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Impacts of Community Forest Management and strictly protected areas on deforestation and human well-being in Madagascar

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Preface

This thesis is submitted in partial fulfilment of the requirements for the double Doctor of Philosophy (PhD) degree at the Section for Global Development, Department of Food and Resource Economics, Faculty of Science, University of Copenhagen and the School of Environment, Natural Resources and Geography, Bangor University

The research was carried out from November 1st, 2012 to March 4th, 2016. I undertook fieldwork in Madagascar. The research focuses on the impacts of forest conservation interventions on forests and local human well-being. The thesis comprises an introductory chapter and the following three manuscripts:

Manuscript 1: Rasolofoson, R.A, P. Ferraro, C. Jenkins and J.P.G Jones 2015. Effectiveness of Community Forest Management at reducing deforestation in Madagascar. Biological Conservation 184: 271 – 277.
Manuscript 2: Rasolofoson, R.A., P.J. Ferraro, G. Ruta, M.S Rasamoelina, P.L Randriankolona, H.O. Larsen and J.P.G Jones. Impacts of Community Forest Management on human economic well-being across Madagascar. Revision submitted to Conservation Letters.
Manuscript 3: Rasolofoson, R.A., M.R. Nielsen and J.P.G Jones. The potential of the Global Person Generated Index (GPGI) for evaluating the perceived impact of conservation interventions on subjective well-being. Submitted to Ecology and Society.

An additional output is:
Rasamoelina, M.S., G. Ruta, **R.A. Rasolofoson**, P.L. Randriankolona, S. Aubert, B.S. Ramamonjisoa, Z. Rabemananjara, A.S. Raharijaona, G. Buttoud, J. Plananska 2015. *Analysis of community forest management (CFM) in Madagascar*. World Bank Group, Washington, D.C. http://documents.worldbank.org/curated/en/2015/11/25485929/analysis-community-forest-management-cfm-madagascar.

We mainly used quantitative methods, although manuscript 3 includes some small qualitative analysis. Particularly, we used rigorous program evaluation design in our attempt to generate rigorous evidence about impacts of nature conservation, which still lags behind many other disciplines in terms of high quality and scientifically rigorous impact evaluation.

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Summary

Protected areas and Community Forest Management (CFM) are among the most widespread interventions to conserve forests in tropical countries. In addition to their impacts on forests and the biodiversity they contain, these interventions also affect human well-being, particularly that of the local communities who are often poor and politically marginalized and whose livelihoods depend directly on the forest resources being conserved. To develop effective interventions, practitioners need to have credible, strong and scientifically rigorous evidence on their impacts on forests (or the biodiversity they contain) and human well-being. However, while scientifically rigorous impact evaluation of programs is well advanced in fields such as development, health and education, it is rare in nature conservation. The rare existing studies focus mostly on protected areas and other interventions, such as CFM, are relatively untouched by scientifically rigorous impact evaluation.

Different challenges account for the limited adoption of rigorous impact evaluation in nature conservation. Among these are the identification and elimination of rival explanations: factors other than the intervention that can explain the observed relationship between the intervention and the outcome. Potential rival explanations are factors that can confound impact estimates by affecting both assignment of units to intervention and the outcome. Another potential rival explanation is baseline outcome data that should have been collected before the intervention was implemented. Baseline data are often missing in conservation studies. Another challenge is the heterogeneity of management practices within and units exposed to the same intervention. A challenge pertaining particularly to studies on human well-being impacts is the multi-dimensional nature of human well-being.

In this thesis, I aim to investigate the impacts of different conservation interventions on environmental and human well-being outcomes while addressing the challenges to conservation impact evaluation discussed above. My case studies are CFM and strict protection in Madagascar; one of the world's hottest biodiversity hotspots. I have three specific objectives which are addressed in three manuscripts with the following titles:

i) Effectiveness of CFM at reducing deforestation across Madagascar (manuscript 1): With colleagues, I investigated the impacts of CFM on deforestation at the national scale between 2000 and 2010 using matching to control for factors confounding impact estimates. We did not detect an impact of CFM, on average, when CFM areas were compared to non-CFM areas, even when the sample was restricted to only where information suggests effective CFM implementation on the ground. However, impacts were heterogeneous conditional on whether CFM permits commercial use of forest resources. No CFM impact was detected where commercial use of natural resources is allowed. However, we did detect some reduction of deforestation in areas managed under CFM that does not permit commercial use, when compared to non-CFM or CFM permitting commercial use. Our findings suggest differentiating among types of CFM is important for estimating the impacts of this conservation approach.

ii) Impacts of CFM on human economic well-being across Madagascar (manuscript 2): In this manuscript, we investigated impacts on household living standards across Madagascar as measured by per capita consumption expenditure. We used matching to control for confounding factors and addressed the issue of missing baseline values of household consumption expenditures using an approach known as the placebo test. We cannot statistically reject the hypothesis of zero impact, but we can credibly reject the hypothesis that CFM has had substantial negative impacts on economic well-being across CFM communities in Madagascar. There were heterogeneous impacts, with a mixture of positive and negative impacts, conditional on household proximity to forest and education level. In conclusion, the impacts of CFM vary with household characteristics: some may lose while others may gain.

iii) The potential of the Global Person Generated Index (GPGI) for evaluating the perceived impact of conservation interventions on subjective well-being (manuscript 3): In this study, we used the GPGI, a subjective and multidimensional well-being instrument, to investigate the relative impacts of strict protection and CFM on human well-being in sites in eastern Madagascar. We used a participatory approach to establish the cause-effect relationship between the interventions and the outcomes (i.e., to eliminate rival explanations). We did not detect statistically significant difference, on average, between the two approaches in three measures we used to examine the magnitude of their relative impacts on subjective well-being. However, we found some differences in the characteristics of subjective well-being component domains impacted by the strict protection and CFM and in the priority domains that could be targeted by increased resource allocation to improve well-being in locally meaningful ways. Combined with the participatory approach to establish cause-effect relationship, we suggest GPGI provides highly relevant insight that can be used to design policy seeking to increase local participation and develop more positive local attitudes towards conservation.

The first two manuscripts (1 and 2) involve analyses at the national scale, objective indicators (deforestation and consumption expenditure) and rigorous quantitative causal inference designs making them of value to external stakeholders, such as government agencies and donors, seeking to know the magnitude of impacts to inform large scale conservation policy. However, these large scale studies may be of limited use for project managers who want to build locally legitimate interventions or those who want a deeper understanding of how conservation interventions affect local people. In the third manuscript, we used a subjective measure of well-being (the GPGI) in combination with participatory approach to establish cause-effect relationship between interventions and locally meaningful outcomes. This has limited value for quantitatively measuring the magnitude of impacts; but holds some promises for project managers who seek local participation and social sustainability. Conservation has long suffered from poor quality evaluation of its impacts. This thesis shows that methods for impact evaluation are available, but the appropriate method that should be applied depends, among other things, on the purpose of the evaluation.

Sammendrag

Landsbybaseret skovforvaltning, naturreservater, afskovning og velvære: sammenhænge på Madagaskar

Fredning af områder og landsbybaseret skovforvaltning er blandt de mest anvendte tilgange til bevaring af skov i tropiske lande. Foruden at bidrage til skov- og biodiversitets beskyttelse påvirker de også velvære, i særdeleshed for fattige og politisk marginaliseret lokal samfund hvor befolkningen er direkte afhængig af adgang til skov. For at kunne udvikle effektive tiltag der tilgodeser såvel skovbevaring som lokale folks velvære er det nødvendigt videnskabeligt at dokumentere hvorledes forskellige tiltag virker. Videnskabelig stringent evaluering af tiltag er veludviklet indenfor fagområder som udvikling, sundhed og uddannelse men er sjældne i forbindelse med naturbevaring. De få eksisterende studier fokuserer hovedsagelig på fredede områder mens andre fredningstiltag, herunder landsbybaseret skovforvaltning, kun er undersøgt i ringe grad. Dette skyldes blandt andet, at det er vanskeligt at identificere og eliminere andre mulige forklaringer: faktorer der ikke relaterer til et tiltag kan forklare observerede relationer mellem et tiltag og målte resultater. Sådanne faktorer kan virke gennem valg af enheder, fx hvilke skove der udvælges til undersøgelse, såvel som resultater; desuden kan de opstå som følge af, at data ikke har været indsamlet før et tiltag implementeres. Dette er typisk tilfældet for studier der omhandler fredning. En yderligere udfordring er de mangeartede forvaltningstiltag der kan følge én type fredningstiltag. Og selv hvis der ikke er variation i forvaltningstiltag kan enheder, som en skov, have karakteristika der indvirker på selve tiltaget. Desuden er det svært at undersøge indvirkning af tiltag på velvære, da denne i sig selv er kompleks og omfatter mange dimensioner.

I nærværende afhandling undersøges hvorledes forskellige fredningstiltag indvirker på miljøbevarelse og velfærd, i det ovenstående udfordringer imødegås. Afhandlingen fokuserer på tiltagene landsbybaseret skovforvaltning og naturreservater på Madagaskar, med en meget høj grad af biodiversitet. Afhandlingens tre specifikke formål, analyseret i hvert sit manuskript, er:

i) Landsbybaseret skovforvaltnings effektivitet til at nedbringe afskovning (manuskript 1): forfatter holdet undersøgte dette på nationalt niveau for perioden 2000 til 2010 ved brug af afstemning (matching) for at kontrollere for confounding (det forhold at to variable kan variere sammen uden direkte kausal sammenhæng). Landsbybaseret skovforvaltning havde, i gennemsnit, ingen effekt på afskovningsrater når sammenlignet med områder uden sådan forvaltning, heller ikke når data blev begrænset til kun at omfatte områder, hvor landsbybaseret skovforvaltning med større vished var blevet implementeret. Dog afhang effektiviteten af, om landsbybaseret skovforvaltning tillader kommerciel brug af skovressourcer – der var ingen effekt hvor sådan brug var tilladt, men en vis effekt (reduceret afskovning) i områder hvor kommerciel udnyttelse ikke var tilladt, både når sammenlignet med områder uden landsbybaseret skovforvaltning og med landsbybaseret skovforvaltning med kommerciel udnyttelse af skovprodukter. Dette antyder, at det er vigtigt at skelne mellem forskellige typer af landsbybaseret skovforvaltning når denne tilgang til fredning skal vurderes.

ii) Landsbybaseret skovforvaltnings påvirkning af økonomisk velvære på Madagaskar (manuskript 2): vi undersøgte påvirkningen af levestandard på husholdningsniveau via måling af husholdningers udgifter til forbrug pr. indbygger. Vi anvendte afstemning (matching) til at kontrollere for confounding og løste problemet med manglende data for husholdningers udgifter til forbrug før implementering af landsbybaseret skovforvaltning ved anvendelse af den såkaldte placebo test. Landsbybaseret skovforvaltning påvirkede ikke husholdningers økonomisk velvære negativt men påvirkningen var heterogen og kunne være både positiv og negativ, afhængig af husholdningers afstand til skov og uddannelsesniveau. Vi konkluderer, at landsbybaseret skovforvaltnings påvirkning afhænger af husholdningers karakteristika: nogle husholdninger mister velvære mens andre får øget velvære.

iii) Anvendelse af Global Person Generated Index (GPGI) til evaluering af hvorledes fredningstiltag opleves subjektivt i forhold til velvære (manuskript 3): vi brugte GPGI, et subjektivt og flerdimensionelt instrument til udforskning af velvære, til at undersøge den relative påvirkning af naturreservater og landsbybaseret skovforvaltning på velvære blandt husholdninger i det østlige Madagaskar. Vi anvendte en participatorisk tilgang til at etablere den kausale sammenhæng mellem tiltag og resultater (for at udelukke andre forklaringsmuligheder). Vi fandt ingen statistisk signifikant forskel, i gennemsnit, mellem de to tiltag. Vi fandt dog forskelle i karakteristika for påvirkede livsdomæner mellem de to tiltag og i de prioriterede domæner der kan påvirkes via øget ressource allokering med det formål at forbedre velvære på lokalt accepterede måder. Vi argumenterer for, at GPGI genererer relevant viden, der kan anvendes til at udvikle politikker der søger at øge lokal deltagelse i, og mere positive holdninger til, fredningstiltag.

De to første manuskripter (1 og 2) omfatter analyse på nationalt niveau, brug af objektive indikatorer (afskovning og udgifter til forbrug) og grundig undersøgelse af kvantitative årsagssammenhænge; dette gør resultaterne brugbare for aktører som offentlige myndigheder og udviklingsorganisationer, der har brug for sådan viden til at forfølge fredningspolitikker. Undersøgelser på nationalt niveau er mindre brugbare for projektledere der ønsker at udvikle lokalt accepteret tiltag, eller andre der tilstræber bedre forståelse af hvordan fredningstiltag påvirker lokalbefolkningen. I det tredje manuskript brugte vi en subjektiv måling af velvære (GPGI) sammen med en participatorisk tilgang til at etablere årsagssammenhænge mellem tiltag og lokalt forståelige resultater. Dette er begrænset anvendeligt i forbindelse med kvantitativ måling af hvorledes tiltag virker; men synes at være anvendeligt for projektledere der søger lokal deltagelse og social bæredygtighed. Fredninger har længe lidt under, at det har været svært at evaluere hvorledes forskellige tiltag virker. Denne afhandling viser, at der er metoder til rådighed og at valg af metode bør afhænge af hvorfor evalueringen foretages.

Abstract

Strong evidence about the impacts of conservation interventions on nature and human well-being is needed to develop effective conservation policy. However, currently available evidence is weak. This thesis attempts to strengthen the evidence on the impacts of conservation interventions by investigating the impacts of Community Forest Management (CFM) and strictly protected areas on deforestation and human well-being in Madagascar, one of the world's top conservation priorities. We addressed some of the weaknesses in other conservation impact evaluations including accounting for rival explanations for the observed pattern between the interventions and the outcomes, investigating heterogeneity of impacts, and considering the multi-dimensional nature of well-being. We cannot detect, on average, statistically significant impacts of CFM on deforestation or on household per capita consumption expenditure at the national scale (we were also able to reject the hypothesis that CFM has a substantial negative impact on consumption). We also did not detect statistically significant differences between CFM and strict protection in the measures we used to examine the magnitude of their relative impacts on subjective well-being in eastern Madagascar. However, impacts on deforestation and consumption expenditure have been heterogeneous, with a mixture of positive and negative impacts, conditional on management practices and household characteristics. This heterogeneity of impacts supports claims that CFM can succeed under certain conditions. In eastern Madagascar, the characteristics of subjective well-being component domains impacted by CFM and strict protection have also been different, suggesting that these two interventions have had different impacts on subjective well-being. The use of objective indicators (deforestation and consumption expenditure) and rigorous causal inference designs (including matching) as those used in the national scale studies can yield information about the magnitude of impacts that may be of interest to external stakeholders seeking cost-effective interventions. Subjective indicators, like the Global Person Generated Index, and the participatory approach to eliminate rival explanations as we used in eastern Madagascar are limited in estimating the magnitude of impacts but provide highly relevant information for practitioners seeking to build locally legitimate interventions. The appropriate method for impact evaluation depends, among other things, on the objectives of the evaluation.

Contents

I- INTRODUCTION

I-1- Why investigate the impacts of Community Forest Management and protected areas?

Protected areas have long been a central approach to forest conservation worldwide. Terrestrial protected areas have increased substantially over the last 30 years; from 3.5% of the world's land area in 1985 (Zimmerer et al. 2004) to 15.4% in 2014 (Juffe-Bignoli et al. 2014) en route to meeting the Convention on Biological Diversity Aichi target 11 of expanding to 17% the total land area under protection by 2020 (CBD 2010). While the primary reason for establishing protected areas is biodiversity conservation (Dudley et al. 2010), protected areas have also been promoted to deliver a range of cultural, social, economic and environmental benefits (Leverington et al. 2010a). Protected areas can play major roles in forest-based climate change mitigation in the tropics through the scheme Reducing Emissions from Deforestation and forest Degradation (REDD+; Scharlemann et al. 2010).

However, the potential negative impacts of protected areas on the well-being of local communities generated a great deal of debate (Brockington & Wilkie 2015) and led to the development of approaches which integrate forest protection and local well-being such as Community Forest Management (CFM; Hutton et al. 2005). CFM refers to forest management under which local forest users are, at least partially, involved in making forest use rules, monitoring, enforcement, and conflict resolution (Ostrom 2000). Community-owned and managed forests comprise over 10% of forests globally (Chhatre & Agrawal 2009). Community forests are also important to the livelihoods of the rural poor in developing countries; such forests are estimated to provide livelihood benefits to more than half a billion poor people (Chhatre & Agrawal 2009). It has been suggested that the environmental, social, human, and institutional capital associated with CFM can also constitute a good foundation upon which REDD+ can build to achieve its objectives (Newton et al. 2015).

Given the global importance of protected areas and CFM, it is crucial to know whether they really work. In other words, credible and strong evidence about the impacts of both conservation approaches on the environment and human well-being is needed. Human society makes investments in terms of land, money and other resources for protected areas and CFM. Thus, strong evidence about their impacts promotes accountability to society (Leverington et al. 2010b). Resources for conservation are limited (Waldron et al. 2013). Therefore, if a particular conservation approach is failing, despite best efforts, then better options must be sought, while if it is performing relatively well, despite serious threats and limited resources, the level of support for implementation and maintenance should be sustained or increased (Bruner et al. 2001). Strong evidence about impacts allows identifying the approaches that perform relatively well. In contrast, weak evidence can misdirect the already scarce conservation resources to interventions that do not have significant impacts (Pressey et al. 2015). Unfortunately, evidence about the impacts of conservation approaches on the environment and human well-being is weak. Rigorously designed empirical evaluations of impacts are rare in nature conservation compared to other fields such as health, education and development (Ferraro & Pattanayak 2006; Baylis et al. 2015). There are many reasons for the slow adoption of rigorous empirical designs to evaluate impacts of conservation interventions (e.g. see Baylis et al. 2015; Craigie et al. 2015). Some of the challenges addressed in this thesis are discussed below.

I-2- Challenges for evaluating the impact of conservation interventions

I-2-1- Prevalence of non-counterfactual thinking in conservation

In program impact evaluation, it is crucial to define the counterfactual scenario; that is what would have happened if there had been no intervention or if other alternative interventions had taken place (Ferraro 2009). Impact is the difference between the intervention outcome values and the counterfactual outcome values (Ferraro 2009). In conservation, such “counterfactual thinking” (Ferraro 2009) is not mainstream (Baylis et al. 2015) and there is a general misunderstanding of what impact is (Pressey et al. 2015). This misunderstanding is reflected in the undue attention to program inputs, outputs, and outcomes (intervention only; without counterfactual outcomes) in influential conservation policy targets, objectives for planning and management, and evaluations of conservation program management effectiveness (Pressey et al. 2015). Although monitoring of program inputs, outputs and outcomes have important roles for adaptive management (Coad et al. 2015), they do not answer the evaluation fundamental question: what would have happened in the absence of the intervention (Ferraro & Pattanayak 2006)?

To assess intervention impacts, a number of studies compare the outcomes in units with intervention to the outcomes in random comparison units (without intervention or with alternative interventions; Joppa & Pfaff 2010), implying that the comparison outcomes represent the counterfactual outcomes. If interventions are randomly assigned, then comparing outcomes in intervention and random comparison units can reveal causal effects of interventions. Randomness of both units would ensure their similarity in terms of other factors that can influence the outcomes (or rival explanations), and thus allow controlling for the bias that could be introduced by these factors (Joppa & Pfaff 2011). However, conservation interventions are not randomly assigned. They are often biased towards locations having characteristics more or less favorable to conservation or development. For example, protected areas are often located in areas with less potential for agriculture and extractive use of natural resources (Joppa & Pfaff 2009); and CFM is more likely to occur in areas with higher human pressures (Ferraro & Pattanayak 2006; Bowler et al. 2012). Thus, comparing outcomes in spatially biased intervention units to random comparison units bias impact estimates because these two groups of units differ along characteristics that are having confounding effects. It is like comparing “apples to oranges” (Joppa & Pfaff 2010). Therefore, random comparison units are poor counterfactuals.

To address the non-random distribution of interventions, a number of studies compared the outcomes in intervention units to the outcomes in neighboring comparison units, assuming that they have similar environmental and socio-economic characteristics (Bowler et al. 2012). While this seems to be a reasonable assumption, evidence shows that proximity does not necessarily guarantee similarity (Joppa

& Pfaff 2010). Thus, comparison units nearby intervention units may poorly represent the counterfactuals.

Another way used to address the non-random distribution of interventions is to compare outcomes before and after the implementation of the intervention (Ferraro & Pattanayak 2006; Joppa & Pfaff 2010; Bowler et al. 2012), and thus implying that outcomes before intervention represent the counterfactual outcomes. However, external factors, which change over time, such as changes in policy or demand for natural resources may be different before and after intervention. These factors can influence the outcomes, and thus confound impact estimates. Therefore, the outcomes before intervention are poor representation of the counterfactual outcomes.

One approach to address the non-random distribution of interventions is a quasi-experimental method called matching. Matching pairs intervention and comparison units that are similar in terms of characteristics that affect both selection of units to intervention and the outcomes (Ferraro & Pattanayak 2006; Joppa & Pfaff 2010). It seeks to compare "apples to apples" (Joppa & Pfaff 2010) by comparing outcomes in intervention units and the matched or similar comparison units. Thus, one assumes that the outcomes of the matched comparison units represent the counterfactual outcomes. Matching seeks to attribute the difference in the values of the outcomes in the intervention and matched comparison units to the intervention (i.e., eliminate rival explanations) by ensuring that the only difference between the two groups of units is the intervention and that the confounding effects of other characteristics are controlled. Relatively few, but increasing, studies in nature conservation have used matching in efforts to better attribute impacts to conservation interventions (Andam et al. 2008, 2010; Somanathan et al. 2009; Joppa & Pfaff 2011); although most of these studies concern protected areas.

Some studies have also attributed impacts to interventions (i.e., eliminate rival explanations) by using a participatory approach (Schreckenberg et al. 2010; Woodhouse et al. 2015), in which communities affected by interventions are directly ask how they perceive the impacts of the interventions on their environment or well-being. Though the participatory approach is subjective and thus can be biased by participants' mood, orientation and cultural norms, and by timing (Camfield & Skevington 2008), it is important for generating information about people's experiences and perspectives, which are needed to address issues that people do not appreciate, in order to gain local support (Woodhouse et al. 2015).

I-2-2- Heterogeneity in impacts of conservation interventions

Protected areas and CFM are not homogenous in their rules and management practices. For example, the International Union for the Conservation of Nature (IUCN) categories of protected areas range from strict protection to protected areas with sustainable use of natural resources (Dudley et al. 2010). Management inputs, such as funding and staffing, also vary largely across protected areas (Leverington et al. 2010a). For CFM, there is a large variation in institutional arrangements, degree of power devolved to local communities, and quality of implementation (Ostrom 2000; Adams & Hulme 2001; Lund et al. 2009). Therefore, it should be expected that there are heterogeneous impacts across protected areas and CFM sites. For example, in Ethiopia, CFM permitting commercial timber harvest increased the income of members of forest user groups, while CFM that only allows subsistence use decreased their income (Ameha et al. 2014). Attention to the heterogeneity of rules and management practices could provide important information about institutional and management elements that promote effectiveness.

Even if an intervention was homogenously applied, heterogeneous impacts could still arise because intervention units have different characteristics that could moderate impacts (Ferraro & Pressey 2015). For example, studies show that protected areas location (e.g., distance to roads, distance to cities, slope) can moderate their impact on avoided deforestation (Ferraro et al. 2013; Pfaff et al. 2014). Household characteristics (e.g., gender of the household head, economic status) moderated the well-being impacts of CFM on household participating in forest user groups (Jumbe & Angelsen 2006; Bandyopadhyay & Tembo 2010). Strong evidence on heterogeneity of impacts caused by moderators would be useful to facilitate more appropriate locating of interventions where impacts can be maximized and cast light on important policy issues, such as equitable distribution of conservation benefits.

Many studies (e.g., Agrawal & Chhatre 2006; Behera 2009; Leverington et al. 2010a; Persha et al. 2011) focused on associations between outcomes and potential sources of heterogeneity to examine the heterogeneity of impacts. While these studies are useful for generating hypotheses, their conclusions cannot have causal interpretations, and thus their usefulness for conservation practices is limited (Ferraro & Hanauer 2015). Relatively rare studies (Ferraro et al. 2011; Ferraro et al. 2013; Ameha et al. 2014; Pfaff et al. 2014) applied rigorous causal effect empirical designs to study the heterogeneity of impacts of conservation interventions. This rarity reflects the challenge involved in building rigorous evidence on heterogeneity of impacts. In some cases, there is a lack of good theory on how different rules, management practices and moderators influence impacts. Empirically, appropriate data on rules, management and moderators can be lacking and heterogeneity analysis requires large sample size and more assumptions (Ferraro & Pressey 2015).

I-2-3- Missing data on outcomes at the baseline

Pre-intervention or baseline measures of outcomes are needed to control for initial conditions that may affect measures of intervention impacts or act as rival explanations of the observed pattern between the interventions and the outcomes (Ferraro & Pattanayak 2006). Particularly, they ensure that post-intervention difference in intervention and counterfactual outcome values is not affected by the pre-intervention outcome values. However, baseline outcome data are often missing in conservation studies (Bowler et al. 2012; Ferraro & Hanauer 2015). This lack of baseline measures is due to the scarcity of conservation resources, which leads project managers to prioritize management actions over monitoring and evaluation (Kapos et al. 2008).

The falsification or placebo test (Rosenbaum 2010) has been recently proposed to address the issue of missing baseline measures (Ferraro & Hanauer 2014a). The idea of the test is to demonstrate that intervention and their counterfactual units have similar outcome values in the absence of the intervention (Ferraro & Hanauer 2014a). If they do, there is some confidence that they had similar outcome values at baseline when there was no intervention. If they do not, the result of the placebo test can be used to explore the implications of the bias. The placebo test has been use to address the issue of unobserved confounding variables in few studies (e.g., Fortmann 2014; Ferraro et al. 2015). However, to my knowledge, there is no tropical conservation study that has used the placebo test to address the missing baseline issue, despite lack of such baselines being a common problem.

I-2-4- Complexity and multi-dimensionality of human well-being

Another challenge for impact evaluation pertains particularly to impacts on human well-being. Over the years the concept of well-being has evolved from a narrow focus on objective and relatively easily measurable economic and social attributes such as income, consumption, assets, education and health to a complex and multidimensional concept that includes material and non-material, objective and subjective components (Brown & Westaway 2011; King et al. 2014). Consideration of the multidimensional nature of well-being is important for a number of reasons. First, there is a potential for trade-offs between the different well-being outcomes of interventions (Milner-Gulland et al. 2014; Woodhouse et al. 2015). An intervention may provide benefits for some well-being dimensions while causing losses in others. Non multidimensional approaches to well-being may miss the benefits or the losses, and thus have limited usefulness for decision making. Second, different stakeholders have different ideas about well-being and how it should be measured (Schreckenberg et al. 2010; Milner-Gulland et al. 2014). On one hand, objective and monetary based outcome measures (e.g., income, consumption, and assets) may be more relevant for governments and donors, who are interested in national or large scale policy and want to know tangible, comparable and quantitative measures of the magnitude of impacts to identify cost-effective interventions. On the other hand, project managers who may seek local acceptance of and participation in the project may be interested in subjective measures of well-being in order to gain information on local experiences and perspectives. Finally, for ethical reason, externally defined measures should not be imposed on local communities (Sayer et al. 2007; Milner-Gulland et al. 2014). While objective and monetary based measures are relevant to external stakeholders, they do not often reflect local communities' priority (Pokharel & Larsen 2007; Sayer et al. 2007), and thus may not reveal impacts that are locally significant.

In the conservation field, the multidimensional aspect of well-being has gained momentum following the Millennium Ecosystem Assessment's emphasis on taking a holistic approach when studying the linkages between ecosystem and human well-being (Millenium Ecosystem Assessment 2005). Since then, efforts have been made to develop methodologies that take the multiple dimensions of well-being into account in conservation impact evaluation (King et al. 2014; Milner-Gulland et al. 2014; Woodhouse et al. 2015). However, empirical evidence on impacts of conservation interventions on the multiple dimensions of well-being is scant.

I-5- The goal and contribution of this thesis

My goal is to investigate the impacts of different conservation interventions on environmental and human well-being outcomes. This thesis contributes to strengthening the weak evidence base for impacts of conservation interventions on environmental and human well-being outcomes by addressing some of the challenges often encountered in developing rigorous impact evaluation studies. In doing so, this thesis widens the application of rigorous empirical methods that are insufficiently, but increasingly, used in conservation (e.g. matching) and promotes other methods that are rarely or not used at all in conservation (e.g., placebo test, subjective and multidimensional well-being instrument). Finally, this thesis extends the geographical scope of rigorously designed impact evaluation of conservation interventions to Madagascar, which is poorly represented in the literature despite being a biodiversity reservoir of global importance.

I-6- The case study: Madagascar

Madagascar is one of the global biodiversity conservation's top priorities because of a high concentration of endemic species and a high degree of threat to natural habitats (Brooks et al. 2006). In efforts to conserve its natural forests, upon which 90% of its unique species depend (Harper et al. 2007), Madagascar has attempted a range of conservation interventions. The island country established Africa's first protected area system comprising ten individual protected areas in 1927 (Tyson 2000). In the beginning of the 1990s, Madagascar adopted the Integrated Conservation and Development Projects (Froger & Méral 2012). The island was also one of the first countries in the southern hemisphere to put a legal framework for CFM in mid-1990s (Andriantsilavo et al. 2006) and was the first country in the Africa region to implement pilot REDD projects (Ferguson 2009).

Given Madagascar's unique experience with a range of conservation interventions, the island is a good case study for investigating impacts of different interventions. Unfortunately, there are scant rigorously designed empirical studies on impacts of conservation interventions in Madagascar. For example, none of the few existing studies on impacts (e.g., Ferraro 2002; Hockley & Andriamarovololona 2007; Sommerville et al. 2010; Toillier et al. 2011; Raboanarielina 2011; Ramamonjisoa & Rabemananjara 2012) adequately control for characteristics that confound impacts and very few consider the multidimensional nature of human well-being. Therefore, well-designed studies on impacts of conservation interventions are needed to inform Madagascar's conservation policy, particularly as the country has recently embarked in a massive extension of its protected area coverage, in which interventions such as CFM and REDD are expected to play major roles (Ferguson 2009; Froger & Méral 2012).

I-7- Objectives

I explore three specific objectives in three manuscripts. These manuscripts are co-authored with a variety of different collaborators (although I am lead author of each one). To acknowledge the involvement of my co-authors I use the pronoun *we* when discussing these papers, but I elsewhere.

i) The effectiveness of CFM at reducing deforestation across Madagascar (manuscript 1): In this manuscript, we investigate the impacts of CFM on deforestation at the national scale from 2000 to 2010 using statistical matching to control for confounding factors. We examine heterogeneity in two ways. Firstly, we look at impacts conditional on quality of implementation of CFM on the ground using a subsample of CFM sites where we have information to suggest that CFM was effectively implemented on the ground. Second, we explore impacts conditional on rules pertaining to commercial use of forest resources.

ii) Impacts of CFM on human economic well-being across Madagascar (manuscript 2): This is another national scale study that complements the previously described study (i) by evaluating CFM impacts on household living standards in Madagascar as measured by per capita consumption expenditures. We also use matching to control for confounding factors in this study. Baseline values of household consumption are missing. We address that issue by using the placebo test. We examine the heterogeneity of impacts as a function of the proximity of the household's location to forest edges and household's head education level.

iii) The potential of the Global Person Generated Index (GPGI) for evaluating the perceived impact of conservation interventions on subjective well-being (manuscript 3): This is a small scale study carried out in a strictly protected area and four CFM sites in Madagascar's eastern rainforests. It complements the previously described study (ii) by looking at subjective and multi-dimensional human well-being by using the Global Person Generated Index (GPGI). While the GPGI have been used a few times in the development field, and its closely related Patient Generated Index extensively used in public health studies, the GPGI has not been applied to conservation. We examine the strengths and weaknesses of the GPGI in evaluating impacts of conservation interventions by using it to evaluate the relative perceived impacts of strict protection and CFM on subjective well-being. This study also relies on participatory approach to establish the cause-effect relationship between the interventions and the outcomes (i.e., to eliminate rival explanations).

II- METHODS

II-1- Study sites

Madagascar, the world's fourth largest island, is located in the western Indian Ocean and lies about 400 km off the southeast coast of Africa (Figure 1). In 2014, the country had an estimated human population of over 23 million, with an annual population growth rate of 2.8%, and a per capita Gross Domestic Product (GDP) a bit below US$ 450 (World Bank 2016). Over 90% of Malagasy people are under the international poverty threshold of US$ 2 of daily consumption expenditure (INSTAT 2013). Over 70% of Madagascar's population live in rural areas, mostly depend on subsistence agriculture for their livelihoods, and use varieties of goods and services provided by the island's different ecosystems (Scales 2012).

Madagascar is renowned for its high level of fauna and flora species diversity and endemism. With a land area of 594,150 km^2 (a bit larger than metropolitan France), the island shelters over 12,000 species of vascular plants, of which 85% are endemic; and over 870 land vertebrate species, with endemism rates of 84% (Goodman & Benstead 2005). For some taxonomic groups the endemism rates are even higher: over 90% for reptiles, 99% for amphibians, and 100% for lemurs (Goodman & Benstead 2003). However, Madagascar biodiversity suffers from a high level of threat. An estimated 90% of the natural forests, which provide habitats for most of the island's unique biodiversity, have been lost since the arrival of its first human inhabitants around 2000 years ago (Goodman & Benstead 2005), with over 40% loss recorded for the five latest decades alone (Harper et al. 2007).

In an attempt to halt the rapid destruction of natural forest habitats, Madagascar has adopted a range of conservation interventions. Currently, over 140 sites covering a total area of about 69,100 km^2 are under some form of protection (Figure 1; Carret 2013). Many of these protected areas have been established after 2003, when the Malagasy government unveiled a plan to more than triple the country's total protected area (Norris 2006). Initiated in the mid-1990s, CFM has expanded rapidly to reach over 1,000 sites covering a total land area of over 30,000 km^2 (Rasamoelina et al. 2015). In the late 2000s, five pilot REDD projects have been implemented in some of the newly protected areas (Ferguson 2009).

The three studies in this thesis are at different spatial scales. While the studies on deforestation (manuscript 1) and economic well-being (manuscript 2) covers Madagascar's entire land area, the one on subjective well-being (manuscript 3) was carried out in Zahamena National Park (ZNP), a strictly protected area, and four CFM sites in the Corridor Ankeniheny-Zahamena (CAZ) protected area (Figure 1). Both ZNP and CAZ lie on the eastern rainforests and are among the world's most irreplaceable protected areas because of a high number of threatened and endemic species (Le Saout et al. 2013).

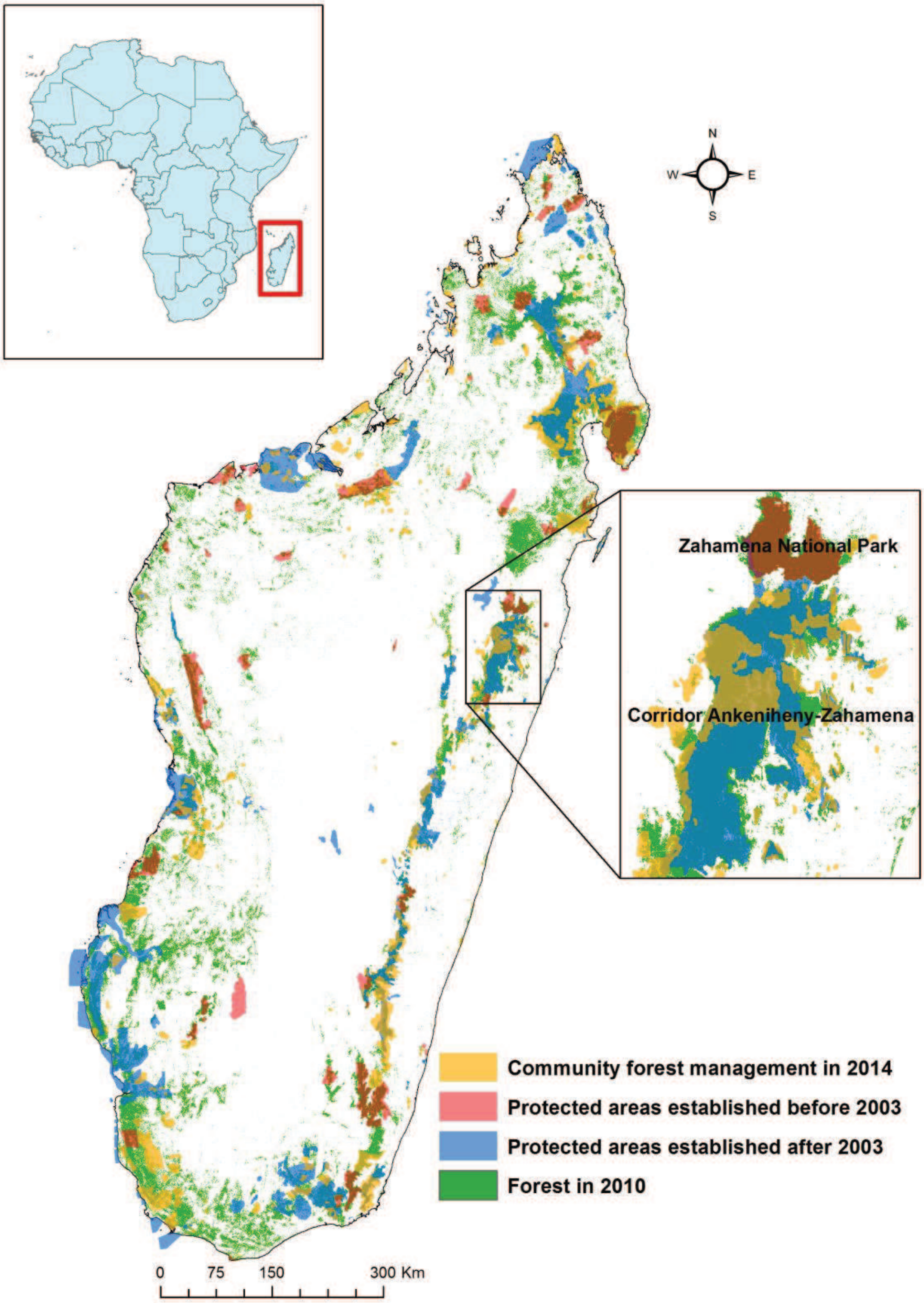

Figure 1. Study sites: Madagascar, Zahamena National Park, and Corridor Ankeniheny-Zahamena (Sources: Direction Générale des Forêts, Office National pour l'Environnement, Asity, Fanamby, Durrell Wildlife Conservation Trust, Conservation International, Wildlife Conservation Society, and World Wide Fund for Nature)

II-2- Units of analyses, outcome variables, and attribution methods

The units of analyses and the outcomes of the three different studies that compose this thesis are shown in Table 1.

Table 1. Description of the different types of main analyses: unit of analysis, outcome variable, and attribution method

Study	**Unit of analysis**	**Outcome variable**	**Attribution method***	**Main analysis**
Manuscript 1: Deforestation	Pixel forested at the 2000 baseline forest cover	Whether a pixel remained forested or not in the 2010 forest cover	Matching	CFM vs. non-CFM
Manuscript 2: Economic well-being	Household	Annual per capita consumption expenditure in 2010 or 2012	Matching	CFM vs. non-CFM
Manuscript 3: Subjective well-being	Household head or replacement	1) Distribution of the frequency of respondents across different numbers (zero to five) of impacted quality of life (QoL) domains 2) Weighted performance in QoL domains that have been perceived to be impacted by the interventions 3) Characteristics of QoL domains perceived to be impacted by the interventions	Participatory	Strictly protected area vs. CFM

*Attribution method is the method used to establish the cause-effect relationship between interventions and outcomes

The outcomes for the deforestation (manuscript 1) and economic well-being (manuscript 2) studies are: whether a pixel is deforested or not in 2010 and per capita consumption expenditure in 2010 or 2012. Impacts of CFM were estimated by comparing outcomes in CFM units and outcomes in non-CFM units. However, CFM is not randomly assigned. The characteristics that affect assignment of units to CFM also affect outcomes, thus confounding attempts to estimate CFM impacts (Ferraro & Pattanayak 2006). I used matching to control for these confounding factors. Matching selects non-CFM units that are similar to the CFM units in terms of their values of the confounding factors at baseline. Thus, one assumes that the outcomes of the non-CFM units equate, in expectation, the counterfactual outcomes of the CFM units had they not been exposed to CFM.

The outcomes used in the subjective well-being study (manuscript 3) came from the GPGI. The GPGI collects information about individuals' quality of life (QoL). Subjective well-being and QoL are synonymous concepts, though QoL has more developed methodology and instrument design than subjective well-being (Camfield & Skevington 2008). Thus, GPGI can be used to assess subjective well-being (Britton & Coulthard 2013). The GPGI comprises three stages. Stage 1 asks respondents to name up to five life domains important in their lives. In stage 2, respondents rate their performance in each of the QoL domains named in stage 1. Then, in stage 3, the respondents give weight to each domain according to its relative importance in their life (i.e., higher weights for more important domains and lower weights for less important domains). For each respondent, a final GPGI score was computed using information from these three stages.

To establish the causal link between QoL and the intervention (strictly protected area or CFM), we added another stage to the GPGI instrument. We asked if the respondents perceived that the intervention contributed to their performance (rated in stage 2) in each QoL domain they identified. Because all five domains identified by a respondent were not necessarily perceived to be impacted by the intervention, the GPGI final score contains some components that are not related to the intervention at all. In other words, the final GPGI score represents an overall measurement of QoL that could be influenced by a variety of factors other than the intervention. We did not compare the final GPGI scores between the strict protected area and CFM in an attempt to estimate their relative impacts because these other factors could confound impacts estimated from such comparison. We attempted to modestly investigate the magnitude of the relative impacts of the strictly protected area and CFM by comparing between the two interventions the distributions of the frequency of respondents across different numbers (zero to five) of QoL domains perceived to be impacted by the interventions. We conducted this comparison separately for perceived negative and positive impacts. Then, because QoL is determined by both the performance in QoL domains (score in GPGI stage 2) and the relative importance or weight (score in GPGI stage 3) of these domains (Bowling 1995; Tovbin et al. 2003), we also compared the weighted performance (GPGI stage 2 score multiplied by GPGI stage 3 score) in domains that have been perceived to be impacted in the two intervention areas. Finally, we compared the impacted domains in the strictly protected area and CFM areas in terms of their characteristics (i.e., types of impacted domains, direction of impact (negative or positive) for each impacted domain, importance of each impacted domain, and the frequency with which each domain is impacted).

Note: In the subjective well-being study (manuscript 3), we performed a needs assessment analysis that is unrelated to impact evaluation, but important to identify, both in strictly protected and CFM areas, domains that could be targeted by development projects or conservation compensation schemes aiming to improve human well-being in locally meaningful ways. This is to take advantage of the potential of the GPGI as a needs assessment tool (McGregor et al. 2009; Martin et al. 2010).

II-3- Exploring heterogeneity in impacts of conservation interventions

We examined heterogeneity of CFM deforestation impacts (manuscript 1) as a function of two management practices. First, we looked at impacts conditional on the quality of CFM implementation, which could range from cases where the community has good understanding of their rights and responsibilities to cases where CFM exists on paper only (Benjamin 2008; Lund et al. 2009). To do that, we carried out an analysis for a subsample of CFM sites with information suggesting implementation on the ground. We used whether a CFM passed the forest department evaluation that is undertaken three years after CFM official creation (Pollini & Lassoie 2011) as an indicator of whether the project was indeed implemented. While not an ideal indicator, this does at least suggest a CFM has met the basic institutional, socio-economic and environmental criteria of the evaluation. Second, we explored impacts conditional on whether CFM permits commercial use of forest resources. The role of commercial use of forests in conservation generates a great deal of debate. Some studies suggest that by assigning value to forests, commercial use provides means and incentives to local communities to protect forests, while others indicate that it can trigger the destruction of the resources being commercialized (Agrawal & Chhatre 2006; Persha et al. 2011; Barsimantov & Kendall 2012).

We investigated the heterogeneity of impacts of CFM on economic well-being (manuscript 2) as a function of two household characteristics known to be capable of moderating impacts of interventions on well-being. First, we examined impacts conditional on the distance from a household location to the nearest forest edge. Previous studies suggest that households located within or nearer forests are more politically and socio-economically disadvantaged and more affected by conservation interventions (Ratsimbazafy et al. 2011; Toillier et al. 2011). Second, we looked at how impacts vary as a function of the education level of the household's heads. Pollini & Lassoie (2011) indicate that more educated household capture more CFM benefits in Madagascar.

The small sample size for the subjective well-being study (manuscript 3) did not allow us to conduct heterogeneity analysis for this study. Such analysis requires large sample size (Ferraro & Pressey 2015).

II-4- Falsification or placebo test to address missing baseline outcome data

For the study on economic well-being (manuscript 2), there is no information on the outcome (consumption expenditure) at baseline; although there had been previous living standard surveys in Madagascar, these were with a different sample of households (i.e., there is no panel data on living standards). This is a problem because it makes pre-existing differences in consumption expenditures between CFM and counterfactual non-CFM households a potential explanation for any post-CFM differences, and thus rivaling CFM as the only possible explanation. To address the issue, we used the placebo test (Rosenbaum 2010; Ferraro & Hanauer 2014a), which tests whether the pre-CFM observable confounding characteristics we used are sufficient to control for the missing pre-CFM household consumption expenditure.

To do the test, we used a household dataset from a 2005 survey. This 2005 survey and those of 2010 and 2012, on which the main analysis was undertaken, were carried out by the same agency (INSTAT) using similar methodology and collected the same types of data (including consumption expenditure and household characteristics). However, the samples are different for these three surveys. None of the sample households selected from the 2005 survey were under CFM intervention in 2005, but some became CFM households after 2005. We matched these soon-to-be CFM (placebo) households to households never exposed to CFM using the same matching procedure and variables we applied to the 2010 and 2012 household data. In 2005, there was no CFM yet, and thus if the matching procedure is effective, consumption expenditures in the placebo CFM and non-CFM households should be similar, on average. If this null hypothesis cannot be rejected, the assumption that the matching procedure balances the unobservable pre-CFM (baseline) consumption levels in the 2010 and 2012 matched samples is more plausible.

III- SUMMARY OF RESULTS

III-1- Manuscript 1: Effectiveness of CFM at reducing deforestation

CFM has not reduced, on average, deforestation in Madagascar (-0.02% deforestation reduction; p.value = 0.99). Even when the sample was restricted to the CFM sites where there is some information to suggest that CFM has been implemented, deforestation reduction by CFM was small (-0.76%) and not statistically significant (p.value = 0.71). Impacts seem to vary as a function of whether CFM permits commercial use of forest resources. CFM that allows such use did not reduce deforestation (1.83% deforestation increase; p.value = 0.16). CFM that does not permit commercial activities reduced deforestation by 2.01% ($p < 0.001$). When CFM with commercial activities was contrasted directly to CFM without such activities, CFM with commercial activities had more deforestation.

III-2- Manuscript 2: Impacts of CFM on human economic well-being

We cannot detect, on average, statistically significant impacts of CFM on per capita consumption expenditure in Madagascar (effect size of US$ 12.57; p.value = 0.43). Due to concerns that CFM can harm local wellbeing by restricting access to forest resources, we also investigated the hypothesis that

CFM has a substantial negative impact on wellbeing but rejected that hypothesis. However, we did find that impacts were moderated by household characteristics. Households located close to the forest edge appear to benefit from CFM (with a maximum benefit of US$ 50), while those farther from the forest edge appear to suffer negative impacts (with a maximum loss of US$ -60). Households with more educated heads seem also to benefit from CFM (with a maximum benefit of US$ 100). Household with low levels of education appear to be negatively impacted, but the estimate was imprecise. The placebo test shows that without intervention, the household consumption expenditure is not different between CFM and non-CFM households (effect size of US$ 13.60; p.value = 0.76). This supports the assumption that the pre-CFM observable confounding characteristics we used are sufficient to control for pre-CFM (baseline) household consumption expenditure; and thus supports that household consumption expenditure was similar between CFM and matched non-CFM households at baseline, when there was no CFM.

III-3- Manuscript 3: The potential of the Global Person Generated Index (GPGI) for evaluating the perceived impact of conservation interventions on subjective well-being

We detected no statistically significant difference between the strictly protected area and CFM sites in terms of the distributions of the frequency of respondents across different numbers (zero to five) of negatively impacted domains (p-value = 0.57). The same holds for respondents who perceived positive impacts (p-value = 0.39). The mean of the weighted performance in domains perceived to be impacted is lower in the strictly protected areas than in CFM sites (0.37 and 0.45 respectively), but the difference is not statistically significant (P = 0.23).

There are some differences in the characteristics of domains perceived to be impacted by the strictly protected area and CFM. Different types of domains were impacted by the two different interventions (e.g., the food domain was not perceived to be impacted in the strictly protected area but it was in CFM). The two interventions can impact the same domain in different directions (e.g., the agriculture domain was negatively impacted in the strict protected area but positively in CFM). The same impacted domain can have different importance in the two interventions (e.g., the impacted work equipment domain was of low importance in the strictly protected area but of high importance in CFM). The frequency with which a domain is impacted can differ in the two interventions (e.g., the infrastructure domain was perceived to be impacted with relatively high frequency in the strictly protected area but in CFM it was impacted with low frequency).

The needs assessment suggests that there were some differences in the priority domains that could be targeted by increased resource allocation in the strictly protected area and CFM sites. For example, the education domain was of high priority in the CFM sites, but it was not so in the strictly protected area.

IV-DISCUSSION

IV-1- Impacts of community forest management and strict protection on deforestation and local human well-being

We found no strong evidence suggesting that the devolution of forest management to local communities (i.e., CFM) across Madagascar has, on average, reduced deforestation and improved local economic living standards. In a case study in Madagascar's eastern rainforests, CFM has also not been significantly perceived by forests communities to deliver more positive impacts than strict protection, the intervention CFM has attempted to replace or complement. However, these results should not be taken to undermine the potential for CFM to benefit both forests and local communities. Impacts have been heterogeneous conditional on management practices and other moderating variables (manuscripts 1 and 2). The deforestation impact of CFM varies whether the management type permits commercial use of forest resources and the economic living standard impact varies as a function of household proximity to forest and education level. The detected heterogeneous impacts confirm claims that CFM can succeed under certain conditions (i.e., management practices and moderating variables; Ostrom 2000; Agrawal 2003). Nevertheless, while most existing studies (e.g., Agrawal & Chhatre 2006; Behera 2009; Persha et al. 2011) examined heterogeneity by establishing associations between different conditions and outcomes, this thesis provides stronger evidence by using rigorous causal inference designs to establish the cause-effect relationships between different conditions and the outcomes. More generally, the studies in this thesis are some of the rare studies that use rigorous designs to investigate the impacts of conservation interventions other than protected areas.

That the characteristics of subjective well-being component domains impacted by CFM and strict protection have been different also suggests that the impacts of strict protection and CFM on well-being have been different (manuscript 3). However, impacted respondents in both interventions may have adapted their standards and values to the interventions, so that the different impacts of both interventions have not been seen in the measures used to investigate the magnitude of their relative impacts (the distribution of the frequency of respondents across different numbers (zero to five) of negatively or positively impacted quality of life (QoL) domains and weighted performance in domains perceived to be impacted by the interventions). This adaptation is called response shift (Schwartz & Sprangers 1999; Schwartz et al. 2006).

IV-2- Magnitude of impacts versus locally relevant information

The use of rigorous causal inference design (including matching) combined with objective environmental (deforestation) and well-being (consumption expenditure) outcomes made it possible to estimate the magnitude of impacts of CFM (manuscripts 1 and 2). Such information is relevant for external stakeholders, such as government agencies, donors, and some non-governmental organizations, which need evidence on magnitude of impacts to inform national scale or other large scale policies (Woodhouse et al. 2015). For example, results of these studies (manuscripts 1 and 2) have been a catalyst for a World Bank' study (Rasamoelina et al. 2015) that reviews, at the national level, the legal and institutional factors that may have contributed to the absence of statistically significant positive impacts of CFM on deforestation reduction and economic well-being. The World Bank' study pointed to gaps in CFM legislation, lack of consistency between CFM and other sector legislation, diverging objectives of CFM's implementation stakeholders, and the prevailing weak rule of law and corruption in the administration and judiciary systems of the country as potential causes for the absence of statistically significant positive impacts at the national level (Rasamoelina et al. 2015). However, the usefulness of these studies (manuscripts 1 and 2) to guide local forest management activities is limited. Externally defined and objective indicators of environmental and well-being outcomes often miss locally significant impacts (Sayer et al. 2007; Pokharel & Larsen 2007) and thus are limited in their capacity to provide appropriate guidance for locally relevant activities, particularly those intended to build locally legitimate intervention (Sayer et al. 2007; Milner-Gulland et al. 2014; Woodhouse et al. 2015).

To provide evidence on impacts that are locally relevant, local communities need to be put at the center of impact evaluation (Woodhouse et al. 2015). The local scale study on the relative impacts of a strictly protected area and CFM in eastern Madagascar (manuscript 3) has attempted to do so in two ways. First, it allows people to define well-being through the Global Person Generated Index (GPGI). The GPGI allows people to define their well-being by letting them make their own assessment of their lives and the circumstances in which they live, which is what subjective well-being is by definition (Diener 2006). The GPGI also makes room for people to define their well-being by recognizing that different individuals may have different views of well-being and thus allowing for the multidimensional nature of well-being. The second way the local scale study (manuscript 3) attempted to put local communities at the center of impact evaluation was by allowing people to define impacts through the participatory approach to establish the cause-effect relationship between the interventions and the outcomes. Together, the GPGI and the participatory approach to establish cause-effect relationship provided information that is relevant to guide local management activities. Information such as which locally valued life domains are perceived to be impacted by interventions and which ones should be prioritized to boost QoL in locally meaningful ways are crucial for project managers who seek local support and social sustainability.

Nevertheless, the participatory approach to establish the cause-effect relationship and subjective well-being indicators, like GPGI, presents some weaknesses in estimating the magnitude of impacts (Woodhouse et al. 2015). They can be influenced by the respondents' mood, orientation and cultural norms, and by timing (Camfield & Skevington 2008). However, as GPGI related measures are constructed from component QoL domains, they may be less affected by these sources of bias than subjective indicators that directly measure overall judgments of well-being (Schwarz & Strack 1999). Another concern for studies looking at impacts on subjective well-being is the response shift phenomenon, in which interventions do have impacts but people's adaptation to the circumstances they face makes the magnitude these impacts not detectable by subjective well-being measures (Schwartz et al. 2006). In such case, the GPGI has also an advantage over overall indicators of subjective well-being. The GPGI has the capacity of detecting the response shift. The GPGI does not only measure overall subjective well-being (GPGI score), but also explores its component domains, how respondents perform in each domain and the relative importance of these domains, and thus makes it possible to examine how individuals might have adapted their internal standards, values, or conceptualization of QoL in response to the interventions (Schwartz & Sprangers 1999; Schwartz et al. 2006). The GPGI is one of the tools in the Wellbeing in Developing Countries (WeD) framework (McGregor et al. 2009), for which there have been recent calls for an increase in use to evaluate well-being impacts of conservation interventions (King et al. 2014; Milner-Gulland et al. 2014; Woodhouse et al. 2015). However, despite these recent calls, to our knowledge this is the first study (manuscript 3) to use a WeD framework related tool, in forest conservation in developing countries.

IV-3- The placebo test: a potential method to address missing baseline outcome data

The placebo test in the economic well-being study (manuscript 2) provides indirect support for the adequacy of our empirical design to control for the missing pre-CFM household consumption expenditure. Many of the recent studies using rigorous causal effect empirical designs to evaluate impacts of protected areas lack baselines (Ferraro & Hanauer 2015). In a systematic review of studies on CFM impacts in developing countries, Bowler et al. (2012) found only two cross-sectional studies that have measures of baseline outcomes. Given this lack, the placebo test could be used more often to strengthen evidence on conservation impact evaluation. There are different ways to do the placebo test (Rosenbaum 2010; Ferraro & Hanauer 2014a; Ferraro et al. 2015). The one used in this study (manuscript 2) was chosen because of the availability of the 2005 household dataset. In addition to addressing the missing baseline outcome data, the placebo test also addresses the issue of unobserved confounding variables (Rosenbaum 2010; Ferraro & Hanauer 2014). If by conditioning on observed variables, the empirical design ensures that the placebo units and intervention units have similar outcome values (i.e., without intervention); then there will be indirect support that it captures other potential unobservable variables. However, the placebo test provides indirect support only for the adequacy of an empirical design to address bias from missing baseline outcome data and unobserved variables. It cannot rule out such bias (Ferraro & Hanauer 2014). In sum, the placebo test cannot replace baseline outcome data or any confounding variables, but it can strengthen evidence when such baseline is missing and given that there is always potential for unobserved variables.

IV-4- Perspectives for further research

The absence of statistically significant CFM deforestation impacts (manuscript 1) may explain the absence of statistically significant CFM economic well-being impacts (manuscript 2) or vice versa. On one hand, there are suggestions that enhanced ecosystem services improve well-being and diminished ecosystem services decline well-being (Suich et al. 2015). Therefore the statistically similar deforestation in CFM sites and non-CFM sites (manuscript 1), which may imply similar provisioning of forest ecosystem services, may have caused the statistically similar economic living standards of

CFM and non-CFM households (manuscript 2). On the other hand, there are suggestions that benefits or losses local communities derive from conservation interventions affect their environmental behavior and engagement in conservation (Adams & Hulme 2001). Therefore, the absence of statistically significant positive economic well-being impacts of CFM for CFM households may explain the absence of statistically significant reduction of deforestation in CFM sites. CFM has not benefited CFM communities, and thus they have not changed their environmental behavior or engaged in conservation. However, these discussed possible relationships between deforestation and well-being are just hypotheses. Rigorous causal mechanism effect studies investigating i) deforestation reduction as a mechanism through which conservation impacts well-being, and ii) well-being improvement as a mechanism through which conservation impacts deforestation, are needed to build strong evidence. Such future studies will greatly advance our knowledge of the conservation, nature and human well-being relationship, given that rigorous causal mechanism effect studies are very rare in conservation (Ferraro & Hanauer 2014b, 2015).

Interpretation of the deforestation (manuscript 1) and economic well-being (manuscript 2) studies in light of the subjective well-being study (manuscript 3) cannot be credibly done because they are at different spatial scales and involve different types of interventions (only manuscript 3 includes a strictly protected area). Future studies could aim to explore environmental outcomes and both objective material and subjective well-being outcomes in a study site that includes different interventions (e.g., strict protection and CFM), which were approximately established around the same time, and non-intervention area. A third well-being dimension, which is relational well-being, ideally could be added. Such studies will follow the three-dimensional (material, subjective and relational) approach of the WeD framework (Britton & Coulthard 2013).

V- CONCLUSIONS

In conclusion, our evidence does not strongly lend support for the decentralization of forest management to local communities as an approach to reduce deforestation or improve household economic standards of living across Madagascar. However, impacts vary as a function of management practices, such as whether CFM permits commercial use of forest resources, and other moderator variables, such as household characteristics. These findings highlight the importance of investigating heterogeneity of impacts because it can shed lights on elements that can be acted upon to promote effective interventions and on policy relevant issues, such as the equitable distribution of benefits. In eastern Madagascar, CFM has not significantly differed from strict protection in terms of the measures we used to compare the magnitude of impacts of these two interventions on subjective well-being. However, our study suggests that the characteristics of the subjective well-being component domains impacted by strict protection and CFM were different and that there were some differences in the priority domains that could be targeted by increased resource allocation to improve well-being in locally meaningful ways. On the one hand, objective outcome variables (e.g., remotely sensed deforestation and consumption expenditure) combined with rigorous quantitative causal inference methods (e.g., matching) can yield information on the magnitude of impacts that may be relevant to identify cost-effective interventions. On the other hand, subjective outcome variables, like the Global Person Generated Index (GPGI), combined with the participatory approach to establish cause-effect relationship provide a wealth of information highly relevant to build local participation and social sustainability. The GPGI gives insight into what life domains people value and their perceived performance in these valued domains. The participatory approach to attribute an effect to a cause allows identifying which of these valued domains people perceived to be impacted by the interventions. Conservation could benefit from program evaluation methods to strength evidence about its impacts on the environment and human well-being, but the appropriate method depends, among other things, on the intended use of the evaluation findings.

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Effectiveness of Community Forest Management at reducing deforestation in Madagascar

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ABSTRACT

Community Forest Management (CFM) is a widespread conservation approach in the tropics. It is also promoted as a means by which payment for ecosystem services schemes can be implemented. However, evidence on its performance is weak. We investigated the effectiveness of CFM at reducing deforestation from 2000 to 2010 in Madagascar. To control for factors confounding impact estimates, we used statistical matching. We also contrasted the effects of CFM by whether commercial use of forest resources is allowed or not. We cannot detect an effect, on average, of CFM compared to no CFM, even when we restricted the sample to only where information suggests effective CFM implementation on the ground. Likewise, we cannot detect an effect of CFM where commercial use of natural resources is allowed. However, we can detect a reduction in deforestation in CFM that does not permit commercial uses, compared to no CFM or CFM allowing commercial uses. Our findings suggest that CFM and commercial use of forest resources are not guarantees of forest conservation and that differentiating among types of CFM is important.

1. Introduction

The major role of tropical forests in biodiversity and climate change has led the world to search for effective ways to slow deforestation. Many approaches have come in and out of fashion. Strictly protected areas, which prohibit most human activities, were popular in the early days of conservation and remain so today. As an alternative to strict protected areas, Community Forest Management (CFM) emerged in the late 1980s (Hutton et al., 2005). By virtue of involving local forest users in management, CFM is promoted as having the potential to benefit both forests and local livelihoods (Behera, 2009). This potential, however, has been questioned (Behera, 2009) and its evidence base has been found to be weak (Bowler et al., 2012). Although Payments for Ecosystem Services (PES) have become the most recent fashion in efforts to reduce deforestation, CFM remains an important part of the forest management toolkit in many developing countries (Blaikie, 2006). It is also promoted as a means by which PES schemes can be implemented. High quality studies evaluating the effectiveness of CFM are therefore important for shaping future development and investment in approaches to reduce deforestation. We aim to provide robust evidence on effectiveness of CFM at reducing deforestation.

Studies investigating the effectiveness of conservation interventions often fail to adequately control for confounding factors that affect both the assignment of interventions and the outcomes of interest (Bowler et al., 2012; Ferraro and Pattanayak, 2006; Joppa and Pfaff, 2010). Recent studies investigating the effectiveness of protected areas at reducing deforestation have made progress in controlling for confounding factors by the use of statistical matching (e.g. Andam et al., 2013, 2008; Carranza et al., 2014; Ferraro et al., 2013). Matching selects comparison areas that have pre-intervention baseline values of confounding factors most similar to intervention area values, and thus makes it possible to control for these confounding factors (Joppa and Pfaff, 2011). However, we know of only one study (Somanathan et al., 2009) that has used matching to investigate the effectiveness of CFM at reducing deforestation.

A significant challenge for evaluating the effectiveness of CFM is the large variation in forest management practices and designs within the approach, both among and within countries (Lund et al., 2009). In terms of practices, examples of this variation range

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from cases where the community has a good understanding of their rights and responsibilities to cases where CFM exists on paper only (Benjamin, 2008; Lund et al., 2009). An example of design variation is that some CFMs allow communities to benefit from commercial use of forest resources within their managed forests while others do not (Persha et al., 2011). Failure to consider this variation compromises the potential for learning about design and implementation factors that promote CFM effectiveness.

The Malagasy government legislated CFM in the late 1990s (Raik, 2007) to reduce deforestation and protect the significant part of the world's biodiversity that is endemic to Madagascar (Le Saout et al., 2013). The number of CFM units increased rapidly and continues to grow (Aubert et al., 2013). Many publications review the institutional and political aspects of Madagascar's forest decentralization process (Pollini et al., 2014; Pollini and Lassoie, 2011; Raik and Decker, 2007; Rives et al., 2013; Urech et al., 2013), but only a few focus on empirically estimating the performance of CFM in terms of conservation outcomes (CIRAD, 2013; Sommerville et al., 2010; Toillier et al., 2011). None adequately control for factors that may confound impact estimates.

Using statistical matching to control for factors that confound impact estimates, we investigate the effectiveness of Madagascar CFM at reducing deforestation between 2000 and 2010. To our knowledge, this is the first national scale study of performance of CFM at delivering conservation outcomes. First, we assess the overall effectiveness of Madagascar's forest decentralization policy at reducing deforestation by looking at all CFM units across the country. Second, we distinguish and study effectiveness in a subsample of CFM units where we have information to suggest that CFM was implemented on the ground. Finally, we differentiate between CFM that allows and does not allow commercial use of forest resources and study effectiveness conditional on whether CFM permits or prohibits commercial use. Note that we do not consider other important potential outcomes from CFM including impacts, positive or negative, on human welfare.

2. Methods

2.1. Study areas

In Madagascar, the transfer of forest management to local communities involves three main steps; the creation of a local forest management group, adoption of forest rules, and signed contract between the local forest management group, the state forest department and possibly the municipality where the forests are located (Aubert et al., 2013; Pollini and Lassoie, 2011). In our study, CFM refers to forests managed by communities that achieved these three steps.

Our study covers CFM established between 2000 and 2005 (Fig. 1). Because 2010 is the end of the period of our analyses, selecting CFM established between 2000 and 2005 allows observing at least five years of deforestation impacts post CFM establishment. There is no national database containing current information on all CFM units. We therefore gathered information from multiple sources including organizations involved in implementation; namely, Direction Générale des Forêts, Office National pour l'Environnement, Asity, Fanamby, Durrell Wildlife Conservation Trust, Conservation International, Wildlife Conservation Society, and World Wide Fund for Nature.

Malagasy CFM varies in their implementation quality. Some were established with little input from local communities (Rives et al., 2013), and others received little or no external support (Hockley and Andriamarovololona, 2007). It is very difficult to get information of the implementation quality of the individual CFM unit. We used whether a CFM unit passed the forest department evaluation that is undertaken three years after the contract (Pollini and Lassoie, 2011) as an indicator of whether the project was indeed implemented. While not an ideal indicator, it does at least suggest the CFM unit has met the basic institutional, socio-economic and environmental criteria of the evaluation. We refer to units that passed the evaluation as CFM units that have information to suggest implementation.

CFM implementation in Madagascar varies according to regulations related to commercial use of forest resources. Commercial CFM allows commercial uses and adopts it as a conservation strategy. Non-commercial CFM does not permit commercial uses and follows a pure conservation strategy (Randrianarivelo et al., 2012). Because there are no reliable national data regarding where commercial uses are permitted within CFM, we conducted analyses on commercial and non-commercial CFM for four sites only, where we were able to ascertain information on commercial uses through field visits, interviews with site managers or search of existing literature. The four sites are Didy, Tsitongambarika, Menabe and Boeny (Fig. 1). All CFM units that we considered in these four sites had passed the forest department evaluation. Table 1 presents the number of CFM units, the area of land and natural forest covered by each type of CFM considered in our analyses.

Non-CFM areas refer to forests that, up to 2010, were not technically and financially supported by particular organizations and thus were under government control. Since the government has been weak and unable to enforce forest laws, these forests are subject to open access (Raik, 2007; Urech et al., 2013)

We excluded six out of the 22 administrative regions of Madagascar where we were unable to collect CFM data (Fig. 1). Because we analyzed CFM established between 2000 and 2005, undated CFM and CFM established before 2000 or after 2005 were excluded. We also excluded protected areas managed by Madagascar National Parks. Finally, extensions of protected areas, temporary and new protected areas created since 2003 were excluded. However, any portions of these newly created protected areas that were known to be community managed were considered as CFM (Fig. 1, see Appendix D Table D1 for how CFM, non-CFM and excluded areas fit into official Madagascar forest statuses since 2003).

2.2. Matching, unit of analysis, sampling

Conservation interventions like CFM are not randomly assigned. The site characteristics that affect where conservation interventions are assigned also affect deforestation, thus confounding attempts to estimate intervention impacts (Ferraro and Pattanayak, 2006). To control for these confounding factors, some empirical studies have used matching (Andam et al., 2008; Joppa and Pfaff, 2011). Matching selects comparison areas that are similar to the intervention areas in terms of their values of the confounding factors at the pre-intervention baseline. Thus, one assumes that the outcomes of the comparison group represent, in expectation, the counterfactual outcomes of the intervention sites had they not been exposed to the conservation intervention.

The unit of analysis is a forested pixel from the 2000 forest cover baseline (See Appendix A for limitations of using 2000 baseline forest cover and CFM established between 2000 and 2005, and Appendix B for how we deal with potential pseudo-replication in which pixels within a particular CFM are not independent). For each forested pixel at baseline, covariates take the values of each confounding characteristic at that pixel location. For each analysis (Table 2), we selected random forested pixels in intervention areas. Then, we used matching to pair each randomly selected pixel with the most similar pixel in comparison areas in terms of covariates. The outcome variable is whether a pixel remained forested or not in the 2010 land cover. The estimated difference in deforestation between intervention and similar comparison

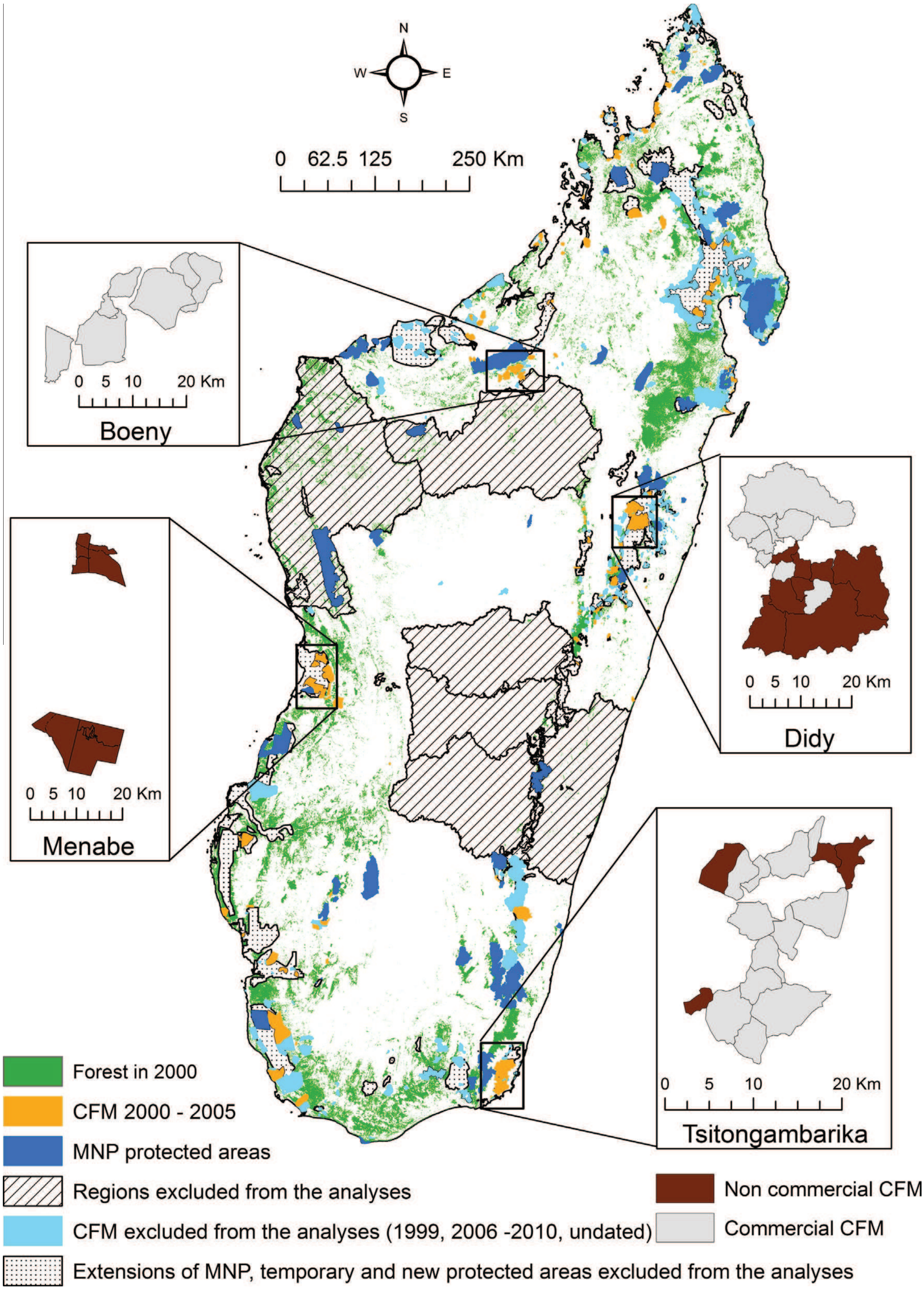

Fig. 1. Map showing CFM established between 2000 and 2005, commercial and non-commercial CFM sites and areas excluded from the analyses (Projection: Laborde Madagascar).

areas represents the impact of the intervention on deforestation for intervention sites or the Average Treatment effect on the Treated (ATT).We used independent samples T-test to compare deforestation in intervention and similar comparison or counterfactual areas.

Our study comprises six analyses (Table 2). The first analysis compares all CFM established between 2000 and 2005 to non-CFM. The second compares the CFM that has information that suggests implementation to non-CFM. The four remaining analyses regard commercial and non-commercial CFM. Ferraro et al.

Table 1
Number of units and dimension of different types of Community Forest Management (CFM).

Types	Study site (scale)	CFM unit	Land area (ha)	Natural forest area in 2000 (ha)
All CFM	Madagascar	231	699,961	308,290
CFM with information suggesting implementation	Madagascar	116	399,861	211,666
Commercial CFM	Didy	8	29,104	23,409
	Tsitongambarika	12	18,089	7214
	Boeny	7	30,920	10,768
Non commercial CFM	Didy	8	40,164	32,757
	Tsitongambarika	4	3757	866
	Menabe Antimena	4	22,042	13,991

Table 2
Different types of analyses.

Analysis	Intervention	Counterfactual	Estimand
Effectiveness of all CFM	All CFM	Non-CFM	Difference of deforestation between CFM and CFM had there been no intervention
Effectiveness of CFM with information suggesting implementation	CFM with information suggesting implementation	Non-CFM	Difference of deforestation between CFM and CFM had there been no intervention
Effectiveness of commercial CFM	Commercial CFM	Non-CFM	Difference of deforestation between CFM and CFM had there been no intervention
Effectiveness of non commercial CFM	Non commercial CFM	Non-CFM	Difference of deforestation between CFM and CFM had there been no intervention
Relative effectiveness of commercial and non commercial CFM on the types of CFM forests where commercial use has been permitted	Commercial CFM	Non commercial CFM	Difference of deforestation between actual commercial CFM forests and these forests had commercial use been prohibited
Relative effectiveness of non commercial and commercial CFM on the types of forests where commercial use has been prohibited	Non commercial CFM	Commercial CFM	Difference of deforestation between actual non commercial CFM forests and these forests had commercial use been permitted

(2013) demonstrated that four ATTs are policy relevant for studies involving two types of intervention. The third and fourth analyses compare commercial and non-commercial CFM to non-CFM. The fifth and sixth ones compare commercial to non-commercial CFM, and vice versa. The difference between these two latter analyses rests upon the type of the sampled pixels used in the comparison. The CFM forests where commercial use is permitted may be observably different from the CFM forests where such use is prohibited (in terms of the confounding factors). To understand how deforestation in commercial CFM forests would have been different without commercial use requires that we compare commercial CFM forests to non-commercial CFM forests that are observably similar at baseline (in terms of the confounding factors). So the comparison of commercial to non-commercial CFM uses an intervention group of all the randomly selected commercial CFM pixels and a comparison group of only the best matches of non-commercial CFM pixels. Dissimilar pixels from the non-commercial CFM sample are discarded. The estimate from this comparison represents the average impact of permitting commercial use on the types of CFM forests where commercial use has been permitted. The impact of commercial use may be different on the types of CFM forests where commercial use has been prohibited. To estimate this impact, we formed an intervention group of all the randomly selected non-commercial CFM pixels and a comparison group of only the best matches of commercial CFM pixels.

In all analyses, we used Mahalanobis covariate matching because it better balances covariates than other matching options. We performed exact matching on vegetation zones (eastern humid, western deciduous and southern spiny forests, Appendix E Fig. E1). We executed bias adjustment regression to correct for any remaining post-matching covariate imbalance (Abadie and Imbens, 2006). We used the "matching" package in R (Sekhon, 2011).

We aimed to select sample sizes that balance our interests in achieving high statistical power and reducing computer processing time. Learning from multiple trial analyses, we decided on a sample of around 30,000 pixels for all intervention areas in each analysis. For comparison areas, we sampled around two to four times more pixels (Appendix D Table D2). The larger sample size from comparison areas increases the probability of finding a good match for each intervention pixel.

2.3. Forest cover

We used 2000 and 2010 deforestation data developed by ONE et al. (2013). These are based on images from Landsat TM and Landsat ETM+ and have a resolution of 28.5 m and an accuracy rate close to 90%. Full methods are in Harper et al. (2007).

2.4. Covariates or confounding baseline characteristics

Based on Madagascar CFM practitioners' opinion, and CFM and deforestation studies in Madagascar and other tropical countries (Barsimantov and Kendall, 2012; Bowler et al., 2012; Forrest et al., 2008; Gorenflo et al., 2011; Sussman et al., 1994), we identified pressure and access as potentially confounding factors. To control for these factors, we used measures of agricultural suitability, slope, elevation, distance to recent deforestation (1990–2000), distance to forest edge, distance to a village, distance to an urban center, distance to a road, distance to a cart track, duration of trip to an urban center and population density (see Appendix D Tables D3, D4 for sources of covariate data). Because community characteristics received little consideration in selection of community forests for CFM designation, we did not consider community characteristics as confounding factors but only condition on these site characteristics indicating pressure and access (see Appendix C).

2.5. Sensitivity analysis to unobservable bias

While matching can ensure that the distributions of observable covariates are similar between intervention and comparison groups, the groups may still differ in terms of unobserved covariates that affect both deforestation and assignment to intervention. To check the robustness of our estimates of effectiveness to such unobservable covariates, we performed Rosembaum's (2010) sensitivity test. A parameter Γ measures the dissimilarity in the likelihood of receiving intervention between intervention and counterfactual units due to unobservable covariates. In the absence of unobservable differences, Γ takes the value of one 1. The higher the value of Γ, the more dissimilar is the likelihood of receiving intervention for the matched pair due to unobserved variables. The sensitivity analysis consists of increasing the values of Γ and determining a critical Γ at which the estimate of effect of intervention is not significantly different from zero. In other words, we seek to measure how strong an unobservable confounder would have to be in order for the estimated effect not to be significantly different from zero. The higher the value of the critical Γ, the more robust is the estimate of intervention effect to unobservable bias. We carry out sensitivity tests with the "rbounds" package in R (Keele, 2010).

3. Results

Before matching, CFM pixels are, on average, located closer to recent deforestation, to a road and to an urban center and are characterized by shorter trip durations to an urban center than non-CFM pixels. Although these patterns suggest CFM is assigned to areas of higher deforestation pressure, CFM is also located on lands less suitable for agriculture and at higher elevation (Appendix D Table D5).

Commercial CFM pixels are, on average, associated with lands more suitable for irrigated rice, closer to a village, a road and an urban center, shorter trip duration to urban center, higher population density, but they are located on lands less suitable for agriculture and on steeper slopes than non-commercial CFM sites (Appendix D Tables D9, D10).

Matching generally improves covariate balance. The mean differences and the mean raw eQQ differences of covariates in intervention and counterfactual areas tend toward zero after matching (Appendix D Tables D5–D10). An exception is suitability for agriculture in the comparisons of commercial and non-commercial CFM, and vice versa. Matching does not improve balance for this factor (Appendix D Tables D9, D10). This is because all suitable lands for agriculture are found only in the non-commercial CFM in Menabe. Thus, there are no matched suitable lands in commercial CFM. We describe potential effects of this imbalance in the discussion.

Between 2000 and 2010, CFM sites had, on average, 0.02% less deforestation than matched non-CFM sites, a statistically insignificant difference ($p = 0.99$, Fig. 2). When we consider only CFM with information suggesting implementation, CFM had 0.76% less deforestation than matched non-CFM, but still statistically insignificant ($p = 0.71$). Differentiating CFM by whether commercial uses are allowed, we estimate that commercial CFM experienced 1.83% more deforestation than matched non-CFM ($p = 0.16$). Non-commercial CFMs reduced deforestation by 2.01% relative to matched non-CFM ($p < 0.001$). When we compare commercial CFM to matched non-commercial CFM, to investigate their relative effectiveness on the types of CFM forests where commercial use has been permitted (i.e., forests on lands more suitable for irrigated rice, closer to a village, a road and an urban center, shorter trip duration to urban center, higher population density), commercial CFM experienced 3.24% more deforestation ($p < 0.001$). Comparing non-commercial CFM to matched commercial CFM, to investigate their relative effectiveness on the types of forests where commercial use has been prohibited (i.e., forests on lands less suitable for irrigated rice, farther to a village, a road and an urban center, longer trip duration to urban center, lower population density), we estimate non-commercial CFM reduced deforestation by 5.59% ($p < 0.001$, Fig. 2).

Table 3 presents the results of the sensitivity of our analyses to hidden bias (i.e., an unobservable covariate). For example, where the parameter Γ is 1.38, the estimate of 2.01% remains significantly different from zero at a p value of 0.05 even if an unobservable covariate makes non-commercial CFM pixels 1.38 times more likely to receive intervention than non-CFM pixels. In other words, unobservable covariates need to increase the likelihood of the non-commercial pixels to receiving intervention by a factor greater than 1.38 in order for the impact estimate not to be statistically different from zero.

4. Discussion

Decentralization of forest management to local communities in Madagascar has not, on average, achieved its forest conservation goal. In terms of deforestation, we cannot detect an effect, on average, of CFM compared to no CFM, even after restricting the sample to only where we have information to suggest CFM implementation on the ground.

Many studies report success and failure of CFM at delivering conservation outcomes (Cox et al., 2010; Pagdee et al., 2006; Porter-Bolland et al., 2012). However, in a systematic review of CFM performance in developing countries, Bowler et al. (2012) showed that evidence on effectiveness of CFM is weak because of poor study design. They proposed a "gold standard" that would produce quality CFM assessment. We believe that our study meets the "gold standard" as far as is possible (though only for a single potential outcome from CFM – that of reducing deforestation). That is, we use comparator sites, baseline forest cover data, multiple CFM across Madagascar and paired or matched design. We also sample randomly the unit of analysis and allow enough time (5–10 years) for impacts to take place. Finally, we identify and control for confounding factors that may bias impact estimates.

While CFM failed, on average, to reduce deforestation relative to non-CFM, non-commercial CFM appears to have had more success, albeit a small one. Putting all types of CFM in one basket would lead to the single conclusion that CFM is not an effective approach to reduce deforestation, obscuring the positive impact non-commercial CFM appears to have had. This result emphasizes the importance of differentiating among types of CFM in evaluation (Lund et al., 2009). Potential mechanisms through which non-commercial CFM may have had more success are complementary direct payments for conservation. Some non-commercial CFM in our study sites in Didy, Tsitongambarika and Menabe practice a direct payment for conservation scheme to offset restrictions introduced by interventions (e.g. Brimont and Bidaud, 2014; Sommerville et al., 2010).

The estimated reduction in deforestation from non-commercial CFM is important given that the role of commercial use of forests in conservation is a subject of much debate in theoretical and empirical studies. Some studies argue that by assigning value to forests, commercial use provides means and incentives to local communities to protect forests, while others show that it can trigger the destruction of the resources being commercialized (Agrawal and Chhatre, 2006; Barsimantov and Kendall, 2012; Persha et al., 2011). Our findings do not support the argument that permitting commercial extraction can enhance the deforestation-reducing impacts of CFM.

Our matching algorithm was unable to remove the pre-matching difference between commercial and non-commercial CFM in terms of agriculture suitability (Appendix D Tables D9, D10). After matching, commercial CFM has lower suitable lands for agriculture (0%) than non-commercial CFM (29%) has. However, knowledge of the direction of the effect of agriculture suitability on deforestation allows us to infer the implications of the post-matching imbalance. Gorenflo et al. (2011) show that lower suitability for agriculture is

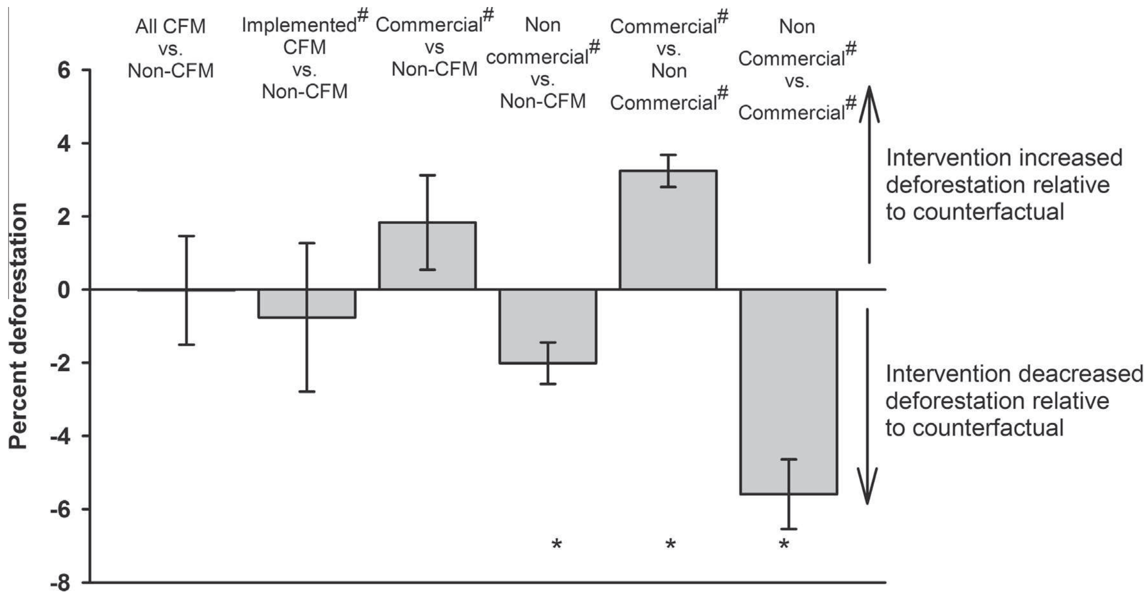

Fig. 2. Differences in percent deforestation between intervention and counterfactual (#CFM where we have information to suggest implementation, * significant at $p < 0.001$, error bars: standard errors for post-matching estimates that are calculated using a variance formula that is robust to heteroskedasticity and adjusts the variance estimator for repeated matches among control units (Abadie and Imbens, 2006).

Table 3
Sensitivity tests to unobservable covariates.

Analysis	Critical Γ at $p = 0.05$
Non commercial CFM vs. non CFM	1.38
Commercial CFM vs. non commercial CFM	1.50
Non commercial CFM vs. commercial CFM	5.85

associated with lower deforestation rates in Madagascar. Thus, the post-matching imbalance should occasion lower deforestation in commercial CFM than non-commercial CFM. Therefore, if matching had balanced the suitability for agriculture between the two types of CFM, commercial CFM performance relative to non-commercial CFM would have appeared even worse because the lower deforestation occasioned by the lower land suitability in commercial CFM would have been erased. Our estimates of impacts for commercial vs. non-commercial CFM, and vice versa are thus conservative.

At the national level, our findings substantiate the rather gloomy pictures of CFM in Madagascar depicted in a number of institutional and policy studies (Pollini et al., 2014; Pollini and Lassoie, 2011; Raik and Decker, 2007; Rives et al., 2013; Urech et al., 2013). To explain the ineffectiveness of CFM, these studies describe inadequate integration of local participation, resource capture by elites, unfulfilled support promises by different organizations, and lack of capacity of the community and state, among other factors. While these studies point to institutional and policy shortcomings, we advance our understanding of CFM performance by empirically showing that at the national scale, there was no impact in terms of delivering a central objective: reducing deforestation. A recent empirical study (CIRAD, 2013) is of particular interest because it also looked explicitly at the impact of CFM on deforestation and covered part of our study areas, and its results contradict ours. It found that deforestation was significantly less in CFM than in areas without community conservation. It also shows that commercial CFM was more effective at reducing deforestation than non-commercial CFM. The results are not directly comparable to ours because the analyses cover a different time period and are at a different spatial scale, but the CIRAD study should be interpreted with care because they did not adequately control for the biases in confounding factors that we do here. Failure to adequately control for such biases can result in incorrect impact estimates (Andam et al., 2013, 2008; Joppa and Pfaff, 2011).

Many factors can influence effectiveness of CFM (Agrawal, 2003). We focused on the potential role of commercial use of forest resources (and given our study area, the potential that complementary direct payment for conservation could have in non-commercial CFM). Another potential moderating factor is the amount of resources invested, which may explain the apparently better performance of non-commercial CFM relative to commercial CFM we observe. During our visit to Didy, commercial CFM officials complained about receiving smaller resources relative to their neighboring non-commercial CFM (implemented by different organizations with different funding). However, we lacked the quantitative information on spending to allow this potential moderator of success to be included in the analysis. Data on this moderator in the future will also offer opportunities to extend our study by exploring CFM cost-effectiveness.

We focused on comparing CFM to non-CFM and different types of CFM. Other studies attempt to compare CFM to strictly protected areas (IUCN categories I–IV) to investigate the relative effectiveness of these two different approaches (Bray et al., 2008; Porter-Bolland et al., 2012). We do not attempt such a comparison because we believe that investigation of the relative effectiveness of strictly protected areas and CFM at reducing deforestation cannot be done credibly for Madagascar with the same robust and rigorous methodology we used here. Matching covariates and baseline forest cover ideally should be measured before intervention (Andam et al., 2008). CFM units in Madagascar were established in or after 2000 while 80% of the strictly protected areas were created before 1970. Thus, strictly protected areas and CFM have different baselines (2000 vs. pre-1970). If these baseline measures are to be used, the start time for the analyses will have to be different for CFM (2000) and strictly protected areas (pre-1970). Therefore, the comparisons of CFM to strictly protected areas, and vice versa, are difficult for Madagascar because the impacts will be estimated for dramatically different time periods. In addition, communities around and managers of strict protected areas and those of CFM have different length of experience in exposure to intervention that may explain the difference of impacts between the two approaches. Such comparisons may yield credible results in specific sites or in other countries, where strictly protected areas and CFM were established around the same time.

In conclusion, we provide robust evidence that CFM and commercial use of forest resources are not guarantees of conservation success. Our findings also suggest that differentiating among types of CFM is important when evaluating effectiveness. By explicitly estimating impacts conditional on the type of CFM, scholars can shed light on the factors that promote effective CFM.

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Appendices. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.biocon.2015.01.027.

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Manuscript 2

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Impacts of Community Forest Management on human economic well-being across Madagascar

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Abstract

Community Forest Management (CFM) involves the devolution of forest management to local communities to deliver both conservation and human well-being goals. However, the evidence for CFM's impacts is mixed, with studies reporting both positive and negative effects. Moreover, interpreting the evidence is difficult because of inadequate attention to rival explanations for the observed patterns. We evaluate, at the national scale, CFM impacts on household living standards in Madagascar as measured by per capita consumption expenditures, controlling for confounding factors and paying particular attention to the pre-intervention values of the outcome measures. We detected no statistically significant impact on living standards on average across CFM communities but found a mixture of positive and negative impacts conditional on household proximity to forest and education. Household characteristics may strongly moderate CFM impacts, and thus scholars and practitioners should expect heterogeneity in impacts within and across sites.

Keywords: Community forest management, effectiveness, falsification test, impact evaluation, Madagascar, matching, placebo test, poverty, REDD+, welfare

Introduction

Community Forest Management (CFM) is one of the most widespread conservation approaches in developing countries. It can also play an important role in the climate mechanism Reducing Emissions from Deforestation and Degradation (REDD+); with evidence suggesting that stronger local participation in forest management can lead to increasing carbon storage (Chhatre & Agrawal 2009). Advocates suggest CFM can avoid negative impacts of forest protection on local communities (Behera 2009). However, evidence for the impact of CFM on human well-being is mixed with studies reporting both negative and positive impacts (Bandyopadhyay & Tembo 2010; Ameha et al. 2014; Gelo & Koch 2014), and many studies having major design limitations (Bowler et al. 2012). Therefore, well-designed studies evaluating the impacts of CFM on human well-being are needed to better direct future efforts.

Quantifying the impacts of conservation interventions is challenging (Baylis et al. 2015). One challenge is that conservation interventions are rarely randomly assigned. Characteristics that influence intervention assignment may also affect the outcome and thus can confound impact estimates (Ferraro & Pattanayak 2006). In studies of CFM impacts on well-being, these confounders are rarely identified and controlled (Engel et al. 2013). When confounders are observable, matching (selecting comparison units that are observably similar to intervention units in terms of pre-intervention confounding characteristics (Joppa & Pfaff 2011)) can address the non-random assignment of interventions (Ferraro & Pattanayak 2006).

Ideally, a study using matching should have outcome baseline data gathered before intervention (Ferraro & Hanauer, 2014) to control for initial conditions that may confound measures of effectiveness. Unfortunately, such data rarely exist in CFM impact evaluation (Bowler et al. 2012). There have been recent suggestions that a falsification or placebo test could be used as an indirect way to address the issue of missing baselines (Ferraro et al. 2015). In such a test, the researcher postulates a hypothesis that is true if the empirical design does not suffer from bias because of missing baselines (Ferraro & Hanauer 2014). If the hypothesis cannot be rejected, the researcher can be more confident in the design's ability to estimate impacts without bias. To our knowledge, no CFM impact studies have used the placebo test to address the missing baseline issue.

Another major challenge in conservation impact evaluation is that different groups within the same community could experience effects of the intervention differently (Milner-Gulland et al. 2014). Consideration of heterogeneous impacts on different groups can inform policy aiming at the equitable distribution of conservation benefits.

Madagascar is world renowned for the biodiversity of its natural forests. Madagascar was one of the first nations in the southern hemisphere to put in place a legal framework for CFM (Andriantsilavo et al. 2006) that aims to conserve its highly threatened forests while providing benefits to local communities (Aubert et al. 2013). Only a few case studies (Hockley & Andriamarovololona 2007; Toillier et al. 2011; Ramamonjisoa & Rabemananjara 2012) have empirically investigated the impacts of CFM on human well-being. None of these studies were at a national scale and none adequately controlled for characteristics confounding impacts.

We investigate the impacts of CFM on household living standards, as measured by household consumption expenditure in Madagascar. CFM could produce both positive and negative impacts on household living standards. Negative impacts could result from benefits forgone (due to restrictions on use of forest resources) or the costs of forest management (e.g. patrolling). Positive impacts could come from improved forest management enhancing forest productivity and ecosystem services important for livelihoods (e.g. watershed protection). CFM communities can also benefit from developing ecotourism or through external support (Hockley & Andriamarovololona 2007). For example, the new protected areas, which include most CFM sites in Madagascar, received up to US$ 10.5 million of external support in 2011 alone (Carret 2013). We also explore the heterogeneity of impacts as a function of proximity to forest and education level because previous studies suggest that households within or nearer forests are more politically and socio-economically disadvantaged and more affected by conservation interventions (Ratsimbazafy et al. 2011) and that more educated households capture more CFM benefits (Pollini & Lassoie 2011).

Methods

Study areas

Our study covers all of Madagascar's land area. We define CFM as natural forests, with clearly defined boundaries, managed by a local forest management group that entered into a signed management agreement with the state forest department under the 1996 or 2001 Malagasy CFM legislation. Our data show there were 1,019 CFM sites in 2014, covering about 15% of the nation's natural forests (Figure 1A, Table S1 for sources of data).

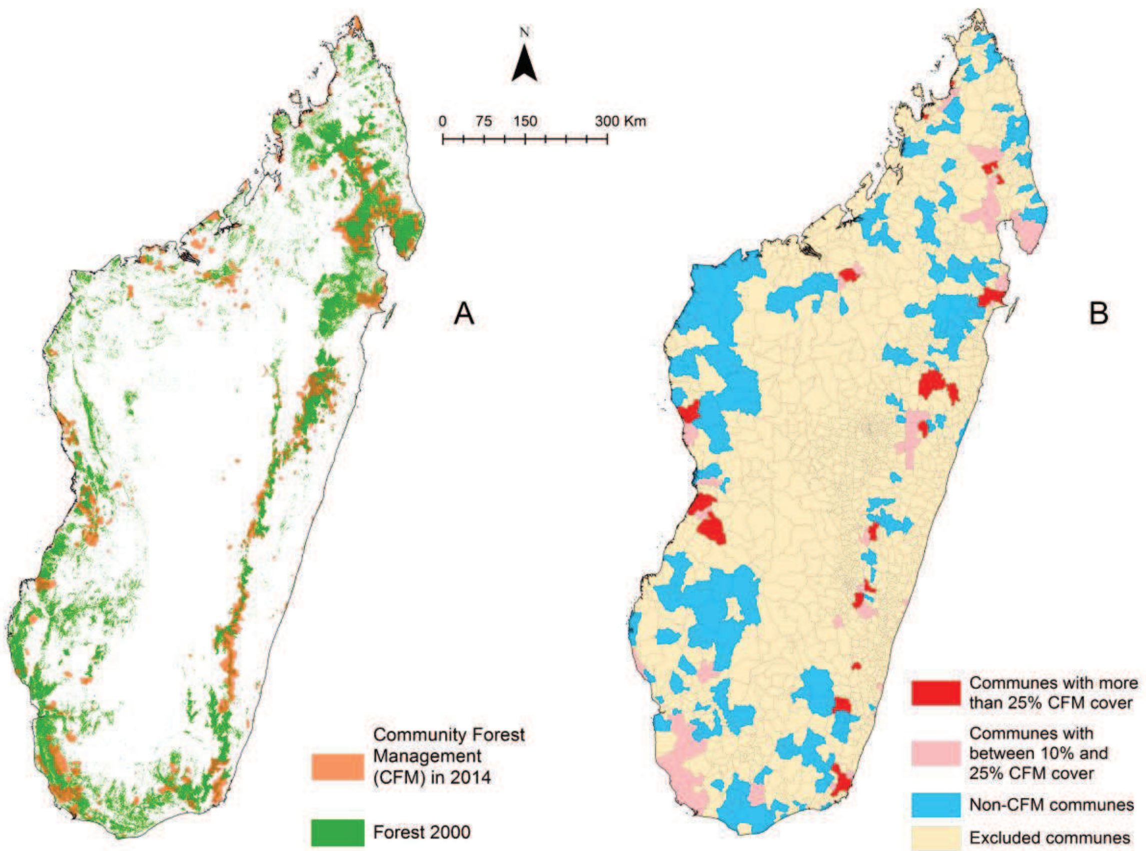

Figure 1. Study sites. A) Community Forest Management (CFM) sites in 2014; B) CFM communes, non-CFM communes, and communes excluded from the analyses (Projection: Laborde Madagascar)

Unit of analysis

Our unit of analysis is the household. CFM households are those within a commune that has 10% or more of its area covered by CFM (we also performed a sensitivity test using a threshold of 25%). Non-CFM households are those within a commune that has less than 1 % of its area covered by CFM. Households within a commune that has between 1% and 10% of its area covered by CFM, urban communes and communes that have less than 5% of their areas forested were excluded (Figure 1B). More detail concerning our justification for choosing the percent CFM cover of a commune as the selection criterion is given in Text S1.

Well-being outcome variable

The outcome variable is annual household per capita consumption expenditure. Although we acknowledge that "well-being" is multi-dimensional (King et al. 2014), we focus on the narrow concept of living standard measured by household consumption because data on other dimensions of well-being at an appropriate scale are unavailable. However, living standard is widely recognized as an important component of well-being (Bérenger & Verdier-Chouchane 2007) and household consumption has been the core of living standard surveys in many developing countries (Beegle et al. 2012).

We pooled cross sectional data on household consumption from the 2010 and 2012 national household surveys undertaken by Madagascar statistical agency (INSTAT). The two surveys, carried out on different nationally representative samples, provide comparable data covering food and non-food consumption, spending on durable goods and housing from 29,380 randomly sampled households. These consumption items were aggregated following Deaton & Zaidi (2002). We adjusted for regional and temporal differences in prices and converted to US dollar using the World Bank 2005 purchasing power parity conversion factor.

We estimated the impact of CFM on consumption for the CFM households, also known as the Average Treatment effect on the Treated (ATT), and tested whether it is statistically different from zero. Because CFM restricts some forest use and past studies suggest that CFM has had negative impacts on human well-being in Madagascar (Hockley & Andriamarovololona 2007; Toillier et al. 2011; Ramamonjisoa & Rabemananjara 2012), we also tested whether we can reject the hypothesis that CFM has caused a moderate decline in per capita consumption, which we define as a quarter standard deviation decline.

To allow at least three years of impact, we only considered CFM established before 2007 inclusive to be analyzed with the 2010 household data. For the 2012 household data, only CFM established before 2009 inclusive was considered. The numbers of sampled CFM and non-CFM households are shown in Table 1.

Table 1. Numbers of CFM and non-CFM communes and sampled households

Dataset	Commune		Household	
	CFM	Non-CFM	CFM	Non-CFM
Threshold 10% CFM cover of the commune				
2010	83	319	698	2,179
2012	107	303	760	1,938
Total			1,458	4,117
Threshold 25% CFM cover of the commune				
2010	31	319	115	2,179
2012	44	303	303	1,938
Total			418	4,117

Matching and post-matching analyses

Matching pairs CFM households with non-CFM households that are similar in terms of potentially confounding characteristics at baseline. After matching, the only systematic difference between CFM and non-CFM households ideally should be the CFM presence. Thus, one can assume that the non-CFM household consumption equates the counterfactual consumption had there been no CFM and the difference in consumption in CFM and similar non-CFM households is an unbiased estimator of the ATT.

We executed one to one matching with replacement with the genetic matching algorithm in the "matching" package in R (Sekhon 2011). To adjust for the remaining post-matching covariate imbalance, we performed weighted mixed effects linear regression, with commune as random intercept on the matched dataset. Studies show that combination of matching and regression yield more accurate estimate than either of them alone (Ferraro & Miranda 2014).

Confounding characteristics

Previous work has shown that site level characteristics, like human pressure and access (Table 2), can affect both assignment of forests to CFM (Rasolofoson et al. 2015) and household consumption (Stifel et al. 2003). Moreover, household characteristics (Table 2) not only influence where households choose to live in Madagascar (IOM 2014), but also their consumption. We thus control for confounding site and household characteristics in the matching analysis. Because the drought in southern Madagascar and the frequent cyclones in the east are known to significantly influence household's living standards, we executed exact matching on arid and cyclonic areas (INSTAT 2011). We also performed exact matching on the year when the data were produced (2010 or 2012). We did not include community characteristics because we do not believe they strongly affect selection of sites to CFM in Madagascar. The establishment of CFM in Madagascar has been driven by external conservation agendas rather than communities themselves (Pollini & Lassoie 2011). Many CFM sites have been designed to improve management of the newly created protected areas or to form a "green belt" to shield the core zones of these protected areas (Rasolofoson et al. 2015). We therefore argue that site characteristics are more important to selection to CFM than community characteristics but we describe the implications of incorrectly excluding them in Text S2. Data sources are in Table S1.

Table 2. Confounding characteristics

	Variables	**Unit**
Site characteristics	Slope (average, maximum)	Commune
	Elevation (average, maximum)	Commune
	Roadless volume	Commune
	Cart trackless volume	Commune
	Suitable for irrigated rice	Commune
	Area of forest land	Commune
	Proportion of forested land	Commune
	Duration of trip to the nearest urban center	Commune
	Population density	Commune
	Proportion of forest protected areas (MNP)	Commune
	Proportion of forest land	Commune
Household characteristics	Household head age	Household
	Household head without any formal education	Household
	Household head with primary education	Household
	Household with secondary education or higher	Household
	Household head gender	Household
	Single female household head	Household
	Presence of a child under 5	Household
	Presence of a disabled individual (5 years old or more)	Household

Placebo test

Ideally, we would confirm that the matched CFM and non-CFM households had similar consumption before CFM began, thus ruling out pre-existing differences as an explanation for post-CFM differences in consumption. We do not have pre-CFM consumption data because earlier surveys used a different sample of households. Instead, we performed a placebo test (Ferraro & Hanauer 2014) to test whether the pre-CFM observable confounding characteristics we used are sufficient to control for pre-CFM household consumption.

For the test, we used data from a 2005 INSTAT survey, which collected, in similar way, the same data as those from the 2010 and 2012 surveys, but from a different sample (Table S2). None of the sample households were in CFM sites in 2005, but some became CFM sites after 2005. We match these soon-to-be CFM (placebo) sites to sites never exposed to CFM using the same matching procedure and variables we apply to the 2010 and 2012 household data. In 2005, there is no CFM treatment yet, and thus if the matching procedure is effective, consumption expenditures in the placebo CFM and non-CFM sites should be similar, on average. If this null hypothesis cannot be rejected, the assumption that the matching procedure balances the unobservable pre-CFM consumption levels in the 2010 and 2012 matched samples is more plausible.

Heterogeneous impacts of CFM

Following Ferraro et al. (2011, 2015), we used a two-stage semi-parametric partial linear differencing model (PLM) to explore the heterogeneity of impacts on household consumption as a function of the distance of the household location to the nearest forest edge and number of years of household head education. The first stage consists of linearly controlling for the confounding characteristics. The second stage uses a non-parametric locally weighted scatter plot smoothing (LOESS) to estimate per capita consumption as a function of the continuous moderator variable of interest (household proximity to forest or household head education). In other words, PLM allows estimating impacts along the possible values of a moderator variable, holding constant the other confounding characteristics (Ferraro & Hanauer 2014). We performed PLM on the matched dataset with the plm and plmplot R functions (Hanauer 2015).

Results

Before matching, CFM and non-CFM households do not differ much in terms of household characteristics (Tables S4, S5). In contrast, there are large pre-matching differences between CFM and non-CFM sites for some site characteristics. CFM communes have more forest area and percentage of forest area, less roadless and cart trackless volume, are less densely populated and closer to urban centers than non-CFM communes (Tables S4, S5).Matching improved covariate balance as shown by the post-matching mean differences and mean raw eQQ differences of covariates (Tables S4, S5).

We cannot reject the null hypothesis of our placebo test, which provides indirect support for the adequacy of our empirical design. The estimated effect is 4.09% (US$ 13.60) more per capita consumption in the placebo CFM, a result that is not statistically significant (p=0.76).

After matching, the estimated effect of CFM on per capita consumption is positive, but not statistically significant, regardless of whether treatment is defined as 10% of the commune covered by CFM (p=0.43) or 25% covered (p=0.52). In both cases, the quarter standard deviation decline in per capita consumption falls outside the 95% confidence interval, meaning that the hypothesis of a moderate negative effect of CFM can be rejected (Figure 2).

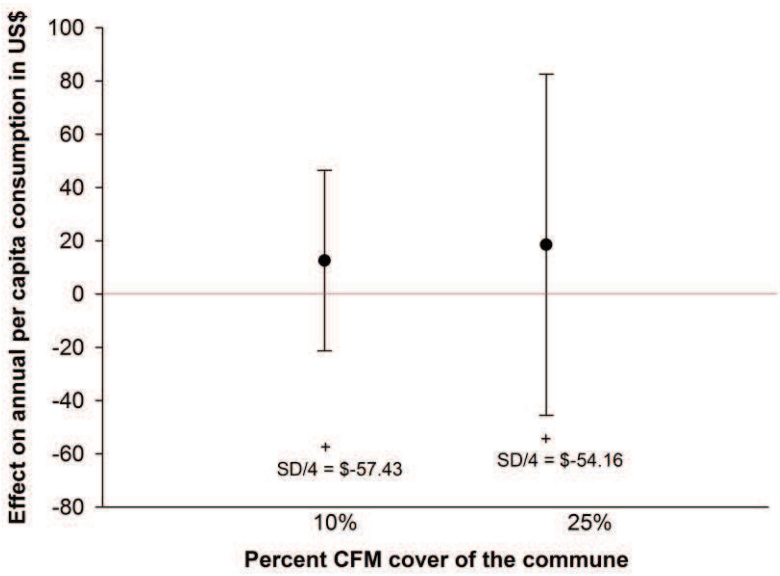

Figure 2. Impacts of Community Forest Management (CFM) on per capita consumption expenditure (+: SD/4 quarter standard deviation decline in per capita consumption expenditure, error bar: 95% confidence interval)

Impacts of CFM are heterogeneous (Figure 3). Close to the forest edge, impacts appear positive (with a maximum effect size of US$50) and become negative as distance from the edge increases (with a minimum effect size of US$-60). Although we do not have enough data to estimate the effect precisely over the entire range, the estimates are statistically significant between one and twelve kilometers from the edge (Figure 3A).

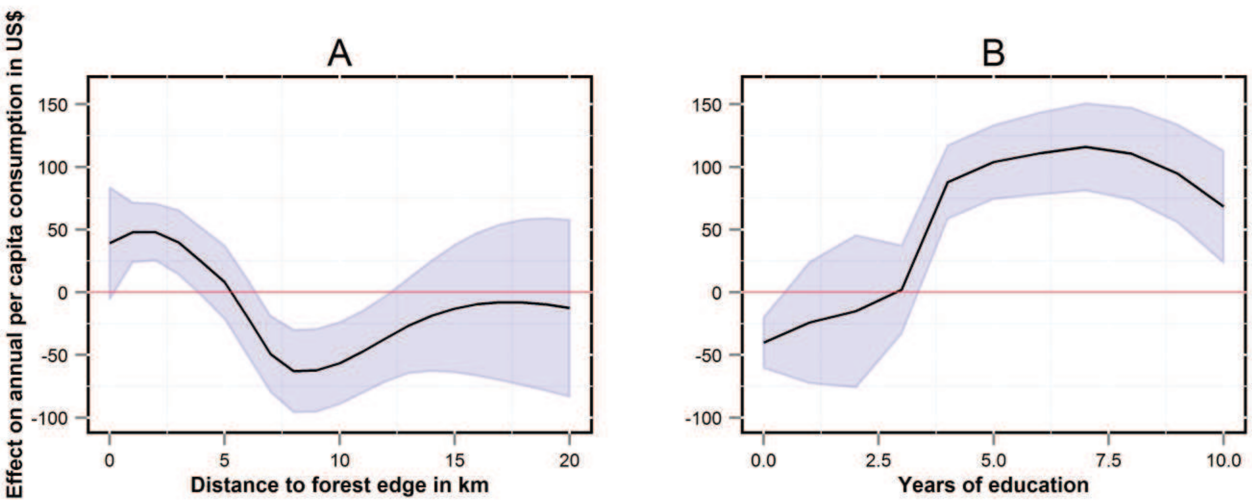

Figure 3. Heterogeneity of Community Forest Management (CFM) impacts. A) Impacts conditional on distance from the household location to the nearest forest edge, B) Impacts conditional on the number of years of education of the household head (blue band: 95% confidence interval)

Impacts also vary with level of education (Figure 3B). The estimated impacts increase with education (with a maximum effect size of US$110). For low levels of education, the estimated impacts are negative, but imprecisely estimated.

Discussion

Despite the hopes for CFM to deliver positive impacts on human well-being, we have not found strong evidence that CFM has had a positive impact, on average, on household living standards in Madagascar. We cannot, however, detect strong evidence for moderate or larger negative impacts, on average, which provides some encouragement given that CFM restricts some forest use and a number of studies have raised concerns that it may have a negative impact on well-being (Hockley & Andriamarovololona 2007; Toillier et al. 2011; Ramamonjisoa & Rabemananjara 2012).

There are two rival explanations for our inability to detect an effect of CFM (two factors that could mask a true effect in our design). First, CFM households, in the absence of CFM, may have had higher or lower consumption than matched, non-CFM households. With higher potential consumption outcomes, negative effects would be masked when contrasting CFM with their matched non-CFM counterparts; with lower potential consumption, positive effects would be masked. The results of our placebo test, which imply that pre-treatment outcomes were on average similar between treated and matched untreated households, are inconsistent with the presence of this form of hidden bias in our estimator, but they do not rule such bias out.

Secondly, restrictions imposed by CFM rules could displace poor households from CFM communities to other communities (Pollini & Lassoie 2011). That displacement would raise the mean household consumption in CFM areas, nullifying the negative impacts in these areas. We looked at the effect of CFM on migration and could detect no effect (see Text S3).

Estimates of average CMF impacts, however, can mask heterogeneity. While the net effect could be close to zero, some households may benefit and others may suffer. We found that households living quite close to forests or with more education appear to benefit from CFM, while households living farther from forests or with less education experience lower consumption as a result of CFM. The heterogeneity conditional on distance could arise because CFM attracts external assistance to CFM communities quite close to the forest edge, which cushions negative impacts of the forest use restrictions. It could also be because households closer to forest are more likely to participate in CFM and perhaps the net benefits of CFM are higher for participants.

The heterogeneous effects conditional on education may arise from a variety of potential mechanisms, including elite capture of CFM benefits, which is a well-known problem with community-based interventions in developing countries (Lund and Saito-Jensen 2013), including in Madagascar (Pollini & Lassoie 2011). Elite capture can cause conflicts jeopardizing effectiveness (Brown & Lassoie 2010) as well as having social justice implications.

Our study has some advantages over earlier studies of CFM impacts in Madagascar, including the careful control for site and household characteristics that confound impact estimates and the consideration of potential rival explanations such as differing baselines and migration. The national scale of the analysis is valuable for evaluating the impact of a national policy but also has its disadvantages as we are reliant on national scale data and do not have the local insights of finer scale studies. Households living right at the forest frontier (or even within the forests) are difficult to access and may be underrepresented in our study because the INSTAT survey was not designed to look at effects of forest use restrictions. Thus, though our results are valid for the households represented in the sample, extrapolation should be done with caution. We also investigated exposure to CFM, rather than participation in CFM because we do not have information on participation of households in forest management groups. Finally, our study includes all CFM sites which exist legally; we do not have information on the quality of the implementation on the ground. Future studies will be improved by data more representative of forest households, containing information on participation of households in forest management groups and implementation of CFM. Such improved study could be used together with other studies on impacts on conservation outcomes (e.g. Rasolofoson et al. 2015) to examine conditions associated with CFM effectiveness both in terms of conservation and welfare outcomes.

Given the ongoing interest in CFM as an approach to reducing deforestation globally, the lack of quality evidence on the impact of the approach on human well-being, and Madagascar's rich experience with CFM over nearly two decades, our national-scale review of the impacts of CFM on consumption expenditure is timely. We have not found strong evidence of positive or substantial negative impacts of CFM, on average, on economic well-being across CFM communities in Madagascar. However, impacts vary across space and are conditional on the education level of the household heads. Because household characteristics may strongly moderate CFM impacts, scholars and practitioners should expect and investigate heterogeneity in impacts within and across sites.

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Manuscript 3

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The potential of the Global Person Generated Index for evaluating the perceived impacts of conservation interventions on subjective well-being

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Abstract

There is growing interest in the importance of ensuring that biodiversity conservation is not achieved at the cost of local people's well-being. It has been suggested that when evaluating the impact of an intervention, the affected population should be allowed to define well-being (requiring a subjective measure), and impacts (requiring a participatory approach), but very few, if any, conservation evaluations live up to these standards. We used the Global Person Generated Index (GPGI) to investigate the relative impacts of strict protection and community forest management on local well-being in Madagascar's rainforests. The GPGI captures the subjective and multidimensional nature of well-being by asking respondents about different domains important for their quality of life, their own-evaluated performance in each domain, and the relative importance of the different domains. We used a participatory approach to establish the cause-effect relationship between the interventions and respondents' performance in each domain. At least half the respondents perceived no positive or negative impacts from the conservation interventions. We found no significant difference, on average, between strict protection and community forest management in the measures we used to examine the magnitude of their relative impacts but there were differences in the characteristics of domains impacted and in the priority domains that could be targeted to improve well-being in locally meaningful ways. Because of its subjectivity, the GPGI cannot provide meaningful information on the magnitude of impacts on overall well-being (e.g., by comparing the GPGI final scores from matched communities with and without the intervention). Its strength lies in the wealth of information it provides on what life domains people value and their performance in these domains. Combined with the participatory approach to establish cause-effect relationship, the GPGI provides highly relevant insights that can be used to design locally legitimate conservation interventions limiting adverse impacts on local well-being.

Keywords: Community forest management; Madagascar; participatory; protected areas; quality of life; social impact evaluation; welfare

INTRODUCTION

Debate surrounds how best to conserve biodiversity while avoiding negative impacts on the well-being of local communities; who are often poor and politically marginalized (Brockington and Wilkie 2015). Consideration and understanding of the well-being impacts of conservation interventions matters both for ethical reasons, as project implementers are morally responsible for ensuring that conservation interventions do not undermine the rights and livelihoods of local communities (Makagon et al. 2014), and because negative impacts on well-being will erode local support and therefore jeopardize conservation success (Adams and Hulme 2001, Woodhouse et al. 2015). The majority of studies evaluating the well-being impacts of conservation interventions use a relatively narrow range of externally defined and objective indicators dominated by income. While these indicators are valuable for providing credible evidence to external stakeholders, they fail to capture the complex and multidimensional nature of well-being and may miss impacts significant to local communities (Woodhouse et al. 2015). There have been recent calls for putting local people at the center of evaluation studies and a more holistic approach to studying human well-being in the conservation community (King et al. 2014, Milner-Gulland et al. 2014, Woodhouse et al. 2015). These calls have been accompanied by methodological guidelines but empirical studies are rare.

Putting local people at the center of impact evaluation studies involves letting them define well-being (Woodhouse et al. 2015). In other words, it allows people to make their own assessment of their lives and the circumstances under which they live (i.e., subjective well-being, Diener 2006), and considers the multidimensional nature of well-being because different individuals may have different definitions of well-being (Milner-Gulland et al. 2014). Putting local people at the center of impact evaluation also involves letting them define impacts. A crucial issue in evaluating well-being impacts of conservation interventions is how specific impacts can be attributed to the interventions rather than other factors (e.g., agriculture potential of the area). One way to deal with this issue, which allows local people to define impacts, is the participatory approach to establish the cause-effect relationship between interventions and well-being outcomes, in which people are directly asked how they perceive the impacts of the interventions on their well-being (Schreckenberg et al. 2010, Woodhouse et al. 2015). Although subjective well-being and the participatory approach to attribute effect to a cause can be influenced by the respondents' mood, orientation, cultural norms, and by timing (Camfield and Skevington 2008), locally perceived well-being impacts are important because they represent people's perspectives on their own circumstances. They can therefore have real consequences on conservation related behavior and engagement in conservation (Raboanarielina 2011, Woodhouse et al. 2015).

The Global Person Generated Index (GPGI) (Martin et al. 2010a) is a tool that takes into account the subjective and multidimensional nature of human well-being. The GPGI collects information about individual's quality of life (QoL). Subjective well-being and QoL are synonymous concepts, though QoL has more developed methodology than subjective well-being (Camfield and Skevington 2008). Thus, the GPGI can be used to assess subjective well-being (Britton and Coulthard 2013). It was developed from the closely related instrument Patient Generated Index, which has been extensively used to assess health-related QoL (Camfield and Ruta 2007). Both instruments define QoL as the measure of "the difference, or the gap, at a particular period of time, between the hopes and expectations of the individual and that individual's present experiences" (Calman 1984:125). The GPGI is “global” in that it is not specifically related to any particular QoL domain (e.g., health) but captures the multiple dimensions of well-being (Martin et al. 2010b). It is “person generated” because it permits an individual to select, rate and weigh the relative importance of domains that matter most for his or her QoL rather than just selecting from a pre-defined list of domains that may miss case-specific domains (Camfield and Ruta 2007, Britton and Coulthard 2013). The GPGI has been used and validated in many developing countries such as Bangladesh, Thailand, Ethiopia, Sri Lanka and Uganda; and in contexts ranging from research on the social and cultural construction of well-being to the exploration of the QoL of HIV patients (Camfield and Ruta 2007, Martin et al. 2010b, Jayasinghe et al. 2015, Mutabazi-Mwesigire et al. 2015). The GPGI is among the tools in the framework developed by the Wellbeing in Developing Countries (WeD) project (McGregor et al. 2009) and there have been recent calls to extend the use of the framework for evaluating and tracking well-being impacts of conservation interventions (King et al. 2014, Milner-Gulland et al. 2014, Woodhouse et al. 2015). However, despite these recent calls, to our knowledge there has been no study that uses the GPGI, or any of the WeD framework tools more generally, in the context of conservation in developing countries. We also know of only one study (Raboanarielina 2011) that uses any explicit measure of QoL in relation to conservation.

The principle that protected areas should not harm local people was adopted at the World’s Park Congress in 2003 (Pullin et al. 2013), but injustices towards local communities due to establishment of protected areas continue (Makagon et al. 2014). In the last few decades conservation efforts have increasingly shifted towards community conservation approaches (such as community forest management, CFM) with proponents arguing that these more locally inclusive approaches have more positive impacts on local well-being (Adams and Hulme 2001). However, the relative well-being impacts of CFM and protected areas (particularly strictly protected areas, which CFM has attempted to replace or complement), and comparison of well-being impacts of different conservation approaches more generally are not well considered in the literature (Brockington and Wilkie 2015). Such evidence is important to determine whether CFM has indeed addressed the potential negative well-being impacts of strictly protected areas.

Madagascar is known worldwide for its exceptionally rich and unique forest biodiversity (Brooks et al. 2006). Faced with a high degree of threats to its natural forest habitats, the island country has attempted a range of conservation approaches. Establishing its first protected area in 1927 (Raik 2007), Madagascar has about 69,100 km^2 of its land area under some form of protection (Carret 2013). The last two decades have seen rapid expansion of CFM across Madagascar with over 1,000 sites covering more than 30,000 km^2 of land in 2014 (Rasamoelina et al. 2015). A number of studies have investigated the impacts of protected areas and CFM on human well-being in Madagascar (Ferraro 2002, Sommerville et al. 2010, Raboanarielina 2011, Rasamoelina et al. 2015). However, very few of these studies explore the multidimensional nature of well-being and none directly compare strictly protected areas and CFM.

We use the GPGI to compare the perceived impacts of a strictly protected area and CFM on people's subjective wellbeing in the eastern rain forests of Madagascar. First, we explore the validity of the GPGI for our particular case study. Validation of the GPGI is not the main goal of this study as this has been done elsewhere (Camfield and Ruta 2007, Martin et al. 2010b). However, as this is the first time the GPGI is used in relation to forest conservation in isolated rural forest communities, we perform a brief validation of the tool. We then compare the locally perceived impacts of the strictly protected area and CFM on people's QoL. Finally, we take advantage of the potential of the GPGI as a needs assessment tool (McGregor et al. 2009, Martin et al. 2010b) to identify, both in the strictly protected and CFM areas, domains that could be targeted by development projects or conservation compensation schemes aiming to improve human well-being in locally meaningful ways.

METHODS

Study areas

We compare communities in Zahamena National Park (ZNP), a strictly protected area, and Ambohilero community managed forests located in the Corridor Ankeniheny-Zahamena (CAZ), a new protected area (Figure 1). Habitat type in both, ZNP and the CAZ, is characterized as humid rain forests. Both sites are also among the world's most irreplaceable protected areas in terms of biodiversity conservation due to an immense diversity and endemicity of fauna and flora and a high number of threatened species (Le Saout et al. 2013).

ZNP covers a total of 643.78 km^2 of land. It is composed of a national park (IUCN category II) in the western part and a strict nature reserve in the eastern part (IUCN category Ia), both managed by Madagascar National Parks. Human consumptive use is prohibited in ZNP but tourism activities are allowed in the western part. The protected area was created in 1927 and since then its boundaries have been amended multiple times. The eight communes within which ZNP lies are inhabited by around 36,000 people (Raboanarielina 2012). There is no human occupancy within the boundaries of ZNP, except in the enclave of Antenina covering an area of 3.5 km^2 (Raboanarielina 2011). This enclave, located in the northern part of ZNP, encloses three villages with an approximate total population of 300 (Rasolofoson, R.A. unpublished data).

Ambohilero forests in the CAZ are located in the Didy commune and cover 644 km^2. Most of these forests have been managed by nineteen CFM groups since 2004 or 2005. The commune of Didy has a total population of about 23,000 (Conservation International 2012). These forests are inhabited by over 2,240 people located in different villages sparsely distributed within the forests (Rasolofoson, R.A. unpublished data).

In both ZNP and Ambohilero forest areas, subsistence farming dominated by swidden rice cultivation is the main economic activity. During fallow periods, cultivation of crops such as beans, peanuts, and maize are practiced. During lean periods, collection of forest products such as honey and wild yams provide additional food. Wild-harvested products are also used for construction materials, weaving, cooking energy, and as traditional medicine (Ravelona 2010, Raboanarielina 2011).

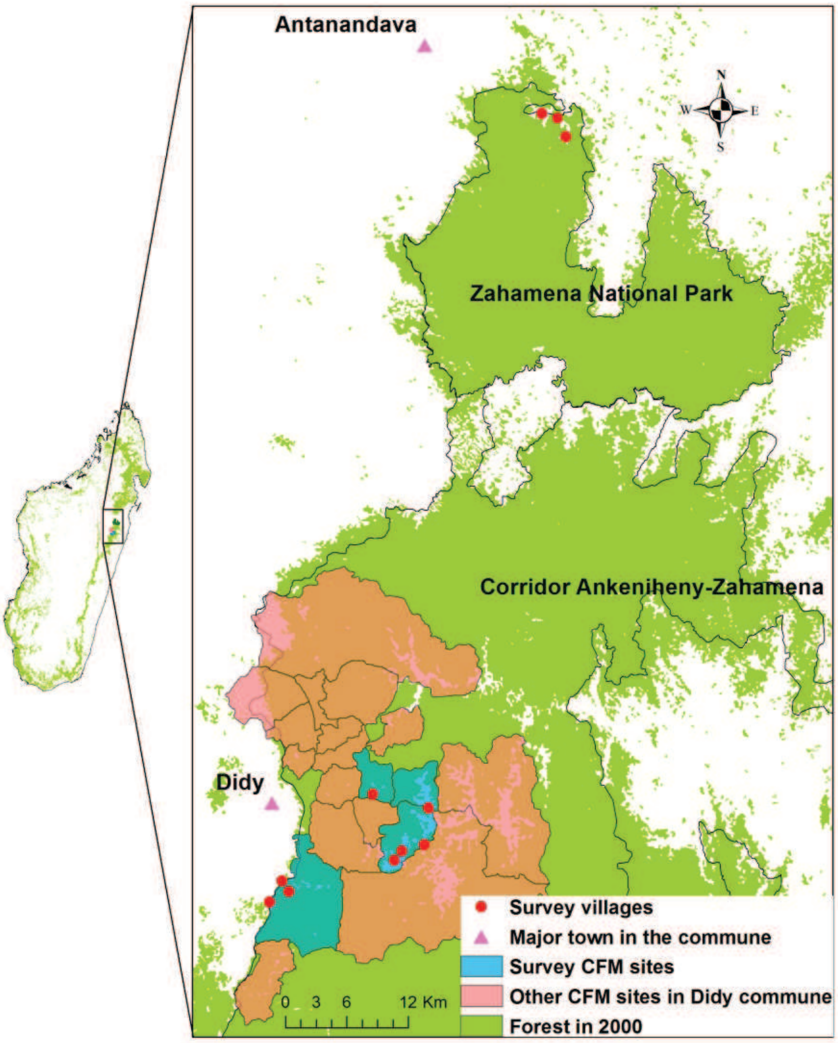

Figure 1. The location of our study sites in eastern Madagascar (CFM: community forest management; sources: Conservation International and Système des Aires Protégées de Madagascar; projection: Laborde Madagascar)

We selected ZNP and Ambohilero forests because they are relatively close (about 50 km apart), comparable in terms of geography and climate, and because the resident communities have similar social and cultural characteristics.

Village selection

We collected information on village characteristics needed for village selection during key informant interviews in Antanandava for ZNP and Didy for Ambohilero forests (the major towns of the communes) in August 2013 (Figure 1). We aimed to select villages from ZNP and Ambohilero forest with comparable characteristics including size, access, and infrastructure. We selected villages located within the forests because they have fewer livelihood alternatives, depend more on forest resources and thus, are more affected by conservation interventions than villages located in forest peripheries or farther from forest edges (Ratsimbazafy et al. 2011). Within ZNP, we selected the three villages within the Antenina enclave (Antenina, Antsahan' i Betavia, and Sahavatana). Among the CFM sites in the Ambohilero forests, we selected four CFM sites (MISI, Ravinala I, Belanonana, and Beririnina) and surveyed all the eight villages within the four CFM sites (Figure 1). These villages have similar characteristics in that they are small (8 to 27 roofs), isolated (2.5 to 6 hours walk from the major town of the commune), and 99% of inhabitants are smallholder farmers (Table 1).

Table 1. Characteristics of the surveyed villages

Village	Location	Distance to major town§ (hours on foot)	Number of households	Primary School
Antenina	ZNP†	4	27	Yes
Antsahan' i Betavia	ZNP†	4.5	16	No
Sahavatana	ZNP†	5	19	No
Andasibe	CFM‡ Ravinala I	3	10	No
Sahamboalaza	CFM‡ MISI	3.5	13	No
Mangalahala	CFM‡ MISI	3	16	No
Ambenja	CFM‡ MISI	2.5	8	No
Saratonga	CFM‡ Belanonana	5	26	No
Betsingita	CFM‡ Beririnina	5	14	No
Ivolobe Felana	CFM‡ Beririnina	4	19	No
Arondramena	CFM‡ Beririnina	6	11	No

†ZNP: Zahamena National Park; ‡CFM: Community Forest Management; §Antanandava for villages in ZNP and Didy for villages in CFM; in both cases the 'major town' is accessible by road and is a locally significant administrative center.

Development of the survey instruments

We used both village and household survey instruments (see Appendix 2 for final version of both instruments). The village survey instrument, administered to focus groups, collected village level information on demography, livelihood activities and infrastructure, and ended with an open ended question asking how the strictly protected area or CFM has impacted villagers' lives. The household survey instrument collected household level information and had three main sections. The first section gathered information on household composition and demography (gender, age, level of education, and main activity of each household member). The second section quantified household assets (furniture, agricultural equipment, livestock, land holding) and housing characteristics. The last section involved the three stages of the GPGI to collect information about the QoL of the respondents. In stage 1, respondents were asked to identify up to five domains that were most important to their lives (e.g., family, health, wealth…). In stage 2, they rated their performance in each domain; from 0 (very bad) to 4 (very good). In stage 3, the respondents scored each domain according to its relative importance in their life. This was conducted by providing 10 pebbles and asking to distribute them among the domains, spending more pebbles on domains perceived as more important and fewer pebbles on less important domains.

The QoL of an individual can be influenced by multiple other factors than conservation interventions in a given area. To establish the causal link between QoL and the intervention (strictly protected area or CFM), we added another stage in the GPGI instrument. We asked if the respondents perceived that the intervention contributed to their performance [0 (very bad) to 4 (very good)] in each QoL domain they identified.

The lead researcher (RAR), who is a Malagasy native speaker, translated the survey instruments from the original English version to the Malagasy language. Then, a person that was not involved in the questionnaire design back-translated the Malagasy version to English. The two English versions (original and back-translated) were then compared. Where there were discrepancies, the Malagasy translation was adjusted.

We pre-tested the household survey instrument in three small villages located on the forest edges not far from the town of Didy. Following the pre-test, some changes were made. For example, many of our pre-test respondents struggled to respond to the question for the first stage of the GPGI: "Could you indicate the five most important things in your life?" The term "important things" is ambiguous in the Malagasy language ("zava-dehibe"). We exchanged it with a term that literally means "priorities" ("laharam-pahamehana"), which consistently elicited sensible responses. Another example of a significant change we made was the scale in the second stage of the GPGI instrument, where respondents are asked to rate their performance in each QoL domain. The original instrument in Camfield and Ruta (2007) has a seven point scale but our respondents had difficulties distinguishing this many points and we reduced it to a five point scale.

Sampling and data collection

The survey was conducted by RAR with two research assistants from the University of Antananarivo from July to September 2014. The three interviewers are native Malagasy speakers and comfortable with the local dialect spoken in the study areas. In each survey village, we first established contact with village leaders and representatives of the local forest management association (applicable in CFM villages only) to explain the purpose of our visit. Then, using the village survey instrument, we collected village-level information from a focus group discussion involving a range of people (of both genders).

After the focus group discussion, we developed an exhaustive sampling frame for the visited village. To do that, we walked from one end of the village land to the other with a knowledgeable local guide to identify every household in the village, taking care to consider isolated households outside the main village. We recorded the GPS coordinates of the location of each household, which was assigned a specific identification number. From this list, we randomly selected households for the surveys. Sampling effort differs between the strictly protected and CFM areas because there are different numbers of surveyed villages in these two types of areas (Figure 1). However, we believe that our sampling efforts in both areas were sufficient for our samples to be representative of the households of each village. In the strictly protected area, we selected 90% of the households of each village; 80% as the first preference sample and 10% as replacements in case any of the households in first preference sample could not be interviewed. In the CFM sites, we selected 70% of the households of each village; 55% as the first preference sample and 15% as replacements. In total, we interviewed 128 households (49 in the strictly protected area and 79 in the CFM sites). Interviews were conducted with the household head or, if they were not available, their spouse or other adult household member. Our replacement rate was 6.25%, mainly due to the first preference households being absent.

The research approach followed the University of Copenhagen research ethics framework. All informants were informed of the aims of the research and our independence from local conservation or state actors was emphasized. We explained that participation in the research was voluntary, that they could leave the interview at any time and that they did not have to answer any question they were not comfortable with. They were also informed that they would remain anonymous.

Data analyses

Validity of the GPGI

We investigated both content and construct validity. Content validity is the extent to which the domains within the GPGI are relevant to the concept of QoL (adapted from the definition of content validity in Haynes et al. (1995)). Here, the purpose was to see if our GPGI is able to capture domains that other studies found relevant to the QoL of people in Madagascar or other developing countries. To do that, we grouped closely related domains mentioned by respondents in the GPGI stage 1 into the same categories. For example, “agricultural yield” and “insecticide to protect agriculture” were categorized under agriculture. Respondents generally understood the task and responded in brief phrases, and thus little categorization was required. Then, we compared the categories of domains derived from our use of the GPGI to those of other QoL studies using the GPGI or other instruments. In particular, we compared with Farnworth (2004), which is the only QoL study in Madagascar that, to our knowledge, has used an instrument collecting data on domains of people’s life to infer conclusion about their QoL.

Raboanarielina (2011) does not disaggregate component domains but uses overall measurements such as happiness and basic need satisfaction and therefore cannot be used to evaluate content validity in this study. We also explored how our QoL domains compare with those of Camfield and Ruta (2007) and Martin et al. (2010b), which used the GPGI in Thailand, Bangladesh, and Ethiopia.

Construct validity is "the extent to which a measure is related to specified variables in accordance with an established theory or hypothetical construct" (Camfield and Ruta 2007:1043). Here, we tested the general theory that materially well-off individuals have higher QoL than those materially worse-off, and healthier individuals have higher QoL than those with ill-health (Ruta et al. 2006, Camfield and Ruta 2007). We used an asset index as a material well-being indicator. We developed the asset index by aggregating the assets and household characteristics collected during the household survey. We applied principal components to estimate the weights given to each asset and household characteristic in the aggregation process (Filmer and Pritchett 2001; Table A1.1). We compared the GPGI scores of individuals in the poorest quintile to those in the richest quintile. We also compared the GPGI scores of individuals reporting poor health to those reporting good health. In both comparisons, we use the Mann-Whitney U non-parametric test.

Relative impacts of strictly protected area and CFM

To investigate the relative impacts of strictly protected area and CFM on people's QoL, we considered a QoL domain to be negatively impacted when the intervention was perceived as having contributed to a very bad (0) or bad (1) performance of an individual in that domain. Similarly, a QoL domain was defined to be positively impacted when the intervention has contributed to a good (3) or very good (4) performance of an individual in that specific QoL domain. To examine the magnitude of the relative impacts of strict protection and CFM, we compared the two interventions in terms of the distributions of the frequency of individuals across different numbers (i.e., zero to five) of impacted QoL domains. We conducted this comparison separately for negative and positive impacts, using Fisher's exact test. Second, because QoL is determined by both the performance in QoL domains (score in GPGI stage 2) and the relative importance or weight (score in GPGI stage 3) of these domains (Bowling 1995, Tovbin et al. 2003), we also compared the mean of the weighted performance (GPGI stage 2 score multiplied by GPGI stage 3 score) in domains that have been perceived to be impacted in the two intervention areas. We used Mann-Whitney U non-parametric test for the mean comparison.

Restricting the analysis just to the domains perceived by respondents to be impacted by the strict protection or CFM, we compared the characteristics of these impacted domains in the two interventions in terms their type, direction of impact (negative or positive) for each domain, importance of each domain, and the frequency with which each domain is impacted. We applied an adapted version of the Importance Performance Analysis (IPA) framework (Martilla and James 1977, Azzopardi and Nash 2013); where domains in quadrant I and III have been negatively impacted by the strict protection or CFM and domains in quadrant II and IV have been positively impacted (Figure 3A and B). Quadrants I and II contain domains with high importance, and thus have heavier weight on QoL than domains in quadrants III and IV that have low importance. We also included the frequency with which a domain was perceived to be impacted as a third dimension. A frequently and negatively impacted domain with heavy weight on QoL is of concern.

Finally, we used content analysis of the transcribed focus group responses to the open ended question on perceptions of how the intervention (CFM or strict protection) had impacted villager's lives to provide quotes to support results from the IPA. We identified three major themes: the domains of villagers' lives impacted by the strict protection or CFM, the direction of the impact (positive or negative) for each domain, and the mechanisms through which the strictly protected area or CFM impacted each domain. Information on the number of participants in each focus groups and the labeling used in quotes (to protected anonymity) is given in Table A1.2.

Needs assessment

The IPA framework is a diagnostic tool used to identify priorities where deployment of scare resources would make the most difference. To identify domains where investment could enhance QoL, we used the original version of IPA framework shown in Figures 4A and B, where domains that fall in quadrant I are of high importance but low performance (suggesting increased resources should be allocated to these domains). Domains in quadrant II are highly important with high performance (suggesting resources should be sustained). Those in quadrant III are of low importance and low performance suggesting no change in the allocation of resources is needed. Domains in quadrant IV are of low importance but high performance; indicating perhaps that resources invested here may be better spent elsewhere. In this analysis, we included all domains mentioned by the respondents (i.e., the entire dataset). We included the frequency with which a domain was mentioned by respondents as a third dimension as more frequently mentioned domains are more significant to the QoL of the communities than less frequently mentioned domains.

RESULTS

Validity of the GPGI

Content validity

The most significant domains mentioned as important to respondents' QoL in the GPGI were agriculture (74%), health (60%), livestock (55%), education (48%), work and agriculture equipment (39%), livelihood activities or jobs (37%) and family, spouse or relatives (22%) with a further 10 domains mentioned by less than 20% of respondents and 15 domains mentioned by less than 5% (see Table A1.3). The study by Farnworh (2004) also looked at farmers in Madagascar and there is strong overlap between the most frequently cited domains in our study and important domains of Farnworth (2004) (e.g., health, education, money, and food). While other important domains in Farnworth (2004), such as social relation, immediate environment and aspiration were not explicitly mentioned in our study, components associated with these domains such as wealth, furniture, livestock, land, community and family relation, forests (forests products), rice, and infrastructure were nominated. Time management and market, which are important domains in Farnworth (2004), were missing in our study (though market was mentioned by one respondent).

The domains in our study are comparable to other GPGI produced domains in studies in other developing countries (Camfield and Ruta 2007, Martin et al. 2010b). Particularly, frequently cited domains in these other studies also include health, education, income activities or job, family or children. However, the frequencies of agricultural related domains (agriculture, livestock, equipment, land) are higher in our study than in Camfield and Ruta (2007) and Martin et al. (2010b). Table A1.3 compares domains nominated in this study with these other studies.

Construct validity

The richest respondents had higher GPGI score than the poorest, but the difference is not statistically significant (Table 2). Respondents reporting good health had higher GPGI score than those reporting poor health, and the difference is statistically significant at the 5% significance level (Table 2).

Table 2. Difference in GPGI score between poorest and richest quintile of asset index and between respondents reporting poor and good health

	Material well-being		Health	
	Poorest quintile	Richest quintile	Poor health	Good health
Sample description†	1.42	10.87	22%	78%
Mean GPGI score	44.50	50.80	36.07	47.73
Difference in mean GPGI score	6.30		11.66	
P	0.38		0.03*	

†Mean asset index for material well-being and percent of respondents for health
*significant at P = 0.05

Relative impacts of strictly protected area and CFM

A high proportion of respondents reported no perceived negative (over 60%) or positive (over 50%) impacts of the strictly protected or CFM interventions. We did not detect a statistically significant difference between the strictly protected area and CFM sites in terms of the distributions of the frequency of individuals across different numbers (i.e., zero to five) of negatively (P = 0.57, Figure 2A) or positively (P = 0.39, Figure 2B) impacted domains.

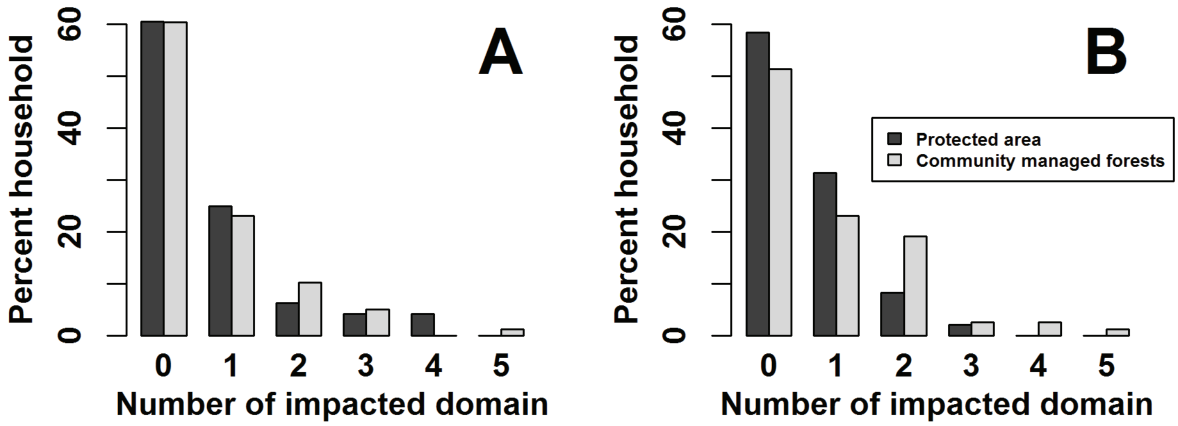

Figure 2. Distributions of the frequency of individuals reporting different numbers (zero to five) of negatively (A) and positively (B) impacted domains

The mean of the weighted performance in domains perceived to be impacted is lower in the strictly protected areas than in CFM sites (0.37 and 0.45 respectively), but the differences is not statistically significant (P = 0.23).

Among people living in the strictly protected area, land and agriculture are two domains of high concern (they are relatively frequently and negatively perceived as impacted and have heavier weight on QoL of impacted individuals (quadrant I; Figure 3A)). The focus groups in the strictly protected area revealed two locally perceived mechanisms through which the strict protection negatively impacted the land and agriculture domains. First, the strict protection restricts access to agricultural lands. Participants in villages ZNP1 explained: “Lands that used to belong to us or to our parents have been locked in the protected area. We cannot use these lands anymore.” (FG-ZNP1; Quote A3.1). Participants in village ZNP3 echoed this concern: “Because the population keeps growing, there may not be enough land in the future.” (FG-ZNP3; Quote A3.2). The lack of agricultural lands has caused conflicts between the three villages in the strictly protected area. People in village ZNP2 stated that: “Agricultural lands are scarce. Villagers of village ZNP1 and village ZNP3 grab our lands. We are left without lands.” (FG-ZNP2; Quote A3.3). Second, the strict protection negatively impacted the land and agriculture domains through creation of expectations that have not been fulfilled. For example, residents of village ZNP1 strongly believe that the construction of a dam reportedly promised by Madagascar National Parks would improve their agricultural yield. However, focus group participants reported that: “Madagascar National Parks has not provided any assistance to us. Development projects like the construction of a dam were promised, but never came.” (FG-ZNP 1; Quote A3.4). We note that though the participants’ perception of the impacts of the strict protection on land and agriculture was overwhelmingly negative, participants in villages ZNP2 and ZNP3 mentioned that by protecting the forests the strictly protected area ensures that: “We have enough rain for agriculture.” (FG-ZNP2;

Quote A3.5) and that: “Our agricultural lands are not destroyed by sands from soil erosion.” (FG-ZNP3; Quote A3.6).

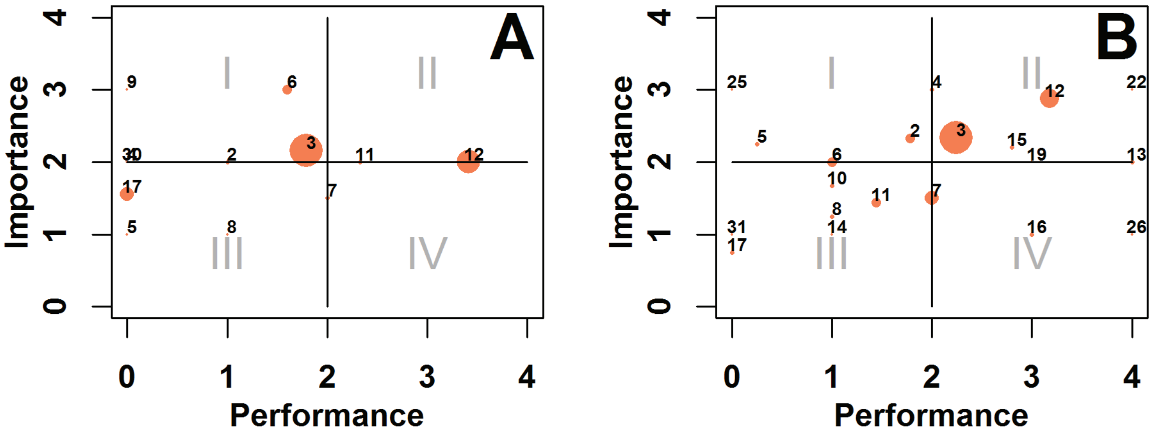

Figure 3. Comparison of the characteristics of impacted domains in (A) the strictly protected area and (B) community managed forest sites [X-axis: mean performance score of impacted domains, Y-axis: mean importance score of impacted domains; I: Negatively impacted domain with heavier weight on quality of life, II: Positively impacted domain with heavier weight on quality of life, III: Negatively impacted domain with lighter weight on quality of life, IV: Positively impacted domain with lighter weight on quality of life; size of symbol indicates the frequency with which respondents perceived a particular domain to be impacted; 2: education, 3: agriculture, 4: rice, 5: work equipment, 6: land, 7: livestock, 8: house, 9: furniture, 10: money or wealth, 11: livelihood activities, 12: health, 13: community relation, 14: forest or water products, 15: food, 16: poverty or development, 17: infrastructure, 19: external support, 22: peace, 25: fence, 26: hospitality, 29: local forest management association, 30: environment, 31: market, missing numbers are not impacted domains]

Among the people living in the CFM sites, the education domain is relatively frequently and negatively perceived as impacted and has heavier weight on QoL of impacted individuals (quadrant I, Figure 3B). The focus group discussions explain the reason for this dissatisfaction: the local forest management associations have raised expectations that they will be able to provide primary schools but only village CFM1 among the seven surveyed CFM villages has a school and that one is in poor condition and has been closed for some years. Participants in the focus group discussion in village CFM1 revealed: “The forest management association built the school and we were responsible for paying the teacher’ salary. But we are so poor that we could not keep paying the teacher enough and he left the village.” (FG-CFM1; Quote A3.7).

The land domain is relatively frequently and negatively impacted, but its weight on QoL of impacted individuals is medium (it is on the middle horizontal line; Figure 3B). The negative impacts on the land domain were due to restrictions enforced by CFM. The focus group participants in village CFM2 mentioned: “We do not have enough land to grow food.” (FG-CFM2; Quote A3.8); and participants in village CFM3 stated: “Population has grown rapidly and we are not allowed to enlarge our agricultural lands. Thus, available lands are not enough to provide for the people.” (FG-CFM3; Quote A3.9).

Agriculture and health are among the domains perceived to experience positive impacts of CFM. They are also among the most frequently impacted domains and have heavier weight on QoL of impacted individuals (quadrant II; Figure 3B). The positive impacts of CFM on the agriculture domain are due to the increased sense of security the communities perceived from CFM. Before CFM, communities did not have any legal claim over their lands within forests. However, under CFM, though forest land ownership still belongs to the state, local people have defined rights to make some management decisions concerning their lands and forests and, crucially, to exclude outsiders. This sense of security provided by CFM was expressed during focus group discussions in five CFM villages through statements such as: "CFM has allowed and legalized our stay and agricultural activities here in the forests." (FG-CFM4; Quote A3.10) and "we have been granted the rights to practice our agricultural activities without fearing eviction." (FG-CFM1; Quote A3.11). However, participant in village CFM5 revealed that: "We have received threat of eviction and imprisonment from the local forest management association because they accuse us of clearing the forests. We are not satisfied with the lands available to us at all." (FG-CFM5; Quote A3.12). CFM villagers also recognized that: "By protecting forests, CFM brings enough rain for our agriculture." (FG-CFM3, Quote A3.13). The perceived positive impacts of CFM on health come from forest ecosystem services such as pure air and medicinal plants as mirrored in the statement of participants in village CFM1: "The forests protected by CFM provide pure air and medicinal plants for us." (FG-CFM1, Quote A3.14).

Needs assessment

In the strictly protected area land is a priority domain (quadrant I; Figure 4A) because it is relatively frequently nominated by respondents, has low performance and high importance. Agriculture and money or wealth are relatively important because they are relatively frequently nominated and have low performance, though their importance is medium (on the middle horizontal line; Figure 4A). Education, health and food are domains, in which a high frequency of individuals are performing well and which have high importance in the strict protected area (quadrant II; Figure 4A)

In CFM sites, priority domains that need to be improved to enhance QoL are education, agriculture, land and money or wealth. They are relatively frequently mentioned, have low performance and high importance (quadrant I; Figure 4B). In CFM sites, family and health are the domains having high frequency, performance, and importance (quadrant II; Figure 4B).

It is important to note that though all these villages are located in the middle of the forests the domain forest products was not mentioned in the strictly protected area (Figure 4A) and it is in the non-priority domain in the CFM sites (quadrant IV; Figure 4B).

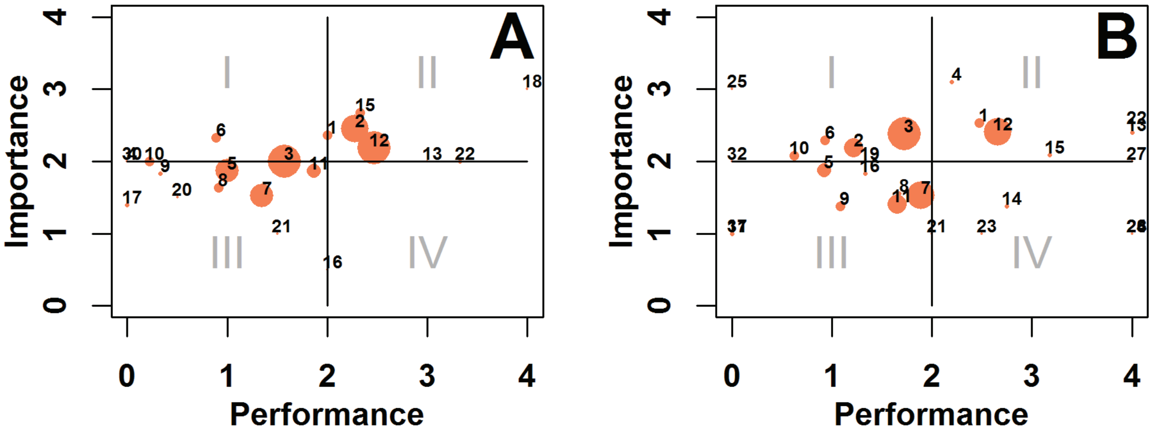

Figure 4. Needs assessment in (A) the strictly protected area and (B) community managed forest sites (B) [X-axis: mean performance score of domains, Y-axis: mean importance score of domains; I: Concentrate here (increase resources), II: Keep up the good work (sustain resources), III: Low priority (no change in resources), IV: Potential overkill (curtail resources); Size of symbol indicates the frequency with which respondents mentioned a particular domain; 1: family, 2: education, 3: agriculture, 4: rice, 5: work equipment, 6: land, 7: livestock, 8: house, 9: furniture, 10: money or wealth, 11: livelihood activities, 12: health, 13: community relation, 14: forest or water products, 15: food, 16: poverty or development, 17: infrastructure, 18: religion, 19: external support, 20: clothing, 21: electricity or light, 22: peace, 23: cigarette, 24: motivation, 25: fence, 26: hospitality, 27: fire, 28: coffee, 29: local forest management association, 30: environment, 31: market, 32: mining; Source: (Martilla and James 1977)]

DISCUSSION

Validity of the GPGI for measuring subjective well-being

Overall, the GPGI appeared to work well at capturing life domains important to the respondents' QoL. The domains identified as important in our study are similar to those identified in other QoL studies in Madagascar (Farnworth 2004) and other developing countries (Camfield and Ruta 2007, Martin et al. 2010b). The small discrepancies between domains in our GPGI and these other studies may result from differences in study settings. For example, the remoteness of our study sites and the absence of market economy may explain why the market domain was not mentioned in contrast to Farnworth (2004) who worked in an area where cash crops are important. The higher frequencies of agricultural related domains (agriculture, livestock, equipment, land) in our study than in Camfield and Ruta (2007) and Martin et al. (2010b) may be because virtually all our respondents are smallholder farmers, whereas respondents in these other studies range from rural farmers to wealthy urban businessmen.

The GPGI furthermore appears to meaningfully reflect respondents' QoL. In accordance with general theory (Ruta et al. 2006, Camfield and Ruta 2007), we found that healthier individuals had a higher QoL, as measured by our GPGI, than those with poor health. We also found that the richest respondents had higher QoL than the poorest, but this difference was not statistically significant. This may be due to the small economic variability in our samples (respondents are nearly all asset poor, smallholder farmers living in remote areas). Camfield and Ruta (2007) and Martin et al. (2010b)'s samples had large economic variability (from rural farmers to wealthy urban businessmen) and they found moderate correlations between material well-being and QoL. Another explanation for lack of statistical difference in QoL between the rich and the poor is that despite the general theory (Ruta et al. 2006, Camfield and Ruta 2007), the relationship between material well-being and QoL is complex and many factors including adaptation, positive cognitive bias, homeostasis, unrealistic optimism and illusions of control can all weaken the relationship (Camfield and Skevington 2008).

Methodological challenges for evaluating impacts of interventions on subjective well-being

Comparison of the GPGI final scores between strict protection and CFM would not give a credible estimate of the relative impact of the two interventions. Some of the five life domains nominated by a respondent may not be perceived to be impacted by the intervention. Thus, the GPGI final score, which measures overall subjective well-being, can include components that are not related to the intervention but can be influenced by other factors. Such factors can confound the estimate of the relative impact of strict protection and CFM obtained by comparing GPGI final scores in the two interventions. A potential way to overcome this would be to use the reflexive approach in which respondents are asked to imagine the scenario had there been no intervention (counterfactual) (Schreckenberg et al. 2010, Woodhouse et al. 2015) and to compare the intervention and reflexive counterfactual outcomes. However, we did not use this approach as we are skeptical about the credibility of the counterfactuals. Changes in individuals' circumstances (e.g., from without the intervention to with the intervention) may trigger changes in the whole way they conceptualize QoL, including the life domains they value, the relative importance of the valued domains, and their performance in each valued domain (Schwartz and Sprangers 1999, Schwartz et al. 2006). It would be hardly possible to have a credible imagination of these three elements of QoL together in the hypothetical scenario of the counterfactual.

Methodologies for establishing causal inference such as matching (e.g., Rasamoelina et al. (2015)) and instrumental variable (e.g., Sims (2010)) have limitations in evaluating impacts of interventions on an overall subjective well-being outcome variable. First, there is the response shift phenomenon, in which there may be no difference in the overall well-being measurement even if the interventions impacted well-being because of individual´s adaptation (Schwartz and Sprangers 1999, Schwartz et al. 2006). Second, there are multiple factors that can systematically bias an overall subjective well-being outcome variable and that is difficult to correct econometrically. For example, subjective well-being indicators are commonly affected by mood, orientation, cultural norms, and by timing (Camfield and Skevington 2008).

Instead, we sought to attribute outcomes (in terms of subjective-wellbeing as measured by GPGI) to conservation interventions (strict protection or CFM) using a participatory approach, where we asked respondents whether the interventions contributed to their performance in each of their valued QoL domain. This participatory approach to attribution applied to the GPGI permits detecting the response shift by allowing examination of the characteristics of the impacted domains that enables exploring how individuals might have adapted their internal standards, values, or conceptualization of QoL in response to different interventions (Schwartz and Sprangers 1999, Schwartz et al. 2006). Furthermore, by virtue of constructing subjective well-being from its component domains, the GPGI may be less affected by the common biases affecting subjective well-being measures. This is because subjective performance scores for component domains may be less affected by these biases than overall judgment of subjective well-being (Schwarz and Strack 1999). Therefore, we would suggest that conservation practitioners interested in knowing people's perspectives and experiences and in improving elements of their projects that are causing negative local well-being impacts in order to gain local support and participation would benefit from using the GPGI and this sort of participatory approach.

Impacts of conservation interventions in eastern Madagascar on subjective well-being

Despite the hope that CFM would have more positive impacts on local well-being than strict protection (Pollini et al. 2014), we cannot detect any statistically significant difference, on average, between the two interventions in the three measures we used to examine the magnitude of their relative impacts: the distributions of the frequency of individuals across different numbers of negatively or positively impacted QoL domains, and the weighted performance in domains perceived to be impacted by respondents. However, a closer look at the characteristics of domains perceived to be impacted suggests that there are differences between the strictly protected area and CFM: different types of domains were impacted by the two interventions, the interventions impacted the same domain in different directions (positive and negative), the same impacted domain had different importance in the two interventions, and the frequency with which a domain was impacted differed.

The fact that we did not detect strong evidence for better impacts on local wellbeing of CFM when compared to strict protection supports a body of work suggesting that CFM has had disappointing results in terms of delivering positive well-being impacts (Dressler et al. 2010, Nielsen and Treue 2012). There have been suggestions that one reason for the lack of positive impacts is that CFM is often not implemented as the theory suggests it should be but in effect acts as a shallow cover to a strict protection agenda and that the coercive power of the state is transferred to non-governmental organizations and local elites (Adams and Hulme 2001, Blaikie 2006, Brown and Lassoie 2010, Dressler et al. 2010, Corson 2012).

However, our findings that the characteristics of the impacted domains under strict protection and CFM are different indicate the two interventions have had different impacts on well-being. Nevertheless, impacted individuals may have adapted their internal standards, values, or conceptualization of QoL in response to the interventions (i.e., there may have been a response shift), so that the different impacts of both interventions have not been seen in the measures used to investigate the magnitude of their relative impacts. For example, impacted individuals in the CFM sites perceived that, on average, CFM improved their agriculture domain through increasing their sense of tenure security. However, by promising schools to the community, the local forest management associations have created expectations that have not been met and caused the impacted individuals to perceive negative impacts of CFM on the education domain. In contrast, in the strictly protected area, agriculture was a major concern due to the strictly enforced conservation restrictions, but because of the presence of a functioning primary school education was not a major concern.

Identifying areas for future investment to improve local well-being

The needs assessment findings indicate some differences in the strict protected and CFM areas in the priority domains that could be targeted by increased resource allocation to improve QoL in locally meaningful ways. We undertook a needs assessment using the Importance Performance Analysis (IPA), which has been used in many sectors such as tourism, food services, education, business, healthcare, banking and public administration as a diagnostic tool to identify priorities (Azzopardi and Nash 2013). However, to our knowledge, IPA has not been previously used in a biodiversity conservation context, although it was used in tourism visitation of protected areas for the purpose of improving the competitiveness of protected areas as tourism destinations (Wade and Eagles 2003, Haahti and Yavas 2004, Tonge and Moore 2007).

Needs assessment was possible because we used the GPGI. An overall subjective well-being measure does not provide any information on well-being component domains from which to prioritize and a focus on narrow objective indicators may misguide resource allocation. For example, a study objectively measuring income from different sources could find that forest products are important sources of income and conclude that they should be the target of increased resources in order to improve well-being. However the forest product domain was not mentioned among the valued domains in the strict protected area and was a non-priority in CFM sites. Respondents may have included forest products in the domains of livelihood activities and food but these domains are not high priority domains where increasing resources could primarily be allocated to improve QoL. This highlights the importance of considering subjective indicators that capture the multidimensional nature of well-being like the GPGI, which suggests that increasing resources allocated to forest products may do little to improve well-being in a locally meaningful ways.

CONCLUSION

The Global Person Generated Index (GPGI) holds promise for the recent push to consider the subjective and multi-dimensional nature of human well-being in conservation intervention impact evaluation. Its strength lies not so much in its final score, which measures individual overall QoL, but on the wealth of information it provides on what life domains people value and their performance in these valued domains (Camfield and Ruta 2007). Participatory approaches can provide some information on the relationship between an intervention and performance in the valued domains.

Combining these two methods, we did not detect, on average, any statistically significant differences between strict protection and CFM in the measures we used to compare the magnitude of their impacts on subjective well-being. However, our study suggests that the characteristics of the impacted domains under strict protection and CFM are different. Our findings also indicate some differences in the priority domains that should be targeted by increased resource allocation to improve well-being in locally meaningful ways. Together, the GPGI and the participatory approach of establishing causal-effect relationship provide highly relevant insights that can be used to design interventions which increase local participation and develop more positive local attitudes towards conservation. These opportunities might be missed if a tool that directly measures overall subjective well-being (without attention to the component domains) or an objective indicator of well-being had been used.

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SUPPLEMENTARY MATERIALS

Manuscript 1: Appendices

Appendix A. Limitations of using 2000 baseline forest cover and CFM established between 2000 and 2005

Ideally, baseline confounding characteristics, particularly baseline forest cover, should be measured at the very time CFM is established (Andam et al., 2008). In this study, baseline forest cover is dated in 2000 while CFM are established from 2000 to 2005. When planners establish CFM, they make decision based on the landscape they are facing. They are likely to establish CFM in location where there are forests at the time of establishment. Thus, if a CFM was established after 2000, it was likely to be forested in that post-2000 year of establishment while its counterfactual, which was forested in the 2000 baseline may already be deforested in the post-2000 year of establishment. The fact that the CFM was still forested in the post-2000 year of establishment could signify that it unobservably has smaller deforestation probability than its counterfactual, which was already cleared. While matching can control for observable bias, it cannot deal with this kind of unobservable bias. That CFM could unobservably have smaller deforestation probability than its counterfactual means that our impact estimates can be considered as upper bounds. That is, if the probability of deforestation of the intervention and its counterfactual were the same, effectiveness of the intervention would be smaller. Where intervention has no significant effect, this will not change the conclusion that it is ineffective. However, where there is significant effect, this means that the effect estimate can be smaller. For the latter, the sensitivity tests to unobservable bias provide means to know how sensitive an estimate is to potential unobservable bias.

Appendix B. Potential pseudo replication

We may have pseudo replication because our units of analysis (pixel) within a management unit (CFM) may not be independent. If we assume that deforestation is affected by pixel-level attributes and pre-treatment management unit-level attributes, but that the pre-treatment management unit attributes are not correlated with treatment assignment, whereas the pixel-level attributes are (and we can observe the relevant confounding pixel-level attributes), then we can estimate impacts by conditioning on the pre-treatment, pixel-level attributes (as we do in our study). But we would have a problem estimating the variance of the estimated impact – we would underestimate the true variance by ignoring pre-treatment management unit effects on deforestation.

Some of the pseudo replication concern is mitigated by our sampling procedure. To address the issue of spatial autocorrelation, we set a minimum distance of 68 meters between sampled pixels (the mean distance between a deforested pixel and the nearest deforested one if deforestation from 2000 to 2010 was randomly distributed throughout the forested areas in 2000; Ebdon, 1985; Mitchell, 2005). But this sampling procedure will not eliminate the pseudo replication problem.

We therefore performed a falsification (placebo) test to provide evidence that our pixel-level matching covariates are sufficiently rich to eliminate effects of the management units in the absence of treatment. To do that, we selected random pixel in CFM areas, matched them with similar pixels in control in terms of pixel-level covariates and compared deforestation in the two areas. But we did the analysis with pre-treatment (1990 – 2000) forest cover data, a period in which no treatment effect should be detectable (because treatment had not yet been assigned). We cannot reject the null hypothesis of zero difference in the deforestation rates in CFM and control sites ($p = 0.11$). That result provides indirect evidence that our pixel-level covariates are sufficiently rich to eliminate effects of the management units in the absence of treatment. In other words, we can assume that the management unit-effects, were they to exist, do not have large impact on estimate of variance.

Appendix C. Selection of sites to CFM in Madagascar

In addition to the physical characteristics used in the matching procedure, there may also be community characteristics that affect which communities a planner selects for being eligible for CFM and which communities self-select to accept CFM. For example, Ostrom (2000) identified seven community attributes that facilitate the emergence of CFM. These attributes are also likely to affect forest management in the absence of formal CFM designation, and thus would be confounding factors. The presence of these attributes is likely to increase the likelihood of CFM designation and reduce deforestation in the absence of CFM (because they promote better forest management). Thus, failing to control for these community characteristics in our analyses will bias our impact estimator upward, i.e. our estimates are upper bound estimates of the true effect of CFM.

We argue that such bias would be small, if it exists at all, in the case of Madagascar. Very few CFM designations were initiated by communities or based on community characteristics. Instead, conservation non-governmental organizations (NGOs), pressured by donors, approached communities and rushed to implement many CFM contracts to fit their agenda (Pollini et al., 2014; Pollini and Lassoie, 2011). For example, many of the existing CFM sites have been established to form a "green belt" to shield the core zones of the newly created protected areas after 2003. Communities around these newly protected areas were approached by conservation NGOs to establish CFM regardless of the community characteristics. The goal was to form the "green belt".

Interviews with a NGO expert in CFM implementation revealed that their first criterion to select CFM sites is pressure. More pressured sites are likely to be selected to CFM. The second criterion is access. Groups of neighboring CFM sites are often implemented together to reduce costs. The only community characteristic is community motivation. However, community motivation is another factor in which access plays a major role. Implementation organizations carry out awareness campaign to boost local motivation. Easier accessed areas closer to implementation organization offices that are often located in larger towns or cities are more likely to receive more intense awareness campaign and thus more likely to be motivated to engage in CFM.

Given that community characteristics receive little consideration in CFM implementation, there is no surprise that only two of Ostrom (2000)'s seven community attributes conducive to CFM have been present in CFM sites established in eastern Madagascar (Urech et al., 2013). Community characteristics have made these sites ineligible for CFM but pressure of the international conservation agenda pushed these sites to be designated CFM sites.

In brief, failure to consider community characteristics as confounding factors is likely to have small effects in our estimates because community characteristics receive little consideration in selection of sites to CFM. The physical characteristics we chose as confounding factors are likely to include factors judged by the international conservation agenda as important to the selection of sites to CFM.

Appendix D. Tables

Table D1. Presence of community forest management areas (CFM), control areas and areas excluded from the analyses in different statuses of forests in Madagascar

Status	**CFM**	**Non-CFM**	**Excluded**
MNP protected areas	No	No	Yes
Extension of MNP protected areas	Yes	No	Yes
Temporary protected areas	Yes	No	Yes
New protected areas	Yes	Yes (if creation of protected area not yet started or at a very early stage)	Yes (if stage of creation of protected area unknown or advanced)
Public domain	Yes	Yes	No

Table D2. Different analyses and sample sizes

Analysis	Sample size (number of pixels)	
	Intervention	Comparison
Effectiveness of all CFM	CFM: 37 679	Non-CFM: 112 709
Effectiveness of CFM with information suggesting implementation	CFM: 30 000	Non-CFM: 112 709
Effectiveness of commercial CFM	Commercial CFM: 30 000	Non-CFM: 120 000
Effectiveness of non commercial CFM	Non commercial CFM: 30 000	Non-CFM: 82 407
Relative effectiveness of commercial and non commercial CFM in commercial CFM setting	Commercial CFM: 30 000	Non commercial CFM: 53 528*
Relative effectiveness of non commercial and commercial CFM in non commercial CFM setting	Non commercial CFM: 30 000	Commercial CFM: 45 657*

*Because of the imposed minimum distance between sample pixels, it was not possible to sample comparison pixels two to four times more than intervention pixels. Thus, we sampled the maximum number of pixels that could be generated from the comparison pixel population.

Table D3. Baseline characteristics likely to affect both assignment to CFM and rate of deforestation

Confounding variables	**Unit**	**Source**
Agricultural suitability	Pixel 9km*9km	IIASA(Fischer et al., 2002) †
Irrigated rice suitability	Pixel 90m*90m	Ramaharitra Tondrasoa, 2012
Elevation	Pixel 90m*90m	SRTM Digital Elevation Model (Shuttle Radar Topography Mission SRTM)
Slope	Pixel 90m*90m	
Distance to recent deforestation (1990 – 2000)	Pixel 90m*90m	ONE, DGF, CI, FTM and MNP (ONE et al., 2013), SRTM Digital Elevation Model (Shuttle Radar Topography Mission SRTM)
Distance to forest edge (2000)	Pixel 90m*90m	
Distance to a village	Pixel 90m*90m	UN OCHA ROSA (UN OCHA ROSA, 2007) , SRTM Digital Elevation Model (Shuttle Radar Topography Mission SRTM)
Distance to an urban center	Pixel 90m*90m	
Distance to a road	Pixel 90m*90m	FTM (Foiben-Taosarintanin´i Madagasikara FTM, 1990), SRTM Digital Elevation Model (Shuttle Radar Topography Mission SRTM)
Distance to a cart track	Pixel 90m*90m	
Duration of trip to urban center	Commune‡	ILO (ILO, 2003)
Population density in 2003	Fokontany‡	Vieilledent et al., 2013

†We have reclassified the agriculture constraints levels of IIASA (Table D4)
‡Administrative levels in Madagascar from the smallest to the largest: Fokontany, Commune, District, Region, Nation

Table D4. Reclassification of the agriculture constraints levels of IIASA (Fischer et al., 2002)

Level of constraints in IIASA	**Reclassification**
No constraints	None*
Very few constraints	Suitable for agriculture
Few constraints	Suitable for agriculture
Partly with constraints	Suitable for agriculture
Frequently severe constraints	Unsuitable for agriculture
Very frequent severe constraints	Unsuitable for agriculture
Unsuitable for agriculture	Unsuitable for agriculture

*There is no “no constraints” area in Madagascar

Table D5. Covariate balance for all CFM vs. non-CFM

Variable	Mean CFM	Mean non-CFM	Difference of means	Mean raw eQQ difference
Suitable land for agriculture (%)				
- Unmatched	18.801	36.798	-17.997	17.997
- Matched	18.801	18.743	0.058	0.058
Unsuitable land for agriculture (%)				
- Unmatched	78.665	61.730	16.935	16.935
- Matched	78.665	78.723	-0.058	0.058
Suitable land for irrigated rice (%)				
- Unmatched	7.710	6.022	1.688	1.688
- Matched	7.710	7.710	0.000	0.000
Slope (degree)				
- Unmatched	6.947	6.488	0.459	0.463
- Matched	6.947	6.945	0.002	0.147
Elevation (m)				
- Unmatched	504.590	423.180	81.410	98.859
- Matched	504.590	511.040	-6.450	14.741
Distance to recent deforestation (km)				
- Unmatched	2.340	3.746	-1.407	1.407
- Matched	2.340	2.149	0.191	0.215
Distance to forest edge (km)				
- Unmatched	0.643	0.369	0.274	0.283
- Matched	0.643	0.555	0.088	0.089
Distance to a village (km)				
- Unmatched	4.792	4.332	0.461	0.465
- Matched	4.792	4.564	0.229	0.287
Distance to a road (km)				
- Unmatched	10.420	11.648	-1.228	1.258
- Matched	10.420	9.835	0.585	0.934
Distance to cart track (km)				
- Unmatched	2.989	3.298	-0.310	0.310
- Matched	2.989	2.982	0.006	0.108
Distance to an urban center (km)				
- Unmatched	60.427	87.909	-27.482	27.507
- Matched	60.427	63.890	-3.463	5.404
Trip to urban center (hour)				
- Unmatched	25.068	32.743	-7.675	10.022
- Matched	25.068	25.273	-0.205	2.146
Population density in 2003 (inh./km^2)				
- Unmatched	14.147	14.469	-0.322	1.391
- Matched	14.147	14.132	0.015	1.020

Table D6. Covariate balance for CFM with information suggesting implementation on the ground vs. non-CFM

Variable	Mean CFM	Mean non-CFM	Difference of means	Mean raw eQQ difference
Suitable land for agriculture (%)				
- Unmatched	13.817	36.798	-22.981	22.980
- Matched	13.817	13.790	0.027	0.027
Unsuitable land for agriculture (%)				
- Unmatched	85.017	61.730	23.287	23.287
- Matched	85.017	85.043	-0.026	0.027
Suitable land for irrigated rice (%)				
- Unmatched	8.817	6.022	2.795	2.793
- Matched	8.817	8.817	0.000	0.000
Slope (degree)				
- Unmatched	6.578	6.488	0.090	0.667
- Matched	6.578	6.654	-0.076	0.192
Elevation (m)				
- Unmatched	532.180	423.180	109.000	138.900
- Matched	532.180	540.610	-8.430	21.194
Distance to recent deforestation (km)				
- Unmatched	2.535	3.746	-1.211	1.212
- Matched	2.535	2.309	0.226	0.255
Distance to forest edge (km)				
- Unmatched	0.704	0.369	0.335	0.342
- Matched	0.704	0.607	0.097	0.098
Distance to a village (km)				
- Unmatched	5.181	4.332	0.849	0.853
- Matched	5.181	4.882	0.299	0.359
Distance to a road (km)				
- Unmatched	11.896	11.648	0.248	0.970
- Matched	11.896	11.089	0.807	1.296
Distance to cart track (km)				
- Unmatched	3.007	3.298	-0.291	0.293
- Matched	3.007	3.025	-0.018	0.152
Distance to an urban center (km)				
- Unmatched	59.889	87.909	-28.020	28.020
- Matched	59.889	64.667	-4.778	7.364
Trip to urban center (hour)				
- Unmatched	31.370	32.743	-1.373	7.189
- Matched	31.370	30.543	0.827	3.029
Population density in 2003 (inh./km^2)				
- Unmatched	11.525	14.469	-2.944	3.268
- Matched	11.525	11.782	-0.257	1.035

Table D7. Covariate balance for commercial CFM vs. non-CFM

Variable	Mean commercial CFM	Mean non-CFM	Difference of means	Mean raw eQQ difference
Suitable land for agriculture (%)				
- Unmatched	0.000	27.956	-27.956	27.957
- Matched	0.000	0.000	0.000	0.000
Unsuitable land for agriculture (%)				
- Unmatched	1.000	70.539	29.461	29.463
- Matched	1.000	1.000	0.000	0.000
Suitable land for irrigated rice (%)				
- Unmatched	23.310	7.216	16.094	16.093
- Matched	23.310	23.310	0.000	0.000
Slope (degree)				
- Unmatched	9.702	8.157	1.546	1.550
- Matched	9.702	9.711	-0.009	0.205
Elevation (m)				
- Unmatched	731.570	519.200	212.370	241.450
- Matched	731.570	721.950	9.620	29.690
Distance to recent deforestation (km)				
- Unmatched	1.499	4.412	-2.913	2.921
- Matched	1.499	1.667	-0.168	0.169
Distance to forest edge (km)				
- Unmatched	0.822	0.386	0.437	0.458
- Matched	0.822	0.677	0.145	0.145
Distance to a village (km)				
- Unmatched	3.112	4.542	-1.431	1.431
- Matched	3.112	3.131	-0.019	0.090
Distance to a road (km)				
- Unmatched	7.256	13.118	-5.862	5.959
- Matched	7.256	7.178	0.078	0.494
Distance to cart track (km)				
- Unmatched	2.233	3.691	-1.457	1.457
- Matched	2.233	2.458	-0.224	0.226
Distance to an urban center (km)				
- Unmatched	34.614	71.736	-37.222	37.227
- Matched	34.614	42.464	-7.850	7.883
Trip to urban center (hour)				
- Unmatched	14.704	32.283	-17.579	17.804
- Matched	14.704	13.972	0.732	4.999
Population density in 2003 (inh./km^2)				
- Unmatched	19.281	13.689	5.592	7.658
- Matched	19.281	19.482	-0.201	2.366

Table D8. Covariate balance for non commercial CFM vs. non-CFM

Variable	Mean non commercial CFM	Mean non-CFM	Difference of means	Mean raw eQQ difference
Suitable land for agriculture (%)				
- Unmatched	29.437	27.842	1.595	1.593
- Matched	29.437	29.380	0.057	0.057
Unsuitable land for agriculture (%)				
- Unmatched	70.430	70.743	-0.313	0.313
- Matched	70.430	70.487	-0.057	0.057
Suitable land for irrigated rice (%)				
- Unmatched	14.923	7.168	7.755	2.793
- Matched	14.923	14.923	0.000	0.000
Slope (degree)				
- Unmatched	6.402	8.090	-1.688	1.699
- Matched	6.402	6.455	-0.053	0.236
Elevation (m)				
- Unmatched	731.470	515.330	216.140	279.240
- Matched	731.470	725.580	5.890	45.265
Distance to recent deforestation (km)				
- Unmatched	1.743	4.409	-2.666	2.677
- Matched	1.743	1.663	0.080	0.237
Distance to forest edge (km)				
- Unmatched	1.177	0.387	0.790	0.794
- Matched	1.177	1.044	0.133	0.133
Distance to a village (km)				
- Unmatched	4.657	4.542	0.114	0.587
- Matched	4.657	4.389	0.268	0.315
Distance to a road (km)				
- Unmatched	12.098	13.087	-0.989	1.706
- Matched	12.098	12.481	-0.383	0.726
Distance to cart track (km)				
- Unmatched	2.778	3.700	-0.922	0.992
- Matched	2.778	3.074	-0.296	0.304
Distance to an urban center (km)				
- Unmatched	47.020	71.739	-24.719	25.727
- Matched	47.020	51.129	-4.109	4.751
Trip to urban center (hour)				
- Unmatched	17.212	32.346	-15.134	17.092
- Matched	17.212	17.487	-0.275	6.447
Population density in 2003 (inh./km^2)				
- Unmatched	9.651	13.599	-3.948	6.719
- Matched	9.651	9.559	0.091	2.327

Table D9. Covariate balance for commercial CFM vs. non commercial CFM

Variable	Mean commercial CFM	Mean non commercial CFM	Difference of means	Mean raw eQQ difference
Suitable land for agriculture (%)				
- Unmatched	0.000	29.207	-29.207	29.207
- Matched	0.000	24.620	-24.620	24.966
Unsuitable land for agriculture (%)				
- Unmatched	1.000	70.625	29.375	29.377
- Matched	1.000	75.380	24.620	24.966
Suitable land for irrigated rice (%)				
- Unmatched	23.310	14.779	8.531	8.530
- Matched	23.310	23.107	0.203	0.187
Slope (degree)				
- Unmatched	9.702	6.462	3.240	3.240
- Matched	9.702	9.384	0.318	0.412
Elevation (m)				
- Unmatched	731.570	731.240	0.330	101.980
- Matched	731.570	680.350	51.220	51.522
Distance to recent deforestation (km)				
- Unmatched	1.499	1.729	-0.230	0.236
- Matched	1.499	1.264	0.235	0.252
Distance to forest edge (km)				
- Unmatched	0.822	1.163	-0.340	0.340
- Matched	0.822	0.796	0.026	0.044
Distance to a village (km)				
- Unmatched	3.112	4.617	-1.505	1.505
- Matched	3.112	3.298	-0.186	0.235
Distance to a road (km)				
- Unmatched	7.256	12.139	-4.883	4.964
- Matched	7.256	6.318	0.938	1.061
Distance to cart track (km)				
- Unmatched	2.233	2.763	-0.530	0.530
- Matched	2.233	2.133	0.100	0.176
Distance to an urban center (km)				
- Unmatched	34.614	46.922	-12.308	12.31
- Matched	34.614	44.160	-9.546	9.541
Trip to urban center (hour)				
- Unmatched	14.704	17.205	-2.501	2.806
- Matched	14.704	15.436	-0.732	0.808
Population density in 2003 (inh./km^2)				
- Unmatched	19.281	9.688	9.593	10.297
- Matched	19.281	17.908	1.373	3.613

Table D10. Covariate balance for non commercial CFM vs. commercial CFM

Variable	Mean non commercial CFM	Mean commercial CFM	Difference of means	Mean raw eQQ difference
Suitable land for agriculture (%)				
- Unmatched	29.437	0.000	29.437	29.437
- Matched	29.437	0.000	29.437	28.669
Unsuitable land for agriculture (%)				
- Unmatched	70.430	1.000	-29.570	29.570
- Matched	70.430	1.000	-29.570	28.797
Suitable land for irrigated rice (%)				
- Unmatched	14.923	23.475	-8.552	8.550
- Matched	14.923	14.923	0.000	0.000
Slope (degree)				
- Unmatched	6.402	9.659	-3.257	3.256
- Matched	6.402	6.619	-0.217	0.435
Elevation (m)				
- Unmatched	731.470	515.330	216.140	279.240
- Matched	731.470	725.580	5.890	45.265
Distance to recent deforestation (km)				
- Unmatched	1.743	1.495	0.249	0.249
- Matched	1.743	1.378	0.365	0.371
Distance to forest edge (km)				
- Unmatched	1.177	0.805	0.372	0.372
- Matched	1.177	1.141	0.036	0.057
Distance to a village (km)				
- Unmatched	4.657	3.093	1.563	1.563
- Matched	4.657	4.159	0.497	0.633
Distance to a road (km)				
- Unmatched	12.098	7.193	4.905	4.973
- Matched	12.098	10.837	1.261	1.805
Distance to cart track (km)				
- Unmatched	2.778	2.240	0.538	0.538
- Matched	2.778	2.517	0.261	0.345
Distance to an urban center (km)				
- Unmatched	47.020	34.720	12.300	12.306
- Matched	47.020	42.138	4.882	4.983
Trip to urban center (hour)				
- Unmatched	17.212	14.506	2.706	2.994
- Matched	17.212	17.252	-0.040	0.723
Population density in 2003 (inh./km^2)				
- Unmatched	9.651	19.534	-9.883	10.560
- Matched	9.651	11.437	-1.786	3.252

Appendix E. Types of vegetation in Madagascar

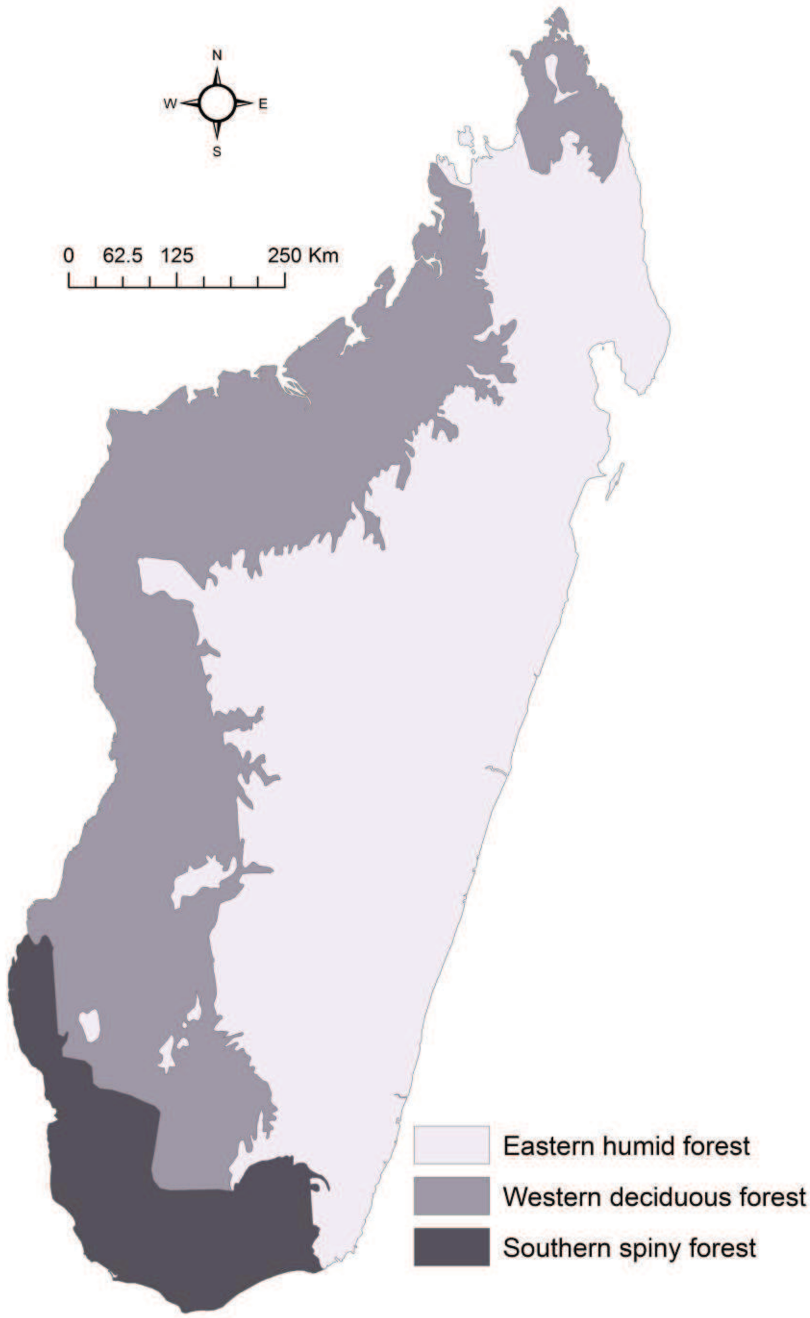

Figure E1. Three major types of vegetation in Madagascar (Sources: Moat and Du Puy, 1997; Schatz and Lescot, 2003; Projection: Laborde Madagascar)

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Manuscript 2: Supporting information

Text S1. Selection of CFM and non-CFM households

We used the percentage of the area of a commune covered by CFM as a criterion to designate CFM (intervention) and non-CFM (comparison) households. CFM households are those located within a commune that has 10% or more of its area covered by CFM. As our results may be sensitive to this arbitrary 10% threshold, we also performed the analysis at 25% threshold. Non-CFM households are those located within a commune that has less than 1 % of its area covered by CFM. Households located within a commune that has between 1% and 10% of its area covered by CFM, urban communes and those that have less than 5% of their areas forested were excluded from the analyses.

Another possible criterion for labeling CFM and non-CFM households is whether a household is located within CFM boundaries. However, in many cases, CFM boundaries only include the locally managed forests and the areas inhabited by the managing communities are outside the boundaries. This study's purpose is to capture the overall well-being impact from the costs and benefits of CFM. These costs and benefits are not restricted to those living closer to forests or those directly participating in CFM. For example, in some communities, CFM facilitated access to development support for dam construction but access to the benefits from the dams has not been conditional on engagement in CFM (Hockley & Andriamarovololona 2007). Moreover, the restrictions imposed by CFM apply to everyone, regardless of whether they personally are engaged in a CFM project, as CFM empowers local management groups to patrol and impose fines on anyone exploiting the forest within the CFM boundaries.

Another reason for using the percentage of the area of a commune covered by CFM as a criterion to designate CFM and non-CFM households is that communes are politically relevant. They are involved in the forest management transfer contract between the local management groups and the forest state department, at least for some CFM sites. The CFM law also requires the commune to integrate CFM in its development policy. Finally, there are also cases where the commune receives taxes from commercial use of forest resources in CFM that permits such activity and thus can play a role in redistributing benefits from commercial use of forest resources among people under its jurisdiction (Randrianarivelo et al. 2012). They may also receive benefits from carbon or other money linked to global ecosystem service capture. For example, in Makira protected area in northeastern Madagascar. funds acquired from carbon marketing are flown to the districts and the regions (administrative units larger than a commune) "to promote sustainable development and improved land stewardship practices more broadly across the landscape and region" (Holmes et al. 2008). Therefore, we chose the percent CFM cover of a commune as the selection criterion.

Text S2. Community characteristics as potential confounders

In other countries, community characteristics may facilitate the selection of a site to CFM (Ostrom 2000). These same characteristics are also likely to positively affect household living standards even in the absence of CFM, and thus are potential confounders. In Madagascar, we do not believe that community characteristics are potentially strong confounders for reasons described in Rasolofoson et al. (2015). However, if they were strong confounders, ignoring them in the matching analysis would most likely bias our estimator in the direction of finding a positive impact on living standards (Engel et al. 2013). Adding these community characteristics among our covariates would remove that bias and would make CFM less effective in our analysis. We found no impacts of CFM on household living standards, so adding these community confounders in our analyses is unlikely to reverse our conclusion that we cannot detect an impact of CFM in improving household living standards.

However, our placebo test supports that community characteristics do not strongly affect selection of sites to CFM in Madagascar. If these community characteristics existed in soon-to-be (placebo) CFM communities and were having an effect on wellbeing, we would detect a difference in the wellbeing of our placebo CFM and matched non-CFM households. We do not detect such a difference. The absence of such a difference could arise because these characteristics did not affect selection of sites to CFM or because they have no effect on wellbeing (in both of these cases they are not confounding variables) or because they correlate to the variables that we already controlled for, and thus the pre-treatment community characteristics are similar in CFM and matched non-CFM households (i.e. our observable variables are sufficient to capture other potential unobservable confounding variables such as these community characteristics).

Text S3. Effects of CFM on migration

Restrictions imposed by CFM rules could displace poor households from CFM areas to non-CFM areas where there are fewer restrictions (Pollini & Lassoie 2011). In this case, the mean household consumption in CFM areas would rise while that of non-CFM areas would go down, and thus may introduce bias in our results.

To test this potential source of bias, we look at whether CFM caused emigration. We used data on migration at commune level collected in 2007 (FID 2007). In this data, focus group in each commune was asked the following question: compared to 2001, are there more people moving out of the commune?

We selected CFM established from 2002 to 2007. Then, we designated as CFM communes those that have more than 10% of their areas covered with CFM and non-CFM communes those with less than 1% of their areas covered with CFM. We excluded from the analyses communes that have between 1% and 10% of their areas covered by CFM, communes with less than 5% forest cover, urban communes and those with more than 1% of their areas covered by CFM before 2002.

We matched CFM and non-CFM communes in terms of the same commune (site) confounding characteristics as in the household consumption analyses (see table S4 for covariate balance). Then, we run a post matching binary logistic regression on the matched dataset. The outcome variable is the focus group response to the migration question: increased or non-increase emigration relative to 2001 (when there was no CFM intervention in the selected sites)

The result shows the effect of CFM on emigration is small (0.035) and not statistically significant (p. 0.94) at commune level. Thus, we have some confidence that the migration scenario could not explain the difference in household consumption between CFM and non-CFM households in our results.

Table S1. Data sources

Data	**Source**
Household consumption expenditures	INSTAT 2006 (falsification test), INSTAT 2011, 2013
Household characteristics	
CFM data (boundaries, year of creation)	Direction Générale des Forêts (Alexio Lohanivo), Office National pour l'Environnement, Asity, Fanamby, Durrell Wildlife Conservation Trust, Conservation International, Wildlife Conservation Society, and World Wide Fund for Nature
Irrigated rice suitability	Ramaharitra Tondrasoa 2012
Elevation	SRTM Digital Elevation Model (Shuttle Radar Topography Mission SRTM)
Slope	
Forest cover 2000	Harper et al. 2007
Roads	Foiben-Taosarintanin´i Madagasikara FTM 1990
Cart tracks	
Duration of trip to urban center	ILO 2003
Population	
Commune boundaries	

Table S2. Numbers of CFM and non-CFM communes and sampled households in the falsification test

	CFM	**Non-CFM**
Commune	27	111
Household	466	2,630

Table S3. Raw (pre-matching) descriptive statistics of household per capita consumption expenditures across different samples

Sample	**Mean (US$)**	**Standard deviation (US$)**
Threshold 10% cover of the commune		
All households	304.627	252.891
CFM households	295.406	220.608
Non-CFM households	307.892	263.325
Threshold 25% cover of the commune		
All households	310.587	262.448
CFM households	337.124	252.424
Non-CFM households	307.892	263.325
Falsification test		
All households	336.655	357.544
CFM households	369.901	574.405
Non-CFM households	329.496	290.101

Table S4. Covariate balance for CFM vs. non-CFM households at the threshold of 10% CFM cover of the commune

Variable	Mean CFM	Mean non-CFM	Difference of means	Mean raw eQQ difference*
Male household head (%)				
- Unmatched	79.698	77.848	1.850	1.852
- Matched	79.698	82.647	-2.949	3.042
Household head age (years)				
- Unmatched	41.690	41.998	-0.308	0.529
- Matched	41.690	41.433	0.257	1.134
Single female household head (%)				
- Unmatched	17.833	19.480	-1.647	1.646
- Matched	17.833	16.804	1.029	0.992
Household head with no education (%)				
- Unmatched	66.735	65.533	1.202	1.235
- Matched	66.735	67.353	-0.618	0.661
Household head with primary education (%)				
- Unmatched	24.005	22.784	1.221	1.235
- Matched	24.005	23.457	0.548	0.595
Household head with secondary education (%)				
- Unmatched	9.259	11.683	-2.424	2.400
- Matched	9.259	9.191	0.068	0.066
Household with children under five (%)				
- Unmatched	45.885	46.247	-0.362	0.343
- Matched	45.885	45.336	0.549	0.529
Household with disable over 5 (%)				
- Unmatched	2.400	2.648	-0.248	0.274
- Matched	2.400	2.400	0.000	0.000
Household in arid zone (%)				
- Unmatched	20.027	24.824	-4.797	4.801
- Matched	20.027	20.027	0.000	0.000
Household in cyclonic zone (%)				
- Unmatched	37.106	32.062	5.044	5.075
- Matched	37.106	37.106	0.000	0.000
Commune forest area (km^2)				
- Unmatched	301.660	185.580	116.080	116.310
- Matched	301.660	229.200	72.460	75.186
Commune forest proportion (%)				
- Unmatched	34.685	24.729	9.956	9.954
- Matched	34.685	31.297	3.388	3.908
Commune average slope (degree)				
- Unmatched	6.179	5.924	0.255	0.838

- Matched	6.179	6.556	-0.377	1.048
Commune maximum slope (degree)				
- Unmatched	36.593	35.373	1.220	4.059
- Matched	36.593	38.276	-1.683	5.351
Commune average elevation (m)				
- Unmatched	472.920	395.770	77.150	88.788
- Matched	472.920	510.490	-37.570	45.062
Commune maximum elevation (m)				
- Unmatched	951.470	845.910	105.560	136.660
- Matched	951.470	966.060	-14.590	85.282
Commune land suitable for irrigated rice (%)				
- Unmatched	11.642	11.225	0.417	4.032
- Matched	11.642	11.300	0.342	2.396
Commune roadless volume (km^3)				
- Unmatched	8084.40	8722.10	-637.70	2175.40
- Matched	8084.40	7847.40	237.00	2503.30
Commune cart trackless volume (km^3)				
- Unmatched	2214.80	2352.50	-137.70	329.16
- Matched	2214.80	2095.50	119.30	402.70
Commune population density (inh/km^2)				
- Unmatched	34.721	38.567	-3.846	7.337
- Matched	34.721	29.801	4.920	4.874
Protected forest proportion (%)				
- Unmatched	10.598	10.967	-0.369	2.637
- Matched	10.598	7.182	3.416	5.024
Duration of trip to an urban center (hours)				
- Unmatched	19.598	31.341	-11.743	11.789
- Matched	19.598	18.364	1.234	5.862

*The mean difference in raw eQQ is a descriptive statistic based on the empirical Quantile-Quantile (eQQ) plot (Sekhon 2011). It measures the mean distance observed in the eQQ plot when the distribution of a variable is plotted in two different samples, such as CFM and non-CFM households (Sekhon and Grieve 2009).

Table S5. Covariate balance for CFM vs. non-CFM households at the threshold of 25% CFM cover of the commune

Variable	Mean CFM	Mean non-CFM	Difference of means	Mean raw eQQ difference*
Male household head (%)				
- Unmatched	79.665	77.848	1.817	1.914
- Matched	79.665	80.622	-0.957	0.903
Household head age (years)				
- Unmatched	42.251	41.998	0.253	0.844
- Matched	42.251	44.263	-2.012	2.447
Single female household head (%)				
- Unmatched	18.900	19.480	-0.580	0.718
- Matched	18.900	18.900	0.000	0.000
Household head with no education (%)				
- Unmatched	63.397	65.533	-2.136	2.153
- Matched	63.397	63.876	-0.479	0.451
Household head with primary education (%)				
- Unmatched	26.077	22.784	3.293	3.349
- Matched	26.077	25.598	0.479	0.451
Household head with secondary education (%)				
- Unmatched	10.526	11.683	-1.157	1.196
- Matched	10.526	10.526	0.000	0.000
Household with children under five (%)				
- Unmatched	46.411	46.247	0.164	0.239
- Matched	46.411	46.651	-0.240	0.000
Household with disable over 5 (%)				
- Unmatched	2.392	2.648	-0.256	0.239
- Matched	2.392	1.914	0.478	0.451
Household in arid zone (%)				
- Unmatched	0.000	24.824	-24.824	24.880
- Matched	0.000	0.000	0.000	0.000
Household in cyclonic zone (%)				
- Unmatched	50.000	32.062	17.938	17.943
- Matched	50.000	50.000	0.000	0.000
Commune forest area (km^2)				
- Unmatched	231.720	185.580	46.140	59.838
- Matched	231.720	184.940	46.780	53.905
Commune forest proportion (%)				
- Unmatched	36.842	24.729	12.113	14.096
- Matched	36.842	37.031	-0.189	5.423
Commune average slope (degree)				
- Unmatched	7.409	5.924	1.485	1.761

- Matched	7.409	7.884	-0.475	0.947
Commune maximum slope (degree) - Unmatched - Matched	 40.886 40.886	 35.373 43.213	 5.513 -2.327	 6.457 4.380
Commune average elevation (m) - Unmatched - Matched	 537.860 537.860	 395.770 558.680	 142.090 -20.820	 157.440 71.733
Commune maximum elevation (m) - Unmatched - Matched	 1027.10 1027.10	 845.910 1081.10	 181.190 -54.000	 204.830 124.450
Commune land suitable for irrigated rice (%) - Unmatched - Matched	 14.339 14.339	 11.225 16.587	 3.114 -2.248	 7.024 5.244
Commune roadless volume (km^3) - Unmatched - Matched	 6613.20 6613.20	 8722.10 6038.80	 -2108.90 574.400	 2498.20 1330.40
Commune cart trackless volume (km^3) - Unmatched - Matched	 1599.50 1599.50	 2352.50 1717.00	 -753.000 -117.500	 774.020 270.870
Commune population density (inh/km^2) - Unmatched - Matched	 44.286 44.286	 38.567 37.694	 5.719 6.592	 15.171 8.821
Protected forest proportion (%) - Unmatched - Matched	 8.990 8.990	 10.967 13.641	 -1.977 -4.651	 6.320 9.072
Duration of trip to an urban center (hours) - Unmatched - Matched	 12.975 12.975	 31.341 17.999	 -18.366 -5.024	 18.676 5.977

*The mean difference in raw eQQ is a descriptive statistic based on the empirical Quantile-Quantile (eQQ) plot (Sekhon 2011). It measures the mean distance observed in the eQQ plot when the distribution of a variable is plotted in two different samples, such as CFM and non-CFM households (Sekhon and Grieve 2009).

Table S6. Covariate balance for placebo CFM vs. non-CFM households for the falsification test

Variable	Mean CFM	Mean non-CFM	Difference of means	Mean raw eQQ difference*
Male household head (%)				
- Unmatched	79.375	80.416	-1.041	0.937
- Matched	79.375	79.375	0.000	0.000
Household head age (years)				
- Unmatched	41.341	42.211	-0.870	1.178
- Matched	41.341	41.591	-0.250	1.129
Single female household head (%)				
- Unmatched	17.500	18.090	-0.590	0.625
- Matched	17.500	20.312	-2.812	2.703
Household head with no education (%)				
- Unmatched	70.000	60.993	9.007	9.062
- Matched	70.000	70.312	-0.312	0.300
Household head with primary education (%)				
- Unmatched	24.063	26.681	-2.618	2.500
- Matched	24.063	23.750	0.313	0.300
Household head with secondary education (%)				
- Unmatched	5.937	12.327	-6.390	-6.390
- Matched	5.937	5.937	0.000	0.000
Household with children under five (%)				
- Unmatched	47.500	45.998	1.502	1.562
- Matched	47.500	47.813	-0.313	0.300
Household with disable over 5 (%)				
- Unmatched	2.812	2.935	-0.123	0.312
- Matched	2.812	2.812	0.000	0.000
Household in arid zone (%)				
- Unmatched	32.500	23.372	9.128	9.062
- Matched	32.500	32.500	0.000	0.000
Household in cyclonic zone (%)				
- Unmatched	27.187	26.254	0.933	0.937
- Matched	27.187	27.187	0.000	0.000
Commune forest area (km^2)				
- Unmatched	238.270	188.580	49.690	119.610
- Matched	238.270	164.100	74.170	103.870
Commune forest proportion (%)				
- Unmatched	22.995	22.488	0.507	4.158
- Matched	22.995	24.869	-1.874	4.598
Commune average slope (degree)				
- Unmatched	6.023	5.742	0.281	1.123
- Matched	6.023	5.994	0.029	0.664

Commune maximum slope (degree) - Unmatched - Matched	 36.672 36.672	 34.916 34.876	 1.756 1.796	 3.507 3.910
Commune average elevation (m) - Unmatched - Matched	 404.760 404.760	 385.710 409.030	 19.050 -4.270	 112.440 86.363
Commune maximum elevation (m) - Unmatched - Matched	 856.440 856.440	 821.280 779.530	 35.160 76.910	 114.270 139.370
Commune land suitable for irrigated rice (%) - Unmatched - Matched	 9.171 9.171	 13.506 8.644	 -4.335 0.527	 5.687 2.508
Commune roadless volume (km^3) - Unmatched - Matched	 7074.10 7074.10	 9630.70 4425.00	 -2556.60 2649.10	 2807.60 3383.10
Commune cart trackless volume (km^3) - Unmatched - Matched	 1971.10 1971.10	 2630.10 1638.20	 -659.000 332.900	 802.750 411.070
Commune population density (inh/km^2) - Unmatched - Matched	 32.579 32.579	 51.620 32.471	 -19.041 0.108	 26.270 8.052
Protected forest proportion (%) - Unmatched - Matched	 5.085 5.085	 14.300 7.239	 -9.215 -2.154	 9.277 2.133
Duration of trip to an urban center (hours) - Unmatched - Matched	 26.897 26.897	 37.430 32.520	 -10.533 -5.623	 11.043 8.159

*The mean difference in raw eQQ is a descriptive statistic based on the empirical Quantile-Quantile (eQQ) plot (Sekhon 2011). It measures the mean distance observed in the eQQ plot when the distribution of a variable is plotted in two different samples, such as CFM and non-CFM households (Sekhon and Grieve 2009).

Table S7. Covariate balance for CFM vs. non-CFM communes for the migration analysis (see text S3)

Variable	Mean CFM	Mean non-CFM	Difference of means	Mean raw eQQ difference*
Communes in arid zone (%)				
- Unmatched	10.938	19.484	-8.546	9.375
- Matched	10.938	10.938	0.000	0.000
Communes in cyclonic zone (%)				
- Unmatched	45.312	35.530	9.782	9.375
- Matched	45.312	45.312	0.000	0.000
Commune forest area (km^2)				
- Unmatched	236.130	136.350	99.780	96.398
- Matched	236.130	197.390	38.740	57.505
Commune forest proportion (%)				
- Unmatched	35.886	23.105	12.781	12.683
- Matched	35.886	35.214	0.672	2.409
Commune average slope (degree)				
- Unmatched	7.332	6.625	0.707	1.078
- Matched	7.332	7.505	-0.173	0.566
Commune maximum slope (degree)				
- Unmatched	38.653	38.297	0.356	3.338
- Matched	38.653	39.930	-1.277	2.218
Commune average elevation (m)				
- Unmatched	510.010	421.220	88.880	121.22
- Matched	510.010	490.530	19.480	38.238
Commune maximum elevation (m)				
- Unmatched	993.880	908.600	85.280	140.810
- Matched	993.880	998.110	-4.230	80.828
Commune land suitable for irrigated rice (%)				
- Unmatched	14.350	13.703	0.647	4.558
- Matched	14.350	16.792	-2.442	4.652
Commune roadless volume (km^3)				
- Unmatched	5219.00	6995.80	-1776.80	2700.50
- Matched	5219.00	5227.40	-8.400	1181.90
Commune cart trackless volume (km^3)				
- Unmatched	1564.10	1831.10	-267.000	712.590
- Matched	1564.10	1329.20	234.900	357.030
Commune population density (inh/km^2)				
- Unmatched	48.572	45.922	2.650	21.621
- Matched	48.572	48.679	-0.107	6.880
Protected forest proportion (%)				
- Unmatched	9.616	10.259	-0.643	3.128
- Matched	9.616	13.250	-3.634	3.672

Duration of trip to an urban center (hours) - Unmatched - Matched	 22.861 22.861	 29.904 22.311	 -7.043 0.550	 9.044 3.664

*The mean difference in raw eQQ is a descriptive statistic based on the empirical Quantile-Quantile (eQQ) plot (Sekhon 2011). It measures the mean distance observed in the eQQ plot when the distribution of a variable is plotted in two different samples, such as CFM and non-CFM households (Sekhon and Grieve 2009).

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Manuscript 3: Appendices

Appendix 1. Tables

Table A1.1. Asset index development

Asset or housing characteristic	Unstandardized weight†	Standard deviation	Standardized weight‡
Own bed	0.805	0.497	1.620
Own table	0.796	0.492	1.618
Own chair	0.708	0.474	1.494
Own stool	0.672	0.477	1.409
Own clock	0.082	0.313	0.262
Own rice mortar	-0.054	0.372	-0.145
Own ax	0.063	0.398	0.158
Own torch	0.157	0.455	0.345
Own dresser	0.091	0.303	0.300
Own mobile phone	0.159	0.365	0.436
Own basin	0.358	0.498	0.719
Own water can	-0.068	0.477	-0.142
Own machete	0.103	0.468	0.220
Own sprayer pump	0.238	0.349	0.682
Own pitchfork	0.250	0.349	0.716
Own shovel	0.095	0.493	0.193
Own chicken	0.031	0.349	0.089
Own other poultry	0.130	0.486	0.267
Own zebu	0.084	0.410	0.205
Dwelling with hard wall (brick or mud)	0.247	0.415	0.595
Number of rooms in dwelling	0.478	0.798	0.599

†Unstandardized weight: weight assigned to each asset or housing characteristic in the linear combination of the assets and housing characteristics that constitute the first principal component, which explains 25% of the covariance.
‡Standardized weight = Unstandardized weight / Standard deviation
Notes: $A_i = b_1 \cdot a_{1i} + b_2 \cdot a_{2i} + \dots + b_k \cdot a_{ki}$, where A_i is the asset index for household "i", (a_{1i}, a_{2i}, … ,a_{ki}) are k indicators of asset ownership and housing characteristics and take the value 1 or 0 (except for Number of rooms in dwelling), and (b_1, b_2, … , b_k) are the standardized weights.

Table A1.2. Focus groups: number of participants and labeling

Village	Number of focus group participants	Focus group labeling
Zahamena National Park (strictly protected area)	26	
Village ZNP1	12	FG-ZNP1
Village ZNP2	6	FG-ZNP2
Village ZNP3	8	FG-ZNP3
Ambohilero CFM†	71	
Village CFM1	10	FG-CFM1
Village CFM2	10	FG-CFM2
Village CFM3	10	FG-CFM3
Village CFM4	7	FG-CFM4
Village CFM5	5	FG-CFM5
Village CFM6	10	FG-CFM6
Village CFM7	7	FG-CFM7
Village CFM8	12	FG-CFM8

†CFM: Community Forest Management

Table A1.3. Domains nominated as important to respondents' quality of life

Domains	Frequency of respondent	Farnworth (2004) [†]	Camfield and Ruta (2007)[ǀ]	Martin et al. (2010)[¶]
Agriculture	93 (73.81%)		X	
Health	76 (60.32%)	X[‡]	X	X
Livestock	69 (54.76%)	X[§]	X	X
Education	61 (48.41%)	X[‡]	X	X
Work equipment / Agricultural equipment	49 (38.89%)			
Livelihood activities / Job	46 (36.51%)		X	X
Family, children, spouse, parents, relatives, marriage	28 (22.22%)	X[§]	X	X
Land / Agricultural land	22 (17.46%)	X[§]	X	X
Money / Wealth	22 (17.46%)	X[‡]	X	X
House	20 (15.87%)		X	X
Furniture	19 (15.08%)	X[§]		
Food	19 (15.08%)	X[‡]		X
Infrastructure	12 (9.52%)	X[§]		
Rice	11 (8.73%)	X[§]		
Community relation	7 (5.55%)	X[§]	X	X
Forest products / Water products	7 (5.55%)	X[§]		
Poverty / Development	7 (5.55%)		X	
Peace	5 (3.97%)		X	
External support	3 (2.38%)			
Electricity / Light	3 (2.38%)			
Religion	2 (1.59%)		X	X
Clothing	2 (1.59%)			X
Cigarette	2 (1.59%)			
Motivation, fence, hospitality, fire, coffee, forest management association, environment, market, and mining were each mentioned once (0.79%)				

[†]Quality of life domains overlapping with those of Farnworth (2004)
[‡]Quality of life domains overlapping with the main domains of Farnworth (2004)
[§]Quality of life domains overlapping with the components of the main domains of Farnworth (2004)
[ǀ]Quality of life domains overlapping with those of Camfield and Ruta (2007)
[¶]Quality of life domains overlapping with those of Martin et al. (2010)

Appendix 2. Survey instruments

VILLAGE SURVEY INSTRUMENT

A. SURVEY INFORMATION

A.1. ADMINISTRATIVE UNITS

	CODE
REGION	(RID)
DISTRICT	(DID)
COMMUNE	(CID)
FOKONTANY	(FID)
VILLAGE	(VID)

A.2. SURVEY TIME AND SPACE LOCATION

VILLAGE/TOWN/CITY OF DEPARTURE		
BETWEEN VILLAGE OF DEPARTURE AND THE VILLAGE OF SURVEY	DISTANCE	*km*
	DURATION OF TRAVEL	*hours and / or min*
	MEANS OF TRAVEL	
DATE OF ARRIVAL IN THE VILLAGE OF SURVEY		
DATE OF DEPARTURE FROM THE VILLAGE OF SURVEY		

A.3. FOCUS GROUP DISCUSSION SUMMARY

INTERVIEWER		
DATE		
TIME	START:	END:
ANY COMMENTS		

A.4. FOCUS GROUP PARTICIPANTS (6 TO 12 PEOPLE)

CODE	What is your name?	SEX **M: 1** **F: 0**	LEADERSHIP POSITION	How long have you been in that position? (YEARS)	What is your main livelihood activity? **FARMER: 1** **SELLER: 2** **OFFICER: 3** **OTHER, SPECIFY: 4**	How old are you?	How long have you lived in this village? (YEARS)	What is the highest grade you have attained in school?	What ethnic group do you belong to?	WEALTH **RICH: 2** **MEDIUM: 1** **POOR: 0**
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										

B. VILLAGE INFORMATION

1. What is the name of the village?		CODE:
2. What are the GPS coordinates of the center of the village	Latitude	*degrees*
	Longitude	*degrees*
	Altitude	*m*

C. DEMOGRAPHICS

1. In what year (or when) was the village established in this site?			
2. What is the current population of the village?			*persons*
3. How many households live currently in this village?			*households*
4. What was the total population of the village 10 years ago?			*persons*
5. How many households lived in the village 10 years ago?			*households*
6. How many persons (approx.) living here now have moved to the village in the past 10 years (in-migration)?			*persons*
7. How many persons (approx.) have left the village over the past 10 years (out-migration)?			*persons*
8. What are the principal ethnic groups in this village?	A.	B.	C.
9. What is the proportion of each ethnic group?	A.	B.	C.
10. What were the principal ethnic groups in this village 10 years ago?	A.	B.	C.
11. What was the proportion of each ethnic group10 years ago?	A.	B.	C.

D. LIVELIHOOD ACTIVITIES

ACTIVITIES	Please rank activities in order of significance (GIVE 0 TO ACTIVITIES THAT DO NOT APPLY)
Agriculture	
Livestock (including pisciculture and bee keeping)	
Collect of forest products	
Fishing	
Handicraft	
Mining	
Other (specify)	
Other (specify)	
Other (specify)	

E. PHYSICAL ACCESS

ADMINISTRATIVE CENTER [AC]	1. Where is the … [AC]?	2. How long does it take to get there? (HOURS AND/OR MIN)	3. What is the main means of transportation used to get there?
Chef-lieu de commune			
Chef-lieu de district			

F. AGRICULTURE

1. What is the main source of water for agriculture in the wet season? LAKE: 1, RIVER: 2, RAIN: 3, OTHER: SPECIFY: 4		
2. What is the main source of water for agriculture in the dry season? LAKE: 1, RIVER: 2, NONE: 3, OTHER: SPECIFY: 4		
3. Which of the following is the main means to transport agricultural products? (CROSS [X] IN THE APPROPRIATE MEANS)	Car/Truck/Taxi-brousse	
	Ox cart (charette)	
	Boat or pirogue	
	Human back	
	Other, specify:	

G. INFRASTRUCTURES

INFRASTRUCTURE [INFR]	1. Where is the main … [INFR] used by the villagers?	2. How long does it take to get there? (HOURS AND/OR MIN)	3. What is the main means of transportation used to get there?	4. When was this … [INFR] established? (BY WHOM)
Market				
EPP or private				
CEG or private				
Lycee or private				
Health (CSB, hospital, dispensaire…)				
Gendarme post				

INFRASTRUCTURE [INFR]	5. Does the village have access to … [INFR]? YES: 1, NO: 0	6. How many households (approx.) in the village have access to … [INFR]?	7. When did the village start to have access to … [INFR]? (BY WHOM)
Electricity			
Clean piped drinking water			
Telecommunication (Telma, Airtel, Orange…)			
Credit (OTIV, CECAM…)			

ROAD		NAVIGABLE RIVER	
8. Is it possible to reach the village by car? YES: 1, NO: 0 (>> 10)		12. Is it possible to reach the village by boat or pirogue? YES: 1, NO: 0 (>> 14)	
9. Is it possible to reach the village by car all year round? YES: 1 (>> 12), NO: 0 (>> 11)		13. Is the river navigable all year round? YES: 1 (>> next section), NO: 0 (>> 15)	
10. How long does it take to go to the nearest road accessible by car?	*hours and/or min*	14. How long does it take to go to the nearest navigable river?	*hours and/or min*
11. How long does it take to go to the nearest road usable all year round?	*hours and/or min*	15. How long does it take to go to the nearest river that is navigable all year round?	*hours and/or min*

H. RISK AND SECURITY

1. Between 2011 and 2014, what is the number of years with…?	Cyclone	
	Flood	
	Drought	
	Locust invasion	
	Too early rain	
	Too late rain	
	Dahalo attack	
	Other, specify:	
2. How do you perceive security in your village in the latest 3 years? (1: very bad to 5: very good)		

I. INTERVENTION IMPACTS

How has the intervention (strictly protected area or CFM) impacted the villagers’ lives?

HOUSEHOLD SURVEY INSTRUMENT

Interview starts at:

Survey information

ACTIVITY/TASK	DATE	PERSON(S) RESPONSIBLE	COMMENTS
INTERVIEW			
CHECKING QUESTIONNAIRE			
CODING QUESTIONNAIRE			
DATA ENTRY			
CHENKING AND APPROVING DATA ENTRY			

Identification

1. HH NAME & CODE	(NAME)		(HHID)
2. VILLAGE NAME & CODE	(NAME)		(VID)
3. FOKONTANY NAME & CODE	(NAME)		(FID)
4. COMMUNE NAME & CODE	(NAME)		(CID)
5. DISTRICT NAME & CODE	(NAME)		(DID)
6. NAME & PID OF PRIMARY RESPONDENT	(NAME)		(PID)
7. NAME & PID OF SECONDARY RESPONDENT	(NAME)		(PID)
8. GPS LOCATION OF THE HH	(LAT)	(LONG)	(ALT)
9. DISTANCE OF HH FROM VILLAGE CENTER	(MINUTES)		(KM)

HH replacement (if applicable)

THIS HH WAS REPLACED BY HH	(HHID)	REASON FOR REPLACING DWELLING NOT FOUND……. ...1 HH ABSENT……………..………...2 REFUSAL………………….............3 OTHER (SPECIFY)….4
THIS HH REPLACES HH	(HHID)	

	HH members	Non HH members
OTHER PEOPLE PRESENT (DO NOT COUNT SMALL CHILDREN) YES….1 NO…...2		

A- INFORMATION ABOUT RESPONDENT(S) AND HH COMPOSITION

1. INFORMATION ABOUT THE HH HEAD AND RESPONDENT

a. Is the main respondent also the HH head? YES……..1 >> "l." NO……...2	g. Why did the HH head move to this village? Study……..1 Land availability…………….4 Work……....2 Moving with parents…..……5 Marriage….3 Other (specify).….6
b. What is the relationship of the respondent to the HH head? SPOUSE……...1 PARENT IN LAW…6 NEPHEW/NIECE…........10 KID..................2 SIBLING……..…....7 STEP/FOSTER CHILD…11 KID IN LAW…3 SIBLING IN LAW…8 OTHER FAMILY……....12 GRANDKID….4 UNCLE/AUNT….…9 NOT RELATED………..13 PARENT……...5	h. What ethnic group does the HH head belong to? Sihanaka… 1 Merina…………………..…...4 Betsimisaraka…2 Betsileo…………...……....5 Bezanozano… .3 Other (specify)…6
c. Why was the HH head unable to respond? Ill……………………....…1 Absent…………………......2 Respondent insisted…...…4 [NAME] refused…3 Other (specify)...5	i. What is the primary occupation of the HH head? Agriculture..1 Daily wage……….…..…4 Govt………2 Collector……..…….……5 Pvt………...3 Other (specify)…6
d. Was the HH head born in this village? YES……1 >> "h." NO…..…2	j. What is the marital status of the HH head? Married & living together………....1 Married & spouse working away…2 Widow…………………………...…3 Never married…………..…5 Divorced………………………….....4 Other (specify)…6
e. How long has the HH head lived in this village? YEARS	k. How long ago was this HH formed? YEARS
f. Where did the HH head come from? (COMMUNE AND REGION)	

l. Were you born in this village? YES……1 >> "p." NO…..…2		p. What ethnic group do you belong to? Sihanaka……….1 Merina…………………..…...4 Betsimisaraka….2 Betsileo……….……...……....5 Bezanozano……3 Other (specify)…6	
m. How long have you lived in this village	YEARS	q. What is your primary occupation? Agriculture..1 Daily wage…………...…4 Govt………2 Collector……..…………5 Pvt………...3 Other (specify)…6	
n. Where did you come from? (COMMUNE AND REGION)		r. What is your marital status? Married & living together………....1 Married & spouse working away…2 Widow…………………………...…3 Never married…………..…5 Divorced…………………………....4 Other (specify)…6	
o. Why did you move to this village? Study….….1 Land availability……..……4 Work……...2 Moving with parents…....…..5 Marriage…3 Other (specify)...6		s. How long ago was your HH formed?	YEARS

2. HH ROSTER

<u>Questions “b.” and “c.”</u>

I would like to make a list of and ask information about all the people who **live and eat their meals together** in this dwelling.

First, I would like to have the names of the HH head, his wife and his children in order of age

WRITE DOWN THE MANES AND SEX

Please give me the names of any other persons related the HH head or to his wife, together with their families (if applicable), who normally **live and eat their meals** here

WRITE DOWN THE NAMES AND SEX

Please give me the names of any other persons not related the HH head or to his wife, together with their families (if applicable), who normally **live and eat their meals** here

WRITE DOWN THE NAMES AND SEX

Are there any other persons not now present but who normally **live and eat their meals** here? For example, any person studying or working somewhere else or who is visiting other people

WRITE DOWN THE NAMES AND SEX

<u>Questions “d.” to “h.”</u>

FOR EACH PERSON LISTED IN QUESTION “b.”, ASK THE QUESTIONS “d.” to “h.”. COMPLETE THE ENTIRE LINE BEFORE GOING ON TO THE NEXT PERSON LISTED

a. PERSONAL ID (PID)	b. MAKE A COMPLETE LIST OF ALL CONCERENED BEFORE GOING TO QUESTIONS “c.” TO “g.” NAME	c. SEX MALE.1 FEMALE..2	d. In what year was [NAME] born?	e. How old is [NAME] ? YEARS IF ≥ 5 YEARS AND MONHTS IF < 5		f. What is the highest education attainment of [NAME]? No school……………..1 Primary……………….2 Secondary…………….3 High school…………...4 University…………….5 Too young for school....6 Other (specify)….7	g. What is the main occupation of [NAME] ? Agriculture……………..1 Govt……………………2 Pvt……………………...3 Daily wage…………….4 Collector……..........…5 In school…………..….6 Too young..…………….7 Other (specify)…8	h. Has [NAME] lived in this HH for 6 months or more? YES…1 NO…..2
				YEARS	MONTHS			
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								

B- ASSETS

1. HOUSEHOLD ITEMS

a. CODE	b. ITEM	c. Do you have any [ITEM]? YES….1 NO……2	d. How many [ITEM] do you have?
1	Radio		
2	Bicycle		
3	Mobile phone		
4	Torch		
5	Bed		
6	Chair		
7	Ax		
8	Dresser		
9	Basin		
10	Bucket		
11	Water can		
12	Table		
13	Rice mortar		
14	Clock		
15	Stool		
16	Other (Specify)		
17	Other (Specify)		
18	Other (Specify)		

2. AGRICULTURAL EQUIPMENT

a. CODE	b. EQUIPMENT	c. Do you have any [EQUIPMENT]? YES….1 NO……2	d. How many [EQUIPMENT] do you have?
1	Shovel		
2	Spade		
3	Plow		
4	Machete		
5	Harrow		
6	Weeder		
7	Sprayer pump		
8	Pitchfork		
9	Other (Specify)		
10	Other (Specify)		
11	Other (Specify)		

3. LIVESTOCK

a. CODE	b. ANIMAL	c. Do you have any [ANIMAL]? YES….1 NO……2	d. How many [ANIMAL] do you have?
1	Zebu		
2	Pig		
3	Chicken		
4	Duck		
5	Goose		
9	Other (Specify)		
10	Other (Specify)		

4. LAND HOLDING

a. PLOT ID	b. Please tell us about each plot of land belonging to your HH and those you used for the last agricultural year (2013-2014). Please give us the name of each plot/site/location of the plot.	c. For what this plot was used for the last agricultural year (2013-2014)? Tavy………..1 Tanimbary…2 Savoka…………………4 Tanimboly….3 Other (specify)…5
1		
2		
3		
4		
5		
6		
7		

5. HOUSING CHARACTERISTICS

a. How many permanent houses do you have?	
b. How many temporary houses do you have?	
c. What is the major construction material of the external walls of the main house? Brick……………………….1 Mud……………….……….2 Wood…………….……...3 Bamboo…………………...4 Pandanus…………………5 Other (specify)…6	
d. What is the major material of the roof of the main house? Metal sheets………………1 Tile………………………….2 Wood……………………....3 Leaves……………………..4 Pandanus…………………..5 Other (specify)…6	
e. What is the major material of the floor of the main house? Wood……………………….1 Mat……………………….2 Concrete….………………...3 Clay/earthen floor…………4 Other (specify)….5	
f. How many floors does the main house have?	
g. How many rooms does the main house have?	

C- QUALITY OF LIFE

STAGE I: SELECTING DOMAINS	STAGE II: SCORING EACH DOMAIN	STAGE IV: LINK TO THE INTERVENTION	STAGE III: SPEND PEBBLES
We would like to ask your opinions about the life you are living now. Could you tell us the five (5) priority domains in your life?	We want to ask you to measure the feeling you have about each of the domains you mentioned using the following measures 4- Very good as you want 3- Good but not as good as you want 2- Medium 1- Bad but not as bad as you fear 0- Very bad as you fear	Do you think that forest protection by the strictly protected area or CFM has contributed to your [SCORE IN STAGE II]? YES….1 NO…….2	We want you to 'spend' 10 pebbles to show which domains of your life you feel are most important. Spend more pebbles on domains you feel are most important to you and fewer pebbles on domains that you feel are not so important. You do not have to spend any pebbles on a domain.
1.			
2.			
3.			
4.			
5.			

Interview ends at:

Appendix 3. Quotes in Malagasy language

Quote A3.1: "Savo-drazana taloha lasa voafaritra ao anatin'i Parka. Tsy azon'ny olona hampiasaina intsony ireny savoka ireny." (FG-ZNP1)

Quote A3.2: "Ny olona mitombo ka mety tsy ho ampy ny tany ampiasaina any aoriana any." (FG-ZNP3)

Quote A3.3: "Tery be ny tany azo ambolena. Ny ilan'ny taninay lasan'i ZNP1 ary ny ilany lasan'i ZNP2. Tsy manan-tany izahay." (FG-ZNP2)

Quote A3.4: "Tsy misy asa fampandrosoana na fanampiana omen'i MNP. Ny fampanantenana toy ny fanamboarana barazy tsy tanteraka." (FG-ZNP 1)

Quote A3.5: "Mahazo ny orana ilaina amin'ny fambolena rehefa misy ny ala." (FG-ZNP2)

Quote A3.6: "Misy ala dia tsy tototry ny fasika avy amin'ny riaka ny tanim-pambolena." (FG-ZNP3)

Quote A3.7: "Ny VOI no nanambotra io sekoly io. Anjaranay ny manome ny karaman'ilay mpampianatra fa noho ny fahasahiranan'ny vahoaka dia tsy araka ilay izy ary lasa ilay mpampianatra." (FG-CFM1)

Quote A3.8: "Tsy ampy ny vokatra noho ny tany tsy ampy." (FG-CFM2)

Quote A3.9: "Mitombo be ny isan'ny mponina. Izahay anefa tsy afaka manitatra tany ka tsy ampy noho izany ny tany fambolena." (FG-CFM3)

Quote A3.10: "Mahatonga ny fipetrahanay sy fitadiavana ary ny asam-pambolena aty anaty ala ho ara-dalana." (FG-CFM4)

Quote A3.11: "Mba mahazo alalana manao fivelomana sy asam-pambolena fa tsy voaroaka." (FG-CFM1)

Quote A3.12: "Mahazo fampitahorana fandroahana sy figadrana avy amin'ny VOI izahay fa hoe mandripaka ala. Tsy mahazo fahafaham-po izahay amin'ny tany azo ambolena." (FG-CFM5)

Quote A3.13: "Ny fiarovana ny ala dia mitondra orana ampy tsara ilaina amin'ny fambolena." (FG-CFM3)

Quote A3.14: "Ny ala arovana dia mitondra rivotra madio sy manome ravina fanao fanafody." (FG-CFM1)