well. Further attempts to match these two data sources by using names are made infeasible by the different level of reporting between administrative data, including family/clan registered parcels, and survey data on the household level[10].

Even though parcels typically do not align either with the ProPFR administrative recorded shapefiles nor the available satellite images for the region, we examine the overlap of the baseline survey shapefiles with the ProPFR shapefiles by using the centroid of the baseline survey parcels to

[10] We would recommend establishing a common ID scheme to be used in both the administrative data and additional evaluation data for future evaluations.

approximate their location. This assumes that the location of the recorded parcel is correct even if the boundaries are not accurately entered. When considering parcels from the baseline survey in treated PFR villages, 79% of them overlap with a parcel recorded from the ProPFR data (and 80% among those parcels still available in the endline survey). The ProPFR data still include parcels which are classified as refusals, owner unknown, or under conflict, all of which cannot be considered as registered parcels. These categories are described in more detail in Section 4. To assess the quality of these matches, we consider the extent to which the PFR treatment status overlaps according to the two definitions, namely the centroid is inside a parcel registered according to the ProPFR data and whether the respondent states that their parcel was measured due to the PFR program. There is a significant positive correlation between the centroid lying within a parcel registered in the ProPFR data and the survey response for treated villages at endline, though this is fairly weak with the correlation coefficient at 0.21.

Table 1 - Overlap in PFR treated parcels according to ProPFR data and survey data

	Parcel registered in ProPFR data		
	No	Yes	Total
Parcel measured due to PFR, survey response			
No	621	326	947
Yes	504	627	1,131
Total	1,125	953	2,078
Correlation coefficient = 0.210			

3.3.3 SAMPLE OVERVIEW

At baseline 2968 household surveys were completed in the 53 villages covered. All 56 households from Sui Gourou were dropped from the sample due to no implementation of the PFR[11]. Among the remaining 2912 households, 2608 were found and interviewed at endline. At baseline the sample households reported 3963 parcels, of which 3064 were included in the endline survey (thus allowing for panel analysis) with an additional 1304 new parcels recorded at endline which were not recorded at baseline. At baseline 2603 women's modules were completed, with 1679 women successfully found and interviewed at endline and 555 women's modules with a different person at endline, meaning a total of 2234 women's modules completed at endline. Similarly, for young men, 676 were completed at baseline, with 215 of those found at endline and 559 new young men interviewed and a total of 774 young men interviewed at endline. Note that the number is lower due to the age restriction of young men, with only 709 households with any eligible young man at baseline and 816 at endline.

Our endline data include 2608 households and 4368 parcels in total, of which 3064 are recorded at both base- and endline for panel analysis. At endline, 2500 households recorded information on at least one parcel of land.

[11] Households in this village would not be a good control group, since the village was determined to be unsuitable for a PFR, so the village was used for piloting the endline questionnaire during enumerator training.

Table 2 - Sample overview

	Non-PFR village Year		PFR village Year		Total Year	
	Baseline	Endline	Baseline	Endline	Baseline	Endline
Households	1513	1345	1455	1263	2968	2608
Parcels	2055	2290	1908	2078	3963	4368

4. DESCRIPTIVE ANALYSIS

For the 52 villages included in the final analysis, 2608 households were successfully interviewed at endline, representing a 90.3 per cent response rate for the PFR villages and 88.8 per cent for the control villages. The main reason for non-response was due to households moving out of the village (5.8 and 6.9 per cent of households in PFR and control villages respectively). In total only 11 households from baseline refused to be interviewed at endline. There are no systematic differences in household level attrition between PFR and control villages.

Parcels belonging to the household at baseline are recognized in over 90 per cent of cases for both PFR and control groups. Information was pre-loaded to help identify parcels to allow us to conduct panel analysis also on the parcel level. Agricultural parcels suffering from attrition were more likely to be loaned but are otherwise similar to those present in the panel at both base- and endline, including in our indicator for no risk of losing rights. While rented parcels have been found to be perceived as less secure in Benin (Prindex, 2019), this link does not carry over to parcels suffering attrition (as may be the case if they are indeed less secure). Conversely, those parcels determined to be borrowed at baseline which are still included at endline are 16 percentage points[12] less likely to be demarcated than other parcels in the balanced panel, suggesting that loaned or borrowed parcels are less likely to benefit from demarcation. In addition to recording information on the parcels recorded at baseline, 1305 new parcels were also added where reported by respondents. These parcels are more likely to be acquired recently (as expected for added parcels), more likely to be managed by a woman (6.1 percentage points more likely than those in the panel), less likely to be first occupation and more likely to be inherited than those covered both at base- and endline. Among the new parcels, it is not more likely for parcels managed by women to be inherited (58 percent of new women managed parcels vs. 51% for men only managed parcels, though the difference is not statistically significant).

Implementation

To better understand the survey data, we compare it with the PFR registration data below in Table 3 for agricultural parcels, since only these were included in the PFR. Here we show information on parcels from PFR villages which overlap with our sample. We note that a lower proportion of parcels are declared as demarcated in our survey data, even for agricultural parcels only, which were the focus of the PFR. Those not demarcated in the PFR were listed as unknown owner, refused or subject to conflict. The difference in reported rate of demarcation may be due to the fact that many parcels were registered at the wider family level rather than at the household level, while in our survey the parcels as managed by individual households were declared. This would also explain the smaller average size as shown by the median parcel area of 3ha for the survey and almost 5ha for the

[12] This is when taking sampling weights into account.

registration data, as well as the proportion declared as individual vs collective, with the latter much higher in the PFR registration data. When considering the geolocation of the survey parcels in PFR villages[13], 68.56 per cent of parcels overlap with a parcel considered registered in the ProPFR data, with 9.28 per cent of survey parcels overlapping with a parcel recorded as "owner unknown" in the ProPFR data, 2.15 per cent recorded as under conflict or refused, and 20 per cent of centroids do not lie within a ProPFR parcel. This suggests that the proportion of parcels included in registration may be higher than the self-reported value of 63.43 per cent but is not as high as the percentage of parcels registered in the ProPFR data. Where parcels remain unregistered in the ProPFR data, these may cover multiple parcels coming from many families and are on average larger, at 9.8 ha median (62.5 ha mean) for those not demarcated compared to 4.6 ha median (20.3 ha mean) for those demarcated.

We also note that many more parcels in the survey data are declared as being gifted, which could be within families for use while ownership rights remain with the inheritor. Parcels are more likely to be inherited in the PFR registration data, further supporting the argument that the level of ownership (individual or collective) at which land is declared differs between administrative data and survey data. This was not anticipated at baseline. There is no appreciable difference in the gender of the parcel owner, which is relatively low compared to the national average, with the recent national agricultural census reporting 15.7 per cent of agricultural household heads to be female, and 6.9 per cent in Borgou (Ministère de l'Agriculture, de l'Elevage et de la Pêche du Bénin, 2021). It is however more in line with the statistics on the delivery of ADC for the respective communes, with an average of 3.4 per cent of ADCs delivered to females. We note that the proportion of female household heads at endline is higher at around 9 per cent of households in the sample.

[13] These are restricted to 1390 parcels in PFR villages available in the panel data at both baseline and endline.

Table 3 - Descriptive statistics on land measurement: PFR registration vs. survey data

	Data Source	
	PFR Registration Data	Survey Data
Total number of obs.	6,480	2,078
% of parcels demarcated	91.13%	63.43%
Number of demarcated parcels	5,905	1,318
Median parcel area in ha	4.897	3
Gender of the registered owner of the parcel		
Male	97.43%	97.51%
Female	2.57%	2.49%
Parcel registered as		
Individual	73.21%	99.62%
Collective	24.10%	0.38%
Public	2.69%	0.00%
Mode of acquisition of parcel		
Bought	1.86%	1.29%
Customary attribution	3.23%	0.00%
Gifted	7.11%	25.32%
Borrowed	0.02%	3.39%
Inherited	58.83%	45.20%
Free installation	28.95%	22.68%
Other	0.00%	2.10%

Note. The sample for PFR Registration Data consists of the list of parcels provided by the ProPFR team excluding the village of Sombouan 2 which is not in our survey sample. The sample for Survey Data consists of parcels reported by households in the treated villages at endline (both agricultural and non-agricultural).

Further details on implementation in the survey sample in Table 4 show that among the parcels in PFR villages 57 percent have been demarcated, among which 72 percent were claimed to be demarcated due to the PFR, meaning in total 42 percent of parcels in PFR villages were demarcated due to the PFR. We note that 16 percent of parcels which were demarcated belonging to households in control villages also claim it was due to a PFR, with all of those claimed to be situated within the village. On the household level, we see that among the households in PFR villages, only 43 percent state that they have any field which was demarcated due to the PFR. We cannot be sure why this figure is not higher, but possible reasons include: a poor understanding of demarcation, a lack of awareness of respondents of the PFR process, and parcels being demarcated at a higher level than the parcel reported in the survey. This has implications for the treatment effect we estimate. Given that we consider being in a treated village as being treated, if more than half of our sample households from PFR villages declared that they had no parcel demarcated due to the PFR, then the treatment measured may be considered an intention to treat (ITT) estimate. While all households in PFR villages can refer to an SVGF in case of conflicts and the process of a PFR has been undertaken, if that household states their parcels has not been demarcated due to the PFR, the key component of the

intervention cannot affect their perceptions of security. Nonetheless, since other PFR components should affect all members of the village, we estimate treatment effects at this level.

Among demarcated parcels, the proportion with boundary stones in place is noticeably different, with 85 percent of demarcated parcels in PFR villages being marked by boundary stones compared to only 7 percent in control villages.

Table 4 - Descriptive statistics on demarcation in the survey sample

	Treatment status		
	Non-PFR village	PFR village	Total
Parcel has demarcation			
Number of non-missing values	2,233	2,047	4,280
Yes	28.08%	57.89%	42.34%
No	71.92%	42.11%	57.66%
Parcel demarcated due to PFR (among demarcated)			
Number of non-missing values	627	1,185	1,812
Yes	15.79%	72.15%	52.65%
No	84.21%	27.85%	47.35%
Household level: any parcel demarcated due to PFR			
Number of non-missing values	1,274	1,215	2,489
Yes	5.02%	43.29%	23.70%
No	94.98%	56.71%	76.30%
Parcel has boundary stones (among demarcated)			
Number of non-missing values	505	1,074	1,579
Yes	7.13%	85.38%	60.35%
No	92.87%	14.62%	39.65%

Survey data

We present sociodemographic characteristics of the respondents disaggregated by treatment status, year of survey, and type of household head.

Table A 3 presents sociodemographic characteristics disaggregated by treatment status and year of survey. First, note that the number of observations is the same between baseline and endline since we remove the households suffering attrition from the sample for descriptive analysis. We lose 361 households due to attrition between baseline and endline, which brings the total sample to 2,607 households for which we have both baseline and endline information. In the non-PFR village category, there is one extra household at endline. This household refused to be surveyed at baseline but agreed to the survey at endline[14]. We have slightly more households in the control group (1,345)

[14] This household cannot be included for panel estimators, but may be used for cross-sectional IPWRA analysis.

than in the treatment group (1,263) due to two treated villages dropping out. One ended up not being treated (Sui Gourou) and one refused survey at baseline (Sombouan 2).

The average age is similar across both treatment groups, with household heads in the PFR villages slightly younger than in the non-PFR villages (46.12 versus 47.02 at endline). In both control and treatment groups, the age at endline is two years higher than the age at baseline. This seems inconsistent with the fact that the endline survey took place almost four years after the baseline survey (baseline survey took place in June-July 2018 whereas endline survey took place in March-April 2022), but it can be explained by changes in the household head. Elderly household heads at baseline might have been replaced by their much younger sons or sons-in-law at endline. In fact, the household head changed between baseline and endline in 12.5% of cases.

At endline roughly 73% of household heads in PFR villages were literate and 69% in control villages, with 71% and 76% Muslim respectively. Ethnic breakdown is similar across treatment and control, with Peulh (Fulani) being the largest ethnic group (roughly 47% in both PFR and control), followed by Bariba and related (roughly 30% in PFR villages and 36% in control).

When considering the place of origin of the household head, we can see that the study sample is not very mobile. The breakdown is similar across treatment status and year of survey. Approximately 80% of the household heads come from the same village in which they currently live.

In Table A 4 we consider the conflicts reported in parcel level data. Since 2018 when the PFR was initiated, there was 0.13 conflicts per control village parcel and 0.07 per PFR village parcel. In PFR villages the conflicts were more likely to be related to boundaries and less likely to be related to quarrels between farmers and herders or related to inheritance issues.

5. RESULTS

5.1 MATCHING QUALITY

For both IPWRA and DRDID, we make use of propensity scores in our estimations. When estimating propensity scores, it is important to include variables which are correlated with the likelihood of treatment as well as correlation with the outcomes of interest. Where these show a high degree of collinearity, we drop one variable from our estimations. Originally, we had hoped to include risk of land grabbing as a matching variable, but this suffered from a high degree of collinearity and so was dropped from the analysis. We include the following variables in the estimation of propensity scores using logit regression for households: a dummy for a female household head, the age of the household head (and a squared term), a dummy for a migrant household head, total agricultural area owned, total non-agricultural area owned, a dummy for the proximity to a national forest, a dummy for major conflicts reported in the village before baseline, a dummy for the presence of a transhumance corridor (known as a “couloir de passage”) through the village, and a dummy for the presence of a pastoral area in the village. For parcel level analysis, the following additional variables are included: year a parcel was obtained, a dummy for a female parcel manager, a dummy for ownership of a parcel, a dummy for the parcel being within the village boundary, and a dummy for the parcel being rain fed. We also substitute the total area owned by a household for the size of the specific parcel and the number of agricultural parcels owned by a household. The marginal effects can be seen in Table A 6.

The treatment and control groups are sufficiently overlapping for analysis, with the distributions for both parcels and households for control having a slightly lower mean, as is often the case when using

matching techniques. We do not suffer from many extreme values close to zero and one, which would be problematic for the use of inverse probability weighting as carried out in both IPWRA and DRDID. The common support graphs can be seen for households and parcels in Figure A 6 and Figure A 7 respectively.

We also show that overall bias is reduced in observed differences between the treatment and control groups in Figure A 8 and Figure A 9, where the bias is on average closer to zero for the matched sample.

5.2 DIRECT IMPACTS

In this section we present the main estimated effects of the PFR on a range of outcomes as defined by the research questions. Each table shows a reference mean to better understand what change has occurred, the ATT which shows the treatment effect of being in a PFR village, this effect displayed as a percentage change, followed by the level of analysis (parcel or household) and the estimation method used. The reference mean for DRDID estimates displays the actual baseline value for the treatment group, while for IPWRA the reference mean shows a "potential outcomes" mean (POmean) determined by the propensity weighting process, which shows a counterfactual of what the treated parcels or households would record in the absence of treatment. Parcels refer to land used for agricultural purposes.

RQ1: PERCEIVED TENURE SECURITY

At baseline for a majority of parcels, respondents felt secure with around 70% stating there was no risk to losing the parcel in the next 5 years and only 5% stating that they felt it was "rather likely" and 8% stating "very likely" on a four-point Likert scale. Among the parcels perceived to be at any risk, there are a higher proportion managed by migrants "allochtones", but no differences for being managed by a woman or young man, nor for being above or below the median wealth index level. When considering the proportions stating no risk at baseline, this is lowest for those parcels loaned or rented.

Below in Table 5 we show the effects of the PFR on perceived tenure security. While the key indicator for believing there is no risk of losing rights on a given parcel in the next 5 years has a positive sign, it is not significantly different from zero. We also do not find significant effects for losing part of the parcel, losing the parcel if it is left fallow, nor a change in the degree of satisfaction with land management in Benin. Overall, the perception of tenure security remains high, even when a parcel is left fallow, as was already true at baseline, and there is a high level of satisfaction with land management institutions, based on a four-point Likert scale with a dummy taking the value of one for quite or very satisfied and zero for not very or not at all satisfied. Given the high level at baseline, this seemed unlikely to be affected. It should be noted, however, that administrative data show that land was often demarcated in the name of the clan or family, and not at the household level, possibly indicating a strategy to prevent fragmentation and individualization, but which also means that the effect of demarcation may not have been noticed at the level of our unit of analysis, which is the individual household.

The only significant change we observe is on indicator RQ1.2, which relates to whether individuals from outside the household take resources from the parcel, where we see a 22.7 per cent increase in respondents stating that only household members take resources, such as firewood, leaves, roots, water or fodder from the parcel. This finding seems to indicate that the demarcation increased control over the parcel by the households, with boundaries being more respected. Given that

resources are taken from a parcel, the most likely products to be taken are firewood (65% of affected parcels, as can be seen in Table A 5), shea nuts (50%), and leaves and roots (52%). There are also some noticeable differences in what is taken with shea nuts more likely to be taken in control villages, while fruits other than baobab/néré/cashew, and water are more likely to be taken in PFR villages. If women from the village can no longer collect shea nuts from a parcel, this may reduce the welfare of marginalized groups who depend on access to fields owned by other households for their livelihoods.

Table 5 - RQ1: Perceived Tenure Security

Indicator	Reference mean [std dev] / (std error)	ATT	% change	Level of analysis	Method
RQ1.1: No risk of losing rights on parcel in next 5 years (1=No risk)	0.697	0.060	8.61%	Parcel	DRDID
n=4856	[0.460]	(0.051)			
RQ1.1: No risk of losing part of a parcel in next 5 years (1=No risk)	0.682	0.025	3.67%	Parcel	IPWRA
n=2528	(0.035)	(0.056)			
RQ1.2: Only household members take resources from the parcel (1=Yes)	0.423	0.096 *	22.70%	Parcel	DRDID
n=5524	[0.494]	(0.055)			
RQ1.3: No risk of losing parcel if left fallow (1=No risk)	0.897	-0.014	-1.56%	Parcel	DRDID
n=5524	[0.303]	(0.028)			
RQ1.4: Degree of satisfaction with land management in Benin (1=quite or very)	0.892	-0.007	-0.78%	Household	IPWRA
n=2526	(0.020)	(0.029)			

Notes: std. errors in parentheses are clustered at the village level; * p < 0.1, ** p < 0.05, *** p < 0.01

Reference mean refers to baseline mean for the treatment group under DRDID and the POmean for IPWRA

RQ2: INVESTMENT AND LAND MANAGEMENT

In Table A 7 we show results pertaining to RQ2 about whether households change their investment in land, which could potentially lead to changes in agricultural outputs. We find a positive and significant effect on whether measures were used to improve soil and water conservation on parcels in PFR villages[15]. These measures may include digging a well, a water pump, a water storage system such as a cistern or barrel, levelling of soil, terracing, stone barriers, the use cover crops, strip farming or planting crops specifically aiming to increase fertility. The size of the impact is also large moving from 41 percent at baseline and increasing by 18 percentage points (an increase of 45 percent).

[15] For robustness purposes we check whether the inclusion of a dummy for the village being part of the Soil Protection and Rehabilitation for Food Security (ProSOL) impacts this result but find no substantive change in the coefficient nor significance for this indicator. An exploratory investigation into heterogeneous treatment effects by the presence of ProSOL in the village is made in section 5.3.4.

Despite this large change, there is no significant impact in overall spending on these measures despite a large magnitude of the coefficient, meaning we find no impact on the intensive margin.

We find no effects on tree planting, the use of fertilizer (expenditure as well as any use of either organic or inorganic fertilizer), the use of pesticides, the use of improved seeds, whether there is infrastructure on a parcel, investment in infrastructure, nor is there any change in the area used for agricultural production. We do, however, find a significant impact on the labor inputs, measured in person days, which increase by 42% on parcels in PFR villages. This contrasts with the findings of Goldstein et al. (2018) who only find impacts on hired labor on parcels outside the village, with no general impacts on labor inputs.

This first indication of changes in investment are apparent with increased time of labor for parcels in PFR villages and any investment in soil and water conservation.

RQ3: LAND RIGHTS AMONG MARGINALIZED GROUPS

In Table A 8 we see that at baseline only around 8 percent of parcels in the panel in PFR villages had any female manager and only 5 percent were managed only by women. In general, we see in our reference mean for PFR villages at baseline that the extent women have access to land is quite low. Only 37 percent of female respondents to the women's module state that they have a parcel assigned, though among those with a parcel, half could decide which parcel was assigned. One notable exception to the negative trend in women's rights is that married women are allowed to purchase land, and the majority of these women may register it in their own name.

We find very little impact of being in a PFR village on the rights of women over land. We allowed for multiple household members to be declared as decision maker for a parcel, where the maximum recorded was six. We can therefore consider whether any of the parcel managers are female, or whether the parcel is only managed by females. In fact, one of the two significant results (though only at the 10 per cent level) is negative on whether a parcel has only female decision makers, which decreases by 22 per cent, decreasing from 4.6 percent of parcels by 1 percentage point. This may reflect that as rights over a parcel are formalized, that men fear the risk of losing long-term control over a parcel if it is registered solely in a woman's name. There are no effects on whether there is any female decision maker on a parcel, suggesting that where a female is involved in decision making, if anything they are now more likely to face the intervention of a male household member than before the implementation of a PFR. The other significant impact we find was on whether the female respondent had inherited since baseline, which increased by 41 per cent, from 9 percent by 3.5 percentage points. On the household level, we find no effects on the number of parcels managed by at least one woman, the number of parcels managed only by women, whether a woman can decide which parcel is assigned to her, whether the female respondent expects to inherit land, whether the female respondent states that women may buy land, or register it in her own name (in the cases she may buy land).

When considering the rights of young men aged 18-35 from the baseline values in Table A 9, we see that very few parcels had a young male manager, with only around 1%. This is reflected on the household level in the number of parcels. However, among the respondents to the young men's module, 37% stated that they were assigned a parcel to work on and manage, and among them 53% could decide which parcel. Inheritance is more common among young men than among women (of any age), with 20% having inherited at baseline and over 70% expecting to inherit in the future. Young men are mostly permitted to purchase land (89%) and of those, almost all may subsequently register it in their own name.

We find no positive effect of the PFR for young men, where the only significant result is that young men are one percentage point (a decrease of 76% over the low baseline level) less likely to be a decision maker over any given parcel (at the 10 per cent level). All remaining indicators (analogous to those for females) are insignificant.

RQ4: LAND MARKETS

On the household level in Table A 10, we consider the number of parcels sold since baseline, ever sold, bought since baseline, currently owned that were bought, rented in or borrowed, rented out or lent to assess land market activity. All of these show less than 0.05 transactions per household in the reference mean, showing very low levels of activity. None of the indicators show significant impacts on land markets in PFR villages.

RQ5: AGRICULTURAL PRODUCTIVITY

Within the theory of change, agricultural productivity is a key channel to achieve improved food security and income. The results for this research question are shown in Table A 11 where we consider the four main crops (maize cotton, soy and sorghum), though it is important to note that according to the GLLM (Lisher J. W., 2019) it is likely too early to expect to find any impacts in this domain. While total production was measured at baseline, the data did not allow the construction of yields and so analysis on yields uses IPWRA with endline data. At baseline total harvest was highest for maize followed by cotton, which is also the case in terms of yields at endline. Due to the distribution of yields, our analysis takes log values, but the raw values are in line with data for local agricultural productivity[16] The share of value lost ranges from 0 to 100, showing that very little was lost. As should perhaps be expected in the short term, we do not find significant impacts on agricultural productivity.

RQ6: ACCESS TO CREDIT, INCOME, AND FOOD SECURITY

The ultimate goal in the ToC is to improve livelihoods, which can be measured in terms of income and food security. In Table A 12 we consider indicators related to income. Annual household income from wage and self-employment was equal to 1,144,000 FCFA at baseline (2130 USD on March 1, 2018). We see that there has been no significant effect on income due to the PFR at the time of the endline survey. There is a reduction in the share of cash crops for households in PFR villages, reducing by almost 10 percentage points compared to a baseline of around 32%, which could be exacerbated by changes in the economic environment between 2017 and 2022, which include the COVID period. The drop is larger in PFR villages as the starting value was higher there, leading to similar levels at endline. The crop diversification index can range from zero to one where one represents complete dominance and zero indicates complete diversity. The mean value of 0.5 at baseline is a moderate value, and no significant impact is found in PFR villages.

[16] For maize we find yields of 1379 kg/ha in control and 1390 kg/ha for PFR villages compared to 1456 kg/ha in Agristat Borgou's records for 2017/18 and 1271.8 kg/ha from the FAO. For soybeans our sample has 1084 kg/ha and 1099 kg/ha for control and PFR respectively, with Sorghum at 959 kg/ha and 911 kg/ha respectively, and Cotton at 1300 and 1313 kg/ha respectively. These are also similar to official values from Agristat Borgou 2017/18(1152 kg/ha for Soy, 948 kg/ha for Sorghum, and 1086 kg/ha for cotton in 2016/17) and the FAO in 2020 (1247.5 kg/ha for Soy, 1100.5 kg/ha for Sorghum).

We show the results for the credit market in Table A 13. Both when considering the counterfactual mean at endline for new loans requested since baseline as well as the baseline value for ever requested a loan, we see that under 25% of households have requested a loan. There is no change in the demand for credit, and in fact the percentage of households obtaining a loan given that they have applied for a loan even decreases by four percentage points from a very high level of 98.5%, though this is only significant at the 10 per cent level. The implementation of a PFR does not appear to increase the uptake of loans, which is not surprising given that no official individual documents had been distributed as part of the project. Among those applying for a loan since baseline, 55% stated that a land document was required for the loan application, though this is not affected by the PFR as no *Titre Foncier* was issued for PFR parcels, contrary to what was expected at baseline.

In terms of food security, at baseline 12.2% of households had experienced a food shortage in the last 12 months, 11% worried about food in the last 7 days, though the coping strategy index suggests that households did not have to adjust their behavior to cope with food related issues (56 would mean they use all recorded coping strategies every day). This is also reflected in the average number of meals per day for both adults (close to 3) and children (above 4) in the counterfactual at endline. As anticipated, we do not find impacts in Table A 14 for any indicators, ranging from food shortages, use of coping strategies, nor the number of meals eaten.

RQ7: CONFLICTS

In Table 6 we see that the number of new conflicts reported on all parcels held by a household since baseline decreasing significantly by 46 per cent from an average of 0.2. This is a large effect, though we note that the number of conflicts reported in the household survey appears to be significantly lower than in the administrative data shared by ProPFR, which included 1078 conflicts occurring during the implementation of PFRs in 27 villages. For the 25 PFR villages in our sample, at endline a total of 166 conflicts were reported to have occurred since baseline, an order of magnitude smaller than the ProPFR data. Nonetheless, if both treated and control households underreport conflicts equally then this result is likely still indicative of a reduction in conflicts faced. The number of unresolved conflicts also decreases by a similar percentage, though the impact on the amount spent to resolve conflicts was not significantly different from zero. The SVGF should also play a role in this and received training as part of the PFR implementation process. The community questionnaire indicates that village administrative authorities are more often involved in solving conflicts (in 80 percent vs. 58% of villages). On the parcel level, less than 5% of conflicts reported at endline were solved by village or communal authorities (including the SVGF or COGEF) while the village chief was reported to resolved 51 percent in control villages and 44 percent in PFR villages.

Table 6 - RQ7: Conflicts

Indicator	Reference mean [std dev] / (std error)	ATT	% change	Level of analysis	Method
RQ7.1: Number of new conflicts since baseline	0.222	-0.103 ***	-46.40%	Household	IPWRA
n=2607	(0.029)	(0.033)			
RQ7.2: Number of new conflicts since end of PFR	0.033	0.016	48.48%	Household	IPWRA
n=2607	(0.009)	(0.014)			
RQ7.3: Number of unresolved conflicts	0.08	-0.039 **	-48.75%	Household	IPWRA
n=2607	(0.013)	(0.015)			
RQ7.4: Amount spent to resolve land conflicts since baseline (1000s FCFA)	1.326	-0.631	-47.59%	Household	IPWRA
n=2607	(1.098)	(1.040)			

Notes: std. errors in parentheses are clustered at the village level; * p < 0.1, ** p < 0.05, *** p < 0.01

Reference mean refers to baseline mean for the treatment group under DRDID and the POmean for IPWRA

5.3 HETEROGENOUS IMPACTS

When estimating the ATT using the doubly robust methods presented above, it is not possible to include interaction terms for the estimation of heterogeneous effects. We therefore present subgroup analysis, showing the estimated treatment effect for each group, and calculate the difference between the ATT for each group. This provides a comparison of the treatment effect to see whether the treatment effect in one group is similar to that of the other. Note that when estimating effects for subgroups, some control variables need to be dropped. The variable defining the subgroup can no longer be used as a matching or control variable, and new issues of collinearity may arise in smaller subsamples, necessitating that further variables are dropped.

To provide an indication whether this difference is significant, thereby establishing whether one group is more or less affected by the PFR than those not in the group, we test for significance by considering the conditional recentered influence function (RIF) for the ATT. An influence function will provide information for each observation on the contribution of that observation to a statistic of interest (Rios-Avila, 2020). In our case the statistic of interest is the ATT, and the RIF can be generated for estimates of DRDID simply within Stata. For IPWRA this is more complex, but code was created building on Jann (2020). Once the RIF has been obtained, the mean of the RIF will provide the overall estimated ATT and allow for estimation of standard errors. This allows us to test analytically whether the coefficients in subgroups are significantly different using a Chi-squared test accounting for sampling weights and clustering.

We consider gender, migrant status, and socioeconomic status to consider heterogeneous impacts. For gender and migrant status, the subgroup is defined according to the parcel manager at baseline for parcel level analysis and according to the household head at baseline for household level analysis. Socioeconomic status is defined according to whether the household is above or below the median

wealth index at baseline. For socioeconomic status, this variable is only available on the household level even for parcel level analysis.

5.3.1 GENDER

When considering the perceptions of tenure security, we note that there is a positive and significant effect on RQ1.2 only among parcels managed by men and that the coefficient has a different sign for women (though is insignificant). We explore the type of resources taken from parcels and find that on parcels where resources are taken, those managed by women are less likely to have shea nuts and cashews taken, but more likely to have firewood, water, and roots and leaves taken. On RQ1.3 and RQ1.4 we observe that men and women again have opposite signs on the coefficients, though neither is significantly different from zero, and nor are the differences in ATTs.

Table 7 - RQ1 by gender

	ATT				
Indicator	**Male**	**Female**	**Difference**	**Level of analysis**	**Method**
RQ1.1: No risk of losing rights on parcel in next 5 years (1=No risk)	0.067	0.070	-0.003	Parcel	DRDID
Observations	4514	342			
RQ1.1: No risk of losing part of a parcel in next 5 years (1=No risk)	0.034	0.030	0.004	Parcel	IPWRA
Observations	2338	190			
RQ1.2: Only household members take resources from the parcel (1=Yes)	0.100 *	-0.045	0.145	Parcel	DRDID
Observations	5116	408			
RQ1.3: No risk of losing parcel if left fallow (1=No risk)	-0.012	0.035	-0.047	Parcel	DRDID
Observations	5116	408			
RQ1.4: Degree of satisfaction with land management in Benin (1=quite or very)	-0.012	0.041	-0.052	Household	IPWRA
Observations	2291	233			

Notes: * p < 0.1, ** p < 0.05, *** p < 0.01

Compared to analysis of the full sample, the dummy for major conflicts is dropped from analysis due to collinearity in the subsample for women

Below in Table 8 we include a selection of indicators for RQ2, with the impact separated by gender. We see that PFRs only had a significant impact on male managed parcels for RQ2.1 and RQ2.5. The coefficients are of a larger magnitude, though not significantly different when tested. We therefore see positive effects on improving soil and water conservation, as well as increased labor inputs, are only present in male managed parcels.

Table 8 - RQ2 by gender

	ATT				
Indicator	**Male**	**Female**	**Difference**	**Level of analysis**	**Method**
RQ2.1: Used measures to improve soil and water conservation (1=Yes)	0.200 **	0.083	0.117	Parcel	DRDID
Observations	5234	418			
RQ2.2: Amount invested in soil and water conservation (in 1000s of FCFA)	1.119	-0.572	1.691	Parcel	DRDID
Observations	4310	262			
RQ2.5: Labor inputs (person-days)	176.295 ***	61.005	-115.290	Parcel	DRDID
Observations	4626	384			

Notes: * p < 0.1, ** p < 0.05, *** p < 0.01

Compared to analysis of the full sample, the dummy for major conflicts is dropped from analysis due to collinearity in the subsample for women

We consider the occurrence of conflicts separated by gender of the household head in Table 9. There is no clear difference in the number of new conflicts, which remains significantly different from zero for both genders, suggesting that PFRs reduce new conflicts equally for male- and female-headed households. When considering unresolved conflicts, we see that the impact on unresolved conflicts is only significant for male headed households but not for female headed households for whom PFRs had no impact. This suggests that PFRs were able to help resolve conflicts more effectively for male headed households, though the potential outcomes control mean is noticeably lower for the female headed households than the males, suggesting in the absence of the PFR they would have had more unresolved conflicts. After the PFR has taken effect the mean number of conflicts in male- and female-headed households is similar.

Neither male- nor female-headed households are significantly affected by the PFR on their spending to resolve land conflicts. Furthermore, even though the impact has a different sign, the difference between the reported ATT for each gender is not statistically significant.

Table 9 - RQ7 by gender

	ATT				
Indicator	Male	Female	Difference	Level of analysis	Method
RQ7.1: Number of new conflicts since baseline	-0.107 ***	-0.108 *	0.001	Household	IPWRA
Observations	2363	242			
RQ7.2: Number of new conflicts since end of PFR	0.016	0.013	0.003	Household	IPWRA
Observations	2363	242			
RQ7.3: Number of unresolved conflicts	-0.045 ***	-0.001	-0.044	Household	IPWRA
Observations	2363	242			
RQ7.4: Amount spent to resolve land conflicts since baseline (1000s FCFA)	-0.802	0.598	-1.4	Household	IPWRA
Observations	2363	242			

Notes: * p < 0.1, ** p < 0.05, *** p < 0.01

Compared to analysis of the full sample, the dummy for major conflicts is dropped from analysis due to collinearity in the subsample for women

5.3.2 MIGRANT "ALLOCHTONES" STATUS

While overall neither non-migrants nor migrants "allochtones" show a clear pattern of significant impact of the PFR on their perception of security, it is noticeable that the coefficients suggest they may be worse off than non-migrants and the test of significance indicates this difference is significant for RQ1.1 and RQ1.3. The coefficients for migrants "allochtones" on RQ1.1 and RQ1.3 are relatively large and negative, though not significant for RQ1.1, perhaps due to the relatively small sample size of migrants "allochtones". From RQ1.3 we see a negative impact on a parcel being safe when left fallow among migrants "allochtones", with the difference between groups also significant. However, when considering whether parcels are actually being fallowed, there is no difference in the rate of fallowing between migrant- and non-migrant-managed parcels in PFR villages, while in control villages migrant-managed parcels are less likely to be fallowed. Despite the PFR aiming to help marginalized groups, it seems that migrants "allochtones" may be negatively affected by the PFR. This may be due to the likelihood of benefitting from the PFR where we see that the parcels managed by migrants "allochtones" are 12 percentage points less likely to be demarcated in PFR villages. This is likely linked to how access to the parcel was obtained. Among endline parcels managed by non-migrants, we see that 44 percent of parcels were inherited (vs 17 percent for migrants "allochtones") and a further 28 percent were appropriation/first occupation of the parcel (vs 17 percent for migrants "allochtones"). Among migrants "allochtones", gifts of land were more common at 39 percent (vs 23 percent for non-migrants) as was loaned land at 22 percent (vs 1 percent for non-migrants).

Table 10 - RQ1 by migrant status

Indicator	ATT		Difference	Level of analysis	Method
	Non-migrant	Migrant			
RQ1.1: No risk of losing rights on parcel in next 5 years (1=No risk)	0.068	-0.138	-0.207 *	Parcel	DRDID
Observations	4456	400			
RQ1.1: No risk of losing part of a parcel in next 5 years (1=No risk)	0.024	0.017	-0.007	Parcel	IPWRA
Observations	2309	219			
RQ1.2: Only household members take resources from the parcel (1=Yes)	0.084	0.001	-0.083	Parcel	DRDID
Observations	5040	484			
RQ1.3: No risk of losing parcel if left fallow (1=No risk)	-0.005	-0.197 **	-0.192 **	Parcel	DRDID
Observations	5040	484			
RQ1.4: Degree of satisfaction with land management in Benin (1=quite or very)	-0.004	-0.028	-0.026	Household	IPWRA
Observations	2246	280			

Notes: * p < 0.1, ** p < 0.05, *** p < 0.01

Compared to analysis of the full sample, the dummy for the presence of a transhumance corridor is dropped from analysis due to collinearity in the subsample for migrants "allochtones"

In Table 11 we consider the impacts on selected indicators for inputs to production and for the rights of marginalized groups (females and youth). For the inputs we see that the impact is significant for both migrant- and non-migrant managed parcels on using measures to improve soil and water conservation, with the impact significantly larger for migrant-managed parcels. The impact on the amount invested is also significant migrant-managed parcels, though not for non-migrant households. Labor inputs increase for both groups.

For the impacts on marginalized groups, the negative impact on only having a female decision maker on a parcel is only significant for non-migrants, though the lack of significance for migrant managed parcels may be linked to the smaller sample size. No other indicator is significant for non-migrants nor migrants "allochtones". While the female respondent's likelihood of having an assigned parcel is not significantly affected in either migrant or non-migrant headed households, the difference is significant, with females in migrant-headed households seeming to be more negatively affected than those in non-migrant headed households. We note also that respondents to the women's module from migrant-headed households in PFR villages were 15 percentage points less likely to have an assigned parcel at baseline, i.e. they were already worse off in access to land.

Table 11 - Selected RQ2 and RQ3 by migrant status

Indicator	ATT		Difference	Level of analysis	Method
	Non-migrant	Migrant			
RQ2.1: Used measures to improve soil and water conservation (1=Yes)	0.211 ***	0.459 ***	0.247 **	Parcel	DRDID
Observations	5152	500			
RQ2.2: Amount invested in soil and water conservation (in 1000s of FCFA)	0.544	3.091 ***	-2.547	Parcel	DRDID
Observations	5152	500			
RQ2.5: Labor inputs (person-days)	145.129 **	252.334 ***	107.205	Parcel	DRDID
Observations	4550	460			
RQ3.1: Only female decision maker(s) (1=Yes)	-0.011 **	-0.011	-0.000	Parcel	DRDID
Observations	5178	504			
RQ3.3: Female respondent has assigned parcel (1=Yes)	0.100	-0.108	-0.208 *	Household	DRDID
Observations	3740	452			
RQ3.5: Woman inherited land since baseline (1=Yes)	0.031	0.082	0.051	Household	DRDID
Observations	3740	452			
RQ3.6: Woman expects to inherit land in future (1=Yes)	0.049	0.082	0.033	Household	DRDID
Observations	3638	434			
RQ3.9: Any male youth decision maker (1=Yes)	-0.012	0.006	0.017	Parcel	DRDID
Observations	5178	504			
RQ3.10: Number of parcels managed by young men	-0.036	0.002	0.038	Household	DRDID
Observations	4132	458			

Notes: * p < 0.1, ** p < 0.05, *** p < 0.01

Compared to analysis of the full sample, the dummy for the presence of a transhumance corridor is dropped from analysis due to collinearity in the subsample for migrants "allochtones"

The reduction in new conflicts since baseline due to the PFR is significant for both groups. While the coefficient is larger for migrant households than non-migrant households, the difference is not significant. To consider heterogeneity, we take the baseline value of the migrant status of the parcel manager. This implicitly restricts us to cover parcels available in the panel, and not the new parcels added at endline. Given the mode of occupancy on the migrant managed parcels, migrants "allochtones" are more likely to lose access to parcels between baseline and endline, which may be a result of conflict over the parcel. This could lead to a sample selection in which parcels remain among those managed by migrants "allochtones", and hence a larger coefficient for reduction in new conflicts. We see that for RQ7.3 on unresolved conflicts, there is a significant reduction only for non-migrant headed households, though the difference to migrant-headed households is not significant.

Table 12 - RQ7 by migrant status

Indicator	ATT		Difference	Level of analysis	Method
	Non-migrant	Migrant			
RQ7.1: Number of new conflicts since baseline	-0.091 ***	-0.176 *	-0.086	Household	IPWRA
Observations	2314	293			
RQ7.2: Number of new conflicts since end of PFR	0.015	0.008	-0.007	Household	IPWRA
Observations	2314	293			
RQ7.3: Number of unresolved conflicts	-0.041 ***	-0.030	0.011	Household	IPWRA
Observations	2314	293			
RQ7.4: Amount spent to resolve land conflicts since baseline (1000s FCFA)	-1.546	0.011	1.564	Household	IPWRA
Observations	2314	293			

Notes: * p < 0.1, ** p < 0.05, *** p < 0.01

Compared to analysis of the full sample, the dummy for the presence of a transhumance corridor is dropped from analysis due to collinearity in the subsample for migrants "allochtones"

5.3.3 SOCIO-ECONOMIC STATUS

While it is informative to consider how household wealth is linked to the observed treatment effects, it is important to note that this categorization (dummy variable) is also linked to other household characteristics. Wealthy households are more likely have more household members and more likely to be in Tchaourou or Sinendé (and less likely to be in Bembéréké or Kalalé). We also note that poorer households are actually less likely to be otherwise vulnerable groups including female headed households or migrants "allochtones".

When splitting the sample according to whether the household was above or below the median level of wealth index at baseline, we see that for RQ1.1, poor households are significantly positively affected, in that they are more likely to state they face no risk due to the PFR. The difference by wealth status is however not significant. The risk of losing a parcel if left fallow take opposite signs for poorer and wealthier households, though neither coefficient is significant and the difference is marginally outside the 10 percent level of significance, which would have indicated that the PFR benefits poorer households more positively for this indicator. With the split sample leading to smaller subgroups, even RQ1.2 is now insignificant despite being similar to the overall impact in Section 5.2. If impacts on the perception of tenure security transpire after a longer period of time, they may be more likely among the economically disadvantaged as reflected by RQ1.1 being significant only in this group.

Table 13 - RQ1 by wealth status

	ATT				
Indicator	Wealthy	Poor	Difference	Level of analysis	Method
RQ1.1: No risk of losing rights on parcel in next 5 years (1=No risk)	0.038	0.100 *	-0.062	Parcel	DRDID
Observations	2642	2214			
RQ1.1: No risk of losing part of a parcel in next 5 years (1=No risk)	-0.013	0.064	-0.077	Parcel	IPWRA
Observations	1388	1141			
RQ1.2: Only household members take resources from the parcel (1=Yes)	0.090	0.108	-0.018	Parcel	DRDID
Observations	3044	2482			
RQ1.3: No risk of losing parcel if left fallow (1=No risk)	-0.042	0.051	-0.093	Parcel	DRDID
Observations	3044	2482			
RQ1.4: Degree of satisfaction with land management in Benin (1=quite or very)	-0.015	0.002	0.017	Household	IPWRA
Observations	1363	1163			

Notes: * p < 0.1, ** p < 0.05, *** p < 0.01

For RQs 2 and 3 we include a selected set of indicators which exhibited either a significant result for the whole population, or a relatively large point estimate, despite remaining insignificant. For RQ2.1, we see that the impact on using measures to improve soil and water conservation is significant for those above but not below median wealth, though the difference in treatment effects is not significant. The fact that is it only significant for wealthy households, suggest this may be due to resource constraints faced by the households. The increase in labor inputs is significant for both sets of households and the difference is not significant.

For RQ3, we see significant impacts on the female respondent having an assigned parcel and whether the female respondent inherited land only among less wealthy households, with the difference also significant for RQ3.3 on having an assigned parcel. Conversely, we see a negative effect on male youth decision makers only among poorer households. Females seem to be more empowered by the PFR within poorer households, while the opposite is true for young men. We note that there are no significant differences in RQ3.3 at baseline in PFR villages according to wealth status, so it is not a case of catching up.

Table 14 - Selected RQ2 and RQ3 by wealth status

	ATT				
Indicator	Wealthy	Poor	Difference	Level of analysis	Method
RQ2.1: Used measures to improve soil and water conservation (1=Yes)	0.266**	0.135	-0.130	Parcel	DRDID
Observations	3130	2522			
RQ2.2: Amount invested in soil and water conservation (in 1000s of FCFA)	3.864	-0.437	-4.301	Parcel	DRDID
Observations	3130	2522			
RQ2.5: Labor inputs (person-days)	170.604 ***	143.729 *	-26.874	Parcel	DRDID
Observations	2748	2262			
RQ3.1: Only female decision maker(s) (1=Yes)	-0.008	-0.013 **	-0.005	Parcel	DRDID
Observations	3142	2540			
RQ3.3: Female respondent has assigned parcel (1=Yes)	-0.000	0.221 ***	0.221 **	Household	DRDID
Observations	2308	1884			
RQ3.5: Woman inherited land since baseline (1=Yes)	0.009	0.059 **	0.051	Household	DRDID
Observations	2308	1884			
RQ3.6: Woman expects to inherit land in future (1=Yes)	0.070	0.037	-0.033	Household	DRDID
Observations	2230	1842			
RQ3.9: Any male youth decision maker (1=Yes)	-0.001	-0.014 *	-0.013	Parcel	DRDID
Observations	3142	2540			
RQ3.10: Number of parcels managed by young men	-0.029	-0.012	0.017	Household	DRDID
Observations	2468	2122			

Notes: * p < 0.1, ** p < 0.05, *** p < 0.01

For conflicts, the impact is significant and negative for both those above and those below median wealth without being significantly different. The number of unresolved conflicts decreases significantly only for poorer households. Overall, the impacts on conflict appear similar by wealth status, with some indication that poorer households benefit more with larger coefficients (though not significant in differences) and RQ7.3 only significant for poor households.

Table 15 - RQ7 by wealth status

	ATT				
Indicator	Wealthy	Poor	Difference	Level of analysis	Method
RQ7.1: Number of new conflicts since baseline	-0.093 **	-0.126 ***	-0.034	Household	IPWRA
Observations	1405	1202			
RQ7.2: Number of new conflicts since end of PFR	0.007	0.019	0.012	Household	IPWRA
Observations	1405	1202			
RQ7.3: Number of unresolved conflicts	-0.022	-0.055 ***	-0.033	Household	IPWRA
Observations	1405	1202			
RQ7.4: Amount spent to resolve land conflicts since baseline (1000s FCFA)	-0.996	-0.279	0.722	Household	IPWRA
Observations	1405	1202			

Notes: * p < 0.1, ** p < 0.05, *** p < 0.01

5.3.4 PROSOL

Evidence of tenure security reform leading to increased investment is mixed, and complementary programs or other investments may be needed to see the full benefits of improved tenure security (Lisher & Huntington, 2021). We therefore consider the case of ProSOL, as briefly mentioned in footnote 15, which is a program focusing on soil rehabilitation in Bembéréké, Kalalé and Sinendé (but not Tchaourou). This means the program is most of interest for RQ2, and so we present the results for RQ2 in Table 16 split by the presence of ProSOL in the village for the household responding for a given parcel. We define the presence of ProSOL according to the priority villages as identified in a dataset shared in 2019.[17] This again uses IPWRA and DRDID where relevant, but is worth noting that the variables used for the estimation of propensity scores and regression adjustment are substantially different to those used in the remainder of the analysis. The selection of villages for ProSOL followed many of the same selection criteria, leading to significant collinearity between the dummy variable for ProSOL with other variables included. Therefore, to split the sample by the presence of ProSOL requires us to drop other variables from the analysis, namely major conflicts in the village, presence of transhumance corridors, presence of pastoral areas in the village, whether the parcel was rain fed at baseline, and year the parcel was obtained.

While results should be read with caution, due to potential issues in identifying a strong counterfactual with so many matching variables dropped, it is noticeable that the ATT has a larger coefficient for each variable reported below, with a significant difference for using measures to improve soil and water conservation, tree planting and even on labor inputs among villages which also benefited from ProSOL.

[17] A more recently shared list indicates which villages have been treated by ProSOL up to early 2023. According to this list, almost all sampled villages in Bembéréké, Kalalé and Sinendé have been treated to some extent, meaning that exposure to ProSOL is almost perfectly correlated with which commune a household is situated in. Since it is not possible to identify any impact or complementarity with this list, we retain the use of the original list to define those villages most intensely treated by ProSOL.

Table 16 - RQ2 by village ProSOL status

	ATT				
Indicator	ProSOL	Not ProSOL	Difference	Level of analysis	Method
RQ2.1: Used measures to improve soil and water conservation (1=Yes)	0.779 ***	0.168*	-0.610***	Parcel	DRDID
Observations	598	5214			
RQ2.2: Amount invested in soil and water conservation (in 1000s of FCFA)	5.579**	1.316	-4.263	Parcel	DRDID
Observations	598	5214			
RQ2.3: Trees planted on the parcel in last 3 years	0.349**	0.029	-0.320*	Parcel	IPWRA
Observations	293	2546			
RQ2.5: Labor inputs (person-days)	425.287 ***	117.295*	-307.992***	Parcel	DRDID
Observations	544	4606			

Notes: * p < 0.1, ** p < 0.05, *** p < 0.01
Compared to analysis of the full sample, the dummy for major conflicts, presence of transhumance corridors, presence of pastoral areas in the village, whether the parcel was rain fed at baseline are dropped from analysis due to collinearity in the subsample for ProSOL

6. CONCLUSIONS

PFR implementation took longer than anticipated and did not cover the full area within the defined village boundaries, with a small proportion of land not demarcated and some areas measured but not registered. Importantly, 40% of households in treated village reported no parcels being demarcated by the PFR, which will also affect findings.

We estimate the impacts of the PFR on treated households, employing doubly robust methods combining the use of propensity scores and regression adjustment. The use of propensity scores allows us to reduce bias and check that our samples are comparable by ensuring we have sufficient overlap in propensity scores.

As the time between treatment and endline data collection is only 2-3 years, we do not expect to find an impact on medium to long term outcomes as laid out in the theory of change. The key issue to enable further changes is to shift the perceptions of security (RQ1). It should be noted that at baseline tenure security was already high, with respondents believing there is no risk to losing rights over around 70% of parcels, with loaned and rented parcels perceived as least secure. At this stage there is little to no evidence of overall improvements in perceived tenure security, though poorer households do respond positively to the PFR in their perceptions of security.

With respect to women, one key consideration in registering land in Benin is that land is typically inherited within the wider family (or clan), and as such true ownership is not traditionally at the individual or household level. Since PFRs are able to register land on this collective level, this may be more reflective of land rights as held prior to the program implementation. However, this would preclude the possibility for females to inherit parcels of land as registered with the PFR, since large clan parcels cannot traditionally be inherited by women. The fact that our study finds fewer parcels managed only by women due to PFR implementation is in line with the fact that formalization may in

fact disadvantage women. In addition, when further subdividing by migrant status, we find weak indications that migrants "allochtones" may be made to feel less secure due to the PFR, with migrants "allochtones" having a lower probability of stating there is no risk to lose a parcel if it is left fallow, as well as a weakly significant difference on the impact on the perceived risk to losing rights over a parcel with migrants "allochtones" worse off.

Under RQ2, we find a positive impact on whether a household invested in measures to improve soil and water conservation, and additional labor, but not in the amount spent. This is true in all subgroups unlike the positive impact on labor inputs, which is significantly positive for male parcel managers, migrants "allochtones" and parcels of wealthy households. This may indicate that women and migrant households are unable to access additional labor. Migrant parcel managers not only were more likely to invest in soil and water conservation but also increased the amount spent. Other inputs requiring additional expenditure, such as fertilizer and new infrastructure, which may be influenced by issues other than tenure security were not significantly affected. We also consider complementarities between a PFR and ProSOL - a program focusing on soil rehabilitation – on impacts on investments in soil and water conservation. Although the identification strategy for causal effects is weakened by the need to drop some matching variables, the results suggest that being in a ProSOL village helped the PFR have a positive impact.

We consider the impacts of the PFR on marginalized groups under RQ3 and find there is a negative impact on whether a parcel has only female decision makers, though this is significant only among non-migrants. There is no effect on a parcel having any female decision maker, which suggests that females are more likely to jointly manage a parcel with a male after the implementation of a PFR rather than alone. With rights being registered, this may enable men to keep control of land. The only significant impact for young males is marginally significantly negative for having any young male decision maker on a parcel. For migrants "allochtones" we find no direct effects, though the subgroup analysis does suggest that migrants "allochtones" may be negatively impacted in perceptions (RQ1), despite exhibiting a larger decrease in conflicts since baseline (RQ7). Furthermore, there is a significant difference in the impact on whether a female respondent has an assigned parcel by migrant status, with migrant households more negatively affected (though neither group significantly different from zero).

Under RQ4 on land markets and RQ5 on agricultural productivity, we find no significant effects for sales and rental markets (which was already very low at baseline). In the data, there is a higher share of parcels suffering attrition between baseline and endline which were loaned. This may be that loan terms are short term by nature, or may reflect a lack of security among those parcels with the need for more secure rental agreements. This pattern of no significant impacts extends to income in RQ6, though there is a slight reduction in in the share of cash crops due to PFRs, though this drop brings PFR and control villages in line with one another having started different at baseline. Under RQ6 as anticipated, we also find no impact on food security or the demand for credit. The only significant effect for credit is a decrease in the success rate given a household has applied.

Importantly, we find a decrease in self-reported new conflicts since baseline, which is true among all subgroups. This is some senses surprising that it comes so soon after the PFR, since many conflicts were likely to need addressing during the implementation of the PFR. In addition to this, under RQ7, we also find a decrease in unresolved conflicts, though in the subgroup analysis this is only significant for men, non-migrants and poor households.

Overall, there have not been strong impacts of the PFR rooted in changes in perceptions of security, though these were high even prior to PFR implementation. In spite of little change in perceptions, we

do indeed find positive impacts on investment in water and soil conservation, labor inputs, and reduced conflict. Currently PFRs are no longer being implemented in Benin, and the future impacts of these PFRs may be reduced by the fact that the ANDF has refused to issue titles on the basis of these PFRs.

BIBLIOGRAPHY

Akowedaho, B. D., Guinin Asso, I., O'heix, B. C., Adéchian, S. A., & Baco, M. N. (2022). Access to Land for Agricultural Entrepreneurial Activities in the Context of Sustainable Food Production in Borgou, according to Land Law in Benin. *Land 2022, 11*(9), 1381. doi:https://doi.org/10.3390/land11091381

Fabbri, M. (2021). Property rights and prosocial behavior: Evidence from a land tenure reform implemented as randomized control-trial. *Journal of Economic Behavior and Organization, 188*, 552-566.

Goldstein, M., Houngbedji, K., Kondylis, F., O'Sullivan, M., & Selod, H. (2018). Formalization without certification? Experimental evidence on property rights and investment. *Journal of Development Economics, 132*, 57-74.

Guinin Asso, I., Adéchian, S. A., Salifou, M., Kouyinampou, B. M., O'heix, B. C., & Baco, M. N. (2022). Effects of the Systematic Cluster Approach (SCA) and Rural Land Plans (RLPs) on Land Tenure Security for Agricultural Household: Insight from Benin (West Africa). *Land, 11*(10), 1681. doi:https://doi.org/10.3390/land11101681

Higgins, D., Balint, T., Liversage, H., & Winters, P. (2018). Investigating the impacts of increased rural land tenure security: A systematic review of the evidence. *Journal of Rural Studies, 61*, 34-62. doi:https://doi.org/10.1016/j.jrurstud.2018.05.001

Jann, B. (2020). Influence functions continued. A framework for estimating standard errors in reweighting, matching, and regression adjustment. *University of Bern Social Sciences Working Paper, 35*.

Lavigne Delville, P. (2020). Les "Plans Fonciers Ruraux" au Bénin (1992-2015). La carrière d'un instrument "pilote" au sein de politiques non stabilisées. *Revue Internationale de Politique Comparée, 27*, 61-86.

Lisher, J. W. (2019). *Guidelines for impact evaluation of land tenure and governance interventions: Developed through a joint initiative of GLTN and IFAD.* United Nations Human Settlements Programme UN-Habitat.

Lisher, J., & Huntington, H. (2021). Reviewing the Evidence on Land: An Overview of Land Impact Evaluation Literature and Lessons Learned. *mimeo*.

Meinzen-Dick, R. (2009). Property Rights for Poverty Reduction? *DESA Working Paper, 91*.

Ministère de l'Agriculture, de l'Elevage et de la Pêche du Bénin. (2021). *Recensement national de l'agrriculture.* Cotonou.

Prindex. (2019). *Comparative report.* London. Retrieved from https://www.prindex.net/reports/prindex-comparative-report-march-2019/

Rios-Avila, F. (2020). Recentered influence functions (RIFs) in Stata: RIF regression and RIF decomposition. *Stata Journal, 20*(1), 51-94.

Rios-Avila, F., Sant'Anna, P. H., & Naqvi, A. (2021). DRDID: Stata module for the estimation of Doubly Robust Difference-in-Difference models. *Statistical Software Components, S458977*.

Sant'Anna, P. H., & Zhao, J. (2020). Doubly robust difference-in-differences estimators. *Journal of Econometrics, 219*(1), 101-122. doi:https://doi.org/10.1016/j.jeconom.2020.06.003

Wooldridge, J. M. (2007). "Inverse Probability Weighted Estimation for General Missing Data Problems. *Journal of Econometrics, 141*(2), 1281-1301.

Wooldridge, J. M. (2010). *Econometric Analysis of Cross Section and Panel Data* (2nd ed.). MIT Press.

Wren-Lewis, L., Becerra-Valbuena, L., & Houngbedji, K. (2020). Formalizing land rights can reduce forest loss: Experimental evidence from Benin. *Science Advances, 6*(26).

Yemadje, R. H., Crane, T. A., Mongbo, R. L., Saïdou, A., Azontonde, H. A., Koussou, D. K., & Kuyper, T. W. (2014). Revisiting land reform: land rights, access, and soil fertility management on the Adja Plateau in Benin. *International Journal of Agricultural Sustainability, 12*(3), 355-369.

APPENDICES

A.1 SAMPLING

Table A 1 - List of Villages

	Bembéréké	Kalalé	Sinendé	Tchaourou
Number of ProPFR vilalges	**9**	**6**	**6**	**6**
ProPFR Villages *ID#. Village name (Cluster number)*	3. Kokabo (1) 2. Kinninkou (1) 5. Saoré (1) 17. Timbouré (2) 13. Dantcha (2) 8.Bouratèbè (2) 9. Sombouan 2 (2) 11. Guera n'kali (3) 10. Boro (3)	24. Matchorè (7) 23. Maréguinta (7) 19. Boca Gando (8) 21. Kourel (8) 28. Ouénagourou (9) 25. Djèga (9)	38. Didi (4) 37. Guessou Bani (4) 37. Diadia (5) 42. Kossia (5) 34. Goro Bani (5) 31. Toumé (6)	54. Agbassa (10) 43. Oloungbe (10) 46. Koda (10) 48. Kika (11) 50. Kokobe (11) 53. Sui-Gourou (11)
Control Villages *ID#. Village name (Cluster number)*	6. Wanrarou (1) 1. Bérou (1) 4. Pédarou (1) 32. Kparo (2) [Note: In Sinendé] 7. Beroubouay Peulh (2) 15. Kpebera (2) 16. Mani Boke (2) 14.Ganro (3) 12. Sissigourou (3)	22. Derassi (7) 27. Kirikoubé (7) 29. Gando-Baka (8) 26. Dunkassa (8) 20. Gbérougbassi (9) 30. Péonga (9)	35. Wari Gando (4) 40. Gourou-Kpérou (4) 39. Gouré-Guessou (5) 33. Dombouri (5) 36. Bouro (5) 18. Konou (6) [Note: In Bembéréké]	45. Alafiarou (10) 44. Agramarou (10) 47. Koko (10) 51. Kpari (11) 52. Kpassa (11) 49. Kika II/Kika Barrage (11)

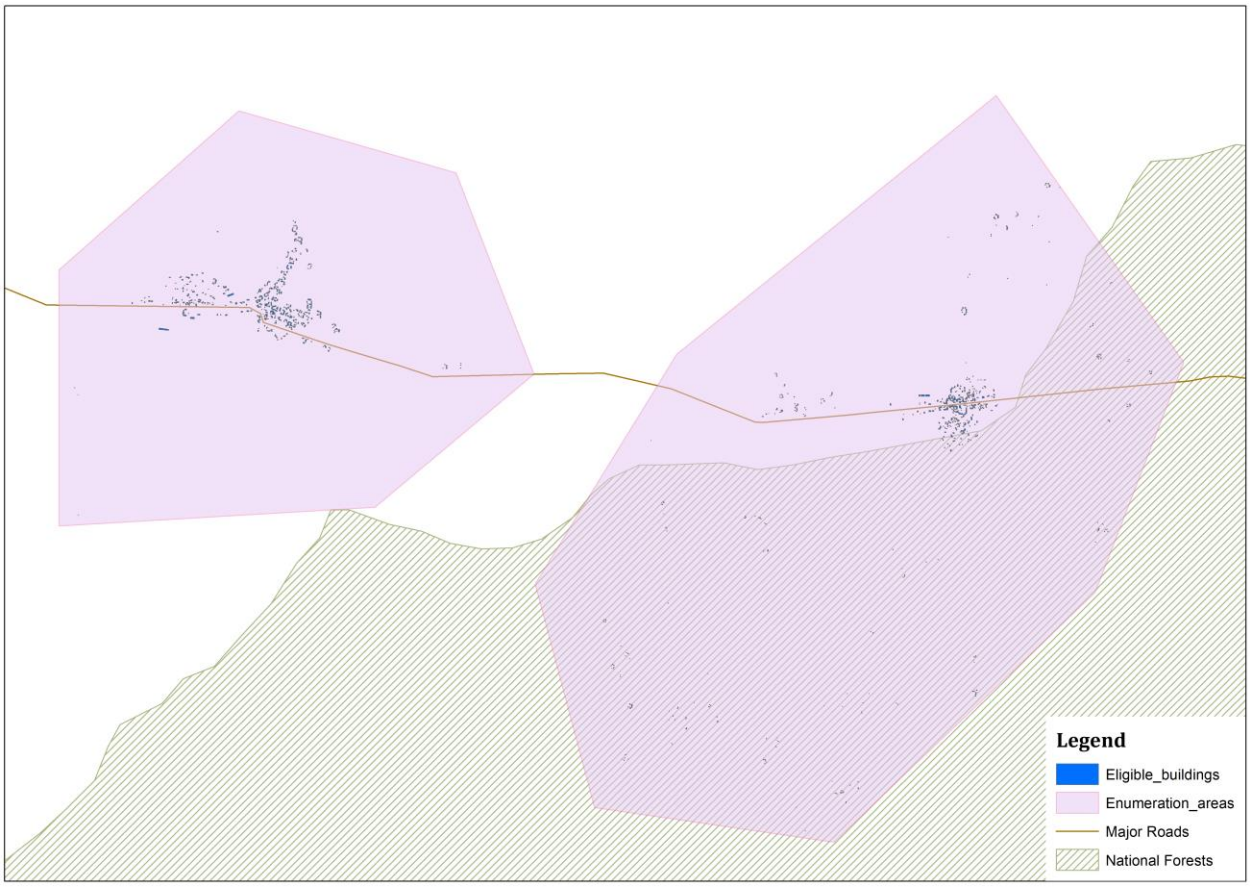
Table A 2 - Village Selection Balance

		(1) Control		(2) Treatment	t-test (1)-(2)
Variable	N	Mean/SE	N	Mean/SE	Difference
Buildings in village	27	398.593	26	434.885	-36.292
		[42.881]		[40.912]	
Distance to forest	27	4865.986	26	6594.297	-1728.311
		[940.594]		[1308.746]	
Forest within 5km	27	0.481	26	0.462	0.020
		[0.098]		[0.100]	
On main road	27	0.667	26	0.500	0.167
		[0.092]		[0.100]	

The value displayed for t-tests are the differences in the means across the groups.
***, **, and * indicate significance at the 1, 5, and 10 percent critical level.

Note: Agbassa/Oloungbé are treated as one village with the number of buildings in the total area divided by two

Figure A 1 - Enumeration Areas Example



A.2 VILLAGE MAPS

Figure A 2 - Map of Bembéréké

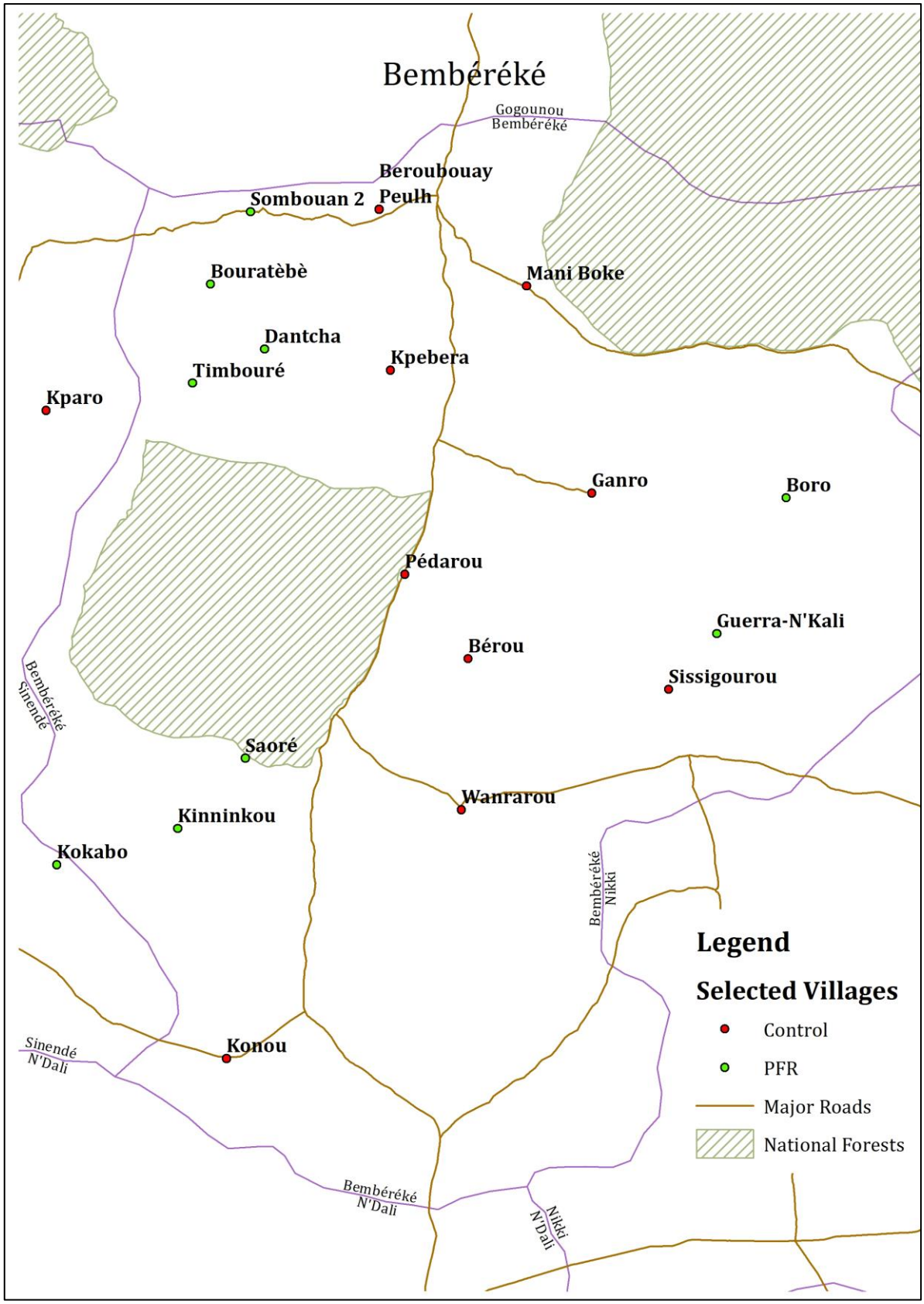


Figure A 3 - Map of Kalalé

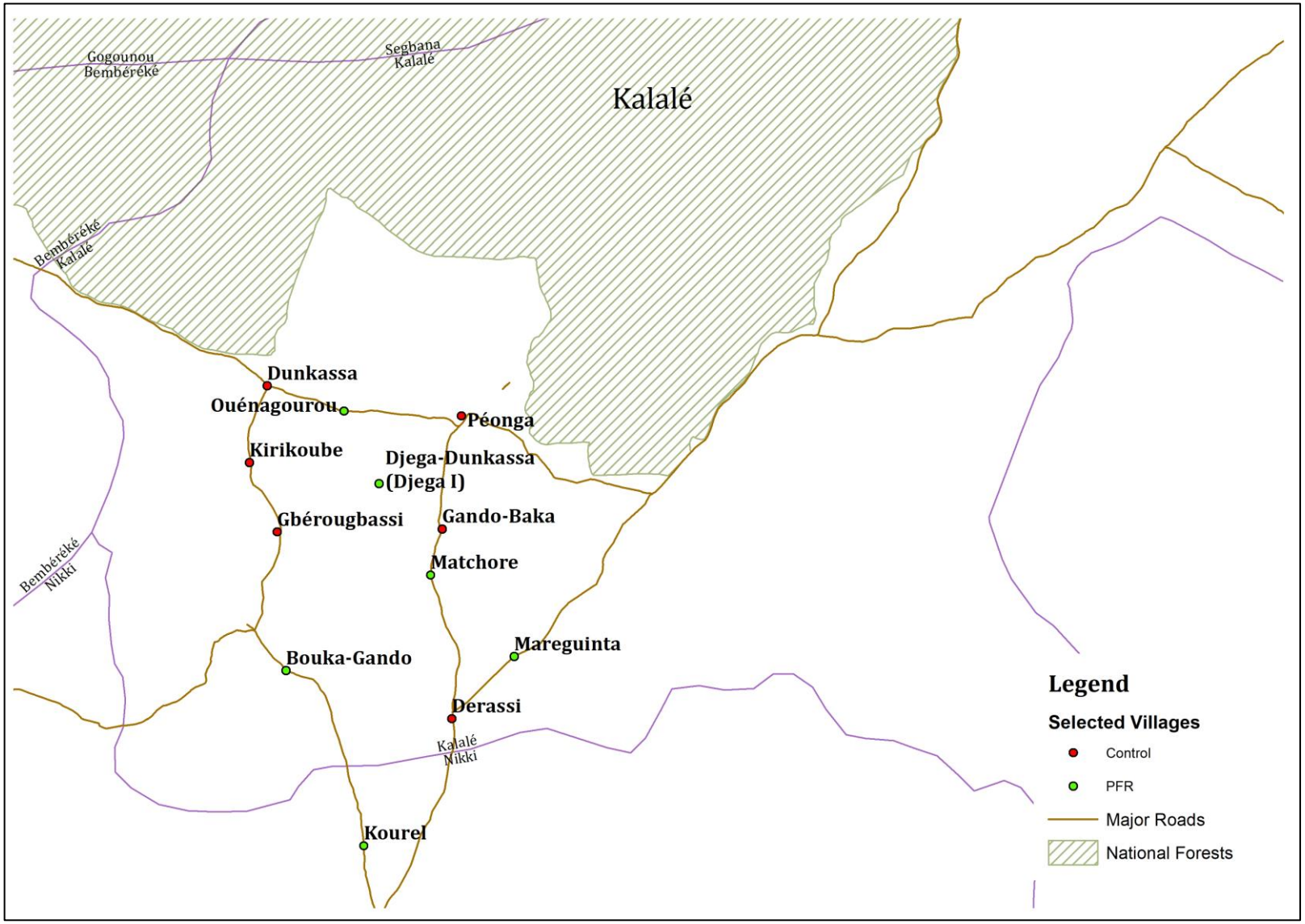


Figure A 4 - Map of Sinendé

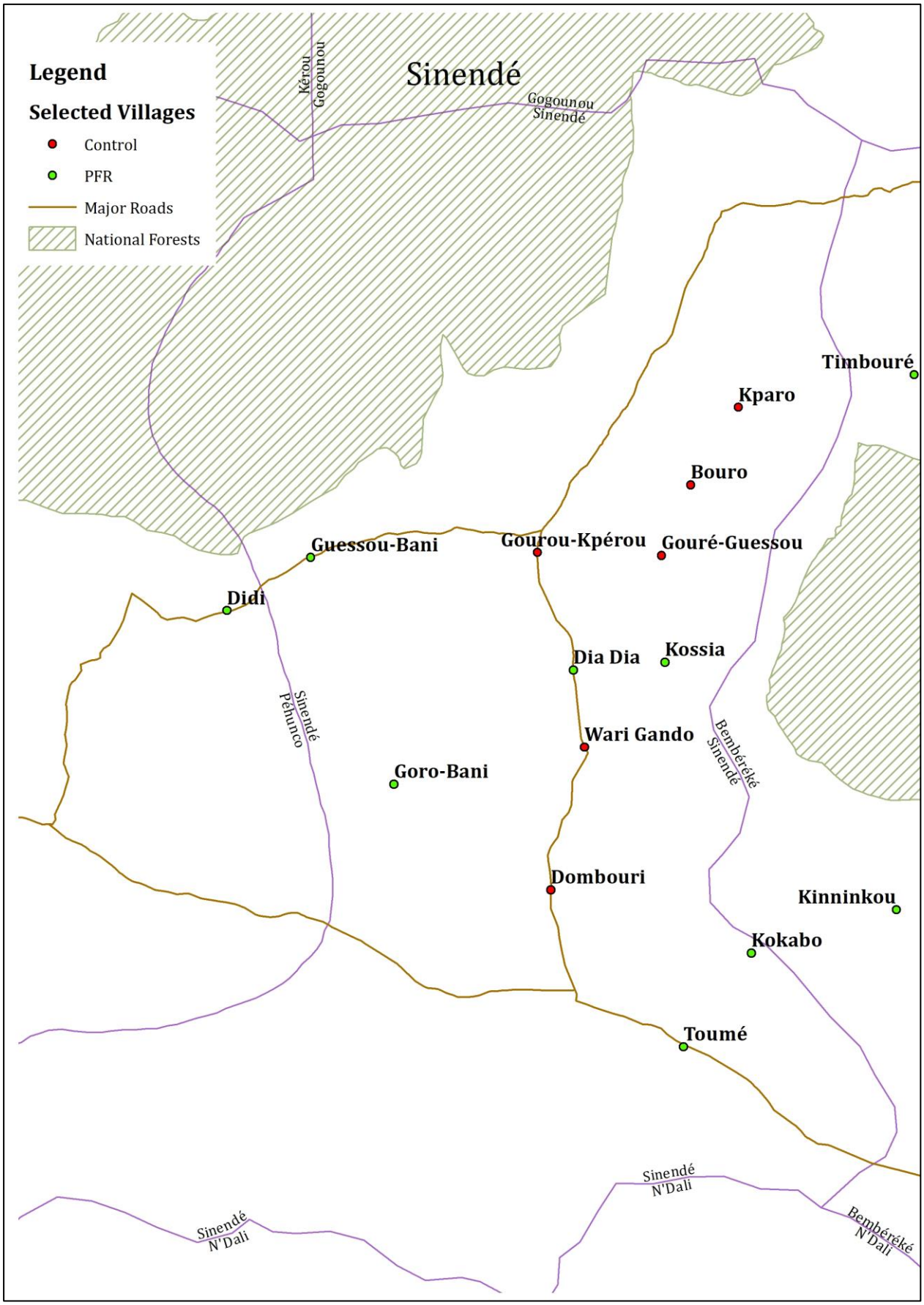
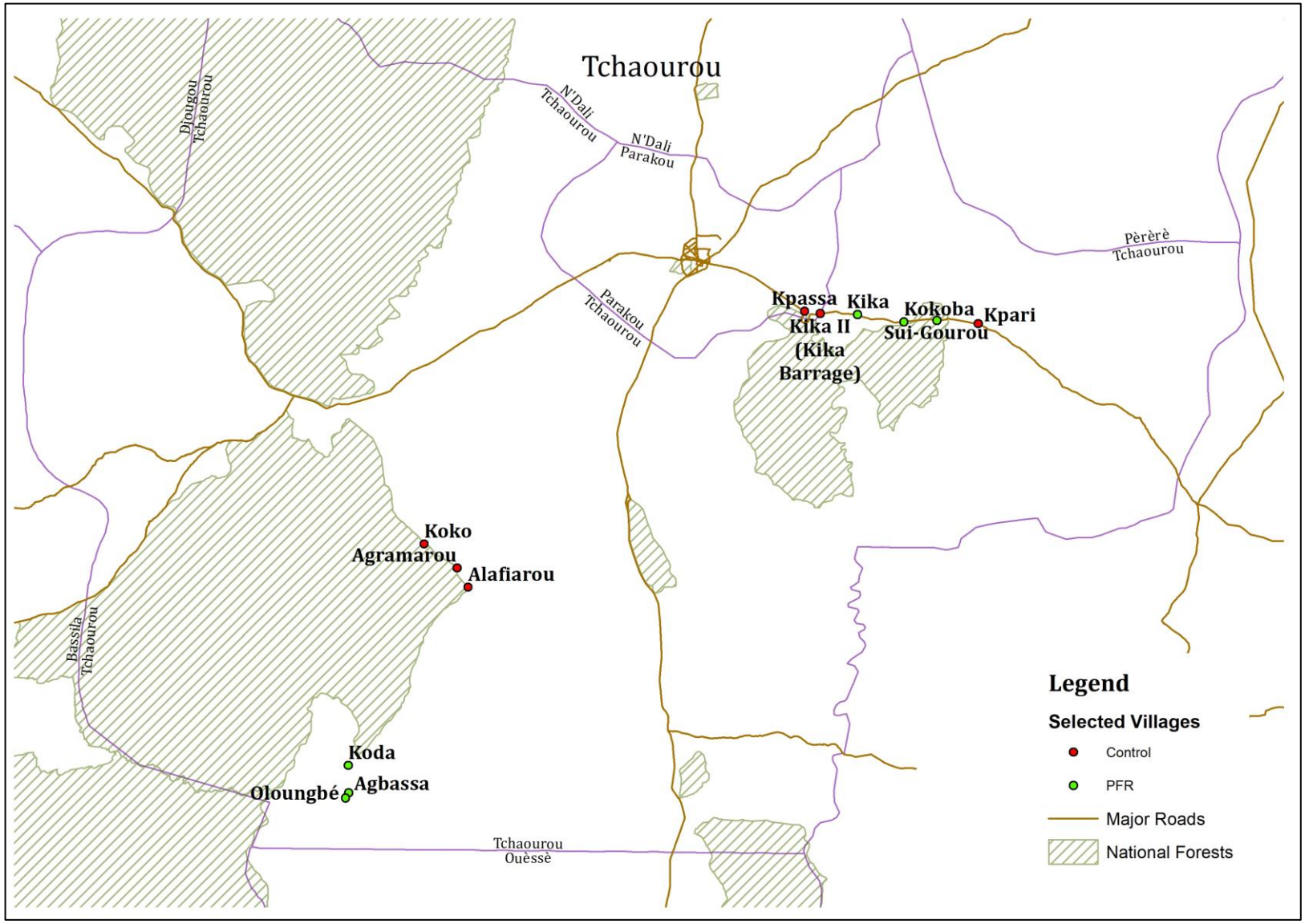


Figure A 5 - Map of Tchaourou



A.3 FURTHER DESCRIPTIVES

Table A 3 - Sociodemographic characteristics of household heads

	Treatment status			
	Non-PFR village		PFR village	
	Year		Year	
	Baseline	Endline	Baseline	Endline
Number of obs.	1,344	1,345	1,263	1,263
Age	45.01	47.02	44.11	46.12
SD	(15.93)	(14.74)	(14.70)	(13.67)
Number of HH members	6.28	7.25	6.37	7.37
SD	(4.11)	(4.66)	(3.92)	(4.50)
HH head illiterate	76.13%	69.14%	76.16%	72.61%
HH head Christian	20.65%	20.66%	23.95%	26.23%
HH head Muslim	74.26%	75.71%	71.65%	71.12%
Ethnicity				
Bariba and related	36.12%	36.63%	30.03%	29.86%
Peulh and related	48.11%	47.53%	47.12%	47.29%
Yoruba and related	6.41%	6.46%	12.20%	12.22%
Other	9.36%	9.38%	10.65%	10.63%
Place of origin				
From this village	81.07%	81.88%	79.70%	80.34%
From another village from the same commune	4.41%	4.09%	2.97%	2.67%
From another village from another commune	2.59%	2.33%	3.84%	4.06%
From another village, not from Borgou	9.48%	9.27%	9.38%	8.85%
From abroad	2.46%	2.42%	4.11%	4.08%

Note. This table displays the weighted means and standard deviations in parentheses for continuous variables, the weighted mean expressed as a percentage for binary variables, the weighted percentage breakdowns of categorical variables, and the number of observations for four groups defined by treatment status and year of survey.

Table A 4 - Parcel level conflict descriptives

	Treatment status		
	Non-PFR village	PFR village	Total
Any conflict on parcel since 2018?			
Mean	0.13	0.07	0.10
Type of last conflict			
Number of nonmissing values	295	145	440
Boundary dispute/encroachment	33.22%	49.66%	38.64%
Quarrel between farmers and herders	48.47%	31.72%	42.95%
Boundaries with state properties	1.36%	1.38%	1.36%
Contested inheritance	10.51%	6.90%	9.32%
Fraudulous sale	0.68%	0.69%	0.68%
Other property rights dispute	5.76%	9.66%	7.05%

Table A 5 - Parcel resources taken by treatment status

	Treatment status		
	Non-PFR village	PFR village	Total
Take any resources from parcel			
Unweighted frequency	1,421	1,294	2,715
Weighted percent	63.39%	59.33%	61.30%
Product taken (given any resource taken)			
Product: shea nut	56.50%	42.94%	49.76%
Product: Cashew nuts/fruit	22.03%	19.67%	20.85%
Product: Néré fruit	16.78%	17.27%	17.03%
Product: Baobab fruit	4.65%	3.95%	4.30%
Product: Other fruit	17.53%	24.50%	20.99%
Product: Firewood	62.98%	67.31%	65.14%
Product: Leaves and roots	52.08%	52.75%	52.41%
Product: Water	7.13%	12.06%	9.58%
Product: Fodder	12.35%	16.76%	14.55%
Product: Other	0.00%	0.11%	0.05%

The frequency shows the unweighted number of parcels with the respondent reporting that any resource was taken from the parcel, while the weighted percent takes sampling weights into account. For the products taken, the share of parcels is weighted.

A.4 MATCHING

Table A 6 - Marginal effects of logit regression for household sample and parcel sample

	household		parcel	
Female HH head	-0.037		-0.278	***
	(0.034)		(0.063)	
Age HH head	0.007	**	0.011	***
	(0.004)		(0.004)	
Age^2 HH head	0.000	**	0.000	***
	(0.000)		(0.000)	
Migrant HH head	0.046		0.097	***
	(0.031)		(0.033)	
Total agricultural area owned (ha)	0.001			
	(0.001)			
Total non-agri area owned (ha)	0.001			
	(0.010)			
Proximity to forest	0.124	***	0.097	***
	(0.020)		(0.019)	
Major conflicts in village	0.114	***	0.239	***
	(0.032)		(0.029)	
Transhumance corridor in village	-0.258	***	-0.232	***
	(0.043)		(0.040)	
Pastoral area in village	-0.173	***	-0.140	***
	(0.045)		(0.040)	
No. agri plots		-0.033		***
			(0.007)	
Parcel size (ha)		0.004		**
			(0.002)	
Year parcel obtained		0.003		***
			(0.001)	
Parcel manager female		0.178	***	
			(0.049)	
Parcel owned		0.038		*
			(0.021)	
Parcel located inside village boundary	-0.045			
			(0.070)	
Parcel rain fed		0.136		***
			(0.025)	
Number of observations	2607		2841	

*** p<.01, ** p<.05, * p<.1
z-statistic in parentheses

Figure A 6 - Common support for households

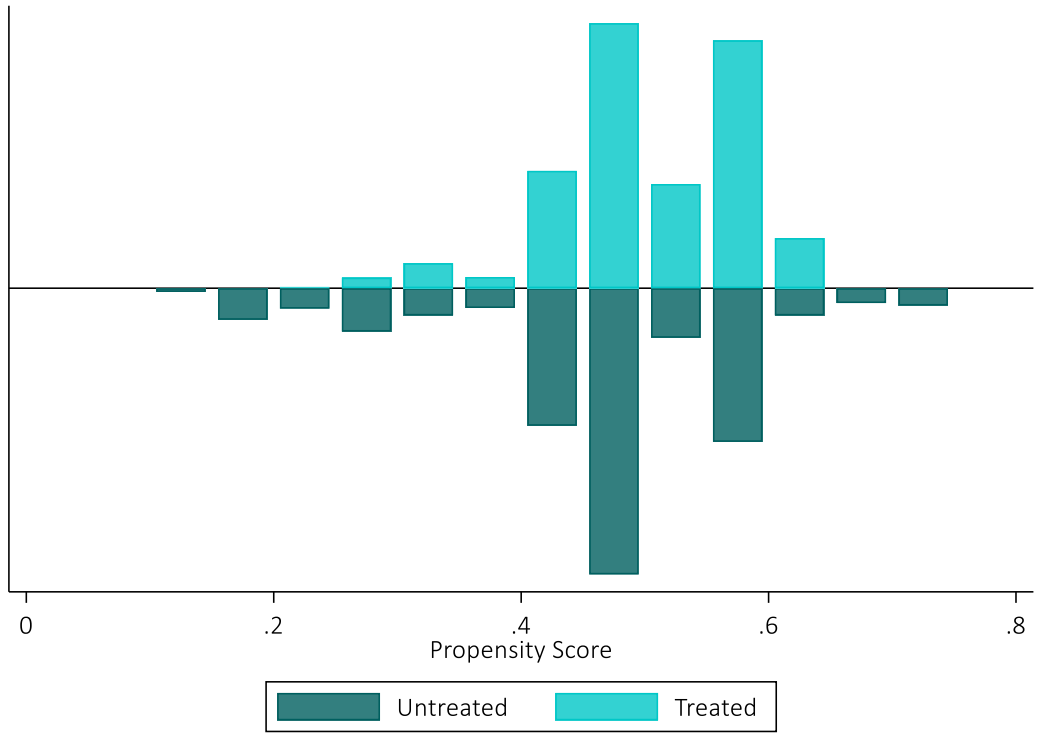


Figure A 7 - Common support for parcels

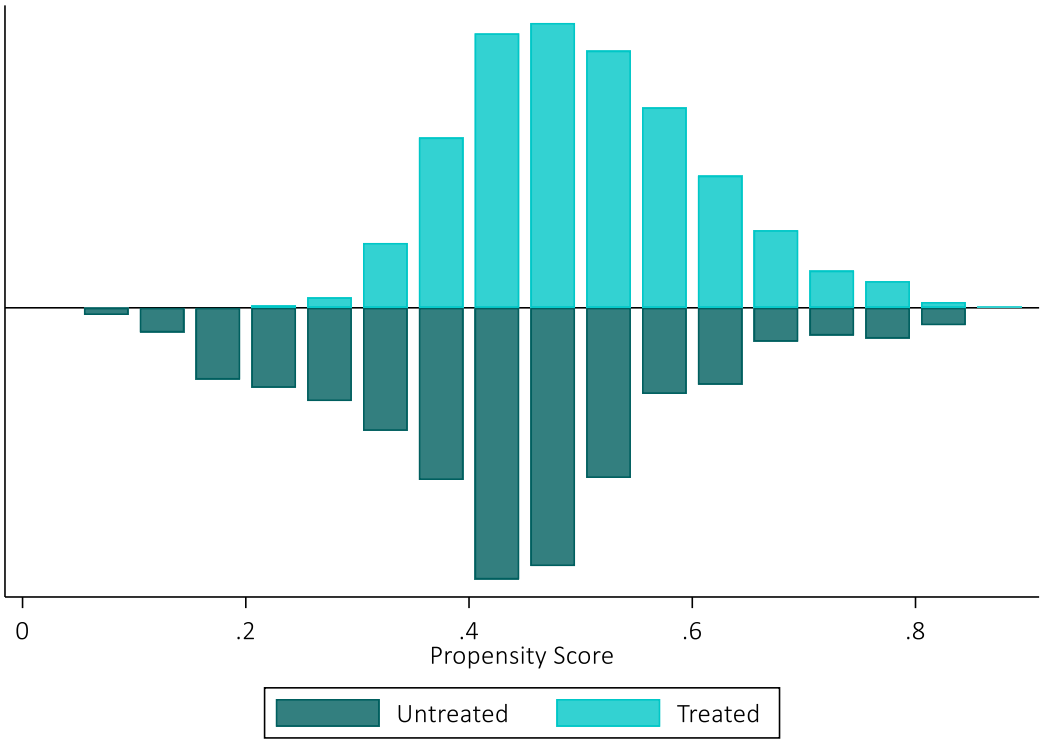
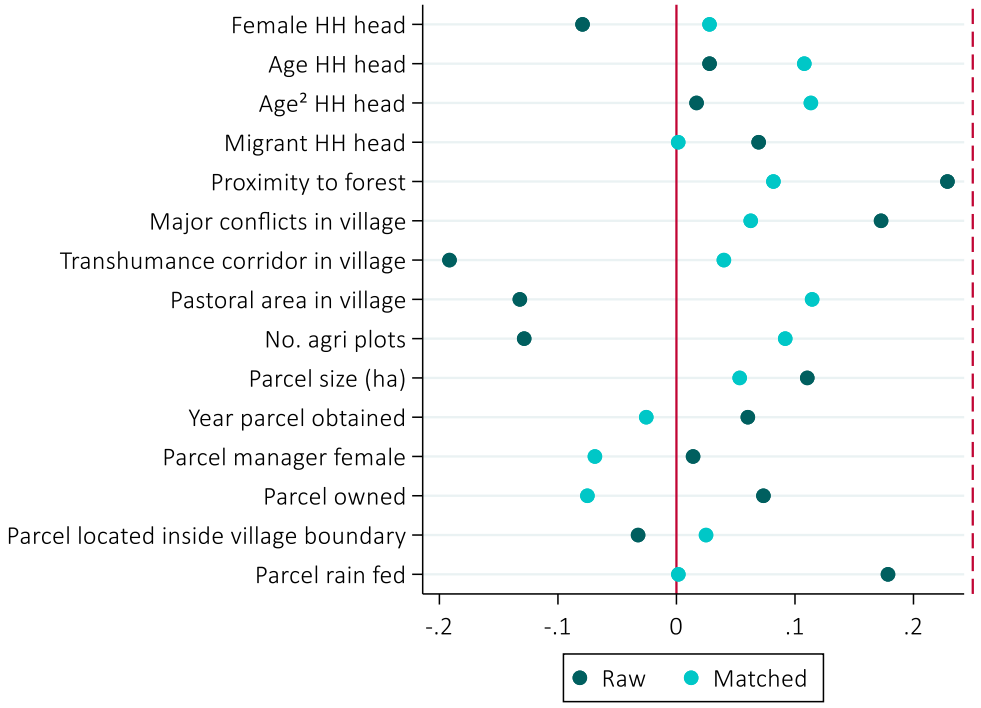
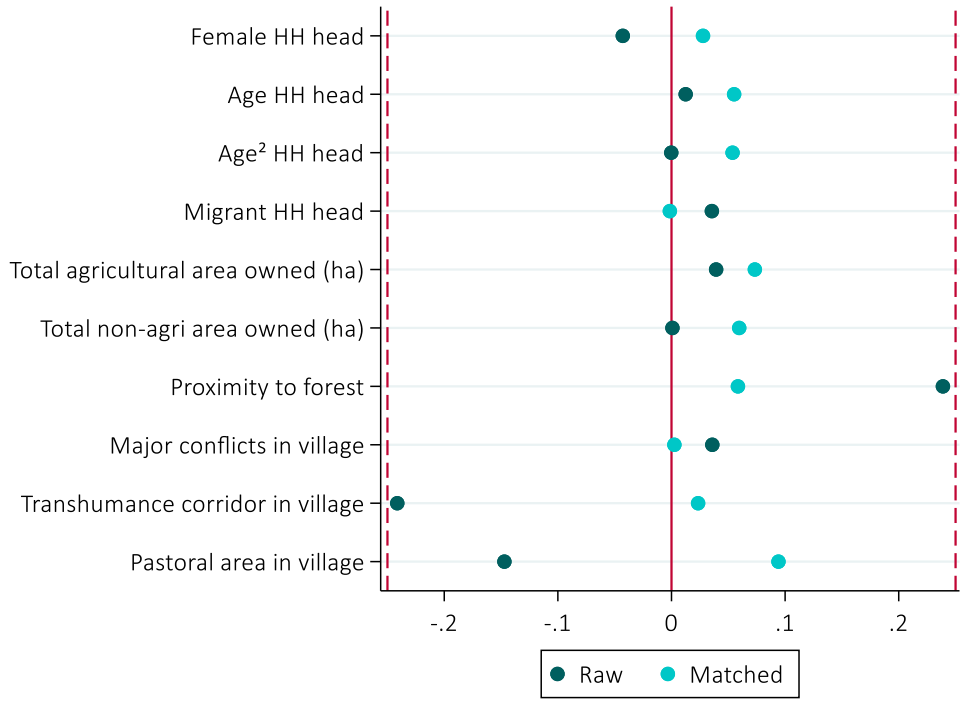


Figure A 8 - Bias reduction for households



Note: this bias is based on the propensity score weighting from IPWRA, though the specification for DRDID is the same for matching.

Figure A 9 - Bias reduction for parcels



Note: this bias is based on the propensity score weighting from IPWRA, though the specification for DRDID is the same for matching.

A.5 FURTHER DIRECT IMPACTS

Table A 7 - RQ2: Investment and Land Management

Indicator	Reference mean [std dev] / (std error)	ATT	% change	Level of analysis	Method
RQ2.1: Used measures to improve soil and water conservation (1=Yes)	0.406	0.183 **	45.07%	Parcel	DRDID
n=5524	[0.491]	(0.082)			
RQ2.2: Amount invested in soil and water conservation (in 1000s of FCFA)	3.997	4.344	108.68%	Parcel	DRDID
n=5294	[23.386]	(2.954)			
RQ2.3: Trees planted in the last year or 3 years	0.284	0.053	18.66%	Parcel	IPWRA
n=2762	(0.037)	(0.062)			
RQ2.4a: Expenditure on fertilizer (1000s of FCFA)	131.91	11.087	8.40%	Parcel	DRDID
n=2402	[147.171]	(13.788)			
RQ2.4b: Expenditure on pesticides (1000s of FCFA)	60.4	11.319	18.74%	Parcel	DRDID
n=3002	[91.801]	(9.742)			
RQ2.5: Labor inputs (person-days)	398.437	166.202 **	41.71%	Parcel	DRDID
n=5010	[506.325]	(66.116)			
RQ2.6: Used improved seeds (1=Yes)	0.034	-0.021	-61.76%	Parcel	DRDID
n=5138	[0.180]	(0.016)			
RQ2.7: Used organic fertilizer (1=Yes)	0.058	0.040	68.97%	Parcel	DRDID
n=5080	[0.234]	(0.030)			
RQ2.8: Used inorganic fertilizer (1=Yes)	0.605	-0.002	-0.33%	Parcel	DRDID
n=5080	[0.489]	(0.038)			
RQ2.9: Used pesticides (1=Yes)	0.74	-0.092	-12.43%	Parcel	DRDID
n=5080	[0.439]	(0.060)			
RQ2.10b: Parcel ever left fallow (1=Yes)	0.093	0.022	23.66%	Parcel	DRDID
n=5524	[0.290]	(0.020)			
RQ2.11: Infrastructure present on the parcel (1=Yes)	0.195	-0.009	-4.62%	Parcel	DRDID
n=5524	[0.396]	(0.044)			
RQ2.12: Improvements to infrastructure in the past 12 months (1=Yes)	0.129	-0.027	-20.93%	Parcel	DRDID
n=444	[0.335]	(0.105)			
RQ2.13: Investment into water supply in the past 12 months (1=Yes)	0.019	0.012	63.16%	Parcel	DRDID
n=5524	[0.137]	(0.012)			
RQ2.14a: Net sown area (ha) (log)	1.012	0.040	4.00%	Parcel	DRDID
n=5082	[1.017]	(0.051)			
RQ2.14b: Gross cropped area (ha) (log)	0.986	0.005	0.50%	Parcel	IPWRA
n=2541	(0.081)	(0.063)			

Notes: std. errors in parentheses; * p < 0.1, ** p < 0.05, *** p < 0.01
Reference mean refers to baseline mean for the treatment group under DRDID and the POmean for IPWRA

Table A 8 - RQ3: Land Rights of Women

Indicator	Reference mean [std dev] / (std error)	ATT	% change	Level of analysis	Method
RQ3.1: Any female decision maker (1=Yes)	0.075	-0.005	-6.67%	Parcel	DRDID
n=5682	[0.264]	(0.010)			
RQ3.1: Only female decision maker(s) (1=Yes)	0.046	-0.010 *	-21.74%	Parcel	DRDID
n=5682	[0.209]	(0.005)			
RQ3.2: Number of parcels managed by women	0.117	-0.006	-5.13%	Household	DRDID
n=4590	[0.378]	(0.016)			
RQ3.2: Number of parcels managed only by women	0.076	-0.005	-6.58%	Household	DRDID
n=4590	[0.305]	(0.013)			
RQ3.3: Female respondent has assigned parcel (1=Yes)	0.365	0.087	23.84%	Household	DRDID
n=4192	[0.482]	(0.065)			
RQ3.4: Woman can decide which parcel assigned (1=Yes)	0.501	-0.023	-4.59%	Household	DRDID
n=680	[0.500]	(0.126)			
RQ3.5: Woman inherited land since baseline (1=Yes)	0.085	0.035 *	41.18%	Household	DRDID
n=4192	[0.279]	(0.021)			
RQ3.6: Woman expects to inherit land in future (1=Yes)	0.097	0.052	53.61%	Household	DRDID
n=4072	[0.297]	(0.055)			
RQ3.7: Married woman is allowed to buy land (1=Yes)	0.69	-0.027	-3.91%	Household	DRDID
n=4192	[0.462]	(0.085)			
RQ3.8: Married woman is allowed to register purchased land in her name (1=Yes)	0.871	-0.060	-6.89%	Household	DRDID
n=2200	[0.336]	(0.045)			

Notes: std. errors in parentheses are clustered at the village level; * p < 0.1, ** p < 0.05, *** p < 0.01

Reference mean refers to baseline mean for the treatment group under DRDID and the POmean for IPWRA

Table A 9 - RQ3: Land Rights of Young Men

Indicator	Reference mean [std dev] / (std error)	ATT	% change	Level of analysis	Method
RQ3.9: Any male youth decision maker (1=Yes)	0.013	-0.010 *	-76.92%	Parcel	DRDID
n=5682	[0.114]	(0.006)			
RQ3.10: Number of parcels managed by young men	0.022	-0.030	-136.36%	Household	DRDID
n=4590	[0.191]	(0.022)			
RQ3.11: Young man respondent has assigned parcel (1=Yes)	0.368	0.002	0.54%	Household	DRDID
n=664	[0.483]	(0.064)			
RQ3.12: Young man can decide which parcel assigned (1=Yes)	0.525	-0.024	-4.57%	Household	DRDID
n=92	[0.501]	(0.197)			
RQ3.13: Young man inherited land (1=Yes)	0.202	0.052	25.74%	Household	DRDID
n=664	[0.402]	(0.106)			
RQ3.14: Young man expects to inherit land in future (1=Yes)	0.719	0.112	15.58%	Household	DRDID
n=610	[0.450]	(0.079)			
RQ3.15: Young man is allowed to buy land (1=Yes)	0.886	0.060	6.77%	Household	DRDID
n=664	[0.318]	(0.066)			
RQ3.16: Young man is allowed to register purchased land in his name (1=Yes)	0.998	0.008	0.80%	Household	DRDID
n=536	[0.041]	(0.021)			

Notes: std. errors in parentheses are clustered at the village level; * p < 0.1, ** p < 0.05, *** p < 0.01

Reference mean refers to baseline mean for the treatment group under DRDID and the POmean for IPWRA

Table A 10 - RQ4: Land Markets

Indicator	Reference mean [std dev] / (std error)	ATT	% change	Level of analysis	Method
RQ4.1: Number of parcels sold since baseline	0.001	0.000	0.00%	Household	IPWRA
n=2607	(0.001)	(0.001)			
RQ4.1: Number of parcels ever sold	0.005	0.000	0.00%	Household	DRDID
n=5214	[0.079]	(0.001)			
RQ4.2: Number of parcels bought since baseline	0.009	0.001	11.11%	Household	IPWRA
n=2518	(0.003)	(0.005)			

RQ4.2: Number of parcels currently owned that were bought	0.007	0.002	28.57%	Household	DRDID
n=4632	[0.094]	(0.005)			
RQ4.3: Number of parcels rented or borrowed in since baseline	0.038	0.002	5.26%	Household	IPWRA
n=2518	(0.011)	(0.013)			
RQ4.4: Number of parcels rented or lent out since baseline	0.047	0.001	2.13%	Household	IPWRA
n=2518	(0.010)	(0.016)			

Notes: std. errors in parentheses are clustered at the village level; * p < 0.1, ** p < 0.05, *** p < 0.01

Reference mean refers to baseline mean for the treatment group under DRDID and the POmean for IPWRA

Table A 11 - RQ5: Agricultural Productivity

Indicator	Reference mean [std dev] / (std error)	ATT	% change	Level of analysis	Method
RQ5.1: Total harvest of maize (in 100 kg)	25.307	3.446	13.62%	Parcel	DRDID
n=5128	[54.879]	(2.817)			
RQ5.1: Total harvest of cotton (in 100 kg)	10.184	-1.377	-13.52%	Parcel	DRDID
n=5114	[26.332]	(1.755)			
RQ5.1: Total harvest of soy (in 100 kg)	3.376	0.712	21.09%	Parcel	DRDID
n=5092	[11.730]	(1.807)			
RQ5.1: Total harvest of sorghum (in 100 kg)	2.715	0.239	8.80%	Parcel	DRDID
n=5098	[8.924]	(0.603)			
RQ5.2: Maize yield (kg/ha) (in log)	7.06	0.048	4.80%	Parcel	IPWRA
n=1554	(0.063)	(0.069)			
RQ5.2: Cotton yield (kg/ha) (in log)	7.124	-0.040	-4.00%	Parcel	IPWRA
n=825	(0.043)	(0.061)			
RQ5.2: Soy yield (kg/ha) (in log)	6.813	0.063	6.30%	Parcel	IPWRA
n=1150	(0.056)	(0.083)			
RQ5.2: Sorghum yield (kg/ha) (in log)	6.691	-0.040	-4.00%	Parcel	IPWRA
n=372	(0.074)	(0.075)			
RQ5.3. Value of crop per ha (log)	5.552	0.014	1.40%	Parcel	IPWRA
n=2172	(0.049)	(0.058)			
RQ5.4: Share of value of crop that was lost	0.886	-0.335	-37.81%	Parcel	DRDID
n=4362	[6.194]	(0.438)			

Notes: std. errors in parentheses; * p < 0.1, ** p < 0.05, *** p < 0.01

Reference mean refers to baseline mean for the treatment group under DRDID and the POmean for IPWRA

The IPWRA regressions include baseline outcome measurements, whose definition differed at endline, as covariate. Regressions of yields and value of crop per ha also control for the gross crop area (in log), the distance to the parcel (in log), type of soil and elevation.

Table A 12 - RQ6: Income

Indicator	Reference mean [std dev] / (std error)	ATT	% change	Level of analysis	Method
RQ6.4: Total annual income from wages and self-employment (in 1000s of FCFA)	1144.096	-4.677	-0.41%	Household	DRDID
n=4166	[1145.864]	(137.318)			
RQ6.5: Crop diversification index (Gini Simpson)	0.501	-0.007	-1.40%	Household	DRDID
n=4372	[0.267]	(0.036)			
RQ6.6: Share of cash crops in sales of crops	0.322	-0.097 *	-30.12%	Household	DRDID
n=3752	[0.357]	(0.049)			
RQ6.7: Share of income from non-agricultural wage & self-employment	0.124	0.008	6.45%	Household	DRDID
n=4166	[0.208]	(0.018)			

Notes: std. errors in parentheses are clustered at the village level; * p < 0.1, ** p < 0.05, *** p < 0.01

Reference mean refers to baseline mean for the treatment group under DRDID and the POmean for IPWRA

Table A 13 - RQ6: Access to Credit

Indicator	Reference mean [std dev] / (std error)	ATT	% change	Level of analysis	Method
RQ6.1: Requested a loan since baseline (1=Yes)	0.227	0.013	5.73%	Household	IPWRA
n=2606	(0.031)	(0.047)			
RQ6.1: Ever requested a loan (1=Yes)	0.245	-0.004	-1.63%	Household	DRDID
n=5212	[0.430]	(0.032)			
RQ6.2: Obtained a loan since baseline (1=Yes)	0.985	-0.042 *	-4.26%	Household	IPWRA
n=707	(0.007)	(0.022)			
RQ6.2: Ever obtained a loan since baseline (1=Yes)	0.993	0.002	0.20%	Household	DRDID
n=594	[0.082]	(0.009)			
RQ6.3: Land document required for loan application (1=Yes)	0.547	-0.005	-0.91%	Household	IPWRA
n=707	(0.048)	(0.066)			

Notes: std. errors in parentheses are clustered at the village level; * p < 0.1, ** p < 0.05, *** p < 0.01

Reference mean refers to baseline mean for the treatment group under DRDID and the POmean for IPWRA

Table A 14 - RQ6: Food Security

Indicator	Reference mean [std dev] / (std error)	ATT	% change	Level of analysis	Method
RQ6.8: Has experienced food shortage in last 12 months (1=Yes)	0.122	-0.005	-4.10%	Household	DRDID
n=5214	[0.327]	(0.041)			
RQ6.9: Has been worried about food shortage in last 7 days (1=Yes)	0.11	0.006	5.45%	Household	DRDID
n=5214	[0.313]	(0.036)			
RQ6.10: Reduced coping strategy index (max. 56, higher is less secure)	1.642	0.701	42.69%	Household	DRDID
n=5208	[4.700]	(0.484)			
RQ6.11: Average number of meals per day for adults	2.894	0.053	1.83%	Household	IPWRA
n=2586	(0.017)	(0.032)			
RQ6.12: Average number of meals per day for children	4.102	0.151	3.68%	Household	IPWRA
n=1610	(0.083)	(0.130)			

Notes: std. errors in parentheses are clustered at the village level; * p < 0.1, ** p < 0.05, *** p < 0.01

Reference mean refers to baseline mean for the treatment group under DRDID and the POmean for IPWRA

A.6 METHOLOGICAL NOTES

In this section we provide a more detailed description of the estimation strategy used to identify causal effects of the program as average treatment effects on the treated (ATT), following the notation in Jann (2020). Recall the ATT tells us the difference between the expected value of an outcome of a treated unit, given it is treated ($D = 1$), against the theoretical counterfactual expected value the same treated units would experience if they didn't get treated (Y^0 is the outcome without treatment). Note we cannot observe the true counterfactual for an observation i, y_i^0 if it has been treated and so we need to credibly impute it.

$$ATT = E(Y^1 - Y^0|D = 1) = E(Y^1|D = 1) - E(Y^0|D = 1) = \eta_1^1 - \eta_1^0 \quad (1)$$

To estimate the ATT, we need to calculate η_1^1, which is the observed outcome mean among the treated and to estimate η_1^0, which is the potential outcome mean among treated had they not been treated. We begin by presenting how the ATT may be estimated through the use of inverse probability weighted regression adjustment (IPWRA) for cross-sectional data as in Wooldridge (2010) and extend this to panel data using difference in differences as in Sant'Anna and Zhao (2020).

INVERSE PROBABILITY WEIGHTED REGRESSION ADJUSTMENT

IPWRA makes use of the conditional independence assumption, $(Y^1, Y^0) \perp\!\!\!\perp D|X$ where X is a vector of covariates. The first step of IPWRA is to estimate the probability of treatment $\Pr(D_i = 1 \mid \boldsymbol{x_i})$ for each observation (known as the propensity score), where treatment status D is indicated by 0 or 1. The propensity score $\hat{p}(\boldsymbol{x_i})$ may be estimated using a logit or probit model, including variables $\boldsymbol{x_i}$ which are correlated with both the treatment status and the outcomes of interest. Estimating with a logistic regression gives us the propensity score as follows for $1 \times k$ vector of predictors.

$$\widehat{p_i} = \frac{\exp(x_i\hat{\beta})}{1 + \exp(x_i\hat{\beta})} \quad (2)$$

These propensity scores are then used to weight the regression adjustment models using the inverse of the propensity score among untreated units to estimate η_1^0, and giving zero weight to treated units, since d_i would equal 1.

$$\widehat{\omega_i^0} = (1 - d_i)\frac{\widehat{p_i}}{1 - \widehat{p_i}} \quad (3)$$

These weights can be used in the regression adjustment equation of Y on Z, including covariates z_i to obtain coefficients $\widehat{\gamma_0}$. This together allows us to estimate the potential outcome mean for the control group as follows.

$$\hat{\eta}_1^0 = \frac{1}{\sum_i d_i} \sum_i d_i (y_i - z_i \hat{\gamma}_0)$$

(4)

We can calculate the outcome mean among treated units as follows. The covariates z in our case mostly overlap with those in x, with additional variables included in some cases.

$$\hat{\eta}_1^1 = \frac{1}{\sum_i d_i} \sum_i d_i y_i$$

(5)

To obtain the ATT, we can then take the difference as shown in equation (1). We use IPWRA to estimate the ATT where the outcome of interest is only available at endline. Nonetheless, we use variables from baseline as controls in X and Z. This method gives us two attempts to control for differences between the treatment and control groups, meaning only one of the two estimating equations needs to be correctly specified, giving us a doubly robust approach.

DOUBLY ROBUST DIFFERENCE IN DIFFERENCES

Under a DiD setup we make use of outcome data from two time periods, before treatment at baseline and after the program has been implemented at endline. This allows us to take any differences observed at baseline into account. This requires additional notation, since our data now has two time periods, so time period t is equal to 0 at baseline and 1 at endline for an outcome for individual i in y_{it}.

For a given individual i, we may consider their measured outcome at $t = 0$ to be equal to a random draw u_i. Over time his observed outcome may change, with this change denoted τ_i. Therefore, an untreated unit at endline will have $y_{i1}^0 = u_i + \tau_i$. If that individual had been treated between baseline and endline, then a potentially heterogeneous treatment effect $\theta_i$may take effect, leading to $y_{i1}^1 = u_i + \tau_i + \theta_i = y_{i1}^0 + \theta_i$, while at baseline this unit would observe $y_{i0}^1 = y_{i0}^0 = u_i$ since treatment has not yet taken place.

In an ideal world, in which we could observe the outcome for the same individual with and without treatment, we would know the individual treatment effect $y_{i1}^1 - y_{i1}^0 = \theta_i$. This is not possible to observe.

Under DiD we combine taking a difference over time, $D1 = y_{i1}^1 - y_{i0}^1 = \tau_i + \theta_i$, which includes the treatment effect and the time trend τ. We could also consider a difference over individuals D2 at endline between individuals i and j, $D2 = y_{i1}^1 - y_{j1}^0 = u_i + \tau_i + \theta_i - (u_j + \tau_j)$. In order to obtain the treatment effect then the difference over time would have to be equal, i.e. $\tau_i = \tau_j$, and the outcomes would have to be the same before treatment[18], i.e. $u_i = u_j$. The latter assumption would be possible under a randomized design, but is a strong assumption to make in our data. By combining both approaches, we can take a difference in these two differences to obtain the following.

$$DD = \left(y_{i1}^1 - y_{i0}^1\right) - \left(y_{j1}^0 - y_{j0}^0\right) = \tau_i + \theta_i - \tau_j$$

[18] It is in this aspect that DiD provides gains over the use of IPWRA, which aims to ensure that the expected values of u are equal conditional on the propensity scores and the control variables.

This means we no longer need to assume that units i and j should have equal outcomes at baseline, but only that the difference over time is equal to obtain the treatment effect. Once this idea is averaged over the treated and control group populations, this is called the parallel trends assumption and is the key assumption in difference in differences.

The parallel trends assumption is difficult to prove, especially when there is no data on the population of interest prior to baseline, which would allow us to assess whether they really moved in parallel before treatment was implemented.

Across many individuals (households or land parcels in our case) we obtain that at baseline $E(y_{i0}^0|D=0) = E(u_i|D=0) = U_0$ for the control while for units in the treated group $E(y_{i0}^1|D=1) = E(u_i|D=1) = U_1$. At endline $E(y_{i1}^1|D=0) = E(u_i + \tau_i|D=0) = U_0 + T_0$ for the untreated, while for treated we obtain $E(y_{i1}^1|D=1) = E(u_i + \tau_i + \theta_i|D=1) = U_1 + T_1 + ATT_1$. The DiD is then as follows.

$$DD = [E(.|D=1, t=1) - E(.|D=1, t=0)] - [E(.|D=0, t=1) - E(.|D=0, t=0)]$$

$$= U_1 + T_1 + ATT_1 - U_1 - [U_0 + T_0 - U_0] = ATT_1 + T_1 - T_0$$

So now our parallel trends means that the expected values of the time differences must be equal to one another, not individually. Note that if we used repeated cross-sections (or an unbalanced panel) then there are additional assumptions which would need to be made.

A standard regression approach to DiD to estimate the ATT would therefore require a parallel trends assumption. However, we can slacken this further to a "conditional parallel trends" assumption by including controls as well as weighting with propensity scores.

By using a regression approach for the panel, we obtain the following.

$$ATT = E(y_{i1} - y_{i0}|D=1) - E(y_{i1} - y_{i0}|D=0) = E(\Delta y^1) - E(\Delta y^0)$$

If we run a regression for the control group, $\Delta y^0 = X_0\beta + \varepsilon_i$, then we can obtain predicted values $X_1\hat{\beta}$ using the coefficients from the control group among the treated individuals to generate a counterfactual of what they would observe in case they had not been treated, $ATT = E(\Delta y^1) - X_1\hat{\beta}$. This is akin to the regression adjustment in IPWRA, except the outcome of the regression is a difference over time rather than just the outcome of interest.

Reweighting with propensity scores implies that the control group's covariates are reweighted to become more similar to the treatment group. For this, propensity scores are estimated as in equation (2) in IPWRA, leading to $ATT = E(\Delta y^1) - E(\Delta y^0; IPW)$ where the change in the control group is weighted with the inverse probability weights.

Combining the two approaches leads to $ATT = E(\Delta y^1 - X_1\hat{\beta}|D=1) - E(\Delta y^0 - X_0\hat{\beta}|D=0; IPW)$. If the outcome regression adjustment model is well specified, then $E(\Delta y^0 - X_0\hat{\beta}|D=0; IPW) = 0$ and so the first component defines the treatment effect. If the estimation of the propensity score is well specified, $E(X_1\hat{\beta}|D=1) = E(X_0\hat{\beta}|D=0; IPW)$, and so the ATT is driven by $E(\Delta y^1) - E(\Delta y^0; IPW)$.