THE ECONOMIC CONTRIBUTION OF MADAGASCAR'S PROTECTED AREAS – *A REVIEW OF THE EVIDENCE*

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FAPBM	Madagascar National Parks
AHT GROUP AG Management & Engineering	

Contents

ACRONYMS

AFD	Agence Française de Développement
ANGAP	Association Nationale de Gestion des Aires Protégées
ASCLME	Agulhas and Somali Current Large Marine Ecosystems
BBC	British Broadcasting Corporation
BIOFIN	Biodiversity Finance
BNCCREDD	Bureau National de Changements Climatiques et de la REDD
C3EDM	Centre for Economics, Ethics, and Environment for the Development of Madagascar
CAZ	Corridor Ankeniheny-Zahamena
CITES	Convention on International Trade in Endangered Species
DBSAPM	Direction de la Biodiversité et du SAPM
CBD	Convention on Biological Diversity
CEPF	Critical Ecosystem Partnership Fund
CGHV	Compagnie Générale Hydroélectrique de Volobe
CMK	Complexe de Mahavavy Kinkony
CoP15	15th Conference of the Parties of the CBD
COP26	26th Conference of the Parties of the UNFCC
COVID	Corona Virus Disease
DBEV	Département de Biologie Végétale
DEAP	Droits d'Entrée aux Aires Protégées
EA	Ecosystem Accounting
ECM	Energy consumption model
EEZ	Exclusive Economic Zone
EID	Emerging Infectious Disease
EIRR	Economic Internal Rate of Return
ENPV	Economic Net Present Value
ES	Ecosystem Service
ESSA	Ecole des Sciences Sociales et Agricoles
ESMP	Environmental and Social Management Plan
EU	European Union
FAO	Food and Agriculture Organisation of the UN
FAPBM	Fondation des Aires Protégées et de la Biodiversité de Madagascar
GCLME	Guinea Current Large Marine Ecosystem
GEF	Global Environment Facility
GDP	Gross Domestic Product
GEP	Gross Ecosystem Product
GNP	Gross National Product
GHG	Greenhouse gas
GIS	Geographical Information System
ICDP	Integrated Conservation and Development Project
IEFN	Inventaire Ecologique et Forestier National
IEM	Initiative pour l'Emergence de Madagascar
IMRA	Institut Malagasy de Recherche Appliquée
INSTAT	Institut National Statistique
IOGA	Institut d'Observation Géographique d'Antananarivo
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for the Conservation of Nature
JIRAMA	Jiro si Rano Malagasy (national power & water utility)
KBA	Key Biodiversity Area
KfW	KfW Banking Group (Kreditanstalt für Wiederaufbau)
LMMA	Locally Managed Marine Area
MEDD	Ministère de l'Environnement et du Développement Durable
MEEF	Ministère de l'Ecologie et des Forêts
METT	Management Effectiveness Tracking Tool
MGA	Malagasy Ariary
MIT	Massachusetts Institute of Technology
MNP	Madagascar National Parks
MPA	Marine Protected Area
MRHP	Ministère des Ressources Halieutiques et de la Pêche

MTTM	Ministère du Tourisme Transport et Météorologie
NAP	Nouvelle Aire Protégée
NBFP	National Biodiversity Finance Plan
NbS	Nature-based Solutions
NEAP	National Environmental Action Plan
NEHO	Nouvelle Energie Hydroélectrique de l'Onive
NERF	Niveau d'Emissions de Référence Forestière
NGO	Non-Governmental Organisation
NHK	Japan Broadcasting Corporation
NMC	North Mozambique Channel
NTFP	Non-timber forest products
NP	National Park
ONE	Office National pour l'Environnement
OECD	Organisation for Economic Cooperation and Development
ONTM	Office National du Tourisme de Madagascar
ORE	Office de Régulation de l'Electricité
PA	Protected Area
PADAP	Programme d'Appui au Développement Approche Paysage
PAG	Plan d'Aménagement et de Gestion
PAGOSE	Electricity Governance and Operations Improvement Project
PAP	Plan d'Aménagement des Pêches
PCD	Plan Communal de Développement
PES	Payment for Ecosystem Service
PIC	Pôles Intégrées de Croissance
PRD	Plan Régional de Développement
PSSE	Plan de Sauvegarde Social et Environnemental
REDD+	Reduced Emissions from Deforestation and Degradation +
RNI	Réserve Naturelle Intégrale
SAPM	Système des Aires Protégées
SCC	Social Cost of Carbon
SEP2D	Sud-Expert Plantes Développement Durable
SRAT	Schéma Régional de Développement
STAR	Species Threat Abatement and Restoration
SWIO	Southwest Indian Ocean
SWIOFISH	SWIO Fisheries Project
TEEB	The Evaluation of Ecosystems and Biodiversity
UNDP	UN Development Programme
UNEP	UN Environment Programme
UNESCO	UN Education Science and Culture Organisation
UNFCC	UN Framework Convention on Climate Change
UNSEEA	UN System for Environmental Economic Accounting
UN	United Nations
USAID	US Agency for International Development
USD	United States Dollars ($)
VAT	Value Added Tax
WAVES	Wealth Accounting for the Valuation of Ecosystem Services
WCS	Wildlife Conservation Society
WEF	World Economic Forum
WHO	World Health Organisation
WIO	Western Indian Ocean
WTP	Willingness to pay
WTTC	World Travel and Tourism Council
WWF	World Wide Fund for Nature

EXECUTIVE SUMMARY

Nature provides many benefits for people, although the economic value of the multiple benefits provided by natural ecosystems are often not well understood and may even be ignored by decision makers. Ignoring nature can lead to economic development planning and market mechanisms that result in the conversion of remaining natural ecosystems to mono-functional uses and the ongoing degradation of protected areas and the essential ecosystem services they provide. In fact, the weight of the evidence shows that in most cases, conserving nature is better for human prosperity than conversion of natural habitats to other uses.[1]

The present report seeks to assemble and review the available evidence of the global, national and local economic contributions of Madagascar's protected areas, including non-monetary beneficial contributions, notably to human health and well-being, and to compare them with the costs of maintaining the protected areas network and the opportunity costs to households living around protected areas. We aim to evaluate the contributions that protected areas make to the world and people of Madagascar and to help Madagascar's decision makers reach appropriate decisions on the maintenance, enhancement and financing of Madagascar's protected areas network.

The protected areas network of Madagascar, made up of 123 protected areas covering 6,233,317 ha of terrestrial and 1,379,029 ha of marine (including intertidal)[2] ecosystems, is the country's greatest natural capital asset and has been described as a 'priceless national treasure' and of 'immeasurable national and global value' [3] as both a national and global good[4]. Yet the full economic contributions of the ecosystem goods and services provided by this asset are not fully understood.

Making use of internationally published global data, national economic data and a series of local case studies, this study uses a combination of recognised methods for estimating the value of ecosystem services from protected areas[5] to demonstrate the global, national and local economic contributions of Madagascar's protected areas and to highlight the critical importance of increasing financial investments in protected areas (Table 0).

At the global level, we estimate that Madagascar's protected areas network, in its current state, and assuming effective conservation, makes a total contribution through climate regulation, biodiversity conservation and related cultural services (tourism, research, entertainment) with an economic value of **$3.67 to $17.27 billion annually (median value $7.74 billion)**. Of this, **$2.19 to 14.64 billion (median value $6.25 billion)** is for climate regulation[6], **$572-660 million**[7] is for biodiversity conservation, $299-809 million from genetic resources and **$623-633 million** for cultural benefits of biodiversity (tourism, research, entertainment). In counterpart, Madagascar expects to earn $47 million annually from the national REDD+ program and receives approximately $52-60 million towards the conservation of biodiversity, or **about 2-4% of the global benefit**. Overall, the global contribution of Madagascar's protected areas to climate regulation and biodiversity conservation has an estimated value many times greater (perhaps as much as 25–50 times greater) than the international investment or credit Madagascar is currently able to attract towards the conservation of its protected areas.

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[1] Bradbury et al 2021
[2] Cooke et al in press
[3] Jones et al in press
[4] Carret & Loyer 2004; World Bank 2013
[5] Including avoided losses, contingent valuation (willingness to pay), market-based pricing methods and transferred value methods (using internationally published values for comparable ecosystem services in other countries)
[6] Assuming a social cost of carbon of $171/tCO2eq as used in WWF 2020
[7] Deutz et al 2020

Table 0 – Economic contributions of Madagascar's Protected Areas network by level (Global, National, Local)

Level	Key ecosystem services	Estimated value $/yr
GLOBAL	Climate regulation by forests in PAs (terrestrial forests and mangroves)	$2.19 – 14.64 bn (range)[8] $6.25 bn (median)[9]
	Biodiversity conservation in PAs	$572-660 million
	Genetic resources from PAs	$299-809 million
	Tourism (global spending based on PAs)	$533-543 million
	Research (global spending linked to PAs)	$8.34 million
	Natural History films (production costs)	$412,500
	Global entertainment (animations)	$88 million
	Subtotal	**Range: $3.67-17.27 bn** **Median: $7.74 bn**
NATIONAL	Carbon storage (theoretical @ $5/tC)	$47 million
	Carbon storage (actual @ $5/tC)	$27 - $29 million
	Biodiversity conservation	$52-60 million
	Tourism (in country expenditure)	$42-174 million
	Scientific research (national expenditure)	$2.8 million
	Natural history films (national expenditure)	$112,000
	Agriculture (MNP managed PAs only)	$22.5 million[10]
	Drinking water (MNP managed PAs only)	$10.1 million
	Hydroelectricity (existing or planned)	$20.75-41.24 million
	Subtotal (terrestrial PAs)	**Range: $215-329 million**
MARINE	Marine Protected Areas (indicative, based on fisheries, mangrove use & tourism)	**Range: $195-199 million**
ALL PAS	Marine and terrestrial PAs combined (national economic contribution)	**Range: $410-528 million**
LOCAL	Selection of 6 terrestrial PAs covering 590,951 ha (9% of terrestrial network)	**Range: $42-55 million**
	All terrestrial PAs (indicative, based on simple area extrapolation)	**Range: $444-579 million**

At the national level, we find that the measurable gross annual economic contribution of Madagascar's Protected Areas network (terrestrial and marine protected areas) captured in the national economy is an estimated **$410-528 million/yr** ($54-69/ha/yr), based on four key economic development sectors – agriculture, energy, tourism (2019 data) and fisheries, plus benefits in international finance secured for Madagascar's global contribution to climate regulation (carbon storage) and biodiversity conservation. The estimate should be regarded as conservative since it includes only certain sectors and because it does not include jobs created, taxes paid or foreign investments attracted (especially in tourism and energy). Marine protected areas, make a significant contribution to the total, estimated indicatively at **$195-199 million annually** based on the existing MPA network of 1.38 million ha ($141-144/ha/yr).

At the local scale, the economic benefits measured for individual protected areas are variable but can be substantial for the sites studied. Based on a series of case studies, the total economic contribution

[8] Based on a Social Cost of Carbon in the range $54 (Weng et al 2019) to $417/tCO2eq (Ricke et al 2018)
[9] Based on a Social Cost of Carbon of $171/tCO2eq (WWF 2020)
[10] A likely underestimate since based on estimate in 2003 (Carret & Loyer 2004) when the purchasing power of $US1 in Madagascar was anomalously less than $US1 in 2021

of seven prominent and relatively well-managed terrestrial PAs covering 590,951 ha (or about 9% of the terrestrial PA network) ranged from about **$42 to $55 million/yr** ($67 to $87/ha/yr). Extrapolated to national scale, this would indicate that the total local economic contribution from terrestrial PAs could reach as much as **$443 to 579 million.** This should not be interpreted as indicating that local values are greater than those generated at the national level, since the estimate is based on a limited number of relatively well managed PAs with particularly valuable ecosystems (humid forests and wetlands). Rather, it serves to highlight that the national economic benefits of PAs indicated above of $410-528 million/yr are likely to be substantially underestimated.

Exceptionally, one PA (Ranomafana National Park) of 40,566 ha in the province of Fianarantsoa (the poorest province in Madagascar) based on a combination of ecotourism, energy from hydroelectricity and carbon storage, yielded annual benefits of **$13.7-22.3 million** ($338-550/ha/yr). Such figures point to the high local economic contribution and importance of well-placed and well-managed protected areas.

The difference between the measurable benefits at global and national scales illustrates the need for more effective national benefits capture together with more equitable distribution of the economic benefits of protected areas between international and national levels. The high level of benefits at the local scale shows that redistribution of benefits to local households to compensate for sometimes high opportunity costs of PAs should be possible. Evidence shows that where local communities capture significant benefits, they will support protected areas, but that this positive effect can take a decade to become established[11] and that a landscape approach is required to allow the development of alternative sources of livelihood[12].

Studies have shown that Madagascar's protected area system has been designed primarily for biodiversity conservation rather than economic contribution through delivery of ecosystem services and has focused on protecting the most representative or pristine habitats for biodiversity. Indeed, the value of the ecosystem services of Madagascar's protected areas was barely considered before 1990 and data are only available for certain values. In this regard, it should be emphasized that the absence of data does not mean an absence of value. Expansion of the existing PA system to include more of the natural capital within Madagascar's 233 Key Biodiversity Areas (KBAs)[13] [14] would considerably increase sustainable economic benefits from protected areas as well as enhance biodiversity conservation and help protect more of Madagascar's critical natural capital assets. At the same time, protected area management objectives need to evolve towards delivering greater local economic benefit within a landscape approach.

It should be understood that the economic contribution of Madagascar's protected areas, based on globally documented ecosystem service values and assuming that Madagascar's protected areas are effectively conserved, will increase with economic development in landscapes around protected areas. International studies have shown that the economic value of ecosystems increases over time, due to a combination of increased benefit capture and resource rarity.[15] Madagascar's protected areas are certainly growing in importance for conservation with time[16].

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[11] Dumas et al 2021
[12] Vezina et al 2020
[13] CEPF 2014 identified 213 KBAs; the number has since increased to 233
[14] KBA Data (keybiodiversityareas.org) – consulted 18.01.22
[15] Costanza et al 2014
[16] Waeber et al 2019

Finally, it should be emphasized that the above estimated values do not include a wide range of less tangible benefits, such as in human health (through clean water, well-being and disease control associated with forests and other natural ecosystems), research and education and international cultural benefits such as wildlife films or animations, access to international finance and Madagascar's prestige and image on the world stage, at least some of which could be measured given more time and data. Nor do we consider spiritual, *intrinsic* or *existence* values of biodiversity that can be very important to society.[17]

In all scenarios and estimates, from the least conservative to the most conservative, the gross economic benefits of protected areas are substantially greater than the costs of management, estimated at $10/ha/year or about $76 million for the PA network. The economic case for maintaining of Madagascar's protected areas if ever in doubt[18] is strongly supported by the economic evidence.

Maintenance and improvement of the PA network should be contrasted with the alternative scenario of inaction, allowing the network to weaken or decline, which would cause a loss of annual benefits to the Malagasy people and deprive future generations of the many benefits and opportunities offered by the network, quite apart from the loss of an irreplaceable global natural heritage. Average rates of forest loss across Madagascar from 2015-2017 were 1.6% and accelerating, with significantly lower rates (about 0.31%) in protected areas. One study has estimated that the annual cost to Madagascar of the 'business as usual' scenario, would be 5.6% of GDP, or a loss of $840 million annually,[19] while a recent World Bank study has estimated that nature loss in Madagascar would cost as much as 20% of GDP annually by 2030 or $3 billion/yr.[20] Maintaining and strengthening the protected areas network will help reduce these losses.

In the context of Madagascar, it is important to acknowledge that the gross benefits of protected areas are not yet efficiently captured or equitably distributed, and that in local situations protected areas may still have negative socio-economic impacts on disadvantaged groups for whom conversion of forest remains the more beneficial option in the short term. For protected areas to be viable they must be supported by local communities. Thus, mechanisms of benefit redistribution are fundamental to achieving the combined objectives of conservation and development[21] and must be developed to ensure that a fairer share of the substantial benefits generated by protected areas is enjoyed by local communities in return for their support to conservation.

In the light of the findings, a series of recommendations are made on international action and response, management of the PA network, research and other technical actions that should be taken:

- Internationally, Madagascar should advocate increased financial contributions in support of its PA system in proportion to the global benefits it provides including leveraging increased private and blended finance through the high biodiversity returns it can offer. To justify the additional finance, Madagascar should reinforce the PA network, innovate and diversity finance mechanisms for PAs and prepare an explicit PA strategy for presentation at CBD COP15, supported by a National Biodiversity Finance Plan. Madagascar should renew efforts to capture benefits from bioprospection, raise the price of carbon used for its REDD+ programme and promote the uniqueness of its PAs for international ecotourism post-COVID.

[17] The Dasgupta Review 2021
[18] MEDD 2020 identifies the need to constitute the arguments for the defence of PAs
[19] WWF 2020
[20] World Bank 2021b
[21] Raharinirina 2009

- In relation to PA management, Madagascar should improve and extend the PA network to optimise biodiversity conservation and ecosystem services delivery, frame PA policy explicitly around biodiversity and ecosystem services, monitor the economic benefits of PAs and integrate ecosystem services into PA management plans. PA managers should explore ways to improve the distribution of economic benefits of PAs, optimise benefit capture, integrate PAs into local and regional development plans, promote the role of PAs in improving human health and drive ecological restoration within and around PAs.

- Research efforts should focus on filling information gaps on the ecosystem services and impacts of PAs, especially for agriculture and hydrological services, measuring the economic impacts of PA management strategies, evaluating the costs and benefits of marine protected areas and evaluating the economic benefits of biodiversity *per se*. An ecosystem services review of Madagascar's PAs should be conducted, along with a study on how to secure greater support for PA finance from the private sector. PAs should be systematically integrated into spatial development plans and a national spatially precise data base of PAs and their ecosystem services should be developed and regularly updated.

Above all we need sincere political commitment at all levels to maintain, strengthen and adapt Madagascar's PA network in order to sustain the flow of benefits, develop and capture the available economic opportunities for PAs, ensure a more equitable distribution of benefits and secure this priceless heritage for present and future generations. President Rajoelina's commitment expressed during COP26 to halt deforestation in Madagascar is an important first step.

INTRODUCTION

The global context

The world is currently undergoing four major crises which represent major obstacles to achieving sustainable development – overconsumption, biodiversity loss, climate change and currently the COVID pandemic. While the science on climate change has demonstrated extraordinary global warming during the Anthropocene[22], the full extent and significance of the biodiversity crisis has proven difficult to grasp, resulting in insufficient effective action to address it to date[23]. Yet more than half the world's GDP depends on healthy, functioning ecosystems.[24] The root cause of biodiversity loss is the growing demand for food, fuel, water and land, combined with well-documented inefficiencies and resource misallocation in global production and consumption systems.[25]

While major efforts and investments have been made to reduce biodiversity loss, particularly over the past 40 years, biodiversity continues to decline at an alarming rate in most countries of the world. To meet this challenge, a global biodiversity action framework has been developed under the Convention on Biological Diversity (CBD) for adoption at the forthcoming CBD CoP15.[26]

Associated with the biodiversity crisis is a substantial and widely recognised shortfall in the level of funding needed to reverse the current trend of biodiversity loss. The most authoritative estimate of the global biodiversity funding gap, which considered over 800 literature references, estimates that the global funding needed to reverse biodiversity loss is between $598 and $824 billion annually (Fig 1).[27] It has been estimated that merely stabilising biodiversity losses would cost $23-32 billion per annum under current conditions[28]. Another estimate suggests that the necessary adjustments to stabilise biodiversity *intactness* would require an average investment of 8% of global GDP, rising to 17% if delayed by 10 years[29]. Finally, UNEP has estimated that *investments* in Nature Based Solutions (NbS) must triple and increase to about $568 billion annually by 2050.[30]

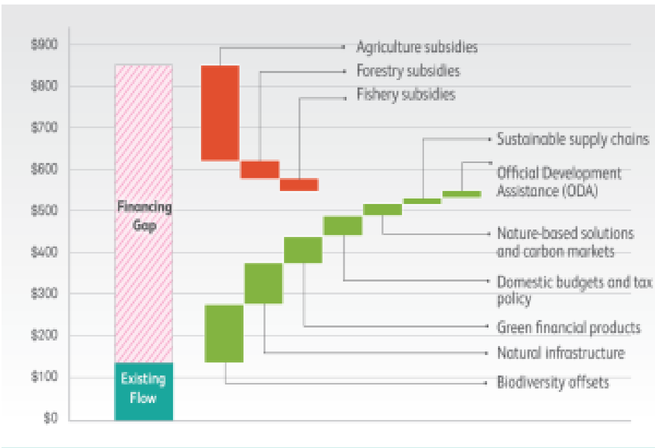


Fig 1 – Global biodiversity finance gap (Source: Deutz et al 2020, p. 64))

[22] Osman et al 2021
[23] Bradshaw et al 2021
[24] World Economic Forum 2020
[25] OECD 2019
[26] CBD 2020
[27] Deutz et al 2020
[28] CBD 2020
[29] Dasgupta Review 2021
[30] UNEP 2021

Madagascar biodiversity

Madagascar is a highly biodiverse country. According to the most recent comprehensive account of its terrestrial biodiversity, Madagascar possesses about 12,000 species of plant of which 83% are unique to Madagascar, divided among five ecoregions. It possesses over 5800 invertebrates (86% endemic) and about [2000] endemic species of land-based vertebrates. While accounting for only 0.4% of the world's land area, Madagascar accounts for 5% of the world's diversity of flora and fauna[31].

Madagascar is also considered a global hotspot because of the combination of very high biodiversity coupled with very high levels of threat[32]. Almost all of Madagascar's unique biodiversity is held within natural forests, especially the humid eastern and dry western and southern forests. Some wetlands also contain significant diversity and Madagascar's marine biodiversity is high compared to other countries of the Western Indian Ocean region[33]. But it must be emphasized that Madagascar's forests are the most critical ecosystems to the survival of its biodiversity.

Madagascar is also a very poor country with a rapid population growth rate. Without strongly developed infrastructure and social capital, Madagascar's economy is heavily dependent on the direct exploitation of its natural capital to meet the nutritional needs and economic aspirations of its growing population. Modes of natural capital exploitation range from stable agriculture in human-transformed landscapes to the direct extraction of resources from, or conversion of, natural ecosystems, especially logging and clearance of primary forests for agriculture, causing irreversible loss of natural ecosystems and biodiversity.

Today is a critical time for the survival of Madagascar's nature and biodiversity[34]. According to the most recent assessments, Madagascar lost 44% of its natural forest cover during 1953-2014 (including 37% lost over the period 1973-2014). In 2014, natural forests covered 8.9 Mha (15% of the national land area) including 4.4 Mha (50%) of moist forest, 2.6 Mha (29%) of dry forest, 1.7 Mha of spiny forest (19%) and 177,000 ha (2%) of mangroves. After 2005, the annual deforestation rate progressively increased to reach 99 000 ha/yr during 2010-2014 (corresponding to a rate of 1.1%/yr)[35].

In the period 2015-2017 the deforestation rate accelerated by a staggering 56% compared with 2010-2014. At the end of 2017 half of the remaining forest (49%) was located less than 100 m from the forest edge, making most surviving forest already accessible to agricultural conversion. Madagascar risks losing all of its forests and associated biodiversity within 50 years or by 2068 (Vieilledent et al 2018b). Since about 80% of Madagascar's biodiversity lies inside forests[36] and 60% of Madagascar's remaining forests lie inside protected areas, protected areas have an increasingly critical role to play in preventing the loss of forests and biodiversity.[37]

A decade or more ago, the primary concern about Madagascar's deforestation was the loss of its unique biodiversity. Today, this is still a major concern, but additionally the rapid loss of Madagascar's forests has important consequences for global climate change. In effect, the high deforestation rate in Madagascar results in large emissions of carbon which contribute to climate change. In contrast, if well

[31] Goodman & Benstead 2005
[32] Myers et al 2000
[33] Cooke et al 2003
[34] Jones et al 2019
[35] Vieilledent et al 2018a
[36] Waeber t al 2019
[37] Waeber et al 2019

conserved, Madagascar's forests could act as a carbon sink, but if deforestation and forest degradation continue Madagascar will rapidly become a significant net emitter of carbon.

Madagascar's protected area system

In line with most other countries, Madagascar's principal strategy to prevent the loss of its irreplaceable biodiversity and forests has been to establish a network of protected areas. Madagascar's protected area network has a long history which dates back almost 100 years to the creation of the first protected areas in 1927. The network has developed in several recognizable phases summarized as follows:

- Pre-colonial period (1745-1896) – while no formal protected areas were created in this period, Madagascar's first king Andrianampoinimerina (1745-1810) declared the protection of forests as a public heritage. [38] Such rules, followed later by the code of 305 Articles of Ranavalona II banning the cutting of forest for agriculture, testify to an early appreciation of the value of forests and protected areas.

- Colonial period (1896-1960) – beginning in 1927, with the creation of 10 strict nature reserves totalling 362,579 hectares, complemented by the first national park, Montagne d'Ambre (18,200 ha) in 1958 and 16 special reserves during the 1950s, totalling 388,869 ha, complemented by a network of classified forests of about 2 million ha.

- Post-colonial period (1960-1990) – Isalo national park (81540 ha) was established in 1962 (in the same year Cap Masoala RNI of 29,977 was degazetted for logging), followed from 1962 to 1986 by 8 new small special reserves (totalling 26,123ha) and in 1966 the expansion of the RNI network from 11 RNIs covering 392,570 ha to 12 RNIs covering 569,542 (a net increase of 176963 ha). In 1968, the first, very small, marine reserve was established at Nosy Tanikely (139ha)[39]. In 1989, Madagascar's first biosphere reserve was established at Mananara-nord (24000 ha including a second small marine reserve at Nosy Atafana of about 1000 ha). At the end of this period coverage of PAs stood at 38 sites covering 1,034,782 ha or 1.76% of the national area, complemented by 158 classified forests and 77 reforestation and restoration areas covering an additional 2,460,196 ha[40].

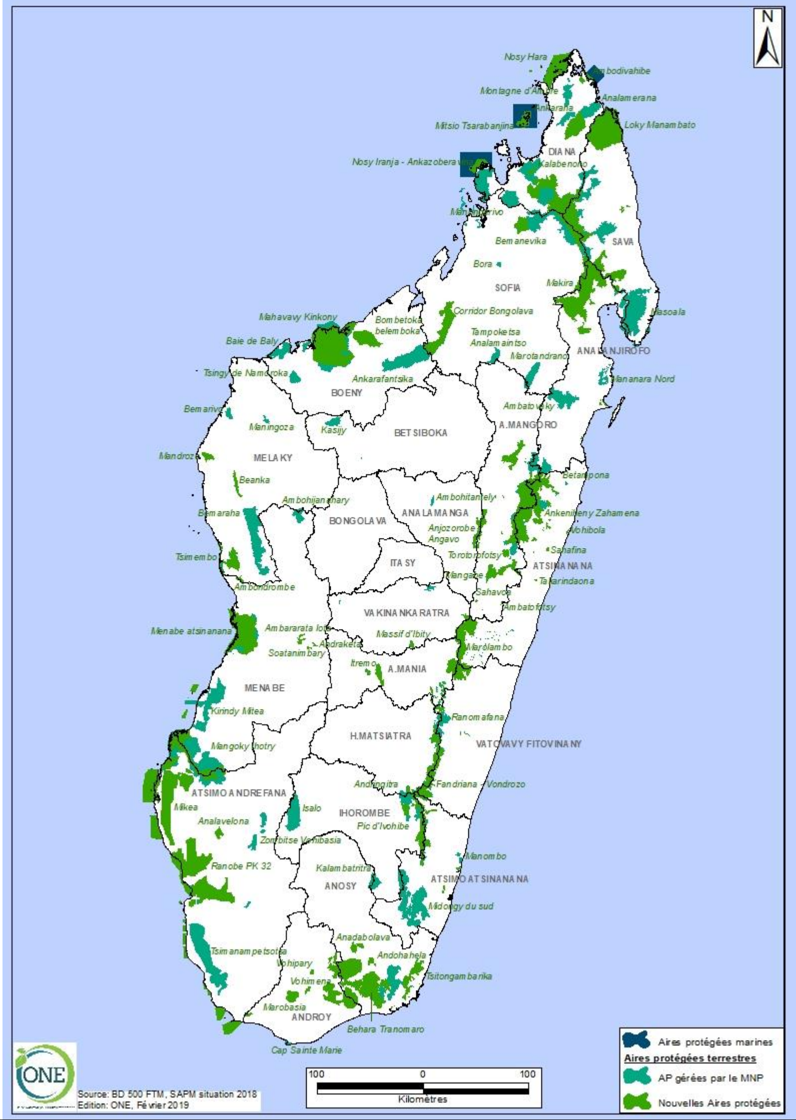
- National Environmental Action Plan (NEAP) period (1990-2003) – The NEAP period added 12 large new national parks linked to integrated conservation and development projects (ICDPs) and reclassified several strict nature reserves as national parks accessible for tourism, bringing protected area coverage to 50 sites, managed by Madagascar National Parks, covering 1.5 million ha or 3% of the land surface.

- Durban Initiative (2003-2015) – following international consensus on the norm that protected areas should cover at least 10% of the land surface[41], Madagascar increased its terrestrial protected area coverage to 123 terrestrial (and mixed terrestrial and marine) protected areas covering 6,165,653 ha (10% of the land surface)[42] complemented by an additional 6,886,931 ha of priority sites for potential conservation, together totalling 24% of the national surface[43].

[38] Jones et al 2021
[39] Arrêté 4730 (Journal Officiel 2232, 30 November 1968) of the Ministry of Equipment and Communications
[40] Goodman et al 2018
[41] 10% is now regarded as insufficient - recent evidence suggests 20-30% is needed e.g. Waldron et al 2020 and within reach (World Bank 2021b)
[42] Goodman et al 2018
[43] Borrini-Feyerabend & Dudley 2005

- Promise of Sydney (2016-2020) – based on new international norms, Madagascar further increased terrestrial protected areas and increased marine protected areas (MPAs) by a factor of 5 times from 221,045 ha in 2016 to 1.38 million ha in 2020 (12% of the continental shelf).

In 1990, the national institution, Madagascar National Parks or MNP (then the *Association Nationale pour la Gestion des Aires Protégées*) was established to manage the expanding network, under the responsibility of the ministry responsible for environment and forests (today the Ministry for Environment and Sustainable Development or MEDD). Today, Madagascar's protected areas network stands at 123 protected areas (including 101 terrestrial and 22 marine) covering 7,712,364 ha, or about 11% of the land and shallow sea surface area (Fig 2).



Madagascar's Protected Area System (SAPM) in 2021:

- **123 protected areas (101 terrestrial, 22 marine)**
- **7,612,346 ha covering terrestrial, aquatic and marine ecosystems**
- **Protected land surface of 6,233,317 ha (10.6% of land area)**
- **Protected marine and intertidal areas of 1,379,029 ha[44] (11.8% of shallow coastal seas)**

(Source: SAPM/ONE)

Fig 2 – Madagascar's protected areas network in 2021 (Source: SAPM/ONE)

In 2004, a Madagascar biodiversity foundation (*Fondation des Aires Protégées et de la Biodiversité de Madagascar* or FAPBM) was established with an initial endowment of $10 million to provide sustainable finance to Madagascar's protected areas network. The fund has since grown to $88 million (FAPBM 2020) to finance the maintenance of protected areas. In accordance with the FAPBM's spending rule, the foundation has disbursed about $2.5 to $3.5 million annually towards the

[44] Données de SAPM de 2017

maintenance of Madagascar's protected areas totalling, or about $0.50 per ha, representing about 5% of the average annual cost of $6.06/ha (assuming a total annual SAPM cost of $42,947,958) as was projected in 2015.[45] [46]

A significant but unquantified part of conservation investments has been dedicated to developing sustainable livelihoods and economic opportunities for local populations living locally within the landscapes in which the protected areas are located, capitalising on the higher rainfall, clean freshwater supplies, good soils, natural forest products, cultural benefits (spiritual, tourism, education), human well-being and infrastructure associated with protected areas.

Over the six years 2008-2013, Madagascar government spending on biodiversity (including natural resources management) was $13.5-18 million, or about $2.25-3.1 million annually[47]. According to a more recent study for the period 2014-2018, government real expenditure on biodiversity ranged from about $4-8 million/yr or about 0.25-0.5% of the annual government budget. Expenditure was well below budgetary provision (spending rate of only 12-20% of budget).[48] These government expenditures are low compared with some other high biodiversity countries such as Costa Rica, where annual government funding for biodiversity reaches $250 million/year for a country of 51,000 km^2 (amounting to about $50/ha/yr). Costa Rica's expenditure includes maintaining 160 protected areas, but also includes significant support for transforming the agricultural and other sectors to more sustainable practices with less impact on biodiversity.

From the early 1990s up to 2013, an estimated $450-500 million of public international funds were invested in environmental action in Madagascar[49], or about $20 million annually. The contribution of bilateral and private grant funding (which does not include public international funds) from 2005-2011 was estimated at $220.57 m, or an average of $36 million annually. Over the period 2000-2013, the Global Environment Facility (GEF) alone contributed $30.666 million or about $2.2 million annually[50]. If expenditure to 2020 is included, including private funds, the total amount grows to an estimated $900 million over 30 years (P Rajenarison pers comm) or an average of $30 million annually, or 0.2% of 2019's GDP.

A review of expenditure on biodiversity conservation for the 5-year period 2014-2018 was recently undertaken by the UNDP/GEF BIOFIN project.[51] The study considered funding from both international public, international private and national sources. Total international public funding in 2018 was $35.65 million (2021 prices), including an average $6.76 million/yr from GEF. To this can be added funding from NGOs and private foundations, amounting to $16.1 million. When all sources are considered including government expenditure of about $5-8 million/yr, the annual amount ranged from **$51.8-59.9 million per annum** (2021 prices).

It has been observed that protected areas in Madagascar have not always succeeded in their twin objectives of conserving biodiversity and improving the economic development of local populations, precipitating a series of roundtables during 2020 coordinated by the MEDD to review experiences.[52] Available evidence clearly shows that deforestation rates have been consistently lower in protected

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[45] Agreco 2012
[46] In this study, we estimate the adequate management of protected areas at an average of $10/ha/yr.
[47] CEPF 2014
[48] BIOFIN 2021
[36] World Bank 2013
[50] CEPF 2014
[51] BIOFIN 2021
[52] MEDD 2020

areas than in unprotected areas.[53] [54] However, declines in deforestation rates may take as much as a decade to stabilize[55] and require site-specific strategies which take time to develop.[56] Thus, deforestation nevertheless continues in many protected areas and the economic benefits from PAs to local populations have been limited[57]. In some cases, economic impacts on local households may even be negative due to lost access to resources[58] and such impacts may persist in the long term[59]. On the other hand, there is evidence of substantial positive economic impacts at popular sites and of a range of environmental benefits. There is also evidence that children's health and human well-being are better in communities living in landscapes with protected areas than in unprotected landscapes[60]. Nonetheless, in the case of protected areas, as with economic sectors, the appropriate distribution of benefits will be fundamental to achieving the twin objectives of conservation and development.[61]

Purpose and Research questions

The main purpose of the present study was to conduct a review of the evidence for the economic contribution of Madagascar's protected areas network.

To this end, we aimed to answer the key following questions:

- What is the economic contribution of Madagascar's protected areas to the global, national and local economy?
- How do the economic benefits of Madagascar's protected areas compare with the costs of maintaining them?
- What other significant economic benefits of protected areas (global, national, local) should be recognised but which may not readily measurable?
- How are the economic benefits of Madagascar's protected areas distributed (internationally, nationally, regionally and locally)?
- What are the approximate levels of opportunity costs suffered by local communities as a result of the creation and maintenance of protected areas?
- How does the situation of Madagascar compare with other countries?
- Based on the findings, what key actions should be taken for the financing and coverage of Madagascar's PA network, and the capture and distribution of benefits?

METHODS

Methodological approach

We began the study with two key **scoping and orientation** steps:

[53] Eklund et al 2016
[54] Waeber et al 2019
[55] Dumas et al 2021
[56] Rafanoharana et al 2021
[57] Sander & Zeller 2007; Rakotonarivo et al 2017
[58] Hockley et al 2018
[59] Poudyal et al 2018
[60] Rasolofoson et al 2018a & 2018b
[61] Raharinirina 2009

1. Undertake a **general literature review** (including interviews, webinars and online research) of global trends and best practice in the economic valuation of biodiversity, ecosystem services and protected areas.
2. Identify the **data and information available from Madagascar** to inform an evaluation of the economic contributions, including costs and benefits, of Madagascar's protected areas globally, nationally and locally.

Based on the types of data and information identified (global, national, local), we adopted a six-tier evaluation approach comprising:

1. **Initial scoping of the potential economic values** of Madagascar's protected areas based on consideration of published ecosystem values to determine the appropriateness and feasibility of adopting a transferred value approach
2. Estimate the **global economic contributions of Madagascar's PAs** to climate regulation, biodiversity conservation and other biodiversity-related benefits (ecotourism, access to genetic resources, scientific research and entertainment) (including the Madagascar government's own expenditure on biodiversity and PAs)
3. Estimate **the gross national economic contribution of terrestrial protected areas** to key economic sectors in Madagascar (including tourism, energy, agriculture, carbon storage and biodiversity conservation)
4. Estimate the **national economic contribution of marine protected areas** based on a combination of internationally published economic valuations of marine and coastal ecosystems, MPAs and the limited data available on MPAs in Madagascar
5. Estimate the **total national economic contributions of the protected areas network** by summating the national contributions of terrestrial and marine protected areas
6. Estimate the **local and landscape-level economic contributions** of protected areas based on available **case studies** of individual protected areas or landscapes

In addition we:

- Highlight the less easily measurable but nevertheless important benefits from Madagascar's protected areas which cannot readily be evaluated in monetary terms (human health & well-being, biodiversity conservation, research & education, entertainment through nature documentaries & films, spiritual and moral values)
- Conduct a review of the literature on the opportunity costs of protected areas to local communities as a basis for a high-level comparison of such costs with benefits
- Review the recent literature on the costs of inaction in relation to natural ecosystems and protected areas
- Review available data and publications on the cost of maintaining terrestrial and marine protected areas in order to generate a robust estimate of the average cost per hectare as a basis for a high-level comparison of management costs with economic benefits.

- Review the experience of a small selection of other countries to assist in understanding and interpreting the results from the present study and to highlight some of the options available to Madagascar.

Main data sources used for the evaluations

- Internationally published information from peer-reviewed sources on the social cost of carbon, economic losses resulting from the loss of biodiversity or protected areas, costs of biodiversity conservation, the costs of inaction, international tourists' willingness to pay for conservation, the value or coral reefs for tourism, the value and benefits of ecosystems and fisheries and on the opportunity costs of conservation for local communities.[62]

- Data on the surface area coverage of four major forest types (humid eastern, dry western and southern dry forest and mangroves) were provided by the BNCCRED+ project (LOFM/BNCCREDD+, 2021)[63].

- Shapefiles for Madagascar's protected area system were obtained from the Directorate of Biodiversity and the Protected Areas System (DBSAPM) held and utilized by the Ministry for Environment and Sustainable Development (MEDD) (2017 version).

- Data on hydro-electric power stations were provided by the *Office de Régulation de l'Electricité* (ORE). Interviews with senior technical staff at JIRAMA and an earlier report commissioned by the World Bank[64] provided guidance on location of small hydro-units and a map used by Conservation International[65].

- Data on land-use including agricultural uses were obtained from a national land use map published by the National Environmental Office[66].

- Data on protected area visitor numbers were provided in excel format from Madagascar National Parks and are used with the kind permission of MNP[67]. No centralized databases yet exist for visitor numbers to New Protected Areas (NAPs) within the SAPM system, few of which are on existing tourism circuits.

- Data on tourism in Madagascar were obtained from the Ministry of Tourism Transport and Meteorology (MTTM) official data and from a range of previous surveys and publictions[68].

- Data on ecosystems within marine protected areas were based upon a literature review of Madagascar's MPAs (including terrestrial PAs containing marine and intertidal ecosystems) and international datasets on marine and coastal ecosystems.

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[62] Notably from WWF 2020; Deutz et al 2020; CBD 2020; Mair et al 2021; Kramer et al 1995; Spalding et al 2017; Costanza et al 1997 & 2014; De Groot et al 2012; Golden et al 2011, 2012 & 2014; Barnes-Mauthé et al 2013; Brenier et al 2011; Naidoo et al 2019; Ouyang et al 2020; Herera et al 2017; Poudyal et al 2018; Rakotonarivo et al 2017; Rasolofoson et al 2018a & b; Desbureaux & Brimont 2015 ; Ferraro 2002; Hockley & Razafindralambo 2006; Hockley et al 2018; Shyamsundar & Kramer 1997; Zeng et al 2021.

[63] E-mail from BNCCREDD+ with data provided on 17 July 2021 (LOFM/BNCCREDD+, 2021))

[64] SHER Ingénieurs-Conseils s.a. & Mhylab 2014

[65] Neugarten et al 2015

[66] ONE 2015

[67] MNP 2020

[68] ONTM/PIC 2012; MTTM 2017-2020

- Data used for the case studies were taken primarily from socio-economic and market data collected by university researchers from the C3-EDM environmental economics department[69] or other sources referenced in the text.

Key variables in economic calculations

The economic calculations made use of data from different dates. We applied the following corrections:

- Standardizing all values to $2021 USD – All final US$ values were corrected to standard $2021 US dollars applying a GDP deflator to the original values for the year.
- Value of GDP – For all calculations involving GDP, we used Madagascar's GDP for 2019 i.e. immediately pre-COVID, which was $14,912,000,000[70].
- Exchange rate – For converting MGA values to USD in the site case studies and reviews of biodiversity expenditure we used an average rate of $1 = 3750 MGA.
- Discount rate – in accordance with Madagascar Central Bank standard practice, where required, we adopted an annual discount rate of 10%.

Specific valuation methods

The study used a combination of economic valuation methods, including *value transfer* (adaptation of existing valuation information to new contexts where valuation data is absent or limited), *direct market pricing* (notably for provisioning services), *direct expenditure* (for biodiversity conservation and tourism) and *avoided cost methods* (for regulating ecosystem services). *Contingent valuation* (such as consumer willingness to pay) was used in relation to biodiversity conservation (where we considered international willingness to invest in Madagascar's biodiversity) and global tourism (where historic willingness-to-pay data were used to estimate the consumer benefits of international ecotourists visiting Madagascar's protected areas[71]).

Initial scoping of PA values based on internationally published ecosystem service values

A search was made of peer-reviewed literature on the economic values of ecosystem services from ecosystems present in Madagascar's protected areas, focusing on those using the most comprehensive data sets. We selected the two papers by Costanza et al (1997 & 2014) and an intervening paper by DeGroot et al (2012). Values were extracted for tropical humid forest, tropical forest (as the closest to dry forest), wetland, mangrove, coral reef and coastal marine ecosystems.

We compared these values using a transferred value study commissioned by WCS for the Makira-Masoala landscape in Madagascar in 2008, which used similar methods using selected international data sets.[72]

Global economic contribution of Madagascar's protected areas

The *global* economic contribution of Madagascar's protected areas was estimated for five ecosystem services encompassing the three main categories of ES (regulatory (including supporting), provisioning and cultural):

Climate regulation (regulatory) – carbon storage by Madagascar's forests (humid, dry, spiny and mangroves) assuming a range of values for the social cost of carbon (SCC) based on large studies

[69] C3EDM 2020 a & b
[70] World Bank data
[71] Kramer et al 1995
[72] Masozera 2008

reporting a lower value of $54[73], a median value of $171/tonne (for a study which included Madagascar) [74] and a maximum recent estimate of $417/tCO2.[75]

Key Assumption

The key assumption is that Madagascar will manage to conserve the forests within the existing network of protected areas.

Calculation

Global benefit in climate regulation = Annual emissions of CO2 avoided by the conservation of forests in Madagascar's PAs x the Social Cost of Carbon

Note: In case it is considered that more attention should be given to reforestation efforts, it is important to understand that natural forests are six times more effective at storing carbon than agroforestry projects, and 40 times more effective than tree plantations. This is due to the very high ancillary carbon content of natural forests, held within the very dense vegetation and underlying soil[76]. Recent scientific research has confirmed that carbon storage, water provisioning, and especially soil erosion control and biodiversity benefits are all delivered better by native forests.[77]

<u>Biodiversity conservation (provisioning)</u> – estimated as a range based on the most recent authoritative estimates of the cost of halting biodiversity loss[78] calculated as a percentage of that cost attributable to the protected areas of Madagascar based on its share of global biodiversity and the proportion of biodiversity finance needed on average for protected areas (20%).

Key assumptions:

The key assumption is that the global community would value the conservation of the biodiversity of Madagascar's protected areas to be at least the cost of preserving it and that such costs represent an international consensus on the world's willingness (if not confirmed ability) to pay for conservation of Madagascar's protected areas).[79]

Specific assumptions included:

- that Madagascar harbours 3% of the world's biodiversity [80]that Madagascar represents 6% of the global species extinction risk[81]
- that Madagascar's PA network harbours 71% of Madagascar's KBAs (and therefore of its biodiversity, while protected areas would account for 20% of those costs (globally, PAs account for about 20% of actual and required biodiversity expenditure or an estimated $149-192 billion annually globally[82]).
- *<u>Ecotourism (cultural)</u>* – the contribution of Madagascar's protected areas to the global ecotourism economy was estimated as a range by summating that part of expenditure on ecotourism visits to Madagascar made *outside* Madagascar's economy (as opposed to

[73] Wang et al 2019
[74] WWF 2020
[75] Ricke et al 2018
[76] Dasgupta 2021, Chapter 19
[77] Hua et al 2022
[78] Deutz et al 20202
[79] CBD 2020, Deutz et al 2020,
[80] 3% is conservative since some sources estimate that Madagascar harbours 5% of global species biodiversity
[81] Mair 2019
[82] Deutz et al 2020

expenditure captured within Madagascar), and the range of values reported in historic studies on tourists' willingness to pay over and above the direct cost of visits to protected areas (in effect representing the international ecotourists' consumer surplus)[83]. To this we added reported ecotourism expenditure in marine protected areas (MPAs).

Key assumptions

The key assumption is that 68% of global total tourism expenditure for Madagascar ($707 million) can be attributed to the protected areas network.

Further assumptions include:

- That consumer satisfaction of tourists visiting PAs would be similar or greater today than at the time of the study published in 1995 (park infrastructure and guiding have improved since that time).
- That coral reef-based tourism and whale shark watching in PAs are specific and recent and can be considered additional to the expenditure and satisfaction relating to terrestrial PAs.

Calculations

Economic contribution of Madagascar's PA network = % of global Madagascar tourism expenditure linked to PAs (68%) x global value of Madagascar tourism ($707 million) + PA visitor satisfaction + tourism relating to MPAs.

- *Biodiversity research (cultural)* – the estimated contribution of Madagascar's protected areas to international biodiversity research was based on the average number of publications on Madagascar's biodiversity reported in a global data base on scientific publications[84], assuming that such studies relate to one or more protected areas and applying an estimated expenditure of $10,000 per research publication.

Key assumptions

It was assumed that all published biodiversity research in Madagascar is related to one or more PAs. The estimated average cost of $10,000 per publication assumed a $2500 return flight for an international researcher, $2500 for field missions in country and a nominal value of $5000 for the time spent by all researchers involved in research and writing up.

Calculation

Global annual value of research of biodiversity in PAs = (Number of publications since 1990/30) x an average $10,000 per publication.

- *Bioprospection and genetic resources (provisioning)* – our estimate of the global benefit of bioprospection and the option value of genetic resources in Madagascar's protected areas is a range based on a global estimate made by the World Bank in 2010[85] (lower end) and an estimate commissioned by WCS in 2008 for the protected forests in the Makira-Masoala forest landscape (which together contain over 50% of Madagascar's species diversity)[86] (upper end) As corroboration, account was taken of the benefits derived from the production of anti-

[83] Kramer et al 1995
[84] Nature News 26 October 2021
[85] Ollivier & Giraud 2010
[86] Masozera 2008

cancer drugs from the Madagascar Rosy periwinkle, reported to be about $100 million annually from a single species.

Key assumptions:

We assume that the estimations conducted by the World Bank in 2010 and WCS in 2008 are accurate. Given that a single species (rosy periwinkle) has generated $100 million annually, a value of $299 to $809 million annually for all genetic resources in Madagascar's PAs appears credible.

National economic contribution of Madagascar's Protected Areas

Available data and publications were identified relating to the national economic contribution of protected areas to key economic sectors, including agriculture (water for irrigation), energy (hydropower), tourism (based on visitor numbers' data for 2019 and average tourist expenditures in published studies), carbon storage (adopting values used by the Madagascar REDD+ program) and biodiversity conservation (based on historic and recently documented international and government expenditures[87]). In the light of the recognised health benefits of PAs in reducing diarrhoea in children,[88] a search was made for economic data on the public health effects of protected areas, such as comparing local expenditure on medicines for the treatment of intestinal illnesses within communities near to protected areas with those further away. However, available data was found insufficient to estimate the monetary value of the health benefits of PAs. Health benefits were therefore considered only in a qualitative manner.

A combination of direct economic and avoided-cost evaluations was used, combined with extrapolation to derive values for multiple protected areas of the same forest type (humid, dry forest, spiny forest, mangrove) and for all PAs across Madagascar. Direct economic valuation was used for agriculture, tourism, energy and carbon storage, complemented by data on avoided cost and contingent valuation (willingness to pay) in the cases of agriculture and energy. Where possible, we explored other valuation avenues in order to test or corroborate the principal values presented and whether they were likely to be conservative.

For sectors for which economic data are not available or which are not readily measurable using quantitative approaches, we provide a qualitative presentation of the benefits at the end of this section (e.g. for human health and well-being).

Specific methods and key assumptions by sector were as follows:

Agriculture

We explored the available evidence on the benefits of Madagascar's protected areas to agriculture through regulating services (such as reducing soil erosion or pollination) and provisioning services (such as the provision of water for irrigation). We found robust studies on the benefits of hydrological protection (the provision of clean water) and soil erosion control (including avoided costs of erosion and the willingness of farmers to pay for upland erosion control).

We found no studies applicable to Madagascar on the benefits of services such as pollination or on the distance over which protected areas exert beneficial effects on agriculture. As a consequence, we based our best estimates on an earlier World Bank publication for Madagascar[89] estimating the service values of a subset of 20 protected areas covering 1,102,949 ha, located upstream of at least 430,000

[87] BIOFIN 2021
[88] Rasolofoson et al 2018a and 2018b
[89] Carret & Loyer 2004

ha of irrigated fields and/or of 17 large towns consuming 8.4 million m3 of potable water, correcting for USD 2021 values.

Key assumptions: The key assumptions were those of Carret & Loyer 2004, namely:

- That each hectare of the protected area contributes equally to the services provided
- That all water provided to the irrigated area can be attributed to the protected area

Agricultural values were thus calculated by the formula:

Annual agricultural value = Irrigated area adjacent to PA in ha x rice production value/ha/yr

Energy (direct contribution & avoided costs methods)

The correlation between hydropower generation and PAs is explained by the role of forests in water regulation. This role can be direct – i.e. forests protect soils and promote infiltration to limit runoff. It can also be indirect – i.e. forest cover improves the water balance and physical properties of the soil.

The study used a georeferenced database maintained by ORE (*Office de Régulation de l'Electricité*) on hydro-electric resources in three categories: 1. Existing operating hydropower stations (totalling 160Mw); 2. Potential identified on-grid large-scale stations (total estimated potential 1500 Mw); 3. Areas suitable for off-grid micro hydro-electric schemes (total estimated potential 6000 Mw). For the purposes of the study we considered the three existing installations (Andekaleka, Namorona, Ranomafana) and two planned dams (Sahofika, Volobe) in catchments downstream of protected areas. Locations of the existing stations and their associated upstream watersheds were overlaid on the map of protected areas and instances of overlap identified.

According to the Volobe General Hydropower Company (CGHV), the entry into service of the Volobe hydroelectric power plant (120 MW) could be compromised due to the lack of water resources. The Ivondro River, which hosts the infrastructure, risks insufficient flow from its tributaries, the Onibe, Namandrahana and Ivoloina rivers, among others. The company recognizes and deplores the massive deforestation of the watershed, in addition to illegal mining.

For the Andekaleka hydroelectric power plant, Conservation International launched strong messages in 2017 on the urgency of restoring upstream forests and protecting watersheds around the Andekaleka dam. For JIRAMA, which manages this centre, the degradation of forests upstream of the hydroelectric dam has an influence on the level and cost of energy production. Forest degradation is cited as one of the main causes of power outages in the capital, especially in the dry season.

Economic assessment method of forest services for hydroelectric power generation

The method is to assess the cost of the degradation and the cost of replacement. The first represents JIRAMA's shortfalls due to production losses at the Andekaleka hydroelectric dam. The estimate of replacement costs provides an indication of the investments needed to partially address environmental degradation. In addition, JIRAMA has taken costly measures to meet the capital's electricity needs using thermal energy.

We corroborated the results obtained for Andekaleka with examples of two hydropower stations operated by the Italian conglomerate Tozzi Green for which certain limited data were available.[90]

- Hydelec power station (Voloina commune, Maroantsetra) – fed by a sub-catchment of the Makira protected forest of 74,494 ha (capacity 2.5MW)

[90] Tozzi Green 2021

- Farahantsana power station (capacity 28 MW, for which an additional $6,325,000 (€5.5 million) investment was required for the construction of a sediment removal facility for incoming water).

Andekaleka Dam: significant decline in hydropower generation capacity due to forest degradation

The Andekaleka Dam is a gravity-fed dam on the Vohitra River near Andekaleka in eastern Madagascar on the western side of the Ankeniheny-Zahamena Forest Corridor (CAZ), a 369,266 ha protected area created in 2015. The dam and power plant were originally installed in 1981 under funding by the World Bank at a cost of $142.1 million with a total theoretical generating capacity of 112 MW (4 units of 28MW).

The Andekaleka hydroelectric dam provides electricity to Antananarivo, Moramanga and Andasibe. It is also linked to Toamasina's power grid providing energy access along an axis used for agro-industrial, mining and port activities. Overall, Andekaleka has contributed to a 30% increase in electricity access, including more than 60,000 new connections for households, the private sector and public services. Business competitiveness, industrialization, and the quality of life of urban and rural populations have all been enhanced by the project. In total, Andekaleka directly benefits more than 400,000 households and 2.5 million inhabitants, generating more than 1,000 direct jobs since its inception.

Over the past 20 years, JIRAMA has seen a significant decline in the Andekaleka dam's power generation capacity. Originally designed for over 100 MW, by 2011, annual production was estimated to have declined to 25 Mw (Portela et al 2012). Actual capacity has been reduced by 71 MW from 93 MW to just 22 MW or a loss of 78%, resulting in frequent outages.

One of the major causes of the decline in output is the degradation of forests upstream of the Andekaleka hydroelectric dam. Analysis of satellite images between 2005 and 2013 shows deforestation of 23,675 hectares in the watersheds upstream of the Andekaleka dam. Analysis of average water flows at the Vohitra Rogez station (near the Andekaleka dam) also showed a large annual decline from an average 76.4m3/s (1980 -1990) to 42.3 m3/s (1990 -2000). In addition, due to deforestation, plant debris clog the grids of the water drain valves to the plant, especially during the rainy season and cyclonic periods. Clearing of the water intake is done manually during shutdowns, adding to the risk of accidents for workers as well as reducing energy production and causing significant financial losses for JIRAMA.[91] [92]

The loss in capacity of 71 MW (93MW-22MW) results in a production loss of 19.170 million kWh/year, representing a shortfall of USD 2,057,900 per year. Assuming that 50% of this shortfall is the effect of deforestation of 23,675 hectares, **the value of hydrological protection is estimated at 43.5 USD/year for each hectare of forest.**

Key assumptions (production value method):

That all clean water feeding the hydroelectric dam could be attributed to the upstream protected areas.

Calculation: The economic contribution of the PA to power generation was thus estimated as:

PA Economic contribution to power generation ($) = (Average annual production of station in kWh) x (On-grid Price of electricity per kWh in US$

Key assumptions (avoided cost method):

[91] General Directorate of Meteorology
[92] Electricity Governance and Operations Improvement Project (PAGOSE), Environmental and Social Management Plan

- We assumed that only 50% of the lost production could be attributed to erosion from the deforested area upstream of the dam (and that 50% resulted from other factors such as management).
- We assumed that every hectare deforested contributed equally to the increased production cost, irrespective of its location in the upstream catchment.

Calculations: The contribution of one hectare of humid forest to the energy economic sector was thus estimated as:

Annual contribution of 1 hectare of forest = Increased annual production cost} / (area deforested since dam construction) x 50%

Tourism and ecotourism (direct contribution methods)
With an average growth of 10% per year from 2010 up until the start of the COVID pandemic, tourism had become one of the major activities of Madagascar's economy. Tourism is a 'buyer driven' market which responds rapidly to consumer preferences[93], such as the trend towards nature-based tourism. In 2013, the annual economic contribution of tourism was estimated at $450-500 million[94]. In 2019 it was one of the major sources of foreign exchange for the national economy, along with agricultural exports. Indeed, the statistics of the Ministry of Tourism put tourism revenues at[95] **US$707 million in 2019**[96], **or about 5% of GDP** which is higher than that of other sectors such as energy (US$302 million). Tourism has been at the heart of the national strategy for poverty reduction and biodiversity conservation and tourism development is a component of the Madagascar Emergence Initiative (IEM). While the tourism sector has been among the most severely hit by the COVID crisis, the uniqueness of Madagascar's nature-based tourism product should underpin recovery.

The ecotourism subsector is an important and growing segment of the tourism sector. Studies in the early 2000s indicated that 55% of all tourists came to Madagascar for ecotourism, of which protected areas provided the major attraction.[97] Based on a more recent survey in 2012[98], 68% of tourists come with an objective of visiting one or more protected areas. Fifteen protected areas (Table 2) received 2,917,939 or 99% of a total 2,951,871 park visits from 1992-2019. These top 15 sites are an important tourist attraction, thanks to their wealth of biodiversity and exceptional landscapes, but also to their accessibility, reputation and the development of associated infrastructure. With a total of 126 protected areas of all kinds of ecosystem and landscape, Madagascar's PA network offers considerable potential for ecotourism development in many regions of Madagascar.

Early studies of ecotourism in PAs

Early studies[99] on the creation of the Mantadia NP (26,787 ha) estimated tourism benefits based on *contingent* valuation (the willingness of tourists to pay) from $1 million to 2.5 million per year (or $37 to $93/ha/year) based on a survey of visitors to the park in 1990. In the same study using direct contribution methods they estimated the annual tourism economic contribution of the small Special Reserve of Périnet (now Andasibe-Analamazaotra) of 865 ha at $253,000/year (or $292/usd/ha) underlining the significant economic contribution of small PAs with flagship species such as *Indri indri.*

93 Raharinirina 2009
94 World Bank 2013
95 World Bank 2013
96 MTTM 2020
97 Carret & Loyer 2004
98 FTHM Conseils 2012
99 Kramer et al 1995

In the present study we used the most recent MNP park visitation data to estimate the contribution of protected areas to the tourism sector as a whole and to the ecotourism sub-sector.

Table 2 – The 15 Protected Areas of most importance for ecotourism (Source: MNP data)

Protected Area	Area ha*	Visits in 2019	Total visits 1992-2019
ISALO	81540	38642	624029
ANDASIBE-MANTADIA	16368	36193	591335
RANOMAFANA	40556	27338	424968
NOSY TANIKELY	341	51285	304956
MONT. D'AMBRE	30689	14844	275729
BEMARAHA	157574	21534	188090
ANKARANA	25354	9851	180159
ANKARAFANTSIKA	136673	4329	92961
MASOALA	223415	4188	55894
ANDRINGITRA	31477	2180	53194
ZOMBITSE-VOHIBASIA	35818	5456	36147
LOKOBE	848	7824	31571
MAROJEJY	55885	1200	22844
TSIMANAMPETS	201505	2171	21677
ANDOHAHELA	76140	396	14385
TOTAL	**1113981**	**227431**	**2917939**

* Surface areas quoted are for total surface area according to Goodman et al 2018

Key assumptions:

- The economic contribution of the protected areas network to the tourism sector as a whole corresponds to the percentage of tourists for whom visiting one or more protected areas is an objective of their stay (estimated at 68% of tourists in 2012)[100] multiplied by the total value of the tourism sector contribution to GDP.
- The specific contribution of protected areas to the ecotourism sector is the number of park visits multiplied by the average daily expenditure of a tourist for one day (the typical duration of a park visit).
- Based on available evidence, in-country tourist expenditure was assumed to be one third (33%) of total tourist expenditure.

Calculations:

The economic contribution to tourism of the protected areas network to the national economy as a whole was calculated as:

PA network contribution to tourism ($) = % of visitors to Madagascar whose objective is to visit one or more protected area x the contribution of the tourism sector to GDP

<u>The specific economic contribution of the PA network for the ecotourism segment</u> – was calculated as:

[100] FTHM Conseils 2012

PA Economic contribution to ecotourism segment ($/yr) = Number of visitors to top 15 PAs per year x Average daily in-country expenditure per tourist in US$ x 33% (the average percentage of expenditure made in-country)

Carbon storage (direct valuation)

With the development of an international market for carbon credits, carbon storage has become a potentially economically important ecosystem service provided by PAs and is an integral part of the national REDD+ strategy. Recognising that forest carbon projects for individual protected areas may allow leakage (representing that part of deforestation which is merely displaced to another location rather than avoided), the Malagasy government has been moving towards 'jurisdictional' REDD+ schemes whereby emissions are managed at the level of forested landscapes, beginning with the Makira and Ankeniheny-Zahamena Corridor (CAZ) protected areas, rather than at the level of individual protected areas. [101] [102]

Key assumptions:

- That the price secured per tonne of carbon through Madagascar's REDD+ program will be sustained at $5/tCO2eq
- The minimum national contribution of PAs to carbon credits will be provided by the Atiala-Antsinanana REDD+ scheme (covering 1,021,644 ha of forest within PAs)
- That all *forested* protected areas including mangroves could potentially contribute to revenue generation from avoided deforestation, representing a maximum attainable contribution.

Calculation: Using the SAPM data base on Protected Areas (2017 version with addition of new sites), the area and forest type (moist eastern, dry western, dry spiny, mangrove) were determined and an annual carbon storage value calculated using the formulas:

Minimum annual national contribution for carbon storage in US$ = PA area in the Atiala-Antsinana landscape x tC/ha for humid forest x Carbon price in $/t

Maximum annual national economic contribution for carbon storage in US$ = PA Area ha x tC/ha for the relevant forest type x Carbon price in $/t (summated for all forest types including mangrove)

Local economic contribution of protected areas

Interest of the local evaluation approach

A local approach to the economic valuation of protected areas is important to inform how costs and benefits of protected areas are distributed and what redistribution of costs and benefits may be needed to ensure that local communities do not bear an unfair share of the costs of conservation. Local economic evaluation is also useful as part of an integrated landscape approach which offers more opportunities for sustainable livelihood improvements, as is currently being undertaken by the PADAP project supported by the World Bank.[103]

Specific sites evaluated

Literature research and enquiries through expert networks on past or existing studies identified a limited number of protected areas for which sufficient local data existed for a complete or partial evaluation of economic benefits from ecosystem services at the local or landscape level:

[101] Jones et al in press
[102] MEEF 2018
[103] World Bank 2017 – Annex 3

- *Complexe de Mahavavy-Kinkony* wetland & Ramsar site (CMK) – for which data exist for the value of lacustrine (including fisheries) and forest products (charcoal)(provisioning services)[104]

- *Antrema Site Ecologique et Culturel* (for which a fully detailed economic evaluation has been conducted of provisioning services (wood, fisheries and mangroves)[105]

- *Ankarafantsika National Park* – for which data exist on the benefit of soil-erosion control (regulating service)[106]

- *Ranomafana National Park* – for which data have been collected on soil erosion control (farmers' willingness to pay), hydropower generation and ecotourism[107]

- *Andasibe-Analamazaotra Special Reserve* – for which data on tourism visitation to the park, park fees and eco-shop sales allow an estimation of the specific economic contribution for ecotourism (cultural ecosystem services)[108 109]

- *Makira Natural Park (southern parcel)* – for which a contribution can be estimated based on the capacity of the Hydelec power station (2.5MW) which depends on clean water from the 74,494ha Makira forest sub-catchment to provide power to the town of Maroantsetra.

Site descriptions

Mahavavy-Kinkony Wetlands Complex

The Mahavavy-Kinkony Wetlands Complex (CMK) is a new protected area located in the northwestern part of Madagascar of about **302,400 ha,** including 77,900ha of dry dense forests, 18,200ha of mangroves, 17,500 ha of marine and coastal space, and 29,000ha of rivers and lakes of which 13,800 ha is represented by Lake Kinkony (Fig 3). The site is managed by the NGO Asity Madagascar, BirdLife International's partner for Madagascar.

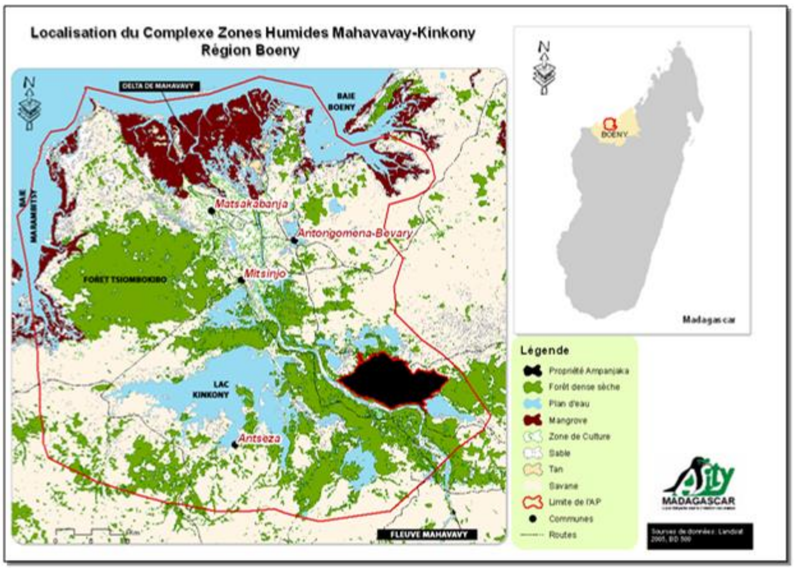

Fig 3 – Map of the Mahavavy-Kinkony Wetlands complex (Source: https://asity-madagascar.org/nos-sites/)

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[104] C3EDM 2018 unpublished data

[105] C3EDM 2018 unpublished data

[106] Rakotoratsimba et al 2020,

[107] MNP Annual Ecotourism Report 2019 ; Serpantié et al 2009

[108] MNP Annual Ecotourism Report 2019

[109] MNP Park Visitor data 1992-2019

The CMK plays an important role as a wetland in the northwestern part of Madagascar through several main ecosystems: forests, lakes and rivers and marine and coastal ecosystems (including mangroves).

The lake ecosystem consists mainly of Kinkony Lake. In addition, there are small seasonal and permanent lakes around Kinkony Lake which are variously connected to the main lake and local rivers.

The river ecosystem is dominated by the Mahavavy River, fed by tributaries from CMK watersheds. The river is connected to Lake Kinkony and small lakes in the vicinity. Other rivers and streams also originate in dry dense forests and flow directly into lakes or into estuaries.

The forest ecosystem is represented by the largest block of Tsiombikibo Classified Forest surrounded by fragments of degraded forest. Other smaller forest blocks are found around Kinkony Lake and in other parts of the site, especially on either side of the Mahavavy River. The forest plays a very important role in conserving soil at the watershed level and the physical-chemical balance of wetlands.

The Mahavavy Delta is the largest of the mangrove ecosystems north of the site and is located in the contact zone between fresh water of the Mahavavy River and salt water of marine origin. Another part of the mangrove lies to the west, along Marambitsy Bay, formed by contact between rivers from the Tsiombikibo Forest and the sea.

Antrema Bio-Cultural site
The Bio-cultural site of Antrema is located on the northwest coast of Madagascar between 15-42’ – 15-50’ S and 46-00’ to 46-15’ E (Fig 4). The site corresponds to the fokontany of Antrema of the rural commune of Katsepy, Mitsinjo District, in the Boeny Region. The site is located 12 km from Katsepy, bounded to the north and west by the Mozambique Channel and the Betsiboka estuary, to the east by the road leading to the Katsepy Lighthouse and to the south by the Mahavavy Delta. The protected area covers **20,620 ha,** including 1,000 ha of marine habitats, including mangroves, and 19,620 ha of terrestrial environment including continental wetlands.

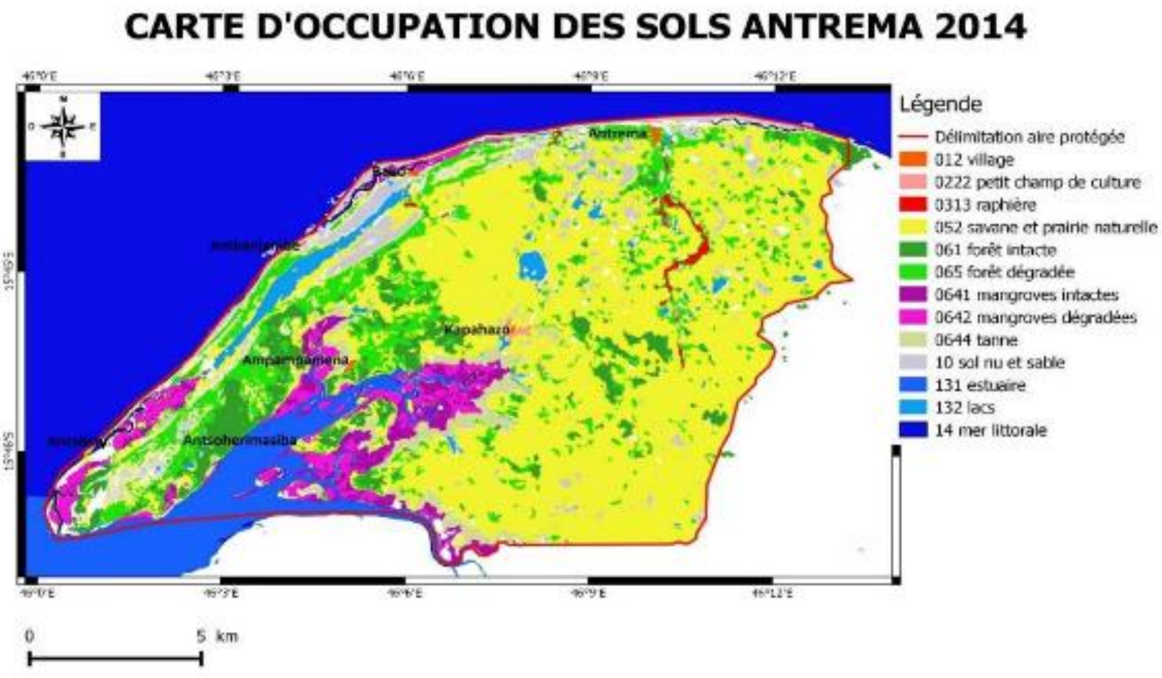


Fig 4 – Map of the Antrema Bio-cultural site (Source: Rakotoniaina et al. 2017)

Calculation of the economic value of ecosystem services at local or landscape level

To carry out the various calculations, we used primary data from research in 2018-2019 from IOGA (*Institut et Observatoire Géophysique d'Antananarivo*), DBEV (*Département Botanique et d'Ecologie Végétale*)) and C3EDM (*Centre d'Economie et d'Ethique pour l'Environnement et le Développement Madagascar*) as part of the COMPTABIO project of SEP2D (*Sud-Expert Plantes Développement Durable*). These data are composed of biophysical accounts of land use and water resources, as well as socio-economic data from field surveys.

For wooded areas, the value calculation is based on the use value of the forest and the ecosystem supply services of each ecosystem. Given the lack of data, only the direct use value could be assessed. For the forest, the economic benefits of forest conservation and management were assessed.

Within the CMK two sites are designated for the production of non-forest tree charcoal. The exploitation of non-forest trees for charcoal at these two sites is authorized by the protected area manager. Bemaratoly has a total area of 780ha producing 210m^3/ha/yr, while Masiakakoho, with 1041 ha, produces 57.6 m^3/ha/yr (on average 1 m^3 of dry wood weighs 175-280kg).

Results are presented in the results section. Further details of the methodology are presented in the appendix.

Ankarafantsika National Park

Ankarafantsika National Park is one of Madagascar's largest dry forest protected areas located in the western part of the Boeny region (Fig 5). It has been at the heart of the news recently with acute problems of land clearing and fires linked to the illegal cultivation of maize and other activities.

Managed by Madagascar National Parks, this park covers an area of **136,513 hectares.**[110] It contributes significantly to the representation of dry western forest biodiversity in Madagascar's network of parks and reserves and has recently been proposed as a World Heritage site. The park undoubtedly provides a number of important ecosystem services that contribute to the improvement and support of the lives of the local population. In this case study, we focused the ecosystem service of soil erosion protection provided by the western half of the park.[111]

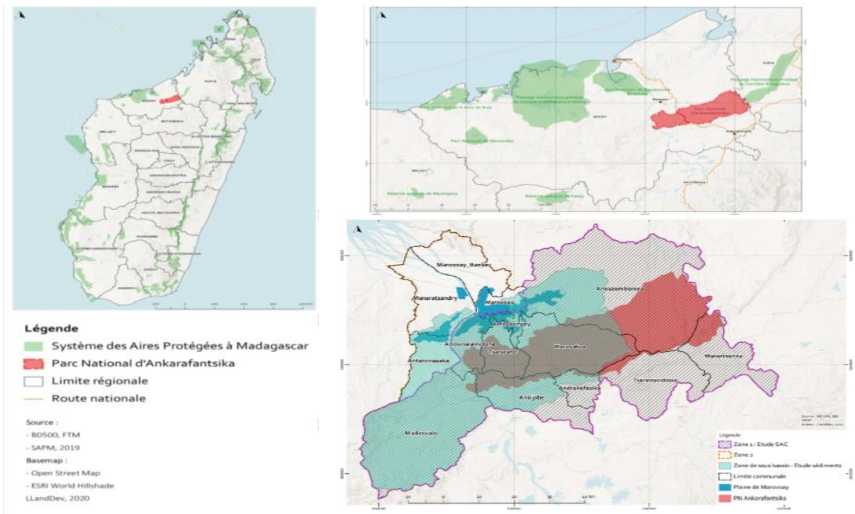


Fig 5 – Map of Ankarafantiska National Park showing its relationship to the Maravoay plain important for rice production (Source: LlandDev 2020).

[110] MEEMF 2015

[111] http://www.parcs-madagascar.com/parcs/ankarafantsika.php

Despite the importance of erosion which is known to be particularly intense in the area, the extent of the forest allows regulation of the water supply of the watershed affecting one of Madagascar's largest rice granaries, the Marovoay plain (with more than 38,000ha of growing area) [112]. The western half of the Ankarafantsika park (which we approximated as 50% of the total park area) acts as a reservoir for water and for flow regulation, but also to protect upstream areas from erosion, thus ensuring supplies of clean water to the Maravoay plain.[113]

Erosion of the massif has negative impacts on rice production in the area by smothering potential rice fields and making them unsuitable for cultivation. The sedimentation results from adverse actions carried out by communities surrounding the national park, including setting fires to clear forest for agriculture or grazing and the unrelenting harvesting of wood fuel and timber.

A study carried out by the Laboratory for Applied Research (LRA) in forestry, development and environment (ESSA Agro) has shown that the loss of land encountered in the sub-watersheds leads to increased sedimentation of the Marovoay plain and thus a loss of rice production area[114]. We evaluated the erosion protection service provided by the western half of the Ankarafantsika National Park from the avoided loss that would be associated with better forest protection.

We considered two scenarios:

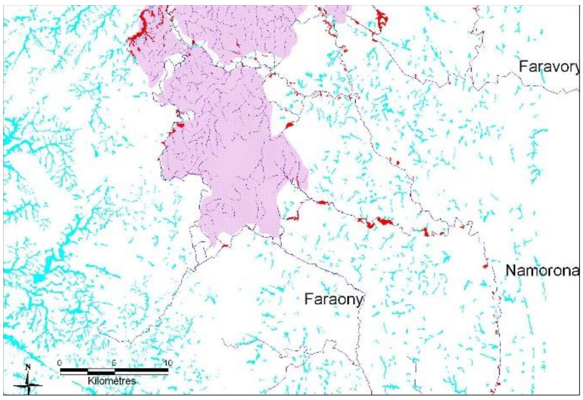
<u>Scenario 1:</u> a situation where Ankarafantsika National Park is better protected over a 30-year time horizon, with fully effective restriction on access to the National Park.

<u>Scenario 2:</u> a situation where access restrictions are not well respected over a 30-year period. In this scenario, no protective action is taken.

Results are presented in the results section. Further details of the methodology are presented in the Appendix.

Ranomafana National Park

Ranomafana National Park is classified as an IUCN Category II Protected Area (National Park) with an area of **40,556 ha** (Fig 6). It belongs to the Eastern Ecoregion and is composed of medium- and low-lying dense humid forest, marshland and bamboo forest. Since its establishment, Ranomafana National Park has had several positive effects not only on the local economy but also on the well-being of the surrounding populations.



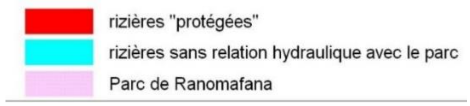


Fig 6 – Map of the Ranomafana National Park and associated rice fields (Source: Serpentié et al 2009, p10).

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112 MEEMF 2015
113 Rakotoratsimba et al, 2020
114 LlanDev 2020

In the case of Ranomafana National Park, the available data allowed estimations to be made of the economic benefits from five ecosystem services:

- Ecotourism
- Hydropower
- Drinking water
- Carbon storage
- Watershed protection

Results are presented in the results section. Further details of the methods used are presented in the Appendix.

Andasibe-Mantadia National Park

Andasibe-Mantadia National Park is located in the Alaotra Mangoro Region, Moramanga District. With an area of 15,480 hectares, it is managed by Madagascar National Parks. The Analamazaotra reserve, at Andasibe and within the park, is Madagascar’s prime ecotourism site, receiving over 36,000 visitors annually[115] who come primarily to see and hear the indri (*Indri indri*), Madagascar’s largest lemur. Available data allowed calculations of economic value for two ecosystem services:

1. Ecotourism
2. Carbon storage

[115] MNP Park Visitor data 1992-2019

Results are presented in the results section. Further details of the methodology can be found in the appendix.

Makira Natural Park (southern parcel)

Makira Natural Park (371,000 ha) is located in the northeast of Madagascar, to the west of the Bay of Antongil, Makira connects in the north with the Masoala national park (210,000 ha) on the eastern side of the Bay, the whole creating a forested landscape of about 900,000 ha. The southern parcel of Makira (74,494 ha) provides a forest catchment for the commune of Voloina where the Hydelec power station is located. Knowing the capacity of the Hydelec plant (2.5MW), and assuming that it runs on average at 50% capacity and that 50% of the clean water it uses comes from the upstream Makira forest parcel, and a price of energy of $0.75/kWh, we are able to estimate the forest value for energy production.

Value of parcel for energy = Value of energy generated in 1 year x 50% capacity x 50% of clean water from catchment

Marine protected Areas

Marine protected areas are relatively new in Madagascar and limited data are available on their economic values. A case study overview approach was taken combining an international literature review on MPA values and analysis of the limited available data for MPAs in Madagascar and generation of a first series of approximations of the economic contribution of Madagascar's MPAs based on fisheries and tourism (see case studies).

Key assumptions for MPAs:

- That the economic contribution of an MPA for fisheries is equal to the value of the fisheries yield from the site.
- That the economic contribution of an MPA for tourism is equal to the number of visits per year times the average tourist spend for one day at the relevant level (national and local)

Calculations:

We made three approximations of the economic contribution of MPAs:

1. The potential value using published values of the package of ecosystem services for marine ecosystems (transferred value);
2. the value based on numerous international studies of MPAs specifically;
3. the value based on actual data for fisheries and tourism in Madagascar MPAs.

For the purposes of the study we retained only value 3, since there was no clear evidence that internationally published values were applicable to the MPAs of Madagascar.

Results of the case study are presented in the results section. Details of valuation calculations can be found in the appendix.

Other benefits of protected areas

Within Madagascar, protected areas provide numerous socioeconomic benefits beyond those that can be readily valued in monetary terms. In particular, there is growing evidence that communities living around protected areas enjoy better health, nutrition and well-being[116] than communities living in deforested or degraded landscapes, mainly due to cleaner water, more productive agriculture and more diverse nutrition. In some cases, these benefits are reflected in lower rates of disease and improved child health.[117]

Madagascar's protected areas also help generate substantial economic activity in the areas of research, education and entertainment, such as through the production and broadcasting of documentary nature films and fictional films linked to Madagascar's wildlife (notably the *Madagascar* series of animations produced by Dreamworks).

Where possible, we have identified economic contributions associated with these benefits which are measurable in monetary terms and have included estimates in our principal value estimates. Where such estimates are possible but either give an incomplete picture of the benefit or are impossible to make based on available evidence or for other reasons, we review the wider evidence of the economic values of such benefits to allow a qualitative appreciation of their economic value.

Cost of managing protected areas

The actual and projected costs of the establishment and management of Madagascar's protected areas have been documented and estimated in several studies. In 2004, the recurrent costs of MNP for managing its network of 43 protected areas were estimated at $3/ha[118]. In 2012 the costs of running the SAPM network were projected to reach $42,947,958 annually by 2015, or about $6.06/ha/yr[119]. The actual (2020) management costs of the MNP network of 43 PAs covering about 1.5 million ha are $7 million annually (an average of $5 per ha). Taking account of these and other studies, as well as analysis of FAPBM data[120], we estimate an average protected area management cost for Madagascar.

Opportunity costs of protected areas in Madagascar

The high opportunity cost of protected areas to local communities living in their periphery who are heavily dependent on natural resources for their livelihoods has often been identified as a barrier to effective biodiversity conservation[121] and has been highlighted in multiple studies[122], including in the first economic evaluation of Madagascar PAs, as being in the order of $1.80 USD/ha/yr, rising to as much as $5.85/ha/yr after 15 years.[123] In other studies, such costs have been estimated to be as much as $300 to $1400/yr per household close to protected areas[124] or about $107/household/yr in the case of REDD+ projects[125] with a range between $40-125/household/yr or 27-84% of household revenues[126]. In the case of a proposed mangrove conservation project they were estimated at $49.30/yr/inhabitant[127]. We review the literature and examine the scope and scale of such opportunity costs and make recommendations on redistribution and other measures to compensate for such costs.

116 Rasolofoson et al 2017, 2018a & 2018b
117 Naidoo et al 2019
118 Carret & Loyer 2004
119 Agreco 2012
120 FAPBM 2021
121 Balmford & Whitten 2003, Kremen et al 2000, Sander & Zeller 2007
122 Brimont 2014, Brimont & Bidaud 2014, Desbureaux & Brimont 2015, Ferraro 2002, Hockley et al 2018, Kramer et al 1997, Poudyal et al 2018, Rakotonarivo et al 2017, Shyamsundar & Kramer 1997
123 Carret & Loyer 2004
124 World Bank 2013
125 Brimont 2014
126 Cannon 2018
127 Blue Ventures 2017

RESULTS

Literature review

General findings

Our review of the literature found that the approach and objectives of the present study are aligned with global trends and emerging best practice in valuing nature[128].

A key recent and globally authoritative publication is the Dasgupta Review on the economics of biodiversity[129]. In line with key findings of the Dasgupta Review, it is appropriate to adopt a natural capital approach and to treat the protected areas of Madagascar and their biodiversity as a critical natural capital asset worthy of sound management.

According to the Dasgupta review, biodiversity *per se* should be considered as a *characteristic* of natural capital, which can influence the economic benefits it can generate. The Dasgupta review identifies the following *economic values* of biodiversity:

1. Human existence depends on maintenance of biodiversity
2. Biodiversity makes a significant contribution to human health
3. Biodiversity provides amenity/enjoyment value to local residents and tourists
4. Biodiversity provides a wide range of valuable goods and services
5. Biodiversity has an 'Existence Value' often keenly felt by people all over the globe
6. Nature also has an intrinsic value (including moral or spiritual worth)

The Dasgupta Review emphasizes that not all values of biodiversity are measurable in monetary terms, but that biodiversity is valuable nevertheless. Dasgupta also argues that it is fully justifiable to evaluate those values of biodiversity for which an economic benefit can be identified and estimated, while not neglecting non-quantifiable benefits such as the spiritual well-being enjoyed by local communities, park visitors or the existence value perceived by distant viewers of nature films made in Madagascar's protected areas.

The Dasgupta review also highlights that all conservation of biodiversity, such as a protected area, is a form of *investment* in the future since it aims to preserve and enhance natural capital for the benefit of future generations and is part of the *national inclusive wealth*.

Important principles from the natural capital economics literature

Our review of the literature highlighted a number of additional principles and insights of relevance to this paper. We highlight below a selection of the most important points to keep in mind, most of which are derived from the Dasgupta Review and from a review of the history of economics[130]:

- Nature has real economic value, but money is merely a *measure* of value, not value itself
- Valuing a natural asset is not to monetise or commodify it, but to measure its *relative* value
- Measuring the relative values of nature helps us to manage it better
- It is acceptable to measure part of nature's value, while not forgetting the other values which are not financially measurable but have great social or cultural value
- It is very important to take account of future values of nature as well as present values
- Values of nature based purely on markets tend to ignore the values for *future generations*

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128 Dasgupta 2021, WEF 2020, Waldron et al 2019, TEEB 2010, WAVES 2016, Bradbury et al 2021
129 Dasgupta 2021
130 Kiashtainy 2017

- Valuing nature requires considering benefits at all levels – local, national and international
- Economic values of nature are not precisely fixed and can be expressed as ranges
- Different natural assets including PAs provide different sets of benefits – each PA is different
- The wealth of nations is built on natural and human capital, as well as on built capital
- Natural capital has particular importance for poverty reduction
- Before industrialisation, natural and human capital were a country's most valuable assets
- In the case of Madagascar, almost 50% of the nation's wealth is based on natural capital [131] (with natural renewable capital accounting for about 25-30% in 2018)[132]
- The services of ecosystems from PAs are public goods and not private property
- The high value of multi-functional ecosystems is often ignored in favour of monofunctional systems, so placing an economic value on these systems is important
- Nations should build their economies on their comparative advantage, such as their unique nature if they have it
- Finally, it is usually worse economically to lose an irreplaceable natural asset than to forego the private gain from destroying it.[133]

Landmark references

A full list of the 250+ literature references considered for this study is included in the bibliography. Where relevant they are cited in other parts of this paper. While all references cited are important in some way, we cite below in abbreviated form a selection of 'landmark' publications of the greatest significance for preparation of this review (full details of each citation can be found in the bibliography):

Bradbury et al 2021. The economic consequences of conserving or restoring sites for nature. Nature Sustainability.

Carret, J-C. & Loyer, D. 2004. *Comment Financer Durablement les Aires Protégées à Madagascar ? Rapport de l'Analyse Économique*. Paris, rance : AFD.

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[131] World Bank 2013; Ollivier & Giraud 2010
[132] World Bank 2021b
[133] Bradbury et al 2021

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Previous key research on Madagascar – a brief review

Early studies of the 1990s (**Kramer et al 1995**; Kramer et al 1997; Shyumsundar & Kramer 1997) on the economics of creating the Mantadia National Park first highlighted the very substantial benefits to visitors (tourists) compared with the relatively modest benefits to local populations in terms of flood protection, and the likely need for compensation payments to local communities closest to the park unable to benefit from the tourism economy.

The first evaluation of the economic costs and benefits of the entire protected areas network was made by **Carret & Loyer 2004** in which the authors estimated net benefits of the national PA network as it was in 2003 just before its expansion from 1.5 million to over 7 million ha following the Durban Initiative. The paper emphasises Madagascar's biodiversity as a global good whose value is manifested by international investments which have been made in conservation. The paper highlights the importance of protected areas for ecosystem services in hydrological protection (notably through sediment control, a regulating service) for agriculture and energy, for tourism and carbon storage while also noting that the opportunity costs of protected areas to local communities can be significant, amounting to $1.8/ha/yr. Values reported for the selected ecosystem services considered (biodiversity conservation, ecotourism, hydrological protection) were estimated (in 2003 $US) from **$10/ha/yr rising to $16.85 ha/yr,** which were only moderately above PA management costs (estimated at $5/ha/yr at the time).

On the subject of bioprospection and products derived from biodiversity using a value-chain approach, **Raharinirina (2009)** made an important contribution to the evaluation and capture of the economic benefits of bioprospection and essential oils from forest plants and the effectiveness of benefit capture from these resources.

Of importance in confirming the effectiveness of protected areas, **Eklund et al (2016)** demonstrated that deforestation is reduced in protected areas in comparison to surrounding areas, while **Vieilledent et al (2018)** provide the most recent and comprehensive assessment of deforestation and fragmentation rates over the past 60 years.

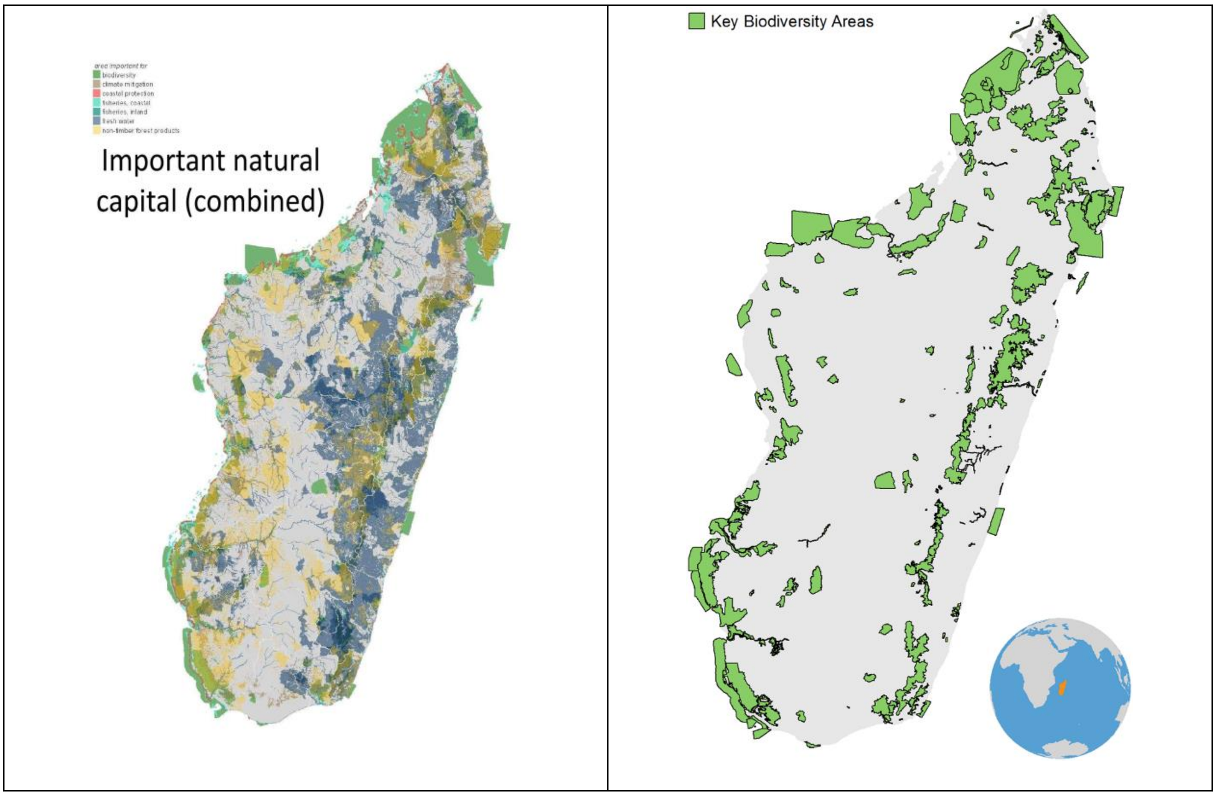
Portela et al (2012) undertook an evaluation of the ecosystem services of the Ankeniheny-Zahamena Forest Corridor (CAZ) Protected Area as part of the **WAVES program** (Wealth Accounting for the Valuation of Ecosystem Services).[134] The study showed that the CAZ protected area provides valuable ecosystem services in carbon storage and sequestration (valued at $306.4 to $570.4 million in $US2010 depending on carbon price) and water for energy (Andekaleka dam), mining, agriculture and tourism. The study highlighted the potential for carbon values to help finance protected areas.

[134] Portela et al 2012

Associated with WAVES is the UN System for Environmental Economic Accounting (UNSEEA) and particularly the methods for ecosystem accounting (EA) **(UN Statistical Commission, 2021).** The SEEA EA is based on five sets of accounts including ecosystem extent, ecosystem condition, ecosystem services (flow accounts, physical and monetary) and monetary ecosystem assets (stocks of ecosystem assets such as protected area networks).[135] SEEA EA takes a **spatial approach** to accounting as the benefits from ecosystems depend on their location, while the SEEA central framework looks at cross-cutting assets such as water or energy resources.

A key review was conducted by the **World Bank in 2013** which, building on Carret & Loyer (2004) provides an estimate of public investments to date (1990-2010) in conservation in Madagascar ($400-500 million). The report states that natural capital represented 49% of the country's wealth. It also highlights tourism as important ($500 million annually) and determines that tourism is primarily based on natural capital and protected areas. It does however highlight the high opportunity costs to local communities around protected areas (which can range from $300-1400 per household).

Of particular significance for the present study has been the work of scientists associated with Conservation International (**McKinnon et al 2015, Neugarten 2015, Neugarten et al 2016, 2020**) which provided a first mapping of ecosystem services and natural capital in Madagascar (Fig 7). The 2020 paper (Neugarten et al 2020) demonstrates that Madagascar's protected areas were primarily conceived for biodiversity protection rather than ecosystem service provision but that with some adaptation and expansion to cover more of the designated 233 KBAs, could make greater contributions to ecosystem services and thus greater economic contributions as well as to biodiversity conservation. The40ubliccations come with very valuable spatial data sets on ecosystem services considered for the present study.



[135] UN 2021

Fig 7 – A. Natural Capital (composite) (Source: Neugarten et al 2015 and B. KBAs and Protected Areas of Madagascar (Source: Neugarten et al 2016).

On the subject of the benefits of protected areas for human well-being, **Herera et al (2017)** and **Raolofoson et al (2018a&b)** have established evidence of benefits to human health, notably children's health, which are vitally important but for which it is difficult and questionable to assign monetary values.

On the cost side, **Rakotonarivo et al (2017)** have provided recent evidence of the opportunity costs of protected areas to local populations and the need to ensure that benefits from PAs are more fairly distributed, while **Ollivier & Giraud (2010)** estimate the high cost to future generations of losing protected areas.

Finally, with regard to expenditure on biodiversity conservation, the recent report of the UNDP-GEF **BIOFIN (2021)** project has been important in confirming the levels of finance for biodiversity conservation in Madagascar.

The WAVES programme in Madagascar

The Wealth Accounting and Valuation of Ecosystem Services (WAVES) global partnership operated a program in Madagascar from 2011 to 2016, for which a national steering committee was established. The program made active initial progress but suffered setbacks as a result of the political crisis of 2012-2013. WAVES Madagascar was relaunched in 2015 and ran until 2016. The main activities of WAVES in Madagascar were monitoring of macroeconomic indicators and development of natural capital accounts for water, forests, mines and tourism. WAVES also promoted the introduction of the new UN System of Environmental-Economic Accounting (SEEA). While not yet in place in Madagascar, some capacity development for SEEA has been achieved.

A key early study the comparison of natural capital values for mining, water and conservation in the CAZ corridor[136] highlighted the value of forest for water for power generation. A study was also undertaken on the potential for natural capital accounting in the fisheries sector which published a brief and draft report just before the crisis[137].

The WAVES final macroeconomic report of 2016 highlighted that the economy is strongly dependent on natural capital and that primary sectors (agriculture, fisheries, forestry) account for 25% of GDP. The local contribution of tourism from protected areas, focusing on park fees and ecoshop sales, was estimated at about $28 million annually[138].

WAVES in 2016 estimated total national wealth at $6500 per person, or about 20 times the GDP per person (then $368 per capita per year) based on a national population of 24.4 million (INSTAT data 2016) or a total wealth of about $160 billion. The proportion of wealth in natural capital, which in 2018 stood at about 25-30%[139], has steadily increased since 2005 as result of a decline in intangible (human) and produced capital, even though the value of natural capital has also declined due to loss of forests. Indeed, WAVES was able to show in 2014 that Madagascar is 'leaking' its natural capital, in part due to

[136] Portela et al 2012
[137] WAVES 2012 & 2013
[138] WAVES 2016
[139] World Bank 2021b

the exploitation of precious woods. The report highlights that human capital is very important for deriving sustainable benefits from natural capital, such as protected areas.

Orientations derived from the literature review

Based on the literature review, and exchanges with the scientific committee[140], our study adopted the following methodological orientations:

- Taking a Natural Capital approach to economic valuation of PAs
- Valuing ecosystem services using a spatial approach
- Estimating ecosystem service values per hectare as a basis for comparison[141]
- *Not* adopting transferred values for ecosystems as a basis for estimating the contributions of protected areas because of insufficient evidence for their applicability.
- As an alternative, using published economic data on climate regulation, biodiversity conservation, global tourism, scientific research and entertainment to estimate the global economic contribution of Madagascar's PAs
- Using real data collected in Madagascar to estimate the economic contributions at national scale to key development sectors for which data are available (energy, tourism, agriculture and carbon storage).
- Using specific case studies of PAs in landscapes in Madagascar for which data are available to measure the measurable economic benefits at local scale (direct benefits & avoided cost methods)
- Identifying and describing further significant benefits of protected areas and their biodiversity to emphasise that PAs provide many further benefits which are not readily measurable in monetary terms
- Reviewing and quantifying the evidence on the opportunity costs of protected areas to local populations
- Deriving an estimate for the average management cost per hectare for Madagascar's PAs as a basis for comparison with the economic benefits of protected areas
- Reviewing the experience of a selection of other countries
- Discussing the results, drawing conclusions and making recommendations

Initial scoping of potential PA values based on transferred value approach

The high-profile papers of Costanza and associates, the first of which was published in *Nature* in 1997[142] documented the high economic value of the world's ecosystems and ecosystem services, amounting to many times global GDP and highlighting the massive contribution to global wealth made by natural ecosystems. Using data gathered from studies around the world in varying contexts they have shown that ecosystems can make very high economic contributions, especially where such ecosystems provide multiple services in the context of economically developed countries. Their research also shows that such ecosystems and their services are becoming more valuable as economies and the demand for services grows, and as the ecosystems and their services become in shorter supply, increasing their unit values and the willingness of users to pay. These trends also show that the degradation of ecosystems carries a particularly high opportunity cost for future generations.

In a first iteration of this paper, in line with an earlier example in Madagascar for the Makira-Masoala landscape conducted in 2008[143], we adopted a transferred value approach for the main terrestrial and

[140] See Acknowledgements section
[141] As done in the first PA valuation study by Carret & Loyer 2004
[142] Costanza et al 1997; DeGroot et al 2012; Costanza et al 2014
[143] Masozera 2008

coastal ecosystem types found in Madagascar (forests, rangelands, wetlands, mangroves, coral reefs etc.), taking values from the Costanza papers (Table 3) to generate a first set of estimates of the possible economic contribution of Madagascar's protected areas. However, it soon became apparent that most of the internationally reported values were much higher than the highest measurable economic values that could be demonstrated for Madagascar's ecosystems within the local, national or global economies. The disparity was especially great for the high value ecosystems such as wetlands, coral reefs and mangroves, where the differences were as much as two orders of magnitude.

Based on further consideration of the format, provenance and assumptions behind the data found in the Costanza papers, reinforced by the comments of our scientific committee, it became apparent that we lacked sufficient evidentiary basis to transfer the internationally published values to ecosystem services in the Madagascar context.

Nevertheless, the multi-service valuation approach adopted by Costanza and others has been very valuable in highlighting that ecosystem values can be very high in certain contexts, and that they become *more valuable with time* (principles that are fully applicable in the Madagascar context and which are demonstrated by the evidence presented). Thus, while the values are undoubtedly higher than those currently perceived or likely to be perceived in the foreseeable future, they testify to the potential for high values in the future.

In an alternative approach, we chose instead to present the measurable economic contributions of protected areas at three different economic *levels* – global, national and local – thus capturing some of the real differences that exist in the economic value of ecosystems and biodiversity according to development context (global vs. national; national vs. local) while offering a clear basis for the government of Madagascar to formulate its policies on protected areas in response to measurable costs and benefits at these three different levels.

Table 3 – Global ES values by ecosystem as reported by Constanza et al (1997 and 2014) & DeGroot et al (2012)

Ecosystem	**Value $/ha/yr in 1995 (Int$US of 2007)**	**Value $/ha/yr in 2011 (Int$US of 2007)**
ALL		
Terrestrial (all combined)	1109	4901
Coastal marine (all combined)	5593	8944
TERRESTRIAL		
Forest (all types)	1338	3800
Tropical forest	2769	5382
Grass/rangelands	321	4166
Wetlands (inland)	20404	140174
Lakes / rivers	11727	12512
MARINE		
Shelf seas	2222	2222
Coral reefs	8384	352249
Mangroves	13786	193843
Seagrass beds	26226	28916

As a record of the of the scoping exercise, we present the initial valuations based on the transferred value approach in Annex 1.

Global economic benefits of Madagascar's protected areas

The principal global economic contributions of Madagascar's protected areas network are climate regulation, biodiversity conservation and contributions associated with the international existence value of Madagascar's biodiversity, keenly felt around the globe[144], which drives ecotourism, scientific research, natural history films and media productions which celebrate Madagascar's biodiversity.

To the above global benefits can now be added the growing interest of international financial institutions in reducing their exposure to biodiversity-related risks, since investments in conservation in Madagascar offer especially high returns in biodiversity extinction risk reduction due to the very large number of threatened species in Madagascar's protected areas network. While Madagascar harbours about 3% of global biodiversity, it represents about 6% of global extinction risk, making it particularly attractive to investors wishing to maximise their contribution to reducing global extinction risk[145] Financial flows driven by this new need have yet to be measured but could become substantial quite rapidly.

Global climate regulation benefits

Based on the methodology described, we estimate the global value of Madagascar's protected areas network for climate regulation to be in the range **$5,78 to $6.32 billion/year**. This equates to a value of $759-831/ha/yr across the entire protected areas network, with the major share from terrestrial forests ($5.9 bn), especially humid forests, and a lesser contribution from mangroves ($312 million/yr).

These estimates depend strongly on the value selected for the *social cost of carbon* (SCC), for which we adopted a range of values (minimum $54/t[146], median $171/tCO2[147], maximum $417[148]).. Recent large studies estimate the social cost of carbon as high as $417/t CO 2 or as low as $54/t CO2 The social cost of carbon (SCC) is the marginal cost of the impacts caused by emitting one extra tonne of greenhouse gas (carbon dioxide equivalent) at any point in time, inclusive of 'non-market' impacts on the environment and human health. The latest studies calculate costs of more than $3000/t$CO_2$.[149]

The estimate is also based on the key assumption that Madagascar will be successful in preventing deforestation in its protected areas. On average, deforestation rates are lower in protected areas than unprotected areas, but certain protected areas (notably the dry forests of Ankarafantsika and Menabe-Antimena) are failing. The global benefit, if claimed, must be backed up by effective conservation action.

Global biodiversity conservation benefits

Based on the methodology described, we estimate the global economic benefit of Madagascar's protected areas to biodiversity conservation at **$572-660 million/yr**, based on the assumed willingness to pay of the international community towards the protected area component of biodiversity conservation in Madagascar as a 20% proportion of *actual* global biodiversity expenditure (which is $124-143 bn/yr) and assuming Madagascar's biodiversity represents 3% of world biodiversity of which 71% is found within Madagascar's PAs. This may be considered conservative, since it considers only the actual global expenditure on biodiversity conservation ($124-143 bn/yr) rather than the estimated global need for all biodiversity in protected areas (149-192 billion or 20% of the total need).

[144] Dasgupta 2021
[145] Mair et al 2021
[146] Wang et al 2019
[147] WWF 2020
[148] Ricke et al 2018
[149] Kikstra et al 2021

In addition, Madagascar's contribution to the maintenance of global genetic resources held within protected areas is estimated at **$299-809 million** annually.

Taken together, the value of Madagascar's contribution to global biodiversity conservation, including genetic resources, is estimated at **$872 million to $1.47 billion annually,** or an average rate of **$115-193/ha/yr** across the entire PA network. This may be considered conservative as it does not account for the particularly high value of biodiversity conservation in Madagascar in terms of **extinction risk reduction**.

As highlighted in a recent paper on spatially measuring rates of species' extinction[150], Madagascar as a whole has the potential to contribute 6.0% of the global species extinction risk reduction for birds, mammals and amphibians. This is the fourth highest country total, after Indonesia, Colombia and Mexico. It has been determined that the Key Biodiversity Areas of Madagascar contribute over 50% of the STAR[151] total for the country[152] and that 71% of KBAs are represented within the SAPM network[153]. Thus, the contribution of Madagascar's protected areas to extinction risk reduction could be valued at as much as double the above values, or **$1.74-2.94 billion annually**.

Global economic benefits linked to existence value of Madagascar's biodiversity

In addition to the benefits to global biodiversity conservation, and the maintenance of the diversity of genetic resources, Madagascar's PA network makes economic contributions to global ecotourism, scientific research and entertainment which derive from the high cultural and existence value that the global community places on Madagascar's unique biodiversity.

We estimate that the value of the global economic contribution of Madagascar's PA network to cultural values of biodiversity (from ecotourism, research, natural history films and media productions) as **$623 million to $633 million annually**, or an average rate of $82 to $83US/ha/yr. This may be considered conservative, as it includes only the 15 most visited PAs managed by MNP, natural history films only of the BBC and a single international media production based on Madagascar (*Madagascar* by Dreamworks). In particular, it ignores the value of Madagascar's biodiversity in PAs to millions of viewers of nature films on Madagascar around the world.

Ecotourism

We estimate the specific contribution of Madagascar's PA network to global ecotourism at **$533-543 million/yr**, highlighting the high average value of the top 15 PAs for tourism ($397-405/ha/yr). Most of the value comes from terrestrial PAs, with MPAs (including Nosy Tanikely) accounting for about $10 million annually, or about 2.5% (based on limited available data for MPAs). The consumer surplus of global tourists is significant, estimated at $16 million, based on an average satisfaction per PA visit of $65 based on research published in 1995[154].

This estimate of global ecotourism benefit can be considered conservative as it does not include any new protected areas (NPAs), because marine protected areas (MPAs) are under-represented and because consumer satisfaction levels for visits to Madagascar's PAs are likely to have increased since 1995, with the improved quality of infrastructure and park guiding services.

[150] Mair et al 2021
[151] Species Threat Abatement and Restoration indicator
[152] Mair et al 2021
[153] Neugarten et al 2020
[154] Kramer et al 1995

Scientific research
We estimate that scientific research based on biodiversity in Madagascar's protected areas generates about **$8.34 million annually**. This estimate is based on a search of a new international scientific data base which found 25,866 publications including the words 'Madagascar' and 'biodiversity' from 1990 up to November 2021, and assumes an average investment of $10,000 for each published paper. It is likely to underestimate research value since it does not consider research grants awarded (which can run into hundreds of thousands of dollars), and because a typical published paper will require many months of skilled work, from field phase to eventual publication, often involving several national and international scientists, their travel expenses and equipment costs.

Natural history films
We estimate that the making of natural history films in Madagascar involves **international expenditures of $412,500 annually**, assuming an average film production cost of $250,000 and 1.65 films per year. This is conservative since it includes only films made by the BBC Natural History film Unit or groups associated with BBC productions which use the BBC Natural History Film Unit. It also only includes expenditures, and none of the *revenues* generated by the broadcasting and distribution of the films (which are difficult to quantify), or the *enjoyment* experienced by the many millions of people who watch nature films about Madagascar every year.

Media productions
We estimate that the making of media productions inspired by the biodiversity in Madagascar's PA network generates **at least $88 million annually**, based on the single series of *Madagascar* animations made by Dreamworks. The *Madagascar* series of animations alone has generated $2.26 billion in revenues over 15 years for a production cost of $502 million (of which we assumed 71% could be related to Madagascar's PA network). While it might be argued that biodiversity accounts for a lesser percentage of the inspiration for the film, the estimate is likely to be conservative overall because of the many productions not considered which take inspiration from Madagascar's biodiversity.

Total global economic benefits provided by Madagascar PA network
Based on the values placed internationally on biodiversity conservation and climate regulation (carbon storage), together with economic benefits of Madagascar's protected areas to the global economy through cultural services, we estimate the global economic benefit generated by Madagascar's protected area network to lie in the range **$3.67 billion to $17.27 billion per year (median value $7.74 billion)** (US$483-2269/ha/yr across the PA network, with median value of $1017/ha/yr). This represents the currently *measurable* global economic contribution of Madagascar's protected area network. This is based on several assumptions as explained in the method section including the key overall assumption that Madagascar's PA network is effectively conserved. It can otherwise be considered conservative in that it does not include the non-measurable benefits or all measurable benefits.

National economic contribution of Protected Areas to key development sectors
The national economic valuation of Madagascar's protected areas based on real data was first attempted by Carret & Loyer (2004) who considered exclusively values derived from studies within Madagascar and of the 41 protected areas existing at the time covering just 1.5 million hectares (3% of the land surface).

Here we take a similar approach but based on more comprehensive and recent data, taking account of the expansion of the PA system and of the ecosystem service values for energy and carbon storage for which data were not available to the 2004 study. We also consider inward finance for climate mitigation and biodiversity conservation which are quantified for the first time. The evaluation of the *national* economic contribution of PAs to key sectors may be considered central to the present study, as providing the closest estimate we can to the measurable economic contribution of protected areas to Madagascar's economy in monetary terms from which Madagascar is already fully benefiting. This valuation approach should be considered conservative because data were available only for a subset of the full range of ecosystem services provided by PAs (energy, tourism, agriculture and environment (carbon storage and biodiversity conservation). With the exception of carbon storage, it considers only a subset of Madagascar protected areas. Marine protected areas, which provide economic benefits from tourism and fisheries, are treated separately.

Results by sector

Environment (climate regulation and biodiversity conservation)

Before we consider specific development sectors (tourism, energy, agriculture, water and fisheries), it is important to appreciate that the Malagasy national economy already benefits from international investments in climate regulation and biodiversity conservation which bring money into the environmental sector of the Malagasy economy, providing many jobs and livelihoods.

Climate regulation

Carbon emissions cause environmental and social economic damages. Carbon storage and sequestration are thus global environmental benefits of Madagascar's protected areas and other forests. These are the benefits delivered by Madagascar to the world through the protection of forests. Part of this benefit is recaptured by Madagascar through the beneficial effect of global emissions on its own climate, and through the receipt of international finance through the REDD+ and other programmes.

The economic value of tropical forests for carbon storage is important because such forests have a strong capacity to accumulate carbon thus contributing to climate stabilization and avoidance of the very high costs of climate change. Internationally, these ecosystems have been valued at as much as $5382/ha/yr,[155] of which a significant portion ($2044/ha/yr) represents climate regulation, and of which carbon storage is an important part.[156] In Madagascar, WAVES studies have estimated the potential value of CAZ forests for carbon storage at $15.88 million or $2708 per hectare, assuming a carbon price of $43/t, $3.6 million ($601/ha/yr) if taking the applicable EU rate of $9.75/tC[157] (or just $1.85 million assuming a carbon price of $5/t).

Based on a conservative carbon price of $5/t as used by the national REDD+ programme, we estimate the actual economic contribution of protected areas for carbon storage at **$21.65 to 29.05 million per year** (or $6.39 to 8.57/ha/yr for all *forest* PAs and mangrove areas). This is conservative because it considers only the carbon credit sales and the project budget for the Atiala-Antsinanana forested landscape REDD+ scheme. It does not include the additional potential benefits from other protected humid forests, or any of the dry forests or mangroves within PAs. Benefit capture in this area can certainly be increased.

Carbon pricing°

The value of carbon storage and sequestration depends strongly on the value assumed for the 'social cost of carbon' emitted. The recent global outlook study by WWF[158] has shown that the global benefit of a conservation scenario in which protected forests store and sequester carbon, has been estimated

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[155] Costanza et al 2017
[156] de Groot et al 2012
[157] Portela et al 2012
[158] WWF 2020

to rise to 5.2% of global GDP by 2050 (based on the difference between business-as-usual scenario and a global conservation scenario. For their study, WWF assumed a social cost of carbon (SCC) of $171 per tonne, being the mid value of a range published in 2008[159] which can be compared with lower and upper estimated values of $54[160] and $417/tCO2[161] The US government currently adopts as value $51/tCO2eq for SCC, projected to increase to $85 by 2050 (Table 4).[162] In 2017, the High-Level Commission on Carbon Prices estimated that the carbon price needed to be $50-100/t by 2030 to meet the Paris Agreement target of keeping warming below 2°C,[163] while the UN Global Compact calls on companies to adopt a minimum price of $100 per metric tonne.[164]

To estimate the carbon storage value of PAs (and other protected ecosystems) which it seeks to recover through international finance, Madagascar uses the cost reduction method. Under its national REDD+ strategy, the country aims to reduce greenhouse gas (GHG) emissions from the forest sector by 14% by 2030, through control of deforestation and forest degradation in PAs and increased national forest cover.

The quantities of carbon used in this study are taken from the national document "Forest Reference Emissions Level" (NERF), developed by the National Office of REDD+ Coordination submitted to the United Nations Framework Convention on Climate Change (UNFCCC). NERF follows the rules and methods recommended by the Intergovernmental Panel on Climate Change (IPCC))[165]. It is based on the earnings and loss approach, i.e. an estimate of the net balance of additions and absorptions from a carbon stock[166] .

Table 4 – Values for the Social Cost of Carbon (SCC) (various sources)

Organisation/Country	Year	Carbon price ($/tCO2)	Remark
United States	2021	51	US government carbon price under Biden administration
High Level Commission on Carbon Prices	2017	50-100	Required carbon price by 2030 to achieve Paris Agreement <2°C rise
European Union Emissions Trading System	2021	69	Prices increasing rapidly at time of publication
UN Global Compact	2022	100	UN call on companies to set as price
Sweden	2021	137	Swedish carbon tax $137 per ton[167]
OECD Effective Carbon rates[168]	2021	125-147	Rate of $147/t required by 2030
Nature Climate Change[169]	2018	417 (range 177-805)	Country level social cost of carbon

The NERF developed from data from the historical reference period from 2005 to 2013 – the most recent and comprehensive data on carbon stock by ecoregion (wet forest, dry forest, spiny forest, mangrove) (Table 5).

159 Tol 2008
160 Wang et al 2019
161 Ricke et al 2018
162 Scientific American 2021a
163 High Level Commission on Carbon Prices, 2017
164 UN Global Compact 2022.
165 Reference emission levels of Madagascar's forests for reducing emissions from deforestation, National Office of Coordination REDD, Ministry of Environment, Ecology, Sea and Forestry, June 2018
166 IPCC, 2006 Guidelines for National Greenhouse Gas Inventories (Volume 4, section 2.2).
167 The Tax Foundation, 2021
168 OECD 2021
169 Ricke et al 2018

Table 5 – Carbon stock by ecoregion (Source: NERF)

LAND USE CLASSIFICATION (NERF)	CARBON STOCKS [TCO2/HA]	CONFIDENCE LIMITS AT 90% [TCO2/HA]	CONFIDENCE LIMITS AT 90% [%]
Rain forest	567.13	71.53	12.61%
Dry forest	151.35	21.83	14.42%
Spiny forests	48.63	6.91	14.22%
Mangrove	290.09	63.31	21.82%
Non-forest in humid forest ecoregions	45.27	8.07	17.83%
Non-forest in dry forest ecoregions	6.73	1.54	22.81%
Non-forest in spiny forest ecoregions	6.73	1.54	22.81%
Non-forest in mangroves ecoregion	76.27	41.31	54.16%

Assumptions

To assess the economic value of carbon that could be recovered by Madagascar, two conservative assumptions were adopted:

- Update forest loss using average deforestation rates: 0.4% for the humid forest ecoregion; 1.7% for the dry forest ecoregion; 1.4% for spiny forests[170]. This is conservative, since the actual rates are likely to be higher than this.
- The carbon sale price used in this study is $5/tCO2, which is the price negotiated with the World Bank under Atiala Atsinanana's Emissions Reduction Program. This is a highly conservative but prudent assumption because the forecast carbon price according to the various international studies ranges from a minimum of $US20/tCO2 to $US75/tCO2. To meet the challenge of climate change, i.e. limiting global warming to 2 degrees Celsius in 2050 compared to 1990, the International Monetary Fund has estimated a necessary price of $US75/tCO2[171]

Economic value of carbon storage

The study shows that without protection, deforestation on PAs would result in the emission of 12.798 million tonnes of CO2 annually. The net present value of carbon dioxide emissions that could be avoided by proper PA management between 2015 and 2045 are estimated at approximately $61.797 million out of 5.7 million hectares of terrestrial protected areas, or an average **of $10.84/ha** (Table 6).

Table 6 – Estimated emissions reductions and revenues from Madagascar's PA network (various sources)

[170] National REDD Strategy, adopted by Decree No. 2018/500 of May 30, 2018
[171] Gaspar et al 2019

Emissions & REL						
Stratum	Carbon stock changes	non-co2 emissions	Annual emissions [tCO2/year]	Surface SAPM	Revenu [USD/ha/year]	Revenu [USD/ha/year]
Déforestation Foret Humide (D_{FH})	6 265 069	453 552	6 718 621	4 605 358,52	33 593 105,69	7,29
Déforestation Forêt Séche (D_{FS})	5 119 833	228 441	5 348 274	2 938 675,08	26 741 370,45	9,10
Déforestation Forêt Épineuse (D_{FE})	641 789	37 373	679 162	121 357,34	1 358 324,96	11,19
Déforestation Mangoves (D_M)	52 117	0	52 117	995 311,18	104 234,09	0,10
	12 078 808	719 367	12 798 175	8 660 702,12	61 797 035,19	7,14

Values for carbon storage per unit area vary according to the ecoregion. The PAs of spiny forests generate the highest income of USD 11.19/ha/year due to current high prevailing rates of deforestation which are reduced in protected areas. But in terms of total economic contribution, it is the rain forests, whose remaining area is larger, which generate a global value of $33.593 million per year for carbon storage.

Benefits of Protected Areas from carbon storage

Governments can invest in adapting to climate change, renewable energy and other technologies which reduce carbon emissions for energy efficiency.

As a reference, under the Atiala Atsinanana Emissions Reduction Programme, which covers a total forested landscape area of 6,235,720 hectares, the total budget over five years is US$158.71 million (more than 600 billion Ariary). Carbon revenues will be prioritized for sustainable development and the continuation of the current program and projects in the 69 municipalities that support several key activities: (i) infrastructure investments in water management and rural engineering; (ii) investments in agriculture, agroforestry, forestry and improved livestock productivity; (iii) investments in the development of sustainable value chains; and (iv) investments in the management and restoration of PA edges.[172]

Use of carbon storage benefits in the government's PADAP project

The PADAP project is designed to deliver a range of benefits to rural stakeholders within the project landscape covering 1,138,334 ha (Table 7).

Table 7 – Projected impacts of PADAP[173]

Total landscape area (ha)	**1,138,334**
Number of communes benefiting	58
Number of communes provided with a lands title office	11
Number of households benefiting	69,200
Roads (km) added or improved	538.92
Hydrographic network added (km)	313.24
Agriculture	
Average rice yield (t/ha)	2.3
Livestock production (heads)	
Herders	15,500
Cattle	318,312
Sheep/goats	3,993
Irrigated area (ha) increase	**43,626**

172 At the rate of 01.02.21 of $1USD - 3950 MGA)
173 World Bank 2017

In addition, the benefits of carbon storage can also be used to reduce poverty and household vulnerability. In the PADAP document[174], whose final beneficiaries are 15,500 herders and 69,200 farmers, these investments could help households earn an additional daily income of between US$1.5 and US$2.10 (or an annual benefit of about US$28-39 million assuming 87,400 households and a 220-day working year). Given an average household size of 5 people and a poverty line of US$1.92 per capita per day, the project's interventions thus reduce household vulnerability. [175]

The economic analysis is based on the aggregation of economic benefits from: (i) improving crop productivity; (ii) reducing siltation in irrigated perimeters, which could result in incremental net benefits of more than US$435,000 over 20 years; and (iii) benefits related to the project's net carbon balance, which is valued at a social cost of carbon of US$30/tCO2e and could result in a value to society of US$10 million per year.

The economic analysis spanning 20 years which assumes a discount rate of 6 percent results in an Economic Net Present Value (ENPV) of incremental net benefits of US$207 million and an EIRR (Economic Internal Rate of Return) of 26.6 percent. Sensitivity analysis demonstrates that the results are largely robust against changes to key variables. Changes in environmental benefits have the largest impact on the EIRR. However, for all changes, the project's EIRR is well above the deposit interest rate which was on average 11 percent between 2011 and 2014.

These economic benefits could be more than tripled if the country manages to sell the carbon credits it could sell within the PADAP landscape area.

Biodiversity conservation

Based on all the known sources of biodiversity funding flowing into Madagascar, from bioprospection, international public funding, NGOs and foundations and taxes raised from PAs about **$52-60 million annually** is injected into the national economy for biodiversity conservation, creating direct and indirect jobs and effectively supporting an entire economic sector. (The upper figure of $60 million takes account of GEF7 funding just coming on stream in 2021, and the annual budget of the PADAP landscape and biodiversity project in the northeast). This is equivalent to $6.35 to 7.43/ha/yr across *all* protected areas.

National benefits from global biodiversity conservation

As an indication of global response to this situation, Madagascar has a biodiversity allocation from the Global Environment Facility (GEF) round 7 (GEF7) over 5 years of $33.8 million USD after Indonesia at $64.5 million and Colombia at $39.1 million. Despite its higher rating on extinction risk reduction, Madagascar has been allocated less than Mexico at $47.4 million and Brazil at $53 million.

In addition to GEF, Madagascar benefits from World Bank funding (PADAP – a minimum of $13 million, potentially as much as $50 million, over 5 years) and other bilateral sources (estimated at $16 million).[176]

In the case of Madagascar, all GEF7 finance and biodiversity-landscape finance (such as PADAP) is related to landscapes in which there are protected areas. Thus, while the finance may not all go towards managing protected areas, it is all premised upon the presence of protected areas in those landscapes.

[174] World Bank 2017
[175] World Bank 2017

[176] BIOFIN 2021

Tourism

Madagascar's protected areas and biodiversity represent a comparative economic advantage and an incomparable sales advantage for Madagascar. A study in 2012 found that 68% of tourists came with the objective to visit one or more protected areas during their trip.[177]

Tourism in Madagascar is worth about $707 million a year**,** or 5% of GNP ($14.115 bn)[178]. Given the small number of tourists visiting Madagascar, the fact that tourism represents no more than 5% of GDP is unsurprising. On the other hand, the percentage of tourists who visit protected areas, at 68% as noted above, is much higher than the global average. On this basis, the economic contribution of Madagascar's Protected Areas could be estimated to be (5% x 68%) = 3.4% of GDP, or **$481 million/year ($432/ha/yr for the top 15 parks, or $67.9/ha/yr across all parks)**.

The tourism sector is the most data rich of the sectors we considered and offered multiple ways of estimating the economic contribution of protected areas. At the *global* level, we found good convergence between the different estimations which value the contribution of protected areas to tourism globally at about $538-548 million annually (2021 USD) of which an estimated 1/3 finds its way into the national economy. When we examine specifically the benefits generated directly and locally in association with visits to the top 15 parks i.e. from ecotourism purely, we obtained an annual benefit of about $41.91 million (2021 USD), reflecting the relatively low capture of tourism benefits by protected areas at the local level.

It has been estimated that an average tourist visit to Madagascar involves expenditure of 33% within the national economy.[179] Assuming 68% of 338,000 tourists (229,840) each spending 33% would suggest that the protected areas network is supporting about $174 million of tourism revenues (or about $156/ha/yr for the top 15 parks, or $23/ha/yr across all 123 parks).

Economic contribution of protected areas to tourism sector overall

Based on the evidence that 68% of tourists include visiting one or more protected areas as part of their stay, and a total sector value of $707 million or 5% of GDP), it can be argued that the PA network helps to underpin 68% of the tourism sector, representing and annual economic contribution of protected areas for tourism as **$481 million per year** (equivalent to $432/ha/yr on average for the top 15 parks, or $69/ha/yr across all PAs). Given uncertainty as to how the annual sector value of $707 million was calculated, we assumed that tourists would spend only 1/3 of their total expenditure in country, or about $174 million, which represents a conservative upper estimate of the PA network's contribution.

Specific contribution to the ecotourism subsector

As a yet more conservative estimate of the national economic contribution of PAs to tourism, based on the number of tourist visits to the top 15 protected areas in 2019 (227,431 visits) and an average daily expenditure per tourist of $165), we estimate the specific contribution of the top 15 protected areas to the ecotourism subsector as **$42.68 million per year** ($38.32/ha/yr on average for the top 15 parks, or $5.61/ha/yr across all PAs).

Overall, we estimate the annual national economic contribution of protected areas to the tourism sector to be **$42 to $174 million/yr**, equivalent to $38-156/ha/yr across the top 15 PAs, or $6-23/ha/yr across all protected areas of the network. This is a conservative estimate, but it helps to demonstrate

[177] FTHM Conseils 2012
[178] World Bank data https://data.worldbank.org/country/MG
[179] FTHM Conseil 2012

that economic benefits from tourism alone approach or exceed the cost of managing the protected area network (which we have estimated to be $10/ha/yr).

Employment benefits of tourism based on PAs

A recent study on world tourism estimates tourism to be worth USD 7.6 trillion per year globally or 10% of the world's GNP, of which $600 billion (8%) is focused on Protected Areas[180] which attract an estimated 8 billion visitors globally[181]. Another study reported that in 2018 wildlife tourism generated $120.1 million and 21.8 million jobs globally[182].

Direct jobs from tourism based on PAs

In 2019, MNP employed 723 people. To this can be added 150 direct jobs generated (including local tourist guides) by the presence of National Parks. In addition, 42 external jobs are directly related to the implementation of the Parks budget, excluding staff costs including 38 for operations and 6 for investment. In total, direct jobs created by the Parks are estimated at 905. With the jobs generated by the household consumption of park staff (induced jobs), the direct benefits of the parks are estimated at 1000 jobs. Assuming an average annual employment contribution of 10 million Ariary, this corresponds to an annual economic contribution of 10 billion Ariary, or **about $2.67 million annually** for the sub-network of 34 PAs managed by MNP. This does not include the jobs created by the more numerous *New Protected Areas* (NPAs) created as a result of the Durban Initiative.

Indirect jobs in PA tourism

Protected Areas help to create jobs in the tourism sector. Tourism is a strong job creator, with an average annual growth of 1900 jobs over the past 12 years[183] and the low level of training required at entry level for most positions (making tourism a strong sector for integration of young people without higher education). Handicrafts is an economic activity that depends largely on the tourism sector and being labour intensive, is among the sectors with one of the highest employment rates.

Conservatively assuming that every direct job in protected area management for the 34 PAs managed by MNP results in at least one indirect job in the tourism sector, there could be a further 1000 ecotourism jobs with an annual value **of $10 billion ariary or $2.67 million.**

Tax revenue contributions of tourism from PAs

Apart from the fact that tourism is the country's second largest source of foreign currency, it also yields substantial tax revenues. In 2018, the hotels and restaurants sub-sector collected USD 144 million in taxes on tourism products[184], of which US$5.60 million was VAT. Applying the proportion of tourists which visit a national park (68%), we estimate that protected areas support the generation of $144 million x 68% = **$97,920,000 in taxes.**

Tourism investment stimulated by PAs

This economic impact is further increased if we add direct investment in the hotel restaurant sector (which stood at US$250 million in 2019, the latest available figure) and in travel and tourism services companies (which was US$1.4 million in 2019, the latest available figure). Investment in the accommodation and restaurant sectors is a major component of tourism investment, representing 91% of tourism commercial investments.[185] Again, applying the 68% figure, it can be estimated that

[180] Dasgupta 2021
[181] World Bank 2021
[182] WTTC 2019, from World Bank 2021
[183] MTTM 2020
[184] Source: National Accounting
[185] FTHM Conseil 2012

protected areas help to generate ($250 million x 68%) in investments, or **$170 million annually** in investments related to parks (Table 8).

Table 8 – Economic contributions of the tourism sector

Tourism economic benefit of PAs	Amount $US	Amount $US
Ecotourism expenditure (15 parks)		36,420,000
Employment (PA related)		
Direct jobs	2,670,000	
Indirect jobs	2,670,000	
All jobs		5,300,000
Tax revenues (PA related)		97,920,000
Investment (PA related)		170,000,000
Benefit of PAs to the tourism sector ($/yr) (higher estimate)		**309,640,000**
Benefit $/ha/yr (top 15 parks)		**277.96**
Benefit $/ha/yr (whole network) $/ha/yr		**43.72**

Adding these direct benefits, we reach a total of $309.64 million, which supports our assessment that the estimate presented is conservative and that the contribution of PAs to tourism could be as much as double the estimate presented of $42-174 million/yr.

Energy

Based on the identified PAs which provide clean water to the five *existing* hydropower stations, we estimate the total economic contribution of humid forest protected areas to the energy sector to be **$20.75 million/yr.** The contribution would double to **$41.24 million/yr** if the planned hydropower projects at Volobe and Sahofika are approved and become operational. This equates to a value per hectare of forest of $43.50/ha/yr for existing projects (which depend on forested catchments of about 477,000 ha), which would decline to an average benefit of $14.90/ha/yr if the Volobe and Sahofika projects go ahead (based on all humid forest PAs covering 2.34 million hectares).

This estimate may be considered conservative for several reasons, While the direct economic contribution of forested PAs to energy production may seem lower than the tourism sector contribution of PAs, it must be emphasised that energy is a stable sector which is critical to other economic sectors. Its indirect economic contribution may be much greater than the direct value of the electricity produced. The estimation also does not consider Madagascar's full potential for hydro-energy which could theoretically be as much as 7GW, or the future contribution of PAs to that potential. As the number of hydropower stations increases, the contribution of PAs to the energy sector will only increase.

Energy and economic development – a look at the wider evidence

The evidence shows that for Madagascar, as in most developing countries, investment in the energy sector has a direct impact[186] on living standards in general. Analysis of the energy consumption model (ECM) showed that there is a long-term equilibrium relationship between electricity, hydrocarbon use and GDP and that the short-term impact of energy availability is very significant (63%). This strong short-term upward momentum means that Madagascar's economy is very far from its growth potential (far from the full use of resources): a small boost in the energy supply leads to a sharp increase in production.

[186] MPRA Paper No. 82967, posted 28 Nov 2017, https://mpra.ub.uni-muenchen.de/82967/)

An increase in electricity production leads to a significant increase in the standard of living in the short and long term; conversely, a decrease in the supply of energy (load shedding, fuel shortage, price increases, etc.) leads to loss of income for economic agents and prevents an increase in production in the long term.[187]

According to the national energy balance in 2017, gross electricity production was 1,970.5 GWh (1,970,500 MWh) in 2017. Electricity production is dominated by diesel thermal units (53%) and hydroelectricity (40%). On the other hand, the national hydraulic potential is estimated at 7,800 MW of which only 160 MW (2%) has been developed. Of the 7800 MW, 1935 MW are potential only while the remainder is likely to be exploited (ORE, 2007).

On the electricity demand side, Madagascar's national electricity coverage rate is about 15% in 2015. In rural areas, where 70% of the population lives, the electrification rate is now only 5%.

By comparing supply (existing and potential) with demand, increasing the electrification rate by exploiting this hydraulic potential contributes to the country's economic growth and social and economic development.

Our estimate of the benefits that PAs generate domestically by producing hydroelectricity is based on the following approach:

- Using GIS, build a location map of hydroelectric stations (geographic coordinates are provided by the Electricity Regulatory Office) and overlay them on the SAPM map to find out which stations are under the influence of which PAs. A list of hydroelectric stations (electric power, power generation) with the associated PAs (surface area, water volume) is obtained.
  - With the total power produced by the PAs, the economic benefit is estimated using the energy intensity of the Malagasy economy (the ratio of energy consumption per unit of economic output) which has increased from 6.3 MJ to 6.4 MJ per US dollar (2005 dollars to PPP) (World Bank, 2015).

Results :

- For the 10 existing stations, 52% of which are located in the downstream watersheds of PAs, total power 160.1MW is provided for the country, with a net benefit of 219.483 million USD per year and a tax revenue between $**13.827 million (6.3%) to $25.021 million (11.4%)**[188]
- 98 potential power stations (i.e. not yet in service) of 0.4 MW to 300 MW (among the 138 potential stations), with a total capacity of 83,041 GWh, are located in watersheds downstream of PAs with an area of 7.64 million hectares. With an energy intensity of 6.3MJ/USD or 1.75kWh/$), there is a **potential net economic contribution to the country of $14.235 billion per year.**
- With an average investment of $3000 per **k**W, the total investment amounts to $12.6 billion over 30 years, or value of $420 million per year.[189]

Agriculture and potable water

While it is widely accepted that agriculture is the largest single driver of deforestation in Madagascar (as in most other countries), and it is generally assumed that the presence of protected areas can be

[187] MPRA Paper No. 82967, posted 28 Nov 2017, https://mpra.ub.uni-muenchen.de/82967/)
[188] https://www.oecd.org/fr/pays/madagascar/statistiques-recettes-publiques-afrique-madagascar.pdf.
[189] Sahofika, investment of $825 million for 192 MW, Volobe investment of $400 million for 120 MW, Andekaleka initial investment of $142 million for 110 MW.

beneficial for agriculture through multiple ecosystem services (water supply, soil stabilisation, local climate regulation, pollination etc.), there is a remarkable lack of studies in Madagascar or elsewhere of the benefits of protected areas to agriculture.

For benefits to agriculture at the national scale we made use of the earlier study of Carret & Loyer (2004) based on Madagascar's PA network as it existed in 2003 (covering just 1,102,949 ha or 3% of Madagascar's land surface) and which evaluated the benefits of hydrological protection for rice irrigation at 115,000 MGA/hectare. Based on that study, we estimate the economic contribution of protected areas to agriculture to be a minimum of **$22.56 million/yr** (or an equivalent of $22/ha/yr based on PAs covering 1,102,949 ha).

This estimate may be considered conservative because it only considers PAs in existence in 2003 and it considers only the benefit of hydrological protection for rice production.[190] The benefits of other ecosystem services and for other crops are not considered due to lack of available evidence.

Reference to Carret & Loyer 2004 did allow us to consider one additional ecosystem service, which is the provision of potable water to urban communities. Based on an average price per cubic meter of water of 5000 ariary (5 ariary/litre) according to UNICEF[191] (= $0.0012/litre), we estimated the contribution of protected areas in drinking water to be a minimum of **$10 million annually** (equivalent to $9.14/ha/yr for the network as it was in 2003).

In sum the combined values for irrigation and drinking water provision by the protected areas network reach about **$32.7 million annually** (or the equivalent of $29.59/ha/yr based on the PA network as it was in 2003). This may be considered an underestimate since it considers only the network as it was in 2003 and considers only irrigation and drinking water.

Agriculture supported by PAs – a look at the wider evidence

Forest PAs attract rains, store them like a sponge and then feed the aquifers and streams downstream of the PA. Analysis of spatial data from the 1996 Ecological and Forest Inventory (IEFN) and statistics from the Water and Electricity Distribution Society (JIRAMA) show particularly obvious hydrological relationships for 20 protected areas out of 41 PAs which are located upstream of 430,000 hectares of irrigated field systems (as well as 17 cities consuming 8.4 million m3 of drinking water annually).[192]

The country's total renewable water resource is 286,550 hm3/year (one hm3 = 1 million m3).[193] Water withdrawals by the agricultural sector were dominant with 14,188 million m3 (2012) from surface water, or about 4% of the total renewable resource.

Another ecosystem service of PAs for agriculture is erosion protection by promoting infiltration to limit runoff. In Madagascar, soils are fragile because of their low organic matter content. Yet in 2014 soils and pasture nevertheless constituted an estimated 45% of Madagascar's natural capital.[194] The process of soil degradation results in a loss of arable land, a decrease in yields on cropland and siltation of dams. The benefit of a protected area can be estimated through the value lost as in decreased productivity that would occur in the absence of the protected area.

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[190] The underestimate will be further compounded by the fact that 2003 was atypical in that, when correcting for the GDP inflator, $US1 in Madagascar in 2003 actually had lower purchasing power than $US1 in 2021.
[191] UNICEF 2020
[192] Unpublished IEFN 2020 data (LOFM/BNCCREDD+, 2021) were only made available in the final phases of the study but could not be used for this analysis
[193] WAVES 2016
[194] WAVES 2016

The effect of forest on the actual runoff has been recognized since the 1960s through experiments conducted at Analamazaotra (Perinet), which that water runoff from *savoka* slopes was 3x that of natural forest slopes. Runoff contributes to rice crop losses. The annual benefits of flood reduction by the creation of the Mantadia NP (in 1993 dollars) were estimated in 1995 at $51,691/year or about $2/ha/year, with a 20-year benefit of $547,176 or $20/ha[195].

Agriculture, as the main economic activity of rural households, has a very strong potential for value distribution. In fact, 80% of the added value directly benefits the most vulnerable households and its role as the main employer, equivalent to more than 3.178 million full-time jobs.

These observations demonstrate that the performance of PA management significantly contributes to the performance of the agricultural sector and makes a significant difference in terms of poverty and food security. By providing support services to agriculture, PAs have a predominant role to play in poverty reduction strategies.[196]

Total economic contribution across multiple sectors

Based on the above findings, the calculated economic contribution across the seven identified key sectors or sub-sectors (agriculture, water, energy, tourism, research/culture and environment) is **$212-328 million/yr** (excluding marine protected areas), broken down in Table 9:

Table 9 – Summary of national economic contributions of terrestrial PAs to key sectors (based on data collected for this study)

Sector	Economic contribution by PAs ($/yr)	Ha of PA contributing	Benefits/ha/yr (USD)
Agriculture	22,566,630	1,102,149	22.00
Water (potable)	10,079,3360	1,102,149	9.14
Energy	20,746,762 – 41,239,256	476,937-2,341,412	14.50-43.50
Tourism	42,682,564 – 173,602,436	1,113,981	38.32-155.84
Scientific research	2,781,290	7,612,346	0.34
Culture (NH films)	117,715	6,233,317	0.02
Environment:			
Carbon storage	21,645,200 – 29,045,200	3,389,324	6.39-8.57
Biodiversity conservation	51,816,368 – 59,976,368	7,612,346	6.35-7.43
Total contribution (exc. MPAs)	**215,102,431- 329,312,897**	**6,233,317**	**34.51-52.83**

This estimation may be regarded as conservative because values for agriculture and water consider only a subset (about 18%) of PAs[197], because the rate used for carbon storage was just $5/t/CO2eq, and because it considers only a limited range of ecosystem services.

Local Economic Contributions (Case Studies)

In addition to the global and national economic sector assessments, we have used case studies of several protected areas to assess the specific economic contributions of PAs **at the local and landscape level**. Evaluations at the local and/or landscape level represent the economic contributions that are captured at the local and/or landscape level and which can be measured in monetary terms. The

[195] Kramer et al, 1995 and 1997
[196] FAO 2014
[197] They are also based on a study in 2003 (Carret & Loyer 2004) when the purchasing power of $US1 was unusually less than $US1 in 2021, the reference year for this study

different studies consider a range of ecosystem service values, including provisioning (timber, charcoal production, non-timber forest products (NTFP), clean water for local hydropower stations, irrigation and drinking, regulating (hydrological protection) and cultural (tourism).

Complex Mahavavy Kinkony

The value of the Mahavavy-Kinkony Wetlands complex (CMK), calculated from the services assessed, is summarized in Table 10 ($2021 values):

Table 10 – Ecosystem service values of the Mahavavy-Kinkony wetlands complex ($2021 values)

Component	Value in $/yr ($2021)	$/ha (PA area 302,400 ha)	Resource area providing ES (ha)	Value in $/ha (resource area)
Charcoal plantation 1 (Bemaratoly)	2,866,424 – 4,586,278	9.48 – 15.17	780	3675 – 5880
Charcoal plantation 2 (Masiakakoho)	973,373 – 1,566,996	3.47 5.27	1041	1008 – 1531
Dry forest (honey, wild boar, rapphia, satrana)	1,076,106	3.66	92,831	11.91
Lakes & reservoirs	5,471,854	96.15	56,910	18.09
Mangroves	13,141,999	43.46	24,845	528.90
Total	**23,635,653 – 25,900,468**	**78.16 – 85.65**	**176,410**	**133.98 – 146.82**

Based on the direct use values of provisioning services, the Mahavavy-Kinkony Complex made an overall annual economic contribution of **$23,635,653 – 25,900,468**, or $78.16-85.65/ha (based on its entire area of 302,400 ha) in 2018 (values adjusted to $2021). The charcoal plantations were extremely productive ($1008-5880/ha/yr) and represent the most valuable form of land use within the PA. Mangroves generated the most revenues overall, at $13,141,999 but were less productive than plantations, at $528.90/ha/yr. Dry forest was the least productive, at $11.91/ha/yr, but still yielded a substantial benefit of $1,076,106. The low revenues from dry forest are largely due to restrictions on use, as it is much more important for biodiversity conservation than mangroves are. Ecotourism at CMK, which has potential (notably for rare wetland birds and lemurs in the dry forest), was not considered, nor was the value of lake water and groundwater resources (because of the lack of available data). The absence of data for certain values does not mean an absence of value, and the results amply demonstrate that wetland protected areas can be highly valuable in the Madagascar context.

Detailed calculations are presented in the Appendix (with values expressed in the original $2018 dollars).

Antrema Biocultural Site

The economic contribution of The Antrema bio-cultural site, calculated from the services evaluated, is summarized in Table 11.

Table 11 – Ecosystem service values of Antrema Biocultural site (20,620 ha)

Component	**Value in $/yr ($2021)**	**$/ha/yr**	**Resource area (ha)**	**Value $/ha/yr (by resource)**
Forest	13,649.21	0.66	4776	2.86
Lakes & reservoirs	64,284	3.12	159	404.30
Mangroves	204,383.48	9.91	1493	136.89

Total	282,316.69	13.69	6,428	43.92

Based on the direct use value of some provisioning services, the value of ecosystem services from the Antrema Bio-Cultural Site was estimated at **$282,316.69/yr**, or an average of $13.69/ha in 2018, (based on services provided by 6,428 ha (about 30% of the PA) which generated $43.92/ha/yr on average). In this case, while mangroves generated the most value overall ($204,338.48 annually), lakes and reservoirs which support productive fisheries, were the most valuable ecosystem by area, with an annual value of $404.30/ha/yr and dry forest the least valuable (at $2.86/ha/yr). The low value of forests is in large part due to the strict controls on forest use because of its high importance for biodiversity. As for CMK, ecotourism, still in its infancy, was not considered, nor was the value of lake water and groundwater for agriculture and other uses, due to lack of available data. As ecotourism develops, the value of the forests will increase. The value of water could also be considerable, since the site has underground water reserves estimated at 4,688,768,386 m^3 at depths of up to 20m[198].

Further details of the methodology and calculations are presented in the appendix.

Ankarafantsika National Park

In the case of Ankarafantsika, the study focused exclusively on the value of a single ecosystem service – soil stabilization – providing protection of the Marovoay rice-producing plain from sedimentation. The value was based on the opportunity cost of sedimentation making land unsuitable for rice cultivation caused by deforestation at the park edge.

The study found that sedimentation due to degradation of the park results in an annual loss of cultivable area of about 2%, the cost of which in lost rice production is estimated at 35-40 billion ariary over 11 years or, a loss of $91,000 –105,000 over 11 years, for the or about $2/ha/yr.

This study considers only a small part of the value of the services provided by Ankarafantsika national park. In particular, it does not consider ecotourism which is highly important at Ankarafantsika, with 4,329 visitors in 2019 (range 1440 to 8095). Assuming a daily ecotourist expenditure of $55, Ankarafantsika could generate as much as $2 million annually, or about $15/ha/yr.[199]

Besides erosion protection, other biophysical services include carbon sequestration and water regulation. In terms of erosion protection, only the effect on rice farming is taken into account. Furthermore, the study document states that only 14.85% of the affected soil losses are deposited in the Marovoay Plain, while 87.5% are dumped into the Betsiboka River and reach the sea, contributing to sedimentation impacts in the marine environment. To this end, the value of the benefit of the erosion protection service calculated can be considered as underestimated.

Ranomafana National Park

Ranomafana (40,556 ha) in the eastern forest ecoregion is an exceptional park in many respects. Its creation in 1991 resulted from a program of scientific research which documented an exceptional diversity of lemur species including one new to science, the golden bamboo lemur. Ranomafana is also exceptional in the range of ecosystem services provided, including tourism, good quality drinking water, clean water for hydropower, carbon sequestration and hydrological protection. Taken together these add up to a considerable total annual contribution by the park of **$13.7-22.3 million/yr** to the local and regional economy (equivalent to of $338-550/ha/yr) in ecosystem services, depending in the precise calculation method used (Table 12).

Table 12 – Ranomafana National Park – the value of ecosystem services

[198] Rambeloarisoa 2017
[199] MNP unpublished data

Economic benefits of Park	Local/Landscape benefit in $ ($2021)	Value $/ha/yr
Ecotourism (1st method) (direct park receipts)	444,229	10.95
Ecotourism (2nd method) ($75 local tourist spend per capita[200]	2,221,144	54.77
Hydroelectricity (1st method) (regional)	13,252,777	305
Hydroelectricity (2nd method) (regional)	20,065,125	462
Drinking water (willingness to pay) (local)	n/a	0.40
Hydrological protection (willingness to pay) (local)	7312.28	0.18
Total local/regional service values (range)	**13,704,309 – 22,293,581**	**338 – 550**

The hydro-electricity value is the highest, at $305-462/ha/yr, depending on the method used, which accrues to the regional level since Ranomafana power station powers the regional capital of Fianarantsoa). By contrast, the values for drinking water ($0.40/ha/yr) and hydrological protection ($0.18/ha/yr) appear very low. However, the latter were based on *contingent evaluation* and are thus based on the willingness of very poor farmers to pay for clean water (which is in abundance at the site) and hydrological protection (for which they were willing to pay $5/ha of rice paddy/yr), a considerable sum for a small-scale farmer.

The benefit from tourism is based on an average local expenditure per tourist to Ranomafana in 2009 of $75[201] which is about half the total daily expenditure per tourist visiting Madagascar of $165. Ranomafana is a very popular park with 27,338 visitors in 2019. Assuming a daily spend of $75. And correcting for $2021 dollars, gives a total economic contribution of Ranomafana for tourism of **$2.221 million/yr** and a value per hectare of $55/ha/yr. This makes tourism a strong local economic contributor which directly supports local jobs. A recent study has shown that Ranomafana has been effective in reducing deforestation rates steadily over a period of 10 years, with even some evidence of forest regrowth, which is attributed to local community compliance in recognition of the economic benefits generated by the park.[202]

Analamazaotra / Mantadia

The Analamazaotra National Park (874 ha) is Madagascar's prime ecotourism site, readily accessible from Antananarivo, to which visitors flock to see and hear Madagascar's largest lemur, the indri or babakoto (*Indri indri*) with its 'hauntingly beautiful', musical cries[203]. Visitor numbers reached 36,193 visitors in 2019[204]. The small size and high pressures on the site, coupled with objectives of biodiversity conservation and providing ecosystem services for local agriculture[205] helped drive the establishment in 1989 of the adjacent Manatadia National Park (originally 10,000 ha, extended in 2002 to 15594 ha).

[200] Serpantié et al 2009
[201] Serpantié et al 2009
[202] Dumas et al 2021
[203] Scientific American 2021
[204] MNP 2021
[205] Kramer et al 1995

If one considers only the special reserve of Analamazaotra (874 ha) where most visitors go to see and hear the indri, assuming 36,193 visitors spending on average $165/3 = $55 on the day of their visit[206], this equates to a total local economic benefit from tourism of $2,030,215/yr in 2019 dollars ($2,199,33

4 in 2021 dollars), or $2517/ha/yr. Spreading the benefit over both sites (Analamazaotra and Mantadia) (874+15494 = 16368 ha), we obtain a tourism economic contribution of $134.37/ha/yr for the combined park (Table 13).

Table 13 – Andasibe-Mantadia – Local/landscape economic value of tourism

Ecosystem service valued	Local/landscape benefit $/yr	$/ha/yr
Ecotourism (direct expenditure) (park fees & purchases) ($205,955 of 2019 to $2021)	**228,576**	**13.96**
Ecotourism (indirect based on average daily tourist spends of $55 (30% of total daily spend of $165)	**2,199,332**	**134.37**

Makira Natural Park (hydro-energy study)

A further example of a protected area contributing to water quality suitable for the production of hydroelectricity for the local economy is the southern parcel of Makira Natural Park in northeast Madagascar which comprises a forest catchment of 74,494 hectares. The catchment feeds the Hydelec dam at Voloina commune which has a capacity of 2.5MW and which supplies energy to the town of Maroantsetra (about 30,000 inhabitants) as illustrated in Fig 8. The operator, Tozzi Green, has observed in recent years that deforestation in the upstream catchment has increased flash flooding causing the transport of sediments and large trees and rocks towards the dam, causing several complete shutdowns.[207] Using a market price calculation, assuming the plant runs on average at 50% capacity at an energy price of $0.70-0.80/kWh) and that 50% of water quality is due to the forest, gives a value for the forest PA catchment of $4.107 million/year or $55.12/ha/yr (which is comparable to the value estimated for the CAZ forests supplying water to Andekaleka of $43.50/ha/yr (calculated by an avoided costs method).

[206] FTHM Conseils 2012

[207] Tozzi Green 2021 and unpublished data

Fig 8 – Representation of a dam above a coastal zone (comparable the Hydelec dam in the Voloina commune, downstream of Makira Natural Park and feeding into the Bay of Antongil, NE Madagascar)

Combined value of case study sites

Based on the 7 case study sites considered, which cover 590,951 hectares (or 9% of the terrestrial PA network), we arrive at a total annual economic contribution in $2021 in the range of **$42 million to $55 million/yr**, or the equivalent of $67 to $87/ha/yr. Thus, even based on locally captured economic benefit, this places the economic contribution of the studied protected areas at almost 7-9 times the average management cost of $10/ha/yr.

Discussion of the case studies

While the highest values were reported for sites supporting hydroelectricity or tourism, the data also show that sites without significant tourism or hydropower, in particular wetlands, can provide significant economic value (case of CMK at $134-147/ha/yr).

It is noteworthy that the total estimated contribution of the 7 selected protected areas at the level of the local economy, at a rate of $67-87/ha/yr, is slightly higher, but of similar order of magnitude to the average rate based on the national economic assessment ($54-$69/ha/yr). This should not be interpreted as showing that the local economic contributions of PAs are greater than the national economic contribution, for the following reasons:

- Estimates of the national economic contribution of PAs are conservative for the reasons indicated
- The terrestrial sites considered were all either wetlands or humid forests which are relatively valuable ecosystems and not representative of the terrestrial PA network as a

whole; indeed, rhe case studies show that rates for dry forests (which occur at CMK, Antrema and Akarafantsika) are considerably lower than for wetlands or humid forests.

Some dry forests, however, are very important for tourism, because of their unique biodiversity. Although not part of the case study, we have estimated that, based on 4329 tourist visits in 2019, Ankarafantsika generates about $700,000 annually from tourism (or $5/ha/yr), complementing its value for agriculture.

Marine protected areas (MPAs) – a specific case study

Madagascar's marine ecosystems and biodiversity are currently protected under a range of MPA regimes that emerged comparatively recently, long after the terrestrial protected areas[208]. In response to the 2014 Promise of Sydney, international norms for marine conservation[209] and in line with Madagascar's blue economy policy[210], Madagascar has rapidly developed a marine protected areas network now amounting to a total of 22 sites considered to be primarily MPAs (plus several primarily terrestrial sites including protected marine habitats) covering 1.38 million hectares of littoral and marine habitats or 11.8% of the continental shelf (Fig 9)[211]. With the proposed addition of large a new MPA in the deep south (*Atimo Vatae*) covering 700,000 ha[212], and a proposed corridor of >300,000 ha linking Ankarea and Ankivonjy MPAs in the northwest[213], MPA coverage will increase to over 2.4 million ha. The MPAs are complemented by LMMAs (locally managed marine areas) with varying surface areas and governance structures, and a growing series of regional fisheries management plans (*Plans d'Aménagement des Pêches*) which are programmed to cover the entire coast.

Marine protected areas provide a range of valuable ecosystem services including supporting productive and resilient fisheries through maintaining intact ecosystems, regulating climate through carbon storage by mangroves, providing a supporting environment for marine ecotourism, coastal tourism and recreation, marine biodiversity and regulating services such as sediment stabilisation (mangroves and seagrass beds) and coastal defence (by coral reefs), providing resilience to climate-change related risks such as coral bleaching, storm surge, coastal erosion and flooding. MPAs have a particular advantage in providing ecosystem services which help alleviate poverty.[214]

[208] Ratsimbazafy et al 2019
[209] Frequent reference is made to international norms as this is a leitmotif of the current presidency
[210] MRHP 2015
[211] Cooke et al in press
[212] Resolve/WCS 2020.
[213] Ziegler et al 2021
[214] Siason et al 2008

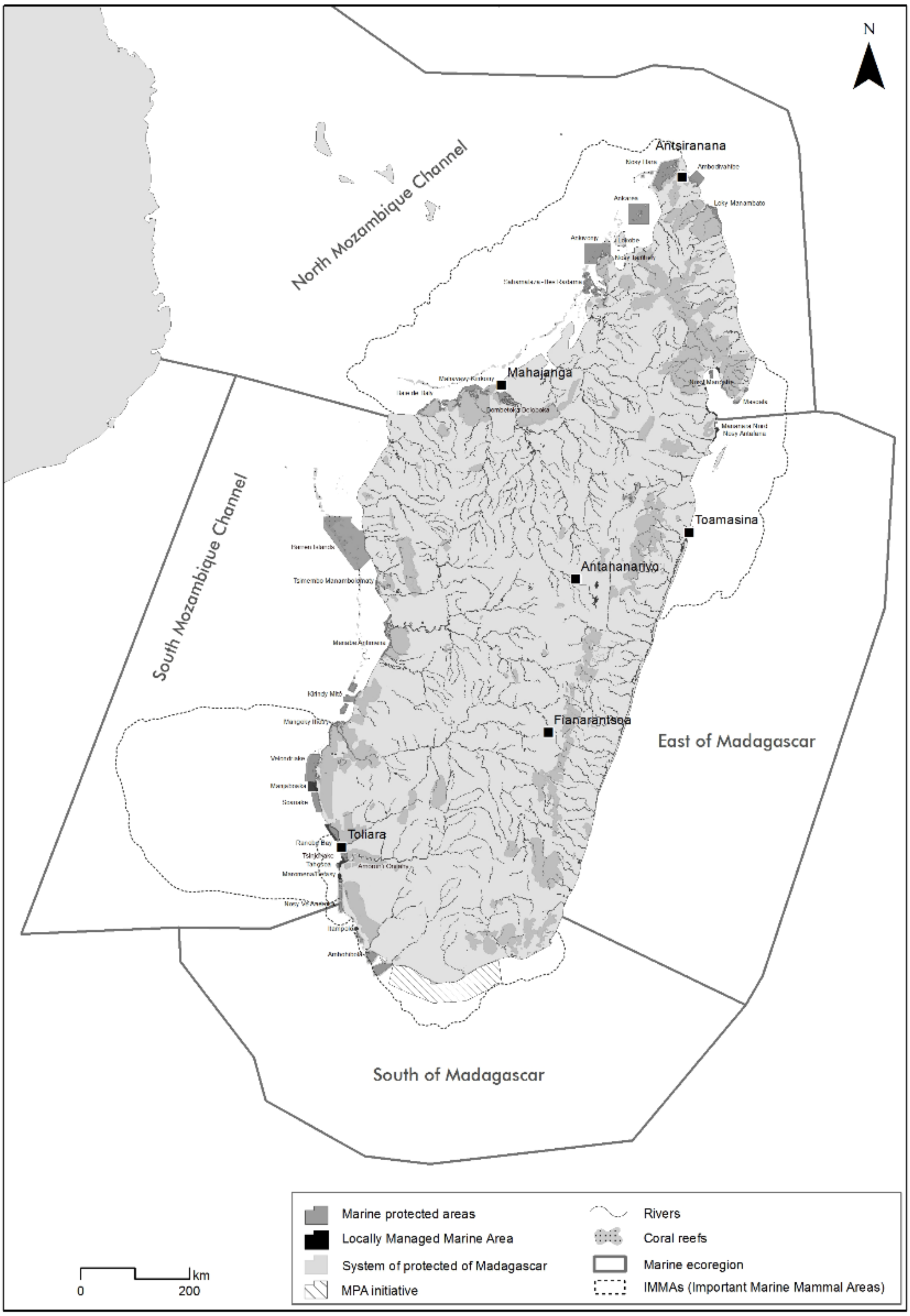

Fig 9 – Map of Madagascar's Marine Protected Areas

Value of marine ecosystems

As we have seen above in this paper, the ecosystem service values of marine ecosystems published in the landmark studies of Costanza et al and De Groot et al[215] indicate very high values for coastal marine

[215] Costanza et al 1997 & 2014, De Groot et al 2012

ecosystems ranging from $5933 to $8944/ha/yr, which would give an estimated annual economic contribution of Madagascar's MPA network (which covers 1.38 million ha) of $7–12 billion. However, as also mentioned, such high values reflect the summation of all potential ecosystem services from well-managed MPAs, often in a highly developed economic context, many of which may not be fully achievable in Madagascar, and so represent aspirational or theoretical values rather than actual values.

Some attempts have been made to value whole tropical marine ecosystems. For example, annual use value of the Guinea Current Large Marine Ecosystem (GCLME) covering an area of 255 million ha, was provisionally estimated at $17.2 billion or $67.60 per ha/yr, taking account of open water ecosystems for fisheries (valued at $53.70/ha/yr covering 253 million ha) and intertidal ecosystems (much more valuable at $1470.20/ha/yr but covering a much smaller area of 1.83 million ha).[216]. The value of ecosystem services in the Western Indian Ocean as a whole (based on 15,000 km of coastline and 8.1 million km^2 of EEZ) has been estimated at about $20.8 billion/yr across 10 countries (an average of $2 billion per WIO country)[217], primarily from tourism (69%), carbon sequestration (14%) and fisheries (9%).[218] Closer to home, the value of the Northern Mozambique Channel (NMC), covering 450,000 km^2, was valued by the ASCLME/SWIOFISH program at $12.5 billion annually, or about $278/ha/yr, perhaps reflecting the higher proportion of high value coastal ecosystems such as coral reefs in the NMC as well as valuable coastal and offshore fisheries.[219] Using the same values per ha as for the NMC, and given an EEZ covering 1.14 million km^2, the marine and intertidal ecosystems of Madagascar's EEZ might be worth about $31.7 billion annually. MPAs account for just 1.2% of the EEZ, which would suggest a value for MPAs of about $378 million annually. According to official statistics for 2011, the total value of Madagascar's fisheries (of which more than 90% are marine) was just $146 million, which likely represents a small part of the total fisheries value[220]

Value of MPAs – international evidence

Globally, ecosystem services from MPAs covering a total 27,761,227 km^2 have recently been valued at $900 billion over 2015-2020 ($180 billion annually), or an average of $65/ha/yr, and with a ratio of benefits to costs ratio of 20:1[221]. The world's largest coral reef MPA, Australia's Great Barrier Reef, with an area of 3,440,400 km^2, has been valued at $6.4 billion annually, or a somewhat lower average of $18.6/ha/yr. [222] Applying the global average value of $65/ha/yr for Madagascar's MPAs would value Madagascar's MPA network of 1.38 million ha at about $90 million/yr. Applying the lower Great Barrier Reef value of $18.6/ha/yr, would value Madagascar's existing MPA network at just $26 million/yr. As we see below, these estimates appear low in relation to documented fisheries and tourism values. In particular, when carbon storage values of MPAs are considered, values increase significantly. An evaluation of 5 MPAs in West Africa gave €260/ha/yr ($292/ha/yr) and of the Banc d'Arguin National Park (PNBA) in Mauritania, which has extensive sea grass beds which act as a carbon sink, up to €400/ha/yr ($450/ha/yr), of which more than 40% was from carbon sequestration by seagrass beds[223].

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[216] Interwies, 2011
[217] With 1.14 million km^2 of EEZ and 5000km of coastline, Madagascar could marshall 15-30% of this value
[218] Obura et al 2017, covering the waters of the SWIO (Comoros, France (WIO possessions), Kenya, Madagascar, Mauritius, Mozambique, Seychelles, Somalia, South Africa and Tanzania)
[219] ASCLME/SWIOFISH 2012.
[220] WAVES 2012 and 2013
[221] Brander et al 2015
[222] Deloitte 2014
[223] Trégarot et al 2018

Fisheries benefits of MPAs – international evidence

Benefits of MPAs to fisheries overall are proportional to area, but the fisheries benefits of MPAs are proportionately greater when the MPAs cover a higher percentage of marine ecosystem area, with a break-even point at about 8.5%[224] (since Madagascar's MPAs today cover 11.8% of its continental shelf seas, the fisheries benefits of Madagascar's MPAs should be proportionately greater today than they were prior to implementation of the Promise of Sydney). It has also been estimated that increasing global MPA coverage by 5% could increase global fisheries yields by 20% and it has been suggested that food production, and thus economic benefit, can be a central driver for MPA design.[225] WWF's global outlook assessment estimated that a future global conservation scenario with MPAs in place would treble fisheries yields globally. The same report, however, suggests that for Madagascar specifically, sustainable use options for marine resources may offer greater positive impact on GDP than strict conservation scenarios.[226] This lends support to current strategies for MPA management in Madagascar which focus more on sustainable use than on strict preservation.

International guidelines on MPAs

International experience has identified five key guidelines for MPAs to be most effective for fisheries – they should be legally fully protected, well enforced, more than 10 years old, more than 100km^2 in area (10,000 ha) and in isolated locations if they are to deliver the greatest fisheries benefit. Most of Madagascar's MPAs created since 2000 potentially satisfy some of these criteria, while most early MPAs were designed as marine nature reserves for tourism and preservation and were too small to be of significant support to sustainable fisheries (e.g. Nosy Tanikely (originally 139ha, now 341 ha), Nosy Atafana (1124 ha) and the three marine reserves of Masoala NP (totalling 10,000 ha), although there is some evidence that Nosy Atafana has had positive impacts on adjacent fisheries.[227]

A *combination* of MPAs and fisheries regulations can be effective for productive sustainable fisheries[228] suggesting that complementing Madagascar's MPAs by establishing LMMAs, regional fisheries management plans (*Plans d'Aménagement des Pêches* or 'PAPs') and better fisheries regulations would further increase the economic contribution of MPAs. Several of Madagascar's MPAs encompass LMMAs or are within regional fisheries management plans (PAPs), including the MPAs of Nosy Atafana and Masoala in the northeast, the MPAs of the southwest (Velondriake, Soriake, Ranobe Bay, Tsinjoriake) and Ankarea MPA in the far northwest (part of the Bay of Ambaro PAP).

Benefits of specific ecosystems within Madagascar's MPAs

Today the main focus of marine protected areas in Madagascar is on the conservation of mangroves coral reefs and seagrass beds, conserving marine megafauna such as nesting sea turtles, marine mammals, whale sharks and dugong, for supporting sustainable fisheries and, in some cases, tourism.

Mangroves

The direct economic benefits of mangroves are provisioning services for food (such as mud crab, shrimp and fish), chalk and wood and appear fairly uniform around the world, with ecosystem service values first globally estimated in 1997 at around \$1839/ha/yr[229]. Assuming such a high value, the 73,072 ha of mangroves inside MPAs could in theory provide ecosystem services worth as much as \$154.68 million/yr (in 1997 US dollars). Available evidence, however, suggests that values are

[224] Rising & Heal 2014
[225] Cabral et al 2020
[226] WWF 2020
[227] Grandcourt 1999; Oréade-Brêche 2010
[228] Pew 2019
[229] Costanza et al 1997

substantially lower than this. A study of mangroves in the northwest of Madagascar[230] shows that fisheries ecosystem services can be valuable (mud crabs 554/t/yr, fish 717t/yr and shrimp 98t/yr, from a 5800ha mangrove area) worth a total of $135/ha/yr in 2017 US dollars[231]. Applied to all mangroves in MPAs, such fishery yields would represent a value of $9.865 million annually in 2017 US dollars **($10.354 million/yr in 2021 dollars)**.

Mangroves also provide valuable regulatory ecosystem services. Madagascar's mangroves have been identified as beneficial for carbon storage[232] and a substantial blue carbon project has been under development in northwest Madagascar for several years.[233] The international Ocean Wealth Explorer Mangrove Restoration app[234] estimates that Madagascar's mangroves could enhance commercial fish catch by as much as 7.505 billion individual fishes, and invertebrate catch by as much as 13.739 billion individuals, of which about 34% would derive from mangroves in MPAs (which cover 73,072ha of a total 213,000 ha of mangroves along Madagascar's coasts)[235]. The same website estimates mangrove restorable area of Madagascar's mangroves at just 8,039 ha, so the main benefit in Madagascar's case will come from conserving rather than restoring mangroves. (While over 100,000 ha of mangroves have been lost since the 1960s[236], opportunities for restoration are limited by the irreversible changes in hydrology caused by some uses of mangrove, such as conversion to rice paddies or salt making).

Coral reefs

The main economic benefits of coral reefs are fisheries, tourism and coastal defence. The tourism benefits of coral reefs are highly variable and depend on their proximity to touristic areas.[237]

Globally, the fisheries benefits of coral reefs have been estimated at an average of $220/ha/yr[238]. Madagascar has an estimated 3934km^2 of coral reefs[239] which therefore have a potential annual value of $220 x 393400 ha = $86.55 million for fisheries. With 107,131 ha of reefs (about 30%) currently within the MPA network, coral reefs within MPAs, with effective management, could contribute an annual value of $23.78 million to fisheries. Madagascar's reefs have been confirmed to support important stocks of food fish (ranging from 100 to 2450 kg/ha) and significant yields for local fishermen (2 to 10 kg of fish per trip or per hour per fisher).[240] Research in the southwest has shown that fish biomass can be increased with protective management[241] and experience in the northeast (in Antongil Bay) has also shown that fish biomass is greater in locally managed marine areas (LMMAs).[242]

A study in 2013 of fisheries production from the Velondriake MPA to the north of Toliara indicated a total annual value of $6 million (based on 5524 t of captures with an average value of $1000 per ton) across a marine and intertidal area of 63,985 ha or about **$94/ha/yr** (in 2013 US dollars) [243.] The fisheries are concentrated over coral reefs, and the coral reefs of Velondriake occupy about 15% of the

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[230] Blue Ventures 2017
[231] Blue Ventures 2017
[232] Zeng et al 2021
[233] Blue Ventures 2017
[234] https://maps.oceanwealth.org/ (Mapping Ocean Wealth Explorer | Mapping Ocean Ecosystem Services)
[235] Jones et al 2016
[236] Cooke et al 2021
[237] Brander et al 2015
[238] Costanza et al 1997
[239] Cooke et al in press
[240] Jadot et al 2015
[241] Gilchrist et al 2020
[242] Komeno & Randriamanantsoa 2013
[243] Barnes-Mauthé et al 2013

MPA (or 3,449ha of reefs, with seagrass beds occupying 1779ha) [244] [245], indicating that the reefs themselves could be providing an annual value of about $625/ha/yr (in 2013 $US) or more. An earlier study of the fisheries of the more intensively fished Bay of Toliara published in 2011 estimated fisheries production at 14.2t/km^2 over an area of 19,014 ha[246]. Catch values and coral reef areas were not provided, but applying the values reported for Velondriake would give about **$154/ha/yr** for all fishing habitats combined for the Toliara bay fishery (in 2013 $US).

Seagrass beds

Seagrass beds provide important ecosystem services as fish nursery, sediment trapping, absorbing wave energy, carbon sequestration and conservation of biodiversity. Seagrass meadows are very efficient at storing carbon and can store 10 times more organic carbon per unit of area than terrestrial forests. Data on seagrass beds in Madagascar's MPAs are limited, but seagrass beds have been studied for some MPAs, notably Nosy Hara (area not measured), Barren Islands (590ha), Kirindy Mitea (about 2200ha) and Sahamalaza/Iles Radama (6465ha) and thus cover at least about 10,000 ha. [247] Adopting a value of $28,916/ha/yr suggested by De Groot et al (2012), would suggest that the seagrasses within Madagascar's MPAs could contribute more than $289 million annually. Taking the value for carbon storage as used for the Banc d'Arguin MPA in Mauritania (about $160/ha/yr) would suggest a value of more than $1.6 million annually. It is clear that the economic contribution of seagrass beds in MPAs merits further research.

Marine megafauna

With the creation of large MPAs and the development of protected seascapes, such as the Bay of Antongil, MPAs are becoming increasingly important for the protection of coastal megafauna with large ranges such as dugong, dolphins, sea turtles and sawfish, but even for highly migratory species such as whales[248] [249]and whale sharks[250].

Marine megafauna are important for marine ecotourism, and whale watching for the humpback whale already generates large tourism revenues for Madagascar and local economies (notably for Ile Ste Marie, Maroantsetra, Toliara and Nosy Be). A recent study on whale shark tourism in Nosy Be, which began in 2011, has shown that whale shark watching generates about $1.5 million annually.[251] About 33% of the whale shark watching in Nosy Be takes place in the Ankarea MPA, which therefore contributes about **$500,000 annually from whale shark watching (or about $1.08-1.23/ha/yr)**.

Earlier MPA value studies for fisheries in East Madagascar

In contrast to these recent valuations of reef fisheries on the southwest coast, two earlier studies on the fisheries benefits of MPAs on the east coast of Madagascar are remarkable for the very low values estimated. A study on Nosy Atafana[252] reported that the MPA of 1124ha yielded 14.5 tonnes of fish and octopus annually, with the finfish component valued at 12.6 million MGA ($3600 or about $3.2/ha assuming 1124 ha). An earlier study of Nosy Atafana by Grandcourt (1999) indicated that fishery yields

[244] Government of Madagascar 6th CBD report 2019
[245] Roy et al 2009
[246] Brenier et al 2011
[247] Cooke et al in press
[248] Rosenbaum & Chou in press; Cerchio et al in press (a) & (b); Davis et al in press

[250] Ziegler et al 2021
[251] Ziegler et al 2021
[252] Oréade-Brêche 2010

both inside and outside the MPA had been increased by conservation action, but the reported finfish yields were still very small (3.3 tonnes in 1999). The low fisheries values may in part be due to the very low productivity of coral reefs on the east coast, where fish biomass is generally about 20% of the biomass of northern and western reefs[253], but also due to the low levels of fishing effort and access restrictions to the park. We chose not to use these seemingly unrepresentative low values in our calculations, but it should be emphasized that east coast MPAs are likely have substantially lower values than west coast MPAs for fisheries purposes.

Value of coral reefs for tourism

A study in 2017 valued tourism on coral reefs at $36 billion globally, based on a combination of 'reef adjacent' values (sandy beaches, sheltered water, food, attractive views) and 'on reef' values (e.g. snorkelling & diving) (Fig 10)[254]. By overlaying Madagascar's MPAs onto the spatial data set, we were able to estimate that Madagascar's coral reefs lying inside MPAs have a global tourism value of about $8.25 million per year in 2017 dollars, or a value to the national economy of about **$2.89 million annually** assuming that one third of tourist spending is incurred in Madagascar**.** Given the high contribution of the Nosy Tanikely MPA alone of **$2.42 million/yr** (infra), we **estimate the minimum value of coral reefs in Madagascar's MPAs for tourism to be about $5.3 million/yr** (or about $49.50/ha/yr for coral reefs in MPAs).

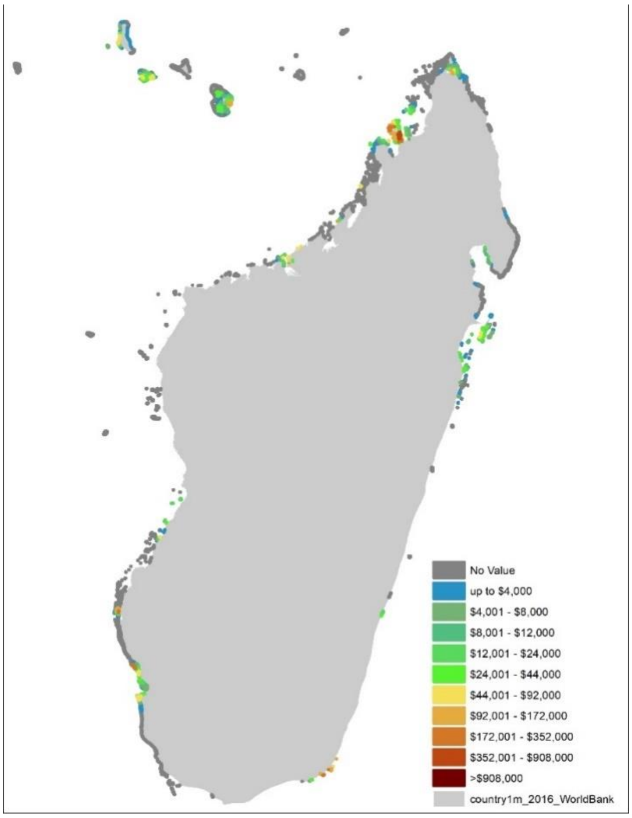

Fig 10 – Economic contributions of Madagascar's coral reefs for tourism (Source: Spalding et al 2017)

Nosy Tanikely MPA – an exceptionally valuable site

Nosy Tanikely MPA, adjacent to Madagascar's principal coastal tourism island, Nosy Be, was the first marine reserve to be created in Madagascar (in 1968)[255]. The high ecological and economic value of

[253] Cooke et al in press
[254] Spalding et al 2017
[255] Arrêté 4730 (Journal Officiel 2232, 30 November 1968) of the Ministry of Equipment and Communications

Nosy Tanikely has been previously reported on.[256] Now under management of MNP, the site of 341[257] ha, including 93ha of coral reefs received 51,285 visitors in 2019 (of which 37,472 were international tourists[258], each paying the admission fee of 10,000 Ariary ($3) and typically spending the cost of a day's excursion to visit the island and one night's accommodation on Nosy Be. Taking the average daily tourist expenditure of $165 in 2012[259], dividing by 3 ($65) and adding the entry fee of $3 (=$68) (without considering additional nights that could be reasonably attributed to the visit) it can be estimated that Nosy Tanikely alone generates as much as **$2.417 million/yr** for the national and local economies (the equivalent of about $7088/ha/yr).

Value of coastal areas for recreation

Prior to the global coral reefs study, a regional study in the Northern Mozambique Channel evaluated recreational values in the coastal areas around Madagascar, valuing coastal recreation across the country at $217.1 million with rates ranging from $46.2/ha/yr (Toamasina) to $433.1/ha/yr (Antsiranana). Given that Madagascar's MPAs cover 11.8% of coastal seas[260], would value Madagascar's MPAs at $25.6 million for recreation ($18.55/ha/yr). Since coastal recreation tends to be concentrated in MPAs, the estimate may be regarded as conservative.

Total estimated economic contribution of Madagascar's MPAs

Based on the above review of the evidence, we were able to generate three different approximations for the annual economic contribution of Madagascar's marine protected areas:

Global contribution of MPAs

As for terrestrial PAs, the global benefit is the gross global benefit *less* the benefit capture at national level. Based the potential for carbon storage, we estimate that the mangroves in Madagascar's MPAs provide a regulating service to the global economy worth about **$312 million annually** in 2021 US dollars. This figure should be considered conservative, since it does not include coral reefs, seagrass beds or other marine ecosystems which also store carbon and does not include the support services of MPAs such as fish breeding grounds.

For global benefits to marine biodiversity conservation we found no evidence on which to base a specific economic estimate for the contribution of Madagascar's MPAs, which are therefore subsumed within the estimates for all PAs, terrestrial and marine.

For cultural services of MPAs, we include the benefit to global tourism of Madagascar's MPAs which we estimate at **$1.2 million/yr**, from coral reefs and marine megafauna in MPAs, excluding Nosy Tanikely (which is included in the Top 15 PAs for tourism). This includes 8000 tourists who undertook whale shark watching in Nosy Be in 2019, about 33% of which occurs in the Ankarea MPA, representing a global annual benefit from MPAs of $542,000 for whale shark watching alone and $577,000 from coral reefs in MPAs.[261]

National and local economic contribution of MPAs

Taking data available within Madagascar on the *actual* values of fisheries and tourism in MPAs, we built an estimate based on an assumed average value for fisheries of $125/ha/yr (approximate median value of $94 and 154/ha/yr) giving $172.38 million for all MPAs for fisheries) plus $5.5-5.6 million as

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[256] Webster 2008
[257] 341 ha is the official area (and used for our calculations) although a circle of radius 1km would normally be 314 ha
[258] MNP Unpublished visitor data 1992-2019
[259] World Bank/PIC 2012
[260] Cooke et al in press
[261] Ziegler et al 2021

the value of MPAs and reefs in MPAs for tourism (including Nosy Tanikely and whale shark watching in Nosy Be MPAs) and $1.26 million for the blue carbon value of mangroves, giving $185-188 million per year for MPAs, converted to **$195-199 million/yr** (or $142-144/ha/yr) in 2021 US dollars.

We should emphasize that this is likely to be a substantial under-estimate since it includes only the provisioning (fisheries) and cultural (tourism) ecosystem services of MPAs and does not include the *regulating* or *support* services of MPAs which can be very valuable (coastal defence, climate change resilience, fish breeding grounds etc.).

Costs of managing MPAs

Research has shown that adequacy of funding for MPAs is a robust predictor of successful outcomes[262]. Global funding need for MPAs covering 20-30% of the world's ocean surface (72.38-108.57 million km^2) has been estimated at $5-19 billion annually[263] or about US$ 0.46-2.62/ha/yr (which would include very large MPAs with low average management costs per hectare). A study commissioned by WCS in 2017 estimated the annual management cost of Madagascar's MPAs at the time to be $1.46-2.88 million/yr (or $4.54-8.72/ha/yr)[264]. More recent data from WCS, place the actual management costs of the Ankarea and Soriake MPAs at $4.9 and $22/ha/yr respectively, the cost depending on the level of management reinforcement, MPA area and category and the level of community participation.[265] In conclusion, the current costs of managing MPAs appear variable but of a similar order of magnitude to those of terrestrial PAs. For the purposes of our global estimate of PA management costs we have assumed $10/ha/yr for all PAs, marine or terrestrial. The trend, however, will likely be towards lower management costs per hectare for MPAs due to their increasing size and less strict management systems which emphasise sustainable use and greater community control.

Opportunity costs of MPAs

Few studies have been conducted of the opportunity costs of MPAs in Madagascar. A study for a possible blue carbon project estimated the opportunity cost of a project involving mangrove conservation at $1.3 million for a 5,800ha area of mangrove supporting livelihoods of 26,363 persons, equating to $214/ha/yr (greater than the total fisheries value of $134/ha/yr) or $49.30 per person/yr, highlighting that the opportunity costs of MPAs, and mangrove protection in particular, can be very significant.[266]

Costs of inaction for MPAs

Studies have found that Madagascar's fisheries are likely to suffer especially strongly from loss of biodiversity and climate change, with losses amounting to as much as 2.8% of GDP if measures are not taken to prevent marine biodiversity loss or mitigate climate effects.[267] Maintaining and strengthening Madagascar's MPAs would help reduce these losses.

Other economic contributions and benefits of PAs

In the preceding sections we have focused on the measurable benefits of protected areas to the global, national and local economies, for which we have evidence for assigning monetary values. In some cases, the economic benefits are clearly important, but available data are insufficient to estimate a monetary value. For others, it is difficult or morally questionable to assign monetary values. In this

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[262] Gill et al 2017
[263] Balmford et al 2004
[264] Iyer 2017
[265] WCS, unpublished data
[266] Blue Ventures 2017
[267] WWF 2020

section we review the evidence for benefits which are challenging to value in monetary terms, from the more tangible to the least tangible.

- Human health benefits of protected areas (local and global)
- Benefits of restoration actions around protected areas
- Research and education, within and outside Madagascar
- Biodiversity conservation and meeting international commitments
- International reputation and access to finance
- Nature documentary and entertainment films linked to Madagascar's biodiversity
- Spiritual, intrinsic and moral values

Human health benefits of protected areas

Health and well-being benefits

The human health impacts of ecosystem alteration began to receive significant scientific attention at the start of this millennium. Negative health impacts have been associated particularly with large dams, deforestation, habitat encroachment, loss of biodiversity, loss of coastal barrier systems (such as mangroves), fertiliser use and loss of tree cover to filter polluted air. [268] Nature and protected areas can also be important for well-being. There is evidence that detachment from nature causes a reduction in well-being, while contact with nature can reduce stress and even improve self-esteem.[269]

There is now a substantial body of evidence that healthy nature means healthy people[270] [271]and that protected areas, including the protected areas of Madagascar, make a significant contribution to improved human well-being and health, especially among children. A recent study across 34 developing countries including Madagascar showed that households near protected areas have higher wealth (by 17%), lower poverty (by 16%) and healthier children, with higher height-for-age scores (by 10%) and less stunting (by 13%).[272] For nature-dependent communities, deriving well-being from nature is not merely passive – evidence from two protected areas in Madagascar suggests that it requires the exercise of human capability in relation to forest values.[273] Consistent with this observation, greater well-being has been claimed for communities in Madagascar who are actively involved in forest conservation management [274].

Protected areas benefit child health especially through the provision of clean water. An earlier analysis of data from the same 34 countries showed that children living downstream of protected watersheds showed lower incidence of diarrhoea which is the second leading cause of death in young children. [275] [276] [277]

The nearby presence of forest is also beneficial for nutritional reasons. A study of 27 countries including Madagascar showed that children near protected forests had healthier diets. [278] [279] A study from 2020

[268] Myers et al 2011
[269] Dasgupta 2021
[270] Dasgupta 2021
[271] FAO 2020
[272] Naidoo et al 2019
[273] Fritz-Vietta 2016.
[274] Rasolofoson et al 2017
[275] Ferreira et al 2021
[276] Herrera et al 2017
[277] Pattanayak & Wendland 2007
[278] Golden et al 2011
[279] Rasolofoson 2018a & b

reports a lower incidence of stunting by as much as 7% in children living within 8km of protected areas and proposes forest conservation as a nutrition-sensitive intervention in low- or middle-income countries such as Madagascar[280]. A specific study on Masoala National Park showed that forest meat was an important source of micronutrients for children and similarly proposed nutritional interventions as a support to conservation.[281]

Protected Areas and disease control

The health benefits of protected areas go beyond matters of clean water and nutrition. Maintaining protected areas also exerts a positive influence in reducing many different animal vector-borne diseases. For example, protected areas reduce deforestation which reduces malaria and respiratory infections.[282] In Madagascar, maintaining protected areas may help to protect against outbreaks of plague, malaria, dengue fever and a range of other diseases in humans.[283] [284]

Outbreaks of plague are associated with episodes of intensive deforestation, which enables black rats to invade newly deforested areas and to transfer the plague bacterium from forest animals to human populations close to the forest edge [285]. In the period 2010-2015, when there was a major rise in deforestation rates, Madagascar reported more plague cases than any other country on earth.[286] A plague outbreak in 2016 in Befotaka, a remote location in southeast Madagascar, was associated with human activities, including deforestation[287.] One of the reasons that Madagascar remains one of the few countries in which outbreaks of plague still occur is the persistence of swidden (slash and burn) agriculture causing deforestation.[288] It has been suggested that transmission of plague could be minimised by reducing deforestation rates to reduce contact between humans and rodents carrying the plague.[289]

Malaria outbreaks have also been associated with deforestation in Madagascar. Clearance of forest creates suitable habitat for mosquitoes and therefore encourages diseases carried by mosquitoes.[290] The effect is not limited to malaria, and potentially includes dengue fever, rift valley fever and chikungunya, all of which increase as a result of deforestation.[291]

The disease control benefits are not limited to humans. Newcastle disease, an RDV virus which causes high mortality in chickens,[292] is ravaging poultry populations on the Masoala peninsular in the northeast, where a high rate of chicken mortality (79%) has been associated with areas where deforestation is proceeding, with negative effects on the nutritional status of local communities.[293]

Finally, protected areas globally help reduce the risk of pandemics such as COVID 19. Since antiquity, the domestication of animals and reduction of natural spaces and wild fauna, including deforestation, have been at the origin of diseases caused by parasites, bacteria and the most dangerous viruses.[294]

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280 Rasolofoson et al 2020
281 Borgerson et al 2020
282 Whitmee et al 2015
283 Tortosa in press
284 Morand & Lajaunie 2021
285 Andrianaivoarimanana et al 2013
286 Cohen 2019
287 WHO 2017
288 USAID 2019
289 Alderson et al 2020
290 Arisco et al 2019 & 2020
291 Tortosa in press
292 Rasambainarivo & Zohdy 2021
293 Borgerson et al 2020
294 Corral-Broto & Rakotomavo 2020

Human encroachment into wild areas such as bush meat hunting increases risks of disease transfer, and there is compelling evidence that HIV, Ebola and Zika viruses all resulted from such transfers.[295] [296]

A recent paper published by IUCN[297] has confirmed that protected areas play an important role in reducing the risk of pandemics and recommends that protected area networks should be expanded and reinforced on public health grounds alone. Protected and conserved areas help avoiding land-use change and thus potentially have a role in reducing the exposure to new emerging infectious diseases of animal origin. This is in line with the principle 'healthy nature for healthy people'.

Forest protected areas are especially important. A large percentage of human emerging infection diseases (EIDs) come from humid forests. Such diseases escape when deforestation or hunting of wild animals brings them into contact with humans. Protected areas, where deforestation and hunting are prevented, can thus help reduce the risk of pandemics, which have enormously costly consequences.

Research has shown that Malagasy animal species include a high diversity of viruses and other potentially zoonotic pathogens that could escape to humans as a result of high levels of ecological disturbance [298] The threat is heightened by the fact that about 90% of Malagasy species rely on forests and natural ecosystems.[299] Potentially dangerous pathogens include *Leptospira* bacteria (found in endemic and introduced Malagasy mammals, causing Weil's disease)[300], and numerous viruses, including coronaviruses which are known from endemic Malagasy bat species (both insectivorous bats and the larger fruit bats) and other mammal species[301], and arboviruses found in insects.[302] Beta coronaviruses, which include Covid-19 and other zoonotic diseases that have been transferred to humans (SARS, MERS, etc.), have been found in Malagasy fruit bats.[303]

In conclusion, the health and nutritional benefits of PAs are difficult to capture in monetary terms but are economically important, particularly for vulnerable communities living near PAs which lack access to health care, markets or technology to maintain good health and nutritional status. Protected areas also have an economic importance for the health of the nation as a whole, helping to control diseases and reduce the risk of zoonotic transfer of new diseases to humans.

Benefits from restoration in and around protected areas

As part of the national reforestation effort, the MEDD has specifically required protected area managers to conduct restoration in and around the protected areas they manage. Restoration around protected areas represents a powerful strategy since the areas restored and monitored and managed by the park manager present and therefore have greater chances of success. They also create local short-term employment and help park managers to build community relations.

According to data available from 2010 to 2019, Madagascar National Parks undertook 9452 ha of restoration, creating 1026 jobs for a total cost of $190,000. For the period 2018-20202 the area under restoration rose to 12601 ha, although the number of jobs created and the cost of restoration has yet to be calculated.[304] **As a rough rule of thumb, restoration around PAs will create one job for every 10**

[295] Myers et al 2011
[296] World Economic Forum global risks report 2020
[297] IUCN 2021
[298] Tortosa in Goodman in press
[299] Goodman & Benstead 2005
[300] Dietrich et al 2021
[301] Hoarao et al 2021
[302] Héraud et al 2021
[303] Razanajatovo et al 2015
[304] MNP, unpublished data

hectares restored. A review of the areas with potential for restoration would allow an estimate of the total number of jobs that could be created by a systematic restoration of the PA network. Recommendations are made at the end of this report.

Biodiversity conservation values – the wider evidence

We have presented above an estimated value of the global benefit of the conservation of the biodiversity in Madagascar's PAs which is based on an assumed willingness to pay of the community of nations. This highlights the major challenge in placing a monetary value of biodiversity conservation. Here we provide a wider review of the evidence.

Biodiversity *per se*, defined as the diversity of ecosystems, species and genes, is a difficult aspect of natural capital to value, and has been described as a *characteristic* of natural capital which affects its value.[305] There is evidence that more diverse ecosystems containing more species provide more valuable ecosystem services, and that genetic diversity can make ecosystems and species more resilient and therefore more valuable. Human society places a very high value on biodiversity, as demonstrated by the global effort to conserve ecosystems and species of Madagascar and other highly biodiverse countries, and the high costs which countries are willing to contemplate spending to ensure its conservation. This contemplated cost formed the basis for our estimate of global economic contribution of Madagascar's protected areas (*supra*).[306]

Biodiversity *per se* can have measurable economic value as a source of bioactive compounds useful in medicine or other purposes. In an evaluation of Madagascar's natural capital in 2010, the World Bank[307] placed a very high capital value of $197 per Malagasy citizen on the bioprospecting values of Madagascar's forests, or about $3.94 billion. Assuming a discount rate of 10%, this would represent an annual value of almost $400 million[308], most (about 71%) of which is held within Madagascar's protected areas network. Given the limited benefit capture from bioprospection to date, this figure has subsequently been criticized as an overestimate[309]. However, Madagascar's biodiversity and its uses do represent an 'inestimable stock of knowledge and possibilities for medical research and biotechnology' and a 'world inheritance' for interested communities.[310] The *risk* associated with *losing* species that may contain valuable bioactive compounds thus remains very great.[311]

Madagascar's status as a biodiversity hotspot has stimulated large international investments which have been estimated at almost $1 billion over the last 30 years. Madagascar is considered to be one of the highest recipients of biodiversity-related aid.[312] While some of these investments are spent outside Madagascar, biodiversity conservation has undeniably become a significant economic sector in Madagascar, creating thousands of jobs in conservation and tourism, as well as in education and research through studentships and research projects, mostly associated with protected areas. The benefit to Madagascar of maintaining its biodiversity commitments was recently illustrated by Madagascar's integration into the BIODEV 2030 program of AFD, IUCN, Expertise France and WWF, which chose Madagascar among 16 countries to pilot participatory approaches which integrate biodiversity conservation into economic activities working with local stakeholders.[313]

[305] Dasgupta 2021
[306] Deutz et al 2021
[307] Ollivier & Giraud 2010
[308] World Bank 2013
[309] Jones et al 2021
[310] Raharinirina 2009
[311] Myers et al 2011
[312] Jones et al 2021
[313] https://www.biodev2030.org/biodev2030/

Madagascar's commitment to the Convention on Biological Diversity (Rio, 1992) and its longstanding adhesion to nature conventions generally (e.g. Africa Convention 1968, Ramsar 1971, CITES 1973, Bonn 1979, Nairobi 1985) has undoubtedly encouraged international investments in biodiversity conservation in Madagascar; thus, compliance with these treaties carries an economic value as well as a reputational benefit within the community of nations. Assuming conservation investments of $1 billion over 30 years from 1990 to 2020, biodiversity conservation in Madagascar has generated benefits on average of **$33.3 million annually** (about 0.23% of GDP in 2019) (or about $35.7 million annually in 2021 dollars).

International reputation and access to international trade and finance
Large scale loss of nature can damage a country's international reputation and result in reduced access to international trade and finance. Following the upsurge of deforestation in Brazil, negotiations of the EU's Mercosur trade deal (with Argentina, Brazil, Paraguay and Uruguay) have been stalled, with the potential loss to Brazil of trade worth $122 billion annually.[314] Whereas Madagascar has attracted investment in the past based on its reputation for nature, recent rises in deforestation and illegal logging (which more than doubled following the 2009 political crisis and are not being dealt with effectively by the government) endanger Madagascar's international reputation and could affect its ability to secure international investment. In 2010, the Antsinanana humid forest World Heritage site was placed on the danger list by UNESCO where it still remained in 2018 despite Madagascar's request to have the site removed from the danger list[315]. Following Madagascar's commitment to halting deforestation at COP26, continued uncontrolled deforestation of Menabe and Ankarafantsika are likely to weaken Madagascar's credibility at COP15 of the CBD in China in 2022 and beyond.

Bioprospection values – the wider evidence
Bioprospection, or the identification of bioactive compounds within plants and animals useful as pharmaceutical compounds, is of potential economic importance. Twenty-five percent of drugs used in modern medicine are derived from rainforest plants while 70% of cancer drugs are natural or synthetic products inspired by nature. In the past 70 years, approximately 75% of approved anti-tumour pharmaceuticals have been non-synthetic, with 49% being wholly natural products or directly derived therefrom. So far, only 15% of an estimated 300,000 plant species in the world have been evaluated to determine their pharmacological potential. Yet, according to some estimates, we are already losing one potential major drug every two years as a result of species extinction[316].

Madagascar has been an important country for bioprospection since the 1950s which has resulted in several patents taken out by the Malagasy Institute of Applied Research (IMRA)[317]. A well-known example of medicinal plant is the Madagascar periwinkle *Cataranthus roseus* which contains compounds used in the treatment of childhood leukaemia, and which has been estimated to generate $100 million annually in recent times, although with no benefit to Madagascar[318]. Bioprospection has been identified as a priority in the national biodiversity strategy[319] but capturing benefits from bioprospection is challenging, and neither laws nor mechanisms for benefit capture are in place.

Only two bioprospection contracts have been negotiated, both of a limited 5-year duration, for the protected areas of Zahamena (1999) and Ranomfana (2005). The major benefit reported for these contracts has been scientific cooperation, with other benefits being very limited and with no

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[314] WEF 2021
[315] https://whc.unesco.org/en/soc/3816/
[316] WEF 2021
[317] Raharinirina 2009
[318] Boisvert 2003
[319] Ministère de l'Environnement 2005

distribution to local communities[320]. Each agreement included a capital investment (Zahamena $200,000 over 5 years, Ranomafana $260,000 over 5 years). Spreading the capital investments over the period since signature gives an annual benefit of about $17,000, although this underestimates the gross expenditures for which data are not available. We have specifically included these contracts in our estimate of national benefits from biodiversity in protected areas (see above). However, it is clear that these bioprospection agreements offer relatively modest benefits from PAs (less than $1/ha/yr).

Reducing risks of extinction

Because of Madagascar's great importance for biodiversity, investments in conservation can yield significant dividends in reducing the risk of extinction of species. IUCN, together with other institutions, has recently developed the STAR (Species Threat Abatement and Restoration) indicator which is designed to provide a measurable outcome from biodiversity extinction investments[321]. Such an indicator will attract investors to countries offering the highest returns on investments in terms of species extinction. Through a functional PA network, Madagascar would be well placed to benefit from such investments, which represents a substantial opportunity value for the country, assuming that it is able to effectively conserve its protected areas.

Documentary films on nature

The production of documentary films on nature is another significant economic activity generated by Madagascar's protected areas, most of which provides enjoyment for television viewers worldwide, but some of which generates value within Madagascar's economy.

The largest single producer of films about Madagascar's natural history is the BBC in the UK, mainly through its well-reputed Natural History Film Unit which is frequently contracted by other organisations. Using UK-based film industry consultants, we conducted a search of databases of natural history films made by the BBC and other entities, identifying 58 films made since 1961, including 34 films made by the BBC or BBC-associated entities and 24 films made by various other producers.[322] While just four films were made between 1960 and 1979, 54 films have been made since 1980 (40 years), or an average of 1.35 films annually.

Film making involves significant expenditure in country. One of the BBC documentaries included a 3-part series on tropical islands, one of which was filmed in Madagascar over a period of 18 months in 2018-2019, at a cost of about $300,000 (£250,000). The film crews spent over 100 days shooting at 9 protected areas and 47% of the budget was spent in country or about $150,000, considered by the BBC personnel consulted to be higher than average for wildlife films, the more typical rate being 25%. [323] Given a film team size of 5 persons (not counting ancillary workers – fixer, drivers, porters and transport costs), each spending 100 days in country, film crew expenditure appears to be $55/day which is closely similar to tourism daily expenditure (also estimated at one third of $165 or $55/day).[324]

In addition to films identified through BBC channels, we identified 8 major films made by NHK, the Japanese television company, which were also high budget productions, making a total of 66 known films since 1980 (1.65 films annually). If one assumes a conservative production cost of $250,000 per film (in today's US$), this represents an investment of about $16.5 million over 40 years, or $412,500 annually of which an estimated 25% or $103,125 will have been spent in-country. Overall, we estimate

[320] Raharinirina 2009
[321] Mair et al 2021
[322] BBC and other sources, unpublished data
[323] BBC, unpublished data and production personnel, pers. comms
[324] World Bank/PIC 2012

that natural history films made in Madagascar's protected areas generate at least $412,500 of investment in the global economy and $103,125 in the national economy every year.

Apart from in country-expenditure, direct benefits in Madagascar from film making appear to be limited. Indeed, data from other countries also appear to confirm that direct revenues from film-making such as fees, are insignificant[325]. Benefits to the global economy, however, are significant. The widespread international broadcasting of the more successful films on national and international TV networks generates significant economic value for the global economy.

Films made in protected areas also generate economic benefits and human well-being globally. Natural history/nature documentary films for television play constantly around the world providing inspiring images of nature and wildlife to millions of television viewers.[326] Such benefits help to promote Madagascar's brand for its unique nature and, while difficult to measure in monetary terms, undoubtedly help to drive Madagascar's nature-based tourism industry and add value to Madagascar's protected area network.

Feature films and animations on Madagascar's nature

Finally, Madagascar's biodiversity has inspired several fictional feature films and animations, most notable of which is the *Madagascar* series of animations produced by Dreamworks. The *Madagascar* franchise films of Dreamworks have generated $2.26 billion in revenues over 15 years, or an average of about $150m annually and have been highly profitable, with a production cost of only $502 million.[327] While such films may contribute little to the economy of Madagascar, such films certainly reinforce Madagascar's unique image and popularity (and thus increase tourism).

Spiritual, intrinsic and moral values of protected areas

Nature and protected areas can be an important source of spiritual fulfilment or religious values which can be considered as benefits to society. In fact, most societies find sacredness in nature or natural sites, such as groves or forests. Societies also see intrinsic worth in nature, and even that nature has moral standing or personality.[328]

The importance of spiritual values of key biodiversity areas and protected areas in Madagascar was confirmed by a national workshop in 2014 which identified protected areas as important for cultural and spiritual identity.[329] Such values are manifested in the many sacred forests and local taboos that have resulted in the conservation of nature, such as the protected areas of the Analavelona sacred forest and Zombitse-Vohibasia national park, both sites which have remained protected for many years as a result of their sacred status for local populations of the Bara culture.[330] While it is difficult or inappropriate to place a monetary value on such benefits, they have indirect economic consequences in human well-being.

The special case of spiritual values

It should be emphasized that *spiritual* values for some, including several traditional communities in Madagascar, are of greater importance than any monetary value. Similar to spiritual values are *existence* values, whereby the international and national public derive enjoyment from Madagascar's nature and protected areas, merely from the *knowledge of their existence*. It is the existence values

[325] World Bank 2021
[326] Fernandez-Bellon & Kane 2019
[327] https://en.wikipedia.org/wiki/Madagascar_(franchise): consulted 14.01.21
[328] Dasgupta 2021
[329] Neugarten et al 2020
[330] Goodman et al 2018

that drive much of the international interest and investment in Madagascar, and its international brand and reputation. In contrast, if Madagascar were to allow its unique nature to be lost, such existence values might turn to sorrow or anger and Madagascar's image and reputation could turn into one of destruction or tragedy and be tarnished indefinitely.

Costs of protected area management

Opportunity costs of protected areas in Madagascar

Conservation interventions originally tended to assume that conservation will inevitably contribute to poverty alleviation at the local scale[331]. However, there is a considerable body of evidence showing that the interests of conservation and local communities do not always align and that conservation can bring significant local costs as well as benefits.[332] Indeed, some of the costs of conservation are born by Madagascar's poorest people[333] and opportunity costs have been estimated to be as much as $100[334] or even $300-1400 per household.[335] Restrictions of access to forest foods can also have significant negative nutritional impacts,[336] leading to suggestions that forest conservation interventions should include investments in promoting alternative sources of nutrition for local populations.[337]

Options for compensating opportunity costs

Many governments recognize the importance of benefit-sharing mechanisms to garner local support for protected areas, but even established mechanisms may fail to deliver benefits for reasons including, but not limited to (i) excessive bureaucratic processes, (ii) poorly designed mechanisms in which benefits do not off-set costs of conservation, are low, or are captured by elites, or (iii) lack of agreement on means of disbursement and recipients.[338] It is also important to note that benefits of living around protected areas accrue collectively, while costs are borne by individual households.[339]

The present study has shown that the economic benefits of protected areas are substantially greater when measured at the global economic scale, than at the national and local scales. This reflects the high value placed by the international community on climate regulation and biodiversity conservation, and the global nature of tourism, whereby about 60% of tourist expenditures, such as airline tickets and agency payments, are captured outside the national economy.

On the other hand, the study shows that the economic contributions generated at the national and local scales can be of similar magnitude. However, from other studies there is also abundant evidence that the economic benefits of protected areas are not equitably distributed at the local level. Numerous attempts have been made to address this gap but with limited success.[340]

One mechanism which has been deployed is the sharing of park admission fees with local communities for the complementation of development projects, or DEAP (*droit d'entrée aux aires protégées*). DEAPs generated as much as $900,000/yr on average from 2003 and 2013, with a peak in 2008 of $1.5 million, of which 50% were designated for local community projects.[341] While DEAPs could be considered a

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331 Freudenberger 2010
332 Jones et al 2021
333 Poudyal et al 2018
334 Brimont 2014
335 World Bank 2013; Ferraro 2002; Hockley & Razafindralambo 2006; Shyamsundar & Kramer 1996 & 1997
336 Borgerson 2020
337 Rasolofoson 2020
338 Spenceley et al 2019 referred to in World Bank 2021
339 Munanura et al 2016 referred to in World Bank 2021
340 Jones et al 2021
341 World Bank 2013

progressive measure at the time, such a system deprives MNP of revenues critical for the management of protected areas. DEAPs also depend on tourist visitors which have dropped to low levels during political crises and to zero since COVID, while community opportunity costs remain the same. The sharing of DEAP revenues is therefore not a stable or sustainable option for compensating opportunity costs.

The highest protected area values we have identified in the present study at the national level of economic sectors include energy ($14.5-43.50/ha/yr), tourism ($38-156/ha/yr), agriculture ($22/ha/yr[342]) and carbon storage (6.5-8.6/ha/yr) (with higher values recorded locally for energy and tourism in some cases). These can be compared for their suitability in compensating for local opportunity costs.

Carbon storage benefits offer long-term potential for the generation of substantial revenues and have the great advantage of applying to forested sites in all regions. While considerable investment will be needed in redistribution mechanisms to enable benefit transfer to forest edge communities helping to protect the forests, there is little need for investment in physical infrastructure to capture benefits, as would be required for energy, agriculture or tourism. However, international carbon markets are volatile and no effective mechanism is yet in place in Madagascar under REDD+ to ensure the sharing of such benefits with local communities in return for forest conservation[343].

An advantage of *agricultural benefits* is that they have application and socioeconomic relevance around most protected areas, but their value is difficult to calculate or attribute, given the multiple services (water, soil erosion, pollination etc.), types of land use and actors involved. Plus, in the case of water for irrigation, significant physical investments in water extraction, containment and canalisation may be needed. The willingness of low-income small-scale farmers to pay for water provision or soil erosion control is limited[344], while agribusiness is insufficiently developed in most regions to serve as a significant source of payments for ecosystem services.

Energy and tourism might therefore seem to offer a better prospect for redistributing benefits to communities at the local level in return for their support to forest conservation. However, while hydroelectric energy producers could theoretically pay land users upstream compensation for maintaining forest cover to reduce energy production costs, the approach has encountered difficulty due to the unwillingness of the state-owned energy company, JIRAMA, to make the necessary payments.[345] There are some indications that private energy producers would be willing to consider supporting forest conservation in upstream catchments, so this avenue should not be abandoned[346] [347].

In normal circumstances, *tourism* might appear a better source of value to compensate opportunity costs, in part because it reflects more accurately the purpose of protected area creation (global biodiversity conservation in response to an international existence value for Madagascar's biodiversity)[348], and the proven willingness of relatively wealthy tourists deriving enjoyment from biodiversity to make contributions to the local community in return for conservation[349]. However,

[342] Considered an underestimate because of the anomalously low purchasing power of the USD in Madagascar in 2003
[343] Brimont et al 2015; Poudyal et al 2018
[344] World Bank 2017 (PADAP document)
[345] Jones et al 2021
[346] NEHO 2019
[347] Tozzi Green 2021
[348] Neugarten et al 2020
[349] Kramer et al 1995

tourism in Madagascar is vulnerable to political and security events and the COVID pandemic has caused a total suspension of all tourism. There is also an apprehension that the risk of further pandemics or greenhouse gas emission limits on international air travel may hinder or prevent full tourism recovery. In any event, other research has shown that compensation mechanisms need to be formalized if community support of protected areas is to be maintained.[350]

In conclusion, the capture and distribution of benefits from protected areas must evolve in the context of national and jurisdictional landscape approaches in which ecosystem-service delivery of protected areas and the distribution of benefits from those services is optimized in response to the national and local context.

Direct cost of maintaining protected areas

The first estimate of protected area management costs was made by Carret & Loyer (2004) for their assessment of the costs and benefits of the protected area network, who calculated an actual cost of $3/ha/yr for the 41 parks managed by MNP. A later study commissioned by the World Bank, following the Durban initiative, projected that costs for maintaining the then SAPM network of 122 protected areas (then covering 7,081,526 ha, including new protected areas), would rise to $42,947,958 or $6.06/ha/yr by 2015.[351] Data from the FAPBM which record the budgeted management costs reported by PA managers in 2020 yield an average figure of $16.32/ha/yr)[352] . Given that the FAPBM figures include investment costs for certain sites as well as recurrent costs and include several small PAs with relatively high management costs per ha, the true recurrent cost is likely to lie somewhere between $6 and $16.32. **For the purposes of this paper, we have assumed an average annual cost of $10/ha/yr or $76 million/yr for the entire network**.

A review of PA management expenditure undertaken for the MEDD in 2020 estimated the distribution of costs between conservation and restoration (22%), sustainable development (32%), improved governance and participation (11%), climate change mitigation (8%) and PA administration (27%).[353] It is important to note that the $10/ha/yr for recurrent costs does not include investment costs, such as in green or grey infrastructure, or transactional investments needed to establish benefit sharing mechanisms (such as REDD+ or payment for ecosystem services schemes). Part of the investment needed to reverse the current trend of biodiversity loss, which has been estimated at 8% of GDP per country[354], will need to be directed to investments to reinforce existing protected areas and their surrounding landscapes. Another recent estimate of the cost of halting biodiversity loss is highly optimistic, suggesting than an additional annual investment of just 0.1% of GDP (which would be about $15 million in Madagascar's case) may be sufficient.[355] However, this is a global average, and probably not representative for high biodiversity developing countries like Madagascar, where the cost of stabilising biodiversity losses would certainly be higher.

According to at least one report, protected area management costs are primarily correlated with PA size, IUCN PA category and tourism development, but not correlated with level of threat or ecosystem type.[356] Analysis of data from FAPBM suggests that the correlation with PA size is not linear. Protected areas become markedly more costly to manage per hectare for sites smaller than about 30000 ha. Conversely, costs per hectare change little for sites more than 100,000 ha. Between these limits, costs

[350] World Bank 2021
[351] Agreco 2012
[352] FAPBM 2021
[353] MEDD 2020
[354] Dasgupta 2021
[355] UN 2021
[356] Agreco 2012

per hectare appear highly variable (Fig 11). The experience of FAPBM also indicates that costs can be affected by level of threat, as evidenced by numerous special intervention funds (FIS) issued to help project area managers address unanticipated threats such as fires, charcoal making, logging, illegal mining or maize farming incursions.

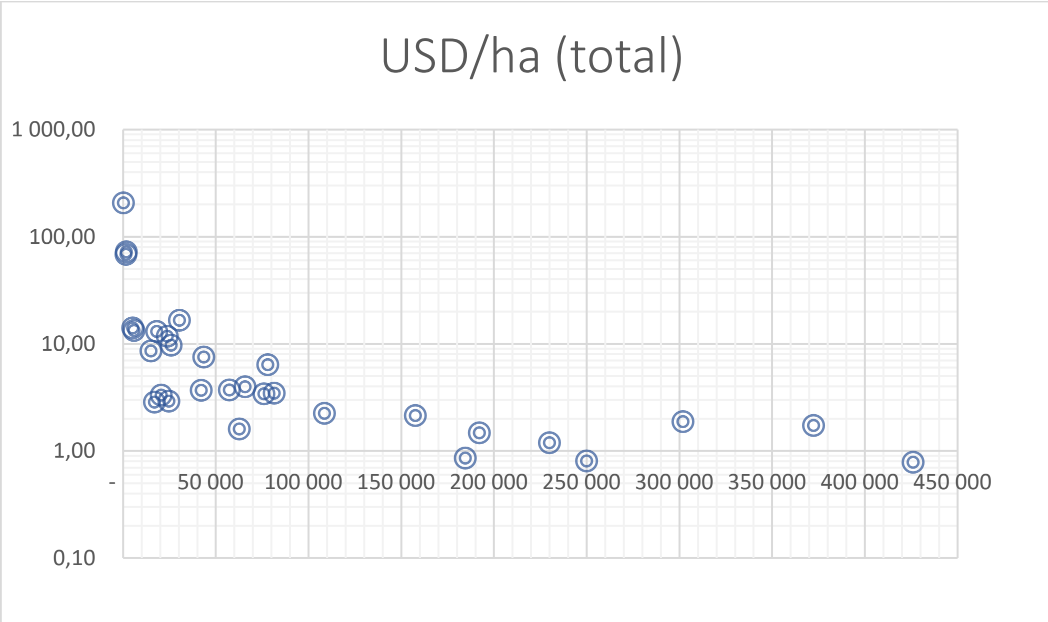

Fig 11 – Management cost per hectare according to protected area size in ha (Source: FAPBM unpublished data) (a logarithmic scale is used on the y-axis to facilitate appreciation of the relationship)

Costs of inaction and degradation

Globally between 1997 and 2011 the world lost an estimated $4-20 trillion per year in ecosystem services owing to land-cover change and $6-11 trillion per year from land degradation[357]. A study by WWF in 2020 estimated that the annual loss from not conserving biodiversity would amount to $US9.87 trillion globally by 2050, or an average annual loss of $330 billion over 30 years).

Countries will also suffer economic losses if they do not meet internationally agreed biodiversity conservation targets. In 2008 the Biodiversity Convention commissioned a first estimate of the annual cost of not meeting biodiversity targets which were estimated to be 7% of GDP.[358] Translated to the Madagascar context this would mean a loss of $778 million/yr in 2021 USD, very similar to the more recent WWF study[359] that estimated the loss of not meeting the biodiversity targets to be 5.56% of GDP (or about $840 million annually). The study was reviewed and reinforced by MIT.[360]

The costs of inaction to Madagascar are considered to be especially high. In its global report on biodiversity risks for six developing countries using data from 2010, WWF estimated that the cost of biodiversity loss to Madagascar would be 4.2% of GDP annually in a 'Business-as-Usual' scenario (or about $400 million annually in 2010 US dollars). Madagascar was assessed as suffering the greatest

[357] Costanza et al 2014
[358] Braat et al 2008
[359] WWF 2020
[360] https://web.mit.edu/12.000/www/m2015/2015/inaction.html

cost in all scenarios, but also had the most to gain from addressing biodiversity loss effectively, such as by maintaining and strengthening its protected areas.[361]

A more recent study by the World Bank, based on data from 2018, estimates that nature loss in Madagascar in a business-as-usual scenario will result in a 19.9% annual loss in GDP by 2030 (or about $3 billion/yr based on GDP for 2019).[362] In particular, nature loss would reduce the production of ecosystem-dependent sectors by 23%, reduce crop production by 33% and reverse GDP growth entirely, making it the most severely affected of all countries studied. The declines in ecosystem-dependent sectors would have knock-on effects on other sectors, causing losses of 55% in manufacturing and 19% in service sectors.[363]

It is sometimes suggested that while the loss of nature may cause losses, the economic benefits of alternative scenarios such as converting remaining forests to agriculture or logging, would be greater. However, the scientific literature has demonstrated that the benefits of conserving nature are almost always greater than the benefits of converting it to other uses.[364] In large part this is because conversion of natural ecosystems is generally irreversible, such that all benefits of an intact ecosystem are lost when it is converted to a non-natural use.

Experience of other countries

During the course of the work, we conducted literature research into the experience of other countries. Such experience helps to understand the potential economic contribution of protected areas in the Madagascar context, and how greater value could be generated from Madagascar's protected area system.

It is important to appreciate that many other countries share similar challenges to Madagascar and have undertaken or facilitated economic valuations of their ecosystems, forests and protected areas, in some cases highlighting the large economic contributions of protected areas. Much useful information about other countries was found in the Dasgupta review[365] and the extensive range of publications which we have considered. Other information was found on official websites or in publications, including peer reviewed publications. We present here a small selection of case studies from four countries - Costa Rica, Rwanda, Uganda and China.[366]

Costa Rica (2014 $)

Cost Rica is a biodiversity 'hyper-hotspot' with 4' of the world's species on just 51,000 km^2 of land surface (Madagascar has 5% but on 595,000 km^2). Costa Rica has 160 protected areas (compared to Madagascar's 126) covering 13%. Forest cover remains very high at 52%. Economically, Costa Rica is a relatively rich country (with a GDP of $61 billion generated by 5 million inhabitants, or $11,700 per capita). Since 1990, Costa Rica has effectively combined protected areas, innovative payments for ecosystem services, and strict enforcement to achieve conservation targets related to biodiversity protection, hydrological services, and carbon sequestration, among others.[367] In 2014, annual expenditure on biodiversity was $250 million (equivalent to $50/ha/year or 0.4% of GDP) which can be compared with Madagascar's current expenditure of about $52-60 million/yr (about 0.4% GNP). Costa

[361] WWF 2020
[362] World Bank 2021b.
[363] World Bank 2021
[364] Bradbury et al 2021.
[365] Dasgupta 2021
[366] **Note:** a case study from a fifth country, Australia, on the Great Barrier Reef marine park, has been included above in the section on marine protected areas.
[367] Whitmee et al 2015

Rica has reported positive impacts to local communities around the entry gates of protected areas[368] but the economic impacts of protected areas *per se* have not been systematically valued.

Rwanda (2019)

Rwanda is one of Africa's smallest countries (26,338 km^2) with the highest population density in Africa. Rwanda has 3 national parks including the Volcanoes Park which is famous for its mountain gorillas. The gorilla parks have been estimated to generate $200 million annually in foreign exchange.[369] In 2019 Rwanda derived a direct income of $19.2 million/year from gorilla tourism alone (through awarding 15,000 permits per year). In Rwanda tourists spend anything between $1000 and $12,000 per person per visit to the country depending on their income level and choice of products. Apart from the gorillas, about 50,000 visitors visit the Akagera 'Park 'or the 'big 5' large mammals. Overall, Rwanda generates on average $1250/ha/year from all its three parks from tourism.

Rwanda has also undertaken economic evaluation of its green growth strategy includes investment in reforestation around protected. Despite successful economic growth and poverty reduction (from 59 to 38%), Rwanda suffered large declines in the value of key ecosystem services (erosion mitigation, climate change mitigation and water provisioning services) in the period 1990-2015. To address this, Rwanda embarked on a green growth strategy with a focus on forestry and agriculture sectors. The economic outcomes of different land-use scenarios were evaluated, including the plantation of forests (mainly around its national parks), promotion of fuel-efficient stoves, increased irrigation, fertiliser use and combinations of these. The report showed that expanded forest cover (in Rwanda's case around national parks) has the potential to mitigate impacts of increased water consumption as well as enhancing erosion mitigation and nutrient uptake, important for green growth.[370]

Uganda (2004)

Uganda has historically taken a strong economic interest in its diverse forests. In 2003, Uganda conducted an economic evaluation of its forests and their ecosystem services, whose value at the time was estimated at $317 million per year or 5.2% of GDP (which for 2002 was about $6 billion). The total area of forests was 4.9 million hectares, corresponding to a value of about **$65/ha/year** (Table 14) in 2003 dollars. The authors consider the value to be an **underestimation** due to underreporting of livelihood benefits and underestimation of watershed values.

The relatively high value of erosion protection (45%) and the relatively low value for biodiversity option values are particularly noteworthy. The high value of erosion prevention was derived from the important benefits of forests in providing water for agriculture, and conversely the high negative impacts of deforestation on agriculture as a result of soil loss and sedimentation. The low value of the biodiversity option value arose from the limited evidence for the economic benefits of medicinal plants or bioprospection. Uganda's tourism economy is little developed, and values for nature-based tourism in forests or protected areas were therefore not considered in the study.[371]

Table 14 – Uganda's forests – relative ecosystem service values (Source: Bush et al 2004)

Hydrological protection	27%
Carbon storage	25%
Biodiversity (option value, e.g. plants)	**3%**

[368] Robelino & Villalobos 2015
[369] Maekawa et al 2003
[370] Bannerjee et al 2019
[371] Bush et al 2004

Soil conservation (erosion prevention)	**45%**
TOTAL	100%

China (2020)

Following a series of natural disasters in the 1990s culminating in flooding of the Yangste due to deforestation, killing 3600 people and flooding 5 million ha costing $36 bn, China introduced the 'ecological civilisation' into its constitution and invested in Payment for Ecosystem Service (PES) schemes. By 2012, working mainly through rural households, the country had invested $66 bn (at current exchange rates) in reducing soil erosion, reforestation of 30 million hectares and reducing flood risk, sequestering carbon, and reducing soil erosion and flood risk. For a country of 9.6 million km^2, this represents an investment of $68.75/ha (for the entire investment period of >10 years). (Madagascar's investment over a similar period was $450-500 million or $7.5 - $8.3/ha).[372]

As part of this process, China developed an environmental accounting process known as 'Gross Ecosystem Product' (GEP) allowing it to measure the economic benefits of environmental restoration and conservation. To pilot the GEP process, China used one of its largest (but also one of its poorest and least populated and rural) provinces Qinghai (at 720,000km^2, a slightly greater area than Madagascar but with a population of only about 6 million).

From 2000 to 2010, ecosystem assessments were undertaken throughout Qinghai which measured the state of health of ecosystems and the provision of ecosystem services from those ecosystems. Using satellite images, soil & hydrological measurement and thousands of field surveys, the province was able to measure an overall improvement in ecosystem service provision over the 10-year period, from between 5% and 40% depending on the ecosystem service (although it should be noted that in the same period, the availability of habitat for biodiversity declined by just under 5%, highlighting the need to include measures such as protected areas to maintain habitats important for biodiversity).[373]

The Qinghai province then used economic valuation methods such as avoided cost, direct cost, tourism expenditure and market pricing to measure the change in monetary value of ecosystem services over an extended period of 2000-2015. Ecosystem services considered included provisioning services (agriculture, livestock, fisheries, forestry, nursery production), regulating services (soil retention, sandstorm prevention, flood mitigation, air & water purification and carbon storage) and cultural services (ecotourism). Through these techniques it was demonstrated that the restoration and conservation measures implemented had resulted more than a doubling (127%) in ecosystem service values in Qinghai province between 2000 and 2015, and that Qinghai's ecosystem service values were valued at $13 billion/yr ($180/ha/yr) or more than three times Qinghai's GDP of $4.2 billion for 2015.[374] Water ecosystem services accounted for about 60% of all services, highlighting the high value of water services (which protected areas are especially good for as we have seen for Madagascar).

DISCUSSION

The evidence assembled confirms the valuable economic contributions of Madagascar's protected area network to the global, national and local economies.

[372] World Bank 2013
[373] Ouyang et al 2016
[374] Ouyang et al 2020

The evidence suggests that global economic contribution of Madagascar's PA network greatly exceeds (by as much as 25-50 times) the benefits that are captured at the national level. The evidence for the value of global benefits is mostly indirect and depends on extrapolation from high level international studies on the global impacts of climate change and biodiversity loss, or assumptions about international willingness to pay for climate action and biodiversity conservation. COP26 did not result in any clear recognition of the value of protected areas or of the scale of commitment towards their financing. The global quantum of willingness to pay for protected areas and their perceived value should become clearer as the Global Biodiversity Framework (GBF) is developed and adopted at CBD COP15. What is clear, however, is that the benefits of protected areas go way beyond the level of financing provided by governments and NGOs and that new sources of finance are needed.

At national level, certain economic contributions are more precisely measurable, particularly for tourism, energy and for the international finance that Madagascar receives for biodiversity and forest conservation. However, economic data on the direct benefits of ecosystem services from PAs for the national economy, especially for agriculture and fisheries, are limited and allow only a partial estimation of the benefits. While there is evidence for significant health and well-being benefits of protected areas, economic data are lacking to allow their evaluation in monetary terms. Thus, the values estimated for terrestrial PAs should be regarded as conservative. For marine protected areas, available data are limited to baseline fisheries assessments, global tourism data and visitor data for a single MPA (Tanikely) and the evaluation of benefits can be considered only as a first approximation. Even so, when this incomplete set of national economic contributions is summated, the national benefits substantially outweigh the costs of managing the protected area network by a factor of several times, supporting the prima facie case that maintaining the protected areas network provides a substantial net national economic benefit for Madagascar.

Drilling down further to the local level, through the case studies, we find that the local economic contributions from protected areas can be substantial, approaching or sometimes even exceeding those measurable based on available data at national level (when measured in $US/ha/yr). Local PA values are also diverse and show a very high variance. In particular, the measurable benefits of PAs perceived by local farmers for agriculture, soil erosion control, water supply or non-timber forests products tend to be small compared to sector-level benefits (such as from tourism or hydro-electric energy) and to be of a similar order of magnitude to, or even less than, the *opportunity costs* experienced by local communities whose access to natural resources in the PA is restricted or excluded. This confirms the findings of many previous studies that the costs and benefits of PAs must be redistributed to ensure the full support of local communities to conservation. Even so, the gross economic benefits of PAs at the local level can be substantially greater than the management costs, indicating that with effective redistribution, there is a strong economic case at the local level for maintaining protected areas.

We were able to assemble a robust set of data on the costs of managing protected areas. Long assumed to be about $3/ha/yr, from studies by the World Bank in 2003 (based on the network as it was before the Durban Initiative), a substantial study commissioned by the World Bank in 2012, which took account of the full range of PA costs, doubled the estimate to over $6/ha/yr. Complemented by studies on MPAs and data on real management costs experienced by MNP and FAPBM (which range from $6 to $16/ha/yr), we have estimated the average PA management cost at $10/ha/yr for all PAs (terrestrial and marine). While the management costs are considerably higher than had often been assumed, the ratio of economic benefit to management cost of protected areas remains robust at all levels – global (96-118:1), national (3.0-4.7:1 for terrestrial only, rising to 5.8-7.5 when MPAs are included) and local (an impressive 8.7-11.3:1).

The evidence points to the existence of a range of important socio-economic benefits of PAs which are not readily measurable in monetary terms but which are substantial. Of particular importance are the health benefits, with strong scientific evidence for reduced child mortality, better child health and reduced stunting in children living around protected areas, based on work by Malagasy and international scientists. There is also a growing body of evidence linking deforestation to outbreaks of plague and malaria and dengue fever in humans, and of livestock diseases. Continued ecological disturbance of protected areas will add to these risks. Also of great importance is Madagascar's international reputation as a country which harbours extraordinary nature. The experience of Brazil shows that national environmental reputation can be rapidly damaged by anti-environmental leadership and result in the loss of access to international finance for development and trade. Madagascar's reputation for nature conservation is strongly reinforced by natural history films which are broadcast around the world. While such films undoubtedly encourage ecotourism, the effect is difficult to quantify economically.

Even though it may appear somewhat trivial, animations such as the *Madagascar* series by Dreamworks, in part based on the biodiversity found in PAs, help to build Madagascar's reputation for unique nature in the minds of millions of young people around the world. Finally, numerous protected areas contain sacred sites of local importance for spiritual values, upon which one should never place a monetary value but which contribute to local well-being. Similarly, the Malagasy urban middle class increasingly gains benefits in well-being from Madagascar's protected areas, likely to become a growing trend.

In undertaking this study, we have amassed evidence on the distribution of economic benefits from Madagascar's protected areas. The report confirms, as has so often been maintained by Malagasy decision makers and other stakeholders, that the world enjoys substantially greater benefits from Madagascar's protected areas than Madagascar itself. While the incremental transformation and summation of economic value is the feature of any value chain, the evidence suggests a remarkable disparity of as much as 25-50 fold between the value of Madagascar's forests and biodiversity to the world and the benefits captured within Madagascar's economy. Capture of benefits from maintaining forest cover, in particular through REDD+, is minimal compared with the global benefit provided.

While conservation NGOs were originally conceived for the purpose of mobilising the civilian willingness of rich countries to pay for global conservation, as a complement to support provided by governments and international agencies, experience shows that NGOs and their supporters can only account for a small percentage of the resources needed for the conservation of PAs. This highlights not only the critical importance of increased support from the international community but also the engagement of the private sector in protected area finance.

At the national and local levels the disparities are less marked. Indeed, well positioned and well managed protected areas, such as Ranomafana, can generate substantial benefits to the local economy, but it can take decades for benefit capture and redistribution mechanisms to develop sufficiently to incentivise local communities to conserve the forest. Where protected areas are directly engaged in ecosystem service provision, such as wetlands where natural productivities are high, large local economic benefits can be provided, highlighting that ecosystem service provision can be a vital and valuable economic role for PAs to play where it is compatible with biodiversity conservation.

While the evidence for the positive gross economic contributions of protected areas may appear almost overwhelming, the evidence also shows that on the local scale, opportunity costs to local communities may be high or even severe, amounting in some cases to the entire household monetary income in the case of terrestrial PAs or, in the case of protected mangroves in MPAs, more than the total value of mangrove fisheries upon which the community depends. All this points to the critical need for a management focus on ecosystem service delivery (where compatible with biodiversity conservation) and much greater emphasis on effective benefit redistribution.

Finally, based on a limited review of experience from other countries (Costa Rica, Rwanda, Uganda and China) the evidence demonstrates that Madagascar compares quite favourably in the economic contribution of its protected areas, but that it compares unfavourably with other countries in the level of expenditure on biodiversity conservation and protected areas. Rwanda's experience suggests that Madagascar could do more to generate revenues from tourism from its PAs, while Costa Rica's suggests that other economic benefits from PAs may be sufficient without tourism revenues to justify supporting an extensive PAs network. Uganda's experience highlights the very high value of erosion protection for agriculture, suggesting more should be done to demonstrate the biophysical linkages between PAs and agriculture in Madagascar. China's experience highlights the great advantage of taking an ecosystem services approach, suggesting that Madagascar's PAs need to develop ecosystem service provision and monitoring, especially of hydrological services, as a key management function.

CONCLUSION

Madagascar's protected areas network makes substantial economic contributions globally, nationally and locally, through the provision of a range of ecosystem services. At the global level, the benefit to the global community appears many times greater than the economic benefits Madagascar is currently able to capture through international conservation finance, NGOs, private investment or through the 'ecosystem dividend' from the services that PAs provide in support of the national economy. Nationally, it is evident that PAs already make significant economic contributions which exceed management costs by a factor of several times but these contributions vary greatly between PAs. Such contributions could be increased with better PA management, benefit capture and reinforcing management orientation towards ecosystem service maintenance and delivery in addition to biodiversity conservation. Locally, the case studies have shown that local economic benefits from PAs are highly variable, but that where PAs are well positioned, or contain productive ecosystems, or are popular for tourism, the benefits can easily outweigh the costs of management by many times. With appropriate redistribution of benefits, working in partnership with other actors in the local landscape, such PAs should be self-sustaining. In conclusion, Madagascar should adopt a 3-level PA policy focusing on 1) better advocacy to secure additional finance at the international level, 2) optimisation of the PA network for ecosystem service support to the economy at national level and 3) context specific management strategies at the level of each PA and surrounding landscape to optimise ecosystem service delivery and benefit distribution to secure the support of local communities for biodiversity conservation.

RECOMMENDATIONS

International action and response

The study has generated recommendations requiring international action or response by Madagascar:

- In global forums Madagascar must advocate for an increased international contribution to its protected areas system which is proportionate to the global benefits that Madagascar's PA network delivers.

- In particular, Madagascar needs to leverage increasing amounts of international private and blended finance through the high returns that Madagascar can offer in extinction risk reduction using the new STAR indicator.
- To justify the requests for increased international support, the Government must demonstrate its commitment by reinforcing the management and extent of its PA network, giving priority to conserving forests and halting deforestation.
- Madagascar also needs to promote innovative financing mechanisms and diversify funding sources for its protected areas to increase the resilience of its PA network and encourage investments in the network.
- Madagascar should actively prepare a reinforced updated strategy for its protected areas system for presentation at the next conference of the parties of the Biodiversity Convention (CBP COP15) together with an associated National Biodiversity Finance Plan (NBFP).
- Madagascar needs to make renewed efforts to develop realistic policies and mechanisms for the effective capture of benefits from bioprospection, especially in its protected areas.
- The price of carbon per ton of $5/tCO2eq used for the purposes of the REDD+ programme is insufficient and must be increased very substantially if REDD+ is to make a significant contribution to forest conservation in Madagascar.
- Following the global COVID19 crisis, Madagascar must respond by more strongly promoting its unique ecotourism product internationally while also adopting policies and strategies to encourage national and residential nature-based tourism based on its protected areas.

Management of the PA network

The study has generated numerous recommendations relating to the objectives and strategies for the management of the PA network and individual protected areas:

At the national level, Madagascar should maintain, improve and extend its protected areas network in order to maximize biodiversity conservation and the delivery of ecosystem services by PAs in ways that support the national economy. In addition:

- Protected Area Management policy should be explicitly framed around biodiversity conservation and the provision of ecosystem services including the development of value chains providing economic benefit to affected communities
- The network and its constituent protected areas should be progressively optimised and expanded to deliver greater benefits through ecosystem services while ensuring the conservation of Madagascar's unique and threatened biodiversity.
- The delivery and monitoring of ecosystem services with appropriate economic indicators should become an integral component of the management of all protected areas, including New Protected Areas. Local communities and households must be encouraged to participate actively in ecosystem service delivery.
- Based on the data gathered, there should be an annual or periodic review of the economic contributions of Madagascar's protected areas as well as lessons learned to ensure progressive optimisation of benefit generation and capture by the PA network.
- Ecosystem Service identification, optimisation and benefit distribution should be integrated into the standard management plan (PAG) and safeguard plan (PSSE) templates for PAs and as a complement to the annual evaluation tool (METT)
- Protected area managers in collaboration with national and local authorities must proactively explore ways in which the economic benefits of PAs are more equitably distributed between

national and local levels with a view to eliminating, reducing or compensating for the opportunity costs of PAs at the level of local households.

- Mechanisms adapted to the local context should be developed for each protected area to optimise the capture of benefits by the protected area and the redistribution of those benefits to incentivise local community support for the protected area.
- Protected areas should be fully integrated into national, regional and communal sustainable development plans within a landscape approach while ensuring the establishment and maintenance of effective mechanisms for the equitable distribution of benefits from PAs.
- Protected area management plans must encourage the promotion of improved human health and nutrition (especially for children) and health monitoring in communities and households around the protected area.
- Restoration programmes around protected areas must be actively promoted as a means of creating local employment while at the same time helping to increase the climate regulation and biodiversity conservation impacts of PAs.

Research

The study has identified numerous ways in which scientific research could contribute to the improved generation and distribution of benefits from Madagascar's PAs:

- A coordinated research effort is required to fill important information gaps on the ecosystem services and economic contributions of protected areas by development sector (especially for agriculture, hydrological services and other key sectors for which data are lacking).
- A coordinated research effort is needed to determine the impacts of management and finance on the benefits generated by PAs and on the dynamic distributional analysis of the costs and benefits of protected area management.
- A specific research programme is needed to evaluate the costs and benefits of marine protected areas (MPAs), including the constituent ecosystems of MPAs (coral reefs, mangroves, seagrass meadows) and key services (fisheries, tourism, carbon storage).
- Research should be encouraged on the evaluation of the direct and indirect economic benefits of biodiversity *per se*, and the means for capturing greater benefits from this unique resource conserved within Madagascar's PAs (e.g. through research, entertainment and other less tangible uses).

Other technical actions

In addition to the main recommendations above, the study has identified various technical actions that would further contribute to reinforcing and extending Madagascar's PA networks and the benefits it delivers:

- Undertake a technical review of Madagascar's PA network in relation to ecosystem services and identify optimal adjustments to maximise ecosystem service delivery.
- Include consideration of protected areas in the template for Communal Development Plans (PCD), Regional Development plans (PRD) and SRATs.
- Undertake a study of the contribution of PAs to research in Madagascar and the value of investments in research both inside and outside Madagascar.
- Develop a more spatially precise data base for the PA network including ecosystems and ecosystem services which should be regularly updated.
- Madagascar should develop capacity and strategy for engaging and securing the support of international businesses deriving value from Madagascar's biodiversity and PAs.

- Studies are needed to determine how the Madagascar private sector could become more effectively engaged in protected area support and finance.

The above recommendations complement and resonate strongly with those identified by the series of MEDD workshops on PAs In 2020.[375]

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[375] MEDD 2020

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Scientific Committee

The authors are deeply indebted to the *ad hoc* scientific committee established for the purposes of the present study. The committee was composed of eight national and international experts with particular expertise relevant to the themes of the present study and included:

<u>National experts</u>

- Professor Bruno Razafimamonjy, Director of ESSA, University of Antananarivo (Environmental Economist)
- Professor Aristide Andrianarimisa, Faculty of Science, Department of Animal Biology, University of Antananarivo (Landscape Ecologist)
- Mr. Rinah Razafindrabe, Director of BPSAPM (National Protected Areas System), MEDD
- Mr. Serge Ratsirahonana (Monitoring & Evaluation Officer, FAPBM, Madagascar) (Protected Area monitoring and finance specialist)

<u>International experts</u>

- Dr Neal Hockley, University of Bangor, UK (Environmental economics and policy)
- Dr Ranaivo Rasolofoson, Cornell University (Protected Areas and human well-being specialist)
- Dr Frank Hawkins, IUCN (Biodiversity conservation and finance specialist)
- Mr Erik Reed, World Bank (Madagascar) (Natural Resources Management Specialist)

The committee met a total of four times over the duration of the work. Prior to each meeting, members were provided with copies of the current draft report, notes of the previous meeting (in the case of meetings 2, 3 and 4) and a list of key questions raised by the authors. Committee members provided general comments on the report and methodology, as well as specific comments in their respective areas of expertise. Their comments and recommendations were systematically taken into consideration in successive drafts of the report, including the final version.

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ANNEXES

Methodological details

Value transfer method

The first approximation of the economic value of Madagascar's Protected Areas is based on the value transfer method. Value Transfer involves adapting existing economic valuation information to new contexts where valuation data are absent or limited. We searched the literature for valuation studies on similar ecosystems to those represented in Madagascar and its protected areas. We selected the most appropriate values based on our knowledge of the Madagascar context, an approach known as expert modified value transfer.

Following a literature review, we identified three major international studies as offering the most comprehensive repertoire of values for application in Madagascar. These were:

Costanza, R. et al 1997. The value of the world's ecosystem services and natural capital. Nature. 387, 253-260 (1997) – this is the landmark reference on global ecosystem service values and includes values for both terrestrial and marine ecosystems. Terrestrial values include forests (all types, tropical), rangelands, wetlands, freshwater lakes/rivers) while marine ecosystem service values include shelf seas, coral reefs, mangroves, and seagrasss beds, all of which are represented in Madagascar's protected areas. Values are given in 1997 USD.

De Groot R et al 2012. Global estimate of the value of ecosystems and their services in monetary units. Ecosystem Services 1 (2012) 50-61 – this paper, building on extensive research since Costanza et al 1997, gives an overview of the value of ecosystem services from 10 major biomes based on a review of over 320 publications at 300 different locations worldwide. The data were uploaded into an ecosystem service database, the largest of its kind, and used to generate the estimated values in the paper. Ecosystem service values covered include most of the marine and terrestrial ecosystems represented in Madagascar's protected areas, including open oceans, coral reefs, coastal systems, coastal wetlands (including mangroves), inland wetlands, rivers and lakes, tropical forest, woodlands and grasslands. The study also includes a comprehensive range of provisioning, regulating, habitat and cultural services including all those that have been recognized for Madagascar's protected areas. Most useful for the present study, the paper gives minimum and maximum values for all such ecosystem allowing use as a precaution to select the lower range values for Madagascar in order to reduce the likelihood of over-valuation. Service values are given in standard international (dollars from 2007 or $USInt) for ease of comparison. Finally, the publication analyses the reasons for high variations and high values for certain ecosystem services and provides caveats useful for guiding the selection of values in the present study.

Costanza et al 2014. Changes in the global value of ecosystem services. Global Environmental Change. 2014, May. 26: 152-158 – this third key paper revisits the ecosystem service values estimated in 1997, taking account of the learning in De Groot et al 2012 and responding to feedback on the earlier papers. Using standardized 2007 dollars, the authors estimate that global ecosystem service values increased from $46 trillion in 1995 to $125 trillion in 2011 (177%), emphasizing that the value of ecosystem services per hectare increases with both economic growth built on ecosystem services, and rarefaction due to loss or degradation of ecosystems. The authors also highlight that between 1997 and 2011, degradation of ecosystems resulted in a loss of $4.3 and $20.2 trillion in value, or up to 16% in lost value. This underlines that Madagascar's ecosystems become increasingly valuable with time and that degradation of ecosystems causes major economic losses. Like De Groot et al 2012, the paper confirmed the exceptionally high values for certain ecosystems which occur in Madagascar's protected areas, including wetlands and coastal wetlands (that latter including mangroves, coastal systems and coral reefs). Adopting the same caveats as in De Groot et al 2012, we selected appropriate ecosystem service values for the present study.

We also considered a unique study conducted in Madagascar on the value of the ecosystem services of the Makira-Masoala landscape:

Masozera, M, 2008. Assessing the value of ecosystem services of the Makira-Masoala landscape, Madagascar. Antananarivo: Wildlife Conservation Society. May 2008 – this paper is an example of applying the value transfer method to a protected area of Madagascar, Masoala National Park (240,000 ha) and Makira National Park (372,400 ha) within the broader Masoala-Makira landscape (900,000 ha), using the value transfer method accompanied by conjoint analysis, a technique using questionnaires to measure stakeholder preference for ecosystem services, to corroborate the comparative values of ecosystem values estimated using value transfer. The author considers 10 different ecosystem services relevant to this part of Madagascar – climate regulation & carbon sequestration, disturbance regulation (e.g. buffering floods and cyclones), water regulation, water supply, waste assimilation/treatment, pollination, biological diversity, habitat refugium (for wildlife), erosion control and recreation (e.g. tourism). The author used a spatially explicit value transfer approach using available published ecosystem service values and a land use land cover map of the landscape. To identify the most comparable ecosystem service values, the author focused on tropical forests in tropical developing countries and non-consumptive uses, and found 77 applicable values from 64 different studies, and converted them into standard 2007 $US corrected for Purchasing-Power-Parity (PPP). Values selected ranged from $150/ha/yr for cropland to $5326/ha/yr for tropical forests. The author highlights the gaps in available data for all ecosystem types and considers that the ecosystem service values are conservative, and that the true value of services from the landscape is likely to be much higher.

Transferred value estimates following Costanza et al

We first tabulated the ecosystem monetary values provided by Costanza et al (1997 and 2014) and DeGroot et al 2012 of relevance to Madagascar, taking the closest equivalent where the precise equivalent was not covered by the authors (Table 15).

As highlighted by the authors[376], it is important to understand that expressing the value of ecosystems in monetary terms does not imply a precise market value. Rather, their value in monetary terms is an estimate of their *benefits to society* and, importantly for protected areas, *the value that would be lost to future generations if the ecosystems were to be destroyed*.

Table 15 – Global ES values as reported by Constanza et al (1997 and 2014) & DeGroot et al (2012)

Ecosystem	Value $/ha/yr in 1995 (Int$US of 2007)	Value $/ha/yr in 2011 (Int$US of 2007)	Expert selected values ($/ha/yr)[377]
ALL			
Terrestrial (all combined)	1109	4901	4901
Coastal marine (all combined)	5593	8944	8944
TERRESTRIAL			
Forest (all types)	1338	3800	3800
Tropical forest	2769	5382	5264 (mean value)
Grass/rangelands	321	4166	2871 (mean value)
Wetlands (inland)	20404	140174*	25,982 (mean value)
Lakes / rivers	11727	12512	4267 (mean value)
MARINE			
Shelf seas	2222	2222	No equivalent
Coral reefs	8384	352,249*	36,794 (minimum value)
Mangroves	13786	193,843*	12,163 (median value coastal wetlands)
Seagrass beds	26,226	28,916	No equivalent

[376] De Groot et al 2012
[377] De Groot et al 2012

***Note** – the exceptionally high values reported for wetlands, coral reefs and mangroves reflect the values that can be generated in highly developed countries in exceptional circumstances where multiple benefits are captured sustainably from these ecosystems. For the purposes of this paper we used the minimum or mean values reported by DeGroot et al (2012) who provide information on the range of values reported, including mean, median, minimum and maximum reported values.

We present below a summary table of calculated economic values of ecosystem services from Madagascar's entire PA network, based on selected published values for terrestrial ecosystems (all types) and marine ecosystems (full table in Annex).

Table 16 – Total ES values for Madagascar's PA network (based on terrestrial, wetland and marine ecosystems) (combined and summated ES values and average $ value/ha)

Ecosystem value types	1997 values (2007 $)	2011 values (2007 $)	Expert selected values (using conservative values for reef, mangrove & wetland)
Combined ecosystem service values (terrestrial and marine) based on • Terrestrial (non-wetland): 4518135 ha • Wetland: 1137345 ha • Marine coastal: 1426406 ha	**$36 billion/yr** *($5111/ha/yr)*	**$194 billion/yr** *($27,441 ha/yr)*	**$64 billion** *($9101/ha/yr)*
Ecosystem service values individually summated (terrestrial and marine) (same areas)	**$37 billion/yr** *($5179/ha/yr)*	$ **206 billion/yr** *($29,022/ha/yr)*	**$29.7 billion** *($4184/ha/yr)*

The first approximation suggested that Madagascar's PA network could provide ecosystem services worth as much as **$36 - $64 billion** annually, or an average of **$5081 -$9074/ha/yr**.

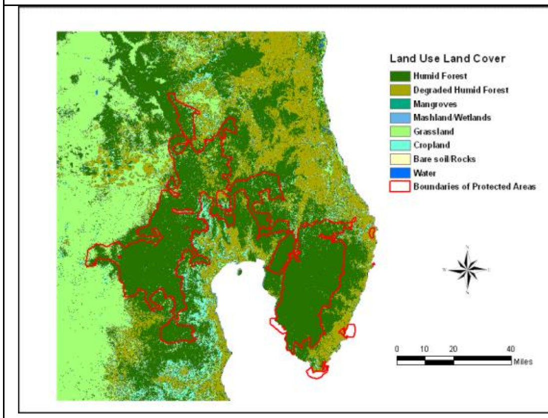
Masoala-Makira Landscape evaluation in 2008

As corroboration of this estimation, we present the results of a study in 2008[378] of the Masoala-Makira landscape in northeast Madagascar (Fig 12), which used similar methods. The study was performed after Costanza et al (1997) but before publication of De Groot et al (2012) and Costanza et al (2014) and was based on ecosystem service values that had been published in the interim.

The Masoala-Makira landscape is dominated by two protected areas (Masoala 210,000 ha), Makira 371,000 ha) within a wider landscape of about 900,000 ha. Land cover data were available for about 65% of the landscape (581,679 ha).

[378] Masozera 2008

Land use cover map (Masoala-Makira)	Land cover types (Masoala-Makira)



Land Cover Types

Existing land cover classes	New land cover classes
Water	Water
Bare soil/Rocks	Bare soil/Rocks
Cultivated areas	Cultivated areas
Wooded grassland/bushland mosaic Grassland/wooded grassland mosaic	Grassland
Eastern humid forest Eastern littoral forest Western dry forest-thicket South western dry spiny forest	Primary Forest
Degraded eastern forest humid forest	Degraded forest
Marshland/ wetland	Marshland/Wetlands
Mangroves	Mangroves

Fig 12 – Map and table of land use cover in the Masoala-Makira landscape (Source: Masozera 2008)

Based on a review of the available literature for similar ecosystems, the author estimated the value of ecosystem services provided by the types of land cover for which area data were available (Table 17).

Table 17 – Ecosystem service values of the Masoala-Makira landscape (Source: Masozera 2008).

		Ecosystem Services (2007 US\$ ha^{-1} yr^{-1})										
Land Cover	**Area (ha)**	**Climate Regulation**	**Disturbance Regulation**	**Water Regulation**	**Water Supply**	**Erosion control and sediment retention**	**Waste Treatment**	**Pollination**	**Biodiversity (Genetic materials)**	**Habitat/Refugia**	**Aesthetic & Recreation**	**Total ESV flow (\$/yr)**
Humid forest	535,504.0	3,220.00	12	6	6	122	115	315	1,286	5	239	\$5,326
Degraded humid forest	23,402.5	1,220.00										\$1,220
Marshlands/ Wetland	111.62	430.00	**559**	4	54	5	347		**258**	**242**	**592**	\$2,491
Grasslands	3,916.0	290.00		4		41	**122**	**35**			16	\$508
Croplands	10,599.3	130.00						**20**				\$150
Bare soil/Rocks	3,102.1											-
Water	5,043.48											-
Total	581,679	6,520	1,758	14	60	433	8,045	370	1,577	365	1,102	\$9,695

Notes:

1. Row and column totals are in hectare \$ yr^{-1} i.e. Column totals (\$/yr) are the sum of the products of the per hectare services in the table and the area of each land cover type, not the sum of the per hectare services themselves.
2. Open cells indicate lack of available information.

The most valuable ecosystem was identified as humid forest, at \$5326/ha/yr. (This is in line with the value of \$5382 reported globally for 2011[379]). On this basis, the study valued ecosystem services from the landscape at **\$2.88 billion annually** across 581,679 ha, or **\$4959/ha/yr** (Table 18).

[379] DeGroot et al 2012

Table 18 – Total value of ecosystem services in Masoala-Makira landscape (source Masozera 2008)

Land cover type	Area (ha)	Average $ value/ha/yr	Total ESV Flow (x10^6 $US/year)
Humid forest	535,504.0	$5,326	$2,852.09
Degraded humid forest	23,402.5	$1,220	$28.55
Marshlands/Wetland	111.6	$2,491	$0.28
Grasslands	3,916.0	$508	$1.99
Croplands	10,599.3	$150	$1.59
Bare soil/Rocks	3,102.1		-
Water	10,339.25		-
Total	586,975		$2,884.50

Applying the rate of $4959/ha/yr to all eastern humid forests in the PA network (2,341,412 ha), would value **humid forest protected areas in the PA network at $ 11.61 billion/yr** (all values are in 2007 standard dollars).

It is important to note that 60% of the service value for all ecosystems, including forest, relate to climate regulation (carbon storage), and that the assumed price of carbon was $10/tC, double the rate currently assumed for the national REDD+ programme of $5/tC. Even so, this highlights the great importance of this global ecosystem service and which Madagascar should aim to capture as effectively as possible via the REDD+ mechanism. Setting aside climate regulation, the residual ecosystem service value for humid forest is **$2975.4/ha/yr,** which is similar to the values reported for 1995 by Costanza et al (1997) and the minimum, median or mean values reported by De Groot et al (2012). On this basis, **the national economic contribution of all humid forests in the PA network would be an estimated minimum of $6.96 billion/yr**.

Economic sector valuation

Tourism

The concept of tourism economic value is developed on the basis of the tourist product: it is the price of exchange of products between tourists and the tourism industry that creates the economic value of tourism. Daily tourism spending based on a key study[380] is therefore used to assess the economic contribution of tourism activity to the national economy. However, limiting the valuation to tourism spending, from an economic point of view, tends to limit the scope of analysis to transactions between tourists and the tourism industry. While the transaction appears to be a relevant argument for measuring tourism economic contribution, there are other circumstances where tourism value is created. Indeed, the exercise of tourism activity requires the use of infrastructure, especially public infrastructure, whose value does not appear, at least in the first approach, in transactions between tourists and the tourism industry.

Ecotourism

The benefits are estimated from the value added per visitor of the PAs whose basis for calculation is the average daily expenditure per visitor, the percentage of park visitors among the number of tourism

[380] FTHM Conseils 2012

and the average length of stay. For this purpose, data from the FTHM Conseils study in 2012 and tourism statistics (Ministry of Tourism, 2020) are selected and compiled.

Agriculture

Method for assessing the economic value of PAs for agriculture

The approach is to measure the benefits of the protected area in preventing soil degradation and hydrological services. The specific steps were as follows:

- Using GIS software, we took the digital land use map (ONE, 2015), cross-referenced it with the data of Neugarten et al (2015) and superimposed the data onto the SAPM protected areas network map in order to determine the areas of land within proximity of protected areas by land use type (i)
- The net benefits per hectare of land (irrigated and non-irrigated agricultural land) were estimated using the same economic modelling developed by the World Bank to assess the impacts of the Ministry of Agriculture's PADAP project[381] (ii).[382]
- We then multiplied (i) by (ii) to estimate the economic benefit provided by the protected area
- We also estimated the creation of agricultural employment using the PADAP method: total number of farmers of 14,74 million in 2010, average population growth rate of 2.8%/year, 8 hours of work/day for 6 months/year

Key assumptions:

- That protected areas have a beneficial influence on agriculture within a radius of 10km of the protected area boundary based on an assumption used by FAO[383]
- That all agricultural production in the delimited area can be attributed to the soil erosion control and hydrological services of the protected area
- That all agricultural employment in the zone of influence of 10 km can also be attributed to the PA

Landscape economic contribution

Ankarafantsika ES valuation method

The Ankarafantsika national park is situated upstream from the Marovoay plain, Madagascar's second largest rice granary.[384] The park edges are subject to significant soil erosion, as a result of the actions carried out communities surrounding the national park. Fires caused by them for agriculture or grazing, and their unrelenting need for energy wood and timber, lead to the degradation of the forest, which plays an important role in protecting the soil from erosion.

A study carried out by the Laboratory for Applied Research in Forestry, Development and Environment (LRAFDE)[385] has shown that loss of soil in the sub-watershed leads to increased sedimentation of the

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[382] World Bank 2017
[383] FAO 2014
[384] MEEMF 2015
[385] Laboratoire de Recherches Appliquées (LRA) en foresterie, développement et environnement, Département des Eaux et Forêts, Ecole Supérieure des Sciences Agronomiques (ESSA-Forêts), ibid

Marovoay plain and thus a loss of rice growing area. We measured the value of the hydrological protection provided protected area as the lost yield that would be avoided by effective protection.

Two scenarios were considered:

Scenario 1: Ankarafantsika National Park is better protected over a 30-year horizon – i.e. there is effective restriction on access to the National Park.

Scenario 2: access restrictions to the park are not well respected over a 30-year period. In this scenario, only ineffective protection is provided.

In relation to these two scenarios, the following aspects should be highlighted:

Scenario 1 is accompanied by the conservation of a larger forest area compared to Scenario 2.

- the amounts of soil loss in the watershed due to erosion are not the same for these 2 scenarios. For scenario 1, where there is greater vegetation cover in the watershed, the loss of soil is reduced. For Scenario 2, there is less vegetation cover, so erosion is greater.
- the amounts of sediment deposited downstream, i.e. in the Marovoay Plain, are also different for the two scenarios: in scenario 1 the amount of sediment deposited is less than that in scenario 2.
    - the deposited sediments translate into non-cultivable land, with production losses due to the reduction of cultivable land
    - The difference between production losses under the two scenarios is considered to be a benefit conferred by the national park, which is called the value of the watershed protection service by the national park.

Application of data to the scenarios

The reference year used was 2019, in which the area sedimented due to erosion was 1450.16 ha.

For scenario 1, the proposed forest area was more than 154,285 ha. Under this scenario, the sediment release from Ankarafantsika NP to the Marovoay Plain in 2030 was compared with the volume of sediment released in 2019 which was 15,046,160.3 m3, bringing the sedimented surface in 2030 to 1822.31 ha.

For scenario 2, forest degradation over the entire area is increased by 79,945 ha, spread within the national park. Under this scenario, the sediment release from Ankarafantsika NP to the Marovoay Plain in 2030 rises by about 20% to 19,645,442.73 m3, increasing the sedimented area in 2030 to 2353.33ha.

Based on this data, our calculation focuses on the net present value of the losses avoided by the protection of the park, using the following parameters:

- Price of paddy rice in 2019: 900 ariary/kg.
- Annual yield of rice paddy: 2t/ha.
- Inflation rate from 2016 to 2019 published by INSTAT: 7.3683%[386]

Discount rate

[386] www.instat.mg

The principle of discounting is to express future or past values as present values.

The current value of an asset that will be worth *V* in a year's time is:

$$\frac{V}{(1+r)^n}$$

In which *r* is the discount rate expressed in %

In the calculation *r* was assumed to be equal to the rate of inflation and the time horizon was taken as 11 years (year 2030).

Assuming *r* to be constant over the 30 years, the formula obtained is:

Sedimented surface in 2030 = Sedimented surface 2019 * (1 + rate of evolution) * 11

Rate if change = $\sqrt[11]{\frac{surface\ sedimented}{surface\ sedimented\ 2019}}$-1

Surface sédimented for the year n = surface sedimented in 2019 * (1+ rate of change) ^{n}

- *Annual rice price change*

We assume that the price of rice changes annually in accordance with the rate of inflation.

Price of rice during the year n = price of rice in 2019* (1+ rate of inflation)^n

- *Value of the loss in Ariary*

The value of the ariary loss in year n is given by the following formula:

Value of loss in year n in ariary = price per kilo of rice in year n in ariary × yield per ha in kg × sedimented area in year n in ha

- *Discounted loss*

Applying the discount principle, the discounted loss in year n is given by the following formula:

$$\frac{loss\ during\ the\ year\ n}{(1+discount\ rate)^n}$$

- *Discounted net loss from 2019 to 2030*

This is the sum of the losses discounted from 2019 to 2030.

$$\sum_{n=0}^{11}\frac{loss\ for\ the\ year\ n}{(1+discount\ rate)^n}$$

As stated *above, the* value of the benefit of protecting the national park against erosion is therefore the difference between the discounted net loss of scenario 1 and that of scenario 2. This is the loss avoided in rice production downstream thanks to the protection of the park. It should always be remembered that scenario 1 corresponds to a situation where the National Park is better protected through the existence and respect of the rules of restriction of access to the park. Scenario 2 is a situation where there are no restrictions on access to the park. In this scenario, no protection action is taken.

Thus, the value of the loss avoided through the park's watershed protection function is obtained through the following formula:

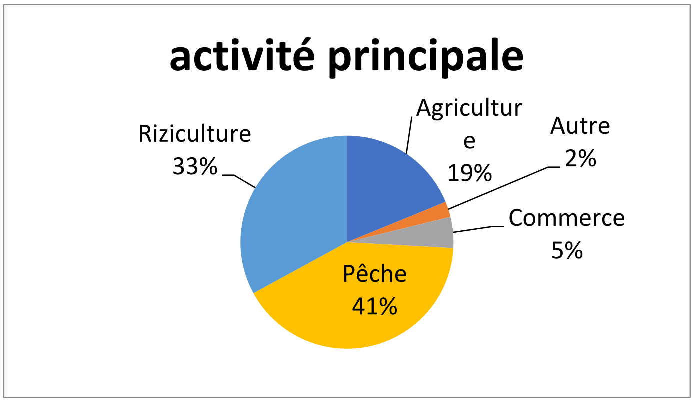
Benefit of protecting the national park from erosion =

Scenario 1 discounted net loss - scenario's discounted net loss2

Detailed calculations by site

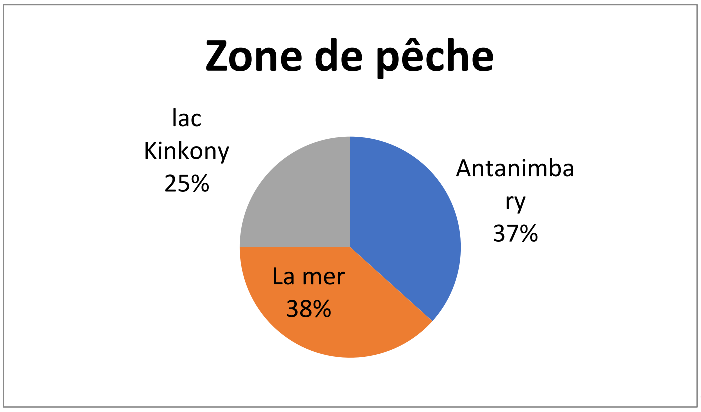
Complexe Mahavavy-Kinkony (CMK)

In the Mahavavy-Kinkony complex, fishing remains the main activity of the area with 41% followed by rice cultivation with 33%.



Source: socio-economic survey C3ED-M, 2018

Agriculture brings together the small crops of "Bahibo" which is generally intended for self-consumption, hence the low value of the average income per year. For fishing, 38% of fishing is done in the sea and 62% on lakes and water reservoirs in the protected area. So lakes and reservoirs are major sources of fish supply services.

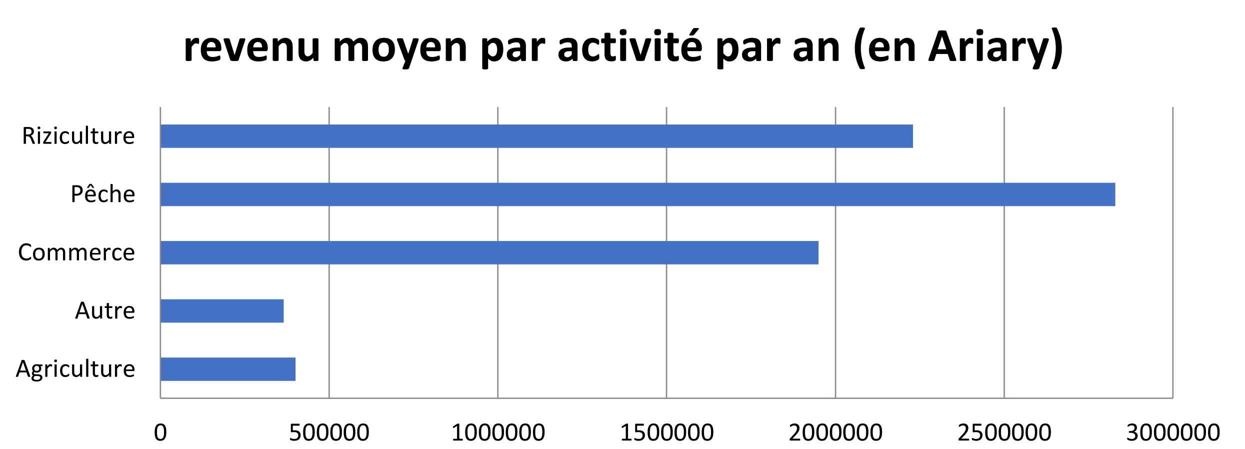


[387]

Source: socio-economic survey C3ED-M, 2018

[387] Antanimbary refers to the water bodies scattered throughout the landscape

The average income per activity within the Mahavavy-Kinkony complex is included in this graphic representation:



	Agriculture	Autre	Commerce	Pêche	Riziculture
Total	400000	365000	1950000	2829677,419	2229910,714
In USD /yr	103,89	94,80	506,49	735	579,19

Value of wooded areas

For tree-lined areas, the calculation is based on **the use value of the forest** and the **ecosystem-based supply services of each** ecosystem. Given the lack of data, the direct use value alone could be assessed. For the forest, the economic benefits of forest conservation and management have been assessed.

Charcoal resource

While charcoal production is commonly a source of threat to protected areas, its high economic value can be turned to advantage in protected areas where space and environmental conditions are favourable for charcoal plantations, For CMK there are, according to the management plan, two sites for the production of non-forest tree charcoal. In Bemaratoly with a total area of 780ha with a volume of wood of 210m3/ha and in Masiakakoho, the exploitable resource is 1041 ha, with 57.6 m^3/ha with an average of 1 m^3 weighs about 175kg to 280kg.

It is therefore possible to determine the charcoal production potential of the Mahavavy-Kinkony complex:

	Area in ha (PAG data)	Quantity by volume (calculated)	Quantity in tonnes (calculated)	
			Lower value	Upper value
Bemaratoly	780	163 800	28 665	45 864
Masiakakoho	1041	59961,6	10 493,28	16 789,25

It is then possible to determine the value relative to charcoal production within CMK:

	Average market price in ariary (survey C3ED-M)	Quantity in tonnes (calculated)		Value in ariary (calculated)	
		Lower value	Upper value	Lower value	Upper value
Bemaratoly	350 000ariary/tonne	28 665	45 864	10 032 750 000	16 052 400 000
Masiakakoho		10 493,28	16 789,25	3 672 648 000	5 876 236 800

	Value in ariary		Value in USD		Value per hectare in USD (extrapolated based on park area)	
	Lower value	Upper value	Lower value	Upper value	Lower value	Upper value
Bemaratoly	10 032 750 000	16 052 400 000	**2 675 400**	**4 280 640**	8,84 $/ha	14,15 $/ha
Masiakakoho	3 672 648 000	5 876 236 800	**979 373**	**1 566 996**	3,23 $/ha	5,18 $/ha

Source: C3ED- M / IOGA/ DBEV surveys 2018

Other provisioning services

For other forest provisioning services **for CMK,** the following table summarizes the services and evaluation methods that are affected.

Ecosystem services provisioning	Method of evaluation	Physical indicator	Estimate quantity (Data of IOGA/DBEV)	prix moyen sur le marché en Ariary	Unités	valeur en Ariary	en dollars $	Valeur par hectare en USD (ramenée à la surface de l'AP)

Honey (forest)	Market price	litre	20000	12 000	Ariary/litre	240 000 000	64000	0,21
Lambo (bush pig)	Market price	kg	9 677	10 200	Ariary/kg	98 702 400	26320,64	0,09
Raphia (donnée du PAG)	Market price	kg	40 147	2 900	Ariary/kg	116 426 300	31047,01	0,10
Satrana	Market price	Unité de feuille	169 081 082	21,42	Ariary/feuille	3 621 716 774	965791,14	3,19
						4 076 845 474	**1 087 158,8**	**3,59$/ha**

Source: our calculations based on the C3ED-M / IOGA/ DBEV surveys 2018

For other provisioning services in **Antrema**, the following table summarizes the services and valuation methods affected:

Provisioning service	**Evaluation method**	**Physical indicator**	**Estimated quantity (Data IOGA/DBEV)**	**Average market price in Ariary**	**Units**	**Value in Ariary**	**Value in $US**	**Value in $US/ha**
Honey (forest)	Market price	Litres	200	12 000	Ariary/litre	2 400 000	640	0,03
Lambo (bush pig)	Market price	kg	117,65	10 200	Ariary/kg	1 200 000,0	320	0,02
Raphia	Market price	kg	488,10	2 900	Ariary/kg	1 415 482,9	377,46	0,02
Satrana	Market price	No. of panels	2 055 647,06	21,42	Ariary/panel	44 031 960,0	11741,86	0,57
						49 047 442,9	13079,32	0,63

Source: our calculations based on the C3ED-M / IOGA/ DBEV surveys 2018

Mangrove CMK

As for the forest, the mangrove assessment was based on the supply of goods, including fish, crabs, shrimp and timber.
The value of these supply services was determined from the quantities of resources harvested and the prices observed on the market.
Value of mangroves CMK

		Technique	Method	UML	Quantity (Date of IOGA/DBEV)	Market price (in Ariary)	Estimated value in Ariary	Value in USD	Value per hectare in USD (extrapolated to surface area)
Use value through provisioning services	Honey (mangrove)	Real market	Market price	Litres	10000	12000	120 000 000	32 000	0,11
	Wood	Real market	Market price	Cut trunks	1 911 070	1900	3 631 032 240	968 275	3,20
	Shrimp	Real market	Market price	kg	1 000 560	20000	20 011 200 000	5 336 320	17,65
	Crab	Real market	Market price	kg	1 558 600	3400	5 299 238 640	1 413 130	4,67
	Fish	Real market	Market price	kg	2 419 536	7000	16 936 752 000	4 516 467	14,94
								12 266 193	**40,46**

Source: our calculations based on the C3ED-M / IOGA/ DBEV surveys 2018

Lake and freshwater reservoir

In calculating the value of the resources contained in freshwater lakes and reservoirs, the approach is to evaluate the supply of goods (fish) through the market price. Based on the survey conducted by the C3ED-M in 2018, we have the following estimates:

Estimated quantity captured/yr

	Quantity of fish (all species) from the lakes and reservoirs in tonnes / yr
CMK	2736
Antrema	33

Source: C3ED-M / IOGA/ DBEV surveys 2018

Values of provisioning services of lakes and reservoirs

	Average price per kg all species (in Ariary)	Quantity captured all species in tonnes / yr	Value in ariary	Value in US dollars ($2018)	**Value per hectare in USD (extrapolated to full PA area in ha) (in $2018)**
CMK	7000	2736 (2736000 Kg)	19 152 000 000	5107200	16,89
Antrema		33 (33000kg)	231 000 000	61600	2,99

Source: our calculations based on the C3ED-M / IOGA/ DBEV surveys 2018

Value of mangroves for the Bio-cultural site of Antrema

		Technique	**Method**	**UML**	**Quantity (Date of IOGA/DBEV)**	**Market price (in Ar)**	**Estimated value in ariary (socio-economic survey C3ED_M 2018)**	**Value in $US**	**Value per hectare in USD (extrapolated to full protected area)**
	Honey (mangrove)	Real market	Market price	litre	155,292	12000	1863504	496,93	**0,02**
Provisioning service use value by resource	Wood	Real market	Market price	Cut tree	29661	1900	56355900	15028,24	**0,73**
	Shrimp	Real market	Market price	kg	15529,2	20000	310584000	82822,40	**4,02**
	Crab	Real market	Market price	kg	24190,2	3400	82246680	21932,45	**1,06**
	Fish	Real market	Market price	kg	37759,2	7000	264314400	70483,84	**3,42**
								190 763,86	9,25

Source: our calculations based on the C3ED-M / IOGA/ DBEV surveys 2018

Ranomafana economic values

Theme	Data used	Sources	Calculation	Value	Comment
ECOTOURISM **1st method - revenues for park manager for a year** **(entry fee, guides, other activities)**	Park entry fees (DEAP) = **1 188 569 000 Ar** Guide fees = **13 218 000 ar** Other activities Green Class = **8 890 200 Ar** Ecoshop = **1 240 500 ar** Kianja Maitso= **350 000 Ar** Research = **400 000 ar** Concession = **450 000 Ar**	MNP, Ranomafana annual ecotourism report 2019	Sum of all these revenues	**1 198 659 200 Ariary** **(311 340 USD)** **$ 7,48 / ha en $2019**	The calculation does not take into account the revenues generated for hotels and restaurants
ECOTOURISM **2nd method (PN, guides and hôtels)**	Overall, a foreign tourist generates *USD 75* to the MNP, guides and hotels (Serpantié et al., 2009, p.13)	Serpantié et al 2009	Assuming that the contribution of each foreign tourist expressed in USD does not change (the increase in prices in Ariary cancels out with the depreciation of the Ariary against the USD): The estimated contribution of 21,605 foreign visitors from	**1 620 375 USD** **$38.95/ha/year with foreign visitors of 2019**	The calculation takes into account only foreign visitors

Theme	Data used	Sources	Calculation	Value	Comment
	Number of foreign visitors (adults + children) in the park in 2019: 21 605 visitors	MNP, Annual ecotourism report Ranomafana 2019	Ranomafana National Park to the NPM, guides and hotels is USD 1,620,375 (21,605 visitors E. * USD 75 / E. visitors)		
HYDROELECTRICITY 1st method Based on the price of electricity	Installed capacity 18,7 MW (BOULOGNE, 2016, p.67)	BOULOGNE 2016	(assuming 100% utilisation) Conversion to power in energy: 18.7 MW= 18700 kW Annual energy = 18700 kW* 24h * 365 days =163 812 000 KWH Baed on household prices only The value is: = 163 812 000 KWH* 451.11ar = 73 897 231 320 ariary	73 897 231 320 ariary **19 194 086 USD** **$461.38 / ha/yr**	
	average electricity price in Madagascar: Household = 451.11 ar/ KWH Business = 443.9/ Kwh	https://fr.globalpetrolprices.com/Madagascar/electricity_prices/			

Theme	Data used	Sources	Calculation	Value	Comment
HYDROELECTRICITY 2nd method (Substitution cost method)	Installed capacity 18,7 MW	Boulogne (2016 p.67)	- Conversion of power into énergy: 18.7 MW= 18700 kW - Energie annuelle = 18700 kW* 24h * 365 jours =163 812 000 KWH - Theoretical quantity of diesel necessary for the annual production: =163 812 000 KWH / 11.4 Kwh/l = 14 369 473 litre Valeur = 14 369 473 litre* 3400 ariary **(Saving in diesel)**	48 856 210 526 Ar **12 689 924 USD** **$ 305 /ha /an** **Saving in diesel fuel needed in thermal production equivalent**	
	Price of 1l diesel : (01 March 2021) 3400 ariary	https://fr.globalpetrolprices.com/Madagascar/diesel_prices/			
	Conversion of 1L diesel in energy for thermal station 1L of diesel liberated 11.4 Kwh	https://forums.futura-sciences.com/chimie/237859-energie-liberee-1-litre-dessence-combien-de-kwh.html			
DRINKING WATER	Quantity if drinking water 42 705 m3:	Word bank, 2011,	- 1 can of 20 liters is worth 30 Ariary therefore 1 m3 is worth 1 500 Ar to users - With the assumption that the 42,705 m3 are fully consumed, this is worth: 42705*1500 = **64 057 500 Ariary**	**64 057 500 Ariary** **16 638 USD** **$ 0,40 / ha /yr**	
	Pricing on hydrants 1 can of 20 litres is worth 30 to 50 Ariary	Information at local level			

Theme	Data used	Sources	Calculation	Value	Comment
SEQUESTRATION CARBON	Carbon T price: 5 USD (over 5 years) That is 1 USD/year	Agreement Forest Carbon Partnership Fund / Atiala Atsinanana Programme signed with the Malagasy Government on 04/02/2021 covering 10 million T of CO2 and giving entitlement to USD 50 million over 5 years (2020 to 2024) https://bnc-redd.mg/fr/11-actualites-nationales/90-madagascar-signe-le-premier-programme-redd-atiala-atsinanana-avec-le-fcpf	Superior hypothesis of CO2 captured by a tropical forest: 220 t / ha and 1 USD / year for 1 T of carbon The sequestration of 9,152,000 tonnes (220 T * 41,601 ha) by the national park is potentially worth 45 760 000 USD over 5 years With a lower CO2 hypothesis captured by a tropical forest of 148 t/ha and 1 USD/year for 1 T of carbon, the sequestration of 6 156 800 tonnes (148 T * 41601ha) par le parc national vaut by the national park 30 784 000 USD over 5 years	Upper hypothesis : **45 760 000 USD in 5 yrs** **$ 220 / ha/yr** Lower estimate : **30 784 000 USD over 5 yrs** **$ 148 / ha/ yr**	
	Carbon T price: 5 € (5,675 USD) in 2017	https://energiesdev.fr/prix-carbone-co2			
	Upper limit of CO2 stored by tropical forest: 220 t / ha Lower limit of CO2 stored by a tropical forest: 148 t/ha	Cornelis et al 2004, Hockley & Razafindralambo 2006.			
WATERSHED PROTECTION	1350 ha of local rice fields protected by the park (Serpantié et al., 2009, p.10) The willingness to pay (WTP) of rice farmers to benefit from protection of their rice field against floods: $5/ha cultivated/year (Serpantié et al., 2009, p.9)	Serpantié et al 2009	5$ *1350 ha	**6 750 USD / yr** **$ 0,16 /ha/yr**	

Andasibe-Mantadia

Theme	Data mobilised	Sources	Calculation	Value	Comment
ECOTOURISM (Revenue entrance fee, guiding, other activities)	Park entry fees DEAP= 753 520 500 Ar	MNP, Annual Ecotourism Report PNAM 2019	Sum of all revenues	**792 928 500 Ariary** **205 955 USD/ yr** **$ 13,30 / ha /yr**	The calculation does not take into account the revenues generated for hotels and restaurants
	Guiding fees = 9 549 000 Ar	MNP, Annual Ecotourism Report PNAM 2019			
	Other activities				
	Camping fees = 2 500 000 Ar	MNP, Annual Ecotourism Report PNAM 2019			
	Green classes = 4 382 000 Ar	MNP, Annual Ecotourism Report PNAM 2019			
	Ecoshop= 22 977 000 Ar	MNP, Annual Ecotourism Report PNAM 2019			

Ankarafantsika

1. For scenario 1

Annual rate of change of the sedimented surface = 2%

Yield per ha: 2000 kg/ha

Inflation rate = discount rate = 7.37%

The following table shows the steps for calculating the discounted net loss (Table 19)

Table 19: The steps for calculating the discounted net loss in Scenario 1

Year	Surface sedimented (ha)	Price of rice/kg (ariary)	Value of annual sediment loss (in ariary)	Value of annual loss discounted
0	1450.16	900	2610288000	2610288000
1	1480.59	966.31	2861430892	2665061189
2	1511.66	1037.52	3136736924	2720983715
3	1543.38	1113.96	3438530896	2778079697
4	1575.76	1196.04	3769361285	2836373756
5	1608.83	1284.17	4132021764	2895891034
6	1642.59	1378.79	4529574792	2956657197
7	1677.05	1480.39	4965377475	3018698452
8	1712.25	1589.47	5443109917	3082041554
9	1748.17	1706.58	5966806294	3146713822
10	1784.86	1832.33	6540888921	3212743145
11	1822.31	1967.34	7170205595	3280158000

Source: Our calculation

The scenario 1 present net loss value is **35,203,689,560 ariary**

Thus, if the Ankarafantsika National Park is better protected, the annual rate of evolution of the sedimented surface is only 2%. These increases in sedimented area imply reductions in the area of cultivable land and therefore cause annual production losses. The present value of these losses for 11 years starting in 2019 is therefore 35,203,689,560 ariary.

1) For the scenario 2

The annual rate of change of the sedimented surface = 4%

Yield per ha: 2000 kg/ha

Inflation rate = discount rate = 7.37%

The following table shows the steps for calculating the discounted net loss (Table 20).

Table 20: Steps for calculating the discounted net loss in scenario 2

Year	Surface sedimented (ha)	Price per kg of rice (ariary)	Value of annual sediment loss (en ariary)	Value of annual loss discounted
0	1450.16	900	2610288000	2610288000
1	1515.4133	966.31	2928732302	2727743945
2	1583.60283	1037.52	3286025488	2850485092
3	1654.8607	1113.96	3686906959	2978749261
4	1729.32498	1196.04	4136694306	3112784973
5	1807.13996	1284.17	4641353842	3252851931
6	1888.4564	1378.79	5207579747	3399221526
7	1973.43187	1480.39	5842882863	3552177360
8	2062.231	1589.47	6555690322	3712015795
9	2155.02585	1706.58	7355457332	3879046530
10	2251.99622	1832.33	8252792599	4053593200
11	2353.33	1967.34	9259599043	4235994000

Source: Authors' own calculation

The scenario 1 present net loss value is **40,364,951,613 ariary**

In the event that the national park is poorly protected, the sedimented surfaces increase at a rate of 4% per year, which is 2 times more important than that in scenario 1. The reduction in the area under arable land is therefore also greater. It is clear that the value of production losses due to the phenomenon of erosion is higher here than in scenario 1. The present value of these losses for 11 years from 2019 therefore amounts to 40,364,951,613 ariary.

1. The discounted net benefit of protecting the national park from erosion

As already mentioned earlier, the value of the loss avoided thanks to the protection of the National Park corresponds to the difference between the values of the discounted production losses of the 2scenarios. More specifically, it is the value of the losses in scenario 1 minus those e scenario2:

Loss of production avoided = net loss discounted scenario 2 - net loss discounted scenario 1

= 40 364 951 613 - 35 203 689 560

= 5 161 262 053 ariary

= 1,340,587.55 USD or 9.82 USD/ha (related to the surface of the Ankarafantsika PN[388])

Thus, the protection of the park, in particular the restriction of access and the application of actions favourable to its maintenance, brings a benefit of USD 9.82/ha or USD 1 340 588 in terms of protection of the Marovoay plain.

Protected areas provide significant services that support the lives of humanity. Their protection could be justified by quantifying the economic value of these services.

[388] 1 USD= 3850 ARIARY

This part of the study showed only a small part of the value of the services provided by the Ankarafantsika PN. In addition to protection against erosion, so many other services are also provided by this park among others e.g. carbon sequestration, ecotourism, water regulation. Even at the level of protection against erosion, only the effect on rice cultivation is taken into account. The LRA document indicates that only 14.85% of the losses in the land concerned are deposited in the Marovoay plain while 87.5% are dumped in the Betsiboka river and reach the sea. For this purpose, the value of the benefit of the erosion protection service by the park calculated here is still underestimated. In other words, the damage caused by these sediments dumped elsewhere is still unquantified. This would undoubtedly increase the value of the benefit in question.

Detailed calculations – all contributions (images of master spreadsheet)

Sheet 1 – Global contributions

THE ECONOMIC CONTRIBUTION OF MADAGASCAR'S PROTECTED AREAS - A REVIEW OF THE EVIDENCE - Final version printing 280522
ANNEXES - DETAILED CALCULATIONS (MASTER CALCULATION SHEET)

KEY VALUES & codes

												% PA in Atiala			
GDP	**14192000000**	GDP in 2019	**Humid forests total**	6235720,00		**2003 Protected Areas**	1102949,00	PASCARRET	**PAs in Atiala REDD+**	1021644,00	ATIALAPAS	0,16	**Case study PA areas**		**Other Pas and landscapes**
Carbon Price	**5**	CARBONPRICE	**Humid forests in Pas**	3 172 849,36	HUMIDPAS2	**Top 15 PAS for tourism**	1113981,00	TOPPAS	**Ratio KBAs/PAs**	**0,71**			Ankarafantsika	136513,00	Makira-Masoalalandscape
									SCC (Lower)						
									SCC Median (in 201	171,00	WWF 2020				
Terrestrial Pas	**6 233 317,29**	TPA	**Dry forests total**	3603712,16	DRYTOTAL	**All KBAs**	10730900	ALLKBAS	**SCC (Upper)**				Ranomafana	40556,00	Atiala-Antsinanana
Wetlands in Pas	**119 678,60**	WET	**Dry forests in PAs**	2130175,51	DRYPAS	**Top 15 PAs visits in 2019**	227431	PAVISITS	**Tourism daily spend**				CMK	302400,00	
Mangroves in Pas	**73071,99**	MANG	**Spiny forests**	1465011	SPINYALL	**Number of PAs**	126	NOPAS					Antrema	20620,00	
Reefs in Pas	**107 131,00**	REEF	**Spinyforests in PAs**	873347,4	SPINYPAS	**Number of KBAs**	240	NOKBAS					Makira South	74494,00	
Marine Pas all	**1 379 029,00**	MPA	**MPAs WCS2017**	822000	MPASWCS	**Biodiversity in PAs %**	0,71	BIOINPA	Neugarten et al 2020; calculation PA/KBA as a percentage				Andasibe/Mantadia	16368,00	
ALL Pas	**7612346,286**	ALLPAS	**All terrestrial forest in P**	3389324,40	ALLTERFORPAS	**Forests in PAs%**	45,44558606								

Note: MPA is defined as all marine habitats within Pas, not just Pas classed as MPAs
Note: All Pas is defined as all area covered by protection irrespective of habitat type

PROTECTED AREA VALUES FINAL CALCULATION SHEETS - GLOBAL NATIONAL LOCAL

Benefit level	ES category	ES type	ES	Site category	Site subcategory	Specific sites/cases	Method	Year $	$Value in study	GDP deflator	Value 2021$	Ha of ES	Value/ha/yr	Other unit value	Share of GDP	Key assumptions e.g rates, values, prices	Key References	Network cost	Benefit cost ratio	Remarks
GLOBAL VALUE DELIVERY BY PAS	**GLOBAL**	**GLOBAL**	**GLOBAL**	**GLOBAL**	**GLOBAL**	**GLOBAL**	**GLOBAL**	**GLOBAL**	**GLOBAL**	**GLOBAL**	**GLOBAL**	**GLOBAL**		**GLOBAL**		**GLOBAL**	**GLOBAL**		**(selected values)**	
CLIMATE REGULATION																				
	Regulatory	Climate regulation	Carbon storage	Terrestrial Pas	All humid forests in PAs	All humid forests in PAs	REDD+ & SCC	2019	1273000201	1,0833	1379041118,09	2341412,10	588,98	171,00		Assume $171 SCC WWF 2020	IEFN1 2000; SAPM 2017; WWF 2020;LOFM/BNCCREDD+, 2021			
		Climate regulation	Carbon storage	Terrestrial Pas	Dry forests	All dry forests in PAs	REDD+ & SCC	2019	267306412	1,0833	289573035,91	2 130 175,51	123,67	171,00		Assume $171 SCC WWF 2020	IEFN1 2000;LOFM/BNCCREDD+, 2021;SAPM 2017; WWF 2020			
		Climate regulation	Carbon storage	Terrestrial Pas	Spiny forests	All spiny forests in PAs	REDD+ & SCC	2019	60881800	1,0833	65953253,85	873347,40	28,17	171,00		Assumes $171 SCC WWF 2020	REDD+ Strategy; LOFM/BNCCREDD+, 2021;WWF 2020			
		Climate regulation	Carbon storage	Marine PAs	Mangroves	All mangroves in PAs	REDD+ & SCC	2019	15832416	1,0833	17151256,55	73071,99	7,33	171,00		Assumes $171 SCC WWF 2020	REDD+ Strategy; LOFM/BNCCREDD+, 2021;WWF 2020			
		Climate regulation	Carbon storage	Terrestrial Pas	Humid E forests	Makira-Masoala Landscape	Value transfer	2007	549075968	1,1028	605520977,51	553504,00	1984,00	10,00		NOT USED - Assumes carbon price of $10/t	Masozera 2008			
		Climate regulation	Carbon storage	Marine	Mangroves	All mangroves in PAs	Blue Ventures	2016	292287960	1,0673	311958939,71	73071,99	4000,00	7,20		Carbon price $7,2/tCO2eq; 1% growth, discount 13.5%; $4000/ha	Blue Ventures, unpublished data; Zeng et al 2021; mangrove area BNCCREDD+			
		Climate regulation	Carbon storage	Terrestrial Pas	All PA forests exc mangroves		SCC	2019	1731758943	1,0833	1876014463,21	5344935,01	350,99	54,00		Social cost of carbon - used min value of $54 (Wang et al 2019)				
		Climate regulation	Carbon storage	Terrestrial Pas	All PA forests exc mangroves		SCC	2019	5483903320	1,08	5940712466,84	5344935,01	1111,47	171,00		Social cost of carbon used WWF value of $171 (WWF 2020)				
		Climate regulation	Carbon storage	Terrestrial Pas	All PA forests exc mangroves		SCC	2018	13373027395	1,07	14327861551,02	5344935,01	2680,64	417,00		Social cost of carbon/ used $417 (Ricke et al 2018)				
Global clmate min									**2024046903**		**2187973403**	**7612346,29**	**287,42**	83,21		Percentage of total value				
Global climate med							Subtotal		**5776191280**		**6252671407**	7612346,29	**821,39**	170,15		Percentage of total value				
Global climate max							Subtotal		**13665315355**		**14639820491**	7612346,29	**1923,17**	84,77		Percentage of total value				
BIODIVERSITY CONSERVATION																				
	Provisoning	Biodiversity	Conservation	All PAs	All	Theoretical share of actual global spend min		2019	528240000	1,08	572242392,00	7612346,29	75,17			Global actual spend min $124bn *3% *71% *20% in Pas	Deutz et al 2020, Deutz 2021			
	Provisoning	Biodiversity	Conservation	All PAs	All	Theoretical share of actual global spend max		2019	609180000	1,08	659924694,00	7612346,29	86,69			Global actual spend max $142bn *3%*71% 20% in Pas	Deutz et al 2020, Deutz 2021			
	Provisioning	Biodiversity	Conservation	All PAs	All	Global species extinction plan	Investment	2019	3173700000	1,0833	3438069210,00	7612346,29	451,64			Min global need if PAs expanced to 30% = $149bn x 3% x 71% in PAs	Deutz et al 2020; Mair et al 2021			
	Provisioning	Biodiversity	Conservation	All PAs	All	Global species extinction plan	Investment	2019	4089600000	1,0833	4430263680,00	7612346,29	581,98			Max global need if PAs expanded to 30% = $192bn x 3% x 71% in PAs	Deutz 2020; Mair et al 2021			
	Provisioning	Biodiversity	Conservation	All PAs	All	Contribution for 6 key ES		2020	794752000	1,0564	839576012,80	7612346,29	110,29			WWF 2020 - national losses of 5.6% GDP in BAU - costs of inaction	WWF 2020			
	Provisioning	Biodiversity	Conservation	All PAs	All	Global Biodiversity Framework	Investment	2021	852000000	1	852000000,00	7612346,29	111,92			CBD BAF $200 bn assumes Mad holds 3% of biodiversity & 71% in PAs	CBD 2020; Mair et al 2021			
	Provisioning	Biodiversity	Conservation	All PAs	All	Global Biodiversity Framework	Investment	2021	1231353000	1	1231353000,00	7612346,29	161,76	16,18		CBD 300bn (FH est), 3% on Mad, 41% on Ag & For, 47% on KBAs, 71% in PAs	CBD 2021; Mair et al 2021			
	Provisioning	Biodiversity	Conservation	All PAs	All	Government spend on PAs	Budget spend	2014	1034913	1,0673	1104562,80	7612346,29	0,15		7,783E-05	Estimated by BIOFIN 2021 (~15% spend on PAs)	BIOFIN 2021			
	Provisioning	Biodiversity	Conservation	All PAs	All	Government spend biodiversity	Budget spend	2014	6899421	1,0673	7363752,03	7612346,29	0,97		0,000518866	Estimated by BIOFIN 2021 (all biodiversity expenditure)	BIOFIN 2021			
Sub-total biodiversity conservation value min									**Subtotal**	**Min Bio**	**572242392,00**	**7612346,29**	**75,17**	**15,57**		**Percentage of total value**				
Sub-total biodiversity conservation value max									**Subtotal**	**Max Bio**	**659924694,00**	**7612346,29**	**86,69**	**3,82**						
	Provisioning	Biodiversity	Genetic resources	All Madagascar	All	All Mada Pas	Genetic resources	2013	284000000	1,0545	299478000,00	7612346,29	39,34			INCLUDED IN MIN ESTIMATE - estimate of World Bank 2013	World Bank 2013			
	Provisioning	Biodiversity	Genetic resources	Makira/Masoala	Makira	Makira-Masoala Landscape	Genetic resources	2007	733946304	1,1028	809395984,05	553504,00	1326,00			INCLUDED IN MAX ESTIMATE - est. WCS 2008 for Masoala/Makira alone	Masozera 2008			
Subtotal global genetic resources min									**284000000,00**		**299478000,00**									
Subtotal global genetic resorces max									**733946304,00**		**809395984,05**									
Subtotal biodiversity+genetic resources min											**871720392,00**	**7612346,29**	**114,51**							
Subtotal biodiversity+genetic resources max											**1469320678,05**	**7612346,29**	**193,02**							
	Cultural	Tourism	Ecotourism	Terrestrial PAs+NTK	Terrestrial+NTK	Top 15 Pas	Direct spend	2019	480760000	1,0833	520807308,00	1113981,00	467,52	69 all parks		Global spend - 68% tourists visit >/=1 parks x $707m in 2019	FTHM 2012, MTTM 2019			Deduct national contrib
	Cultural	Tourism	Ecotourism	Terrestrial Pas	Andasibe-Mantadia	Tourism consumer surplus	Existence value	1991	5458344	1,0854	5924486,58	1113981,00	5,32	24,00		Assumes similar satisfaction for all Pas	Kramer et al 1995			
	Cultural	Tourism	Ecotourism	Terrestrial Pas	Andasibe-Mantadia	Tourism consumer surplus	Existence value	1991	14783015	1,0854	16045484,48	1113981,00	14,40	65,00		Assumes similar satisfaction for all Pas	Kramer et al 1995			
	Cultural	Tourism	Tourism	Coral reefs in Pas	All MPAs	Reef tourism global benefit	Direct spend	2017	5500000	1,0496	5772800,00	107131,00	53,89			Assumes 2/3 of reef MPA value is global, based on reef area	Spalding et al 2017			
	Cultural	Tourism	Ecotourism	Megafauna in MPAs	Ankarea NA	Whaleshark total spend	Direct spend	2019	500000	1,0833	541650,00	135556,00	4,00			Assumes $1.5 m to global tourism economy from whale sharks x 1/3 in MPAs	Ziegler et al 2021			
Gobal tourism MPAs subtotal									**6000000,00**		**6314450,00**					**Subtotal of benefits from MPAs NOT INCLUDED HERE_SEE UNDER MPAs**				
Subtotal global tourism min exc MPAs									**486218344**		**526731795**	**1356668,00**	**388,25**							
Subtotal global tourism max exc MPAs									**495543015**		**536852792**	**1356668,00**	**395,71**							
Subtotal global tourism min INC MPAs									**492218344**		**533046245**									
Subtotal global tourism max INC MPAs									**501543015**		**543167242**									
Subtotal scientific research	**Cultural**	**Biodiversity**	**Research**	**All PAs**	**All**	**All research publications**	**Direct spend**	**2021**	**8343871**	**1**	**8343870,97**	**7612346,29**	**1,10**	**Assume average $10,000 per paper**		**25866 papers 1990-2021; assume all biodiversity research relates to PAs**	**Publications search link**			
	Cultural	Entertainment	Films & documentaries	Terrestrial PAs	Terrestrial	Natural History Films	Total global spend	2021	412500	1	412500,00	7612346,29	0,05	1.65 films/yr*$250000=$16.5m/40yrs		66 films since 1980 prod cost only (excludes royalties or distribution costs)	BBC consultants for this study			
	Cultural	Entertainment	Films & documentaries	All PAs	All	Dreamworks	Global revenues	2020	83212000	1,0564	87905156,80	7612346,29	11,55			2,26 bn in 15 yrs less $502m*0,71 (71% of Madagascar's biodiversity is in PAs)	Wikipedia on Dreamworks			
Subtotal entertainment									**83624500,00**		**88317656,80**	7612346,29	11,60							
Subtotal global cultural contribution min									**578186714,97**		**623393322,35**	**7612346,29**	**81,89**							
Subtotal global cultural contribution max									**587511385,97**		**633514320,25**	**7612346,29**	**83,22**							
Subtotal biodiversity related benefit min									**Subtotal**	**Min Biod+Cultural**	**1486769843,38**	**7612346,29**	**195,31**							
Subtotal biodiversity related benefit max									**Sub Total**	**Max Biod+Cultural**	**2629566792,88**	**7612346,29**	**345,43**							
Total min GLOBAL BENEFIT DELIVERY									**TOTAL**	**Reg+Biod+Cult**	**3674743246,30**	**7612346,29**	**482,73**		**0,258930612**		**Add nat & local ES not already counted**	**76123462,86**	**48,27**	
Total Med Global Benefit Delivery											**7739441249,92**		**1016,70**							
Total max GLOBAL BENEFIT DELIVERY									**TOTAL**	**Reg+Biod+Cult**	**17269387283,61**	**7612346,29**	**2268,60**		**1,216839577**		**Add nat & local ES not already counted**	**76123462,86**	**226,86**	

Sheet 2 – National Contributions

NATIONAL CAPTURE OF GLOBAL PA VALUES		NATIONAL	NATIONAL	NATIONAL	NATIONAL	NATIONAL	NATIONAL		NATIONAL	NATIONAL	NATIONAL	NATIONAL		NATIONAL			NATIONAL	NATIONAL			
National (theoretical potential)	Regulatory	Climate regulation	Carbon storage	Terrestrial PAs	Humid E forests		REDD+	2021	37222228	1	37222228,11	2341412,10	15,90				Theoretical capture - humid forests in Pas @ 5$/tCO2				
	Regulatory	Climate regulation	Carbon storage	Terrestrial PAs	Dry forests		REDD+	2021	7815954	1	7815954,33	2130175,51	3,67				Theoretical capture - dry forests in Pas @ 5$/tCO2				
	Regulatory	Climate regulation	Carbon storage	Terrestrial PAs	Spiny forests		REDD+	2021	1780192	1	1780192,21	873347,40	2,04				Theoretical capture - spiny forests in Pas @ 5$/tCO2				
	Regulatory	Climate regulation	Carbon storage	Marine PAs	Mangroves		REDD+	2021	462936	1	462936,15	73071,99	6,34				Theoretical capture - MAngrove forests in Pas @ 5$/tCO2				
	Regulatory	**Climate regulation**	**Carbon storage**	**All PAs**	**All**		**REDD+**	**2021**	**47281311**	**1**	**47281310,80**	**6306389,28**	**7,50**				**Theoretical capture under REDD+ - all forests in Pas @ 5$/tCO2**				
National (actual)	Regulatory	Climate regulation	Carbon storage	Terrestrial PAs	Humid E forests	Atiala-Antsinanana	REDD+	2021	10000000	1	10000000,00	1 444 880,04	6,92				Includes areas outside Pas; assumes $50m over 5 years	REDD+ Strategy 2018			
	Regulatory	Climate regulation	Carbon storage	Terrestrial PAs	Terrestrial	Atiala-Antsinanana	FCPF REDD+	2021	2600000	1	2600000,00	1444880,04	1,80	$5/tC			Assumes 13m available over 5yrs (Ereed pers comm) - assume all from PAs	E Reed pers comm			
	Regulatory	Climate regulation	Carbon storage	Terrestrial PAs	Terrestrial	Atiala-Antsinanana	Project budget	2021	19045200	1	19045200,00	1021644,00	18,64				Project budget %158.71m over 5 years x % of forest in PAs				
Subtotal Climate regulation capture min									**21645200**		**21645200**	**3389324,40**	**6,39**	**$5/tC**			**Annual value of terrestrial PAs for carbon**				
Subtotal Climate regulation capture max (potential)									**29045200**		**29045200**	**3389324,40**	**8,57**	**$5/tC**			**Annual value of terrestrial PAs for carbon**				
National	Provisioning	Biodiversity	Global funding	All	All	All Pas	Internat fin est	2021	33333333	1,00	33333333,33	7612346,29	4,38				Estimate quoted by Patricia Rajenarison seems accurate				
	Provisioning	Biodiversity	Bioprospection	Terrestrial	Terrestrial	All PAs	Revenu/option	2013	284000000	1,0545	299478000,00	7612346,29	39,34				based on WB2013 for Pas only	World Bank 2013			
	Provisioning	Biodiversity	Bioprospection	Terrestrial	Terrestrial	Zahamena	ICBG Investment	1999	10000	1	10000,00	64935,00	0,15				Invesment $200,000/5 yrs not renewed - GDP deflator correction	Raharinirina 2009			
	Provisioning	Biodiversity	Bioprospection	Terrestrial	Terrestrial	Ranomafana	ICBG Investment	2005	17333	1	17333,33	40556,00	0,43				Investment $260,0000/4yrs not renewed need GDP deflator correction	Raharinirina 2009			
	Provisioning	Biodiversity	Conservation	All PA types	All	International Public Funds	Investment	2018	33271653	1,0714	35647248,49	7612346,29	4,68	MGA=3455			BIOFIN 2021 - international public finance				
	Provisioning	Biodiversity	Conservation	All PA types	All	GEF7	Investment	2021	6760000	1	6760000,00	7612346,29	0,89				$33.8 m spend over 5 years = 6760000/yr	This study			
	Provisioning	Biodiversity	Conservation	Terrestrial PAs	NE only	World Bank PADAP	Investment	2021	1400000	1	1400000,00	2341412,10	0,60				PADAP in landscapes with Pas	PADAP			
	Provisioning	Biodiversity	Conservation	All PA types	All	NGO & Foundations spend	Investment	2018	15008182	1,0714	16079766,19	7612346,29	1,97				BIOFIN 2021 WWF 36% WCS 24.55% FAPBM 11.7%				
	Provisioning	Biodiversity	Conservation	Terrestrial PAs	Terrestrial	DAPT fiscale receipts	Tax from PAs	2018	57887	1,0714	62020,26	6233317,29	0,01	MGA=3455							
Subtotal global biodiversity values national capture min									**48365055**		**51816368,28**	**7612346,29**	**6,35**		**17,32**						
Subtotal global biodiversity values national capture max									**56525055**		**59976368,28**	**7612346,29**	**7,43**		**16,25**						
National capture global cultural	Cultural	Tourism	Ecotourism	All PA types	Terrestrial	15 MNP sites only	National spend	2019	160253333	1,0833	173602436,00	1113981,00	155,84			**0,012232415**	1/3 of tourism spend is national, 2/3 global	FTHM 2012			
	Cultural	Tourism	Ecotourism	Terrestrial PAs	Terrestrial	Top 15 Pas	Site-based spend	2019	37526115	1,0833	40652040,38	1113981,00	36,49				Sums spent at MNP (entry, guides) on 227431 visits	MNP Data 2020, FTHM 2012			
	Cultural	Tourism	Ecotourism	All PA types	All	All PAs	PA level receipts	2018	1895206	1,0714	2030523,56	7612346,29	0,27	MGA=3455			BIOFIN 2021 - figure for all Pas in 2018 divided by rate of exchnage $1=3455mga				
National tourism values capture min									**39421320,86**		**42682563,94**	**1113981,00**	**38,32**		**5,61**						
National tourism values capture max									**160253333,33**		**173602436,00**	**1113981,00**	**155,84**		**22,81**						
National entertainment capture	**Cultural**	**Entertainment**	**Films & documentaries**	**Terrestrial PAs**	**All**	**All sites**	**National spend**	**2019**	**103125**	**1,0833**	**111715,31**	**6233317,29**	**0,02**				25% of the global production cost of NH documentaries spent in country	**BBC consultants**			
National research capture	**Cultural**	**Research & ed**	**Research & ed**	**All PAs**	**All**	**All sites**	**National spend**	**2021**	**2781290**	**1**	**2781290,32**	**7612346,29**	**0,37**				Assumes 1/3 of research budgets spent in country for all PAs (including MPAs)				
National capture of global cultural values min									**42305736,18**		**45575569,57**										
Natural capture of global cultural values max									**163137748,66**		**176495441,64**										
National capture of all global values min									**151737312,00**		**161719701,79**				**4,40**		**Percentage of global benefits**				
National capture of all global values median															**2,09**		**Median capture**				
National capture of all global values max											**439119445,92**				**2,54**		**Percentage of global benefits**				
NATIONAL ECONOMIC CONTRIBUTIONS																					
	Provisioning	**Water**	**Agriculture**	**Terrestrial PAs 2003**	**Terrestrial**	**Pas supporting irrigation**	**Carret & Loyer**	**2003**	**24264878**	**0,9296**	**22556630,59**	**1102949,00**	**22,00**		**20,45**		15 sites of Carret&Loyer 2004, actualised to 2021 USD	Carret&Loyer, WAVES ($/m3 water)			
	Provisioning	**Clean water**	**Drinking water**	**Terrestrial PAs**	**Terrestrial**	**Carret&Loyer sites**	**Direct value**	**2003**	**10842660**	**0,9296**	**10079336,74**	**1102949,00**	**9,14**				Based on Carret & Loyer 2004 - asssumes water price of 5mga/ltr = $0.0012/ltr	UNICEF 2020			
Subtotal agriculture and drinking water									**35107538**		**32635967**	**1102949,00**	**29,59**								
	Provisioning	Clean water	Hydroenergy	Terrestrial PAs	Terrestrial	5 Eastern sites only	Avoided costs	2021	20746762	1	**20746762,00**	476937,06	43,50				Assume 50% avoided cost due to Pas	JIRAMA (Andekaleka) plus 4 other sites (Ranomafana and 3 others)			
	Provisioning	Cleanwater	Hydroenergy	Terrestrial PAs	Terrestrial	Potential sites	Avoided costs	2021	20492494	1	**20492494,00**	2341412,10	8,75				Assume 50% avoided cost due to Pas	JIRAMA (Andekaleka) for 2 potential sites Sahofika and Volobe			
	Provisioning	Clean water	Hydroenergy	Terrestrial PAs	Terrestrial	Sahofika (potential)	Avoided costs	2021	1151489	1,00	1151488,50	26471,00	43,50				Assume 50% avoided cost due to Pas	Sahofika ESIA (potential site) NOT INCLUDED DOUBLE COUNTING			
Subtotal hydroenergy min								**2021**	**20746762**	**1,00**	**20746762,00**	**43,50**					**Percentage min benefits**				
Subtotal hydroenergy max								**2021**	**41239256**	**1,00**	**41239256,00**	**14,50**					**Percentage max benefits**				
Subtotal min NATIONAL exc MPA									**207591612**		**215102431**	**6233317,29**	**34,51**			**0,015156597**	**Values for all terrestrial PAs**		**6668175,365**	**51041088,95**	**3,07**
Subtotal max NATIONAL exc MPA									**314212138**		**329312897**	**6233317,29**	**52,83**			**0,023204122**	**Values for all terrestrial PAs**		**10208699,79**	**51041088,95**	**4,70**
Subtotal min NATIONAL inc MPA									**392731622,32**		**410274983,88**	**7612346,29**	**53,90**			**0,028908891**	**Percentage NATIONAL inc benefits**		**0,185542541**	**6564399,742**	**5,86**
Subtotal max NATIONAL inc MPA									**502699603,78**		**528020444,73**	**7612346,29**	**69,36**			**0,037205499**	**Percentage NATIONAL inc benefits**		**0,144167643**	**8448327,116**	**7,54**

Sheet 3 Local contributions & MPAs

LOCAL BENEFIT CAPTURE	LOCAL	LOCAL	LOCAL	LOCAL	LOCAL	LOCAL	LOCAL	LOCAL	LOCAL	LOCAL	LOCAL	LOCAL	LOCAL	LOCAL	0,012232415	Percentage CAPTURE benefits	Ecotourisme contribution au PNB			
Local	Regulatory		Reduced soil erosion	Terrestrial PAs	All	**Ankarafantsika**	Avoided Loss	2018	125000	1,0714	133925,00	136513,00	1,96	0,98		Ankarafantsika case study	C3EDM 2018		502218750	
	Provisioning		Hydrological protection	Terrestrial PAs	All	**Ankarafantsika**	Production value	2019	364800	1,0833	395187,84	136513,00	5,79			Value of hydrological protection to Marovoay plain			Value in MGA	
			Reduced soil erosion		All	**Ranomafana**	WTP	2019	6750	1,0833	7312,28	40556,00	0,18	0,18		Local farmer willingness to pay, assumed to be the benefit	This study			
	Provisioning	Terrestrial	Charcoal plantation 1 Bemaratohy		All	**CMK**	Market price MIN	2018	2675400	1,0714	2866423,56	780,00	3674,90	9,48		Value per resource and over whole PA	C3EDM 2018			
	Provisioning	Terrestrial	Charcoal plantation 1 Bemaratohy		All	**CMK**	Market price MAX	2018	4280640	1,0714	4586277,70	780,00	5879,84	15,17		Value per resource and over whole PA	C3EDM 2018			
	Provisioning	Terrestrial	Charcoal plantation 2 Masiakakoho		All	**CMK**	Market price MIN	2018	979373	1,0714	1049300,23	1041,00	1007,97	3,47		Value per resource and over whole PA	C3EDM 2018			
			Charcoal plantation 2 Masiakakoho		All	**CMK**	Market price MAX	2018	1566996	1,0174	1594261,73	1041,00	1531,47	5,27		Value per resource and over whole PA	C3EDM 2018			
	Provisioning	Terrestrial	Other (honey etc.)		Forest	**CMK**	Market price	2018	1087159	1,0174	1106075,57	92831,00	11,91	3,66		Value per resource and over whole PA				
	Provisioning	Terrestrial	Wood		Forest	**Antrema**	Market price	2018	12740	1,0714	13649,21	4776,00	2,86	0,66		Was 0,61/ha/yr in calc - check	C3EDM 2018			
		Aquatic	Fish	Lakes & reservoirs	Lakes & reservoirs	**CMK**	Market price	2018	5107200	1,0714	5471854,08	56910,00	96,15	18,09		Was 16,45/ha/yr in calc - check	C3EDM 2018			
			Fish	Lakes & reservoirs	Lakes & reservoirs	**Antrema**	Market value	2018	60000	1,0714	64284,00	159,00	404,30	3,12		Value for Lakes&res covering 159ha - was 9,9/ha/yr in calc	C3EDM 2018			
	Provisioning		Mangroves			**CMK**	Market price	2018	12266193	1,0714	13141999,18	24848,00	528,90	43,46		NOT INCLUDE -was 841 for all area, 1024 mangroves alone - stock not yield	C3EDM 2018			
	Provisioning	Various	Mangroves	Mangrove	Mangroves	**Antrema**	Market price	2018	190763	1,0714	204383,48	1493,00	136,89	9,91		Was 15 based on all area, 207 based on mangrove area	C3EDM 2018			
	Provisioning	Clean water	Hydroenergy 1	Forest	Forest	**Ranomafana**	Market price	2018	12369580	1,0714	13252768,01	40556,00	305,00	326,78		305 based on all area	This study			
	Provisioning	Clean water	Hydroenergy 2	Forest	Forest	**Ranomafana**	Market price	2018	18727950	1,0714	20065125,29	40556,00	461,78	494,75		Value per resource and over whole PA	This study			
	Provisioning	Clean water	Hydroenergy	Forest	Forest	**Makira Parcel south**	Market price	2021	4106250	1	4106250,00	74494,00	55,12	55,12		Plant 2.5MW at 50% capacity avge cost $0.75/kWh assuming 50% due to forest	This study			
	Cultural	Terrestrial	Ecotourism 1	Forest	Forest	**Ranomafana**	MNP sales	2019	410070	1,0833	444228,83	40556,00	10,95	10,95		MNP receives 20% of tourism spend	This study			
	Cultural	Terrestrial	Ecotourism 2	Forest	Forest	**Ranomafana**	Tourist spend	2019	2050350	1,0833	2221144,16	40556,00	54,77	54,77		Tourism spend by 27338 visitors $75/head (Serpantie 2009)	This study			
	Cultural	Terrestrial	Ecotourism	Forest	Forest	**Andasibe/Mantadia**	MNP sales	2019	211000	1,0833	228576,30	16368,00	13,96	13,96		Value per resource and over whole PA	This study			
	Cultural	Terrestrial	Ecotourism	Forest	Forest	**Andasibe/Mantadia**	Tourist local span	2019	2030215	1,0833	2199331,91	16368,00	134,37	2516,40		Value based on assumed tourist local spend of $55/day				
	Cultural	Terr & Marine	Ecoutourism	Forest & Marine	Top 15	**TOP 15 MNP Pas**	MNP sales	2019	110574800	1,0833	119785680,84	1113981,00	107,53	107,53		Assumes 23% of ectourism spend is local	FTHM 2012			
Ankarafantsika local value									**125000**		**133925**	**136513,00**	**0,98**	**0,98**						
Ranomafana local value min									**12786400,00**		**13704309,12**	**40556,00**	**337,91**	**337,91**		**15481224,44**				
Ranomafana local value max									**20785049,68**		**22293581,72**	**40556,00**	**549,70**	**549,70**		**22293581,72**				
CMK local value MIN									**22115325,00**		**23635652,62**	**302400,00**	**78,16**	**133,98**		**176410,00**				
CMK local value MAX									**24308188,00**		**25900468,25**	**302400,00**	**85,65**	**146,82**						
Antrema local value									**263502,60**		**282316,69**	**20620,00**	**13,69**	**43,92**		**Productivity of 6428 ha of ES**				
Makira Parcel 6 value									**4106250,00**		**4106250,00**	**74494,00**	**55,12**	**55,12**						
Andasibe/Mantadia local value MIN									**211000,00**		**228576,30**	**16368,00**	**13,96**	**13,96**						
Andasibe/Mantadia local value MAX									**2030215,00**		**2199331,91**	**16368,00**	**134,37**	**2516,40**		**Value of Analamazaotra at 874ha**				
Subtotal local values min									**39607478**		**42091030**	**590951,00**	**67,02**	**71,23**	**0,031283383**	**Based on 6 terrestrial parks 590951ha =**		**443973769,7**	**62333172,86**	**7,12**
Subtotal local values max									**51618205**		**54915874**	**590951,00**	**87,35**	**92,93**	**0,040815212**	**Based on 6 terrestrial parks 590951ha =**		**579249487,6**	**62333172,86**	**9,29**
MARINE PROTECTED AREAS NATIONAL BENEFITS																				
National	Regulatory	Climate regulation	Carbon storage	MPAs	Mangroves	All mangroves in Pas	REDD+	2018	1096080	1	1096079,85	73071,99	15,00			Assume $5/t, 100% stop of 1% deforestation, $300tC/ha	REDD+ Strategy, Zeng et al 2021; LOFM/BNCCREDD+ 2021			
	Regulatory	Blue carbon	Carbon storage	MPAs	All MPAs	Mangroves in (M)Pas	REDD+	2017	0	1,0496	0,00	73071,99	0,00			Area based on average value/ha for carbon	Blue Venures unpublished data, Zeng et al 2021; LOFM/BNCCREDD+, 2021			
	Provisioning	Fisheries	Fisheries	MPAs	All MPAs	Based on Velondriake & Toliara Bay	Market price	2013	172378625	1,0545	181773260,06	1379029,00	125,00			Average 100/ha/yr - Assumes same value/ha for all MPAs for fisheries 1.38m ha				
	Provisioning	Mangroves	Fisheries	MPAs	All MPAs	Based on NW mangroves study	Market price	2017	9864719	1,0496	10354008,70	73071,99	135,00			Combination of mud crab, fish and shrimp	Blue Ventures 2017; LOFM/BNCCREDD+ 2021			
	Cultural	Tourism	Tourism	MPAs	All MPAs	Coral reefs in MPAs (exc Tanikely)	Tourism revenues	2017	2750000	1,0496	2886400,00	107131,00	25,67	49,46		Assumes1/3 value of reefs in MPAs ($8.25m) spent in Madagascar	Spalding 2017			
	Cultural	Tourism	Ecotourism	Ankarea	Ankarea	Whale shark watching around Nosy	Tourism spend	2019	146667	1,0833	158884,00	135556,00	1,08			8000 tourists - assume daily spend 165/3 in Mad and 1/3 in MPA				
	Cultural	Tourism	Tourism	MPAs	Ankarea	Whale shark watching around Nosy	Tourism revenues	2019	166667	1,0833	180550,00	135556,00	1,23			Total $1,5m from 8000 tourists - assume 1/3 in MPA, and 1/3 spent in Mad	Ziegler et al 2021			
	Cultural	Tourism	Ecotourism	MPAs	One MPA	Nosy Tanikely	Tourism spend	2019	2231376	1,0833	2417249,62	341,00	6543,62			(2019 foreign tourists 38472*daily spend ($(165/3)+3)	FTHM 2012			
National tourism MPAs subtotal min			Tourism	MPAs	All MPAs	All MPAs	Tourism spend	2019	5128043	1,0833	5555208,62	1379029,00	3,72			Tourism value for all MPAs				
National tourism MPAs subtotal max							Tourism spend	2019	5148043	1,0833	5576874,62	1379029,00	3,73							
	Subtotal MPAs								**188487466**		**198707548**	1379029,00	**144,09**	8,72	**0,014001377**	Management Cost/ha based on 820000ha (WCS 2017)	WCS 2017 on MPA costs (high cost scenario		13790290	**14,41**
Subtotal MPAs min									**185140010,32**		**195172552,76**		**141,53**	4,54			Cost High 2017		6830481	
Subtotal MPAs max									**188487466,17**		**198707548,23**		**144,09**				Cost Low 2017		3551850	