Knowledge Mobilization in Water and Carbon PES projects implementation in Madagascar

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INTRODUCTION

The current craze around payment for ecosystem services (PES) is the result of a rhetoric initiated at he end of the 1990's, promoting direct payments from beneficiaries to ecosystem services providers (Ferraro et Kiss 2002). This rhetoric is based on positive externalities internalized through payment. This approach called "coasian", from the name of one of the fathers of externalities theory, Ronald Coase, is considered as more efficient than other environmental policy instruments (command and control, taxation…) under some conditions. One of the main conditions is perfect information. Indeed retained information engenders extra costs, reducing theoretical advantage of PES compared to other instruments. After not questioning for a while the theoretical foundations of PES, literature started pointing insistently the fragility of this rhetoric (Muradian *et al*., 2010; Kosoy and Corbera, 2010 ; Farley and Costanza, 2010). Our point is not as much the critic of theoretical foundations of PES but to underline that belief in market approach superiority in a theoretical world without friction where transaction costs are negligible, is not the right basis for addressing real questions on concrete PES implementation. Questioning those coasian PES foundations implies tackling the problematic of governance structures associated with those devices (Norgaard, 2010).

This position advanced by environment institutionalists (Muradian et al., 2010 ; Vatn, 2010) emphasizes the importance of information for PES mechanisms implementation ; and relates to even more basic questions regarding PES: what are ecosystem services and how to estimate them? Who are the beneficiaries? What are the opportunity costs? What are the possible leakages? How to secure additionality? Etc.

This communication aims at fueling debates on the role of information and scientific and technical knowledge, highlighting two important aspects. First, this problematic finds its relevance during PES implementation. Ex-ante position is a key point to deal with this problematic as it determines and shapes PES governance modalities and its durability. Second, this information question varies depending on PES type, an under discussed point in literature. Finally the process of information and knowledge acquisition in PES implementation addresses the roles given to different actors in the predefined governance modalities.

We propose here an analysis of information role in the genesis of Carbon and Water PES schemes in Madagascar.

First, we will go back over the link between theory and practice in the literature. Then we will propose a panorama of current PES implementation attempts in Madagascar before focusing our attention on two different PES types. The first one concerns REDD pilot projects and national policy, the second exposes a Water PES project. In the last part, we suggest outcomes and perspectives.

OVERVIEW OF INFORMATION ROLE IN PES IMPLEMENTATION

Before entering into Malagasy study cases, we propose a quick synopsis of coasian approach on which relies PES theorization and we will explicit its perfect information hypothesis. Our point being that albeit the centrality of this hypothesis, it does not seem to be verified in several PES experiences through the world.

Theoretical foundations

PES genesis is the result of a process which began in the middle of 1990s and which found its apogee in the 2000s. During that period, the rhetoric around PES was constructed from several contributions. First, the reassessment of conservation policy with ICDPs (Wells et al. 1992, Ferraro et Kiss, 2002), second, through research of extra biodiversity conservation financial resources (Landell-Mills et Porras, 2002) and third, the buildup of the framework proposed by conservation biologists, then institutionalized at the international level through the Millennium Ecosystem Assessment, pointing up services produced by ecosystems.

The conjunction of these three tendencies put the theory of externalities theory back under the spotlight; that is to say that threats on ecosystems are principally linked to the absence of recognition of their value in prices system (which is the base of current economies regulation). MEA, for example, states : « *Although people benefit from ecosystem services such as the regulation of air and water quality or the presence of an aesthetically pleasing landscape, there is no market for these services and no one person has an incentive to pay to maintain the good*" (MEA, 2005 ; p.10). FAO is even more explicit in its PES report: "*It [this report] focuses on the use of payments to providers of ecosystem services from beneficiaries of those services as a way of reducing negative externalities and enhancing the provision of positive externalities.*" (FAO, 2007; p.6)

The internalization of external effects bears out by different mechanisms already identified by Pigou in 1920 and by Coase in 1960: regulation, taxation, bilateral negotiation (Pigou, 1920 ; Coase, 1960). Economical analysis principally took an interest to this theory, above all for the internalization of negative externalities, mechanism well-known through the name "polluter-pays principle". The apparition of ecosystem services and biodiversity conservation issues led to focus on internalization of positive externalities, following another complementary principle "depolluter-payed".

The force of this theory comes from its intuitive character and positive a priori vis-à-vis market regulation. Yet, ecosystem services internalization faces two problems: the characterization of actors and of external effect; the characteristics of the bilateral negotiation (service provision exchanged with payment through a more or less contractual base). These two problems concern the nature of information.

The first problem is the identification of actors and of external effects (information and tangibility of provided service). In theory, externalities often concern one or several economical actors (producers and/or consumers), whose function of production (for producers) or utility function (for consumers) are known. And we know that internalization of externalities is problematic

when several actors are involved in Common Pool Resources (CPR: characterized by rivalry and non-exclusivity) situations which is the case of most environmental externalities.

Difficulties also grow regarding positive externalities. If nuisance, pollution, i.e. external deseconomy is intuitively easy to comprehend, the positive effect (especially when nature is the furnisher) is much less as it combines factors of invisibility: it is usual, noticeable only when gone, this being the situation that we seek to prevent. One of the inherent issues of PES (and more largely of ecosystem services) is to in-form the furnished service, meaning to translate a fact into a formalized, explicit, measurable economic object. For economists, this information is given through a proxy which is costs and benefices variation for different actors.

Ecosystem services materialization which serves as a support for PES projects is all the more necessary if it is exchanged in a market. The climate mitigation service is materialized through "Carbon storage" which itself materialized through its general equivalent: CO^2 ton…

The second problem identified in our analysis of the literature may be qualified as information and contract. Theoretical literature on PES explains quite rightly the importance of information during the implementation. The reference to Coase theory and more generally the reference to public choice originate from the principle that without transaction costs (administration, organization, information…), a negotiated solution between actors (i.e. without third party intervention like State or one of its substitutes) is the only one that will lead to an optimal solution. Also, it is important to note that in presence of such costs; the optimal internalization modality (taxes, regulations, negotiations…) is not possible, suggesting that modality choice needs to be at lesser cost. In that situation, economic reasoning suggests choosing a governance structure with lesser transaction costs.

Information needs revolve around two main concerns: costs and benefits for different stakeholders and contracting costs. In the first case, variation of utility of the different actors linked to external effect internalization must be identified. Opportunity cost evaluation comes within this principle. Theoretically, compensation relies on the evaluation of those marginal calculations.

In the second case, the question of the guarantee of contract between producers and beneficiaries is addressed. Theoretically, those aspects precisely emerge in the case of imperfect information and thus in an asymmetrical situation between actors. This implies two problems (hazard moral and adverse selection) reduced by the strengthening of regulations (Pattanayak et al., 2010).

In brief, information problems are key points of PES economical analysis, both for their link to the theory of externalities which problematic is gathered under the appellation of transaction costs, and for the nature of the positive services furnished by ecosystems. The problems mentioned above (identification of actors, identification of provided services, contract respect) are actually perfectly represented by Wunder's five conditions (2005). One can thus interpret his definition not only as one giving conditions for PES implementation but also as one underlining information problems to be solved in order to make a PES project operational.

At last, it has to be said that the more PES aim at approaching canonical model of market internalization of externalities, the information needs and costs are important.

From theory to practice

Despite a rich literature on PES, information questions on ecosystem services are not very documented. In several cases, the ecosystem services assessment and/or opportunity costs assessment are not done. For example, in their bundled PES "biodiversity and hydrology" at Los Negros (Bolivia), Asquith *et al.* (2008, p680) state that « *baseline water flow and bird species diversity were not established before the initiation of the scheme* ». Also, "*no formal economic analysis or PES feasibility study was implemented*" (p. 678). In their comparative analysis of two PES in Equator, Wunder and Alban (2008, p.690) explain that « *there is no evidence to assess additionality in terms of water services proper* » or « *How different water services (annual flow, dry season flow, water quality) are affected by potential land-use changes in Nueva America, has not been studied* » (p.689). Pagiola (2008, p719), in his PES analysis from Costa Rica also posits : « *Expectations that the PSA program's would improve water services are based on the view, well entrenched in Costa Rica as in most of Central America, that forests are always beneficial to water services. In fact, the evidence on the links between land use and water services is far from clear, and monitoring has not been undertaken on the impact of PSA supported land uses on the desired water services* ». Echevarria (2002, p.93) reaches the same conclusion from an analysis of a Water PES case study in Equator: « *There are critical information gaps concerning the hydrological system, how it works, what benefits it offers to local populations, and how these are affected by human intervention* ».

Yet, all recognize the importance of that information. Milder et al. (2010, p.4) for example, mention « *Scientific research documenting the links between ecosystem functioning and human well-being can motivate demand for ecosystem services by helping prospective beneficiaries understand the importance of investing in such services* ». In the same manner, Echevarria (2002, p99.) poses: « *FONAG's success in delivering watershed benefits is dependent on its understanding of local hydrological relationship* ». In a first level, several authors consider than PES implementation may free oneself from perfect information if (and only if) it leans on a compromise between actors, eventually based on precautionary principle (Wunder and Alban, 2008). As underlined by Pascual *et al.,* (2010), there is a trade-off between the need for information as complete as possible and the necessity of implementing the device.

In a second level, the lack of information may greatly restrict the device effectiveness in a long term; hence the importance given to monitoring. Pattanayak et al. (2010, p.14) expose the « *urgent need for quantitative causal analyses of PES effectiveness* ». For other authors, this incomplete information question discredits the theoretical model: « *High levels of uncertainty surrounding PES schemes under incomplete information constitute a problem for Coasian PES designs* » (Pascual et al. 2010, p.1238)

Finally, if information problematic (knowledge, uncertainties, controversies) will become more and more structuring in PES analysis, it makes sense to find an analytical framework specifically dedicated to this problematic. Such an analysis is proposed here through Malagasy case studies.

CONTEXT AND METHODOLOGY

PES in Madagascar: between carbon and watersheds

PES emergence in Madagascar is the result of a quite recent story, even if the conditions of this emergence appear very clearly in environmental planning starting in 1989-1990 (Andriamahefazafy et al., 2010). Historically, one finds trace of the firsts PES within ecotourism and the redistribution of the parks entrance fees to managers and neighboring residents. Assimilated to ICDP instruments at that time, entrance fees may be considered retrospectively as the first PES in Madagascar. After that, Biodiversity PES found a totally new application with Durrell at the beginning of 2000s through conservation contracts (Durbin, 2001; Sommerville et al., 2010).

Then carbon PES drew donors and NGOs attention at the beginning of 2000s, through international carbon problematic, and notably since afforestation appears in UNFCCC agenda. In Madagascar the first forest carbon estimations are initiated by the USAID in 2001 (Rarivoarivelomanana, 2001), and the first projects are elaborated from 2004. Among them, four are significant regarding their geographical cover as well as their institutional set-up.

- Starting in 2004, the WCS created a 350 000ha new protected area in Makira with the intentions to fund conservation activities and practices changes of neighboring residents thanks to the carbon market.

- FORECA, a GTZ and Swiss Intercooperation project, started in 2007 with the general objective to support the Malagasy Government in establishing a national REDD mechanism, helping with accounting methodology and policy development.

- The CAZ (corridor Ankeniheny-Zahamena) and the COFAV (corridor Fandriana-Vondrozo) initiated by Conservation International in 2008 are two conservation and restoration projects of respectively 425 000 and 240 000 ha dedicated to carbon storage.

- PHCF (Holistic project for forest conservation), a GoodPlanet Foundation project financed by Air France and implemented by the WWF Madagascar also started in 2008, seeking to improve scientific knowledge and reinforce WWF conservation activities on 500 000 ha of forests.

Other smaller-scaled carbon PES projects, falling under the REDD+ framework, are currently being developed (Fanamby, MATE, Tany Meva, MNP) (Pricewaterhousecoopers et CFA, 2010).

At the national level, the REDD+ policy development fulfilled through FCPF (Forest Carbon Partnership Facility), a World Bank program which "builds the capacity of developing countries in tropical and subtropical regions to reduce emissions from deforestation and forest degradation

and to tap into any future system of positive incentives for REDD+"[1]. FCPF provides countries withs up to 3.6 million USD if they submit a document called Readiness Preparation Proposals (R-PP).

The Malagasy REDD technical committee has been working on R-PP since 2008. The last version has been unofficially submitted to FCPF participating committee in October 2010. Because of the Malagasy political situation, the country could not submit it officially and will not be able to obtain FCPF funds as long as the political crisis goes on.

Two third of the provisional budget of the last R-PP version are devolved to the scientific section, maybe because those technical aspects are perceived as untied to the political context, and because availability of reliable information is seen as necessary to obtain carbon funds.

The other great PES category in-the-pipeline concerns water. Three of them caught our attention: (i) Tolongoina PES initiated by the Gret and who relates to hydro-electric power production; (ii) Andapa PES implemented by the APMM and the WWF for potable water and (iii) Fianarantsoa PES also managed by the APMM and the WWF for potable water.

Similarly, other projects are planned, notably by Madagascar National Parks. As a national protected area managing agency, those PES correspond to bundling ecosystem services projects (for example: Montagne d'Ambre (water PES), Ranomafanana (Hydro-electric PES).

Finally, another bundled PES is developed by the Honko Association and the WWF in Tulear with three services: biodiversity, littoral protection and scenic beauty.

In Madagascar as in several developing countries, two types of PES are mostly developed: carbon and water PES.

Methodology

The aim of this article is to define the importance of knowledge (and more general information) mobilization in the Malagasy PES implementation, in an institutionalist perspective. In order to do so, we approached the question through two different angles. First the analysis of on-going PES implementation programs, which gives us an ex-ante perspective on such projects. Secondly we compared the two main categories of PES implemented in Madagascar, considering how different bio-physical processes mobilize knowledge and information.

Considering the theoretical framework and the issues identified in literature, two entries seems important to us: (i) information's research and treatment to qualify the ecosystem service and (ii) socio-economic information treatment in the making of the PES device.

[1] www.forestcarbonpartnership.org

SCIENTIFIC QUALIFICATION OF HYDROLOGICAL AND CARBON SERVICES

Hydrological Service

- **Description of the service**

Generally, from the different hydrological services provided by a watershed, five may be detailed:

- « purification » service maintains a quality (bacteriologic, chemical, etc) above a threshold. This is a qualitative service opposing to following services related to rate of flow (quantitative services).

- "rise clipping" service regulates the quantity of water delivered instantaneously from a water flow in order to reduce the wrenching attributes of flood.

- "umbrella" service reduces streaming causing erosion, solid charge and flood peak.

- "stocking" service concerns the orientation of water balance towards infiltration and stocking.

- "water tower" service regulates quantities delivered in the long term (ensuring storage and slow restitution) favoring low water flow.

Hydrological service is a complex service, as it is context-dependent, local, unequally distributed among users, and geographically diffused able to reach out of the watershed (natural spreading basin or artificial distribution).

For example, in Antarambiby PES case[2], the following diagnosis was done: "The water shortage [that hit the city of Fianarantsoa in September and October and the rice-fields owners in the downstream part of the watershed] originated from a reduction of the vegetation cover. This problem was caused by phenomena. First an illicit exploitation of timber resources, second an intensive and water-consuming regeneration of the pines populations due to the lack of management of these populations, and finally, the devastation of these areas by fires enjoying the zones devastated by the cyclones. The combination of these human-activities and management flaws resulted in an increased streaming of water on the slopes of the watershed and a lower retention of the resource where it was needed. (APMM 2003)

In this case, what is expected from ecosystem services providers is an increase of low water flows ("water tower" service) and a diminution of erosion ("umbrella" service), which is supposed to be obtained by an improved upper infiltration (to reduce flows) and by a reduction of the water losses volume (to limit vegetation cover). More recently, maintaining dam water quality was also evoked (no bacteria no nitrate in the water) (APMM, 2010).

Different scientific questions are raised by the implementation of hydrological service provision project which may be summarized in five main points: 1) identification and delimitation of the hydrological system; 2) identification and delimitation of the water resource use system and its evolution when expectable; 3) characterization of changes at the atmosphere-hydrological

[2] Antarambiby artificial lake, fed by a watershed situated in a pine reforestation in 1955-1965, is the principal potable water source of Fianarantsoa city.

system interface (land use, vegetation, developed site…), in the past, in the present or in consequence to predictable factors; 4) characterization of consequences of those changes and identification of the projected alternatives to the use of the changing resources to be developed by actors; 5) characterization of consequences on other system (leakages). Principal tools to fulfill those objectives are surveys, maps and resources and uses monitoring, experiments and modelizations.

- **Historic of accomplished studies**

At the national level, relations between forest, water and erosion have been a privileged scientific concern from 1962 for the Center of Tropical Forest (CTFT) on some forest and savanna sites. Kramer *et al*. (1997) took up the file by linking it to economical benefits for rice fields. Those studies essentially served as a rhetorical support on the importance of forest conservation and reforestation. They do not correspond to actual water PES, and those projects do not refer to these studies.

Other studies, in an economical perspective essentially, has been lead by USAID with PAGE/IRG[3] project consultants from 2000 (Solonitompoarinony, 2000 ; Brand et al., 2002 vers Maroantsetra), but also Razafindralambo (2001) in Fianarantsoa completing previous results. They are limited to collecting opinion (perceptions, payment consent of consumers) from different actors.

In Fianarantsoa region where two water PES are being implemented, first economic studies on hydrological functions were done at the beginning of the 2000s (like Razafimamonjy's (2001) thesis realized in Ambohimahasoa region, cited by Rabetaliana *et al*, 2003)[4].

Following those preliminary studies and actions, experts from the USDA mandated by the LDI (an american project supporting conservation policies in the corridor) led a study that resulted in an action plan. It proposed environmental measures to be implemented in the different forest perimeter of the region (annex 1) (Townsley 2001). One of their focuses regarded the Mandaratsy forest as water provider for neighboring towns.

The principal message these experts conveyed was the need for a change of objectives in order to comply to long term sustainability, which implies shifting from a production goal (preferred by farmers and water companies) to a sustainable provision of these products. The limiting factor remains the lack of data on hydrology.

In 2003, a data base is built thanks to a mandate from the Berne University Center for Development and Environment (CDE). This mandate consists in getting a reliable data base as a help to decision-making tool to guide the first consultations between upstream (basin) and downstream (Fianarantsoa city) actors. A water consultation workshop is launched in Fianarantosa in July 2003 (APMM, 2003). APMM then carries on data collection thanks to

[3] PAGE (programme d'appui à la gestion de l'environnement) / IRG (International Resource Group)

[4] Parallel to those first economic studies, the H^2O coalition (organizations group based on sensibilization on water-forest links), realize their first sensibilization actions on water question in 2000 in Fianarantsoa-Antarambiby (APMM, 2003).

American government funds (2003-2004). A study on land use and its evolution is done with remote sensing.

Therefore there are collected data from different expert studies before 2004 according to UNESCO Help, yet still unpublished. But there is no method nor hydrological analysis able to answer to the first questions asked by 2001 experts.

Anew, experts commissioned by PTE which succeed to LDI, recommended in 2004 a better knowledge of the hydrology of the basin, of water quality (nitrate, fecal germ, etc.) and of **hydrological functions**.

Malagasy researchers of CNRE were called by APMM in 2005 to enrich the data base with ecological and hydrological measures. Fieldwork has been done but no official fund was proposed to carry on a complete hydrological study and no report was written.

In May 2009, the AGIRE Program (Grand Lyon-Burgeap-Région Haute Matsiatra) seemed to be the first project to try to understand and propose a usable management tool, and not only an incomplete and unused formal data base. Above all, the AGIRE Program studied the link between climate and water resource in the basin, in order to forecast a management plan and to monitor the resource. Nothing emerged on the hydrological function, but this study was an important prerequisite because this model explained the climatic origin of the 2006 water shortage that was caused by combined pluviometric deficits. From these results, responsibilities could then be fairly leveled, lightening the charge on primer users and asserting the responsibilities of other exploiters. Yet despite previous research on water-forest relations in Madagascar, despite repeated expertise in English recommending hydrological studies, there is still no complete, synthetic, and accessible to the main actors' hydrological report clarifying ideas on hydrological issues in the Antarambiby watershed.

Principal solicited actors as PES beneficiaries (Jirama) and water state services (water direction) deplore this lack of hydrological arguments from PES promoters.

- **Uncertainties and controversies**

APMM conclusions (conducted by forest engineers) are above all based on actors discourses: naturalist opinions on "useful environment" (water resource dynamics and "springs number", rice fields and forests roles and their management, constrains for downstream cultural system, canals maintenance role). Until now, those opinions do not refer to any well identified and independent methodic study. Data base have no identifiable authors and are scattered by contradictions and disconnected quotations. Experts recommend scientific confirmation but started planning actions as soon as 2001.

Beside the fact that a potential resource availability drop has never been formally established, beside the discourse divergences between American experts and the APMM NGO, an astonished drift appears on basic data which should have unanimous support. Different studies have measured the Antarambiby basin; their results are displayed in the following table:

Report Name	Date	Surface (ha)	Commentaries
APMM-U.Berne	2003	3500	« channeling basin » from a rough map done at too little scale
Carte PACT	January 2004	1997	Presented in Help UNESCO
Program Help UNESCO	2004-2005	2900	Add another basin even if not exploited by Jirama
Rapport Agire	2008	2000	
G. Serpantié (IRD)	2010	2006	compatible to PACT and Agire considering layout uncertainties
Rapport 1 PSE Antarambiby	2010	3500	

From the first meticulous map (PACT) to PES project, the basin almost doubled in size.

Serpantié *et al.* (2009) showed the possible drifts in the hydrological service assessment made only by promoters. Thus some forests are promoted "water tower" even if their water has no users, or which the effect on flow regulation or water quality on distant place is marginal or too diluted to justify durably its recognition. It appears that it is values and logic that originated in the process of social valuing (promotion, sensibilization, or even propaganda) on forest function that were taken into account in the service evaluation and not the hydrological and water use realitiesThe result is the promotion of a supposed service, resting on a shared but precarious belief which may be detrimental to the durability of the process and to equity.

So the whole discourse feels more like one justifying pro-environmental measures (useful in principle but not necessarily in practice) than a discourse indorsed by measures and methodical surveys. It looks like experts are invited to convey a different another message (theoretical principles of sustainable development), the chosen focus (water) being more a pretext, privileged exemplary cases than real questions to be resolved.

Carbon storage service

- **Service description**

The ecological service is here carbon storage: trees absorb and store atmospheric carbon. The REDD+ mechanism relies on the idea that eviction of deforestation (an essential problematic in tropical world), will reduce CO^2 emissions in the atmosphere, therefore mitigate climate change. It is a decontextualized and global service, provided to the whole humanity.

Carbon transfers between atmosphere and Malagasy forest. It is both visible -as it represents 50% of dry biomass - and invisible as it happens at a molecular level. What is sold is concrete as it corresponds to a number of carbon tons exchanged on the voluntary market (until the REDD+ will be signed by UNFCCC Parties). But it is abstract as it concerns non emitted carbon tons thanks to deforestation eviction.

Carbon has so invaded media and discourses that some actors deplore a reduction of a complex problem (deforestation) to one single variable (carbon).

- **Biophysical questions**

The principal scientific question for a REDD+ project is to assess carbon tons not emitted thanks to afforestation. This question may then be declined in several questions like: what is the forest surface? What is the tree density? What is the deforestation rate?

- **Historic of completed studies**

Forest carbon studies increase in number and substance. More and more researchers, institutions, technologies are enrolled to answer scientific basic questions of REDD+ mechanism.

As in the case of water PES, the first Malagasy studies on carbon has been led under USAID initiative in 2001, notably by PAGE/IRG consultants (Rarivoarivelomanana 2001, Meyers 2001a, Meyers 2001b, Rakotomaro 2002). The studied site is Makira in North Eastern Madagascar, where carbon storage potentialities are the most important. As WCS was already settled in this region to manage the Masoala National Park (which economical opportunity from carbon was underlined in an article from Stanford University (Kremen 2000), this NGO was appointed to the task of carrying the Makira carbon project with Winrock International methodological support (Martin et al. 2004), and CI funds (Holmes et al. 2008).

Winrock International remains the reference organism for carbon methodology of projects managed by the American NGOs WCS and CI. They ensure local agents and consultants training and verify field data since 2004.

From 2007, FORECA project organizes a partnership between a Malagasy university, ESSA-forêt, and a German one, vTi Hamburg.

The most accomplished research network is the PHCF project one which started in 2008 to recruit new skills to answer more accurately to the fundamental questions of REDD+ mechanism. Malagasy partners are ESSA-forêt (socio-economic aspects and biomass measure), l'IOGA (remote sensing), and LRI (ground carbon measurement and evolution). French partners are the CIRAD (development of allometric formula), the IRD (ground carbon measure and evolution; sociological sciences studies), Marne la Vallée University (LAI measure). One American partner is the Carnegie laboratory which brings Claslite, satellite analysis software and the LIDAR[5] technology to the project. Both these technologies have been integrated into the Malagasy R-PP and accounted for 30% of the R-PP scientific section.

First forest carbon estimations in Madagascar are American and go back to around ten years. In the last two to three years, the number of researchers, institutes and technologies increased, diversifying the questions addressed from the single interrogation on forest carbon measuring.

[5] Light Detection and Ranging

- **Uncertainties and controversies**

All questions asked by REDD+ problematic are controversial:

- Forest definition and forest surface
- Deforestation rate is also a very divisive question for scientists (Amelot et al., on press), but one of the studies has been legitimated by the Malagasy government formalizing a national figure for this deforestation rate (MEFT, 2009).
- Carbon density estimations are new strategic questions for REDD+ projects but figures vary.
- Afforestation needs to be estimated and so does the amount of carbon emissions prevented thanks to the project. Predictions to 10 to 30 years are produced by models. But some promoters refer to the models outputs as science-fiction expressing their distrust in these results.
- Other technical and political questions concern, for example, the investigation or not of the below-ground compartment.

Several unsolved uncertainties exist on all key questions regarding REDD+ projects. New technologies like LIDAR are seen as more reliable. But how can these tools uncertainties be assessed?

SOCIO-ECONOMIC ASPECTS OF WATER AND CARBON PES

Water PES

- **Profiling beneficiaries and providers**

The public water company JIRAMA supplies potable water to the city of Fianarantsoa part of it (2/3) thanks to the Antarambiby artificial lake located 15km from the city, at the heart of the industrial reforestation area of Mandaratsy[6]. In terms of quantity, quality, regularity and treatment costs, this supply source coming from a natural drainage of a forest massif is the best of the three used provisions (there is also another dam and a direct pumping in the river).

But this forest area is exploited today, locally degraded by fires and more inhabited than during the installation of the forest and hydrological infrastructures (43 hab/km²). Those forest residents live essentially from (legal or illegal) forest exploitation (planks), and secondary from agriculture and livestock, which may modify land use as well as fire and water patterns.

Additionally, considering that the Jirama and urban consumers have a legal priority for water use (attested in the Water Code), and that the agricultural water needs increase as downstream communities grow, it becomes necessary to question the current water sharing rules. If new

[6] Basin of 2000 ha, situated in a P*inus patula* massif of originally 4242 ha

difficulties were to appear, several objectives could be pursued: easing a potential social conflict, protecting equity, offsetting collateral economic costs, and preventing resource degradation to maintain a constant price of water.

At the same time, as forest exploitation resumed in a more formal mode (sale by auction) new investment opportunities were created, professionalism emerged, tax resources were harvested, increasing the economic effects but also the risk for more conflicts with the informal sector.

This problematic has been addressed since 2001 by a local NGO, Tambohitravo Malagasy, from the APMM network, until the proposal for a PES project in 2010 permitted to bound financially urban water users and rural people living in the basin. Referring to the APMM Quito experience (Equateur), the National Development Strategy for Mountain Regions of the international NGO APMM promotes the adoption of compensation principles for provided services by upstream basin (and their inhabitants) to downstream regions (water users in Fianarantsoa).

- **Socio-economic questions**

Economic and social questions could be scientifically documented before any negotiations between parties. Economic issues are multiple, and they depend on stakeholders, providers and beneficiaries.

From the point of view of the service providers, several costs must be compensated which requires specific studies of opportunity costs (renunciation to practices and past incomes), and of potential leakage toward zones that do not fall under the PES regime.

From the point of view of services beneficiaries, one must know the price that beneficiaries can pay, and how much they would agree to pay and/or to know the benefice of the service through, for example, the expenses that would be undertaken to reach the same results.

About social questions, documentary field also looks very diverse. Perceptions of the different actors have to be collected, the changes the previous social organization will suffer need to be forecast. And finally the question of money redistribution requires an answer.

- **Review of past studies on socio-economic questions**

In Antarambiby, social data relating to political questions were mostly mobilized in the PSE study: inequity claims concerning access to the resource, compensation demands, operators' requests).

There are also data on consent to pay for urban people to get potable water (Razafindralambo, 2001).

- **Uncertainties and controversies**

Social perception data collected in Antarambiby in 2003 (data base APMM 2003) are the result of sensibilization procedures completed in 2000 by the H^2O group. PES is then the logical outcome of this process more than a genuine uprising.

Carbon PES

- **Description of beneficiaries and furnishers**

Even if this service is provided to the whole humanity, not everybody invest in deforestation reduction. As long as REDD+ has not been signed by UNFCCC parties, investors will participate through the voluntary market. Then it is not really about selling carbon credit, but looks more like classical sponsorship.

Service providers are forest residents that commit themselves not to deforest anymore and to protect the forest.

The link between beneficiaries and providers is made through conservation NGOs who implement the project and new forest use rules, measure evicted carbon tons. Then those NGOs can also be seen as service providers.

We have already shown how this service is complex to prove at a biophysical level, and we will see the difficulties to implement carbon PES depending on socio-economic context.

- **Socio-economic questions**

A project of deforestation eviction (either promoting hydrological or carbon service) requires to identify deforestation causes, and so, land uses and land use changes, but also renunciation costs of destructive practices. All of them are complex socio-economic questions.

Just like for water PES, one of the main questions of carbon PES is the question of leakage: if a project implies natural resources use restriction, will population renounce their activities or will they displace them to areas that are not subjected to the newly established restrictions? Will this project provoke an increase of emissions in another site?

Finally, Carbon PES implementation also requires a scheme of fund redistribution, which implies the setting-up of specific carbon governance and then institutional questions. What would be a fair distribution of carbon benefices? This question is politically charged, knowing that several actors can claim carbon property: the State is the legal owner of the forests; local populations are legitimate owners; NGOs are project promoters and de facto managers of protected areas in-the-pipeline.

In front of so many socio-economic questions, how do project managers mobilize sciences?

- **Past studies on socio-economic questions**

Many socio-economic studies on land use questions were capitalized by every project[7]. New studies are starting in REDD+ project, notably by ESSA forêt, in which researchers and students are recruited on those questions by FORECA and PHCF projects. In addition, other studies,

[7] NGO produce socio-economic studies in their sites but do not diffuse them. Also it is difficult to say the importance and reliability of those studies.

indirectly linked to projects are led by individuals or PhD candidates, but their results are potentially not used or usable to implement the PES project.

Leakages constitute another problem called in a humorous way, « fuitology » by a Malagasy project manager. Leakages are modelized by CI and WCS REDD+ projects thanks to Idrisi software which take into account static variables (population density, cities, roads, etc.) and can also integrate dynamic variables like fire.

Redistribution questions are, until now, not really investigated. Only one distribution scheme has been proposed by WCS for Makira, that is to say, 50% for local populations, 25% for protected area manager (WCS NGO), 15% for Department of Environment and Forest, 5% to "Makira Carbon Company", 2,5% for an independent agency for validation and certification, 2,5% for a state foundation. This distribution scheme has been accepted by the past government but it is not prioritized for the national policy. In the R-PP submitted to FCPF, this question is asked without being answered. Moreover even once this parting is acknowledge, the division of the population share raises again many questions, as to know which communities undergo effects of the PSE and thus await for retribution. The problem of carbon revenue distribution remains unsolved.

- **Uncertainties and controversies**

As studies have not yet been finalized, controversies are not vivacious. Project managers do not use the same software which may have consequences on results. But those socio-economic aspects, as well as the biologic ones will be verified by an independent organism of carbon credit validation.

During the REDD national methodological workshop in September 2009 which gathered project managers and REDD experts in the country, CI exposed its zero leakage concept, explaining that thanks to their generating revenue activities projects, there will be no leakage. But this explanation has not been validated by the VCS standard which currently educates CI agents to leakage prediction.

This organization plays a scientific role for verification and validation of data produced by the projects and their partners. As socio-economic section is not the principal issue of REDD+ projects, VCS focuses on carbon quantification. Other organizations emerge like CCBA (Climate, Community & Biodiversity Alliance) in order to control socio-economic aspects as well as biodiversity conservation safeguards in REDD+ projects.

ANALYSIS ON CASE STUDIES

Similitude on socio-economic aspects in Water and Carbon PES

A same research questioning is raised for both water and carbon PES that may be summarized by different points: agriculture practices study, opportunity cost calculation, leakage questions, and benefits distribution schemes.

Several studies on agricultural practices exist in Madagascar, and more specifically on the future PES project sites. However they have not always been published nor capitalized. Research authorizations are allocated by Malagasy State to researchers who commit to providing a mission report in return. Even if an office of the Water and Forest Department gathers several documents, their visibility and availability are questionable making it difficult to capitalize information from past studies.

The other socio-economic questions are too specific to PES to have been addressed in past studies and need researchers' mobilization.

Generally, socio-economic questions are not key research issues for both water and carbon PES. Until now, carbon projects are in an early stage and focus their attention on carbon quantification questions, when socio-economic questions will probably be addressed later on.

This similitude in question linked to water and carbon PES implementation is specific to the socio-economic domain. We switch now on differences between the scientific mobilization on biophysical questions.

Differences in natural sciences mobilization

- **Hydrological service's specificity**

It seems that in the Antarambiby PES case, hydrological science has not been invited or did not get involved, for several reasons. Because ecological action is still essentially at a symbolic stage (so-called "protected" areas in texts and official documents, established but uncollected taxes supposed to "protect" water, "signed" but unimplemented community management transfer), it shows in an emergency feeling which leads to forget fulness of hydrological prerequisite. Another driver of ambitious theoretical statements for conservation and environment stewardship is the new preponderance of environmental issues as justification for development institutions. They need to be seen involved in environmental projects.

For the Andapa PES, the same process as in Antarambiby is observable. Scientific aspects of the ecosystem services are laid aside. On the one hand, a consensus seem to exist between actors, on the other hand, the project considers that scientific data were already available in the WWF protected area project on the same basin site. But those data focused on biodiversity inventory.

For 10 years, experts, NGOs and donors throng and succeed one another on the basin bedside, declared afflicted without any proof. Not the less preoccupied with science, actors discuss. "Water service serves communication" (Main NGO representative). "Water issues fires Donors" (Main ICDP project manager). We could add "urban residents, peasants, mayors also are fired by water issues". If water fires everybody, maybe we should not look deeper?

- **Carbon Storage Service Specificity**

Methodologies to estimate deforestation and forest carbon quantification are numerous. Pilot REDD+ projects use almost the same methodology but don't use to the same technologies and reach thus different same precision levels.

Given the sensitive Malagasy political position and investors reluctance, the REDD technical committee members opted for an important investment on sciences which represents two third of the total budget asked to the FCPF. By using technologies like LIDAR, they hope to produce more reliable data and be inscribed in the IPCC "tier 3" which is the more precise level with the smallest uncertainty (IPCC, 2003).

Therefore science plays a central role in the implementation of REDD+ projects in Madagascar, even if none of them has yet been validated by a certification organization[8].

- **Why such a difference?**

While related to the same ecosystem services rhetoric, and raising the same socio-economical questions, the implementation of water service payment and carbon storage projects remuneration does not implicate scientific knowledge in the same way. Efforts displayed to prove reduction emissions from deforestation are much more important when regarding financial, human and technological aspects than those to prove forest role in water flows.

This fact may be explained by a different balance between the need to scientifically demonstrate the service and the transaction cost of that service. We will discuss here two points that may explain those differences: additionality and market flux governance.

Additionality

Institutional and social questions are keys for water service projects, because local actors need come to an agreement. As it falls under common sense and direct perception, the enunciated service is not questioned. Evaluation is not based on scientific results, but on the respect of water and forest management rules (for example fire banning). That is why, in spite of the fact that it is easier to prove than carbon storage service, the hydrological service is generally not backed by ad hoc hydrological studies (not even basin delimitation, comparison of different managed basins flows, water analysis, experimental basin references). Science, besides reference to publications on forests' hydrological functions out of the Malagasy context would rather be an obstacle to water PES as it may hamper several actors: promoters and donors (slowing or even reconsidering foundations for action and their funding), consumers and water users (they would have to pay the real price of water and not only a symbolic tax), ecosystem services providers (their role and salary could be reduced). Calling for science could unveil a doubt, and would undermine a consensual belief acquired through the first sensibilization campaigns, and could therefore delay

[8] Volontary Carbone Standard is currently evaluating Makira (WCS) and COFAV (CI) projects.

and take apart financial inputs. Hydrologists could advice to stop a badly supported action and to report finance on other solutions (like finding water elsewhere). Environmental action often looks for, in the name of supposed emergency, jumping the gun and getting key actions which will set a precedent. Thereby Antarambiby may be considered as a "reduced model", a "precedent" for a more ambitious policy. Nevertheless the no-science-situation could become explosive on a long term, and give a chance to the more powerful actors who might oppose the PES regime to escape their responsibilities.

Anyway, additionality does not stand out as an implementation PES project requirement.

REDD+ project additionality is however pregnant: in order to obtain carbon credit certification, one needs to prove that carbon would have been emitted without the project, and because of that, scientific technologies and methodologies deployment is a sine qua none condition to get the certification. On the field, REDD+ pilot projects look like classical conservation projects with the setting up of protected areas surrounded by management transfer contracts to forest community, sometimes completed with conservation contracts establishing revenues (patrols, ecological monitoring, etc.).

But those conservation projects will be evaluated through their performances. Experts will come to measure forest carbon evolution and will compare it to modelized projections. Hence the obligation for project promoters to invest in scientific questions, to mobilize experts and research institutes on those problematic.

Monetary flows and governance structure

Another difference between water and carbon PES relates to implied governance structure. Indeed, carbon PES reveal or should be related to a generic commodity. Godard (2005, p7) talks about general equivalent ("CO^2 equivalent as a universal measure"). Carbon market cannot work without trust in the nature of the sold service. And yet if this guaranty has been painfully acquired for MDP Projects, it is even more difficult in the case of biophysical process. Hence the importance of certification; it works as an access (a password) to a market under construction.

On the contrary, in water PES cases, the proximity between actors and the existence of an ecosystem services beneficiary which is in most of cases a public or private firm, create a very different situation. It is a contractual logic, close to channel integration; ecosystem services providers act as subcontractors of the downstream firm which benefits of the service before selling it to final users. Payment may be considered as a salary that the firm gives to their employees to maintain the quantity and the quality of the inputs (ecosystem services). That partly explains that opportunity costs calculation is not compulsory. Payment constitutes not only a fixed-term compensation to stop past practices (as slash and burn for instance), but also a continuous flux, a salary-equivalent, for the furniture of a service to the downstream firm. Hence the importance given to the negotiation (as a wage negotiation) rather than compensation based on shortfall.

In such a situation, what matters, as clearly shown by institutionalist economists, is the way this channel segment organizes, with a more or less strong integration of that channel.

To summarize, the highlighted differences between water and carbon PES make economic sense. For carbon, what matters is the initial access to certification in order to access a (future) international carbon market; for water, the main element is the nature of the contract.

CONCLUSION : A PARADOXE ?

In both cases, scientific queries on water regulation and carbon storage services were brought in Madagascar by American organizations at the end of the 1990s. Ecosystem services rhetoric also came from United States, and was linked to conservation objectives. The service providers targeted here are people living around the forests.

Despite those similarities, we see that science mobilization is very different depending on the studied service (see summary table in annexe 1).

Carbon storage service refers quasi-exclusively to technico-scientific field (climate sciences, carbon cycle, and international finance device) and requires important methodology and technology developments and demands the mobilization of human resources among a diversity of disciplines.

Water regulation service is accessible to common sense. People have verifiable immediate perceptions, intuitive perceptions, and beliefs easy to manipulate (Serpantié et al, 2009).

Thus, when comparing the place of science in water and carbon PES, a paradoxical situation appears. While carbon service is global, decontextualised, volatile and difficult to measure, it becomes very concrete, accounted for and cut up in tons to be sold on the international market.

While water service is local and could be more objectivized (hydrology and precise identification of watersheds), it is not studied nor demonstrated. It is sold as a conceptual principle: forest regulates and produces water, but we do not know how much or how to proceed, not even if the PES choice is justified compared to other choices which could result in the same resource availability.

Despite complex and comparable scientific questions for those two types of services, role and place of scientists are very different according to the service type which itself depends on political, institutional and financial context. Science is a tool mobilized if needed but not an a priori for the implementation of PES devices.

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ANNEXE 1: Comparison frame

Description	Watershed PES or hydrological service	REDD or carbon storage service
Ecological function	Basically, regulation function in hydrosystem is a complex scientific question. The service's object (water resource) is a familiar, concrete and visible object. Intuition as well as common experience accredit forests of beneficial effects on water quality and quantity, compared to any other land use.	Basically, carbon storage function is a complex scientific question. Carbon exchange between biosphere's atmosphere and Malagasy forest. It is both visible as it represents 50% of biomass and invisible because at molecular scale. Carbon gets media coverage and is so audible in discourses than some actors deplore a reduction of a complex problem (deforestation) to one variable (carbon).
Scientific questions	Identification and delimitation of hydrological system, a water resource use system linked to this hydrological system and its evolution when predictable ; characterization of changes on atmosphere-hydrosystem interface; characterization of consequences on those changes and envisaged alternatives on resource, its use and on other systems (leakages)	The main scientific question of REDD project is to determine carbon tons not emitted thanks to deforestation eviction. This question may be decline in several questions: what is the forest area? What is the tree density? What is the deforestation rate?
Expertise's place	Little verily no hydrological expertise before the project. Expertise settle for determine project flow to proportion the fitting-out or the preparation of an ecological database without ad hoc use	Numerous experts and networks of universities and research institutes to answer different scientific questions (allometric formula; ecosystems classification; ground carbon calculation; …
Studies history in Madagascar	Initiated by USDA	Initiated by USAID
PES	Sale of the water regulation q and Q principle thanks to forest (conceptual)	Sale of carbon tons (concrete)
Beneficiaries and providers	Providers are forest side resident who engaged not to deforest. Beneficiaries are water consumers downstream	Providers are forest side resident who engaged not to deforest. Beneficiaries are the humanity but only few investors support it.
Socio-economic scientific questions	Study on land use and land use changes, opportunity cost calculations, leakage question, benefices distribution mode. Transaction cost calculation and consent to pay	Study on land use and land use changes, opportunity cost calculations, leakage question, benefices distribution mode.
Expertise's place	Few studies on those aspects Study on consent to pay of urban resident to get potable water Social data on political order (inequity perception for resource access, compensation revendication for imposed rules, revendication of users downstream of the dam.	Socio-economic questions treated in the shadow of REDD projects. Past studies capitalized and new ones undertaken by ESSA forêt but are not a key issue for research which focus on carbon quantification. Leakages are mobilized on mapping software. Governance questions and revenus sharing are until now shelved.
Concretisation of the PES project	Forests Conservation and works construction	Forests Conservation
Scale	Local Service	Global Service decontextualized Service
Additionality	Additionality has not to be proved. Evaluation is on rules respect (example : fire banning)	Additionality question is pregnant : REDD project need to prove that emissions would have without the project
Monetary flows	Restrict to local actors	Important with international flows