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CERDI
65 BD. F. MITTERRAND
63000 CLERMONT FERRAND – FRANCE
TEL. + 33 4 73 17 74 00
FAX + 33 4 73 17 74 28
www.cerdi.org

The authors

Sebastien Desbureaux
PhD Student - CERDI, Université d'Auvergne, UMR CNRS 6587, 63009 Clermont-Ferrand (France) ; CIRAD-BSEF, Montpellier (France). E-mail: sebastien.desbureaux@udamail.fr

Sigrid Aubert
Researcher - CIRAD-GREEN, Antananarivo (Madagascar); ESSA-Agro Management, Antananarivo (Madagascar). E-mail: sigrid.aubert@cirad.fr

Laura Brimont
Researcher - IDDRI, Paris (France). E-mail : laura.brimont@sciencespo.fr

Alain Karsenty
Researcher - CIRAD-BSEF, Montpellier (France). E-mail : alain.karsenty@cirad.fr

Alexio Clovis Lohanivo
PhD Student - CIRAD-GREEN, Antananarivo (Madagascar); ESSA-Agro Management, Antananarivo (Madagascar). E-mail : alexioclovis@yahoo.fr

Manohisoa Rakotondrabe
PhD Student - ESSA-Agro Management, Antananarivo (Madagascar). E-mail : manohichou@gmail.com

Andrianjakarivo Henintsoa Razafindraibe
Engineering Student - ESSA-Agro Management, Antananarivo (Madagascar)
E-mail : andrianjakarivo@gmail.com

Jules Razafiarijaona
Teacher-Researcher - ESSA-Agro Management, Antananarivo (Madagascar). E-mail : razafiarijaonaj@yahoo.fr

Corresponding author: Sébastien Desbureaux

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Abstract

Protected areas (PAs) remain the primary conservation instrument of Madagascar's unique but threatened biodiversity. We combine matching and panel regressions in a quasi-natural experiment setting to analyze PAs' environmental effectiveness annually between 2001 and 2012 and study two channels that moderate the impact: initial poverty rates and local variations in law enforcement. Our findings show that PAs have stabilized deforestation around a positive trend without having halted it. Their overall environmental impact is however limited: PAs created before the 2000 have helped to slow down deforestation by approximately 20%, meaning that 80% of forests are still cleared even though they are protected. As for new PA created from the mid-2000s, the early impact is statistically not significant. As a result, the total welfare impact of protection is currently uncertain. We show that PAs have been effective for municipalities where overall law enforcement was the lowest: PAs have helped to limit what we call opportunistic deforestation. Meanwhile, PAs have been poorly effective when poverty rates were high: when necessity is the driver of deforestation, PAs are not sufficient to slow down deforestation. As a consequence, effectively stopping deforestation in Madagascar will require ambitious policies to trigger the necessary agricultural transition for the country.

Keywords
Impact Evaluation; Protected Areas; Africa; Madagascar

JEL codes
Q2, Q28, Q58, 013

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Authors' contributions: S.D. built the dataset, performed statistical analyses and wrote the paper. S.A, L.B, A.K, and M.R contributed to the writing of specific paragraphs in Section 2 and Section 5. S.D, S.A, L.B, A.K, A.C.L, M.R, A.H.R, and J.R conducted fieldwork that provide background for Sections 2 and 5.

1 Introduction

Impact evaluation of conservation policies is a growing topic. Yet it still lags behind many other fields such as education, health and development policies (Baylis et al. 2015). The majority of these studies focus on Protected Areas (PA) (Geldmann et al. 2013)[1], the doimant instrument in conservation policies. However, little attention has yet been devoted to studying the mechanisms that explain the impact of PAs (Ferraro and Hanauer 2014b). This paper contributes to the literature by presenting an analysis of the impact of PAs on deforestation in Madagascar annually between 2001 and 2012 and considers two mediators to explain the only partial effectiveness of PAs: differences in initial poverty rates and in initial law enforcement levels.

Madagascar is known for its exceptional and threatened biodiversity. The most recent IUCN Red List of Threatened Species warns of the possible disappearance of 927 of Madagascar's animal and plant species, the second highest figure in Africa after Tanzania (958 species). What makes Madagascar unique is that the vast majority of its species are endemic. For example, 94% of the 101 endemic lemur species on the island are threatened with extinction, a statistic that sadly illustrates Madagascar's status as a global biodiversity Hotspot *Hot Spot* (IUCN 2014; Myers et al. 2000).

Threats of extinction in Madagascar can be explained by the reduction and fragmentation of natural habitats, most notably generated by a continuous process of deforestation over recent decades (Allnutt et al. 2008; Vallan 2002). While it would be difficult to precisely estimate the original surface area of the island's forests (McConnell and Kull 2014), it is possible that half of them have disappeared, particularly

[1] For the ones that are said to meet "best practices guidelines", see for example: Ferraro and Hanauer 2014a : Andam et al. 2008; Bruner et al. 2001; Gaveau et al. 2009; Nelson and Chomitz 2011; Nolte et al. 2013; Pfaff 2009; Sims 2010.

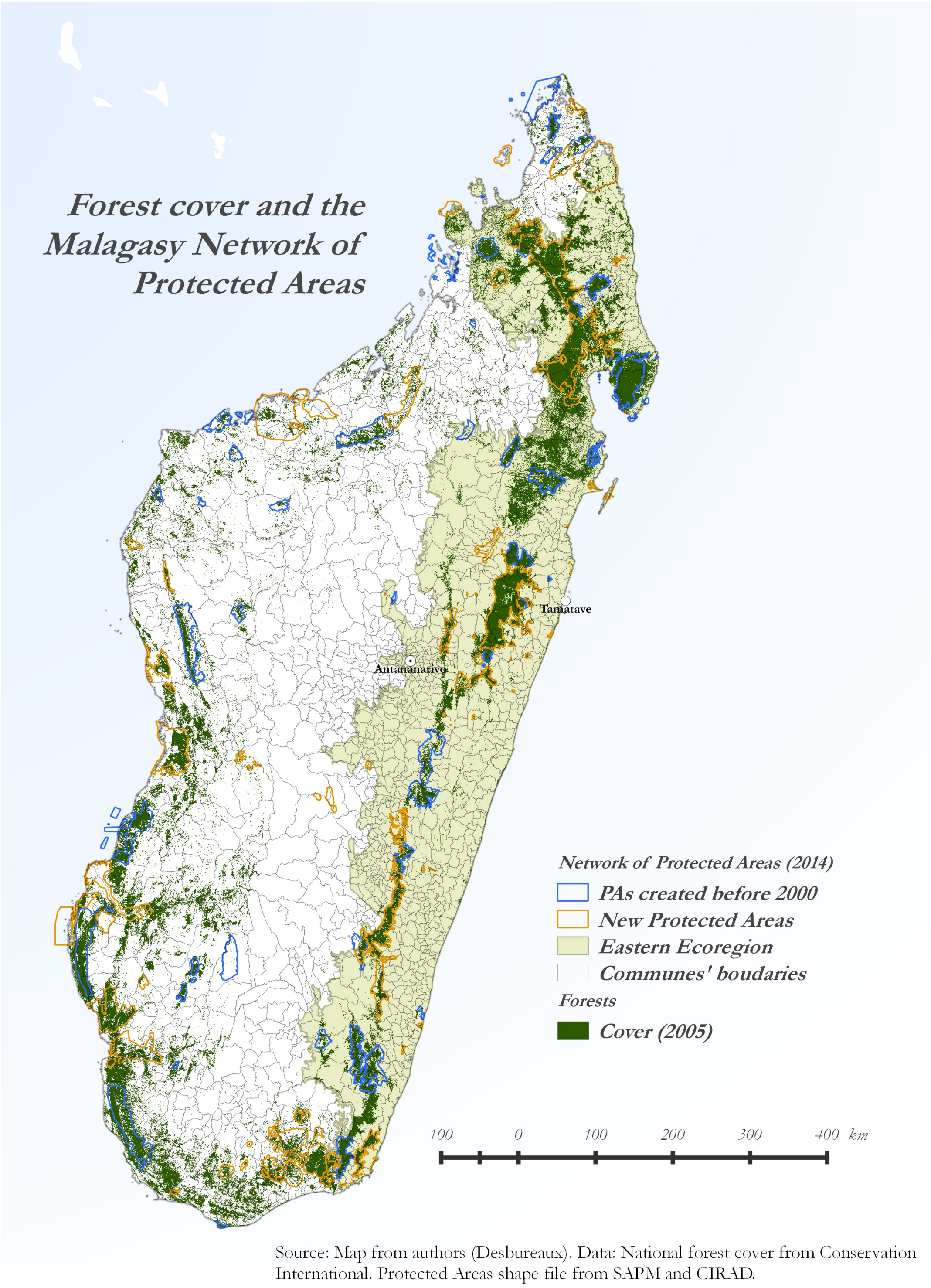
since the mid-1950s (Harper et al. 2007). The eastern rainforest corridor, the focus of our study, clearly illustrates this phenomenon. Whereas only thirty years ago there was an uninterrupted band of forest running the length of the island from north to south, today only a mere narrow scattered strip remains (Figure 1). This deforestation can be attributed to anthropic pressures, the most damaging of which include the itinerant farming practice of slash and burn (or *tavy* in Malagasy), along with logging and coal and other mining activities (Styger et al. 2007).

In 1927, the first PAs were established as a means of conserving a "few specimens of the fauna and flora"[2]. With the emergence of a willingness in the political agenda to stem the accelerating deforestation of the end of the 20th century, PAs have remained the dominant instrument on which public action hinges. By the early 2000s PAs in Madagascar covered 1.7 million hectares, and in 2003 an ambitious plan to triple the protected surface was launched with the creation of New Protected Areas (NPAs). Many inhabitants living adjacent to these lands saw restrictions placed on their access rights. Compensation schemes have been established for these inhabitants, mainly in the form of Integrated Conservation and Development Programs (ICDP). In addition, more than 1,248 transfers of local community management were carried out from 1996 to 2014[3] and have been primarily used to accompany the creation of NPAs in order to enable local residents to invest in the sustainable use of resources. PAs and NPAs currently cover 40% of Madagascar's remaining forests [4] and a number of parties involved in conservation are continuing to press for the

[2]Madagascar. Bulletin économique (Tananarive). 1927: p 105. Digital French colonial archives can be found on Bibliothèque Nationale Française's web portal GALICA.

[3]Data collected in 2012-13 by Alexio Lohanivo, joint project between CIRAD Madagascar and Ministère des Eaux et des Forêts.

[4]Authors' computation. We calculated the area of forest that lies into a PA using Conservation International's 2005 forest cover map and the 2014 SAPM shapefile.



Source: Map from authors (Desbureaux). Data: National forest cover from Conservation International. Protected Areas shape file from SAPM and CIRAD.

Figure 1: PAs and Forest cover

extension of this network (Schwitzer et al. 2014)[5]. Yet we know very little of the environmental effectiveness of these PAs.

To our knowledge, two published studies (Gorenflo et al. 2011; Thomas 2007) and one unpublished manuscript (Gimenez 2012) have explored the environmental impact of PAs in Madagascar. All suggest that PAs have contributed very little towards limiting deforestation. Gorenflo et al. (2011) found that the probability of a plot becoming deforested between the years 1990 and 2000 was only 5% less when it was located inside a PA. Put another way, there would be a 95% chance that an area inside a PA which was expected to be deforested was in fact deforested, regardless of the establishment of the PA. A fourth study (Vieilledent, Grinand, and Raudry 2013) confirms this low impact of PAs for two of four case studies in the humid forest and spiny-dry forest between 2000-05 and 2005-10. This limited additionality appears to be in line with recent findings of the apparent ineffectiveness of community forests on the island (Rasolofoson et al. 2015) [6]. Nevertheless, it must be pointed out that the evaluation of PA effectiveness is not the central issue of these three published studies. No particular strategy to tackle the endogeneity of the localization of PAs was implemented in any of the studies, which thus potentially biases obtained estimates (Joppa and Pfaff 2009). In addition, the authors offer little explanation of the nature of the causal mechanism that would explain this limited effect.

In this paper, we clarify the causes of deforestation in Madagascar and draw up an analytic framework for studying the year by year environmental additionality of PAs between 2001 and 2012. Environmental additionality is defined here as the de-

[5] Going in this direction, President Hery Rajonamimpianina announced at the 2014's World Park Congress an extension by three of Marine PAs by 2020 as the core of his so-called "Sydney's Vision".

[6] Direct comparisons between impact of PAs and impact of Community forest management have to be done with extreme caution as characteristics between these sites largely differ and it has yet not been shown that PAs would have done better than CFM when corrected for these differences.

crease in the deforestation rate brought about by the presence of PAs, compared to similar unprotected areas. We propose distinguishing two simultaneous processes that are driving deforestation in Madagascar: deforestation "by necessity" rooted in the "poverty-environment trap" (Angelsen and Kaimowitz 1999; Barrett, Travis, and Dasgupta 2011) , and opportunistic deforestation attributable to weakness of law enforcement institutions. Stylized facts exhibit that the principal environmental contribution of PAs has consisted in a trend of stabilizing deforestation while overall deforestation was erratic over the period. We provide quantitative estimates of the impact of PAs by combining matching and panel regressions in a quasi-natural experiment framework, i.e., the creation of NPAs. Overall, we find that the effect of PAs has been limited, with only a one-fifth reduction in deforestation rates inside PAs established during the 20th century compared to similar but unprotected areas and we find no clear evidence of any impact inside NPAs. Furthermore, NPAs exhibit no sign of an increasing impact on deforestation when considering the number of years that an NPA has been established. We explain this limited impact by two mechanisms that echo the distinction we have made between deforestation by necessity and opportunistic deforestation. First, the additionality of a PA decreases with an increase in poverty rates for both historic PAs and NPAs, suggesting that attempting to tackle deforestation by necessity primarily through PAs may not be effective. Second, PAs have been able to significantly reduce deforestation only when the initial law enforcement level within the territory was at the lowest (i.e., virtually non-existent) before the PA's creation. PAs have managed to bring back some law enforcement in quasi lawless areas thanks to clarification of land tenure and some increased means for protection, etc., but have failed to increase enforcement when existing (minimal) capacities were present. The limited environmental impact of PAs makes their total welfare impact uncertain when translating avoided forest loss into preserved environmental and ecosystem services.

We believe the contribution of this paper to the literature to be threefold. First, we combine spatial data with a detailed census at the municipality level. Using census data rather than solely bio-geographic data (slope, euclidean distances etc) allows us to better analyze the socio-economic channels of the impact. Second, the new time series of deforestation data compiled by Hansen et al. (2013) enables us to draw additional insights compared to most existing studies by exploring the time dimension of the impact of PAs over 12 consecutive years. Finally, our analysis extends the scope of this research in three important areas. We extend the geographic scope of the "Conservation Evaluation 2.0" research program (Miteva, Pattanayak, and Ferraro 2012) to a little-studied continent – Africa, politically to the context of an unstable country governed by a fragile state, and socio-economically to the context of one of the least developed countries on the planet. In Madagascar's economic and political context, PA management is underfunded, leading some to wonder if PAs are not simply "paper parks", PAs that exist *de jure* but not *de facto*. If it is the case, one can strongly suggest that will not have any effectiveness (Blackman, Pfaff, and Robalino 2015).

The remainder of the paper is organized as follows: Section 2 revisits the pressures that are leading to deforestation in eastern Madagascar, Section 3 describes the data and Section 4 presents the empirical strategy and results. In Section 5 we discuss the welfare and policy implications of our findings.

2 Background: Deforestation and Protected Areas in Madagascar

2.1 The Anthropic Factors of Deforestation

The principal driver of deforestation in Madagascar is small scale agriculture through the practice of slash-and burn rice cultivation, known as *tavy*. *Tavy* involves cultivating rainfed rice on hill slopes and using the burnt plant matter to naturally fertilize soil after 3 to 10 years of fallow. In the eastern eco-region, around 90% of the population practices agriculture as their primary activity (ILO-Cornell database), and 71% crop primarily rice, the staple food of Madagascar. Despite being officially prohibited since the 1860s, *tavy* remains the dominant farming technique. Irrigated rice cultivation, the alternative to slash-and-burn, was used by an average of only 12% of households in 2001.

Tavy has been recognized as the main source of pressure on the forests since the beginning of the colonial era in the early 19th century (Jarosz 1993). In the context of high population growth (a 2.9% annual national average according to World Bank data, and even greater in rural settings), fallow lengths have diminished, resulting in more rapid exhaustion of the soil and rendering it unsuitable for farming after 4 or 5 rotations (Brand and Pfund 1998). Yields, in the order of one ton per hectare, don't always cover families' needs and are less than those obtained by lowland farming or that require more sophisticated agronomic techniques.

The continued illegal practice of *tavy* coincides in part with the difficulty of transition towards alternative technologies, associated with a lack of infrastructure that would enable lowlands to be farmed, a lack of access to agricultural inputs, and a lack of knowledge of alternative practices. Risk aversion might also represent an important barrier to farmers shifting to new technologies (Barrett, Moser, et al. 2004). Likewise, farming the slopes allows farmers to reduce their exposure to the high risk of cyclone damage in this part of the island (Brimont et al. 2015; Delille 2011). Finally, more than a simple economic activity, *tavy* is a socially and culturally rooted practice which replicates a traditional type of social organization (Aubert, Bertrand, and Razafiarison 2003; Desbureaux and Brimont 2015).

Moreover, households devote part of their time to income generating activities so as to acquire basic necessary goods. These include cash crops (vanilla, cloves, sugar cane, etc), logging, coal mining and other mining activities. Logging, coal mining and mineral extraction (notably gold), all illegal in the natural forests, are currently reported by conservation actors as the second greatest cause of deforestation. In some areas, these activities may represent the only source of monetary income for numerous households (as noted in our field observations (2012) regarding gold mining in the commune of Didy).

2.2 The "Poverty-Environment Trap": Deforestation By Necessity

As illustrated above, as rural households are almost entirely dependent on access to forests to survive, and continuous clearing of new plots attests of their socio-economic fragility. This socio-economic fragility can be attributed to a number of factors. Households live in a state of land and property insecurity, and their members have a low level of education (Sandron 2008). There are also economic factors: peasant households are directly exposed to the strong volatility of markets for agricultural commodities, including rice, vanilla and cloves. This exposure to market volatility, coupled with geographic isolation, limits inhabitants in the development and diversification of income generating activities: 42% of rural communes in Madagascar are a more than 24 hour drive from the nearest urban commune during the six months of the rainy season. Rural households present all of the characteristics of capability deprivation, as articulated by Sen, which explains their difficulty imagining a future without *tavy*.

Households respond to their limited situation by clearing the forest, which leads to a situation that we call here deforestation by necessity, one which enables households to fulfill their subsistence requirements in response to their state of socio-economic fragility. This situation fully corresponds to the well-known "poverty-environment trap" (Angelsen and Wunder 2014; Barrett, Travis, and Dasgupta 2011).

2.3 Opportunistic Deforestation

The economic fragility of households at the local level is reinforced by the shortcomings of the country's legal and institutional framework. One typical shortcoming is a preponderance for a certain blurring of legal contours, in particular where forestry is concerned (Karpe 2005). Furthermore, laws are made by decision makers in the capital who are far removed from village conditions and influenced by various lobbies. In the absence of a legal code the legal and regulatory framework is often misunderstood or disregarded by citizens (Gore, Ratsimbazafy, and Lute 2013), while government officials often come up with numerous flaws and inconsistencies in interpreting laws (Aubert 2015).This legal blurring is further amplified by an unstable political context. In recent years, the country has experienced two coups d'états, in 2002 and 2009, the most recent giving way to a so called 4-year period of transition.

During these crises, the state's capacity to apply its laws has been impeded due to both a drop in available government means and a rise in corruption. Even before each crisis, ILO-Cornell data indicate that police officers (i.e., *police* and *gendarmes*) were present in only half of the municipalities.

These institutional factors have led to a major rise in deforestation and forest degradation and there has been a massive increase in illegal logging of precious species and softwood in a context of relative impunity (Randriamalala and Liu 2010). As an illustration, in the rural commune of Didy during 2009-2010, our fieldwork suggests that 99.7% of the illegal removal of timber from the forest took place without any sanctions, regardless of the fact that the lorries transporting it must have crossed several barriers and checkpoints [7].

In addition to deforestation by necessity, Madagascar experiences what we refer to as *opportunistic deforestation*, i.e., additional deforestation enabled by the authorities' inability to enforce the law within the bounds of its territory to such an extent that locals have taken advantage by extending their forest clearing above and beyond their strict subsistence requirements and by blurring property rights over land tenure.

In clarifying the difference between deforestation by necessity and opportunistic deforestation, we are not aiming at differentiating one group of people clearing the forest by strict necessity from another merely taking advantage of opportunities, nor is it our intention to quantitatively measure the difference between the two. Indeed, the boundary between the two phenomena is too porous for that, making it quite

[7] Estimates of the amount of timber removed are those recorded by Andriantahina, Diagnostic du fonctionnement de la filière illicite de bois d'oeuvre dans la Commune Rurale de Didy District d'Ambatondrazaka Région Alaotra –Mangoro, s.l.: Projet Cogesfor (2010). We compared these estimates with the number of penalty notices issued by the forestry commission in the locality that year, as recorded by the DREF (regional environment and forestry agency) at Ambatondrazaka in May 2012. Additionally, these sanctions concerned the stripping of 87 ha of forest between 2003 and 2011 (DREF), when our calculations from Hansen's data testify to a clearing of around 3000 ha of forest, for the dense forests alone.

difficult in many circumstances to differentiate between them. We can illustrate this porosity with internal migrations, a hot topic in Madagascar. Indeed, if a small farmer settles in newly forested lands to cultivate rice for his family, he directly fulfills his needs by illegally deforesting. In the absence of this possibility, he could also have migrated to a town to find a legal paid job: settling in a forested area and clearing it is only possible because opportunities to deforest exist: the two phenomena exist simultaneously and only jointly explain the phenomenon of deforestation. It would be wrong to assume that deforestation by necessity and opportunistic deforestation act independently of each other and that the level of deforestation is merely the sum of the two. We believe, on the contrary, that these two types of deforestation interact. Applying the logic of Boserup 1965, it makes little sense to view Malagasy farmers as mere passive players incapable of adapting to the legal context of intervention: faced with a ban on forest clearing, we could assume that a farmer would adapt his practices in favor of more sustainable farming methods. Otherwise, how would we explain the persistence of *tavy*? An existing failure to enforce land protection laws (i.e. opportunities) hardly provides an incentive for farmers to innovate towards new practices to reduce deforestation.

2.4 Curbing Deforestation With Protected Areas?

Curbing deforestation in Madagascar is a dual task. It seems necessary to address both the dependency of local residents on resources, (the source of this deforestation by necessity), and the fragility of the institutional framework, which enables opportunistic deforestation to persist. In a fragile state such as Madagascar, creating PAs might be an effective way to increase law enforcement on the ground by curtailing the shortcomings of the national legal framework and by reinstating the areas “by law” in poorly controlled zones. The appointment of a management officer, who acts as an intermediary for the forestry administration, would theoretically make it easier to apply closer controls on anthropic activities and influence local populations by enhancing awareness. The establishment of PAs thus aims largely at addressing opportunistic deforestation.

Furthermore, various local development compensatory programs have been initiated jointly with PAs by conservation NGOs. The purpose of these has been to reduce the causes of deforestation by necessity. These development programs are often launched on a community-wide level, based on management transfers that NGOs generally create to accompany NPAs.

PAs and NPAs are all included in Madagascar's network of protected areas (SAPM - *Système des Aires Protégées de Madagascar*). Currently, there are 138 PAs in Madagascar. Fifty of them are the "historic" PAs created between 1927 and 1999. They are managed by the public agency Madagascar National Parks. The other 88 are new PAs (NPA)s that began being established in 2004 with the help of national and international conservation NGOs.

3 Data

Our study deals with the environmental effectiveness of PAs and NPAs with respect to the additional deforestation in natural forests their presence has or has not prevented. Our analysis is focused on the eastern ecoregion as defined by WWF (see Figure 1) where the rainforest corridor is located. The eastern ecoregion is where the authors have the most field experience.

3.1 Protected Areas

We take into consideration every PA and NPA from the eastern ecoregion that was officially included in the SAPM in 2012. We have 24 historic PAs and 31 NPAs impacting 109 and 126 municipalities, respectively [8]. Figure 2 displays the evolution of the number of PAs and NPAs within the period of this study for the area of interest.

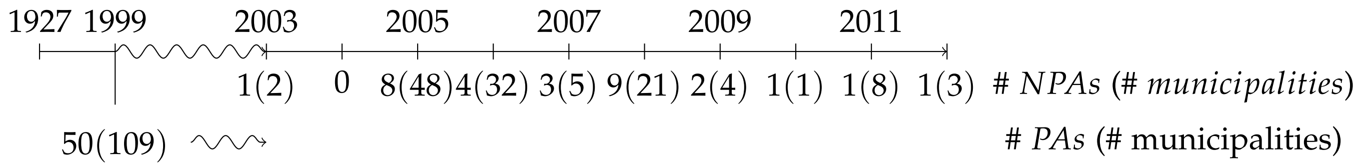


Figure 2: Timeline of the creation of PAs and NPAs

3.2 Socio-Economic Variables

We use the ILO-Cornell commune census from 2001 jointly conducted by Cornell University, FOFIFA and INSTAT. It includes information on economic, social and political characteristics at the municipality level. It covers 1,385 of the 1,392 country's communes [9]. We complete the census with annual population data from INSTAT at the district level. We spatialize the database using official GADM (Global Administrative Areas) commune borders in order to merge socio-economic and forest cover data.

[8]Madagscar is administratively divided in 22 *Régions*, 112 *Districts*, 1395 *Communes* i.e. municipalities and 17 544 *Fokontany*. *Communes* can be either urban ones or rural ones. Communes would correspond to U.S. municipalities.

[9]The database can be downloaded at the project website http://www.ilo.cornell.edu/index.html

3.3 Environmental Outcome: Forest Cover

We use data of vegetation cover from Hansen et al. 2013 version 1 from Global Forest Watch. Hansen et al. 2013 compiled more than 740,000 Landsat TM images to produce annual global deforestation maps between 2000 and 2012 with a resolution of 30m at the equator. We base our analysis on two spatial layers: original tree cover from 2000 and annual vegetation loss from 2001 to 2012. For our area of interest, we define natural tropical rainforest as areas presenting a forest canopy greater than or equal to 78% per pixel in 2000 [10]). We then focus on annual vegetation loss on pixels that we initially defined as forests in 2000. Because we are interested in natural habitats, we do not take into account vegetation regrowth as we are unable to characterize whether these pixels correspond to dense forests or to another type of vegetation (namely *savoka*, the vegetation regrowth in pastures between two cropping cycles in the practice of *tavy*). We finally retain only the communes where the surface area of forest is at least 50ha as PAs aim at protecting sufficiently large and continuous patches of forest.

Our outcome variable is the deforestation rate in commune i for year t, that is, the percentage of forest cover loss between the end of year $t-1$ and the end of year t:

$$Def_{i,t} = \left| \frac{Forest_{i,t} - Forest_{i,t-1}}{Forest_{i,t-1}} \right| \tag{1}$$

[10]The definition of what represents a forest is a multi-controversial issue. There are two basic approaches: one is based on the type of soil usage, the second on the density of trees present in a contiguous area. On the basis of our data, we adopted the second definition. The FAO defines a closed forest as a contiguous zone of 1ha with a tree density of at least 40%. In the case of Madagascar, a threshold of this order would have lead us to consider non natural forests such as eucalyptus plantations. A 78% threshold allowed us to closely reproduce the reference map of non- degraded forests in Madagascar drawn up by Conservation International. See for example, (Harper et al. 2007.

where $Forest_{i,t}$ represents the surface of forest cover in locality i at the end of year t. We take the absolute value of the percentage so that higher deforestation rate means higher $Def_{i,t}$.

Likewise, we incorporate a selection of biophysical data (slope, elevation). The list of covariates and the origins of data and summary statistics are presented in Table 1. In total after spatial matches of dataset, the information was gathered for 561 municipalities.

Table 1: Data and summary statistics

Source	Data & Variables	Mean All (Standard Deviation)	Mean PA (Standard Deviation)	Mean NPA (Standard Deviation)	Mean Unprotected (Standard Deviation)
SAPM-CIRAD	Network of protected areas	\			
Hansen/UMD/Google/USGS/NASA (2013)	Annual mean deforestation rate (commune, 2000-12, in %)	2 (5)	0.8 (1)	1.4 (2)	2.7 (6)
	Forest cover in *ha* within communes	8 445 (17 134)	18 469 (25 915)	13 676 (20 070)	3 067 (7 217)
ILO-CORNELL	Travelling time to nearest town – rainy season (hours)	22 (24)	25 (24)	23 (28)	21 (22)
	Population in agricultural sector (%)	88 (16)	87 (16)	89 (15)	88 (18)
	Irrigated rice paddy per inhabitant (%) [a]	13 (24)	14 (26)	13 (24)	13 (24)
	Poor people (%)[b]	51 (25)	50 (27)	48 (25)	54 (25)
	Destitute people (%)[c]	9 (13)	7 (11)	9 (13)	10 (14)
	Police (1 if yes)[d]	0.59 (0.49)	0.55 (0.49)	0.6 (0.48)	0.6 (0.49)
	Population commune 2001	13 451 (8 202)	12 118 (8 361)	13 189 (7 634)	13 995 (8 294)
INSTAT	Population district (Average 2001-12)	193 615 (70 897)	164 939 (73 584)	185 672 (61 406)	206 274 (70 176)
DEM data (500m x 500m)	Average slope (%)	8.4 (3.5)	10.7 (3.4)	9.2 (2.9)	7.4 (3.4)
	Average elevation (meters)	580 (515)	725 (399)	609 (454)	522 (559)

a: Share of rice paddy coming from irrigated fields as opposed to slash and burn)
b:"Those who face food security problems seasonally, whether it is a bad year or not" (ILO-Cornell)
c: "Those who do not have enough to eat throughout the year" (ILO-Cornell)
d: Presence of police officers refers here to both the presence of *Policiers* and-or *Gendarmes*

4 The Impact of Protected Areas on Forest Cover Losses and its Mediators: Methodology and Results

First, we quantitatively validate our hypothesis of dual deforestation drivers. We present stylized facts to support it, then cross-section matching results to gain initial insights on the nature of the impact of PAs and to justify our identification strategy. Post-matching panel regressions will then allow us to quantify the impact and the mediators.

4.1 Stylized facts

4.1.1 Deforestation Drivers and Protected Areas

Over the period, the average deforestation rate within municipalities was 2%. (Table 1). Our data provide the poverty rate for each municipality. Poverty is expressed in the data in terms of the share of households experiencing seasonal (for poor people) or constant (for destitute people) food stresses. We use this information as an indicator of the prevalence of the deforestation by necessity issue: larger poverty rates suggest a high necessity for deforestation so that deforestation should be higher in poorer areas. Figure 3 suggests that this is the case: in communes that have up to a 40% poverty rate, deforestation steadily increases, then stabilizes.

The data indicate whether policemen are present in the municipality. Within these municipalities, opportunities to transgress the law are lower: elucidation of offenses and crimes are significantly higher (see Appendix 1). In these municipalities, data also suggests that deforestation is significantly lower (1.7% vs 2.4%, p.value=0.00). These findings are also valid when studying deforestation drivers in a standard re-

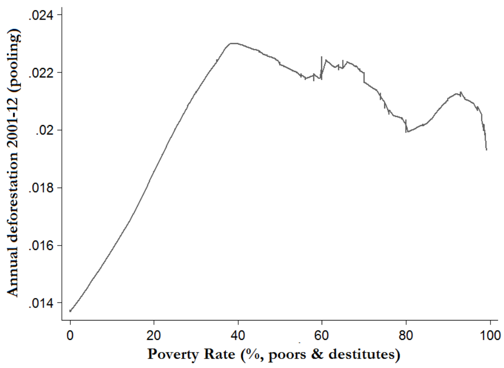


Figure 3: Deforestation and Poverty rates, loess smoothing

gression framework to tackle omitted variables biases: *ceteris paribus*, deforestation decreases with poverty rates and is lower in the presence of police officers.

Table 1 also indicates that average deforestation rates are four times lower inside municipalities impacted by PAs than outside them (0.8% vs 2,7%). It has now been widely documented that PAs are generally located in areas that are in essence less prone to forest clearing (Joppa and Pfaff 2009). This is the case for eastern Madagascar: PAs are, for example, located in structurally more isolated and less populated municipalities and thus in more forested areas(Figure 4). A simple mean comparison of deforestation rates within and outside of PAs would thus be unsatisfactory to obtain a quantification of a causal impact of PAs. In statistical terminology, we face a standard endogeneity problem: the treatment is not randomly assigned and taking unprotected municipalities as controls would constitute a poor counterfactual of what would have happened in the absence of PAs.

(a) Surface of forest (b) Distance to nearest town (c) Population (2001)

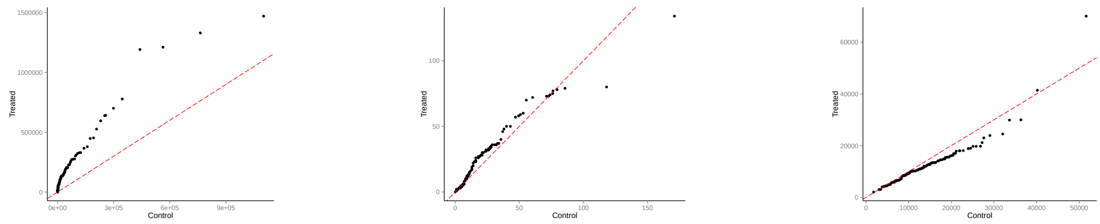


Figure 4: A poor counterfactual before matching: An illustration

4.1.2 Cross-Sectional Matching, Observed Heterogeneity, Unobserved Confounders

Matching methods have been extensively used to tackle the endogeneity of the localization of conservation instruments (Andam et al. 2008; Blackman, Pfaff, and Robalino 2015; Ferraro and Hanauer 2014b; Ferraro, Hanauer, et al. 2015; Gardner et al. 2013; Gaveau et al. 2009; Gimenez 2012; Rasolofoson et al. 2015). They aim at obtaining better counterfactuals by creating pairs of observations that are comparable in every observable aspect X_i that is likely to influence the level of deforestation (apples to apples comparisons) but one: being impacted by the policy reform (treated group, T) or not (control group, C). The underlying assumption to obtain an unbiased causal estimator is that Xi is taking into account all of the variables that are affecting deforestation (unconfoundness hypothesis (Rosenbaum and Rubin 1983)). When pre-treatment observations of the outcome are available, the researcher can partially relax the uncounfoundeness hypothesis by implementing a Difference in Difference (DID) framework. The consistency of the estimates then relies on the conditional parallel trend assumption in which we assume that unobserved heterogeneity may be present among observations but is time invariant.

We implement a cross-sectional matching procedures to obtain a baseline estimate of a causal impact of PAs and NPAs in Madagascar using the Genetic Matching approach developed by Diamond and Sekhon (2012) (Diamond and Sekhon 2012).

Genetic Matching finds the optimal weight to give to each covariate in order to maximize the quality of the balance between control and treated groups and so reduce both the bias and the mean square error of the estimated causal effect. We choose one-to-one nearest neighbor matching. To limit further potential bias, we use calipers to improve covariate balance. Calipers define the limit of tolerated quality of our matches. If a match does not lie below the caliper limit, it is excluded. We fix this limit to half of the standard deviation of matching covariates as in Andam et al. (2008). As robustness checks, we use different matching estimators (Mahanalobis, Propensity Score, equal weights, 2 nearest Neighbor). Each method provides consistent estimates of the Average Treatment of the Treated (ATT) over the years 2001-12 (Appendix 7.3).

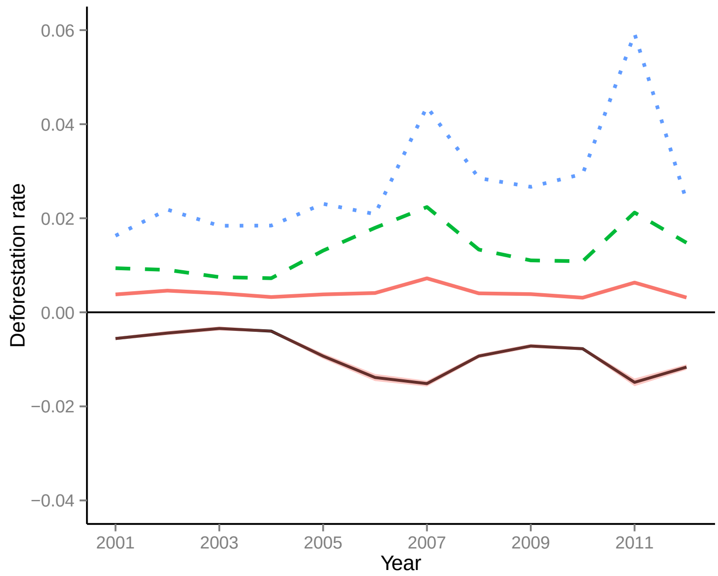
For both PAs and NPAs, we use as rolling control groups all the municipalities that were not impacted by PAs during the studied year, that is, municipalities that have never been impacted by any PA over the period and municipalities that will be impacted by a PA in the coming years. Because we do not precisely observe the month of the creation of the NPA, we stop taking them as a control the year before creation and consider them as treated from the year after.

Matching results are synthesized in Figure 4. The balance is presented in Appendix 7.2. The average deforestation rate in treated areas is in red (plain) and the average deforestation rate in control areas is in green (long dash). In blue (small dash), we draw the deforestation rate for every unprotected municipalities. Finally, the ATT is in black. For the period 2001-2012, Figure 4-a strongly suggests that historic PAs have helped curb annual deforestation without halting it. As for NPAs (Figure 4-b and 4-c), the early impact appears much more limited, particularly because of the higher heterogeneity in the impact among municipalities as reflected by larger confidence intervals.

Deforestation in unprotected areas has been erratic, with a major upsurge in overall deforestation from 2007, closely coinciding with the beginning of the disintegration of state power, leaving even greater windows of opportunities for deforestation. By contrast, deforestation within PAs, and to a lesser extent within NPAs, has been stable, only wavering marginally from one year to another in a consistently positive direction (around 0.5% per year), and has been systematically inferior to deforestation within unprotected municipalities. This trend however does not appear to show signs of having receded over the previous 12 years, revealing, for the time being, a level of deforestation which is incompressible.

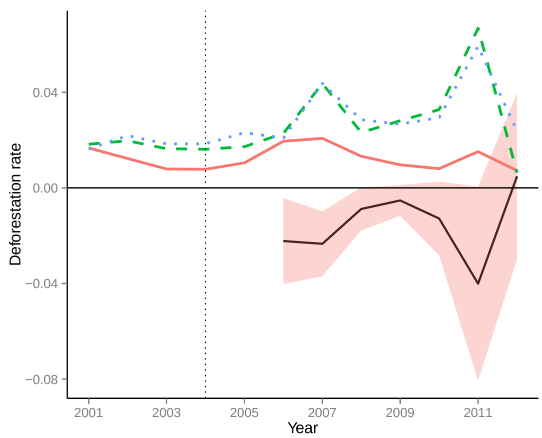
These first matching results strengthen the hypothesis of two moderators: (1) PAs may have reduced opportunities for deforestation (no upsurge during the political crisis) while (2) the persistence of a stable positive trend of deforestation suggests that deforestation by necessity continues.

(a) PAs vs unprotected areas that year vs all unprotected areas, 01-12



(b) NPAs vs matched unprotected areas vs all unprotected areas, DID estimate, 06-12

(c) NPAs created before 2007 vs matched unprotected areas vs all unprotected areas, DID estimate, 06-12



Note: Treated group in (b) and (c): we take before 2004 every localities as none was impacted by PAs at the time. From 2005, we take as treated localities the ones in which NPA has been established the yea before and keep the ones not yet impacted in the control group.

Figure 5: The impact of PAs and NPAs on deforestation in the Eastern forest corridor, 2001-12

Differences in outcomes before treatment when dealing with NPAs suggest that unobserved heterogeneity might remain in our estimates between protected and matched unprotected areas. When controlling it with DID for NPAs, we no longer find systematic additionality. Focusing on early created NPAs does not seem to provide a larger impact either. However, the common trend hypothesis necessary for DID is hardly satisfied. Applying the standard approaches in our context is hence not sufficient to obtain unbiased estimates of the environmental impact of PAs. We now present our identification strategy to correct for both observed and unobserved confounding effects to obtain quantitative unbiased estimates.

4.2 Econometric analysis: Identification Strategy

Matching is effective to remove observed differences between control and treated groups as highlighted by Figure 4-b to 4-c. To control for the remaining unobserved confounding effects, we use the rolling-base classification of new PAs to construct a tighter control group by taking only municipalities targeted for the creation of NPAs. The forest from 129 municipalities were classified as NPAs during the 2000s within a pool of 452 municipalities that had unprotected forests. If these 129 sites were chosen, it might reveal stronger similarities between these forests and existing PAs in terms of anthropic pressures and ecological dynamics, as compared to the 323 that remained unclassified at the end of the period.

We define a 3-level treatment variable Tr with $Tr = 0$ for municipalities with historic PAs created before 1990, $Tr = 1$ for municipalities not yet under protection and $Tr = 2$ for municipalities when the NPA has been created. We use $Tr = 0$ as a baseline and observe potential shifts in values when new municipalities become protected.

We believe that focusing on the protection status change for municipalities requires a finer definition of the treatment that allows for accounting for the time dimension of the policy implementation. Creating an NPA is not a simple before-after treatment but rather the result of a long implementation process so that we can expect impacts of NPAs of an undefined sign both before and after the official creation. On the one hand, the official creation of an NPA generally symbolizes the embodiment of several years of actions so that before creation, early interventions might have initial positive impacts. For some other projects, the creation of the NPA could be part of their initial activities. For them, one might expect lags before initial effects. On the other hand, purely economic reasoning through anticipation effects from locals can lead to a negative impact: it is better to clear forest before the creation rather than after as sanctions and controls will increase over time. We construct the variable *Ttreat* - the time in years between the date of observation and the official creation of the PA, to capture the length of exposure to the treatment to make explicit this dynamic in the measurement of the effect:

$$Ttreat_{i,t} = Year - Year\ creation_{i,t} \tag{2}$$

We hence have $Ttreat_{i,t} < 0$ and $Ttreat_{i,t} > 0$ respectively before and after the creation of the NPA in municipality i at date t.

We enrich the dynamic of our model by exploring differences in the intensity of the effect between years by conditioning the impact on year dummies on top of standard year fixed effects. We finally analyze the heterogeneity of the impact with regards to initial law enforcement and initial poverty rates with interaction terms. The full model we estimate is:

$$Def_{i,t} = \alpha + \beta_1 Tr + \beta_2 Tr \times Ttreat + \beta_3 Tr \times \mu_t + \beta_4 Tr \times Police + \beta_5 Tr \times Poverty$$
$$+ x'_{i,t}\gamma + z'_i\zeta + v_{i,t} \; ; \; v_{i,t} = u_{i,t} + c_i \quad (3)$$

with μ_t a year fixed effect, $x'_{i,t}$ a 2-dimensional row vector of time varying explanatory variables, z'_i a vector of time invariant explanatory variables, $u_{i,t}$ a normally distributed error term and c_i a random effect.

We expect for a current efficiency of PAs $\hat{\beta_1}|_{Tr=1} > 0$: : meaning that deforestation in unprotected areas should be higher than inside PAs, everything else being equal. When unprotected areas become protected, we expect this difference in deforestation rates to disappear, that is $\hat{\beta_1}|_{Tr=2} = 0$. If a difference however remains ($\hat{\beta_1}|_{Tr=2} > 0$), we should at least observe a decrease of this difference over time ($\hat{\beta_1}|_{Tr=2} < 0$) so that in the long run it becomes null.

4.3 Estimates of the Causal Impact

Regression results are presented in Table 2. Standard errors are clustered at the municipality scale. We present several specifications of the model to progressively enrich the definition of the impact. These results confirm the additionality of historic PAs whatever the specification ($\beta_1|_{Tr=_1} > 0$)and the uncertain additionality of NPAs: for half of the specifications, we find a significant difference between NPAs and PAs after their creation ($\beta_1|_{Tr=_2} > 0$) and no clear sign of dynamic efficiency after treatment ($\hat{\beta_2}|_{Tr=2} = 0$).

Table 2: Regression results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Binary Tr	Tr x Year	Tr x Time_Tr	Tr x Policemen	Tr x Poor + Des	Tr x Policemen + Tr x Poor + Des	Mechanisms / Tr x Time_Tr
Treat (base = Historic PAs)							
Unprotected ($\beta_1\|_{Tr=1}$)	0.00287**	0.00378**	0.00211	0.00550*	0.00868*	0.0107**	0.0117***
	(0.00131)	(0.00185)	(0.00246)	(0.00310)	(0.00463)	(0.00472)	(0.00345)
NPA ($\beta_1\|_{Tr=2}$)	0.00475***	0.00214	0.00150	0.00395	0.0112**	0.0124**	0.0160***
	(0.00177)	(0.00194)	(0.00270)	(0.00372)	(0.00567)	(0.00606)	(0.00531)
Unprotected x Time Tr			0.000913**	0.000916**	0.000903**	0.000906**	
			(0.000419)	(0.000422)	(0.000416)	(0.000419)	
NPA x Time Tr			4.65e-05	4.09e-05	6.39e-05	6.02e-05	
			(0.000442)	(0.000443)	(0.000446)	(0.000447)	
Unprotected x Policemen				-0.00701***		-0.00626**	-0.00632**
				(0.00261)		(0.00257)	(0.00259)
NPA x Policemen				-0.00504		-0.00401	-0.00409
				(0.00367)		(0.00359)	(0.00360)
Unprotected x Poverty rate					-0.000102*	-8.61e-05*	-0.000102**
					(5.37e-05)	(5.19e-05)	(5.00e-05)
NPA x Poverty rate					-0.000158**	-0.000146**	-0.000164**
					(7.14e-05)	(6.96e-05)	(6.80e-05)
Time Tr			-1.00e-04***	-9.49e-05***	-8.05e-05**	-7.82e-05**	
			(3.37e-05)	(3.50e-05)	(3.42e-05)	(3.50e-05)	
Policemen	0.000368	0.000470	8.86e-05	0.00319*	-0.000143	0.00253	0.00279
	(0.00140)	(0.00140)	(0.00142)	(0.00189)	(0.00143)	(0.00185)	(0.00191)
Poverty rate	-0.000164	-0.000165	-0.000129	-8.84e-05	-4.68e-05	-2.14e-05	-3.61e-05
	(0.000136)	(0.000136)	(0.000138)	(0.000130)	(0.000123)	(0.000119)	(0.000120)
Poverty rate^2	1.40e-06	1.41e-06	9.19e-07	4.91e-07	7.83e-07	4.35e-07	7.73e-07
	(1.20e-06)	(1.20e-06)	(1.23e-06)	(1.18e-06)	(1.18e-06)	(1.15e-06)	(1.12e-06)
Tree Cover	-1.65e-08***	-1.64e-08***	-1.58e-08***	-1.52e-08***	-1.54e-08***	-1.49e-08***	-1.54e-08***
	(3.52e-09)	(3.51e-09)	(3.57e-09)	(3.39e-09)	(3.57e-09)	(3.42e-09)	(3.42e-09)
Slope	-0.000460*	-0.000488**	-0.000371	-0.000446*	-0.000338	-0.000407	-0.000480**
	(0.000235)	(0.000236)	(0.000247)	(0.000257)	(0.000245)	(0.000254)	(0.000242)
Elevation	6.76e-06**	6.54e-06**	6.19e-06**	6.40e-06**	6.05e-06**	6.24e-06**	6.61e-06**
	(2.84e-06)	(2.80e-06)	(2.85e-06)	(2.81e-06)	(2.77e-06)	(2.74e-06)	(2.69e-06)
Population district	0	0	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Population locality (2001)	3.45e-08	1.92e-08	2.05e-08	1.49e-08	8.00e-09	4.66e-09	8.12e-09
	(1.06e-07)	(1.06e-07)	(1.08e-07)	(1.07e-07)	(1.03e-07)	(1.03e-07)	(1.01e-07)
Share irrigated rice	-7.85e-05**	-7.43e-05**	-8.62e-05**	-8.54e-05**	-8.92e-05**	-8.83e-05**	-8.21e-05**
	(3.74e-05)	(3.69e-05)	(3.87e-05)	(3.86e-05)	(3.83e-05)	(3.84e-05)	(3.71e-05)
Travel time nearest city (rainy season)	-1.70e-05	-2.13e-05	-2.34e-05	-2.76e-05	-2.21e-05	-2.58e-05	-2.21e-05
	(2.54e-05)	(2.59e-05)	(2.54e-05)	(2.69e-05)	(2.52e-05)	(2.65e-05)	(2.66e-05)
Constant	0.0164***	0.0165***	0.0205***	0.0190***	0.0157***	0.0150***	0.0112***
	(0.00448)	(0.00433)	(0.00434)	(0.00410)	(0.00428)	(0.00409)	(0.00424)
Observations	2,853	2,853	2,841	2,841	2,841	2,841	2,853
Number of id	248	248	247	247	247	247	248
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year x Tr	No	Yes	No	No	No	No	No
Time Treat x Tr	No	No	Yes	Yes	Yes	Yes	No

Clustered standard errors at the locality scale in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Overall, we find that the impact of PAs has been quite limited. Deforestation in historic PAs is only 0.2% lower than in unprotected forests in the majority of our estimates (with a lower bound of 0.1% and an upper bound of approximately 0.35%), which corresponds to a one-fifth decrease in deforestation directly attributable to PAs. For the 561 municipalities from our complete sample that were covered by 2,290,156 ha in 2000, the annual saved forest is likely to be around 6,573 ha per year (3,435 ha to 10,077 ha) according to our estimates. However, 80% of forests inside PAs are still lost despite being protected (26,292 ha every year).

We find that the length of exposure to the treatment alters the impact of PAs only before their creation: before PAs are created, as we get closer to the official date of creation ($Ttreat \rightarrow -1$), the difference in the deforestation rate between existing PAs and unprotected PAs increases. In our statistical modeling, a kind of anticipation effect seems to play a role, pushing initial deforestation upward before the creation of PAs. However, after creation, another year spent under protection no longer changes the level of the impact. In addition, the magnitude of the impact appears quite stable over time when conditioning *Tr* on year fixed effects Table 4.

Table 3: Yearly variations of the impact (Details of Column (2) - Table 3)

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Unprotected x Year	Baseline	-0.00141	-0.00712***	-0.00134	0.000474	-0.00187	0.00422	0.0180**	0.000331	0.00185	-0.0136**	-0.00162
		(0.00202)	(0.00271)	(0.00176)	(0.00216)	(0.00192)	(0.00362)	(0.00861)	(0.00243)	(0.00206)	(0.00602)	(0.00182)
NPA x Year				-0.00363	-0.00475	0.000522	0.00143	-0.000217	0.00227	0.00570***	0.00817***	Baseline
				(0.00358)	(0.00350)	(0.00159)	(0.00194)	(0.00179)	(0.00210)	(0.00191)	(0.00309)	

4.4 Mechanisms

In Section 2, we stated that the intrinsic logic of establishing PAs in a fragile state like Madagascar was to increase law enforcement on the ground in order to tackle opportunistic deforestation. We test how the impact varies regarding initial variations in law enforcement measured by the presence of police in the municipality. We find that the impact of PAs is greater in the absence of police officials: where the initial law enforcement level was lower, the additional impact of the PAs was larger. However, when police officials are present in the municipality, the additional presence of a PA does not bring as much impact. In some sense, PAs and police might appear as substitutes: both can increase law enforcement on the ground but only to a certain extent. The extent of the territories under consideration are generally large and located in extremely remote areas, and the means put in place to achieve protection are limited. Madagascar has one forestry officer for approximately 30,000 ha of natural forest compared, for example, with one to every 421 ha in the neighboring La Reunion Island, a French territory [11]. The combinations of large territories and limited resources might explain this limited increase in the level of conservation law enforcement.

To address deforestation by necessity for marginalized households, PA managers have developed ICDP programs. Meanwhile, our results show a decreasing impact of PAs as long as poverty rates increase: higher initial poverty rates mean lower environmental effectiveness of PAs. The persistence of weaker but yet existent opportunities to deforest have allowed locals to continue to deforest to satisfy their needs and the establishment of PAs and ICDP programs seem to have had little effect on the improvement of local populations' living conditions, as recognized by some conservation actors themselves (Gardner et al. 2013).

ICDPs have notably been financed de jure allocating 50% of the income generated from park entrance fees. This revenue was ultimately paltry and unequally

[11] Environment Secretary, presentation during PHCF Day - 18 September 2012, quoted by Brimont 2014: p 68 (Brimont 2014).

distributed. Of the 30 PAs open to public visits and managed by Madagascar National Parks, two accounted for almost 45% of total visits between 2005 and 2010, and five other parks generated a further 45% of visits. The rest, more than two thirds of PAs, generated less than 10% of visits (Figure 5). As a result of the low revenues generated, the margins to finance programs was very small for almost all PAs [12].

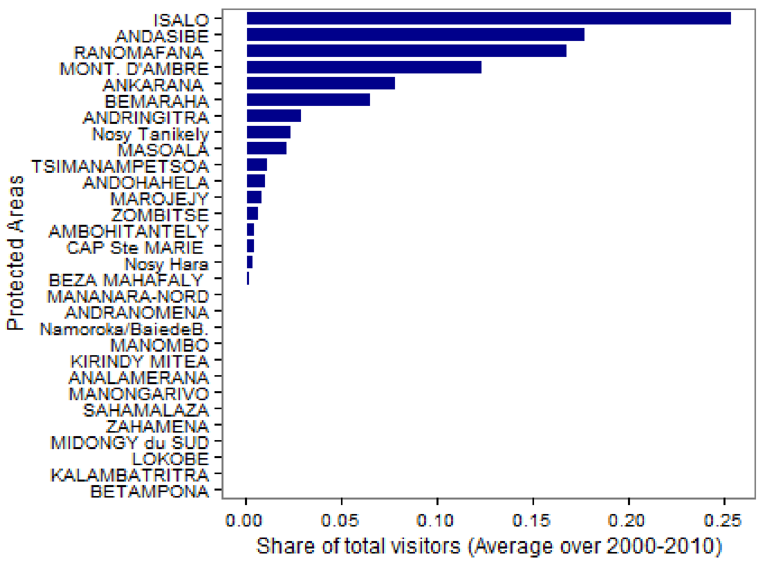


Figure 6: An unequal repartition of visitors

Beyond the lack of means, development programs haven't always had the expected effects due to deficiencies in the way they have been set up and because of strong local resistance to adopting new practices. Several ICDPs have aimed to replace *tavy* by sedentary modes of rice farming. The number of farmers who agree to give up *tavy* has rarely been consequential (Moser and Barrett 2003) and, even when an improvement in yields is observed, once the project is completed, the number of

[12]Zahamena National Park, which has an average of five visitors a year, was only just capable of refunding $7 a year to the affected communes (personal communication, Manistra Razafintsalama 2014). Data cited here are the courtesy of MNP.

farmers who abandon the alternative method is high. Other programs aim to replace rice farming by alternative animal-rearing activities (fish or poultry farming) or cash cropping (sometimes referred to as "conservation by distraction" mechanisms (Ferraro and Kiss 2002)). In these cases, geographic remoteness can hinder the sale of produce. In addition, such programs, which lack insurance mechanisms, have exposed farmers to important fluctuations of commodity prices as in the multiple vanilla price slumps. Such situations have driven farmers to increase forest clearance to make way for new *tavy* as well as illegal felling or overfishing and poaching as documented in the Mananara Nord Reserve (Huttel, Toubel, and Clüsner-Godt 2002). In addition, some authors have highlighted the intrinsic restrictions of ICDP schemes which embody the inherent causes of future upsurges in deforestation (rebound effects) by virtue of the increased costs of conservation opportunities created automatically by the programs' successes (Niesten and Rice 2004).

5 Discussion

5.1 On the Uncertain Net Economic Benefit of the Current Protection

Deforestation in Madagascar is a persistent feature despite the establishment of PAs. Our results suggest that historic PAs have helped to slow down deforestation by approximately 20%. Nevertheless, this means that 80% of forests are still cleared even though they are protected. As for NPAs, even the early impact is statistically uncertain.

Madagascar is actively engaged inside the REDD+ dynamic (i.e., reducing emissions linked to deforestation and forest degradation) with 6 REDD+ projects as of October 2014 in eastern Madagascar (Simonet et al. 2015) as well as a newly announced National Strategy. REDD+ projects come with the establishment of NPAs and deforestation baselines are determined to infer the amount of avoided CO2 emissions the project will allow. Three of these projects have received a VCS certification that is supposed to guarantee the environmental credibility of their proposed baselines of what would have occurred without NPAs. However, in comparison to our estimates, the proposed deforestation decreases are surprisingly optimistic: from a 77% decrease (0.9% annually to 0.20%, (CI-VCS 2013a)), to an 84% (1.26% to 0.2%, (CI-VCS 2013b)) or even 91% decrease (0.23% to 0.02%, (WCS 2012)). The three estimates are at a minimum two times higher than our most optimistic average estimate for historic PA effectiveness, while we have not yet found any significant impact for NPAs. The risk of "hot air" for REDD+ projects is thus high (Karsenty 2008).

Despite the limited additionality of PAs, the approximately 6,573 ha of forests saved every year inside historic PAs are key biodiversity areas. PAs also help to secure the provision of water services for the population. Carret and Loyet have estimated that each hectare of forest provides an average monetary equivalent of approximately \$3 of biodiversity benefits, \$3 of water benefits and an additional \$4 thanks to tourism every year (Carret and Loyer 2003): adding up the three could correspond to \$10 y^{-1} ha^{-1} or \$65 730y^{-1} for the amount of forest saved.. Furthermore, as humid forests in Madagascar are able to store 2.24 $\text{tCo}_2\ \text{y}^{-1}\ \text{ha}^{-1}$ (Vieilledent, Grinand, and Raudry 2013),the estimates of 6,573 ha saved annually would correspond to avoided emissions of 14,723$\text{tCo}_2\ \text{y}^{-1}$. At the current market price of about \$5$\text{tCO}_2{}^{-1}$, this would correspond to \$73 617 y^{-1}. Considering the social value of carbon of \$100 tCO

$_2$ $^{-1}$ (Ferraro, Hanauer, et al. 2015), it would correspond to \$1,472,300y^{-1} for a total benefit of the three ecosystem services of \$139,347 y^{-1} to \$1,538,030y^{-1}.

On the other hand, each ha of saved forest comes at an average estimated opportunity cost of approximately \$4 y^{-1} ha^{-1} for local farmers (\$26 292y^{-1} in total), and total management costs of \$3.5 million that must be paid whether forest has been saved or cleared: because of these management costs and the limited additionality of PAs, when taking Carret and Loyer estimates, the total balance between economic benefits and costs is negative. With these values, only an efficiency level $2^{1/3}$ times higher can provide a net economic benefit of PAs.

Nonetheless, estimating the economic benefits of biodiversity is as challenging as it is uncertain and while Carret and Loyer's estimates might appear low and dubious, the economic value is revealed from net payments made by conservation NGOs for biodiversity protection but not from an evaluation per se of its value. Also, our cost-benefit evaluation relies on the restrictive assumption of homogeneous benefits across the rainforest (Vincent 2015). While this may be satisfactory for carbon storage, it appears more uncertain for other benefits. The economic value of water provision varies greatly across space. As for tourism, it is highly probable that the number of visitors has not yet decreased because of current deforestation as this is taking place off the touristic path. Assuming no loss of revenue from tourism only would already make the balance positive.

5.2 Promote a Greater Articulation of Sectoral Policies

Despite certain assertions (Carret and Loyer 2003; Schwitzer et al. 2014), it is hard to believe that the tens of thousands of Malagasy farming households who still depend on forests to fulfill their basic subsistence needs will convert to becoming tour guides and eco-tour operators. In light of the scarce amenities in Madagascar, tourism will most likely continue to be concentrated in the few suitably adapted zones and remain strongly linked to the national, if not international, political situation, which is unstable and economically weak. It appears, therefore, that a true agricultural transition to alternative farming methods is necessary and unavoidable for the improvement in living conditions of local populations (Minten and Barrett 2008).

Yet the means mobilized by conservation stakeholders have often been insufficient to generate this agricultural transition. In the Ankeniheny-Zahamana Corridor (CAZ), the management documents allow for only around $13 per household per year (average between 2007 and 2012) to bring about agricultural transition. In the Programme Holistique de Conservation des Forêts (PHCF) in the south of the country, the invested sums are even lower: $3 in 2010 and 2011 (Brimont 2014). Meanwhile, even projects which have invested $100 per household haven't managed to make the implemented transition last last[13]. Pointing at the failure of small rural development programs is not new but rather dates back to the end of the first phase of the first ambitious conservation policy of the early 1990s, the National Environmental Action Plan (Pollini 2011). Despite these criticisms, the same programs continue to be implemented.

In Madagascar, not only is public expenditure targeting the agricultural sector low (around 8% of public expenditures (Green Revolution in Africa 2013)), but agricultural development programs are also concentrated in places where maximization of food production is the most likely (suitable soil, infrastructure and climatic condi-

[13]We refer here to the COGESFOR project and its interventions in the area of Didy. See the project's capitalization material (Montagne, Razafiaritiana, and Razafindrakoto 2014).

tions). In the eastern region of Madagascar, one of the only "ecological intensification" projects is in the Alaotra Lake region, one of the largest rice production areas of the country, where no-tillage practices are developed and proposed to farmers. Recent official documents such as the Readiness-Preparation Proposal(R-PP), submitted by the Government of Madagascar to the Forest Carbon Partnership Facility for REDD+, emphasize the need to promote more intensive agricultural practices in order to settle slash-and-burn-oriented farmers. However, the proposal fails to recognize the need to combine important investments in applied research with the adoption of new agro-silvo-pastoral practices by farmers surrounding the PAs. Indeed, the R-PP seems hesitant to take this approach, as it mentions the risk of the rebound effect and warns of the possibility that an increase in agricultural intensity may raise the pressure of forest resources. This concern is widespread within environmental NGOs – especially non-Malagasy ones – operating in Madagascar and probably explains why NGOs frequently give priority to non-agricultural income generating activities (such as beekeeping and ecotourism) over efforts towards what is called agricultural ecological intensification (Caron, Biénabe, and Hainzelin 2014) around the core of the PAs. This concern over rebound effect is also reflected in publications by Angelsen and Kaimowitz who suggest strategies of agriculture intensification only in areas far away from forests (Angelsen and Kaimowitz 1999).

To address the issue of potential rebound effect, we would suggest combining investment for ecological intensification of agriculture (on a broad scale, including husbandry and agroforestry) and direct conservation incentives. A potential instrument for this would be a program of investment-oriented PES (Karsenty 2011), which could integrate conditional payments for conservation and control in a single instrument, and additional investments for introducing more productive and sustainable agricultural practices. These practices would also be conditional to conservation efforts but the investment component would be separate from the direct payments associated with conservation results – which is not the case today with the few PES-like schemes used by some REDD+ projects.

A prerequisite for this strategy to work is clarity and security of land and resource tenure for the targeted farmers. The transfer of resource management to local communities is an available instrument to achieve this. Furthermore, Madagascar received assistance in 2006 from the Millennium Challenge Account to undertake a large land securization program through simplified and decentralized land titling ("*certificats fonciers*"). This program nonetheless terminated with the 2009 coup. In the event that this initiative resumes with the new political situation, it would be appropriate that it also target forested areas, including farmers within PAs.

Given the hybrid dimension of such investment-oriented PES schemes, funding of such programs would not have to rely only on conservation-oriented budgets and international aid (such as a national REDD+ fund). For a revitalization of investment in the agricultural sector to occur, it would be critical that the efforts to implement ecological intensification of agriculture through PES schemes in forested areas be supported largely by public expenditures for agriculture.

6 Conclusion

In this article, we have outlined the factors which we believe explain deforestation in eastern Madagascar. We also measure the environmental impact of PAs and explore the determinants of their limited success. We argue that current deforestation originates from a combination of a need to clear the forest (deforestation by necessity) and opportunities provided by deficiencies in the country's legal and institutional framework (opportunistic deforestation). We find that the establishment of PAs appears to succeed in lowering deforestation by 20%. NPA efficiency is not yet certain and more time may be necessary to observe first impacts. We find that PAs do act as a means to better enforce conservation law on the ground but that their additionality decreases with the rate of poverty inside municipalities. Consistent with this finding, the persistence of a stable deforestation trend testifies to the failure of local development programs (Gardner et al. 2013) and to the persistence of deforestation by necessity. Because additionality remains limited, it is unclear whether the current decrease in deforestation is generating net economic benefits.

We believe that in order to permanently eradicate deforestation in Madagascar and ensure a better welfare outcome for the society, an adjustment in the current conservation policy strategy must be applied. The necessary transition in agricultural practices is far too often a secondary measure and used by conservation stakeholders to buy social peace following the implementation of access restrictions. It is crucial, however, that a transitions to agricultural practices be a primary objective and strike a new balance between development and conservation agendas. Obviously, achieving an agricultural transition is not simply a question of resources and will not be without its challenges. The failure of a transition towards new agricultural practices is not only the fault of conservation actors but also the failure of agronomists and development actors to propose credible alternatives to peasants. At this juncture, we do not have all the available answers to develop the best strategy for implementing such a policy In a very hierarchical almost caste-based society, it is a challenge to reach the most vulnerable families through collective programs and to avoid funds being siphoned off by the local elite. It would also be equally challenging to develop more individualized programs in a traditional, community-based society. Madagascar's poverty, political instability and traditions must be taken into account and addressed in by conversation program designers. The country's unique and significant challenges cannot be solved easily but these difficulties should not serve as a pretext not to adjust the national policy strategy.

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7 Appendix

7.1 Confirming Deforestation Drivers

7.1.1 Policemen and opportunities to override law

Table 4: Presence of policemen and elicitation rates in our sample

	No Policemen	Policemen	p-value
Number of stolen cattle, 1999 to 2001	71.09697	57.45	0.03***
	(4.57)	(4.64)	
Number of cattle found, 1999 and 2001	9.57491	21.38314	0.00***
	(.47)	(2.55)	
Rates of elicitation (cattle)	0.32	0.35	0.00***
	(.007)	(.009)	
Number of killings, 1999 to 2001	1.04	1.42	0.00***
	(0.03)	(0.05)	
Number of arrested killers	.76	1.32	0.00***
	(0.03)	(0.06)	
Rate of elicitation (killings)	0.82	0.97	0.00***
	(0.02)	(0.02)	
N	3898	3393	

Note: P-value obtained with standard t-test. In overall, crime rates are lower and elicitation rates higher in presence of policemen.

7.1.2 Panel without matching

Table 5: Validation of deforestation drivers

Variables	Poor + Destitutes (1)	Destitutes (2)
Policemen	-0.00333*	-0.00353*
	(0.00189)	(0.00182)
Poors	0.000303*	
	(0.000173)	
Poors^2	-2.78e-06*	
	(1.60e-06)	
Destitutes		0.000260
		(0.000229)
Destitute^2		-3.65e-06
		(3.31e-06)
Travel time (rainy season)	-6.99e-05	-5.93e-05
	(4.92e-05)	(5.21e-05)
Irrigated rice	-0.000167***	-0.000172***
	(4.54e-05)	(4.55e-05)
Population (district)	0	0
	(0)	(0)
Population 2001 (locality)	1.36e-07	1.59e-07
	(1.44e-07)	(1.41e-07)
Tree cover	-1.47e-08***	-1.33e-08***
	(4.78e-09)	(4.52e-09)
Slope	-0.00132***	-0.00129***
	(0.000335)	(0.000337)
Elevation	2.56e-05***	2.56e-05***
	(4.27e-06)	(4.40e-06)
PA	-0.00863***	-0.00851***
	(0.00204)	(0.00206)
NPA	-0.00728***	-0.00727***
	(0.00189)	(0.00189)
Constant	0.00499	0.00890**
	(0.00557)	(0.00443)
Observations	6,571	6,571
Number of id	558	558
Year FE	Yes	Yes

Panel regressions with Random Effects. Clustered standard errors (locality) in parenthesis. *** p<0.01, ** p<0.05, * p<0.1

7.2 Balance

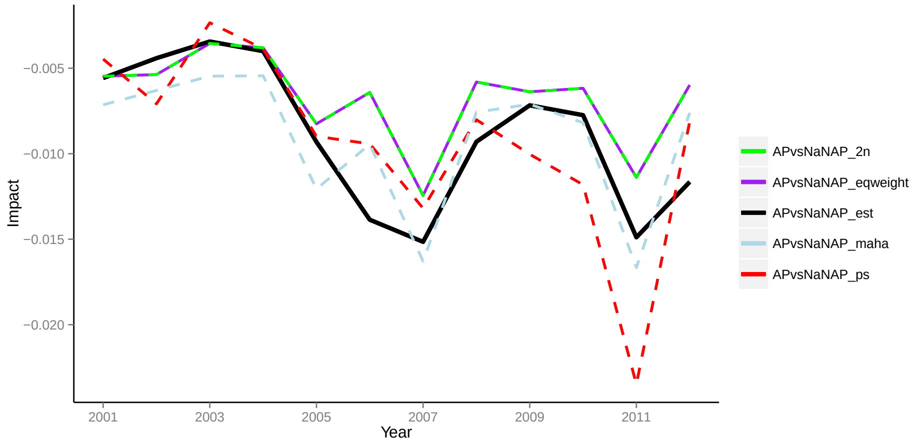
Table 6: Balance of the matching

	(a) PAs, mean difference		(b) NPAs, mean difference	
	Before	After	Before	After
Population 2001	-22.3	-1,6	-10	12
Slope	96***	14***	63***	9*
Slope square	125***	18***	52***	9
Elevation	51***	3	21**	8
Travel time to nearest city (rainy season)	16**	3	7	5
Population in agricultural sector (%)	-10	-12	56	-15
Irrigated rice paddy per inhabitant (%)	2	10	-1	11
Poor people (%)	-12	-4	-22	-14
Destitute people (%)	-28**	3	-3	-0.3
Pop district 2005	-55***	-0,7	-30***	-6
Pop district 2011	-61***	1	-39***	-1
Irrigated rice paddy per inhabitant (%) * slope	13	11	6	8

*Mean difference between treated and control. Bootstraped p-value used (1000 iterations). * : significant at 10% ** : sign at 5%*** : sign at 1%.*

7.3 Robustness Checks 1: Different Matching Procedures

7.3.1 Cross Section Matching



7.3.2 Panel Results

Table 7: 2 nearest neighbors pre-matching

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	Binary Tr	Tr x Year	Tr x Time_Tr	Tr x Policemen	Tr x Poor + Des	Tr x Policemen + Tr x Poor + Des	Mechanisms / Tr x Time_Tr	Mechanisms / Tr x Time_Tr
0.Treat_NAPvsAP	0.00381***	0.00325*	0.00469**	0.00703**	0.0135***	0.0147***	0.0131***	0.0131***
	(0.00130)	(0.00190)	(0.00236)	(0.00280)	(0.00449)	(0.00442)	(0.00322)	(0.00322)
2.Treat_NAPvsAP	0.00601***	0.00328*	0.00365	0.00505	0.0157***	0.0160***	0.0178***	0.0178***
	(0.00180)	(0.00193)	(0.00263)	(0.00348)	(0.00560)	(0.00584)	(0.00519)	(0.00519)
0.Treat_NAPvsAP#c.time_treat			0.00100**	0.00101**	0.000987**	0.000991**		
			(0.000417)	(0.000419)	(0.000413)	(0.000416)		
2.Treat_NAPvsAP#c.time_treat			0.000219	0.000215	0.000234	0.000233		
			(0.000443)	(0.000443)	(0.000446)	(0.000447)		
0.Treat_NAPvsAP#1.pres_policiers				-0.00511**		-0.00406*	-0.00381*	-0.00381*
				(0.00222)		(0.00223)	(0.00220)	(0.00220)
2.Treat_NAPvsAP#1.pres_policiers				-0.00317		-0.00183	-0.00161	-0.00161
0.Treat_NAPvsAP#c.pauvres_dem					-0.000132***	-0.000121**	-0.000128***	-0.000128***
					(4.97e-05)	(4.93e-05)	(4.58e-05)	(4.58e-05)
2.Treat_NAPvsAP#c.pauvres_dem					-0.000189***	-0.000182***	-0.000191***	-0.000191***
time_treat			-5.56e-05*	-5.68e-05**	-2.64e-05	-2.87e-05		
			(2.89e-05)	(2.88e-05)	(3.01e-05)	(2.97e-05)		
1.pres_policiers	-0.00103	-0.000947	-0.00106	0.000991	-0.00142	5.83e-05	-9.95e-06	-9.95e-06
	(0.00133)	(0.00132)	(0.00135)	(0.00146)	(0.00140)	(0.00150)	(0.00150)	(0.00150)
				(0.00336)		(0.00332)	(0.00329)	(0.00329)
pauvres_dem	-0.000128	-0.000128	-0.000117	-9.88e-05	-3.92e-06	2.84e-06	2.74e-06	2.74e-06
	(0.000134)	(0.000134)	(0.000135)	(0.000130)	(0.000123)	(0.000120)	(0.000120)	(0.000120)
pauvres_dem2	1.18e-06	1.18e-06	9.67e-07	7.65e-07	6.70e-07	5.42e-07	6.38e-07	6.38e-07
	(1.14e-06)	(1.14e-06)	(1.16e-06)	(1.12e-06)	(1.09e-06)	(1.08e-06)	(1.07e-06)	(1.07e-06)
Tree78_	-1.20e-08***	-1.18e-08***	-1.17e-08***	-1.13e-08***	-1.10e-08***	-1.08e-08***	-1.09e-08***	-1.09e-08***
	(3.18e-09)	(3.16e-09)	(3.22e-09)	(3.04e-09)	(3.25e-09)	(3.12e-09)	(3.11e-09)	(3.11e-09)
pente_mean	-0.000409*	-0.000436**	-0.000361*	-0.000388*	-0.000324	-0.000347	-0.000378*	-0.000378*
	(0.000209)	(0.000210)	(0.000217)	(0.000218)	(0.000215)	(0.000216)	(0.000208)	(0.000208)
altitude_mean	5.61e-06*	5.37e-06*	5.43e-06*	5.38e-06*	5.11e-06*	5.10e-06*	5.08e-06*	5.08e-06*
	(2.92e-06)	(2.88e-06)	(2.97e-06)	(2.89e-06)	(2.85e-06)	(2.79e-06)	(2.72e-06)	(2.72e-06)
pop_dist200	0	0	0	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
pop2001	4.09e-08	2.51e-08	4.50e-08	4.88e-08	2.93e-08	3.29e-08	1.83e-08	1.83e-08
	(9.30e-08)	(9.34e-08)	(9.59e-08)	(9.62e-08)	(9.11e-08)	(9.18e-08)	(9.03e-08)	(9.03e-08)
pourcentagederiziresirriguesprb	-7.28e-05*	-6.82e-05*	-8.21e-05*	-8.26e-05**	-8.56e-05**	-8.59e-05**	-7.93e-05**	-7.93e-05**
	(4.02e-05)	(3.97e-05)	(4.20e-05)	(4.17e-05)	(4.15e-05)	(4.14e-05)	(3.98e-05)	(3.98e-05)
dureduvoyageverslecupensaisonds	-3.16e-05	-3.59e-05	-3.17e-05	-3.40e-05	-3.15e-05	-3.33e-05	-3.56e-05	-3.56e-05
	(2.50e-05)	(2.56e-05)	(2.49e-05)	(2.60e-05)	(2.46e-05)	(2.53e-05)	(2.54e-05)	(2.54e-05)
					(6.83e-05)	(6.78e-05)	(6.54e-05)	(6.54e-05)
Constant	0.0155***	0.0163***	0.0185***	0.0177***	0.0122***	0.0120***	0.00989**	0.00989**
	(0.00422)	(0.00406)	(0.00429)	(0.00412)	(0.00440)	(0.00424)	(0.00398)	(0.00398)
Observations	2,853	2,853	2,841	2,841	2,841	2,841	2,853	2,853
Number of id	248	248	247	247	247	247	248	248
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year x Tr	No	Yes	No	No	No	No	No	No
Time Treat x Tr	No	No	Yes	Yes	Yes	Yes	No	No

Clustered standard errors in parentheses at the municipality level. *** p<0.01, ** p<0.05, * p<0.1

Table 8: Matching with Equal weights

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VARIABLES	Binary Tr	Tr x Year	Tr x Time_Tr	Tr x Policemen	Tr x Poor + Des	Tr x Policemen + Tr x Poor + Des	Mechanisms / Tr x Time_Tr
0.Treat_NAPvsAP	0.00381***	0.00325*	0.00469**	0.00703**	0.0135***	0.0147***	0.0131***
	(0.00130)	(0.00190)	(0.00236)	(0.00280)	(0.00449)	(0.00442)	(0.00322)
2.Treat_NAPvsAP	0.00601***	0.00328*	0.00365	0.00505	0.0157***	0.0160***	0.0178***
	(0.00180)	(0.00193)	(0.00263)	(0.00348)	(0.00560)	(0.00584)	(0.00519)
0.Treat_NAPvsAP#c.time_treat			0.00100**	0.00101**	0.000987**	0.000991**	
			(0.000417)	(0.000419)	(0.000413)	(0.000416)	
2.Treat_NAPvsAP#c.time_treat			0.000219	0.000215	0.000234	0.000233	
0.Treat_NAPvsAP#1.pres_policiers				-0.00511**		-0.00406*	-0.00381*
				(0.00222)		(0.00223)	(0.00220)
2.Treat_NAPvsAP#1.pres_policiers				-0.00317		-0.00183	-0.00161
				(0.00336)		(0.00332)	(0.00329)
0.Treat_NAPvsAP#c.pauvres_dem					-0.000132***	-0.000121**	-0.000128***
					(4.97e-05)	(4.93e-05)	(4.58e-05)
2.Treat_NAPvsAP#c.pauvres_dem					-0.000189***	-0.000182***	-0.000191***
					(6.83e-05)	(6.78e-05)	(6.54e-05)
time_treat			-5.56e-05*	-5.68e-05**	-2.64e-05	-2.87e-05	
			(2.89e-05)	(2.88e-05)	(3.01e-05)	(2.97e-05)	
			(0.000443)	(0.000443)	(0.000446)	(0.000447)	
1.pres_policiers	-0.00103	-0.000947	-0.00106	0.000991	-0.00142	5.83e-05	-9.95e-06
	(0.00133)	(0.00132)	(0.00135)	(0.00146)	(0.00140)	(0.00150)	(0.00150)
pauvres_dem	-0.000128	-0.000128	-0.000117	-9.88e-05	-3.92e-06	2.84e-06	2.74e-06
	(0.000134)	(0.000134)	(0.000135)	(0.000130)	(0.000123)	(0.000120)	(0.000120)
pauvres_dem2	1.18e-06	1.18e-06	9.67e-07	7.65e-07	6.70e-07	5.42e-07	6.38e-07
	(1.14e-06)	(1.14e-06)	(1.16e-06)	(1.12e-06)	(1.09e-06)	(1.08e-06)	(1.07e-06)
Tree78_	-1.20e-08***	-1.18e-08***	-1.17e-08***	-1.13e-08***	-1.10e-08***	-1.08e-08***	-1.09e-08***
	(3.18e-09)	(3.16e-09)	(3.22e-09)	(3.04e-09)	(3.25e-09)	(3.12e-09)	(3.11e-09)
pente_mean	-0.000409*	-0.000436**	-0.000361*	-0.000388*	-0.000324	-0.000347	-0.000378*
	(0.000209)	(0.000210)	(0.000217)	(0.000218)	(0.000215)	(0.000216)	(0.000208)
altitude_mean	5.61e-06*	5.37e-06*	5.43e-06*	5.38e-06*	5.11e-06*	5.10e-06*	5.08e-06*
	(2.92e-06)	(2.88e-06)	(2.97e-06)	(2.89e-06)	(2.85e-06)	(2.79e-06)	(2.72e-06)
pop_dist200	0	0	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)	(0)	(0)
pop2001	4.09e-08	2.51e-08	4.50e-08	4.88e-08	2.93e-08	3.29e-08	1.83e-08
	(9.30e-08)	(9.34e-08)	(9.59e-08)	(9.62e-08)	(9.11e-08)	(9.18e-08)	(9.03e-08)
pourcentagederiziresirriguesprb	-7.28e-05*	-6.82e-05*	-8.21e-05*	-8.26e-05**	-8.56e-05**	-8.59e-05**	-7.93e-05**
	(4.02e-05)	(3.97e-05)	(4.20e-05)	(4.17e-05)	(4.15e-05)	(4.14e-05)	(3.98e-05)
dureduvoyageverslecupensaisonds	-3.16e-05	-3.59e-05	-3.17e-05	-3.40e-05	-3.15e-05	-3.33e-05	-3.56e-05
	(2.50e-05)	(2.56e-05)	(2.49e-05)	(2.60e-05)	(2.46e-05)	(2.53e-05)	(2.54e-05)
Constant	0.0155***	0.0163***	0.0185***	0.0177***	0.0122***	0.0120***	0.00989**
	(0.00422)	(0.00406)	(0.00429)	(0.00412)	(0.00440)	(0.00424)	(0.00398)
Observations	2,853	2,853	2,841	2,841	2,841	2,841	2,853
Number of id	248	248	247	247	247	247	248
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year x Tr	No	Yes	No	No	No	No	No
Time Treat x Tr	No	No	Yes	Yes	Yes	Yes	No

Clustered standard errors in parentheses at the municipality level. *** p<0.01, ** p<0.05, * p<0.1

Table 9: Matching with Propensity Score Matching

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VARIABLES	Binary Tr	Tr x Year	Tr x Time_Tr	Tr x Policemen	Tr x Poor + Des	Tr x Policemen + Tr x Poor + Des	Mechanisms / Tr x Time_Tr
0.Treat_NAPvsAP	0.00381***	0.00325*	0.00469**	0.00703**	0.0135***	0.0147***	0.0131***
	(0.00130)	(0.00190)	(0.00236)	(0.00280)	(0.00449)	(0.00442)	(0.00322)
2.Treat_NAPvsAP	0.00601***	0.00328*	0.00365	0.00505	0.0157***	0.0160***	0.0178***
	(0.00180)	(0.00193)	(0.00263)	(0.00348)	(0.00560)	(0.00584)	(0.00519)
0.Treat_NAPvsAP#c.time_treat			0.00100**	0.00101**	0.000987**	0.000991**	
			(0.000417)	(0.000419)	(0.000413)	(0.000416)	
2.Treat_NAPvsAP#c.time_treat			0.000219	0.000215	0.000234	0.000233	
			(0.000443)	(0.000443)	(0.000446)	(0.000447)	
0.Treat_NAPvsAP#1.pres_policiers				-0.00511**		-0.00406*	-0.00381*
				(0.00222)		(0.00223)	(0.00220)
2.Treat_NAPvsAP#1.pres_policiers				-0.00317		-0.00183	-0.00161
				(0.00336)		(0.00332)	(0.00329)
0.Treat_NAPvsAP#c.pauvres_dem					-0.000132***	-0.000121**	-0.000128***
					(4.97e-05)	(4.93e-05)	(4.58e-05)
2.Treat_NAPvsAP#c.pauvres_dem					-0.000189***	-0.000182***	-0.000191***
					(6.83e-05)	(6.78e-05)	(6.54e-05)
time_treat			-5.56e-05*	-5.68e-05**	-2.64e-05	-2.87e-05	
			(2.89e-05)	(2.88e-05)	(3.01e-05)	(2.97e-05)	
1.pres_policiers	-0.00103	-0.000947	-0.00106	0.000991	-0.00142	5.83e-05	-9.95e-06
	(0.00133)	(0.00132)	(0.00135)	(0.00146)	(0.00140)	(0.00150)	(0.00150)
pauvres_dem	-0.000128	-0.000128	-0.000117	-9.88e-05	-3.92e-06	2.84e-06	2.74e-06
	(0.000134)	(0.000134)	(0.000135)	(0.000130)	(0.000123)	(0.000120)	(0.000120)
pauvres_dem2	1.18e-06	1.18e-06	9.67e-07	7.65e-07	6.70e-07	5.42e-07	6.38e-07
	(1.14e-06)	(1.14e-06)	(1.16e-06)	(1.12e-06)	(1.09e-06)	(1.08e-06)	(1.07e-06)
Tree78_	-1.20e-08***	-1.18e-08***	-1.17e-08***	-1.13e-08***	-1.10e-08***	-1.08e-08***	-1.09e-08***
	(3.18e-09)	(3.16e-09)	(3.22e-09)	(3.04e-09)	(3.25e-09)	(3.12e-09)	(3.11e-09)
pente_mean	-0.000409*	-0.000436**	-0.000361*	-0.000388*	-0.000324	-0.000347	-0.000378*
	(0.000209)	(0.000210)	(0.000217)	(0.000218)	(0.000215)	(0.000216)	(0.000208)
altitude_mean	5.61e-06*	5.37e-06*	5.43e-06*	5.38e-06*	5.11e-06*	5.10e-06*	5.08e-06*
	(2.92e-06)	(2.88e-06)	(2.97e-06)	(2.89e-06)	(2.85e-06)	(2.79e-06)	(2.72e-06)
pop_dist200	0	0	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)	(0)	(0)
pop2001	4.09e-08	2.51e-08	4.50e-08	4.88e-08	2.93e-08	3.29e-08	1.83e-08
	(9.30e-08)	(9.34e-08)	(9.59e-08)	(9.62e-08)	(9.11e-08)	(9.18e-08)	(9.03e-08)
pourcentagederiziresirriguesprb	-7.28e-05*	-6.82e-05*	-8.21e-05*	-8.26e-05**	-8.56e-05**	-8.59e-05**	-7.93e-05**
	(4.02e-05)	(3.97e-05)	(4.20e-05)	(4.17e-05)	(4.15e-05)	(4.14e-05)	(3.98e-05)
dureduvoyageverslecupensaisonds	-3.16e-05	-3.59e-05	-3.17e-05	-3.40e-05	-3.15e-05	-3.33e-05	-3.56e-05
	(2.50e-05)	(2.56e-05)	(2.49e-05)	(2.60e-05)	(2.46e-05)	(2.53e-05)	(2.54e-05)
Constant	0.0155***	0.0163***	0.0185***	0.0177***	0.0122***	0.0120***	0.00989**
	(0.00422)	(0.00406)	(0.00429)	(0.00412)	(0.00440)	(0.00424)	(0.00398)
Observations	2,853	2,853	2,841	2,841	2,841	2,841	2,853
Number of id	248	248	247	247	247	247	248
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year x Tr	No	Yes	No	No	No	No	No
Time Treat x Tr	No	No	Yes	Yes	Yes	Yes	No

Clustered standard errors in parentheses at the municipality level. *** p<0.01, ** p<0.05, * p<0.1

Table 10: Matching with Mahanabolis distance

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VARIABLES	Binary Tr	Tr x Year	Tr x Time_Tr	Tr x Policemen	Tr x Poor + Des	Tr x Policemen + Tr x Poor + Des	Mechanisms / Tr x Time_Tr
0.Treat_NAPvsAP	0.00377***	0.00327*	0.00462*	0.00730**	0.0148***	0.0159***	0.0139***
	(0.00124)	(0.00185)	(0.00240)	(0.00296)	(0.00433)	(0.00436)	(0.00314)
2.Treat_NAPvsAP	0.00587***	0.00277	0.00338	0.00510	0.0168***	0.0171***	0.0185***
	(0.00172)	(0.00169)	(0.00270)	(0.00365)	(0.00546)	(0.00579)	(0.00503)
0.Treat_NAPvsAP#c.time_treat			0.000987**	0.000990**	0.000971**	0.000974**	
			(0.000414)	(0.000416)	(0.000410)	(0.000412)	
2.Treat_NAPvsAP#c.time_treat			0.000255	0.000251	0.000272	0.000270	
			(0.000439)	(0.000439)	(0.000443)	(0.000444)	
0.Treat_NAPvsAP#1.pres_policiers				-0.00522**		-0.00371*	-0.00365*
				(0.00224)		(0.00219)	(0.00216)
2.Treat_NAPvsAP#1.pres_policiers				-0.00323		-0.00143	-0.00140
				(0.00340)		(0.00330)	(0.00327)
0.Treat_NAPvsAP#c.pauvres_dem					-0.000153***	-0.000141***	-0.000145***
					(4.90e-05)	(4.83e-05)	(4.55e-05)
2.Treat_NAPvsAP#c.pauvres_dem					-0.000210***	-0.000202***	-0.000208***
					(6.74e-05)	(6.64e-05)	(6.41e-05)
time_treat			-5.39e-05**	-4.83e-05*	-2.07e-05	-1.89e-05	
			(2.63e-05)	(2.64e-05)	(2.72e-05)	(2.72e-05)	
1.pres_policiers	-0.00107	-0.000995	-0.00130	0.000854	-0.00178	-0.000439	-0.000336
	(0.00132)	(0.00131)	(0.00135)	(0.00144)	(0.00139)	(0.00143)	(0.00145)
pauvres_dem	-0.000115	-0.000115	-0.000106	-9.87e-05	7.91e-06	6.40e-06	7.33e-06
	(0.000126)	(0.000126)	(0.000127)	(0.000122)	(0.000109)	(0.000108)	(0.000108)
pauvres_dem2	1.16e-06	1.16e-06	9.74e-07	8.68e-07	8.00e-07	7.44e-07	7.94e-07
	(1.08e-06)	(1.08e-06)	(1.09e-06)	(1.05e-06)	(1.01e-06)	(9.91e-07)	(9.77e-07)
dureduvoyageverslecupensaisonds	-3.90e-05	-4.31e-05	-4.15e-05	-4.18e-05	-3.87e-05	-3.92e-05	-4.11e-05
	(2.62e-05)	(2.66e-05)	(2.59e-05)	(2.69e-05)	(2.57e-05)	(2.63e-05)	(2.64e-05)
Tree78_	-1.18e-08***	-1.16e-08***	-1.09e-08***	-1.11e-08***	-1.10e-08***	-1.12e-08***	-1.14e-08***
	(3.18e-09)	(3.14e-09)	(3.18e-09)	(3.02e-09)	(3.28e-09)	(3.17e-09)	(3.13e-09)
pente_mean	-0.000710***	-0.000735***	-0.000667***	-0.000685***	-0.000594***	-0.000611***	-0.000632***
	(0.000220)	(0.000220)	(0.000230)	(0.000232)	(0.000225)	(0.000227)	(0.000215)
altitude_mean	6.59e-06**	6.34e-06**	6.30e-06*	6.33e-06**	5.86e-06*	5.91e-06**	5.87e-06**
	(3.16e-06)	(3.11e-06)	(3.23e-06)	(3.15e-06)	(3.05e-06)	(3.02e-06)	(2.91e-06)
pop_dist200	0	0	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)	(0)	(0)
pop2001	1.05e-07	9.07e-08	1.04e-07	1.07e-07	8.89e-08	9.21e-08	7.89e-08
	(9.60e-08)	(9.57e-08)	(9.95e-08)	(9.93e-08)	(9.14e-08)	(9.20e-08)	(8.95e-08)
pourcentagederiziresirriguesprb	-7.94e-05*	-7.46e-05*	-8.83e-05**	-8.86e-05**	-9.12e-05**	-9.13e-05**	-8.54e-05**
	(4.30e-05)	(4.24e-05)	(4.49e-05)	(4.43e-05)	(4.37e-05)	(4.36e-05)	(4.19e-05)
Constant	0.0164***	0.0172***	0.0197***	0.0187***	0.0125***	0.0123***	0.0105***
	(0.00410)	(0.00397)	(0.00423)	(0.00404)	(0.00398)	(0.00390)	(0.00359)
Observations	2,853	2,853	2,841	2,841	2,841	2,841	2,853
Number of id	248	248	247	247	247	247	248
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year x Tr	No	Yes	No	No	No	No	No
Time Treat x Tr	No	No	Yes	Yes	Yes	Yes	No

Clustered standard errors in parentheses at the municipality level. *** p<0.01, ** p<0.05, * p<0.1