Master's Thesis

The value of tropical ecosystems

With a case-study of the Trésor nature reserve in French Guiana

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Keywords: Ecosystem services, Payment for Ecosystem Services, PES, Trésor Nature Reserve, French Guiana.

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Citation: Steur, G. (2013) *The value of tropical ecosystems. With a case-study of the Trésor nature reserve in French Guiana*. Master of Science Thesis. Copernicus Institute of Sustainable Development & Trésor Foundation, Utrecht University, Utrecht.

Cover image: The possible ecosystem services of the Trésor nature reserve.
Based on http://vermontfurnitureblog.com/tag/rainforest/ and Google Earth, 2013.

Preface

This Thesis has been written as part of the Master of Science programme Environmental Biology at the Utrecht University. The prescribed study load of this Master Thesis is 5 weeks of full-time study, equal to about 210 hours. It is up to the student to choose any topic within the Life Sciences for review or as the subject for a (mock) grant proposal for PhD research, as long as it is relevant to the programme and different from the other topics tackled in the research projects for the programme. This particular Thesis has been organised as a review with recommendations and suggestions for future research. It was produced between April and July 2013 with a break between May and June.

Acknowledgements

This Thesis could not have been of this quality without the contributions of my supervisor Pita Verweij and my second reviewer Vijko Lukkien who provided valuable comments and insights. In addition, I would like to thank Lieke Guinée and Jelmer de Ronde for reading trough the draft version of the Thesis and providing useful feedback on the written English.

This Thesis is dedicated to my parents who supported my studies over the years including that for my Master of Science in Environmental Biology, for which I am forever grateful.

Abstract

Ecosystem services with their biodiversity fulfil essential services that benefit mankind. A relatively new way to improve conservation of ecosystems and their biodiversity is to not only express their ecosystem services in monetary values but to also provide payment for them: Payment for Ecosystem Services or 'PES'. It is hoped that besides raising awareness, PES will provide a financial incentive that facilitates more preservation and restoration of ecosystems.

Presently, PES schemes are hastily being adopted while resources are limited. In this Thesis the question about whether PES can actually provide a monetary incentive that provides for ecosystem conservation was investigated. The question was subdivided into two sub-questions: (1) Does PES provide a monetary incentive that is higher than the relevant alternative land-uses; and (2) If so, does this lead to improved conservation of ecosystems?

To answer these sub-questions an investigation into the literature was carried out which was complemented with a newly described case-study of the Trésor nature reserve of French Guiana. The Trésor nature reserve is a largely privately funded nature reserve that aims to conserve its tropical ecosystems, provides education on nature, facilitates scientific research on tis ecosystems and fulfils a role of focal point of nature conservationism.

Literature addressing aspects of the efficiency of PES schemes in achieving nature conservation was found to be scarce and therefore the case-study of the Trésor nature reserve played an important complementary role in the answering of the research question.

Although literature was scarce and with the case-study many assumptions had to be made, it was found that (1) PES does not guarantee that an economic incentive is created that is economically more interesting than the alternative conversion of nature. The literature study additionally found that (2) if there was a higher economic incentive, it did not automatically lead to better conservation of nature and if so, the effect was marginally positive.

Because PES schemes are being hastily adopted it is therefore highly recommendable that future research into the questions posed is carried out and communicated to the scientific community and the relevant policy makers. The most important identified recommendations for this research would be: (a) That a future search query incorporates complementing literature through additional search words and involvement of expertise; and (b) The case-study presented in this Thesis is improved by further research for future utilization for comparisons.

Introduction

Thesis question and aims

Tropical ecosystems are particularly rich in biodiversity and form complex units of interactions. Tropical ecosystems use photosynthesis to incorporate solar energy into living matter that deliver valuable services to mankind such as storing carbon, controlling the local and global climate, purification of air and water, the recycling of nutrients and producing biomass suitable as biofuel, timber and non-timber forest products (Brown *et al*., 2013). The world almost universally recognized the importance of ecosystems with their biodiversity and their services with the Convention of Biological Diversity (CBD) in 1992 (UN, 1992).

Presently, the services that ecosystems provide are being recognized as 'ecosystem services'. The Millennium Ecosystem Assessment of 2005 (MA, 2005) investigated the state of the world's ecosystems and took the concept of ecosystem services further. The MA found that ecosystems were being degraded on a world wide scale (MA, 2005), which was found to continue up to today (TEEB, 2010). In particular, tropical ecosystems are currently and increasingly being degraded and converted for quick monetary profits, with a subsequent loss of biodiversity and loss or reduction in the quality of the ecosystem services they deliver (Brown *et al*., 2013).

The MA provided methods to monetary value ecosystem services in order to raise the perceived value of ecosystems. Currently, initial studies have already been carried out to map and assess ecosystem services of tropical ecosystems in monetary value (Verweij *et al*., 2009).

A relatively new way to improve conservation of ecosystems and their biodiversity is to not only express their ecosystem services in monetary values but to also provide payment for them: Payment for Ecosystem Services or 'PES' (Schomers & Matzdorf, 2013). It is hoped that besides raising awareness, PES will provide a financial incentive that facilitates more preservation and restoration of ecosystems (Marris, 2009). Although PES schemes are relatively new, it is known that they are hastily being adopted (Gómez-Baggethun *et al*., 2010; Kumar *et al*., 2013). As resources to protect nature are limited, these resources are to be used wisely.

Therefore, the following question can be raised:

'Can current payment for ecosystem services (PES) provide a monetary incentive that enables the conservation of ecosystems?'

This question can be subdivided into the following two sub-questions:
1. *Does PES provide a monetary incentive that is higher than the relevant alternative land-uses*; and
2. *If so, does this lead to improved conservation of ecosystems*?

This Thesis will try to sufficiently answer these questions based on a literature review and a complementary case-study of a tropical ecosystem for which payment already is being provided in order to conserve it: the Trésor tropical nature reserve of French Guiana. The Trésor nature reserve is a largely privately funded nature reserve that aims to conserve its tropical ecosystems, provides education on nature, facilitates scientific research on tis ecosystems and fulfils a role of focal point of nature conservationism.

Despite the many studies that have been made in and in relation to the Trésor nature reserve, it has never extensively been studied with respect to its ecosystem services and the concept of PES. Therefore, this Thesis will also provide a thorough study of the Trésor nature reserve in particular for its relevance for PES.

In addition to the answering of the Thesis question, the outcomes of this Thesis are aimed at: providing insight into the current situation of ecosystem services and PES; clarify why Trésor is a focal point of nature conservationism; establishing a comprehensive and current overview of the ecosystem services that the Trésor ecosystem fulfils; how the ecosystem services of the Trésor nature reserve are being valued; and to what extend they can serve as indication for similar ecosystems.

Scope and demarcation

Because of the Thesis question and the availability of the case-study of the Trésor nature reserve, this Thesis will focus mainly on tropical ecosystems because of their relative importance to biodiversity and the many gaps in knowledge currently exist in tropical ecosystems (Kricher, 2011).

The CBD, amongst other things, provides a widely adopted definition of the terms biodiversity and the ecosystem. The CBD was signed by 169 countries from all over the world in between 1992 and 1993 (CBD, 2013). Currently (05 July 2013) according to the CBD website, apart from two small countries only two significantly large countries have not signed the CBD: the United States of America and the recently founded South-Sudan. Therefore, it can be taken that the given definitions are recognized and adopted worldwide and almost universally. Therefore, these definitions will be used for this Thesis.

Ecosystem services as a topic in science is relatively new and different interpretations of the concept exist (*e.g.* MA, 2003; MA, 2005; Gómez-Baggethun *et al*., 2010; Maes *et al*., 2012). The MA of 2005 was a high impact study that introduced the term 'ecosystem services' into wide political use. Moreover, it provided a practical definition of ecosystem services and a comprehensive classification system. Therefore, the definition of ecosystem services and their classification of the MA (2005) will be used for this Thesis.

Not all experts and policy makers are convinced that monetary valuation of/payment for ecosystem services could ultimately contribute to conservation (Ludwig, 2000; MA, 2003; MA, 2005; Marris, 2009; TEEB, 2010) and its discussion is still taking place. However, as several highly influencing publications have adopted the approach of valuating ecosystem services (MA, 2005; TEEB, 2010), it can be justified that regardless of the outcomes of the discussion, it would be pragmatic to assume that valuation of ecosystem services will remain on policy-agendas and therefore it is relevant to research the added value of the concept. An in depth review of the discussion on the contribution of valuation of/payment for ecosystem services falls out of the scope of this Thesis as the Thesis has limited time-resources by default and the research question has a different focus.

As case-study for PES for a tropical ecosystem, the ecosystem of the Trésor nature reserve, henceforth 'Trésor', is highly suitable because of several reasons. Firstly, according to Achard *et al*. (2002) Trésor resides in the tropical forest biome of Latin-America; therefore Trésor can function as an example of a tropical ecosystem. Secondly, although no tropical ecosystem has been entirely described (Kricher, 2011) Trésor was co-founded by Utrecht University and has been studied extensively over the last 18 years. This information and first-hand experience is therefore readily available. Thirdly, Trésor has been funded directly and indirectly over the years which documentation is available. This can provide data to estimate a PES value for Trésor and similar ecosystems.

Choosing the Trésor ecosystem as a case-study also increases the potential social impact of the Thesis. The Trésor ecosystem lies within French Guiana, which as a part of the EU is bound to follow the EU biodiversity strategy towards 2020 which aims to halt all biodiversity loss in the EU at 2020 and states that all ecosystem services within the EU territory should be mapped and assessed by 2014 (EC, 2011). A review of the progress of the member state's assessment of their ecosystem services shows that France was still in early development of this assessment (Brouwer *et al.*, 2013). There have historically already been some initial beginnings of identification and research on the ecosystem services that Trésor provides, in particular by Fontein (2007) and Malotaux (2010). It must be noted, however, that these beginnings are clearly not complete. As Trésor is officially part of the EU territory, a more comprehensive assessment of its ecosystem services, which will be provided in this Thesis, would certainly contribute towards reaching the goal of the EU biodiversity strategy towards 2020. Moreover, by establishing such an overview, it can lead to new insights in the validation of Trésor and similar ecosystems.

Last but not least, French Guiana as a part of the EU should have easy access to the European Union's public, market and institutions, providing a positive and ideal environment for applying PES to ecosystem services similar to that of Trésor (Gómez-Baggethun *et al*., 2010).

In addition to providing an overview of the ecosystem services that Trésor fulfils, several other side-products will be delivered that can contribute to the (public) understanding of Trésor. A lot of different reports were created providing data on the organisation, activities and ecology of the Trésor nature reserve. However, at the time of writing no synthesis has ever been created. To provide the data for ecosystem services assessment, Trésor and its organisation will be studied with the help of these reports and employees of the Trésor organisation. As such, this study will provide a consolidated overview of Trésor and its activities.

Economic valuations of ecosystem services are generally made in US$/ha. In order to allow easy comparison of the monetary value of Trésor, its monetary values will be expressed in US$/ha. Because Trésor lies within the EU and the major beneficiaries also come from the EU, the values will be additionally expressed in €/ha to facilitate additional easy economic comparison. The conversion rate between Euros and US dollars will held at € 1:1.3 US$.

Approach

To answer the Thesis question within the time-restraints, assumptions and estimates must be made and established that will link to and build on each other. In order to separate the important sections of assumptions and estimates the results will be clustered into four sections.

The first section presents the literature study and will focus on the concept of ecosystem services and their valuation to also provide the necessary background and methodology for the case-study. The second section will describe Trésor organisation, its ecosystem and other relevant characteristics in order to provide the data as case-study to answer the Thesis question. The third section will discuss the applicability of possible ecosystem services of Trésor and their relevance. In the fourth section these results for the case-study will be used to produce a valuation of the present ecosystem services of Trésor. This result will be put in perspective to other valuations of ecosystems services and similar ecosystems and will be compared with alternative land-uses of Trésor.

These four sections will be followed by a discussion of relevant issues and consequences from the chosen scope and demarcation, approach as well as the reliability of the finding of this study including the case-study. In the discussion recommendations for future research will be made were possible. Last but not least, a synthesis will be made from the results of the literature study and the case-study which will be used to answer the Thesis question. This Thesis will conclude with the short answer to the Thesis question and will be accompanied by the most important possible recommendations.

For this Thesis literature was collected through the following ways:

- The knowledge and experience of the author gained through his education in Biology;
- A provided selection of literature from the supervisors;
- A Google Scholar search for relevant literature based on the search words henceforth referred to as 'the search query': [Ecosystem] AND/OR [services] AND/OR [conservation] AND/OR [Payment] AND/OR [Environmental] AND/OR [PES] AND/OR [nature]; and
- Additional literature that followed from the found literature from the search query
- As no digital archive existed of publications and reports on the Trésor nature reserve at the time of writing, a preliminary overview was made by a quick scan of the paper publications and reports available in the Trésor office. Additionally the overview was populated by the items that were suggested by the supervisors of this Thesis. From this list possible relevant literature was selected on the basis of the title and the language. Because of language proficiency of the author the main focus was laid on English and Dutch works.

Acronyms used in this Thesis

AGB	Above Ground Biomass
Association	The Association of Trésor
ca.	*circa*, 'about'
CBA	Cost-Benefit Analysis
CBD	UN Convention on Biological Diversity
CEN	*Conservatoire d'espaces naturels*
EAR	Environmental Assessment Report
EC	The European Commission - the executive body of the EU.
ECB	European Central Bank
e.g.	*exempli gratia*, 'for example'
et al.	*et alii*, 'and others'
EU	The European Union including its predecessors
€	Euro (currency).
FAO	Food and Agriculture Organization of the United Nations
Foundation	The Trésor Foundation
FTE	Full-time equivalent.
Gg	Gigagram, *i.e.* $1 * 10^9$ gram
GHG	Green House Gas
ha	Hectare, *i.e.* 0.01 km^2
IPBES	The Intergovernmental Platform on Biodiversity and Ecosystem Services
i.e.	*id est*, 'that is'
IUCN	International Union for Conservation of Nature
Mg	Megagram, *i.e.* $1 * 10^6$ gram
MOU	Memorandum of Understanding
NTFPs	Non-Timber Forest Products
OJEC	Official Journal of the European Communities, official publication journal of the EU
per	'with each'
PES	Payment for Ecosystem Services
RISEMP	The Regional Integrated Silvopastoral Approaches to Ecosystem Management project
PSA	The *Pagos por Servicios Ambientales* project
RWTP	Revealed Willingness To Pay
s.l.	sensu lato: 'in the broad sense'
s.s.	sensu stricto: 'in the strict sense'
SCI	Site of Community Importance
Trésor	The area of the Trésor Nature Reserve, unless otherwise stated
UN	The United Nations
USA	The United States of America
US$	United States of America dollars (currency)
USGS	United States of America's Geological Survey
WWF	World Wide Fund for Nature
WWF-NL	WWF Netherlands
WWF-USA	WW United states of America
WTA	Willingness To Accept
WTP	Willingness To Pay
ZNIEFF	*Zône Naturelle d'Intérêt Écologique, Faunistique et Floristique*

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Figure: the value of ecosystem services. Copyright Waller.

I. About ecosystem services

Through the study of ecology and ecosystems a world-wide anthropogenic degradation of nature was brought to light (UN, 1992). Although nature is protected for various reasons, an important argument is the fact that nature is important for the life sustaining systems of the earth and provides us with irreplaceable benefits, both of which legitimize protection of nature (Ehrlich & Mooney, 1983; UN, 1992).

An important step was taken to halt the degradation of nature with the signing of the Convention of Biological Diversity (CBD) (UN, 1992). The CBD expresses nature in the quantifiable unit of biological diversity or 'biodiversity' which, according to the CBD, is '*the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems*'. An ecosystem is '*a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit*' (UN, 1992).

The CBD dictates three major objectives alongside relevant definitions that signees adopt by signing. The objectives of the CBD are:

1) To conserve biodiversity;
2) To sustainably use its components; and
3) To fairly and equitably share the benefits from the use of genetic resources.

Since its establishment in 1992, these definitions and objectives have been taken forward by all but four countries of the world by signing the CBD (CBD, 2013).

Despite these political efforts, it has become clear that degradation of nature has continued. The Millennium Ecosystem Assessment ('MA'), the largest assessment of ecosystems ever undertaken, in 2005 found that ecosystems still were being degraded on a global scale (MA, 2005). The MA was undertaken to investigate the consequences of ecosystem degradation for human well-being and to assess the scientific basis for possible further actions that could also be used by policy makers (MA, 2005). The MA adopted the view of organizing the benefits that human beings obtain from nature into so called 'ecosystem services'.

Ecosystem services

The notion that ecosystems perform services that are beneficial to nature and mankind and should therefore be protected originates in the late 1960ties or 1970ties (MA, 2003; Gómez-Baggethun *et al.*, 2010). Over time, public interest in the concept of ecosystem services grew but it was only after the first publications of the MA in 2003 (MA, 2003) that the term ecosystem services started to consequently appear on policy agendas and became increasingly popular as a topic in the scientific literature (Gómez-Baggethun *et al.*, 2010; TEEB, 2010; Maes *et al*., 2012). Since 2012, a special international platform to provide expert scientific advice modelled after the intergovernmental Panel on Climate Change (IPCC) has even been launched: IPBES, the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES, 2013).

The MA defines ecosystem services as '*the benefits people obtain from ecosystems*' (MA, 2003). '*Services*' according to the MA (2003) include goods, services and cultural services; and ecosystems may refer to either natural or human-modified ecosystems. The MA definition for ecosystem services was built from two other commonly referenced definitions of the time (MA, 2003) and can therefore be taken as a broad definition of ecosystem services. The MA also classifies ecosystem services into four categories: provisioning, regulating, cultural and supporting which were based on functional lines within the MA (MA, 2003).

The four categories of ecosystem services are explained as follows (MA, 2003):

- Provisioning services, which are the tangible products obtained from ecosystems;
- Regulating services, which contain the benefits obtained from the processes of ecosystems;
- Cultural services, which are nonmaterial benefits linked to individual perception; and
- Supporting services, which are services that are essential for the production of all other ecosystem services that are indirect or occur over a '*very long time*'.

Examples of these categories are given in table 1. Some ecosystem services can be categorised in more than one category, such as erosion control, which can be a regulating service but also a supporting service, and fresh water, which can be a provisioning and a regulation service. More information on these services can be found in MA (2003).

Table 1: Overview of the categories of ecosystem services with examples, modified after MA (2003).

Category	Examples
Provisioning services	
	Food and fibre
	Fuel
	Genetic resources
	Biochemicals, natural medicines, and pharmaceuticals
	Ornamental resources
	Fresh water
Regulating services	
	Air quality maintenance
	Climate regulation
	Water regulation
	Erosion control
	Water purification and waste treatment
	Regulation of human diseases
	Biological control
	Pollination
	Storm protection
Cultural services	
	Cultural diversity
	Spiritual and religious values
	Knowledge systems
	Educational values
	Inspiration
	Aesthetic values
	Social relations
	Sense of place
	Cultural heritage values
	Recreation and ecotourism
Supporting services	
	Soil formation and retention
	Production of atmospheric oxygen (photosynthesis)
	Primary production
	Nutrient cycling
	Provisioning of habitat

Payment for Ecosystem Services - PES

The field of ecosystem services is currently rapidly developing and expanding (MA, 2003). Originally, the concept of ecosystem services was meant to raise public awareness towards nature conservation, for example in the highly influential studies of the MA (2005) and '*The Economics of Ecosystems and Biodiversity*' or '*TEEB*' (TEEB, 2010) (Gómez-Baggethun *et al*., 2010). Currently, the benefits of ecosystem services are increasingly being expressed in monetary values and finding their way into payment mechanisms and markets (Gómez-Baggethun *et al*., 2010).

The term 'payment for ecosystem services', also 'called payment for environmental services' or just 'PES' as a concept to provide an extra incentive to protect nature was first used in a scientific article in 1974 but only really started to be used around 2005 (Schomers & Matzdorf, 2013). It is often brought forward as a '*novel conservation approach*' (Schomers & Matzdorf, 2013). However, although the wide applications of the term PES and its relatives is relatively new, the underlying concept is not entirely 'novel' (Gómez-Baggethun *et al*., 2010), see for instance Article 11 of the CBD (UN 1993) and the fact that since 1992 the EU has had Agro-Environmental schemes providing payment to farmers that used more environmental friendly methods and land-uses (OJEC, 1992a).

Although no formalized definition of PES exists, it is often brought as '*a voluntary, conditional agreement between at least one 'seller' and one 'buyer' over a well-defined environmental service*' (Hein *et al*., 2013; Schomers & Matzdorf, 2013). However, this definition has been criticized as being too narrow (henceforth refered to as PES s.s.: *sensu stricto*: 'in the strict sense') as it would exclude all other form of payments for ecosystem services, for instance excluding those that involve governmental intervention and public payment schemes (Schomers & Matzdorf, 2013). To not exclude valuable mechanisms and experience, it can therefore be practical to define PES s.l. (*sensu lato*: 'in the broad sense') as '*a transfer of resources between social*

actors, which aims to create incentives to align individual and/or collective land use decisions with the social interest in the management of natural resources' as has been suggested by Schomers & Matzdorf (2013).

Because most of the cited PES cases in the literature use a PES s.l. definition (Wunder, 2007; Schomers & Matzdorf, 2013), 'PES' in this Thesis will henceforth refer to PES s.l. unless otherwise stated.

Valuing ecosystem services

Valuing ecosystem services is complex. Although people derive benefits from ecosystem services, these benefits can be derived directly or indirectly. Benefits can moreover be used at the present but also in the future. Additionally, it depends on the size of the decision making body (1 person versus multiple persons), the motivation and preferences on how much a certain ecosystem service will be actually used and valued. Last but not least, actual use of ecosystem services is hard to measure. Besides values that can be directly used, also 'non-use values' exist: ecosystem services which cannot be used but are a part of a culture and/or religion (MA, 2003).

To express the actual benefits of direct and indirect ecosystem services in the most universal unit, they are often measured in monetary terms (MA, 2003). According to the MA (2003) using monetary terms has multiple benefits:

1) The unit is often well recognized by users;
2) It saves the effort of using units that probably will eventually be expressed in monetary values; and
3) It facilitates comparison with other activities that also contribute to well-being.

Multiple valuation approaches for ecosystem services are currently used (Ecosystemvaluation.org, 2013a). Often used methods include: cost-benefit analysis (CBA), contingent valuation, and revealed preferences (Verweij, 2001; Kaimowitz, 2002; MA, 2003) which each having its advantages and disadvantages.

CBA assigns monetary value to an ecosystem service on the basis of the costs that would be made if the ecosystem service would be removed and people had to substitute the service (Ecosystemvaluation.org, 2013b). CBA is best used in situations where damages have already been made or are expected to be made in the near future (Ecosystemvaluation.org, 2013b). The advantage of CBA is that costs of producing benefits are often more easily calculated than benefits themselves; however, a recognized disadvantage of the CBA method is the general lack of necessary information to calculate the costs (Verweij, 2001; Ecosystemvaluation.org, 2013b).

Contingent valuation is the estimate of what people are willing to pay or to accept for a non-marketed resource in a hypothetical situation which is measured with surveys (Ecosystemvaluation.org, 2013c). Often contingent valuation is expressed in 'Willingness To Pay' (WTP) and 'Willingness To Accept' (WTA) (MA, 2003; Ecosystemvaluation.org, 2013c). WTP should be used in situations where the beneficiary does not own the resource providing the service while WTA should be used where the beneficiary does own the resource providing the service (MA, 2003). According to the MA (2003), in practice often WTA estimates are higher than those of WTP and therefore WTP estimates are more often used because they are more conservative and therefore reflect the under-limit of valuation. Advantages of WTP are that it can be used to estimate the monetary value of anything, including non-use values and that it is widely used (Ecosystemvaluation.org, 2013c). However, the use of WTA to estimate the value of ecosystem services seems controversial (Ecosystemvaluation.org, 2013c) as the recognized disadvantages of WTA are that the survey assumes that people adequately understand the ecosystem service in question, it easily allows the subjective valuation of the resource and that WTA reflects willingness to pay and not the pay that people will actually provide if prompted outside of the hypothetical situation (Verweij, 2001; Ecosystemvaluation.org, 2013c).

Revealed preferences are the opposite of estimating WTP: revealed preferences estimate monetary value by actual costs made for obtaining or supporting an ecosystem service instead of on the hypothetical willingness and therefore is also called Revealed Willingness to Pay (RWTP) (Ecosystemvaluation.org, 2013a). RWTP can be estimated by using for example market prices, travel costs and voluntarily payments (Ecosystemvaluation.org, 2013a). A major advantage of using the RWTP method is that the obtained estimates of value often represent the real marketable value (Kaimowitz, 2002; Ecosystemvaluation.org, 2013a). Possible disadvantages of RWTP are that: not every ecosystem service is being paid for on the market or voluntarily; payment for certain ecosystem services are made indirectly, *e.g.* paying for a collection of ecosystem services; and payment for ecosystem services does not reflect the real value of the service (Ecosystemvaluation.org 2013d; 2013e).

Impact of PES on nature conservation

Despite the time that PES schemes could have been running and the occurrence of many projects that cite its use, not much information could be found on the efficiency of PES schemes on nature conservation in the scientific literature provided by the search query. The bulk of found scientific literature focuses on things such as the (management of) beneficiaries of PES (*e.g.* Pereira, 2010; Corbera *et al*., 2007) and the history/philosophy/economics behind PES (*e.g.* Gómez-Baggethun *et al*., 2010; Farley & Costanza, 2010; Kumar *et al*., 2013; Schomers & Matzdorf, 2013). Van Hecken & Bastiaensen (2010) seem to confirm the notion that a substantial part of the literature focusses on economic perspective.

According to Wunder (2007) PES in developing countries '*remain*[s] *poorly tested*', suggesting that not much information about the efficiency of PES schemes in developing countries is known. However this seems to be the same case with regard to PES schemes in 'developed countries'. The only study on PES and their efficiency in developed countries was that of Steur (2013), which in its overview of important EU policies or mechanisms that should contribute to European biodiversity conservation, lists measures that can be identified as PES schemes, in particular agro-environmental funding.

When regarding the available and relevant scientific literature on the question whether PES can provide an incentive that is economically more interesting than conversion of nature, the literature seems to suggest that this is not guaranteed (MA, 2003; Marris, 2009; TEEB, 2010). This can be due to that:

- Not all ecosystem services are actually economically valued and paid for, for instance recreation and/or spiritual and cultural importance (Muriithi & Kenyon, 2002; TEEB, 2010);
- An economical undervaluation of the ecosystem services (TEEB, 2010); and/or
- The ecosystem in question does not provide sufficient ecosystem services to provide a sufficient economic incentive (Kosoy *et al*., 2007; Marris, 2009).

With regard s to the effect of an economic incentive to protect nature, hardly any studies were found. If studies were found, these often addressed habitat restoration (*e.g.* Johnson & Schwartz, 1993; McMaster & David, 2001) and not the effect of PES on the conservation of intact ecosystems. Hein *et al*. (2013) hypothesize that rare or threatened species may not be responsible for any valuable ecosystem service and therefore are not protected by PES. Therefore, according to Hein *et al*. (2013) additional measures might be needed to conserve these rare or threatened species.

Steur (2013) found for the EU that despite agro-environmental funding, the major part of the assessed natural habitats and biodiversity in continental Europe are in an unfavourably conserved state. The reasons for this state are manifold (Steur, 2013) and unfortunately it is currently not possible to distinguish the contribution of agro-environmental funding to nature conservation in the EU.

With the search query, two relevant case-studies were found. Both of these case-studies found a weak positive effect of PES on nature conservation. The first addressed a famous case-study in Costa Rica, the *Pagos por Servicios Ambientales* (PSA) project undertaken between 1997 and 2000 aiming to reduce deforestation by PES (Pfaff *et al*., 2008; Robalino *et al*., 2008) and the second addressed the Regional Integrated Silvopastoral Approaches to Ecosystem Management project (RISEMP) in Nicaragua which was undertaken between 2002 and 2008 and aimed to promote silvopastoral practices through PES (Van Hecken & Bastiaensen, 2010).

The PSA initially found no proven positive effect because it was unclear whether the positive effect on nature conservation was due to the PES scheme or other factors (Pfaff *et al*., 2008). Nevertheless, another empirical study found a small positive effect in the original PSA area between 2000 and 2005: an additional 0.4 per cent of the originally forested parcels were left forested in this period that otherwise would have been deforested (Robalino *et al*., 2008). The RISEMP found that participating farmers had increased the amount of trees and shrubs on their pastures and accoding to Van Hecken & Bastiaensen (2010) therefore seemed to have recognized the benefits of (at least some of the) silvopastoral practices.

II. Trésor as case-study for PES assessment

History and current status of Trésor

Trésor nature reserve, henceforth 'Trésor' is a privately owned nature reserve and lies near the coast in French Guiana, South-America which resides in the tropical forest biome of Latin America (Achard *et al.*, 2002).

Trésor was established in 1995 by acquisition of 2464 ha or 24.64 km^2 of tropical rainforest almost undisturbed by human activities from the Catholic church of French Guiana by the Trésor Foundation to '*contribute to the conservation of the tropical rainforest through cooperation between* [the] *private, business and scientific world*[s]' (Fontein, 2007). Trésor represented one of the first nature reserves in French Guiana at the time and was the first and current only Regional Nature Reserve (Annex II) in French Guiana. In 1997 the prefect of French Guiana granted Trésor the status of Voluntary Nature Reserve, an official reserve status under French law. In 2009 Trésor was promoted to the status of Regional Natural Reserve (Boeraeve & Zomer, 2012).

Currently Trésor is actively managed by the '*Association Trésor*' in French Guiana while the Trésor Foundation, which is based in the Netherlands, provides financial, scientific and political support. The most important long-term management objective of Trésor currently is conservation of the Trésor ecosystems with its biological diversity through the following pillars:

- Active protection of Trésor;
- Management of Trésor;
- Initiating and facilitating research on and in relation to Trésor; and
- Providing education and communication on and about Trésor.

(Modified after Fontein, 2007; Duden & Roelink, 2011, Lukkien & Jeurissen, 2013):

Trésor is surrounded by the Kaw-hills to the north-east and the river 'Orapu' to the west (figure 1). A higher part of Trésor is situated on the top and slopes of the Kaw-hills and reaches a maximum altitude of *ca.* 267 meters. Trésor then slopes downwards in direction of the Orapu river (Ek *et al.*, 2006; based on '*Kaart 2*' from Pineau *et al.,* 2008; figure 1). In Trésor, on the slope of the Kaw-hills, creeks have cut deep gullies into the hill and are tributaries to the main creek 'Favard'. Favard on its turn is a tributary to the Orapu (Ek *et al.*, 2006), which flows to the north, through the village Roura before reaching the city of Cayenne (based on Figure 3 from Fontein, 2007; Annex I).

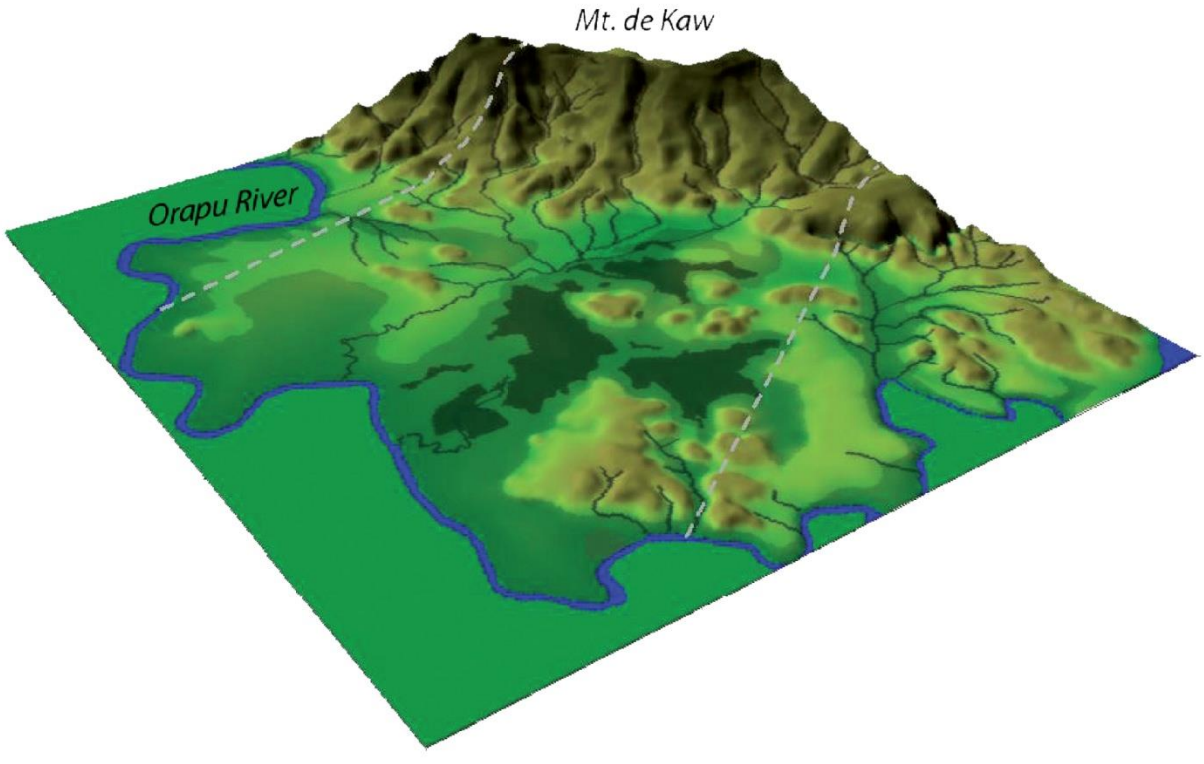

Figure 1. The Trésor area as indicated by dotted lines and bordered by the Kaw-hills ('*Montage de Kaw*') and the Orapu river. Taken from Ek *et al.* (2011).

On the top of Kaw-hills runs the D6 road from Roura to the ferry of the village of Kaw. The D6 forms the North-eastern border of Trésor, is the only official road in the area and allows the reaching of the entrance building of Trésor by car. The D6 connects to the N2 north of Roura which is the main road to Cayenne. The N2 runs from Cayenne to the south-west, to connect with other roads to the border of French Guiana and Brazil. Northward on the D6 from Trésor and before Roura, lies another connection between the D6 and N2 with a ferry crossing that runs through the hamlet of 'Fourgassié' (or 'Fourgassier') (based on Figure 3 from Fontein, 2007; Lukkien & Jeurissen, 2013).

Actions are underway to in the future include the stretches of tropical ecosystem north and south of Trésor, to be managed by the Association and used as buffer zones to the main reserve (this is still underway despite earlier references citing it as *fait accomplis* [Lukkien & Jeurissen, 2013]). In this Thesis 'Trésor' in the context of its area refers to the core Trésor area, *i.e.* without the added areas, unless otherwise stated.

For more information about the to-be-added areas, the study of Ek *et al*. (2009) is recommended. Additional information on the history of Trésor can be found in Annex II.

Environmental data

The Trésor area is wet and warm. The area of Trésor is subject to two relative seasons:

- A wet season during December to July with an average precipitation of 456 mm/month; and
- A dry season during August to November with an average precipitation of 130 mm/month.

On average, Trésor receives around 4000 mm of precipitation *per* year. The driest month is October with an averaged 91 mm. During the year the temperature of the Trésor area averages between around 22.1 and 30.0°C.

French Guiana lies on the Guiana Shield formation, which is one of the oldest known geological formations Precambrian metamorphic and granite rocks on the planet (Boeraeve & Zomer 2012), consisting amongst other things of the geological 'greenstone belt.' The Kaw-hills are part of the '*Northern greenstone Belt*' (Doomen, 2003). Because of its age, the Guiana Shield is relatively nutrient poor (Hammond, 2005). Trésor is relatively nutrient rich for the Guiana Shield according to Kruijt *et al*. (2006) citing personal communication with H. ter Steege. It is likely that the floodplains of Trésor which lie near the river Orapu are nutrient richer than the soils on the slopes of the Kaw-hills because floodplains are often fed by river sediments.

One important characteristic of the greenstone belt is its subsequent '*large tonnage–low grade gold deposits*' (Hammond, 2005). Gold deposits in French Guiana were known to exist in commercial quantities since the 1820's and by 1900 in French Guiana 25% of the population were gold miners, the principal economic activity of the territory (Hammond, 2005). However, before 1995 gold production from the Guiana Shield never accounted more than 1% of the total global output (Hammond, 2005). Since the 1990s gold production has seen exponential growth in French Guiana (Hammond, 2005) and in 2010 was held as one of the most important industries of French Guiana, in addition to aerospace, fishing and forestry (USGS, 2011).

It is known that an Environmental Assessment Report exist that addresses the availability of gold in the soil in the Trésor area (Lukkien & Jeurrisen, 2013), but unfortunately at the time of writing this EAR was unavailable. According to a U.S. Geological survey of 2010, the concession areas east to Trésor referred to as the 'Camp Caiman Project', is known to hold an average of 2.8 grams of gold *per* tonne of ground that is currently feasibly minable (USGS, 2011).

Although large gold-mining operations generate 'considerable' revenue to the government, they also bring along many possible risks to people and the environment (Hammond, 2005). Possible environmental risks are that in the practice of gold mining: often large patches of forest are completely deforested; the industry activities are lighted day and night; and workers are known to illegally hunt the area surrounding the gold mine (Lukkien & Jeurissen, 2013). Massive influx of sediments associated with gold mining alters the biophysical characteristics of water such as the acidity and clearness, influencing standing vegetation and animals/people that drink from it. Moreover, the use of chemicals in gold mining, such as mercury as a cheap gold amalgamating agent, causes severe contamination of the water, its sediment and its animals which has '*potential severe downstream public and environmental health consequences*' (Fréry *et al*., 2001; Hammond, 2005; Fontein, 2007).

For more climatological data on Trésor, see Annex VI. For more information on gold mining activities around the area of Trésor, see Annex VII. For further geological and hydrological details of the soils of Trésor, Doomen (2003) is recommended.

Ecological importance of Trésor

Although little is known about the ecology of tropical forests in general (Kricher, 2011), Trésor has been studied extensively over the years. The '*Montagne de Kaw*' area in which Trésor lies was firstly officially recognized for its high and special biodiversity in 1989 by receiving the status of protected biotope (Fontein, 2007). Then, in 2001, the same area was identified as *Zône Naturelle d'Intérêt Écologique, Faunistique et Floristique de type I* (ZNIEFF type I, natural area of ecological, floristic and faunal interest type I; Fontein, 2007). ZNIEFF is a French classification to identify areas of important ecological interest, where type I indicates areas which have a limited surface and contain species or habitats that are either of high interest to the local, regional or national community or are of great local ecological importance (Wikipedia, 2013a). An indication of the ecological importance of ZNIEFFs is provided in the fact that continental European ZNIEFFs were proposed as Sites of Community Importance (SCIs) by France (Wikipedia, 2013a). SCIs are areas suggested for protection under the Habitats Directive of the EU (OJEC, 1992b). Research on the ecological importance of Trésor between 1997 and 2007 has at least confirmed a relative high plant biodiversity (Fontein, 2007). According to Fontein (2007), citing Ek (2004), Trésor is one of the '*main biodiversity hotspots*' of the Guiana's.

According to Ek *et al.*, (2006) the vegetation of Trésor can roughly be divided into three types: mixed forest, swamp forest and savannah. The slopes of the Kaw-hills with its gullies are mainly covered with Mixed forest while in the lower parts of Trésor patches of savannahs are surrounded by mixed forests swamp forests (figure 2). According to Kruijt *et al*. (2006) these three rough forest types can be further divided into six biotopes:

- Plateau forest;
- Forest on slopes;
- Temporarily inundated forest;
- Swamp forest;
- Forest on isolated hills; and
- Savannahs.

At the time of writing recent research into the biotopes of Trésor is showing a preliminary distinction of 22 biotopes (Trésor, 2013a).

Figure 2. Sketched biotope covering over a virtual transect in Trésor. Terrain units: I: higher areas on lateritic plateau, II: sloping hills, III: steep areas near gullies, IV: flat areas bordering creeks, V: swamp, VI: isolated hills, VII: wet savannah. Modified after Ek *et al*. (2006).

Through inventories of Trésor over the years a total of 1106 plant and ferns-and-fern-allies species were found of which 40 are considered to be endemic, rare or protected (Ek *et al*., 2006). When regarding the evolution of species discovery over the inventories, it can be expected that future inventories will also add significant

amounts of new species (Ek *et al*., 2006). Indeed, recent research into the biotopes of Trésor found 44 new plant species (Trésor, 2013a).

Additionally, over 65 species of bryophytes have been discovered in Trésor (Ek *et al*., 2006) and it is known that research on mammals, birds, bats, fish, amphibians, reptiles and earthworms in Trésor has been carried out (Lukkien & Jeurrisen, 2013), unfortunately the reports of these studies were unavailable at the time of writing because they have not yet been indexed by the Foundation so a complete review could not be made for this Thesis.

According to personal communication with a Forest Ranger of Trésor, currently a total of 1299 plants (including fern and moss), 54 fishes, 56 amphibians, 80 reptiles, 329 birds and 114 mammals (terrestrial and bats) species have been identified in Trésor (Villette, 2013). Importantly, it is known that for some of the studied species in Trésor, some were new to science (Lukkien & Jeursisen, 2013). Taking these facts together, it is clear that Trésor is providing a large contribution to science.

A preliminary overview of the research that has been performed in relation to Trésor can be found in Annex III.

Activities of Trésor

Trésor has had no recent alteration by human activity (Pineau *et al*., 2008). Before it was acquired by the Foundation, in the beginning of the 1980s, a road surfaced by crushed laterite to the adjacent '*Placer Trésor*' (south-east of Trésor) was established which partly ran through Trésor itself. This road was established to facilitate accessibility of the Placer Trésor and the practices of hunting and timber extraction (Annex I). This laterite road, which is still visible on some maps, has been barricaded since the acquisition of Trésor and therefore has seen a decline in its use. Currently, it is hardly ever used and is only accessible on foot (Pineau, *et al*., 2008; Lukkien & Jeurissen, 2013). The old laterite road seems not to enter the reserve more than 3 km from the western border. The map also mentions two old laterite excavations. Laterite is widely used in French Guiana as pavement for roads (Lukkien & Jeurissen, 2013). In addition, Fontein (2007) provides an overview of vegetation types within Trésor and the mentioning of possible human disturbance. Based on Fontein (2007) and Pineau *et al*. (2008) some relatively large disturbing practices have been carried out in the past. In recent time, the only alterations made to the reserve were made with the construction of an entrance building and an educational trail near the D6 road. Only illegal hunting is known to occur at irregular intervals and is prevented by active monitoring and patrolling. According to Fontein (2007) it can be concluded that human activities have had minor impact on Trésor. Taking these facts into account, it is assumed that Trésor currently is more or less undisturbed by human activity.

A general overview of the activities undertaken by the Foundation and the Association is presented in table 2 which was based on Fontein, (2007) and Lukkien & Jeurissen (2013).

Table 2. Overview of activities undertaken by the Foundation and Association.

Trésor Foundation	*Trésor Association*
- **General coordination incl. work visits (2x *per* year)** - **Funding of the Association** - **Public relations** - **Maintenance of the website** - **Cooperation in the execution of management activities** - **Translation of documents** - **Project development** - **Production of a newsletter** - **Fundraising** - **Adoption of m^2s** - **Organisation of activities for donors, *e.g.* trips to Trésor and gathering events** - **Botanical research programme** - **Validation of biodiversity** - **Facilitation of scientific studies**	- **Daily management (field and office) incl. monitoring** - **Education & information programmes** - **Guiding of tourists** - **Fundraising at the local and European level** - **Project proposals and development** - **Coordination of developments of local laws and regulations** - **Contact with local stakeholders** - **Representation of Trésor in local organisations** - **Coordination of other nature reserves in French Guiana (board)** - **Species inventories** - **Validation of biodiversity** - **Facilitation of scientific studies**

Relevant activities to this Thesis include:

- Ecotourism: the Foundation and Association facilitate ecotourism to its reserve. Trésor has an entrance building which facilitates education on the reserve, its ecology and biodiversity. An educational trail is also present to teach visitors about the ecology of Trésor and facilitate access to Trésor for various

activities (Lukkien & Jeurissen, 2013). This trail was originally developed as a botanical trail. Trésor is readily reachable by road D6 and with its *ca.* 50 km from Cayenne and *ca.* 20 km from Roura by road, can serve as a day-trip. On site, every weekend visitors are guided by staff of the Association and the reserve is freely accessible but unguided during the week. A new way of counting the amount of visitors accessing the botanical trail was introduced in 2012 and the preliminary findings suggest that around 50 to 100 persons visit the educational trail *per* month (Trésor, 2013c).
Moreover, since 2003 the Foundation organises in cooperation with the tourist bureau '*JungleTours*' a yearly, multiday trip for (normally) 19 donors to visit amongst other things, Trésor. The current price for this trip is € 3200 *per* person (JungleTours, 2013).

- Research: the Foundation and Association facilitate and initiate research on the ecology and the biodiversity of the reserve from which the findings are shared with other reserves (see also Annex III).
- Education: for over 15 years Trésor receives visits of school children from schools all over French Guiana but mainly from the community of Roura (Lukkien & Jeurissen, 2013). Trésor is used to educate on nature conservation and the ecology and biodiversity of Trésor and Tropical forests in general. The employees of the Association Trésor also carry out an education programme in some French Guianian villages and cities, *i.e.* Cayenne, Kourou and Cacao (Lukkien & Jeurissen, 2013).
- Adoption of m^2s of rainforest: Since 1998 with the original aim to pay off the loan of the acquisition of the Trésor area and later also to fund the activities of Trésor, the Foundation offers m^2 of Trésor for adoption in return for a financial deposit. People who have adopted m^2s in this way are called donors. With the help of *inter alia* donor money the original loan was paid off in 2012 (Annex II). Since 1998 up to 5 July 2013 42,897 m^2 has been adopted (Lukkien & Jeurissen, 2013) (less than 0.2 % of the m^2 available of the core Trésor area).
- CO_2-compensation: persons can choose to voluntarily compensate CO_2 emissions produced by traveling by car or by plane through the financing the Foundation which, according to the Trésor website citing an report from an ecological consult (Kruijt *et al.*, 2006), acts as CO_2 sink, trapping a net 700 to 4400 kg of CO_2 *per* hectare *per* year (Trésor, 2013b).
- Various private funding: it is also possible to fund Trésor incidentally or periodically through gifts, wills or sponsoring.
- External funding: Utrecht University has been providing the salary and small additional expenditures of the Coordinator of Trésor since 2003 and 'Région Guyana' (an institute of the government of French Guiana; Villette, 2013) has been providing the salary, office costs and other expenditures of the Conservator and 2 Park Rangers of the Association completely since 2010. The 'coordinator of Trésor' manages the Foundation, the Association, the scientific research and the supervision of BSc and MSc students and is funded for 0.2 FTE and with small a budget for operational costs. A future new employee will also be financed for 0.5 FTE by Région Guyana and 0.5 FTE by WWF (Lukkien & Jeurissen, 2013; Villette, 2013).
- Validation of biodiversity: currently Trésor is involved in validation and benefit sharing of biodiversity from Trésor. Under the name 'The Ficus Project' a population of *Ficus guianensis* Desv. ex Ham. was found in Trésor and is being brought under commercial exploitation in Europe from which a percentage of the profits will flow back to the country of origin (benefit sharing) to protect nature in the form of funding Trésor. This is a pioneer project in addressing Benefit Sharing under the CBD aims and EU regulations (Lukkien & Jeurissen, 2013). Moreover and originally, the *Ficus* plant was meant to be used as a bird-attractor in French Guiana. It is unclear what the current state of this particular project is.
- Project development: currently, the coordinator of Trésor, on the basis of its expertise from Trésor is co-developing a similar project in Surinam called 'The Peperpot Project' (Lukkien & Jeurissen, 2013).
- Experience: the experience that the Foundation and in particular the Association has developed in managing and monitoring a nature reserve is being used to improve the managing and monitoring of other nature reserves in French Guiana. For this reason, the conservator of the Association is a member and for a 'long time' the chair of the *Conservatoire des Espaces Naturels* (CEN) an association of cooperating nature reserves in French Guiana (Lukkien & Jeurissen, 2013). The CEN shares knowledge on and about its nature reserves, develops and implements educational programmes and applies for (French) subsidies.

External human activities in and around Trésor

Based on figure 3, which was taken from Fontein (2007), nearby human activities include:

- The city of Cayenne, the capital and largest city of French Guiana, (ca. 59,750 inhabitants in 2010; Wikipedia 2013b) *ca.* 50 km to the north;
- The village of Roura (ca. 2000 inhabitants) *ca.* 20 km to the north (Fontein, 2007);

- The hamlet of Fourgassié *ca.* 15 km to the north, with two areas where agriculture is taking place, an area with tourism activities and lodge construction on both sides of the Orapu river (Fontein, 2007; Lukkien & Jeurissen, 2013);
- The hamlet of Dégrad Limousin *ca.* 2 km to the south which has known commercial flower production in the past (but currently is out of production), and potential new lodges construction (Fontein, 2007; Lukkien & Jeurissen, 2013);
- The lodge Camp Caiman *ca.* 8 km to the west (Lukkien & Jeurissen, 2013); and
- The village of Kaw, reachable by driving *ca.* 33 km by the D6 road and a ferry.

(distances based on Annex I and Google Maps, 10-July-2013):

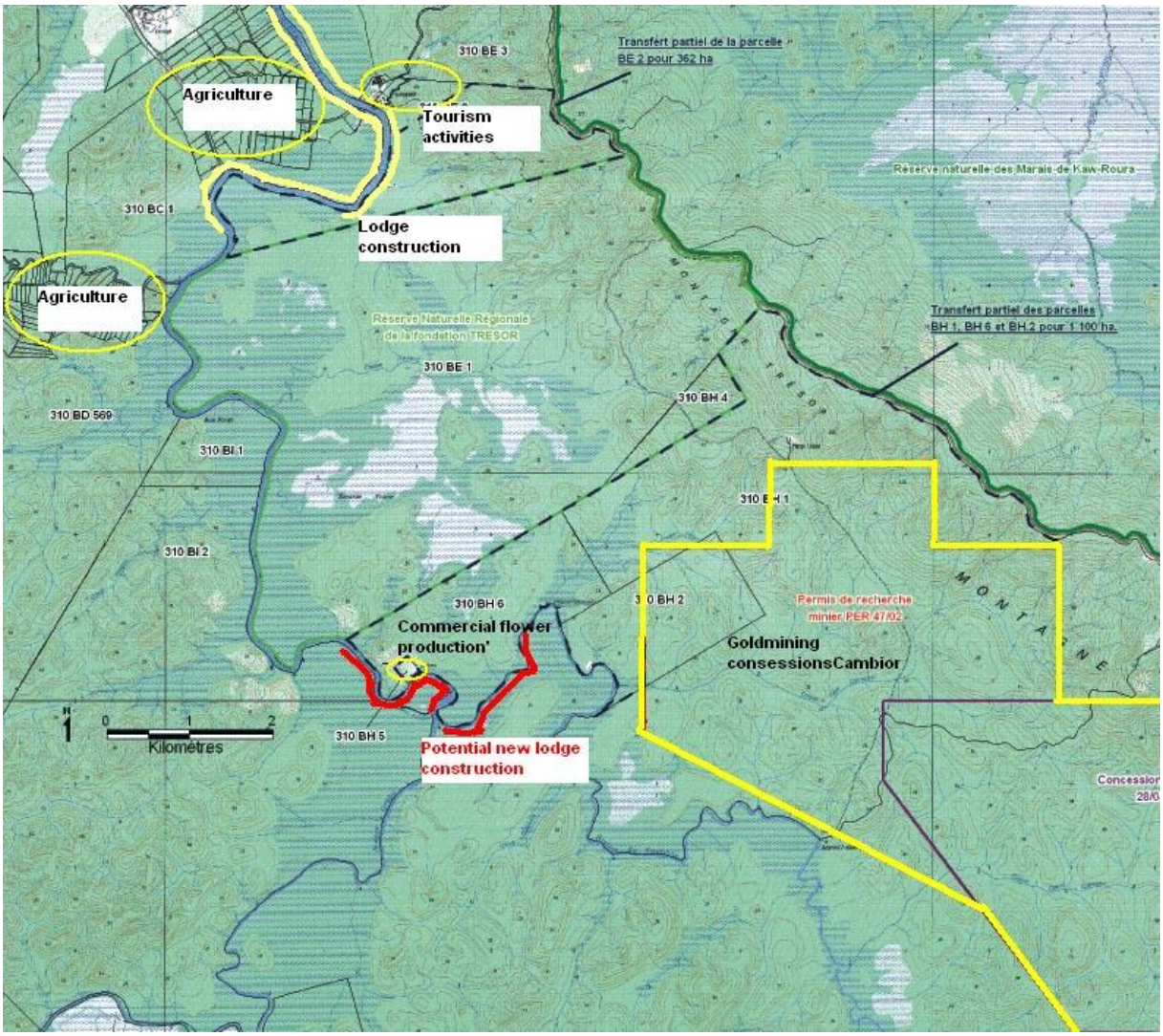

Figure 3. Overview of human activities in 2007 near vicinity of Trésor. Note that the Gold mining concessions currently have been denied. Taken from Fontein (2007).

In addition to these hamlets and cities, it is known that communities of Amerindians live within the forests south of the Orapu river and a special Amerindian reserve is located upstream of the Orapu river (See figure Annex VII; Lukkien & Jeurissen, 2013). These Amerindians depend on the tropical forests for their livelihood (Lukkien & Jeurissen, 2013).

Pineau *et al*. (2008) mentions several external human activities in and around Trésor of which the following are relevant to this Thesis:

- (Eco)Tourism: the Kaw-hills are an important tourist attraction. The Kaw-hills and swamps attract a lot of tourists that visit multiple locations in the area, including Trésor (Lukkien & Jeurissen, 2013). Important sites that facilitate tourism are the inn of Fourgassié, the lodge 'Camp Caiman', Camp Patawa on the Kaw-hills and the village Kaw at the end of the D6 road;
- Exploitation of timber in several areas: Exploitation of timber is happing legally but also illegally. Historically, there has been at least one case of illegal harvesting of wood in Trésor. Although it is not

possible to distinguish from Pineau *et al.* (2008) the exact nature and location of these activities it can be assumed that illegal logging is taking place at a small scale and cannot be completely avoided in the Trésor area (Lukkien & Jeurissen, 2013); and

- Hunting: '*A lot*' of hunting takes place around the D6 road and forest roads. Hunting on the D6 is legal as it is not part of the protected parks. However, hunting on forest roads is illegal when these lie within one of the Nature Reserves.

Agriculture is being carried out at the hamlet of Fourgassié but not at large scales (Fontein, 2007). Other, smaller patches of agriculture are also found in the Trésor area, for instance along the D6 road (Lukkien & Jeurissen, 2013). The agriculture in the area mainly consists of growing coconut-, banana- and other edible fruit-baring trees (Lukkien & Jeurissen, 2013).

Another important external human activity is gold mining. Because the area of Trésor and its surroundings are known to hold gold deposits, gold mining companies have had an interest in the area since the concessions were put up for auction in 1994. Most notably, three concessions east of the Trésor were purchased by a gold mining company (Fontein, 2007) in 1994 and preliminary drillings found gold in commercially exploitable quantities (IAMGOLD, 2013). Over the years the ownership of the concession areas changed from company to company and currently (2013) this is the 'IAMGOLD corporation' (IAMGOLD, 2013).

Chronologically, permits to allow large scale drilling and gold exploitations were applied in 2003 at the French government, which is directly responsible for mining exploitation in French Guiana (IAMGOLD, 2013). However, in 2006 the application for mining permits was frozen by the French Government in prospect of an environmental assessment (Fontein, 2007). In 2008 the permits were denied by the French President in expectation of a total ban of gold winning activities (IAMGOLD, 2013). In 2009 the owning mining company issued an appeal to this decision but the permits got denied again by the French government in 2010 with additional reasoning to forbid mining activities (IAMGOLD, 2013). The mining company issued a second appeal which was dismissed in 2012 (IAMGOLD, 2013). Although gold mining activities in the Kaw area are currently forbidden, the current mining company who owns the concessions is appealing to a higher court with the compensation claim of € 763 million in damages and missed revenue (IAMGOLD, 2013). In expectation of the result of the latest appeal of IAMGOLD the future of large scale the gold mining activities near Trésor is unclear. Moreover, small scale illegal gold mining is known to occur in French Guiana (Fréry *et al*., 2001). Thus gold mining can still be a potential threat to Trésor.

The exact cause and effects of the ban on gold mining in the Kaw area are difficult to distinguish. However, according to Lukkien & Jeurissen (2013) and a radio interview of ecologist P.A. Verweij and her MSc student E. Fontein (Verweij & Fontein, 2008), the permits were denied because French ecologists who had studied the area under French Governmental commission underlined the importance of the area for the human population downstream of Orapu and the surrounding nature. These were the same reasons that the Trésor organisation was communicating to stop the gold mining activities. The official reasoning of the French Government to deny the permits for large scale gold mining in 2012 could not be found at the time of writing. According to Verweij (2013), the permits were probably denied because of the Kaw area's importance as a fresh water source.

Additional information on the history of gold mining around the Trésor area can be found in Annex VII.

Impact of Trésor

It can be argued that Trésor as organisation and area has a high impact factor and is a 'focal point of nature conservationism', seeing as Trésor (with its organisation):

- Was one of the first nature reserves in French Guiana;
- Is the single regional nature reserve of French Guiana;
- Provides knowledge and experience to other nature reserves, *inter alia* through CEN and project development;
- Promotes validation of biodiversity, facilitating better nature conservation;
- Offers CO_2 compensation schemes;
- Acts a tourist attractor for the whole Kaw area;
- Facilitates research on tropical ecosystems of which little is known;
- Promotes education and schooling about nature conservation and tropical ecosystems and has been doing so for over 15 years;
- Likely contributed to the stopping of gold winning in the Kaw area;
- Is unique for at least French Guiana with being a partly voluntarily run organisation, receiving part external funding and additional funds from donors and sponsors that are largely from outside French Guiana; and
- Has a good working relation with the Government of French Guiana, Utrecht University and WWF.

The sum of evidence creates a unique multiplier effect that increases the impact factor of Trésor. However, because of its uniqueness, caution must be applied when using characteristics of Trésor as case-study for other similar ecosystems.

III. Ecosystem services in Trésor

Verweij *et al*. (2009) investigated the applicability of the ecosystem services classification based on the MA (2003) on the Amazon forests (of which Trésor is part) and their subsequent possible monetary value. Because the study of Verweij *et al*. (2009) forms a present, relevant and comprehensive overview of the possible ecosystem services provided by Trésor, it will be used as a check list to assess the possible ecosystem services for Trésor. In order to be comprehensive as possible, the check list was expanded with any possible other ecosystem services that were identified in MA (2003), Fontein (2007), Malotaux (2010) and the author's own insights. Specifications to the ecosystem services identified by Verweij *et al*. (2009) will be indicated with an asterix ('*').

With the data on Trésor and its organisation, the following ecosystem services were discussed on their applicability for Trésor, of which the outcome is shown in figure 4.

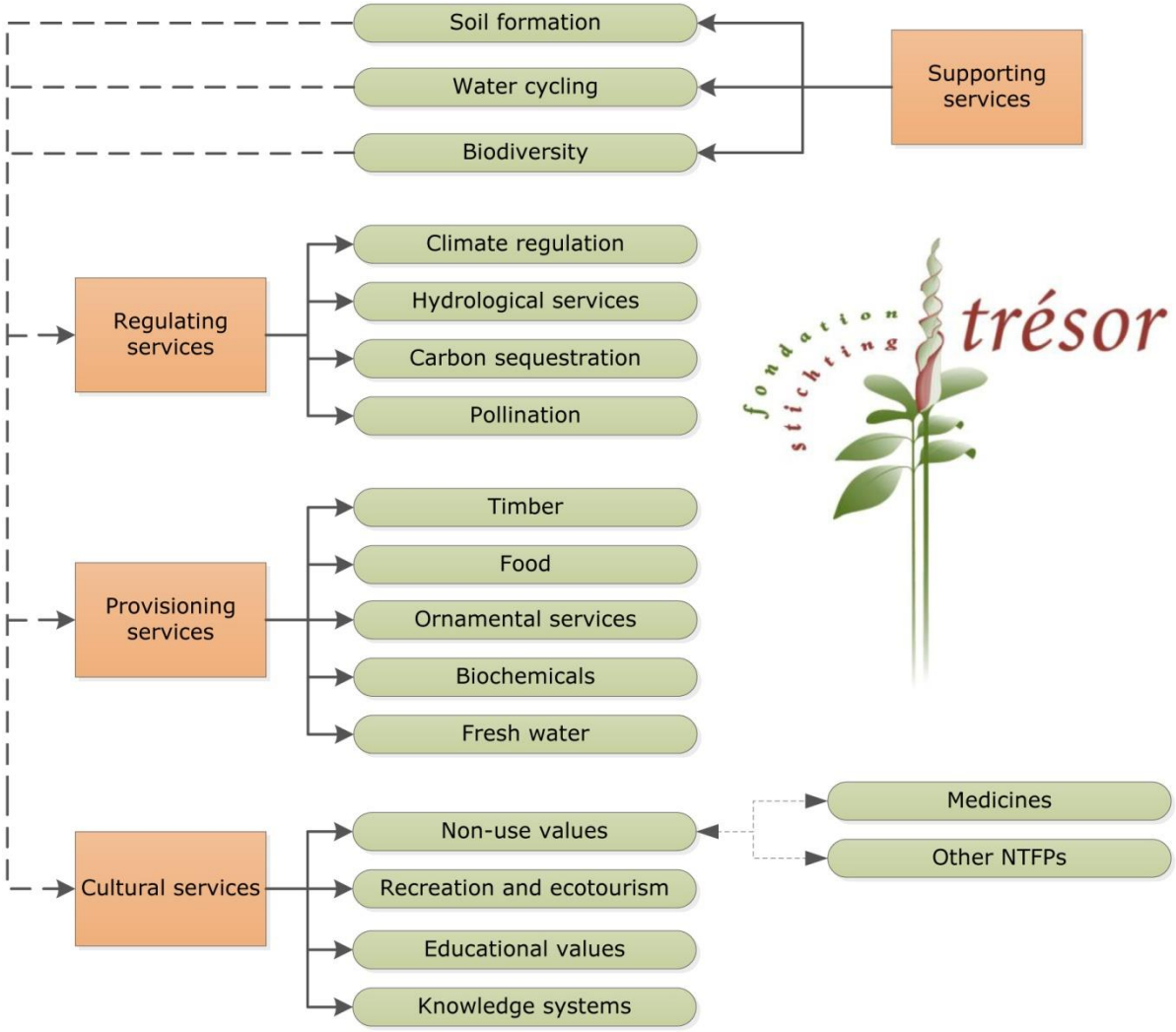

Figure 4. Overview of the current applicable ecosystem services of Trésor, modified after Verweij *et al*. (2009).

Supporting services

1.1. Soil formation. Due to geological history of the soils in the Guiana Shield and heavy rainfall, the soils in the Guiana Shield are often leached of nutrients (Hammond, 2005). Vegetation is known to have a positive effect of retaining the nutrients in the soil (Verweij *et al*., 2009). Moreover, standing vegetation, together with soil fauna are known to determine the presence of humus layers, which can provide habitats, control moisture and nutrition content as well as aeration and protection against soil erosion (Verweij *et al*., 2009). As Trésor

resembles an ecosystem that is almost undisturbed by human influences, it most likely provides this ecosystem service.

1.2. Water cycling. Water is an important feature of the Guianas (Guyana, Surinam and French Guiana) which harbour vast quantities of fresh water (WWF Guianas, 2012). Freshwater forms the habitat of fresh water fish. French Guiana has a total renewable water resource *per* capita index around a factor 100 higher than the world average and can therefore act as a fresh water source (WWF Guianas, 2012). Because of the ability of water to dissolve many solid and gaseous substances it can often have a major influence on the local climate (Verweij *et al*., 2009). Trésor receives a high amount of precipitation which fills creeks, swamps, ponds and eventually contributes to the Orapu river. It is therefore most likely that Trésor provides this ecosystem service.

1.3. Biodiversity conservation. Biodiversity is an important supporting ecosystem service as most ecosystem services derive from biodiversity (Verweij *et al*., 2009). Relative to the rest of the world tropical forests form a major source of biodiversity (Verweij *et al*., 2009; Kricher, 2011). Trésor has been confirmed as a major source of biodiversity (Ek *et al*., 2006; Lukkien & Jeurissen, 2013) and therefore provides this ecosystem service.

* 1.4. Corridor function. Fontein (2007) hypothesised that, seeing as Trésor was the only protected part on the eastern slopes of the Kaw-hills and the areas north and south of Trésor would show an increase of human activities (*e.g.* increased agriculture, tourism and the mining of gold), Trésor would therefore function as an important corridor between the nature east and west of Trésor. To facilitate the potential corridor function, the D6 road over the Kaw-hills along the Trésor border at both sides has been left forested up to the road. This has been done specifically different from the normal method of clearing both sides of a road up to 6 m (Lukkien & Jeurissen, 2013). However, as the corridor function has never been studied and the gold mining concession has currently been denied (Annex II), the possible importance of the corridor function was unclear at the time of writing and is therefore not considered in the case-study.

Regulating services

2.1. Climate regulation. Vegetation cover influences albedo, water cycle and CO_2 storage of an area and therefore its climate (Verweij, *et al*. 2009). Because Trésor consists mainly of forest and thus has a high vegetation cover, it is likely that it co-determines the local climate in and around Trésor. However, as Google Earth (Accessed 13-July-2013) shows an equally high vegetation cover in the surrounding areas and Trésor forms a relatively small part of this area, the extent of its impact on the local climate is probably small.

2.2. Hydrological services, *i.e.* 2.2.1. Regulation runoff; 2.2.2. Sediment control; and 2.2.3. Regulation of flooding. Because the vegetation of Trésor is almost undisturbed by human activities it probably contributes to maintaining these hydrological services that have been around for hundreds of years. The vegetation dictates the water flow from fallen precipitation towards the river Orapu (2.2.1.), the amount of erosion of its soils by water and thus the sediment load that enters Orapu (2.2.2.), the resistance against flooding (2.2.3.) and resistance against meandering of Orapu.

Tropical forests act as a 'natural sponge', slowing and distributing the water flow from precipitation, which has an additional effect of providing more water than actually precipitates during the dry season (Bruinzeel, 2004). Sediment load could influence fish stocks and because fish is an important protein source for people living in the Guiana's, *e.g.* French Guiana (WWF Guianas, 2012), it is probable that this would have an effect on people's wellbeing. This is probably also true for animals living off fresh water fish.

Malotaux (2010) stated that the Orapu river is getting polluted by '*soil erosion and the flooding of water basins*'. However, this was not confirmed by Lukkien & Jeurissen (2013). Although no information was found on the vulnerability of human settlements downstream of Orapu, it is clear from figure 3 and Annex I that people do live/work nearby the river (note Fourgassié and Roura), thus a possible increase of flooding by increased water runoff and a decrease in flooding resistance of the Trésor area would probably cause inconvenience to the people living nearby and downstream Orapu.

Taking these factors into account it is clear that Trésor most likely provides this ecosystem service.

2.3. Nutrient retention. Nutrient retention is a valuable asset for agriculture (Verweij *et al*., 2009). In Trésor there are no other uses of nutrients known besides as a supporting service, therefore this ecosystem service is being used and not considered in the case-study.

2.4. Carbon sequestration. Carbon sequestration is not only about current sequestration but also about what amount of carbon is currently stored into the ecosystem (Verweij *et al*., 2009). Carbon in the form of CO_2 is an important Green House Gas. Anthropogenic activities such as industries, transport and forest degradation and deforestation have been pumping increasing amounts of CO_2 in the atmosphere which is affecting the climate of the world (Mitsiou, 2011). This could trigger climate change on such a temporal scale that human populations and nature cannot easily adapt to these changes. Recognizing this threat, policies are underway to reduce CO_2 emissions and it has become important to know the carbon content and sequestration of an ecosystem.

It is known that tropical forests play an important role in the world's carbon balance as they store large quantities of carbon in their biomass (Verweij *et al*., 2009). However estimating current stored carbon and sequestration in biomass is complex because each biotope has its own characteristics and the various methods applied each have their limitation (Verweij *et al*., 2009).

In Trésor, various studies have been carried out addressing its carbon content, *e.g.* Kruijt *et al.* (2006), Duden & Roeling (2011), Laporte-Bisquit (2011), Mitsiou (2011) and Boeraeve & Zomer (2012). Unfortunately, the MSc Thesis of Laporte-Bisquit (2011) was not available at the time of writing of this Thesis and could therefore not be addressed.

Kruijt *et al*. (2006) provides carbon estimates for Trésor on the basis of data obtained from an inventory of a plot in Trésor by Ter Steege *et al*. (2003) and data from relevant literature. Duden & Roeling (2011), Mitsiou (2011) and Boeraeve & Zomer (2012) add additional data from own inventories. Except from using the data from Ter Steege *et* al, (2003), none of these studies reflect on the data presented in Kruijt *et al*. (2006). Boeraeve & Zomer (2012) provide a consolidation of the data gathered by Ter Steege *et al*. (2003), Duden & Roeling (2011), Mitsiou (2011) and their own. From these studies only Kruijt *et al*. (2006) provides an estimate of the amount of carbon that is currently sequestered by Trésor.

A new estimation on the total carbon content of Trésor can be made when the data from Kruijt *et al.* (2006) and Boerhaeve & Zomer (2012) are combined. The Above Ground Biomass (AGB) per hectare estimate of Boerhave & Zomer (2012) was converted using the same methods of Kruijt *et* al. (2006) in to total carbon content per hectare. The results of the combination would estimate a carbon content of 442.3 to 619.4 Gg (Gigagram) *per* hectare (See table 3). This is lower than the old estimate of Kruijt *et al*. (2006), *i.e.* 560.6 to 828.8 Gg/ha. This lower estimate is the result of lower estimates for forest on the lateritic plateau and forests on slopes.

Table 3. Overview of the carbon estimates of Kruijt *et al*. (2006), Boerhave & Zomer (2012) and these combined.

Kruijt *et al*. (2006)				Boerhaeve & Zomer (2012)				
Biotope	Proportion represented (ha)	Carbon content (Mg C/ha)	Total Carbon (Gg C/ha)	Biotope	AGB (Mg/ha)	Carbon content (Mg C/ha)	Total Carbon (Gg C/ha)	Combined (Gg C/ha)
Forests on the lateritic plateau	14	300-450	4.2-6.3	On mountain top	273.7	268.226	3.755164	3.755164
Forest on slopes	890	400-500	356.0-445.0	on slopes	273	267.54	238.1106	238.1106
Temporarily inundated forest	548	140-300	76.7-164.4					76.7-164.4
Swamp forest	758	140-250	106.1-189.5					106.1-189.5
Forest on isolated hills	37	350-450	13.0-16.7					13.0-16.7
Savannas	232	20-30	4.7-7.0					4.7-7.0
Total	2479		560.6-828.8					442.3-619.4
*dry biomass = 45% carbon content *AGB = 50% AGB+BGB				*AGB = 49% carbon *AGB = 50% AGB+BGB				

There are several important remarks to be made about this presented new estimate. Firstly, Kruijt *et al*. (2006) report a larger amount of total hectares of Trésor than any other document that has been found (*i.e.* 2479 vs. 2464 ha). This larger amount of hectares is used in the calculations presented here in the absence of a more accurate division of hectares over the biomes. Secondly, it assumes that the estimates from Boerhaeve & Zomer are more accurate than that of Kruijt *et al*. (2006). Thirdly, it uses the conversion parameters of that AGB contains 49% carbon (adapted from Mitsiou, 2011) and that AGB represents 50% of the total biomass (adapted from Kruijt *et al*., 2006). Last but not least, it uses the same methods of using data from outside Trésor and extrapolation used by Kruijt *et al*. (2006).

As Kruijt *et al*. (2006) is the only study that provides an estimate on the sequestration rate of Trésor, it is assumed for this case-study that the provided sequestration rate of 0.48 to 2.94 Gg carbon *per* year (which seems to reflect the reported 0.5 to 3 Gg C/yr although the link is not explicitly given, nor any other explanation for this number) is correct. The Trésor Foundation uses the sequestration rate of Kruijt *et al*. (2006) in the context of possible CO_2 compensation measures (Trésor, 2013b). Taking these factors into account, in this case-study it is assumed that Trésor provides this ecosystem service.

2.5. Fire protection. Some regions in the Guiana Shield can be plagued by (deliberate) fires, in particular in partially logged forests during dry El Niño years (Hammond, 2005). Hammond (2005) calculated on a rough map of forest cover that during the period 1997 and 2003 about 8.3 % of the French Guiana forest had been subject to fire. A mission report of 2 employees of the IUCN Guiana Shield program on reconnaissance mission in French Guiana in 1998 report that '*French Guyana has been fortunate not to have been affected by the forest fires, the reason perhaps being the annual rainfall that exceeds three meter per* [cm]^2 *per year. The small settlers commit some arson and there are the usual little fires in the savanna'* (Muntingh & Veening, 1998). It can therefore be assumed that because of its high precipitation the Kaw-region is probably not prone to fires. As Trésor forms a relatively small component of the total area of tropical, humid forest (see 2.1) its contribution to Fire protection is probably not very high. Therefore, for this case-study it is assumed that Trésor does not provide this ecosystem service.

2.6. Pollination. Although agriculture is taking place around the Trésor area and this agriculture is likely to benefit from pollination services, the service is likely not taking place on such a large scale that significant financial benefits are being reaped. Moreover, as the area that Trésor contributes to the overall ecosystem is likely to be relatively small, Trésor supplies this ecosystem service in negligible amounts. Therefore, for the case-study this ecosystem service will not be included.

2.7. Disease regulation. Although a causal effect has not yet been found it is suspected that ecosystems that are undisturbed by human activities have a regulatory effect on diseases and keep them in moderate quantities (Verweij *et al*., 2009). No information on disease regulation by ecosystems similar to or around Trésor could be found. Therefore, for this case-study it is assumed that Trésor does not provide this ecosystem service.

Provisioning services

3.1. Timber. Timber is an important provisioning service of the Amazon forests (Verweij *et al*., 2009). Although it is strictly forbidden, it is likely that timber is being extracted at a small scale from Trésor. Trésor therefore currently provides this ecosystem service, however undesirably in the eyes of the Trésor organisation. At the time of writing no estimation could be found or given of the scale on which this ecosystem service is being used by whom and is therefore not considered in the case-study.

3.2. Non-Timber Forest Products (NTFPs). NTFPs have been defined as *'all wild plant and animal products that can be harvested from forests or other types of natural ecosystems* [, excluding] *the use of industrial timber, but* [including] *the small-scale use of wood for canoes, crafts, house construction and fuel*' (WWF Guianas, 2012). These can be food, oil products, fibre, rubber, aromatics, medicines, gums, tannins and bioenergy (Verweij *et al*., 2009; WWF Guianas, 2012) and therefore this ecosystem service is actually an umbrella term of what an ecosystem may produce as provisioning service except from timber. However, for many of these products data on their use, harvest or trade do not exist (WWF Guianas, 2012). Currently, no NTFP extraction is taking place by people other than employees from Trésor or people mandated by in Trésor (*e.g.* scientists, for example for Herbarium specimens. Several of NTFPs extracted by or in mandate of Trésor will now be discussed.

* 3.2.1. Ornamental services. Currently, Trésor has provided a *Ficus* plant that is about to enter the commercial markets as ornamental in at least the Netherlands and Europe (Lukkien & Jeurrisen, 2013). It is planned that the cooperation that will commercialize this *Ficus* plant will direct a percentage of the monetary revenue of each of plants sold towards the Trésor organisation. Although it is likely that this project will continue (Lukkien & Jeurrisen, 2013) the project is yet to provide revenues and it is not considered in this case-study.

* 3.2.2. Biochemicals. Trésor is currently setting up a validation project in cooperation with the University of Wageningen and the government of French Guiana to investigate the taxonomy of orchids in French Guiana by their scent. As a side effect the scents of orchids would be commercially investigated (*e.g.* as possible perfumes) and therefore monetary valued. This project is however in starting-up phase and it is therefore unclear what the future is of this project and the applicability to Trésor. This ecosystem service is therefore not considered in this case-study.

* 3.2.3. Medicines. According to the study of Van der Sluis (2007) Trésor has (had) a leaflet containing information on Trésor as source of current and future medicines. Although this leaflet was currently unavailable at the time of writing of this Thesis, the Trésor website hosts a short article written by T. van Andel *PhD* (an expert on medicinal plants amongst other places in the Guianas) who states about the medicinal plants in Trésor: '*The tropical rainforest of the Trésor Reserve contains a very diverse flora. Although research into the medicinal plants that grow in the reserve has not yet been done, the botanical inventory by Renske Ek and*

colleagues offers a fair view on the contents of the medicine treasury of Trésor. The woods and savannahs of the reserve contain a large number of plants whose medicinal effects have been scientifically proven. There are also numerous plants which are being used by the local population in French Guiana, but whose pharmaceutical effects have never been researched.' (Trésor, 2007). Although this states that medicinal plants are indeed present in Trésor, their extraction or use is not known. Therefore, this ecosystem service will be excluded for the case-study.

* 3.2.4. Food. Although strictly forbidden, it is known that illegal hunting is taking place within Trésor from the D6 road (Pineau *et al*. 2008). It is probable that this illegal hunting being practiced by humans to provide for an extra source of protein. Moreover, it is known that occasionally Amerindian people enter Trésor from the Orapu river to illegally hunt for food (Lukkien & Jeurissen, 2013). It is highly likely that this is being done to provide protein to the Amerindian people. Trésor therefore currently provides this ecosystem service however undesirably in the eyes of the Trésor organisation. At the time of writing no estimation could be found or given on the scale on which this ecosystem service is being used by whom and is therefore not considered in the case-study.

* 3.2.5. Fresh water. Trésor receives a lot of precipitation that eventually find its way to the Orapu river. Malotaux (2010) states that the Orapu river functions as source of drinking water for Roura and communities further downstream, citing Fontein (2007). However, no such statement in Fontein (2007) could be found. Lukkien & Jeurissen (2013) confirm that the Orapu most certainly serves as a fresh water source for the Amerindian communities downstream. It can moreover be assumed that it provides the surrounding vegetation and animals with water. For instance, during at least the driest month of the year it would be probable that for agricultural purposes additional water is needed that would be extracted from the Orapu river.

Taking in the suggestion that gold-mining activities in the Kaw-area were banned because of the fresh-water supply to the communities living downstream of the Orapu river, this ecosystem service will be considered in the case-study.

Cultural services

4.1 Non-use values. The awareness of ecosystem services for the future and intrinsic value of nature are non-use values, as these ecosystem services are not being currently used. Trésor clearly has non-use values as its donors are willing to pay for its existence through the adoption of m^2, people make incidental financial deposits to Trésor and employees of the Trésor Foundation and Association are externally financed by the government of French Guiana and the Netherlands (indirectly through the Utrecht University). A study in 2007 into the donors of Trésor showed that of the given options, the recipients valued the protection of plant and animal species the highest and at least one recipient additionally mentioned the protection of the ecosystem (Van der Sluis, 2007; See also Annex IV).

4.2 Recreation and ecotourism. According to Verweij *et al*. (2009) some rainforest areas have become a major tourist attraction. The Trésor area also has important recreational and ecotourism values. Apart from people from French Guiana also tourists are known to visit Trésor for its recreational and ecological value, also because to its relation to the rest of the Kaw area (Kaw-hills and Kaw-swamps).

* 4.3 Educational values. For over 15 years Trésor has had an educational value for the school children of French Guiana. Trésor is used to educate on nature conservation, and ecology and biodiversity of Trésor and tropical forests in general.

* 4.4 Knowledge systems. The expertise of Trésor is being used to improve the managing and monitoring in other Nature Reserves in French Guiana (Lukkien & Jeurrisen, 2013). Presently, this experience is also being used to start up a similar project in Surinam (called The Peperpot Project) (Lukkien & Jeurrisen, 2013).

* 4.5 Other cultural services. People can derive other benefits of tropical ecosystems such as Trésor through for instance their social culture, cultural heritage and spiritual and religious values. It is likely that the native Amerindian populations of French Guiana have such values tied to tropical ecosystems such as Trésor. However, as officially no Amerindian people live in Trésor and data on their visits to Trésor for these purposes are unavailable, these ecosystem services are not considered in the case-study.

IV. Comparison of the value of different land-uses for Trésor

The monetary value that the current identified ecosystem services that Trésor provides can be estimated with the methods of CBA, WTP and RWTP (See also section Valuing ecosystem services, page 14) on the basis of information provided in sections II and III and with the financial year reports of the Trésor Foundation since 1995 (See also Annex V). The monetary value of the current identified ecosystem services that Trésor provides can be seen as a PES value for current Trésor. Additionally, theoretical market values can be used to provide a monetary value for some of the ecosystem services that Trésor provides. The estimated monetary values of the individual ecosystems services can be used to assign value to similar ecosystems.

It can be argued that Trésor, as focal point of 'nature conservationism', i.e. the practice of a broad range of nature conservation practices (e.g. management, monitoring, research and education) produces a multiplier effect on the valuation of Trésor which cannot always be taken as a good estimation of surrounding, similar ecosystems. Therefore, it can be good to distinguish two categories in the estimated values of Trésor: values that are comparable to other, similar ecosystems and values that are more unique for Trésor because of its multiplier effect.

The monetary value of current Trésor scenario

From the current identified ecosystem services that Trésor provides, the following are considered to be relevant for the estimate of a PES value because they are expected to be provided and/or funded in significant amounts:

- Supporting services: Soil formation (1.1); Water cycling (1.2); and Biodiversity conservation (1.3).
- Regulating services: Hydrological services (2.2) and Carbon sequestration (2.4).
- Cultural services: Non-use values (4.1); Recreation and ecotourism (4.2); Educational values (4.3); and Knowledge systems (4.4).

At present, Trésor and its organisation are funded by multiple sources for multiple reasons. From the financial year reports 1995 to 2012 (Annex V) the following types/sources of funding can be distinguished:

- The donors of Trésor,
- Incidental small and large donations (*e.g.* by WWF and the Dutch Lottery; Lukkien & Jeurissen, 2013),
- Cases of CO_2 compensation,
- The external funding of the Conservator and two Park Rangers by the French Government; and
- The external funding of the Coordinator at Utrecht University.

These various contributions that the Trésor Foundation received were for the most part not specifically earmarked and therefore it is not known which percentage of a contribution was given for a particular ecosystem service. Van der Sluis (2010) carried out a study on the motivations of the donors of the Trésor Foundation. The study of investigated the connectivity of communication between Trésor and its donors and found that donors donate money to Trésor for multiple reasons, which can be considered to fall under multiple ecosystem services (Annex IV). As the highest marked reasons are the conservation of animal and plant species, conservation of biodiversity can be considered to be the most important reason for the donors to financially support the Trésor Foundation. The next highest marked reasons are research, education and climate change, respectively (Annex IV).

Taking the findings of the study of Van der Sluis (2010) and the official aims of the Trésor Foundation into account, it can be argued that donors and other external funders can be considered to provide payment for the following of the relevant ecosystem services: soil formation (1.1), water cycling (1.2), biodiversity conservation (1.3), non-use values (4.1) and educational values (4.3). These ecosystem services were paid for in one 'lump sum'. The remaining ecosystem services: Hydrological services (2.2), Recreation and ecotourism (4.2) and Knowledge systems (4.4) fall out of the lump sum because they were not specifically referenced in the findings of the study of Van der Sluis and the official aims of the Trésor Foundation. Additionally, the ecosystem service Carbon sequestration (2.4) was the only ecosystem service that was specifically earmarked in the financial year reports.

Supporting services are often left out of valuation as their value is already represented in the ecosystems services they support. This reasoning seems to also applicable to the Trésor case. Excluding these ecosystem services in estimation of the PES value of Trésor leaves the assumption that the ecosystem services of non-use values (4.1) and education values (4.3) are being paid for by the lump sum.

Non-use and Educational (4.1 & 4.3) values

Non-use and Education values are being paid for by various sources. RWTP can be used to estimate the contribution of the donors, sponsors of Trésor as well as the organisations that are funding employees of the Trésor organisation to these ecosystem services. Additionally, WTP can be used to estimate an additive monetary value for Educational values represented by the costs made for visiting Trésor for educational purposes.

An investigation by the author into the exploitation accounts of Trésor between 1995 and 2012, shows that when excluding the assets received for specific ecosystem services, in total an amount of € 2,099,968 (€ 2.1 million) has been donated between 1995 and 2012 (See Annex V). This means that taking the size of Trésor of 2464 ha into account, the Non-use and Education values of Trésor have been valued at around 47.6 €/ha/yr (equalling 61.6 US$/ha/yr).

The exploitation accounts of Trésor do not mention the contributions of Utrecht University and by Région Guyana to the Trésor Foundation or Association. According to the financial year reports of the Trésor Foundation, the Foundation was hesitant to express these contributions in monetary value.

No current valuation exists of the contribution of the Utrecht University to the Trésor Foundation. However, the pay for the coordinator by Utrecht University (0.2 FTE) including office costs and other, diverse costs was estimated on a € 45,000 *per* year in 2003 (Lukkien & Jeurissen, 2013). For easy comparison, it is assumed that the contribution of the Utrecht University to the coordinator did not increase over time, ignoring inflation corrections and natural growth in salary. The latest financial year report of the Trésor Foundation argues that the monetary value of the salary of the three employees of the Association provided by Région Guyana would be around € 73,000 (Trésor, 2013c). For easy comparison, it is assumed that this estimate represents all financial contributions of Région Guyana, ignoring the fact that Région Guyana was/is also proving an office to the Association.

Together, the government of French Guiana and Utrecht University currently fund Trésor with around € 118,000/yr. This represents *ca.* € 48/ha/yr (equalling 62 US$/ha/yr).

An appended value to the Educational value of Trésor can be provided by calculating the money spent by people traveling to Trésor for educational purposes, in this case a guided activity. According to the financial year report of 2012 (Trésor, 2013c) a total of 398 people visited Trésor in 2012 for an educational activity, all of whom all originated from the village of Roura. Assuming that:

- All of these people travelled to and from Trésor by car as no public transportation exists to and from Trésor and schools from villages probably do not have busses to use;
- Around 4 people populated each car;
- The cars used petrol as fuel;
- Drove around 14 km *per* litre;
- The distance from Roura to Trésor is around 20 km; and
- The petrol price in French Guiana was around € 1.5 *per* litre,

Then this would amount to a total of € 389 traveling costs for educational purposes by people visiting Trésor over 2012. This resembles an additional € 0.17/ha/yr (equalling 0.22 US$/ha/yr) worth of educational value.

It must be noted that Educational visits to and from Trésor target not only Trésor specific topics but also subjects of nature conservation in general. These last subjects could also be taught if Trésor would not be available. Because it is unknown what specific subject are addressed during the educational activities of Trésor, Trésor specific subjects will be estimated to make up 50 % of the educational programmes.

Taking the estimates of 61.6 and 62 US$/ha/yr together provides a lump sum value of 123.6 US$/ha/yr for the Non-use and Education ecosystem services. It is currently impossible to accurately divide this lump sum over non-use and education values. For practical reasons, this division is estimated at 50:50. With this division Non-use values and Educational values are both estimated at ~61.8 US$/ha/yr.

The Educational value has the additive value of 0.22 US$/ha/yr but the total amount must be divided by the factor two because of the contribution of Trésor to the total educational programmes. Taking this and the above into account, the following estimates can be given:

- Non-use values: ~61.8 US$/ha/yr
- Educational values: ~61.8 + 0.22 = 62 US$/ha/yr of which 31 US$/ha/yr is the value that is provided specifically for Trésor

Recreation and ecotourism (4.2) value

A value of Recreation and ecotourism can be estimated by using the costs of the trip for donors of Trésor and the visits that people made for recreational and ecotourism purposes.

The Tourism bureau JungleTours has been organising a yearly trip for normally 19 of the donors of Trésor in cooperation with the Trésor Foundation since 2003 (Lukkien & Jeurissen, 2013). Only in the initial year of 2003 was the trip incorporated into the exploitation overview of Trésor; afterwards it was deliberately kept out the exploitation of Trésor (Lukkien & Jeurissen, 2013). However, the current price can be used with the RWTP method to provide an estimate of the Recreation and ecotourism value of Trésor.

The donors-trip to Trésor in 2013 will cost € 3200 *per* person in which the trip visits Surinam and French Guiana during 23 days (including traveling hours) (JungleTours, 2013). Roughly a week of this trip will used to visit Trésor with the surrounding Kaw-area for which the employees of Trésor will assist the trip the whole week (Lukkien & Jeurissen, 2013). Of this week, 2 days will be actually spent in Trésor (Lukkien & Jeurissen, 2013). Overnight stay and food is included in this price (JungleTours, 2013).

If it is assumed that the salary of the employees falls out of the estimation for a monetary value of ecotourism, it can roughly be estimated that since 2 of the 23 days will be spent in Trésor, the ecotourism value of Trésor of the donors-trip is 2/23 of € 3200, which is *ca.* € 278 *per* person *per* year. If it is then assumed that the trip will always be made by 19 persons it would amount to € 5287/yr which is *ca.* 2.1 €/ha/yr (equalling 2.8 US$/ha/yr).

An estimate on the further recreational and ecotourism visits can be made with the WTP method. Unfortunately, no information was available at the time of writing on the actual amount of tourist visits Trésor receives each year except from the donors-trip. However, a rough estimate can be provided by extrapolating the preliminary amount by the counting mechanism of visitors *per* month (*i.e.* 50 to 100; Trésor, 2013c) for a year. This would mean that Trésor would have been visited by 600 to 1200 people in 2012. As it is known from the activities reported in the year report 2012 that for educational purposes a total of 728 people have visited the education trail and when it is assumed that people that visited Trésor for an educational purpose always visited the educational trail (this is where the counting mechanism is located) then Trésor would have had the visit of between minus 128 and plus 472 tourists, on average 172.

The costs of recreation and ecotourism would consist of travel costs, overnight costs and food, as access to Trésor is free. A rough estimate would be that if it is assumed that of the average 172 people that visited Trésor in 2012:

- People did not visit Trésor as the main purpose but tended to stay at least a couple of days in the area, assumed on average a total of 4;
- They would all sleep and eat in an inn with similar accommodations and prices of that of other tourist service suppliers, *e.g.* € 145/person/night (full board; En Foret Guyana, 2013);
- Initial travel is based on the distance between Cayenne and Trésor; assumed 50 km;
- Additional traveling distances would be on average 20 km *per* day; and
- People travelled by car with one other person which was rented for *ca.* € 170 (based on EuropCar French Guiana), runs on petrol and drives 14 km on 1 litre;

Then *per* couple such a trip would cost *ca.* € 618. If Trésor is visited one of the total four days then this would amount to € 155. If all the 172 people spend € 155 *per* couple on Trésor then a total of € 13,284 would have been spent on visiting Trésor in 2012, which resembles € 5.4/ha/yr (equalling *ca.* 7.0 US$/ha/yr). It must be noted that this estimate does not take the large costs such as travel costs to and from French Guiana into account and therefore likely is an underestimation of the real WTP value.

Together, the values of Recreation and ecotourism of Trésor equal to 2.8 + 7.0 = 9.8 US$/ha/yr.

Hydrological services (2.2) and Fresh water (3.2.5.) value

It has been argued in sections II and III that Trésor provides Hydrological and Fresh water services to people living downstream of the Orapu river in the form of drinking water, by providing a current fish stock for consumption and other hydrological characteristics. If the use of Trésor would be severely altered, these services are likely to decrease.

When it is assumed that the ban on gold-mining activities in the Kaw area was caused by the importance of the Trésor and surrounding area to the drinking water supply to the communities downstream of the Orapu, then this information can be used to estimate a value of this service. To estimations can be made with the CBS method: one with the use of the compensation claim of the IAMGOLD company and the other with an estimation of the use of drinking water.

The current owner of the concessions recently valued the damages of not being able to exploit the gold supply at € 763 million (Annex VII). This estimate could however not be checked at the time of writing. Verweij (2013) estimated the damages € 600 million on the basis of memory of a quoted figure. In this view, the Trésor and surrounding areas would be valued between € 600 – 763 million for its Hydrological and Fresh water services.

It is currently not known what the contributing factor of Trésor is in the whole area providing the water catchment and controlling the characteristic of the Orapu river. If it is assumed in lack of better data that the Trésor area contributes $1/14^{th}$, then Trésor for its Hydrological and Fresh water services in total is valued at a net present value of € 43 – 55 million. This equals to 17,393 – 22,119 € *per* hectare. If we take into account that most gold mining operations start and stop within 15 years (Hammond, 2005) this net present value represents an average 1160 - 1475 €/ha/yr (equalling 1507 - 1917 US$/ha/yr).

The population numbers of Roura and Cayenne form a total of 61,750 (see Section II). To include possible Amerindian people, this value is rounded off to 62,000 people that are estimated to be dependent on the Orapu river drinking water supply. In 2010 the annual cost of drinking water in French Guiana ranged from 15.1 to 12.4 US$ depending on whether it was being provided through a house connection or a well (World Health Organization, 2012). Because it is unknown what percentage of the 62,000 people have a house connection or use a well for their water supply, the yearly costs are averaged at 13.8 US$. The total drinking water's worth of the Orapu river would then be 880,000 US$. Assuming the same contribution factor of Trésor of $1/14^{th}$, the hydrological services of Trésor would be worth 26 US$/ha/yr (equalling 20 €/ha/yr).

These two estimated ranges together form a range of 26 - 1917 US$/ha/yr for the value of the hydrological and Fresh water services of Trésor.

Carbon sequestration (2.4) value

As was estimated in Section III, Trésor probably contains between 442.3 to 619.4 Gg of carbon *per* hectare and sequesters 0.48 to 2.94 Gg carbon *per* year. This carbon currently has monetary value as carbon emissions have to be financially compensated. The Trésor Foundation and other voluntary markets currently provide the option to financially compensate CO_2 emissions. These financial compensations can be used as a RWTP method to provide a estimate on the value of Carbon sequestration.

Trésor provides the option to let people compensate their CO_2 emissions from travelling by car and plane through financially supporting Trésor. According to the Trésor website the Trésor area sequesters a net 700 to 4400 kg of CO_2 *per* hectare *per* year (Trésor, 2013b). Trésor has received financial CO_2 compensations since at least 2009 (Lukkien & Jeurissen, 2013). Unfortunately, these contributions have not been earmarked in the Exploitation overviews. Scanning the texts of the year-reports of 2005 to 2012 for the words 'CO2' returned the mentioning of a total of 6 donations for CO_2 compensations between 2008 to 2012. These amounts have been declared under the exploitation post of 'sponsors' but were subtracted for this Thesis from the initial amount for comparison (See Annex V).

The current and recent Treasurer of the Trésor Foundation cordially investigated an account of donations separate from the year reports on CO_2 compensations. In this investigation the total amount of € 1215 through CO_2 compensations was found up to July 2013 (Schuurmans, 2013). This amount was probably accounted over the years in the post 'donations' (Schuurmans, 2013).

Taken together, a total of € 13,222 was donated to Trésor between the years 2008 and 2012 as CO_2 compensation (Annex V). Divided by the amount of years (five) and the larger reported size of Trésor used in the calculations of the carbon content and sequestration of Trésor (2479 ha; Kruijt *et al*., 2006), the total value of Carbon content through the Trésor Foundation can be estimated at to 1.0 €/ha/yr (equalling 1.4 US$/ha/yr).

Currently, two important policy mechanisms are under development which are relevant for the monetary value of the carbon content and sequestration of Trésor.

Firstly, the Kyoto protocol, an international agreement between a large set of countries (or 'parties') from all over the world, tries to limit greenhouse gas (GHG) emissions such as CO_2 through amongst other things, providing a financial market for trading carbon emissions. It proposes that developed countries and countries whose economy is in transition (Annex I Parties) financially reward the developing countries (Annex II Parties) for reduction of their GHG emissions by fossil fuels. In order to prevent countries to emit GHG by deforestation or forest degradation the Reduced Emissions from forest Degradation and Deforestation mechanism (REDD) is being initiated. In short, under REDD payment will be provided to Annex II Parties for keeping their forest standing. However, French Guiana, as part of France, is officially an Annex I Party and can therefore not receive benefits from the REDD mechanism.

Besides the REDD mechanism, voluntary trading mechanisms are being set up in and between the Annex I Parties. The existing voluntarily markets for carbon emissions in 2010 on average provided 5.60 US$/Mg CO_2 emission (Diaz *et al*., 2011). Kruijt *et al*. (2006) provides an estimate of yearly carbon sequestration by Trésor in the abstract of the report of 0.5 to 3 Gg carbon. Despite that it is not specifically stated, this estimate probably reflects the reported 0.48 to 2.94 Gg carbon sequestration *per* year as reported in the result section of the report. If this last carbon sequestration rate is converted to CO_2 emissions by a 3.67 factor (Watson, 2009) and valued with the average from the voluntary markets, then Trésor would have an theoretical estimated monetary value between 9865 – 60423 US$/yr. Compensating this value for the amount of hectares of the Trésor area used by Kruijt *et al*. (2006), this amounts to a range of 4.0 - 24.4 US$/ha/yr (equalling 3 – 18.7 €/ha/yr).

Knowledge systems (4.4) value

Currently the expertise of Trésor is helping improvement of management of other nature reserves in French Guiana through CEN and developing the Peperpot Project. However, at the time of writing no structural funds have been provided (or reported) for Trésor for these activities. Together with the fact that Peperpot is still in its start-up phase and no financial accounts were available at the time of writing, it is therefore impossible to provide an estimate on this service of Trésor.

Overview of estimated monetary value of the ecosystem services of Trésor

To compare the PES monetary values of Trésor, the values based on market values for Trésor and other similar ecosystems, table 4 was established.

Table 4. Overview of the estimated monetary value of the ecosystem services that Trésor provides. All estimates in in US$/ha/yr. Total range Trésor consists of data estimated for current Trésor, actual PES values with additional estimated values. Trésor estimates are only the current PES values of Trésor. Other estimates are values of similar ecosystems as Trésor, where: NA is Not Available, [a] is data from this report, [b] is data from Verweij *et al*. (2009).

Ecosystem service	Total range Trésor	Trésor estimates	Other estimates
Hydrological + Fresh water	26 - 1917	NA	26 – 1917[a]
Carbon sequestration	1.4 - 24.4	1.4	4.0 – 24.4[a]
Non-use values	61.8	61.8	10 – 26[b]
Educational values	31 - 62	62	31[a]
Recreation and ecotourism	9.8	9.8	3 – 7[b]
Knowledge systems	NA	NA	NA
Total	**130 - 2075**	**135**	**-**

It can be seen in table 4 that the estimated possible value range for Trésor does not necessarily predict the actual value that is being paid for. Currently, Trésor is being valued at 135 US$/ha/yr ('Trésor estimates') which resembles the current PES value of Trésor. The PES value can sometimes be lower and higher than the predicted possible total range for Trésor. For instance:

- The PES value is lower for the Hydrological + Fresh water services because, according to this case-study, they are not currently being paid for;
- The PES value is also lower for Carbon sequestration than the estimated worth on the voluntarily markets; and
- The PES value for Educational values is higher because Trésor is also receiving funds for education on Nature conservation in general, which is not specifically linked to Trésor.

Not all of the PES estimates can be used to value similar ecosystems because of the discussed multiplier effect that Trésor provides. 'Other estimates' are the monetary values that should be representable for similar

ecosystems such as Trésor, which have been estimated based on data used in this Thesis or on data from areas outside Trésor (*i.e.* from the study of Verweij *et al.*, 2009). In cases for which data from both sources were available, data from Trésor was preferred as it should represent more up to date data.

It can be seen that the Trésor specific estimates differ from other non-Trésor specific estimates although the order of magnitude is the same. Nevertheless, caution must be applied when using the economical estimates for the ecosystem services of Trésor for other, similar ecosystems.

The monetary values of exploited Trésor scenarios

The same information used to estimate the PES value of Trésor can be used to estimate monetary values of alternative land-uses.

When protection is excluded as land-use the most probable alternative land-uses for the Trésor area are those that are being carried out in the vicinity, in a similar environment. In French Guiana gold-winning has been a popular land-use since at least 1900 and gold production has seen exponential growth since 1990s (Hammond, 2005). Unfortunately, exact estimates of the current gold deposits in Trésor and estimation methods to express these into a monetary value were unavailable at the time of writing. Therefore, a specific estimate on the gold value of the Trésor area could not be made.

In the neighbouring country of Brazil, which also hosts parts of the Amazon forest, several possible alternative land-uses are known and have been studied. Butler & Laurance (2009) investigated several land-uses in Brazil, including the potentially emergent oil palm agriculture. Butler & Laurance (2009) provide a practical overview of different land-uses in Amazonia and their net present value (accounting for a multiple year's worth of exploitation) which is presented in figure 5.

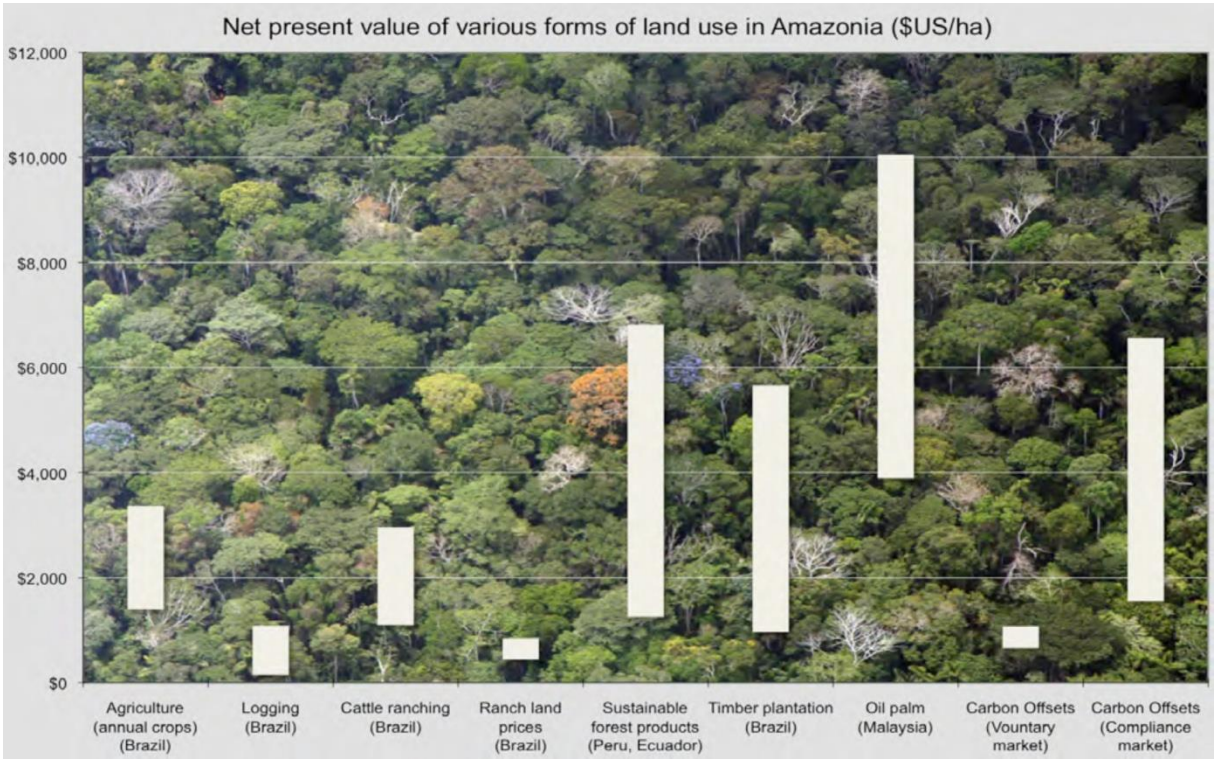

Figure 5. Net present value of various forms of land use in Amazonia in US$/ha. Taken from Butler & Laurance (2009).

For practical reasons, four land-uses where chosen for further investigation from these alternatives: logging, cattle ranching, sustainable forest products and oil palm.

To allow a comparison of net present values with the annual PES value of Trésor *per* hectare, the net present values must be converted into an estimate *per* hectare *per* year. From Butler and Laurence (2009) and their used references it is not always clear what the annual values *per* hectare are or on what time span the provided net present values were calculated. To still provide a crude estimate of the value *per* year, the present value was converted into an estimate *per* year by using a linear decreasing function based on the net present value as the total revenue and a cited average operating time as the maximum time limit.

The references cited in Butler and Laurence (2009) provided the following l information:

- Logging: Clear cutting is worth a single 1,000 US$/ha (Peters *et al*., 1989).
- Cattle ranching: Butler and Laurence cite personal communication with J.C. Carter in 2007 so the details of the calculation cannot be checked. The estimate that Butler and Laurence provide seems to be *ca.* 2,800 US$/ha based on figure 5.

- Sustainable forest products: Peters *et al*. (1989) estimate that the sustainable harvest of timber, fruit and latex harvest in the patch of forest they investigated had the net present monetary value of 6,820 US$/ha. The annual harvest of fruit and latex would provide 422 US$/ha/yr and 310 US$/ha for each cycle of sustainable use, which according to Peters *et al*. (1989) is every 20 years. If we convert the timber value *per* hectare *per* 20 year into a yearly average (310 US$/ha/20 years) this is comparable to 15.5 US$/ha/yr. When this is added to the estimate for fruit and rubber, together this land-use is estimated at a mean 437.5 US$/ha/yr.
- Oil palm: According to Butler *et al*. (2009) oil palm plantation can yield a value of 3,835 to 9,630 US$/ha/yr depending on the suitability of the land for oil palm and the initial costs of converting lands into an oil palm plantation.

With these four land-uses the following three sub-scenarios can be set:

Scenario 2.1: The Trésor area is logged and then kept for cattle ranching.

For this scenario it is assumed that in one year Trésor is completely logged and afterwards the land is immediately suitable and used for cattle grazing. According to Mattos & Uhl (1994), historically since the 1960s most pastures for cattle ranching in the eastern Amazon were abandoned within 10 years because of a decline in soil fertility, invasion of weeds or overgrazing. Taking this maximum into account, the function of the economic revenue of this scenario shows a onetime 1,000 US$ *per* hectare and then the total revenue of 2,800 US$/yr with a gradual decrease to 0 US$ within 10 years.

Scenario 2.2 Trésor is sustainably harvested for timber, fruit and latex.

For this scenario it is assumed that Trésor provides the same timber, fruit and latex revenues as supposed in Peters *et al*. (1989). According to Peters *et al*. (1989) sustainable harvest is possible when a maximum timber harvest of 30 m^3/ha (of the measured 93.8 m^3/ha available) every 20 year is achieved. However, sustainability is often not actually reached with initial assumptions and according to Verweij *et al*. (2009), with a rotational cycle of between 20 to 40 years each new cycle only 20-30% of the volume of the previous year will have been regenerated. Taking this all into account the function of the economic revenue of this scenario shows a stable revenue from fruit and latex but a gradual decrease in timber revenue over the years until a timber revenue is reached of 0.00 US$.

Scenario 2.3 Trésor is used as oil palm plantation.

For this scenario it is assumed that Trésor is converted into a high-yield oil palm plantation. According to the assumptions of the estimation of Butler *et al*., (2009) for Trésor to be a high-yielding oil palm plantation, the available timber is used to facilitate the conversion of the land into an oil palm plantation. Although the aspects of sustainability of oil palm plantations are not often addressed, it can be expected that oil palm plantations are not sustainable as in a standard oil palm plantation the nutrient cycle is disturbed. Within the time-limitations the only study that was found that addressed the life-cycle assessment of an oil palm plantation estimated that an oil palm plantation yielded oil up to 25 or 30 years (Mattsson *et al*., 2000). Taking this all into account the function of the economic revenue of this scenario shows a gradual decrease in oil palm revenue over 30 years until a revenue is reached of 0 US$.

Comparison of the scenarios

With the PES value and the alternative land-use values a comparison can be made to what extend the PES value of Trésor provides a higher financial incentive relative to the alternative land-uses.

For a practical comparison the functions of the economic revenue for the four scenarios are plotted in in a graph (figure 6).

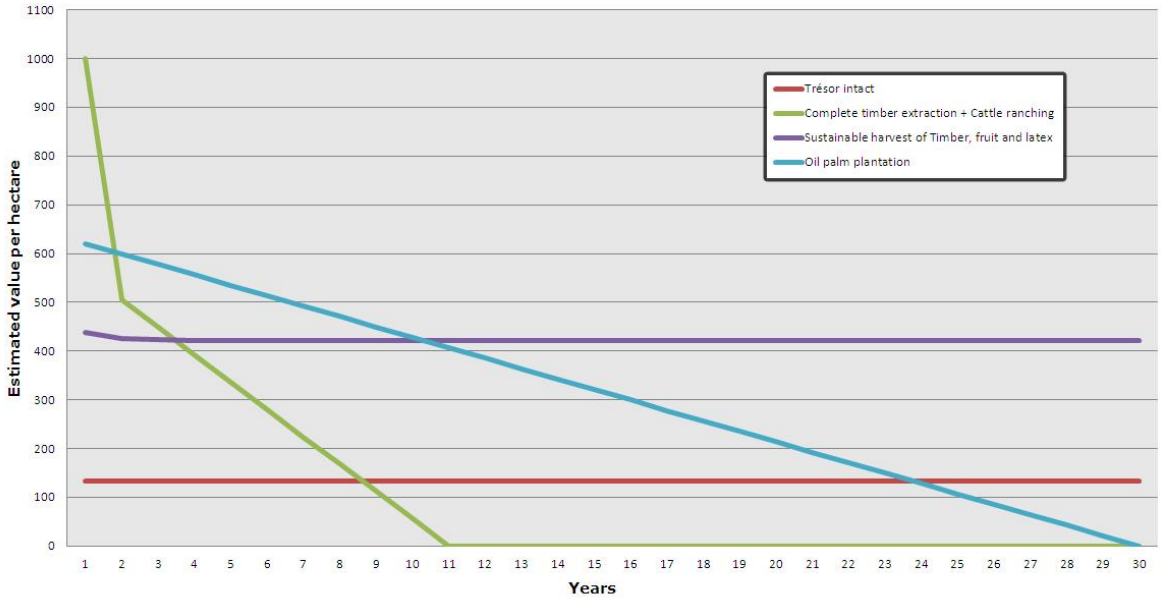

Figure 6. The yearly evolution of estimated value of a hectare of Trésor under different scenarios.

The break-even point in which the current PES value of Trésor will have provided the same amount of revenue that is estimated in the net present value can also be calculated. When the net present values are taken from Butler & Laurance (2009) these break-even points can be calculated with the PES value of Trésor. These break-even points are shown in table 5.

Table 5. Overview of the break-even points of the current value of Trésor against net present values of three scenarios.

Scenario	Break-even point reached after
2.1 Logging + Cattle ranching	28 years
2.2 'Sustainable' harvest	51 years
2.3 Oil palm plantation	71 years

In figure 6 can be seen that although initially all alternative land-uses have a higher monetary value *per* hectare, over time Trésor eventually will produce higher economic gains in comparison to the Logging + Cattle ranching and Oil palm plantation scenarios. For the scenario of complete timber extraction and cattle ranching, this point is reached after 9 year and for the scenario of an oil palm plantation this point is reached after 24 years (figure 6). The scenario of 'sustainable' extraction of timber, fruit and latex in this study always will provide a higher monetary value *per* hectare.

It can be argued with this comparison that the only way that the current land-use of Trésor will provide a financial incentive that is higher than the other addressed land-uses is when the person or body making the decision has a time-horizon of more than 71 years (table 5). Such a time-horizon is unlikely to be used by a single person, in particular when the person is in need of financial resources on the short term.

Nevertheless, the payment that Trésor currently receives for its ecosystem services can theoretically provide the financial incentive to protect the current Trésor ecosystem as long as there is a long time-horizon. Whether the payment that Trésor currently receives for its ecosystem services would actually stop a different person to follow a different land-use Trésor depends on the person, specifically, his or her time-horizon and need for short term economic gain.

Figure: the value of ecosystem services.
Copyright Waller.

Discussion and possible recommendations

Scope and demarcation

For this Thesis the focus was laid on tropical ecosystems because of their relative importance to biodiversity and the many gaps in knowledge science currently has on tropical ecosystems. Taking the findings of this Thesis into account, no reason was found to doubt the relative importance of tropical ecosystems. Because it was found in this Thesis that hardly anything was known about the contributions of PES to nature and it is suggested that PES schemes are currently hastily being adopted (Gómez-Baggethun *et al*., 2010; Kumar *et al*., 2013), the importance of the research question was further underlined. It is therefore recommended that the efficiency of PES schemes is further investigated by the scientific community and communicated to the relevant policy makers.

Definitions

To answer the Thesis question it was decided that several definitions would be used in this Thesis: The CBD definition of ecosystems and biodiversity and the MA definition and classification of ecosystem services. The use of these definitions caused no practical problems during the investigation of this Thesis.

To facilitate comparison of economic values by the Thesis audience, monetary values of ecosystem services were expressed in US$ and in € were practicable. A constant conversion rate of € 1:1.3 US$ was chosen for the report even though in reality the conversion rate is not constant. An *ad hoc* short investigation into a yearly average shows that the actual exchange rate between 26 July 2012 and 26 July 2013 averages on 1.2985 (ECB, 2013) so this conversion rate was accurately chosen for the present. If the data from this Thesis would be used further it is advisable to recheck this conversion rate.

Trésor as case-study

In advance of the research carried out for this Thesis it was decided that Trésor would be used to answer the Thesis question. Therefore, the demarcation and approach were adapted to include Trésor as a case-study. This resulted that Trésor was a *de facto* good case-study for the answering of the Thesis question. A discussion on its potential of being a suitable case-study was therefore not necessary.

In hindsight, the in advance decision to take Trésor as a case-study to investigate the Thesis question proved to be very practical as the literature study returned little relevant data. It also increased the social impact of the Thesis because of the expected demand for information on the ecosystem services that Trésor provides the description of the Trésor organization and the impact that Trésor has had over the years by *i.a.* the Trésor Foundation, the French Government and other parties.

Approach

The approach to cluster the results into four chapters proved to be a practical approach as this allowed the answering of the Thesis question based on a literature study and on the basis of the case-study of Trésor. A possible disadvantage of this approach is the unclear organization of the usually separate results and discussion sections. Often some discussion had to be made within the clusters in order to be able to provide data to be used in the next section. With the taken approach, implications of chosen assumptions may not be clear and assumptions could not always be thoroughly checked.

In this Thesis many assumptions have been made because of time-constraints and lacking data. In general a point of discussion would be whether or not these assumptions are realistic and supported in the literature. However, to discuss this for every assumption would be impractical but also unnecessary as the chosen assumptions provide a rough comparison which should be sufficient to answer the Thesis question within the set time-limitations. Nevertheless, some important discussion points of the chosen approach can be identified, which will be briefly discussed.

Literature study on the impact of PES on nature conservation

Hardly any relevant information on the efficiency of PES in conserving nature was found by using the search query. Wunder (2007) states that PES schemes in developing countries 'remain poorly tested', which suggest that literature that focusses on developing countries is scarce. The idea that information on the efficiency of PES schemes is lacking seems to be confirmed by the following a statement from Gómez-Baggethun *et al*. (2010): '*note that* [PES schemes] *are being adopted with great speed, and often without much critical discussion across the spectrum of conservation policy debate, developing a life of its own independent of its promulgators*'.

Nevertheless, time that PES schemes supposedly have been running suggest that there must be information available. It is therefore probable that the used search query was inadequate. Because of time-limitations the research query for literature on the efficiency of PES schemes on nature conservation focussed mainly on digital literature, which was found by using the chosen search words in Google Scholar as given in the approach and the possible relevant cited references in the found literature. To allow finding of more relevant literature it is recommended that a future search query incorporates additional search words such as 'agro-environmental funding', uses un-digitalized literature and additional expert knowledge.

The view that the scarcely found literature suggests is that PES schemes do not guarantee that a sufficient economic incentive is created. This can be due to the fact that not all ecosystem services are being taken into account, economic undervaluation, or not enough ecosystem services are being provided. The literature furthermore suggests that a higher economic incentive does not immediately lead to a positive effect, and if so, this is only marginal.

Establishing an preliminary overview of research in relation to Trésor

A preliminary overview of the research carried out in relation to Trésor was made to identify possible relevant literature. This preliminary overview is shown in Annex III. Although not complete, the overview presented is already extensive and multiple studies were found to be relevant and usable on the basis of their title and language, *i.e.* Doomen (2003), Kerharo & Ferrier (2005/2006), Ek *et al*., (2006), Ek *et al*. (2009), Kruijt *et al*. (2006), Fontein (2007), Morison (2009), Malotaux (2010), Breeman (2011), Duden & Roeling (2011), Laporte-Bisquit (2011), Mitsiou (2011) and Boeraeve & Zomer (2012). These items were scanned to ascertain their added value in consultation with V.P.A. Lukkien *MSc*. The MSc, BSc and Higher education reports and/or theses were treated with relative additional scrutiny because they were products of persons who were still being trained in the practice of science. The resulting selection was used in this Thesis and can be found cited in the References. Unfortunately, Laporte-Bisquit (2011) was unavailable at the time of writing and could therefore not be scanned. The information provided in this Thesis resembles a synthesis of the relevant and accurate data on Trésor (See the Annexes).

For future research and easy access it is recommended to the Trésor Foundation that the overview of research carried out in relation to Trésor is made complete and the studies are made available. It is also recommended to investigate and translate into English (at least the main points of) the possible relevant studies that have been reported in a language other than English.

Overview of the current ecosystem services of Trésor

On the basis of Verweij *et al*. (2009), Fontein (2007), Malotaux (2010) and the author's own insights, the possible applicable ecosystem services of Trésor were identified. From this selection a list of current ecosystem services was established on the basis of available data and reasoning, which is shown in figure 4.

The selection of possible applicable ecosystem services includes all the ecosystem services that could be proposed based on the current information. It is possible that with new information additional or specifications of existing ecosystem services can be identified that Trésor currently is providing. However, because the data and sources that were used for the selection can be considered to be comprehensive, this should not be likely.

The discussion on ascertaining which ecosystem services were relevant for Trésor was sometimes difficult because of a lack of data, for instance in the discussion on possible Hydrological services (2.2) and the possible Corridor function (1.4). Overall, it can be argued that in order to be sure that a complete and justified overview of current ecosystem services is established, additional research must be carried out to confirm the irrelevancy of the selection of possible applicable ecosystem services that have not been taken into consideration. For some

of the ecosystem services the necessary information could be retrieved relatively easy, for instance with Hydrological services (2.2) or Other cultural services (4.5). In other cases, more exact estimations must be made, for instance the contribution Trésor has on the larger ecosystem, *e.g.* in the case of Hydrological and Fresh water services (2.2 and 3.2.5). This could for instance be estimated by using GIS-software. Using GIS-software to express the ecosystem services of Trésor would furthermore facilitate possible future comparisons of similar ecosystems and their ecosystem services.

The Non-use value of Trésor could be further established by exploring the potential of Trésor to provide marketable timber and other, not yet mentioned marketable NTFPs, such as *'plant oils, resins and latexes, fibres for furniture and handicraft manufacture, food plants, collection of wildlife for the pet trade, and fish and bushmeat'* as well as *'biochemical components of plants and animals'* (Hammond, 2005).

It is therefore recommended to the Trésor Foundation that in order to make a complete and justified overview of the current ecosystem services that Trésor provides, all possible applicable ecosystem services are re-assessed in an follow-up investigation with additional information. Furthermore, it is recommended to the scientific community and the Trésor Foundation map the current ecosystem services by using GIS-software to facilitate comparison.

Figure 4 shows the current ecosystem services of Trésor as found in this Thesis. This overview also includes ecosystem services that are being used unwantedly by the Trésor organisation, such as Timber (3.1) and Food (3.2.4) because regardless of their desirability, they are ecosystem services that Trésor provides and which are being used. Ornamental services (3.2.1) and Biochemicals (3.2.2) are also already included because projects utilizing these potential ecosystem services have already been started up and it is likely that they will be continued in the future. Medicines (3.2.3) and other NTFPs are currently not used but as Trésor promotes their presence as reason to protect Trésor, they have been included in the overview.

Estimating the monetary values of the current ecosystem services of Trésor

Estimations of monetary value

Economical valuations of ecosystem services in the literature are expressed in the unit currency *per* hectare and if possible, *per* year. However, caution must be applied with this approach for it assumes that all hectares are the same, which can lead to skewed valuations. In reality, the Trésor ecosystem consists of at least six biotopes. For instance, the value of ecotourism is partly based on visits to the educational trail of Trésor, which is laid out in only two of the biotopes of Trésor: plateau forest and forests on slopes. People indirectly pay only to see these biotopes and therefore the derived valuation of ecotourism is potentially inaccurate for the other biotopes of Trésor. This maybe the same case for other ecosystem services, however, as all other literature used this unit of expression, it is advisable to use this unit to allow comparison. If necessary, a more accurate estimation *per* biotope and this for the whole of Trésor may be provided with the use of GIS-software, in which multiple biotopes can be distinguished and are taken into account.

Hydrological services

To estimate the potential value of the Hydrological services (2.2) of Trésor two estimations were used. One of these estimations assumed that gold mining activities in the Trésor area were banned because of the importance of the drinking water supply to the downstream communities of Cayenne and Roura, as suggested. However, this assumption has, to the knowledge of the author, never actually been confirmed by the French government. According to the IAMGOLD website a (more) reasoned statement of the French government to ban mining activities in the Trésor area was released in 2010 (Annex VII), but this statement was unfortunately unavailable at the time of writing.

It is therefore recommended to aquire access to this statement or to ascertain in another way the reason to ban gold mining activities in the Trésor area so this assumption can be checked.

With the stated assumption the missed revenue of gold mining in the Trésor area could be used to provide an estimate on the value of hydrological services of Trésor. Unfortunately, the EAR reporting on actual gold deposits was unavailable at the time of writing and the author had insufficient experience and time-resources to provide an own estimation of the missed revenues. Therefore the estimate of IAMGOLD was used although IAMGOLD is the beneficiary of the damages claim together with an anecdotal estimate from Verweij (2013).

If the assumption proves to be justified, it is recommended that the EAR is accessed and a better estimate is provided with an independent and reasoned estimation on the missed revenue of gold mining.

The other estimation consisted of assuming that the total population of Cayenne, Roura and Amerindian people downstream of the Orapu river partly used the hydrological services of Trésor for their drinking water. It was however unknown if indeed this is the case. Moreover, although estimates of the inhabitants of Cayenne and Roura are probably accurate, the relevant Amerindian population was estimated at 250. However, this estimate was based on the fact that Amerindians have been reported to live downstream of Trésor and to practically round off the total affected amount of people to be further used in the estimation. Therefore, this amount of Amerindian people is likely to be incorrect.

If this estimation proves to be justified, it is recommended that a better estimate is established with additional data on how many people downstream are using these hydrological services.

Carbon content and sequestration

Although a new carbon content of Trésor was estimated, the within the time-restrictions explored payment schemes for present carbon storage and carbon sequestration that were applicable for French Guiana only targeted carbon sequestration. Therefore, only the reported carbon sequestration of Trésor was used to estimate its possible market value. However, it is possible that also payment schemes for present carbon storage exist that are applicable to Trésor.

To provide a better estimate of the theoretical market value of the carbon content of Trésor it is therefore recommended to explore all the possible current payment schemes applicable for Trésor.

The only report that provided an estimate on the carbon content and sequestration rate of Trésor was that of Kruijt *et al*. (2006). However, because the report of Kruijt *et al*. (2006) resembles a '*quick scan*', was not (publicly) peer-reviewed to the knowledge of the author, made assumptions on *e.g.* allometric functions, carbon sequestration and biomass to carbon ratios applicable for the year 2006 and used a deviating size of Trésor which is larger than the normally reported size, the estimates of Kruijt *et al*. (2006) may not represent a currently justifiable estimate. However, because no other reports were available that targeted the carbon content and sequestration of the whole of Trésor area and because of time-limitations, the estimates were nevertheless used in the Thesis. Nevertheless, it can be stated that found positive carbon sequestration rate by Kruijt *et* al. (2006) is in line with the other studies on the sequestration rates of the Amazon forests quoted in the study of Verweij *et al*. (2009).

It is therefore recommended that a new study on the carbon content and sequestration rate of Trésor is made that consolidates and reflects on all other reports that have made a relevant estimate of carbon content for (parts of) Trésor, including that of Kruijt *et al*. (2006)

The amount of carbon sequestered according to Kruijt *et al*. (2006) was converted to the corresponding sequestered CO_2 emissions used by Mitisou (2011), which in turn based the used conversion method on peer-review of the literature. Although Verweij *et al*. (2009) provides market values of CO_2 emissions, the more up to date market values of Diaz *et al*. (2011) as suggested by Mitisou (2011) was used. This market value was used to calculate the theoretical market value of the carbon sequestration services of Trésor.

The actual paid sequestration values of Trésor were estimated by using the provided data from the financial year reports of the Trésor Foundation and additional information from the current Treasurer of the Trésor Foundation. Unfortunately, the CO_2 compensation donations were not specifically earmarked on the exploitation overviews of Trésor.

It is therefore recommended to the Trésor Foundation that future donations made for CO_2 compensations are specifically earmarked on the yearly exploitation overview of the Trésor and a complete overview is made on past CO_2 compensation donations to facilitate future utilization of data on CO_2 compensation.

It must be noted that the Trésor website currently has a special page on CO_2 compensation that provides the estimate that Trésor currently sequesters a net 700 to 4400 kg of CO_2 *per* hectare *per* year (Trésor, 2013b). However, this estimate is not accompanied by the underlying calculation and possible assumptions. The provided estimate on the webpage functions as a hyperlink to the report of Kruijt *et al*., (2006). However, in

the report of Kruijt *et al*. (2006) no estimate on the amount of CO_2 sequestration is given, only on carbon sequestration.

Because of the public accessibility and informational value of the Trésor website, it is highly recommended to the Trésor Foundation that the accompanying calculations and assumptions of the provided estimate on CO_2 sequestration as stated on the Trésor website are provided on the website as soon as possible. Moreover, because Trésor is actively promoting CO_2 compensation the earlier mentioned new study on the carbon content and sequestration rate of Trésor is underlined.

Non-use values & Educational values

Non-use values (4.1) and Educational values (4.3) were calculated from the lump sum in which both values were incorporated. The contribution of Utrecht University to Trésor in the form of the salary and small budget for office costs was made on the basis of a valuation in 2003. It is likely that at least the salary of the coordinator has increased over time under Dutch collective agreement between employers and employees. Because of time-constraints this was not taken into account in the estimation.

For an up to date estimate of the contribution of Utrecht University to Trésor it is therefore recommended to provide a current estimate of the salary and budget for office costs.

At the time of writing it was impossible to make an educated guess of the division of non-use and educational values within the lump sum. Therefore, a 50:50 ratio was used which may not reflect the accurate contributions.

To arrive at a better division of Non-use and Educational values in the lump sum it is recommended to involve the employees of the Association in the estimation of a more accurate division.

An additional Educational value of Trésor was estimated by using data on educational visits to Trésor. According to the year report, all educational visits came from the town of Roura. However, it can be expected that normally also education visits from other hamlets/towns/cities would have been made on the basis of the data on the activities of Trésor.

It is therefore recommended that the additional Education value on the basis of education visits uses information of multiple years to arrive at a reliable estimate of visits and distance travelled.

Recreation and ecotourism

The monetary value of Recreation and ecotourism (4.2) was estimated on the basis of the trip for donors of Trésor and amount of visits to the educational trail.

In the estimation of the money spent on the donors-trip, the salary and other costs that the employees of the Association made were left out of the estimation because of lack of information. However, this may represent a significant amount of money spent for the donors-trip and would increase the monetary value of the donors-trip to Trésor. However, it is important to note that this amount would then have to be subtracted from the value of Non-use and Educational services as the salary of the employees of the Association has been used as an estimate for these services.

It is therefore recommended to make an estimation on the money spent by the presence and expenditures of the employees of Trésor for the donors-trip.

The amount of tourists visiting Trésor besides the donors-trip was estimated with the preliminary estimation of amount of total visits to the education trail each month.

To provide a more accurate estimate on the amount of visitors each year it is therefore recommended that visitors to the educational trail are continued to be counted.

Knowledge systems

Currently Trésor is adding to Knowledge systems (4.4) by its membership to CEN and the development of the Peperpot project. As Knowledge systems are hard to express in monetary value, the travel cost method could be used if information on travelling for this purpose was available.

It is therefore recommended to estimate the value of the current Knowledge systems of Trésor by acquiring information on travelling done for this ecosystem service and using the travel-cost method.

Comparison of the value of ecosystem services of Trésor

Table 4 shows that not all economic valuations of Trésor are representative for other ecosystems. For each comparison it should be checked which ecosystem service is being provided and actually used. The only monetary value that can be used as a good estimate for other, similar ecosystems is that of carbon sequestration, as the service is used universally by mankind.

A higher current value of Trésor can help protecting Trésor from different land-uses. It was found that the actual monetary value of Carbon sequestration Trésor is lower than the theoretical monetary value. If the theoretical value was reached then the economic incentive of an intact Trésor would be higher than it is currently. Other ways to increase the current economic incentive provided by Trésor is by researching the actual value of its Hydrological services and to identify added value of Non-use NTFPs.

It is therefore recommended that Trésor promotes its function as CO_2 emission compensator, investigates the actual potential monetary value for its hydrological services and explorers the potential other NTFPs to increase its non-use value.

Estimating an monetary value for alternative land-uses for Trésor

No estimates on the gold deposits in Trésor were available at the time of writing and therefore no monetary value of a possible scenario where Trésor was minded for gold could be provided. An estimation of the Gold deposits of Trésor should be included in an EAR as suggested by Lukkien & Jeurissen (2013). If this EAR would be available together with the expertise to convert the data from this EAR into a justified estimate on the monetary value of gold mining in Trésor, then this land-use could be used for comparison.

It is therefore recommended that the EAR concerning the gold availability in Trésor and the expertise to provide a justified monetary value of gold mining in Trésor is made available.

Other alternative land uses of Trésor were valued by data from Butler & Laurance (2009). Because of time-limitations it was assumed that the economic valuations of the different land-uses could be used for the Trésor area. However, as: not all estimates could be checked; some estimates were probably out-dated (*e.g.* the value of timber from of one hectare of forest was estimated at 1000 US$ in 1989 which probably does not represent the present value in US$); and the net present value had to be forced into a value *per* year, the provided estimates could be incorrect for the Trésor situation.

It is therefore recommended to investigate the applicability of the alternative land-uses in Trésor with the help of updated resources and methods to convert net present value into a value *per* year.

Results from the case-study on the Thesis question

When the estimated current monetary value of Trésor was compared with the monetary value of the three alternative scenarios it could be seen that currently Trésor does not provide an economic incentive that is higher than any of the provided scenarios. Only when a time-horizon of more than 71 years was taken into account the current monetary value Trésor would provide more economic gain than two of the alternatives of Logging + Cattle ranching and establishing an Oil palm plantation. Compared to the current theoretical monetary value of 'Sustainable' harvest, Trésor would never provide more economic gains in the comparison.

It must be stated that the value economic incentive is also dependant on the amount of people that it must be shared with. The *per* capita economic gain will be always higher when the decision maker is also the single owner compared to a situation where the decision maker is a larger body that must share the revenues of the

monetary value. The currently made comparison can only be valid if we assume that in the other scenarios than current Trésor also a body with the same size as the current Trésor organisation is the decision maker and owner.

Regardless of the many assumptions in the estimations of the alternative monetary values, comparison shows a difference in amounts in order of hundreds of US$ in the estimated initial value *per* hectare *per* year and therefore shows sufficient difference to serve as a result to answer the Thesis question.

It can be argued that the case-study of shows that PES for Trésor does not always lead to a higher economic incentive. It in reality depends on:

- The current PES value, *i.e.* the monetary value estimated from what is actually being paid;
- The time-horizon held by the decision maker;
- The size of the decision-making body that also owns the area in question; and
- The alternative land-use compared.

Synthesis of the literature and case-study results on the Thesis question

The findings of the case-study confirm the view from the literature study that suggests that PES schemes do not always guarantee that a sufficient economic incentive is created. Unfortunately, the question whether or not a higher economic incentive leads to better protection of nature was not answerable with the case-study and was only answerable by the literate study.

If Trésor should be completely protected by the PES concept, four conceptual ways to facilitate this can be distinguished:

1) The PES value of Trésor is increased to be higher than all other alternative land uses, for instance by proving payments for current and to be discovered unpaid ecosystem services;
2) The time-horizon of the decision maker is made as large as possible, for instance by organizing all decision making for Trésor in an organising body for with time is of lesser consequence;
3) PES schemes are supplemented by additional policies enabling the protection of Trésor; and/or
4) Policies are introduced that reduce the economic incentive of the alternative land uses.

Conclusions

The approach chosen for this Thesis produced the desired information and it is hoped that can thereby serve to provide insights into these subjects to third parties. The choice to use Trésor as a case-study provided additional data that in hindsight was necessary to provide a better answer to the Thesis question.

The research question posed in this Thesis was: *'Can current payment for ecosystem services (PES) provide a monetary incentive that enables the conservation of ecosystems?'*. This thesis question was subdivided into two sub-questions*:* (1) *Does PES provide a monetary incentive that is higher than the relevant alternative land-uses*; and (2) *If so, does this lead to improved conservation of ecosystems?*

Although literature was scarce and for the case-study many assumptions were made, the findings suggest that PES schemes do not guarantee that an economic incentive is created that is economically more interesting than conversion of nature. The question whether or not a higher economic incentive leads to better protection of nature was not answerable with the case-study but the literature study suggested that this is often not the case, and if it is, the effect thereof on nature conservation is marginally positive.

Because PES schemes are being hastily adopted it is therefore highly recommended that future research into the Thesis question is carried out and communicated to the scientific community and the relevant policy makers.

For this research the most important identified recommendations would be:

- That a future search query incorporates additional search words such as 'agro-environmental funding', uses un-digitalized literature and additional expert knowledge.
- The case-study presented in this Thesis could be improved by:
    - Re-assessing all possible applicable ecosystem services of Trésor in a follow-up investigation with additional information;
    - Mapping the current ecosystem services by using GIS-software to facilitate (future) comparison;
    - Providing an independent and reasoned estimation of the missed revenue of gold mining;
    - Establishing a better estimate of how many people downstream are using hydrological services including fresh water;
    - Carrying out a new study on the carbon content and sequestration rate of Trésor that consolidates and reflects on all other reports that have made a relevant estimate of carbon content for (parts of) Trésor, including that of Kruijt *et al*. (2006); and
    - Re-investigating the applicability of the alternative land-uses in Trésor with the help of up-dated resources and methods to convert net present value into a value *per* year.

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URL: http://www.teebweb.org/wp-content/uploads/Study%20and%20Reports/Reports/Synthesis%20report/TEEB%20Synthesis%20Report%202010.pdf

Ter Steege, H.; Sabatier, D.; Molino, J.F.; Bànki, O.; Prévost, M.F.; Pelissier, R. (2003) *Report of the establishment of a permanent one-hectare plot in Réserve Naturelle Volontaire Trésor*. Internal report, NHN-Utrecht Branch, Utrecht University.

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URL: http://www.tresorrainforest.org/frame_en/tn024.html

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URL: http://minerals.usgs.gov/minerals/pubs/country/2010/myb3-2010-gf-gy-ns.pdf

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In: European Tropical Forest Research Network - ETFRN (2002) *Innovative Financing Mechanisms for Conservation and Sustainable Forest Management*. ETFRN news 35, 2001/2002. Edited by Brinkman, W. Tropenbos International, Wageningen, The Netherlands.

URL: http://www.etfrn.org/file.php/23/etfrnnews35.pdf

Verweij, P.A.; Fontein, E. (2008) Dutch radio interview. Radio station 'Radio 1', broadcaster: NCVR, programme 'Casa Luna', carried out in the night of 18-February-2008.
URL 1: http://www.tresorrainforest.org/nl/images/kuifjes1.mp3
URL 2: http://www.tresorrainforest.org/nl/images/kuifjes2.mp3

Verweij, P.A.; Schouten, M.; van Beukering, P.; Triana, J.; van der Leeuw, K.; Hess, S. (2009) *Keeping the Amazon Forests standing: a matter of values*. WWF-Netherlands, Zeist (January, 2009).
URL: http://www.wwf.se/source.php/1229304/Keeping%20the%20Amazon%20forests%20standing.pdf

Verweij, P.A. (2013) Personal communication. P.A. Verweij *PhD* is an ecologist who is also scientific advisor to the Trésor Foundation and supervises Master of Science students in Biology who are carrying out research in and in relation to Trésor. In particular, P.A. Verweij *PhD* was the supervisor of E. Fontein who was carrying out research in the Trésor area at the time preceding the ban on mining activities in the Kaw-area.

Van Hecken, G.; Bastiaensen J. (2010) *Payments for Ecosystem Services in Nicaragua: Do Market-based Approaches Work?* Development and Change vol 41, no 3, p.421-444.
URL: http://onlinelibrary.wiley.com/doi/10.1111/j.1467-7660.2010.01644.x/pdf

Villette, B. (2013) Personal communication. Mr B. Vilette is one of the current park rangers of Trésor.

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URL: http://www.who.int/water_sanitation_health/publications/2012/globalcosts.pdf

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URL: http://fr.wikipedia.org/wiki/Zone_naturelle_d'int%C3%A9r%C3%AAt_%C3%A9cologique,_faunistique_et_floristique

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URL: http://fr.wikipedia.org/wiki/Cayenne

WWF Guianas (2012) *Living Guianas Report 2012*. Authors: Plouvier, D; Laurens Gomes. L.; Verweij, P.A.; Verlinden, N. Produced by WWF Guianas, Paramaribo, Suriname.
URL: http://awsassets.panda.org/downloads/living_guianas_report_web_version.pdf

Annex I. Maps of Trésor.

Figure Annex Ia. Location of Trésor (dark green) on the Kaw-hills on the south eastern coast of French Guiana. Taken from Fontein (2007).

Annex I. Maps of Trésor (continued).

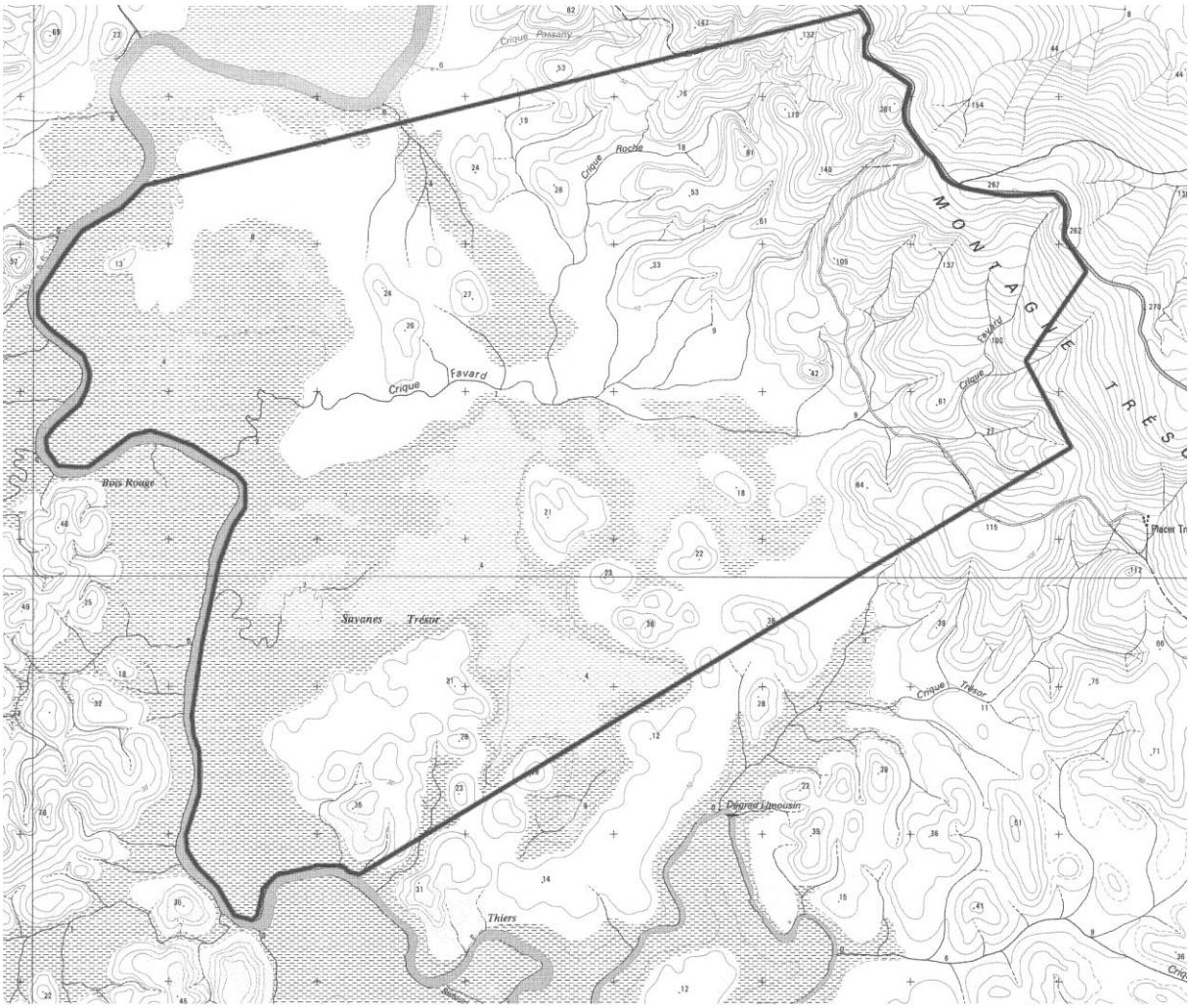

Figure Annex Ib. Geographical map of Trésor with present borders indicated with a thick black line. The old laterite-road to the placer Trésor (which can just be seen indicated on the left of this map) can be seen originating from the D6 road in around the middle of the border of Trésor against the D6, running partly through Trésor. Taken from Fontein (2007).

Annex II. History of the Trésor Nature Reserve

Updated and modified after Duden & Roeling (2011) and Lukkien & Jeurissen (2013).

1991 The Roman Catholic Diocese of Cayenne of French Guiana offers the area of Trésor (total of 2464 ha) for sale in order to aquire funding to build a new church in Cayenne.
1991 J. Moonen, director of an ecotourism bureau writes a proposal to establish a park on the Trésor area: '*Tresor Tropical Park, a proposal*'
1992 The Botanic Gardens of Utrecht University forward the Trésor Tropical Park proposal as a potential way to involve Dutch industries into nature conservation.
1994 On the initiative of Utrecht University the Trésor Foundation is established in Utrecht (The Netherlands).
1995 The foundation buys the Trésor area in cooperation of WWF-NL and WWF-USA with money provided from the Dutch industries and a loan form a bank with Utrecht University vouching for the loan.
The Trésor Foundation establishes a nature reserve on the Trésor area, thereby establishing the first (and only) regional nature reserve in French Guiana.
1996 The reserve is proposed as a Voluntary Nature Reserve (*Réserve Naturelle Volontaire*).
The Trésor Association (Association Trésor) is established with an own (voluntary) board and paid personnel to coordinate the daily management of the Trésor area. Note: according to Pineau *et al*. (2008) this should be 1999.
1997 By ordinance of the prefect of French Guiana, Trésor becomes a Voluntary Nature Reserve (*Réserve Naturelle Volontaire*).
1998 Trésor starts their crowd-funding action of the possibility of donors adopting square meters of Trésor for a financial deposit.
1998 The government of French Guiana establishes a 100.000 ha nature reserve in the Kaw-swamps north-east of Trésor which is currently partly a RAMSAR area.
1999 Trésor Foundation launches their magazine Trésor news (*Trésor nieuws*).
2000 Creation of the botanical trail. The trail is used to give guided tours for tourists and school classes. Tourists can also enter the trail freely without a guide.
2001 The Trésor area is recognised by the French Government as an important ecological area ('ZNIEFF, type I').
Construction of the entrance building (*carbet*).
2002 The first 'donors-day', a day organised specially for donors, is organised in the UU Botanic Gardens
2003 Utrecht University starts to contribute to Trésor by funding of the function of Coordinator.
The first trip for donors to visit amongst other things, Trésor is organised.
2004 Trésor Foundation launches their website.
2005 Signing of the Memorandum of Understanding (MOU) by WWF (sections France, the Netherlands and the United States) and Trésor (Foundation and Association). The MOU was formulated to support the natural-and-environmental education projects, the creation of a conservation management plan and a plan for fund raising.
2005 The entrance building is set alight by arson and is completely destroyed.
2006 The first conservation management plan is introduced (2007-2012)
2006 The reserve is proposed as a Regional Nature Reserve (*Réserve Naturelle Régionale*).
2008 The French government cancels the gold-mining concession nearby Trésor
2008 The entrance building is rebuilt and is now called '*maison de la Réserve*' (House of the reserve)
2008 Trésor proposes the French Guianian government to add two flanking areas of rainforest (total of 1447 ha) to the management of the Trésor Association. It is proposed that this new area can act as buffer zone to the core, Trésor area.
2009 Status of the reserve is upgraded to Regional Nature Reserve (*Réserve Naturelle Régionale*).
Thereby French Guiana starts to finance the conservator and two park rangers of the Trésor Association.
2010 Signing of a second MOU between WWF-NL and Trésor, coordinating the 3 shared goals of climate research, stakeholder involvement and development and publication of educational flyers in line with all other nature reserves in France.
2012 The original loan to acquire the Trésor area is entirely paid off with the help of financial contributions from Utrecht University and WWF-NL.
2012 The new entrance building is again set alight by arson and is completely destroyed.
2013 A new staff member for research and education on carbon storage of forests and climate change of the Association Trésor is partly financed by French Guiana.

Underway/in the near future
2013 A new management plan (2013-2017) is established.
???? Complete financing of the new staff member of the Association for research and education is accomplished.
???? The Association Trésor launches their website.

Annex III. List of publications and reports made in relation to Trésor

Note: this list was created with the first attempt to consolidate all (scientific) publications in relation to Trésor and is incomplete.

Peer reviewed articles

Courtois, E.A.; Pineau, K.; Villette, B., Schmeller, D.S.; Gaucher, P. (2012) *Population estimates of Dendrobates tinctorius (Annura: Dendrobatidae) at three sites in French Guiana and first record of chytrid infection*. Phyllomedusa vol 11, no 1, p.63-70.

Internal reports

Cremers, G.; de Granville, J.J.; Jansen-Jacobs, M.J.; ter Welle, B.J.H. (1996) *Inventaire préliminaire de la flore de la concession Trésor (Guyane Française)*. Internal Report.

Marty, C.; Gauier, P. (1996) *Liste préliminaire de la flora de la concession Trésor (Guyane Française)*. Further details currently unknown.

Poncy, O.; Martin, C. (2000) *Inventaire de la flora sur le sentier botanique de la Réserve Naturelle Volontaire Trésor*. Direction regionale de l' environement Guyane & Laboratoire de Phanérogamie M.N.H.N.

Ek, R.C.; Bordenave, B.G.; Sluiter R.; van der Knaap, E.C. (2000) *The floristic composition and vegetation structure of the Trésor Reserve, French Guiana / Inventaire de la composition floristique et de la structure de la végétation de la Réserve Trésor, Guyane Française*. Internal report, Utrecht University.

Deville, T.; Andy, L.; Menseau, A.; Lochon, S. (2002) *Liste synthétique des Oiseux de Trésor*. GEOPOG. Further details currently unknown.

Ek, R.C.; van de Riet, B.P.; Doomen, M.C. (2003) *The savannas of the Trésor Reserve, French Guiana / Les Savanes de la Réserve Trésor, Guyane Française*. Internal report, Trésor Foundation.

Ter Steege, H.; Sabatier, D.; Molino, J.F.; Bànki, O.; Prévost, M.F.; Pelissier, R. (2003). *Report of the establishment of a permanent one-hectare plot in Réserve Naturelle Volontaire Trésor*. Internal report, NHN-Utrecht Branch, Utrecht University.

Dommen, A. (2003) *Physical geographical characteristics of the savannas of the Trésor Reserve, French Guiana*. Utrecht University, Faculty of Earth Sciences, Department of Physical Geography.

Ek, R.C.; Hartmann, F.A.; van de Riet, B.P. (2004). *The gullies of the Trésor Reserve, French Guiana / Les Ravins de la Réserve Trésor, Guyane Française*. Internal report, Trésor Foundation.

Ek, R.C.; Jansen-Jacobs, M.J.; Vonk, R.; Pineau, K. (2006) *La diversité floristique de la Réserve Trésor, Guyane Française/The botanical diversity of the Trésor Reserve, French Guiana*. Internal report, Trésor Foundation.

Ek, R.C.; Jansen-Jacobs, M.J.; Pineau, K.; van Dam, J.A.C.; van Proosdij, A.S.J.; Briand, C. (2009) *La Réserve Trésor, la version étendue / The Trésor Reserve, extended version*. Internal report, Trésor Foundation.

Ek, R.C.; Tostain, G.; Leotard, G.; Pelletier, V.; Deville, T.; Villette, B.; Szpigel, J-F. (2011) *La forêt marécageuse et les collines isolées de la Réserve Trésor, Guyane française / The swamp forest and isolated hills of the Trésor Reserve, French Guiana*. Internal report, Trésor Foundation.

Melki, F. (2011) *Etude ichtyologique des criques forestières et des têtes de bassins de la Réserve Naturelle Trésor. Deuxième inventaire ichtyologique de la Réserve Naturelle Trésor*.

Management plans

Pineau, K.; Briand, C.; Delafosse, I.; Gault, E.; Garnier, L.; Fortune, O.; Tostain, O.; de Pracontal, N.; Fontein, L.; Lukkien, V.P.A.; Thierron. V. (2008). Beheersplan 2008-2012. Internal report, Association Trésor in cooperation with WWF. Translated from French into Dutch by A.M. Posner.

External reports

Kruijt, B.; Nabuurs, G-J.; Arets, E. (2006) *The potential for conservation of carbon stocks and carbon sequestration in the Trésor rainforest reserve, French Guiana: a quick scan*. Short report / advisory letter. Alterra, Wageningen University and Research Centre, Wageningen, Netherlands.

Poncy, O.; Martin. C. (2000) *Inventaire de la flore sur le sentier botanique de la Réserve Naturelle Volontaire Trésor, Première évaluation*. D.I.R.E.N. & Laboratoire de Phanérogamie M.N.H.N.

MSc Project reports and Theses

Fontein, E. (2007). *RAPPAM Assessment of Tropical Rainforest Conservation in the Trésor Natural Reserve (French Guiana)*. Project report. Supervised by P.A. Verweij *PhD* & V.P.A. Lukkien *MSc*.

Duden, A.; Roeling, I. (2011) *Calculations of human impact on carbon stocks in the coastal Kaw region, French Guiana*. Supervised by P.A. Verweij *PhD* & V.P.A. Lukkien *MSc*.

Laporte-Bisquit, A. (2011) *Effect of selective logging and road edge-effect on carbon stocks. Spatial and temporal variation in above-ground biomass in tropical forests in French Guiana; Regional spatial variation and the effects of selective logging on above-ground biomass*. Thesis. Supervised by P.A. Verweij *PhD* & V.P.A. Lukkien *MSc*. [currently unavailable]

Van der Sluis, A.A.M. (2007) *Maak meer lawaai!, Onderzoek naar de aansluiting tussen de communicatie vanuit Trésor en haar donateurs*. EN: Make more noise! Study on the connectivity between communication from Trésor and its donors. Project report. Supervised by Hovinga, D. *PhD* & V.P.A. Lukkien *MSc*.

Mitsiou, A. (2011). *Impacts of selective logging on tree aboveground biomass and carbon stocks in tropical forests, French Guiana.* Project report. Supervised by P.A. Verweij *PhD* & V.P.A. Lukkien *MSc*.

Boeraeve, F.; Zomer, P. (2012) *Estimating tropical forest structure: Sampling Designs and Spatial variation*. Project report. Supervised by P.A. Verweij *PhD* & V.P.A. Lukkien *MSc*.

BSc Theses

Morison, M.A. (2009) *De impact van beschermde gebieden in tropische bossen*. EN: The impact of protected areas in tropical forests. Supervised by V.P.A. Lukkien *MSc*.

Malotaux, J. (2010) *Ecosysteemdiensten in het natuurreservaat Trésor*. EN: Ecosystem services in the Trésor nature reserve. Supervised by V.P.A. Lukkien *MSc*.

Standaert, M. (2010) *REDD als redmiddel? De sleutelrol van tropische bossen in klimaatbeleid*. EN: REDD as save mechanism? The key role of tropical forests in climate policy. Supervised by V.P.A. Lukkien *MSc*.

Van Doorn, A. (2010) *De impact van Trésor. Over wat de stichting heeft bereikt in 15 jaar*. EN: The impact of Trésor: about what the Foundation has accomplished in 15 years. Supervised by V.P.A. Lukkien *MSc*.

Zwerts, J. (2010) *Trésor; an example of innovative nature conservation management*. Supervised by V.P.A. Lukkien *MSc*.

Breeman, L.B.S. (2011) *Het behouden van tropische bossen. Kunnen we tropische bossen behouden door ze te valoriseren?* EN: Conservation of tropical forests. Can we conserve tropical forests by valorizing them? Supervised by V.P.A. Lukkien *MSc*.

Kupers, S. (2011) *Tropical forest conservation projects: Local, regional or national*?. Supervised by V.P.A. Lukkien *MSc*.

Higher education Theses

Kerharo, L.; Ferrier, E. (2005/2006) *Beschrijving van een ecosysteem van een tropisch regenwoud: het vrijwillige natuurreservaat Trésor*. EN: Description of an ecosystem of a tropical forest: the voluntariy nature reserve Trésor. Translated from French into Dutch by: Anon. Student Theses for Guyane Technopole, 'LPPE 2005/2006'. Further details currently unknown.

Miscellaneous

Lukkien, V.P.A. (2008) *Trésor voortrekkersrol in bosbescherming Frans-Guyana*. EN: Trésor lead role in forest protection in French Guiana. Ecologie & Ontwikkeling, vol. 16, no. 76, p.66-69. IUCN, National committee of the Netherlands, Amsterdam, The Netherlands.

Financial year reports

Financial year reports of the Trésor Foundation including (since establishment) the year report of the Association, 1995 to 2012. The financial year reports of 1995 to 2010 were established by the Audit, Tax and Advisory company KPMG. Year reports from 2006 on are digitally available.

Annex IV. Excerpt of a study into the donors of the Trésor Foundation

Note: these results were taken from Van der Sluis (2007) and modifed. N = 27.

Q: What do you feel are important aspects in the protection of the Trésor area?
(Allocate numbers from 1 to 10. A number may only occur once. 10 indicates the most important and 1 the least.)

Aspects of protection	Mean
Protection of animal species	7.85
Protection of plant species	7.85
Research	7.78
Education in French Guiana	6.52
Climate control	6.28
Informing the Netherlands	5.28
Medicine conservation	4.58
Cooperation between the University and Industries	4.39
Stimulating ecotourism	3.13
Other:	Protection of the ecosystem
	Exemplary role

Annex V. Simplified overview of Exploitation Assets of Trésor between 1995 and 2012.

Assets	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Sponsoring	0	0	0	45,378	107,092	91,890	160,457	13,295	74,802	149,293	70,680	6,250	6,040	42,410	41,546	22,166	32,129	16,080
Donations by individuals	217,308	78,958	53,024	21,403	20,133	21,477	11,781	22,471	22,349	19,008	25,473	24,149	36,998	40,812	29,458	47,073	37,139	39,251
Contributions to specific projects	0	0	0	0	0	27,227	0	0	0	0	0	37,451	0	2,709	18,500	2,500	11,800	11,830
Contributions to fullfill mortgage dept	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	145,000
Interest	179	162	8,173	310	132	162	182	15	6	38	29	23	326	1,167	100	0	0	0
Other	0	0	0	0	0	0	0	0	51,992	0	90,756	17,475	19,298	276	0	3,745	129	500
Total EUR	**217,487**	**79,120**	**61,198**	**67,091**	**127,357**	**140,757**	**172,421**	**35,781**	**149,149**	**168,339**	**186,938**	**85,348**	**62,662**	**87,374**	**89,604**	**75,484**	**81,197**	**212,661**

CO2 compensation	0	0	0	0	0	0	0	0	0	0	0	0	0	2,633	2,343	2,693	2,218	3,335

Total invested without CO2 compensation	Total invested in CO2 compensation	Total invested
2,099,968	13,222	2,113,190

Note: Values between 1995 and 2001 were in NLG and were converted into EUR with € 2.20371 : 1 FL
Note: Various contributions to specific projects were lumped into one category
Note: The first donors-trip was organised in 2003 and was part of the explotation overview of Trésor. In the years after this donors-trip was kept out of the exploitation overview. To allow the drawing apart of ecotrourism costs the 2003 donors-trip was removed from this overview.
Note: donations and sponoring to compensate for CO2 emissions were subtracted from these posts

Annex VI. Additional Climatological data on Trésor.

No climatological station is present in the Trésor reserve but there are several stations measuring separate climatological factors within a radius of 40 km: 'Km 33 Route de Kaw', 'Camp Caiman', 'Roura' and 'Rochambeau airport' (Ek *et al*., 2006; Pineau *et al*., 2008).

According to data from Pineau *et al*. (2008) data (with measuring lengths of 2 and 29 years) from the weather stations of 'Km 33 Route de Kaw', 'Camp Caiman' and 'Roura', the Trésor area is subject to a wet and dry season (Figure Annex VI.1). During December to July it is relatively wet with an average precipitation of 456 mm/month, while during August to November it is relatively dry with an average precipitation of 130 mm/month. The monthly average minimum precipitation throughout the year is 91 mm in October. Precipitation data from Rochambeau was ignored in this overview because according to Ek *et al*. (2006) the uplift of water-saturated air from the ocean against the Kaw-hills causes a '*considerable increase in rainfall compared to the rainfall measures at Rochambeau*'.

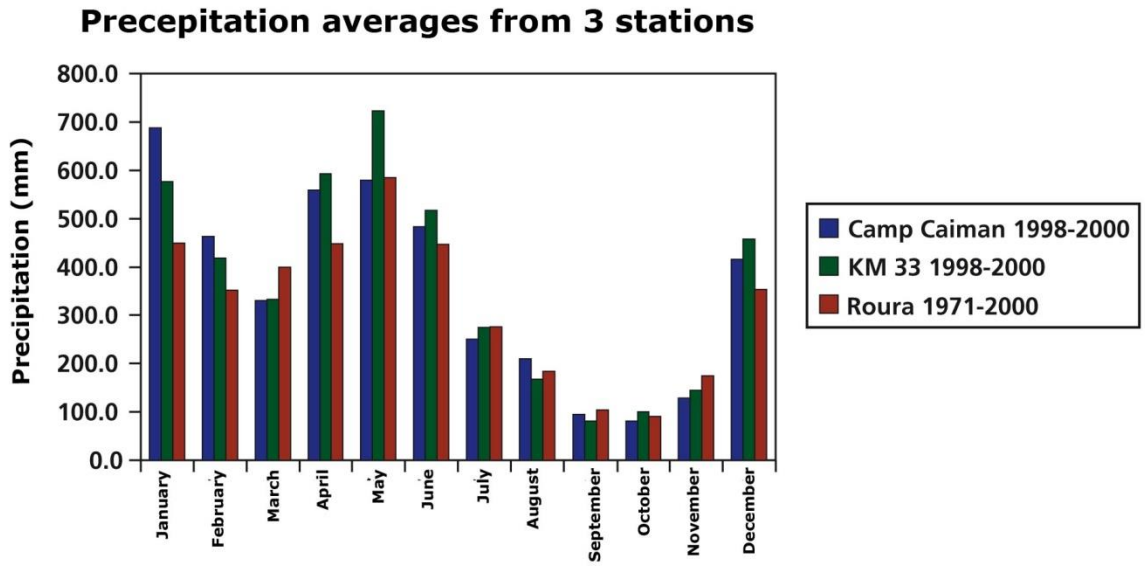

Figure Annex VI.1. Precipitation averages taken from 3 weather stations nearby Trésor. Modified after Pineau *et al*., 2008.

According to Duden & Roeling (2011) citing data from the Rochambeau weather station nearby Cayenne, the temperature in Trésor on average never falls below 22.1 °C and can reach 30.0 °C, however it must be noted that because of considerably higher amounts of precipitation in the Kaw-Hills in relation to Rochambeau, the temperatures can be expected to be slightly lower on average.

Annex VII. Short history and status of gold mining concessions around the Trésor area

Overview created with contributing information from Fontein (2007), Verweij & Fontein (2008), Lukkien & Jeurissen (2013) and IAMGOLD (2013).

1994 The concession areas east of what later would become Trésor are auctioned by the French Government. The company *Asarco Guyane Française* (AGF), a subsidiary of the American mining, smelting, and refining company Asarco, wins the bid of three adjacent concession areas.

1996-1999 Initial drilling and exploration of gold deposits of the three concession areas, which are now called the 'Camp Caiman area'.

1999 First mining permit is filed.

2002 The company of 'CBJ-France S.A.R.L.' which is a subsidiary of The Ariane Gold Corporation, purchases the shares of AGF for the Camp Caiman area.

2003 Ariane Gold Corporation merges with the Canadian company Cambior Incorporation.

2003 The mining permit application is updated.

2006 Cambior Incorporation merges with the IAMGOD Corporation which is based on Nassau, the Bahamas.

2008 The permit is denied by the French President in expectation of a ban on gold mining in the area.

2009 IAMGOLD files a litigation challenging the denial of the permit and requesting € 275 million in compensation of damages.

2010 The French Government again denies a mining permit accompanied with a new, more reasoned statement. IAMGOLD files a second appeal to receive a mining permit.

2012 The second appeal is dismissed by the Administrative Tribunal. IAMGOLD sets an appeal to the higher court of the Administrative Court of Appeals in Bordeaux and raised its compensation claim to € 763 million to account for the increase in gold price.

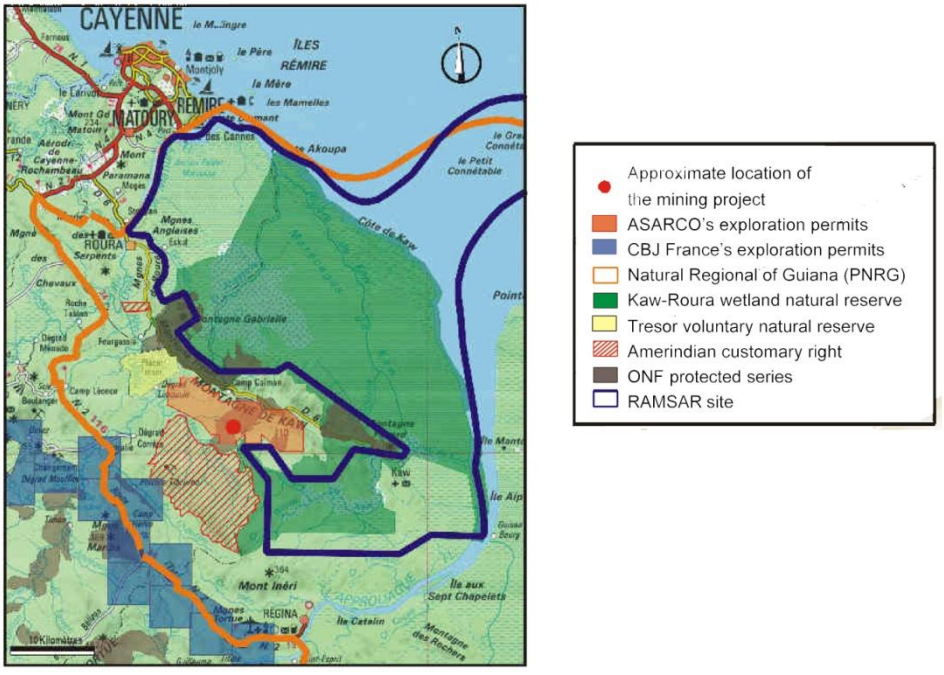

Figure Annex VII. Location of the Camp Caiman area and relation to the surrounding areas. Figure taken from Ariane Gold Company (2003).