MESCAL
Mangrove Ecosystems for Climate Change Adaptation and Livelihoods

Technical report

April 2013

IUCN

Pacific Mangroves Initiative

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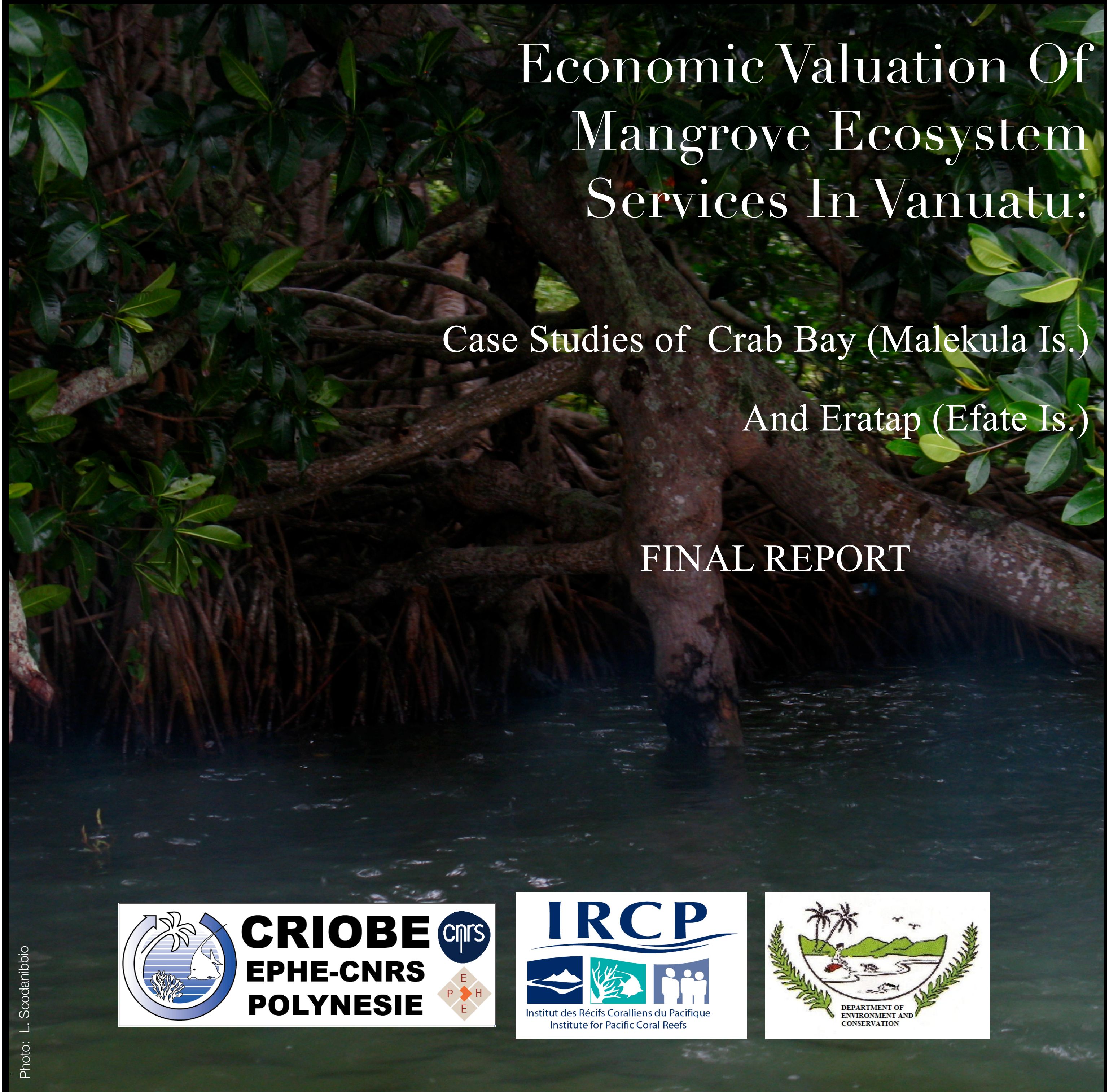

Economic Valuation Of Mangrove Ecosystem Services In Vanuatu:

Case Studies of Crab Bay (Malekula Is.) And Eratap (Efate Is.)

FINAL REPORT

CRIOBE EPHE-CNRS POLYNESIE

IRCP
Institut des Récifs Coralliens du Pacifique
Institute for Pacific Coral Reefs

DEPARTMENT OF ENVIRONMENT AND CONSERVATION

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For:

Project MESCAL, Mangrove EcoSystems for Climate Change Adaptation & Livelihoods. Implemented by IUCN Oceania under the emerging Pacific Mangroves Initiative. The project is being funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) under its International Climate Initiative. Project partners include University of the South Pacific (USP), Secretariat of the Pacific Regional Environment Programme (SPREP), WorldFish Solomon Islands Pacific Base, and Tonga Community Development Trust, as well as the governments of the participating countries.

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The method described in the annexes of the report is based on a working paper coordinated by the author with the participations of Michel Allenbach (UNC), Thomas Binet and Pierre Failler (CEMARE), Julien Hardelin (MEEDTL/SEEI/ERNR1), Arthur Katossky (CGDD/SEEI/ERNR3), Elen Lemaître-Curri (MEEDTL/SEEI/ERNR1), Gilbert David (IRD), Philippe Méral (IRD), Mahé Charles (AAMP) et Jean-Baptiste Marre (CRIOBE).

EXECUTIVE SUMMARY

OBJECTIVES AND CONTEXT

This study objective is to produce the economic valuation of mangrove ecosystem services in Vanuatu. It is part of the MESCAL project developed to address the main challenges to mangrove management and conservation. Specifically, the study contributes to the outcome nº1 (National Baseline Information about Climate Change Scenarios, use and values of Mangroves and Associated Ecosystems) as well as to the outcome nº4 (Increased Awareness, Advocacy and Capacity development).

In response to market failures, economic valuation of mangrove ecosystem services (ES) is viewed as a promising approach at different levels. In this study the ES valuation was undertaken to raise awareness among decision-makers, policy-makers and the public regarding the benefits of the environment for society. Based on the general recognition that "money talks", its role will be to strengthen the support to environment regulation and resource management actions. At the same time, this study can be part of a monitoring routine to inform management with economic indicators ("we manage better what we can measure").

ANNUAL VALUE OF THE ECOSYSTEM SERVICES OF THE MANGROVES

Based on the economic valuation of 9 ecosystem services (ES1 to ES9), we found the following results:

In Crab bay, mangrove ecosystems (136.5 ha) have produced in 2012 a total of Vt 53 M (equivalent to US$ 586K) comprised between Vt 36M and Vt 70M. In Eratap, the mangrove (31.2 ha) was estimated to produce annually a value of Vt 24M (equivalent to US$ 266K) with a minimum of Vt 17 M and a maximum value of Vt 31 M.

For comparison between sites this is equivalent to Vt 386k per year per ha ($US 4 300.$y^{-1}$.$ha^{-1}$) in Crab bay and Vt 768k per year per ha ($US 8 500.$y^{-1}$.$ha^{-1}$) in Eratap.

In Crab bay, the principal ecosystem services in economic terms are the value of carbon sequestrated (ES9), the proteins from subsistence fishery (ES1), the commercial fishery (ES2) and the wood extraction (ES4) summing almost 98% of the total value.

In Eratap, the principal ES are the value of carbon sequestrated (ES9), the revenues from tourism linked to mangroves (ES5), the avoided costs from coastal protection against flood (ES6) and proteins for subsistence fishery (ES1) for a total of 85% of the total value. Commercial fishery (ES2), wood extraction (ES4) and recreative fishery (ES3) are the other ES.

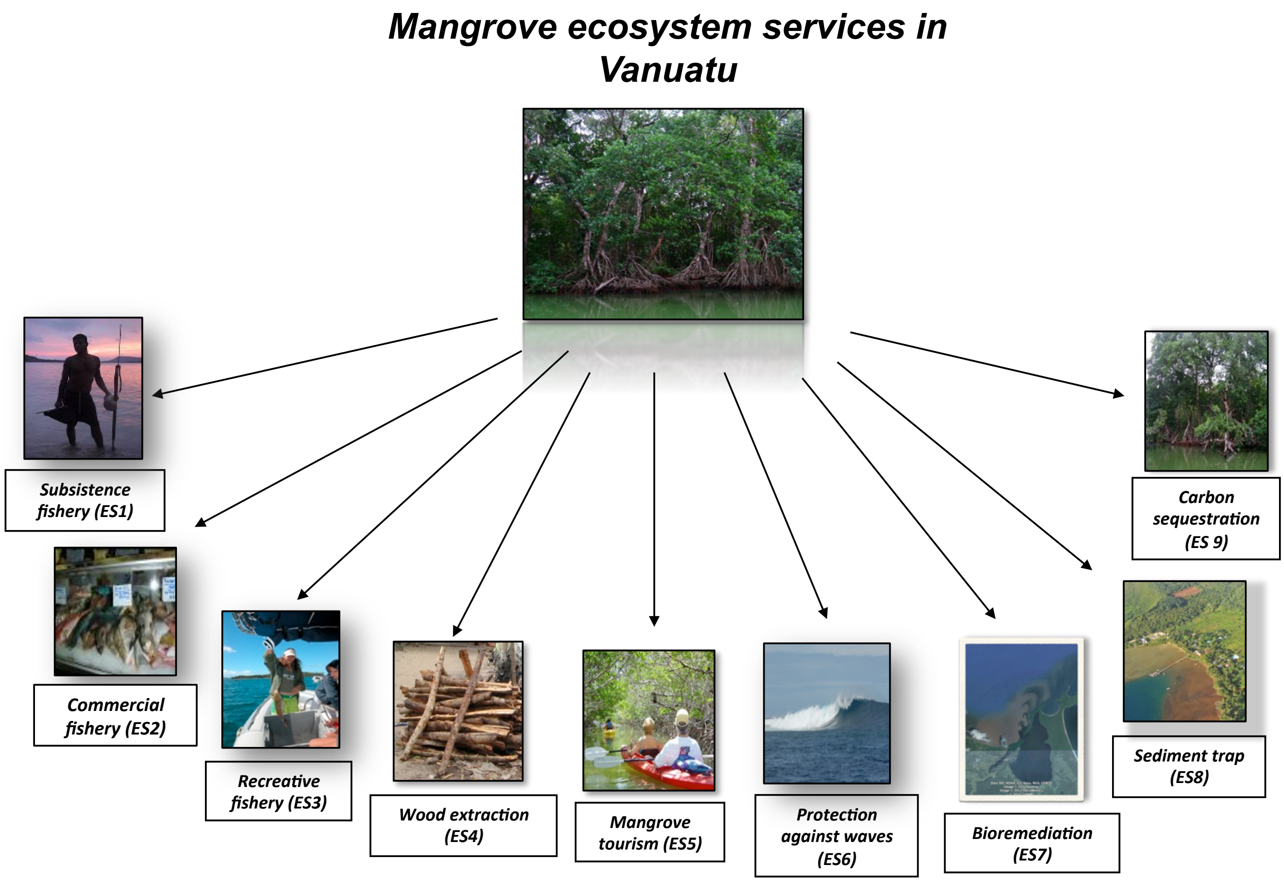


Figure 1: Mangrove ecosystem services in Vanuatu

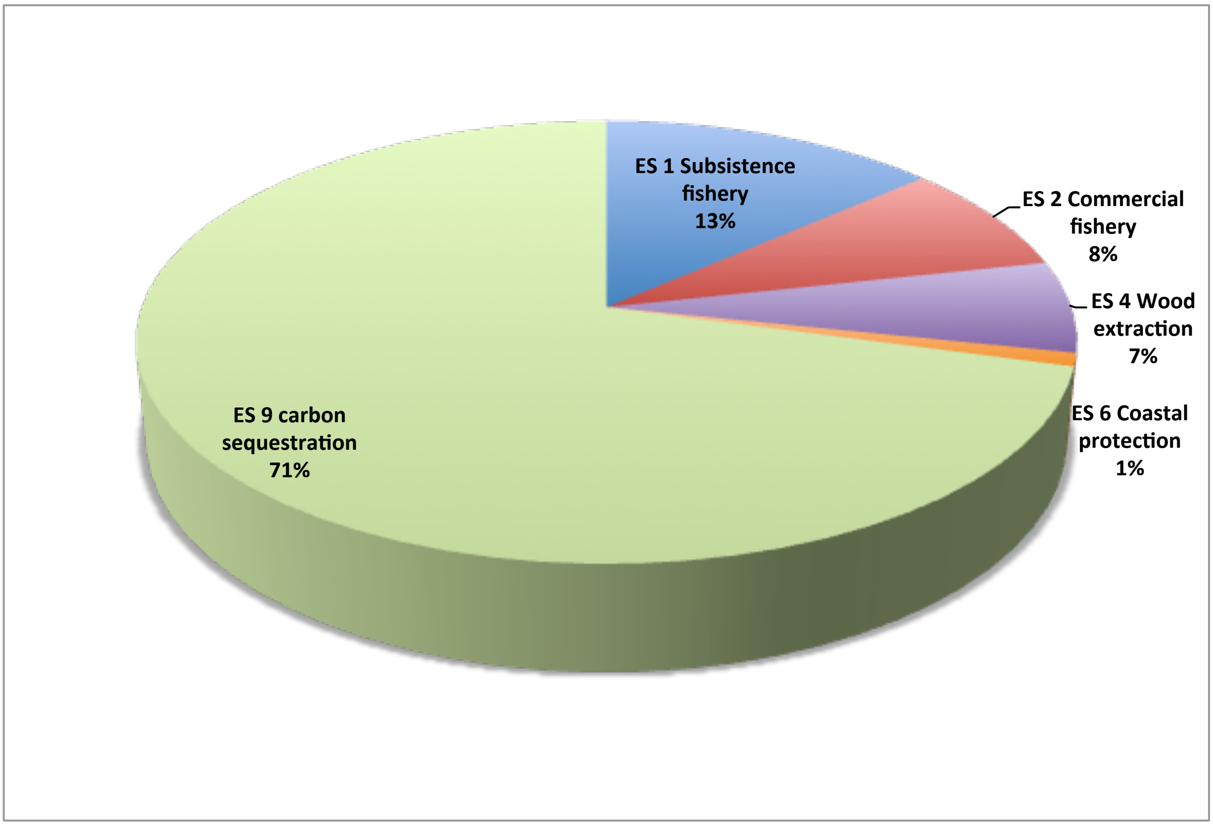
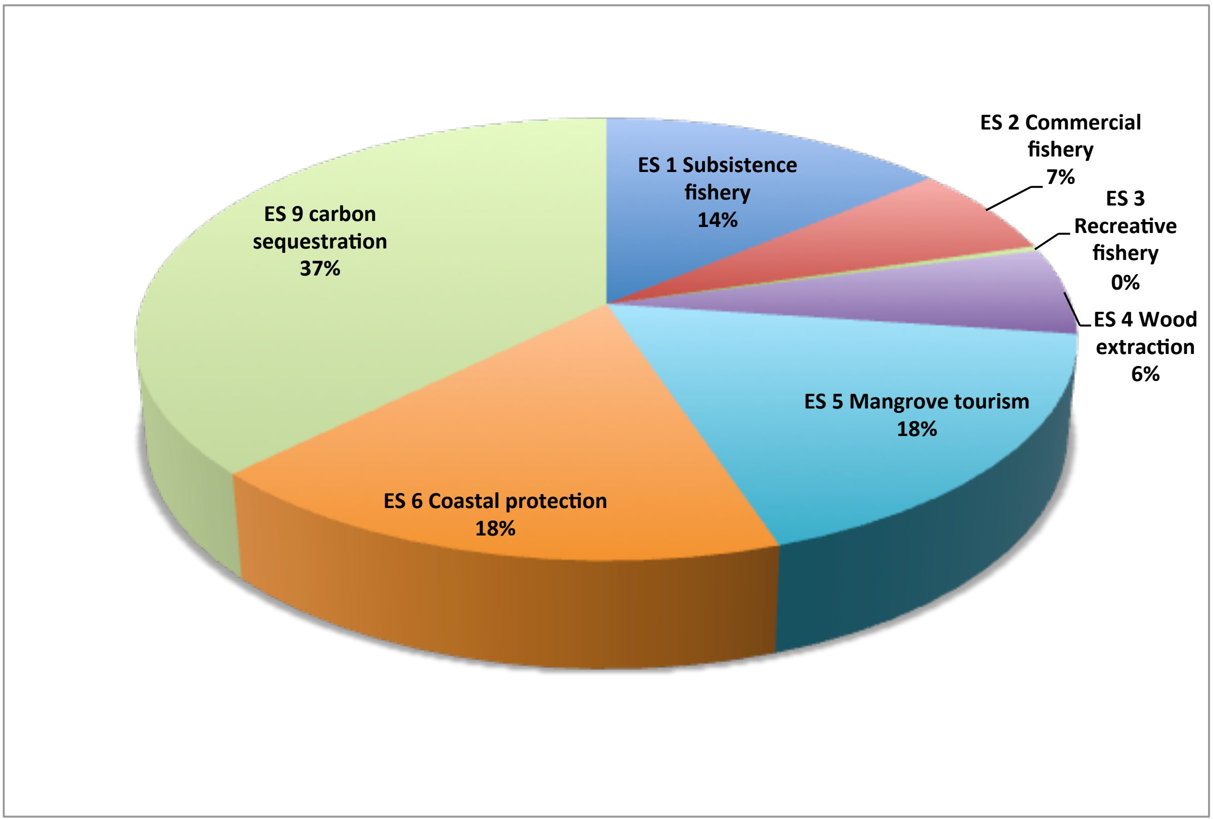


Figure 2: Distribution of ecosystem service valuation in Crab bay. 2012, total value estimated: Vt 53 M.

Figure



3: Distribution of ecosystem service valuation in Eratap. 2012, total value estimated: Vt 24 M.

Beneficiaries:

An important result of the study is the identification of social groups who are beneficiaries of ecosystem services in Crab bay and Eratap. The figure below summarizes this. The main beneficiaries are:

- Fishermen of the commercial artisanal fishery (300 in Crab bay and 50 in Eratap)
- Local families for whom fishing in the mangrove and in the reef is a source of regular protein (160 households in Crab bay and 80 households in Eratap)
- Local families benefiting from firewood and construction material (150 households in Crab bay and 45 in Eratap)
- Tourism entrepreneurs in Eratap proposing mangrove tourism (2 businesses, 800 tourists a year)
- Real estate owners protected from coastal flooding (2 tourism resorts in Eratap> 3 000 m2) as well as plantation owners (300 ha in Crab bay)
- The global community to benefit from carbon sequestration and biodiversity.
- Tourism entrepreneurs in Eratap whose business depends on the quality of water of the lagoon as well as beach formation (2 businesses, 21 jobs, 11 500 tourists a year)[1].

In total, nearly 800 people depend on one or more of the mangrove ecosystem services in Crab bay and 400 in Eratap.

[1] The exact relationships between mangroves ecosystem processes and the benefits of clean water for recreative use have to be better studied. We mentioned it in the present work as a potential benefit but the service was not valued.

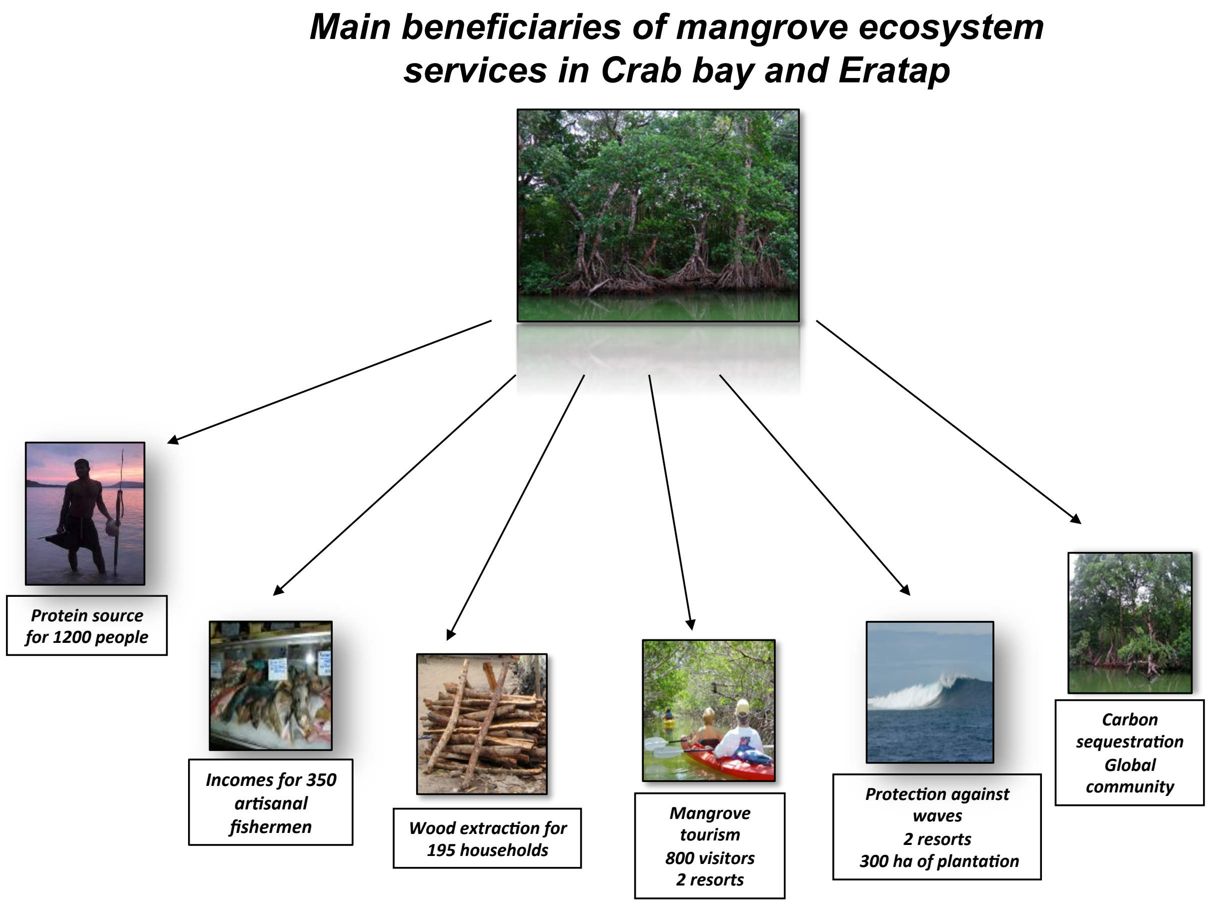


Figure 4: Main beneficiaries of mangrove ecosystems in Crab bay and Eratap

RECOMMENDATIONS:

Following the presentation of the results of this study to the officers of the Environment Department, several recommendations were identified:

1. The importance of the benefits from mangroves should be reflected in the regulation and policies addressing mangrove management and conservation. More specifically, all the procedures about compensation of anthropogenic damages to mangroves (e.g. destruction, contamination, partial clearing) should take in account the 9 ecosystem services identified. It forms part of the outcome 2 of the MESCAL project, to have a "Policy and Legislative Review, so that loop holes and gaps in existing separate policies and regulations that lightly address mangrove ecosystems can be addressed. Additionally, specifically assign a policy or incorporated piece of legislation into the existing environment act that will govern and set laws on mangrove forests to prevent further destruction".

It is important to remind that the main principle of compensation is the "No Nature Loss", meaning that every mangrove destroyed should be compensated[2] by mangrove of similar characteristics ("in kind") and in the proximity ("in site"). Compensation can be made through restoration, re-seeding or conservation of existing mangrove and is always the responsibility of the developers. A ratio of compensation is applied to take in account ecological differences, recovery time and risks of ecological engineering. Payments for damages are made only when the developers do not have the technical capacity to sub-contract the compensation measures. In this case, one option is that they can pay the cost of compensation to a specific structure regulated by the government. It is a recommendation made by most of the international organisations but still in exploration in most of the countries. The wetland compensation banks in the U.S. are one illustration of these mechanisms.

2. The results may be incorporated in a policy brief to convince policy makers to better support mangrove management. A clear communication about the beneficiaries, the ecosystem services and policy needs should contribute to this "inform&convince" objective. The departments of Environment, Fisheries and Lands, NGOs and bilateral agencies might use the results in their communication and strategy. With the same objective, the identification of the rate of degradation of mangroves will help make a concrete case for strengthened mangroves management.

[2] Offset laws usually recommand that compensation of project impacts should be the last option after undertaking strategies to avoid and reduce impacts.

ACKNOWLEDGMENTS

This project would not have been possible without the support from the Department of Environment Protection and Conservation that provided supervision and assistance to this study. The presence of Rolenas Baereleo, coordinating the MESCAL project in Vanuatu was one of the conditions of success of this study.

We give our acknowledgement to Milika Sobey from IUCN ORO (International Union for Conservation of Nature's Oceania Regional Office) coordinating the project MESCAL, a German funded project for her financial support and making possible this study.

We would like to give our acknowledgement to the Government departments that received us for technical meetings, in particular:

- The Fishery department
- The department of Lands, Survey and Registry
- The department of Forestry
- The Malampa Province

Realising more than 500 surveys in 20 villages in a limited time is always a challenge in Vanuatu. Difficulties in the field including responsible committee members having other commitments on the day and last minute program changes are quite common. Patience and self-confidence are qualities that are strengthened after such an experience for all the data collection team.

I, Molu Bolu, directly involved in the survey organisation, would like to transmit my gratitude to the team involved in the collection of data at the two demonstration sites: Eratap on Efate and Amal Crab Bay on Malekula; Ms. Donna Kalfatak, Ms Primrose Malosu, Mr. Trinison Tari, Mr. Reedly Tari, Mrs. Rolenas Baereleo, Mr. Tony Kanas, Mr. Philip Koroka, Mr. Rodson Aru, Mr. Kalmasing Peter, Mr. Numa Fred, Mr. Spetly Jonah, Mr. Ritson Josen, Mr. Leonie Mark, Mr. Susan Tahi and Mr. Morry Ruben.

I, Nicolas, would like to acknowledge the capacities of Molu Bulu to face field realities with remote support from my part.

We would like to give a special thanks to the 480 households surveyed in the 20 Communities of both demonstration sites, who have shared their time with the survey team and accepted to transmit their knowledge about their uses of mangroves and fisheries.

We have good expectations that the ecosystem service approach developed in the present study will be progressively incorporated in the ecosystem management and conservation in Vanuatu.

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OBJECTIVES

GENERAL CONTEXT OF MESCAL

Today most Pacific territories are facing challenges such as: (i) increased fish demand from human population growth (planned to increase by 50% by 2030 with projected food requirements well in excess of what coastal areas are currently likely to produce without significant improvements in management and productivity) (Bell et al., 2009); (ii) the rapid introduction of market economy with its associated rural migration, loss of traditional customs and urban poverty (Cinner and Aswani, 2007); (iii) a small island context with limited economic options (Beukering et al., 2007) and, (iv) potential climate change effects on their marine ecosystems services (Baker et al., 2008; Knowlton, 2000). These challenges are reinforced by the fact that national budgets are usually small and face considerable demands to meet human development priorities such as health, education and food production.

Mangrove ecosystems are renowned for providing services that are highly valued by the people of the Pacific. They are under continued threat from overharvesting, degradation and land reclamation. Weak governance, disconnect between formal and traditional management systems, limited baseline information, weakening traditional management, lack of awareness and limited capacity are some of the key challenges of mangrove management faced in the Pacific.

Under the Pacific Mangrove Initiative, the MESCAL project was developed to address these key challenges to mangrove management and conservation. Adopting an Ecosystem-based Management (EbM) approach, the project focuses on finding stakeholder-based solutions supported by scientific evidence and traditional knowledge to positively influence decision-making at all levels of governance. The project aims to assist in climate-proofing coastal communities and sustaining livelihoods by promoting investments in mangrove and associated coastal ecosystems in the five participating countries.

The MESCAL project focuses on five Pacific Island countries (Fiji, Samoa, Solomon Islands, Tonga and Vanuatu) to achieve its objectives.

Specifically, the project outcomes are:

1. National Baseline Information about Climate Change Scenarios, use and values of Mangroves and Associated Ecosystems

2. Co-management of mangroves for adaptation to Climate Change Governance

3. Improved conservation and/or restoration of mangroves at selected demonstration sites

4. Increased Awareness, Advocacy and Capacity development

OBJECTIVES OF ECOSYSTEM SERVICES VALUATION

In response to market failures, economic valuation of mangrove ecosystem services (ES) is viewed as a promising approach at different levels.

ES valuations can be undertaken to address one or several objectives from among the following (Laurans et al., 2013):

(i) "Decisive" valuations are intended to allow an ex-ante choice or ex-post appraisal over a given set of options by weighing the ecologic and economic consequences of those options; it is a way to incorporate the present and future values of negative and positive externalities with a common metric and provide 'correct' signals (Campbell and Brown, 2003; Whitten and Bennett, 2004).

(ii) "Technical" valuations are designed to "fine tune" economic instrument internalizing "externalities". For example, it may provide the price baseline for negotiation in the setup of a payment for ecosystem services, user fee or environmental taxes (Chevassus-au-Louis et al., 2009; Engel et al., 2008; Meignien and Lemaître-Curri, 2010; PNUE, 2004); and,

(iii) "Informative" valuations are intended to raise awareness among decision-makers and the public regarding the condition of environment. Based on the general recognition that "money talks", their role is to strengthen the support to environment and resource management actions. At the same time, they can be part of a monitoring routine to inform management with economic indicators ("we manage better what we can measure") (Beukering et al., 2007; David et al., 2007; Pascal et al., 2008).

Within this classification, Total Economic Valuation (TEV) of mangrove ecosystem services enters in the third category of "informative" objectives. Usually covering more than 12 services (Moberg and Folke, 1999), mangrove TEV has been recognized as a useful way to compare and synthesize very different services (e.g. subsistence fishery can be compared with coastal protection). Decision-makers easily grasp that "you can't manage what you don't measure" (Seidl et al., 2011). Managing a portfolio of ecosystem services – those that are well reflected in markets as well as those that are not – is the central message from TEV estimates. TEV also provides guidance about the main stakeholders who benefit from the ecosystem processes. This is valuable information for decision makers to identify the socio-economic group affected by a particular policy.

In turn, Cost-Benefit Analysis (CBA) of a project or a policy belongs both to the previous first and third category of valuation exercises. They improve decision-making comparing different scenarios, make appraisal of investments and inform about implicit or explicit costs and benefits for host communities, nations and donor agencies. CBA is a policy assessment method that quantifies in monetary terms the value of all consequences of a policy to all members of society. The CBA of a project or policy generally leads to an aggregate value or net social benefits. Although in practice not all benefits and costs are or should be quantifiable, CBA provides a useful tool to help social decision-making and to make it more rational. For example, CBA of Marine Protected Areas, an essential component of the policy for the preservation of coastal ecosystems (Bell et al., 2009a; Mumby and Steneck, 2008b), is expected to both convince policy makers and identify the losers and winners amongst the main stakeholders (Mangos and Rojat, 2008) (TEEB, 2009)

SPECIFIC CONTEXT OF THE STUDY

The study is focused on economic valuation of ecosystem services of mangroves in specific locations in Vanuatu. The objectives are to produce clear "informative" valuations to raise awareness among decision-makers and the public regarding the condition of environment.

Based on the general recognition that "money talks", their role is to strengthen the support to environment and resource management actions. At the same time, they can be part of a monitoring routine to inform management with economic indicators ("we manage better what we can measure") (Beukering et al., 2007; David et al., 2007; Pascal et al., 2008).

More specifically the study conducted field surveys to determine cultural and commercial uses of mangrove resources (subsistence and/or commercial artisanal fisheries, firewood, timber, medicine, etc) and assess their economic values. The team has conducted a desktop review on indirect uses of mangrove ecosystems (coastal protection, water treatment, carbon sequestration and sediment trap) and assessed their economic values.

With the present document, we present the results of the economic valuation of the ecosystem services.
9 ecosystem services have been identified and analysed: the subsistence fishery (ES1), the coastal commercial fishery (ES2) including professional and non professional fishery as well as coastal and mangrove linked pelagic fishery, the recreational or sport fishing (ES3), the other extractive uses such as wood, medicine (ES4), the tourism activities linked to mangroves (ES5), the coastal protection against flood (ES6), the bio remediation of waste waters (ES7), the service of sediment trap to reduce coastal erosion (ES8) and the carbon sequestration (ES9).

STUDY CONTEXT

SOCIO-ECOLOGICAL CONTEXT

Villages in Crab bay (16 villages and plantation settlements) and Eratap (10 settlements) comprise between 10 and 50 households with a mean household size of 5 persons (generally an extended family). The Crab Bay sums a total of 750 people and Eratap 240 people approx. In Malekula most of the population come from the island with some immigration in the 70's. In Eratap, there is a major mix with local populations from Efate cohabiting with whole settlements of people from other islands (such as Tanna). These settlements generally do not follow the same rules as the villages and do not recognize customary management from Eratap. No conflict has been identified so far but, as noticed during the surveys, this reality has a clear effect on the resource management of the area.

Most of the villages have a young age structure with an important part of the population (40% approximate) aged less than 15 years and only 5% aged over 60 years. Results are similar to the last demographic census (Vanuatu National Statistics Office, 2009). In both islands, most of the houses in the villages are permanent houses with a galvanized iron or similar roof and cement floor. In Malekula, no village has access to electricity service meanwhile in Eratap it seems that almost all houses have been connected to the electricity services 10 years before.

All the households produced incomes through subsistence production (e.g. crop food, fish, firewood, house building materials) and the majority is engaged in the sale of agricultural products, fish and handicrafts. The Household Incomes and Expenses Survey (Vanuatu National Statistics Office 2008) estimated the average income of rural households in Vanuatu to be around US$ 500 per household per month. This revenue is equivalent to international US$1.300 per household per month when applying PPP and Geary–Khamis dollar conversion (Heston et al., 2009).

On a national scale, approximately 40% of this income comes from subsistence production. Results of surveys and focus groups conducted in the villages confirm that for Eratap, this part of subsistence production seems to be less important whereas Crab bay seems closer to the national level. Following Cinner and Aswani (2007), this variability may be explained mainly by proximity to the capital (Port-Vila for Eratap), that facilitates the access to salaries and commercial markets. A different mix between subsistence and market economy is therefore expected between the villages.

Fishing is a common activity in the villages. The last HIES conducted in 2006 (Vanuatu National Statistics Office 2008) estimated that in Vanuatu, more than 75% of the adult population is implicated in one form of fishing. On the other side, the commercial fishery is not developed as a formal activity and represents for most of the households a complementary and irregular income to agricultural activities (Amos, 2007;

Bartlett et al., 2009; Hickey, 2008; Pascal, 2011). As described in the following chapters, this has been confirmed by the results of the surveys

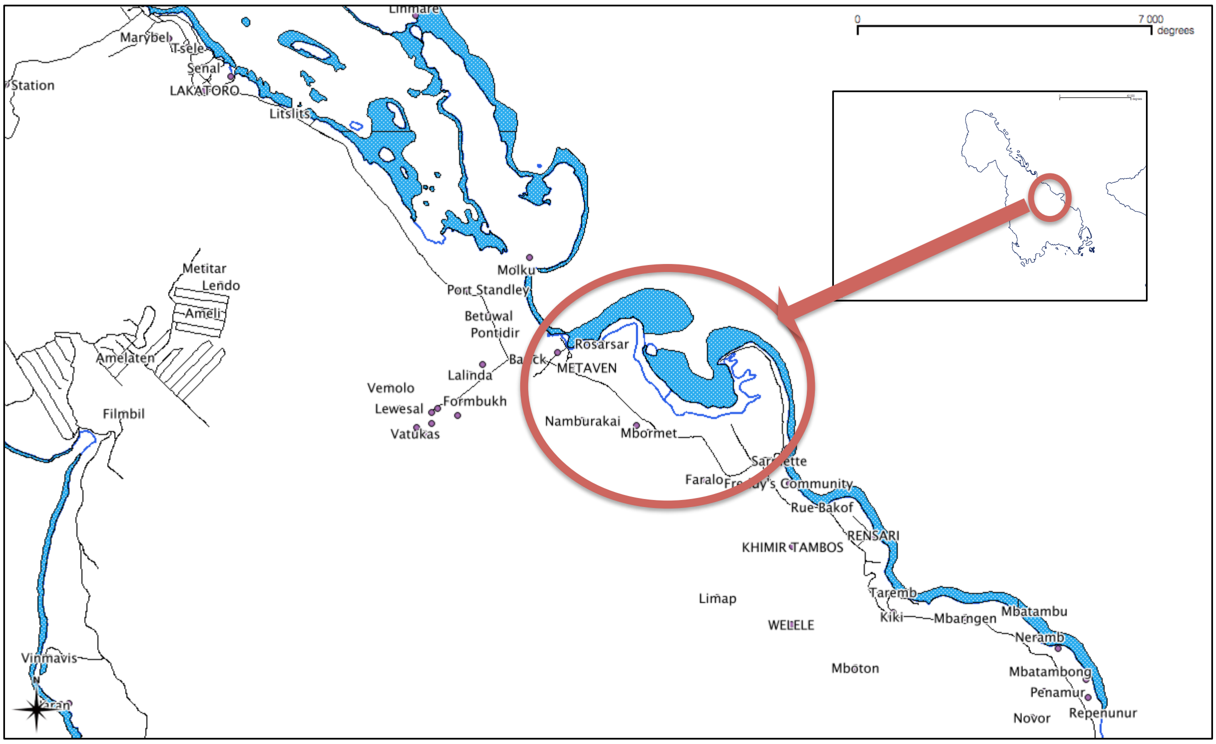

Figure 5: Crab bay study site map (Malekula Is.)

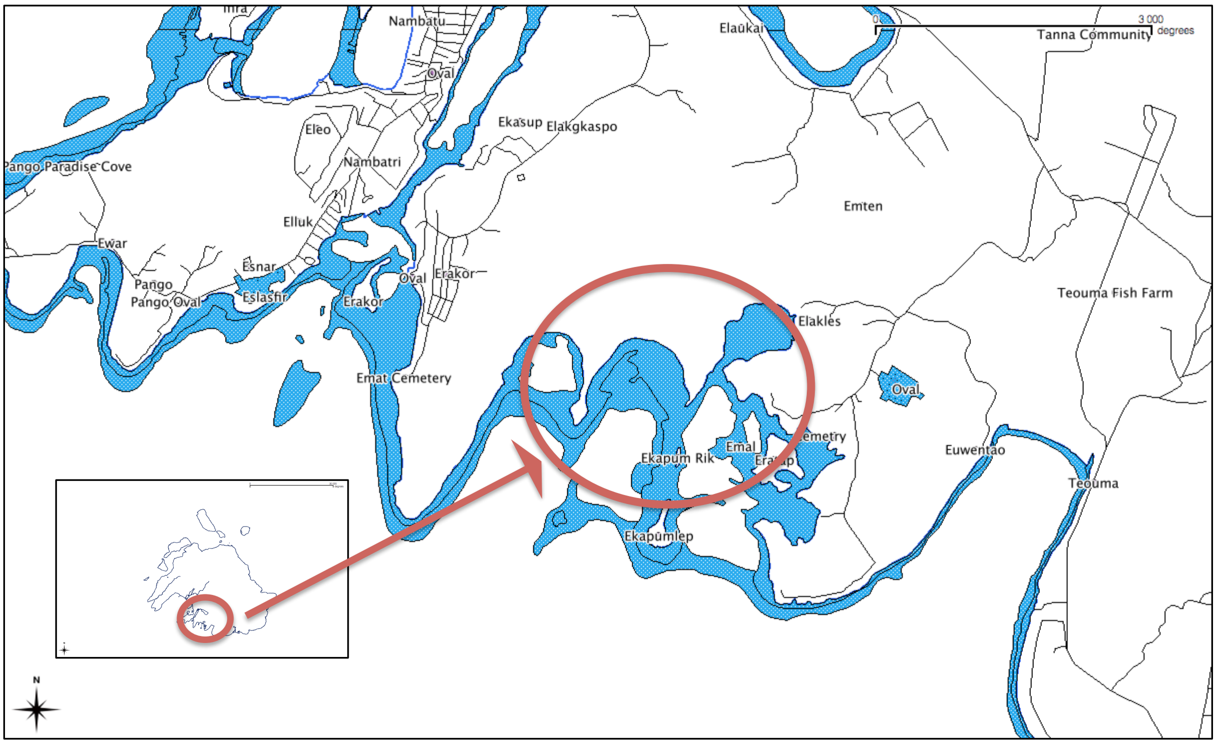

Figure 6: Eratap study site map (Efate Is.)

MPA AND OTHER FISHERY MANAGEMENT RULES DESCRIPTION

The Crab bay MPA (Amal-Krab bay Tabu Eria (AKTE)) is associated to 16 villages and plantation settlements. The MPA size is less than 1km², which is similar to most of the small MPAs in the Pacific (Govan, 2009) and represents an average 15% of the reef fishing ground. The villages manage it since 2002 through a committee formed by members of the villages. The MPA is a permanent closure for all harvest (fish, crabs, wood, shells) and periodic harvest events cannot occur for village subsistence or celebration. Other management rules include some restrictions on crabs' collection outside the AKTE (number, size, spawning season). The AKTE was planned to last 3 years initially (up to 2005) but communities have been reconducting the AKTE every year. Some activities around the MPA have been observed between 2010 and 2012 (e.g. regular meetings, participation in workshops and trainings, rubbish cleaning, organization of environment awareness campaign, monitoring).

In Eratap, no MPA or resource management is present. Previous attempts have been made but have failed mainly due to a lack of respect for the rules. The situation of settlements with people from outside of the community and the proximity to Vila may explain this erosion of customary governance.

Other fishery management rules are in place in both sites. Following a classification adapted from Johannes and Hickey (2004) who conducted a study of fishery management in more than 20 villages in Vanuatu, we identified several fishery management rules present: a trochus (*Trochus sp.*) ban, a giant clam (*Tridacna sp*.) ban and a tabu on the harvest of turtles and their eggs[3].

ECOLOGICAL HABITATS

The results expressed here are extracted from the MESCAL mangrove baseline vegetation mapping study conducted in 2012 in Crab bay and Eratap. "The aim of the study was to develop and establish a Baseline boundary definition of the mangrove vegetation beyond Mean Sea Level, above Mean sea level and Mean Sea Level within the Project Site. The outcome of this activity is the determination of the total areas of mangroves from back boundary species to shoreline mangroves.

The team has created a baseline map of the mangroves from the offshore mangroves to the highest high water mark to the back boundary species of mangroves. The common back boundary species of mangroves at both demonstration sites is *H. litoralis* and the common offshore mangrove is *R.stylosa*. Baseline maps were created for 3 sites in Vanuatu, Amal, and Crab Bay on Malekula and Eratap on Efate.

The total area of mangroves from off shore to high water mark and to back boundary species of mangroves is 135.5 ha and 31.2 ha in Crab bay/Amal and Eratap respectively (source: Vanuatu Department of Environment and Conservation).

Data extracted from the Millennium Coral Reef Mapping Project show that the dominant reef geomorphologic type is the ocean and the intra-seas exposed fringing reef (classes 222 and 230 respectively) (Andréfouët et al., 2005) in both sites.

[3] In addition to those specific rules, there is a 'rule' related to controlling the access permitted for non-locals.

RESULTS

CONSOLIDATED

Annual value of the ecosystem services of the mangroves

In Crab bay, mangrove ecosystems (136.5 ha) have produced in 2012 a total of Vt 53 M (equivalent to US$ 590K[4]) comprised between Vt 36M and Vt 70M. In Eratap, the mangrove (31.2 ha) was estimated to produce annually a value of Vt 24M (equivalent to US$ 270K) with a minimum of Vt 17 M and a maximum value of Vt 31 M.

For comparison between sites this is equivalent to Vt 390k per ha per year ($US 4 300.$y^{-1}$.$ha^{-1}$) in Crab bay and Vt 770k per ha per year ($US 8 500.$y^{-1}$.$ha^{-1}$) in Eratap.

In Crab bay, the principal ecosystem services in economic terms are the value of carbon sequestrated (ES9), the proteins from subsistence fishery (ES1), the commercial fishery (ES2) and the wood extraction (ES4) summing almost 98% of the total value.

In Eratap, the principal ES are the value of carbon sequestered (ES9), the revenues from tourism linked to mangroves (ES5), the avoided costs from coastal protection against flood (ES6) and proteins for subsistence fishery (ES1) for a total of 85% of the total value. Commercial fishery (ES2), wood extraction (ES4) and recreative fishery (ES3) are the other ES.

In total, nearly 800 people depend on one or more of the mangrove ecosystem services in Crab bay and 400 people in Eratap.

[4] Conversions of Ni-Vanuatu Vatu to US Dollar are based 2012 average exchange rate of 90 Vt for 1 US$.

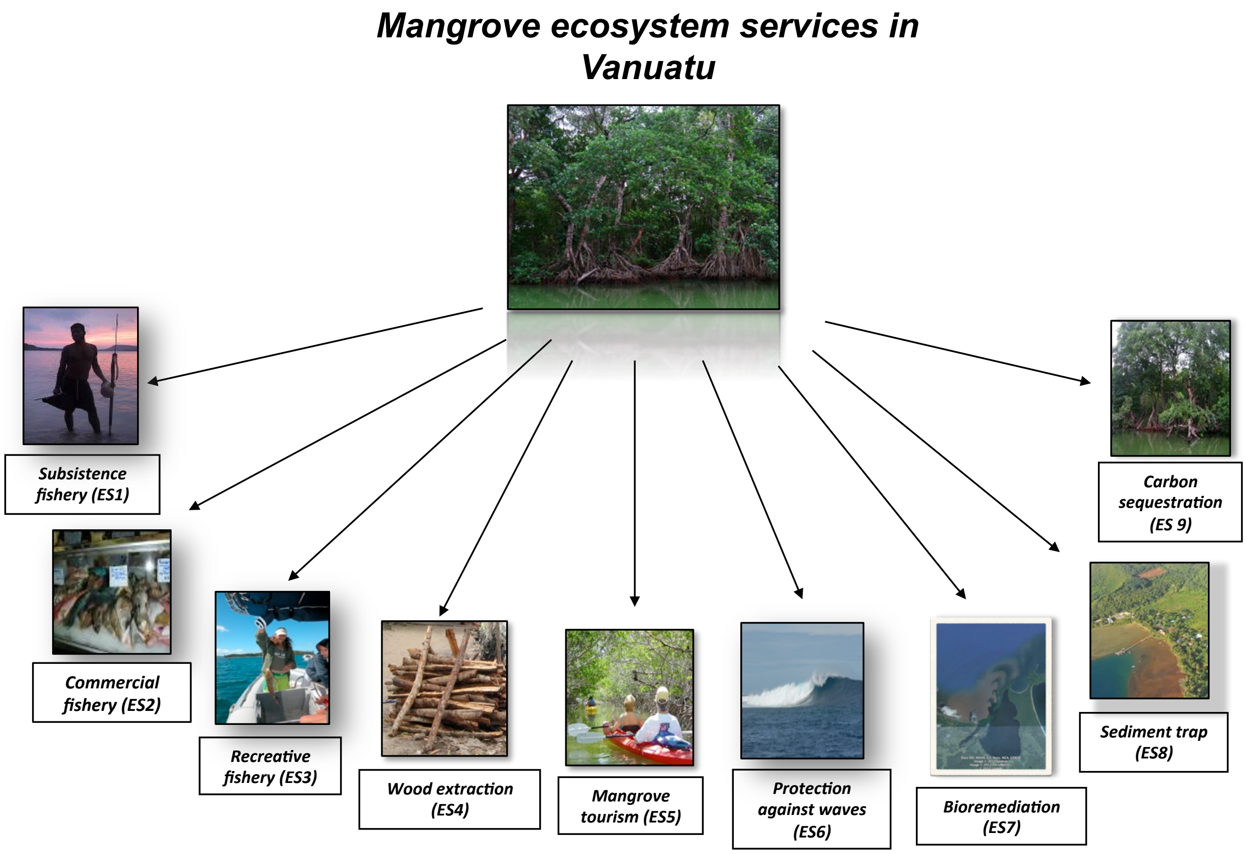

Figure 7: Mangrove ecosystem services in Vanuatu

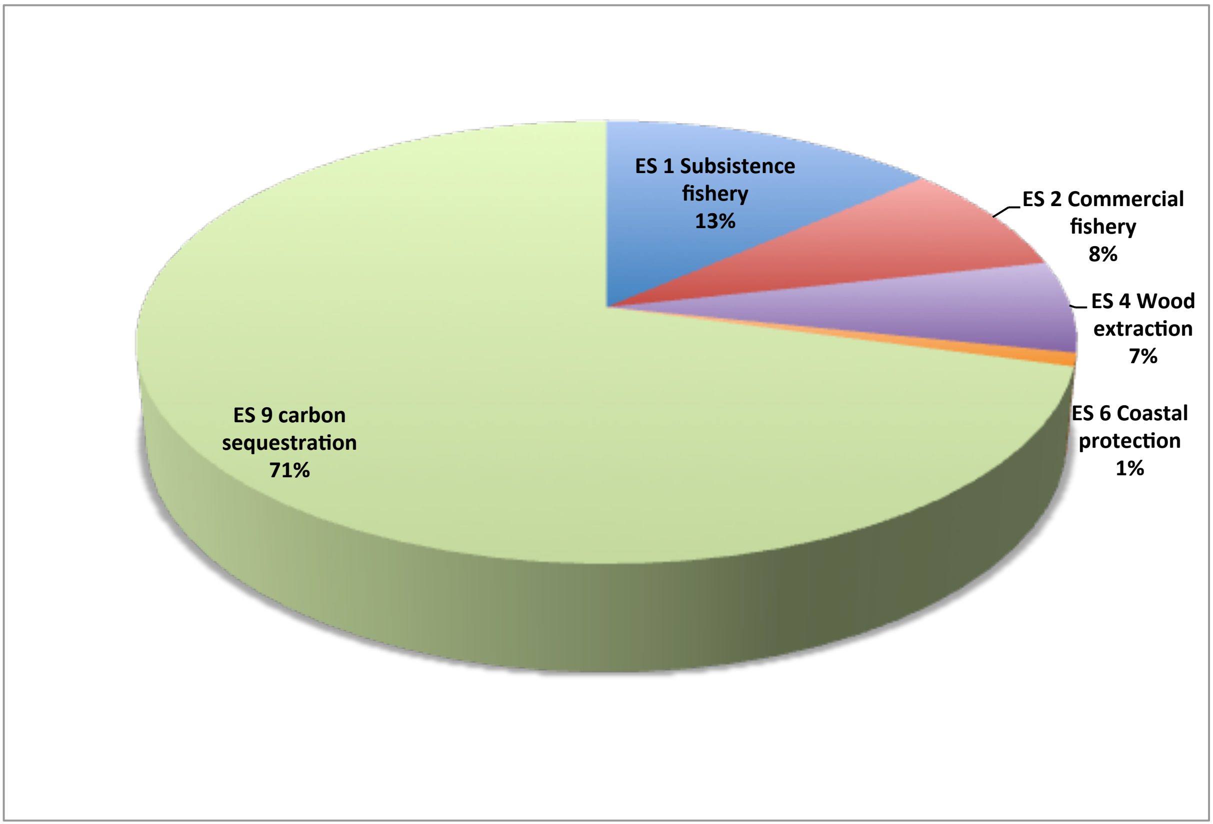

Figure 8: Distribution of ecosystem service valuation in Crab bay. 2012, total value estimated: Vt 53 M.

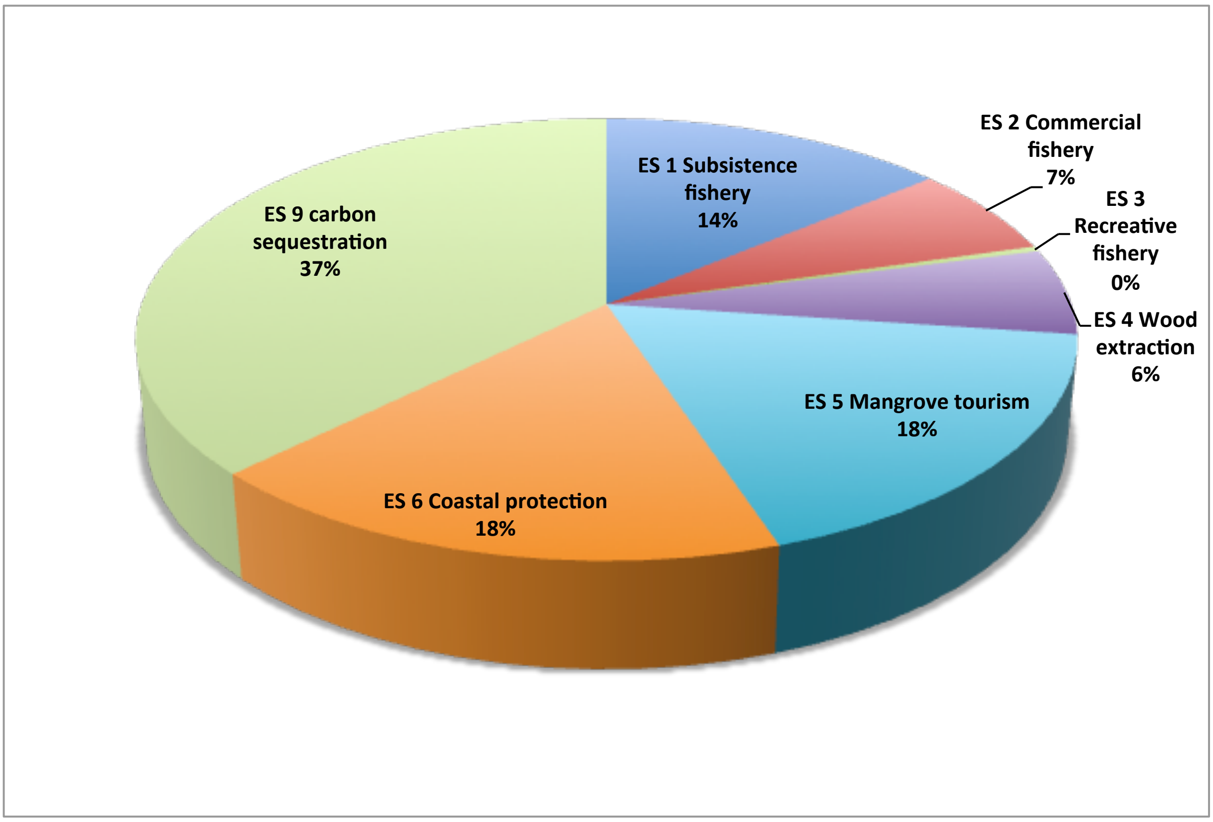

Figure 9: Distribution of ecosystem service valuation in Eratap. 2012, total value estimated: Vt 24 M.

The following table indicates the main results described in the next chapters:

$ us	Crab bay			Eratap		
	min	max	**average**	min	max	**average**
ES 1 Subsistence fishery	67 722	90 600	**79 161**	30 311	43 700	**37 006**
ES 2 Commercial fishery	32 933	61 633	**47 283**	10 344	24 756	**17 550**
ES 3 Recreative fishery	Service non-existant			800	1 200	**1 000**
ES 4 Wood extraction	27 467	51 000	**39 233**	11 778	21 867	**16 822**
ES 5 Mangrove tourism	Service inexistant			35 378	58 967	**47 172**
ES 6 Coastal protection	4 156	7 133	**5 644**	34 833	59 722	**47 278**
ES 7 bioremediation	Service almost negligible			Service almost negligible		
ES 8 sediment trap	Service almost negligible			Service almost negligible		
ES 9 carbon sequestration	265 489	563 333	**414 411**	68 922	130 000	**99 461**
Total	397 767	773 700	**585 733**	192 367	340 211	**266 289**
	2 914	5 668	**4 291**	6 166	10 904	**8 535**

Table 1: Economic valuation of ecosystem services of Crab bay and Eratap mangroves in 2012, Vatu.

Beneficiaries:

An important result of the study is the identification of social groups beneficiaries of ecosystem services in Crab bay and Eratap. The figure below summarizes this. The main beneficiaries are:

- Fishermen of the commercial artisanal fishery (300 in Crab bay and 50 in Eratap)
- Local families for whom fishing in the mangrove and in the reef is a source of regular protein (160 households in Crab bay and 80 households in Eratap)
- Local families benefiting from firewood and construction material (150 households in Crab bay and 45 in Eratap)
- Tourism entrepreneurs in Eratap proposing mangrove tourism (2 businesses, 800 tourists a year)
- Real estate owners protected from coastal flooding (2 tourism resorts in Eratap> 3 000 m2) as well as plantation owners (300 ha in Crab bay)
- The global community to benefit from carbon sequestration and biodiversity.

- Tourism entrepreneurs in Eratap whose business depends on the quality of water of the lagoon as well as beach formation (2 businesses, 21 jobs, 11 500 tourists a year)[5].

In total, nearly 800 people depend on one or more of the mangrove ecosystem services in Crab bay and 400 in Eratap.

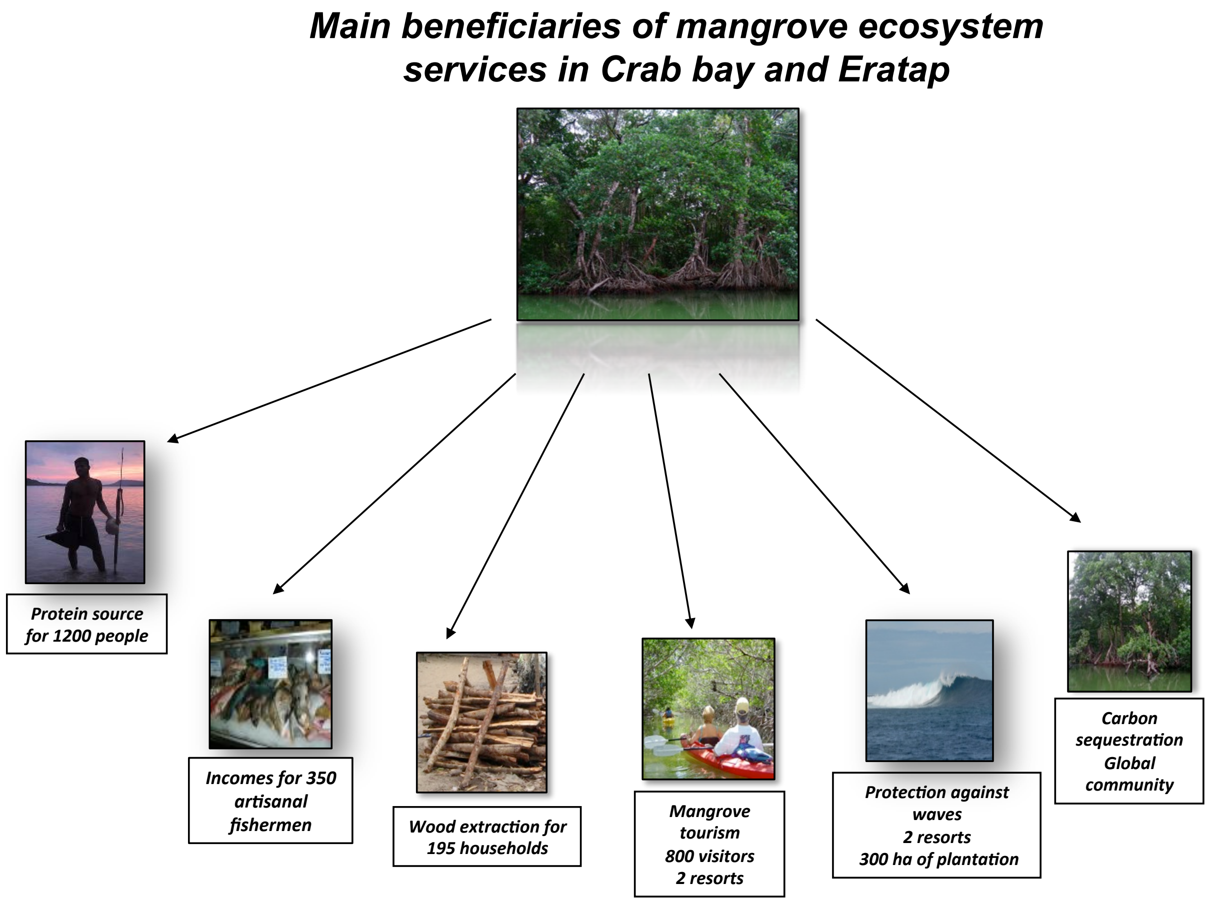

Figure 10: Main beneficiaries of mangrove ecosystems in Crab bay and Eratap

COMPARISON OF RESULTS WITH OTHER STUDIES

[5] The exact relationships between mangroves ecosystem processes and the benefits of clean water for recreative use has to be better studied. We mentioned it in the present work as a potential benefit but was not valued.

In the following table we have compared results per ecosystem service with other studies of economic valuation of mangrove ecosystem services. We based this approach on the outputs of 2 meta-analysis conducted by Brander et al (2012) and Salem & Mercer (2012) on 41 and 44 studies of mangrove economic valuation respectively. For both, most of the studies have been conducted in SE Asia and the majority of values concern direct and indirect uses. All values have been converted to values per hectare of mangrove in 2010 international dollar using PPP conversion factors (c= 39.81) taken from the Penn World Table of 2011 (Heston et al., 2011).

Except for coastal protection in Eratap and carbon sequestration, most of the values of mangrove ES in Crab bay and Eratap are in the lower-end of the range of results from the meta-analysis. The context of low-development of commercial fishery and mangrove tourism as well as the low density of constructions on the shore may be one of the explaining factors of this observation.

For coastal protection ES in Eratap, values are slightly above the average values from meta-analysis and reflect the presence of the resorts protected by the mangroves.

For carbon sequestration ES, the values are above the maximum value from meta-analysis and may be explained by two aspects:

(i) Carbon markets have changed during the last 10 years with the development and consolidation of calculations of carbon sequestration volumes and voluntary credits;

(ii) We have reflected the whole value of carbon sequestered in the upper part of the soil of mangroves whereas some studies may valuate only the avoided amount of carbon released in the atmosphere.

Int. $US/ha (2010)	Crab bay			Eratap			Values from meta-analysis *		
	min	max	**average**	min	max	**average**	min	max	**average**
ES 1 Subsistence fishery	1 122	1 501	**1 311**	2 196	3 166	**2 681**	10	555 168	**26 613**
ES 2 Commercial fishery	545	1 021	**783**	750	1 794	**1 272**	10	555 168	**26 613**
ES 3 Recreative fishery	Service non-existant			58	87	**72**			
ES 4 Wood extraction	455	845	**650**	853	1 584	**1 219**			
ES 5 Mangrove tourism	Service non-existant			2 563	4 273	**3 418**	1	507 368	**37 927**
ES 6 Coastal protection	69	118	**93**	2 524	4 327	**3 426**	10	8 044	**3 116**
ES 7 bioremediation	Service almost negligible			Service almost negligible					
ES 8 sediment trap	Service almost negligible			Service almost negligible					
ES 9 carbon sequestration	4 397	9 330	**6 864**	4 994	9 420	**7 207**	40	4 265	**967**

Table 2: Comparison of values per hectare of ecosystem services of Crab bay and Eratap mangroves with other studies. (Int. $US, 2010 PPP). *Meta-analysis consulted are (Brander et al., 2012; Salem and Mercer, 2012)

SUBSISTENCE AND COMMERCIAL FISHERY ECOSYSTEM SERVICE (ES1 AND ES2)

Implicated ecosystem processes:

Several ecosystem processes of the mangroves are identified in the service of fishery production. We distinguish mainly the process of biomass production and the maintenance of habitat complexity, nursery role and ecosystems connectivity.

Therefore, 2 fisheries received benefits from one or several of the ecosystem processes: the crab fishery and the reef fish fishery.

In Crab bay, the reef fishery occurs mainly in the part of the bay that is opened to fishery and outside of the bay (barrier reef). Based on fish biological assessment (Hickey, 2007), it was found that almost all the target species caught by the Crab bay villages spend a part of their life cycle in the mangroves (as a nursery, a spawning site, a shelter or for food).

A contributing factor comprised between 30 and 40% was applied to the added value of the reef fishery. This factor was estimated through expert opinions (Planes S., Galzin R., pers. comm.) and a review of the scientific literature (Barbier, 2007b; Barbier and Strand, 1998; Friedlander and Cesar, 2004; Harrison et al., 2012; Hixon and Beets, 1993; Holmlund and Hammer, 1999; Ronnback, 1999; Ruitenbeek, 1994; Walters et al., 2008). In particular, the results of Barbier[6] (2007) gave us some quantitative insights about the relationships between mangrove habitat and reef fish production. The factor is based on a combination of selected geomorphologic factors (connectivity between ecosystems, mangrove size, reef type, mean depth, main currents) and biotic variables (fish species, mangrove species, reef complexity).

In Eratap, the reef fishery concerns activities on the fringing reef and barrier reef. One principal aspect of Eratap is that the configuration of the bay where the mangroves are, reduces the connectivity between reef and mangroves. Connection between both ecosystems occurs in a reduced number of shallow and narrow channels. Combined with the other factors described before, a mangrove-contributing factor comprised between 10 to 15% was applied to the added value of reef fishery.

The 3 species of crabs (*Cardisoma carnifex, C. hirtipes* and *Scylla serrata*) are directly related to the existence of the mangrove. *Cardisoma* use the mangrove habitats during their ontogenic migrations and

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[6] The study modelised a mangrove-shrimp fishery linkages with a standard bioeconomic fishery model. It accounts explicitly for the effect of a change in mangrove habitat area on carrying capacity and thus production of fishery in Mexico. One of the results is that a 0,23% annual reduction in mangrove habitat may have generated a 0.4% loss in fishery revenues.

during spawning. Some studies have shown that juveniles use directly the mangrove leaf litter as a food source (Hickey, 2007). The mangroves represent the main habitat for the adult mud crab (*Scylla serrata)*.

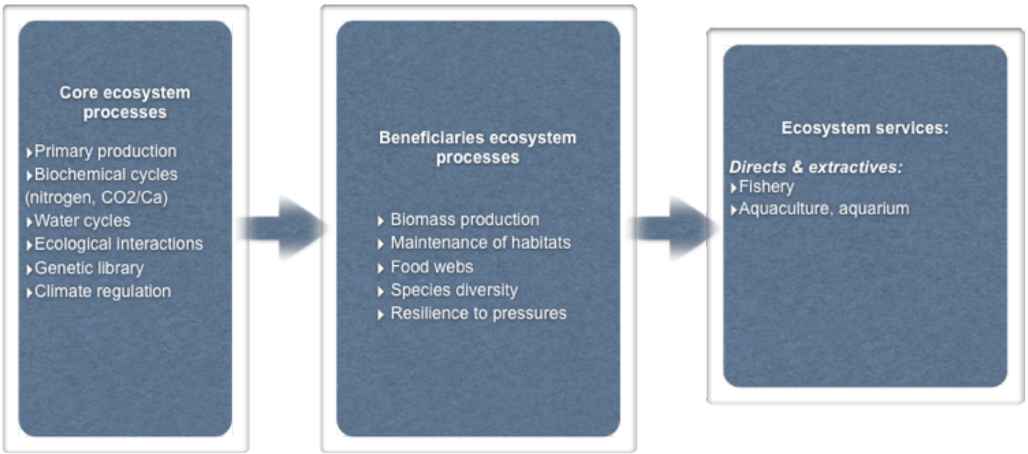

Figure 11: Main ecosystem processes implicated in the fishery ES

DESCRIPTION OF FISHERY:

For reef fisheries, the 3 main gears in terms of fish catches are the gillnets[7], hand lines (from the shore or canoe) and the spearguns[8]. The frequency of use of the fishing gears and their distribution amongst households vary between the sites (next table).

[7] The gillnets are used principally in the form of circle nets. A fishing trip is composed of 2 to 3 fishermen and up to 50 m length of nets. The nets are used to surround groups of fish in depths cof 3 to 10 m. They can repeat several times this action without moving the nets or nets can be set up in a new location. Depending on water conditions and fish catches, a fishing trip can last from 1 to 5 hours. Nets are monofilament gillnets with 3-inch diagonal mesh.

[8] These gears usually target coral reef species such as Scaridae sp., Acanthruridae sp. and Serranidae sp. Some other gears used on an irregular basis are: cast nets (depending on the migration of some species), hand collecting (common at low tide efficient for Octopus sp. and shells) as well as some other traditional gears (e.g. hand spear).

% of total households surveyed	Use canoe	Spear gun at day	Spear gun at night	Cast net	Reef net	HandLine	Boat with engine
Eratap (average)	45%	15%	24%	18%	33%	80%	3%
Crab bay (average)	29%	20%	15%	13%	45%	65%	4%

Table 3: Fishing gears distribution (% of total households surveyed, Eratap: n= 30, Crab bay, n=112).

Few fishing activities are conducted by women (hand collecting and handline from the shore principally).

In Crab bay, reef fishing activity is well spread with 25% of households doing at least 3 fishing trips per week and 50 to 60% of the households doing 1 fishing trip per week on average. Reef fishery corresponds mainly to a subsistence activity with less than 15% of the households (concentrated in 2 and 3 villages) selling their catches to a wholesaler (coming from the villages generally) or directly to the market in Lakatoro. The fundraising activities, when people sell prepared meals or fresh fish in their village to raise funds for community events or specific family events (weddings, school fees, etc.) were considered as subsistence activities because of the low price of transactions (less than 100 vatu per ration of cooked fish). Fundraising activities occur on a sporadic frequency depending on the context (e.g. school calendar). Annual catches of reef fish were estimated between 28t and 41t for all the 15 villages surveyed in Crab bay[9]. Catches vary from 300 to 4 000 kg per year depending on the village size and fishing effort. These results are coherent with qualitative estimates of fishing efforts of previous studies (Hickey, 2007). Approx. 75% of the total catch was consumed which is equivalent to an annual consumption of fresh fish of 17 kg per capita. Recent studies have found that the level of consumption of fresh seafood vary between 16 and 26 kg per year per capita in Vanuatu (Bell et al., 2009b; Pascal, 2011{Vanuatu National Statistics Office , 2008 #1)

In Eratap, reef fishing activity is also well spread with 10% of households doing at least 3 fishing trips per week and 30 to 50% of the households doing 1 fishing trip per week (in average). It was estimated that 25 to 30% of the households realised regular or sporadic sales of fish to a wholesaler or to the market in Vila. As well, sales in the villages through local bars ("nakamals") are increasing and reflect the progressive introduction of market economy in the villages. Prices in the nakamals are similar to market price in Vila (400 to 500 Vt per rope equivalent to 570- 700 Vt per kg). In the same way, prepared meals with fish

[9] Based on CPUEs estimates of the surveys (average number of fish per fishing trip) and converted in kg using an average weight of 0,3 kg per fish (Kronen, M., 2007. Monetary and non-monetary values of small-scale fisheries in Pacific Island countries. SPC Women in Fisheries Information Bulletin #16 – March 2007.(Pascal, N., 2011. Cost-Benefit analysis of community-based marine protected areas: 5 case studies in Vanuatu, South Pacific. Research report, CRISP-CRIOBE (EPHE/CNRS), Moorea, French Polynesia, 107pp.

("laplap", rice, etc.) are sold also in the market. The market price per ration (250-300 Vt) gives a very similar price than for fresh fish per kilo[10]. The practice of fundraising is less spread than in Crab bay. Based on the survey results (questions 3,4 and 6 of the fishery surveys), annual catches of reef fish were estimated between 12t and 20t for the whole of Eratap. Approx. 60% of the total catches were consumed which is equivalent to an annual consumption of fresh fish of 9.6 kg per capita (lesser than the estimates of consumption of fresh seafood per capita in Vanuatu (Bell et al., 2009b; Pascal, 2011)

In Crab bay, most of the households (80%) collect white and black crabs (*Cardisoma carnifex and C. hirtipes*) at some time of the year in the mangroves (frequency of fishing trips seems independent of the crab season). It is an activity shared by all the members of the family. They usually walk (85% of the households) and fish at low tide or use a canoe to reach some distant mangroves. Similar to fish, it corresponds mainly to a subsistence activity (approx. 70% of the catches are consumed with an average of 10.4 meals with crabs per month per household). Commercial sales are done on a very irregular base when catches exceeded the basic needs of the families. The main channel of distribution is to sell them directly in the market of Lakatoro at an average price of 20vt per unit. Based on the surveys results (questions 6, 7 and 12 of the household surveys), approximately between 135 000 and 250 000 crabs were estimated[11] to be collected every year in Crab bay (equivalent to 31 t and 57 t per year). This level of catches represents an annual consumption of approx. 8.9 kg of fresh seafood per capita per year[12]. Summing with reef fish consumption (approx. 26 kg per capita per year in total) we would be in the upper band of the annual estimates (30 kg per capita per year in rural zones. (Bell et al., 2009b; Kronen et al., 2010; Pascal, 2011)). Considering the level of uncertainties and approximations in these figures as well as the fact that we are working for some studies with national figures, we consider these estimates as valid.

For mud crab, we found that an important part of the catches (between 60 to 80%) in Crab bay was sold in the local market, to wholesalers or exported by plane to the Port Vila market. Even if not specifically targeted by the surveys, it seems that almost 40% of the households have been implicated in the fishing

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[10] The "usual" ration of prepared fish with rice and complements was estimated to an equivalent of 300g of fresh fish. On the base of a 300 vt selling price and discounting the costs of ingredients (estimated at 70 vt per ration) the price equivalent is 760 vt per kg of fresh fish.

[11] Based on estimates of declared number of fishing trip during crab and non crab season, average catches per trip and average consumption of crab per week per household.

[12] Based on a conversion between total weight of adult crabs (mean 230g per unit) and comestible part (35%). Kronen, M., 2007. Monetary and non-monetary values of small-scale fisheries in Pacific Island countries. SPC Women in Fisheries Information Bulletin #16 – March 2007.

effort at different degrees (from regular to very opportunistic fishery). No household depends on the mud crab fishery for more than 30% of their weekly cash needs. Final prices vary from 200 Vt/kg to 1000 Vt/kg depending on the place of selling (Port Vila being the most expensive). Intermediary costs of this fishery are mainly in transport and distribution (200 Vt per kg to export them to Vila). Based on the survey results (questions 6,7 and 12 of the household surveys), it was estimated an approximate number between 1900 and 3700 crabs caught every year in Crab bay .

In Eratap, a small part of the households (between 10 and 20%) collect white and black crabs (*Cardisoma carnifex and C. hirtipes*). It is an activity shared by all the members of the family but dominated by the parents (the new generation has shown a low interest in crab collection). Similar to fish, it corresponds mainly to a subsistence activity (approx. 80% of the catches are consumed with an average of 6 meals with crabs per month per household). Sales are done in the villages through the nakamals or during fundraisings. Based on the survey results (questions 6,7 and 12 of the household surveys), approximately between 85 000 and 150 000 crabs were estimated to be collected every year in Eratap (equivalent to 19.5 t and 34.5 t per year). This level of catches represents an annual consumption of approx. 7.1 kg of fresh seafood per capita per year[13].

For mud crab, we found that most of the catches (between 80 to 90%) were sold in the Port Vila market or to wholesalers. No household depended on the mud crab fishery for more than 20% of their weekly cash needs. Final prices vary from 800 Vt/kg to 1000 Vt/kg depending on the place of selling (Port Vila being the most expensive). Based on the survey results (questions 6,7 and 12 of the household surveys), it was estimated an approximate number between 500 and 1400 crabs caught every year in the Eratap zone.

Main trends

The perceived trend by Crab bay local people is a recent recovery of the crab stocks and stability in the fish production. In Eratap, the perceptions are more diffused with some preoccupation about overfishing and access conflicts due to demographic pressure of recent settlements.

Social importance and economic value of ES1 and ES2:

Approximately 800 persons have been implicated in some form of crab collection and reef fishing (for subsistence mainly) in Crab bay in 2012. In Eratap, the number was close to 400 persons.

[13] See previous footnote

Ecosystem service of subsistence catches (ES1) has represented a protein equivalent value[14] comprised between Vt 6 and Vt 8 M (equivalent to approx. US$ 68k and US$ 91k)[15]in 2012 for Crab bay. Protein from crab fishery represents 40% of this value.

In Eratap, the value of ES1 is comprised between Vt 2.8 and 4 M in 2012 (equivalent to approx. US$ 30k and US$ 43k). The crab catches have represented 80% approx. of this value.

Ecosystem service of artisanal commercial fishery (ES2) in Crab bay has produced an added value comprised between Vt 3M and 5.6M in 2012 (equivalent to US$ 33 k and US$ 62 k). Crab fishery generated 80% of this value (50% from mud crab).

In Eratap, the added value of ES2 was estimated between Vt 0.9M and 2.2M ($US 10k and US$ 25k) for 2012. Crab fishery represented 90% with a similar distribution between *Cardisoma* and mud crab fishery.

As described in the method annex and highlighted in Laurans et al (Laurans et al., 2013), this valuation does not reflect some important advantages of subsistence and artisanal commercial coastal fishery (ES1 and ES2) for local populations. Some of them are: (i) the fishing activity needs low requirement of investment and training (SPREP, 2007), (ii) it can be a factor of social cohesion in villages because it contributes to maintain the women in the villages instead of seeking a cash income outside (Bensa and Freyss, 1994), (iii) for some household the part of the protein obtained from fishing in the total diet is non-replaceable (Pollnac et al., 2000) and, (iv) fishing is a stable food source against future uncertainties and a way to spread alimentary risks (Johannes, 2002).

To reflect these benefits of the subsistence fishery, we applied a weight-correcting factor of 1.3 on the results of added value of ES1 and a similar multiplier for ES2 (Seidl et al., 2011).

We obtained that ES1 and ES 2 were equivalent to Vt 9.2 M and Vt 5.5 M ($US 103k and $US 61k) in 2012 in Crab bay. In Eratap, ES 1 has represented Vt 4.3 M and ES 2 an added value of Vt 2.1 M ($US 48k and $US 23). The following table presents the main results:

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[14] Conversion of kg of fresh seafood into protein content following protein table of Ramseyer Ramseyer, L.J., 2000. Predicting whole-fish nitrogen content from fish wet weight using regression analysis,. N. Am. J. Aquac. 64: 195–204.. Price is equivalent to the protein price of the canned tuna (in oil) provided by the the Vanuatu Statistics Office (average price of 555 vt/kg). Results give a price of 390 Vt/kg of reef fish and 132 Vt/kg of cardisoma crabs (both are not so different from current market prices).

[15] Conversions of Ni-Vanuatu Vatu to US Dollar are based on a 2012 average exchange rate of 90 Vt for 1 US$.

Vatu, 2012	ES 1		ES 2	
	min	max	min	max
Crab bay	7 920 000	10 600 000	3 850 000	7 210 000
Eratap	3 550 000	5 110 000	1 210 000	2 900 000

Table 4: Added value of ES 1 and ES2 (in Vatu, results truncated at 10^3 for easy reading).

Geographic distribution:

The following maps describe the fishing grounds of both sites. These maps were drawn based on information from focus group with fishermen in Eratap and Crab bay.

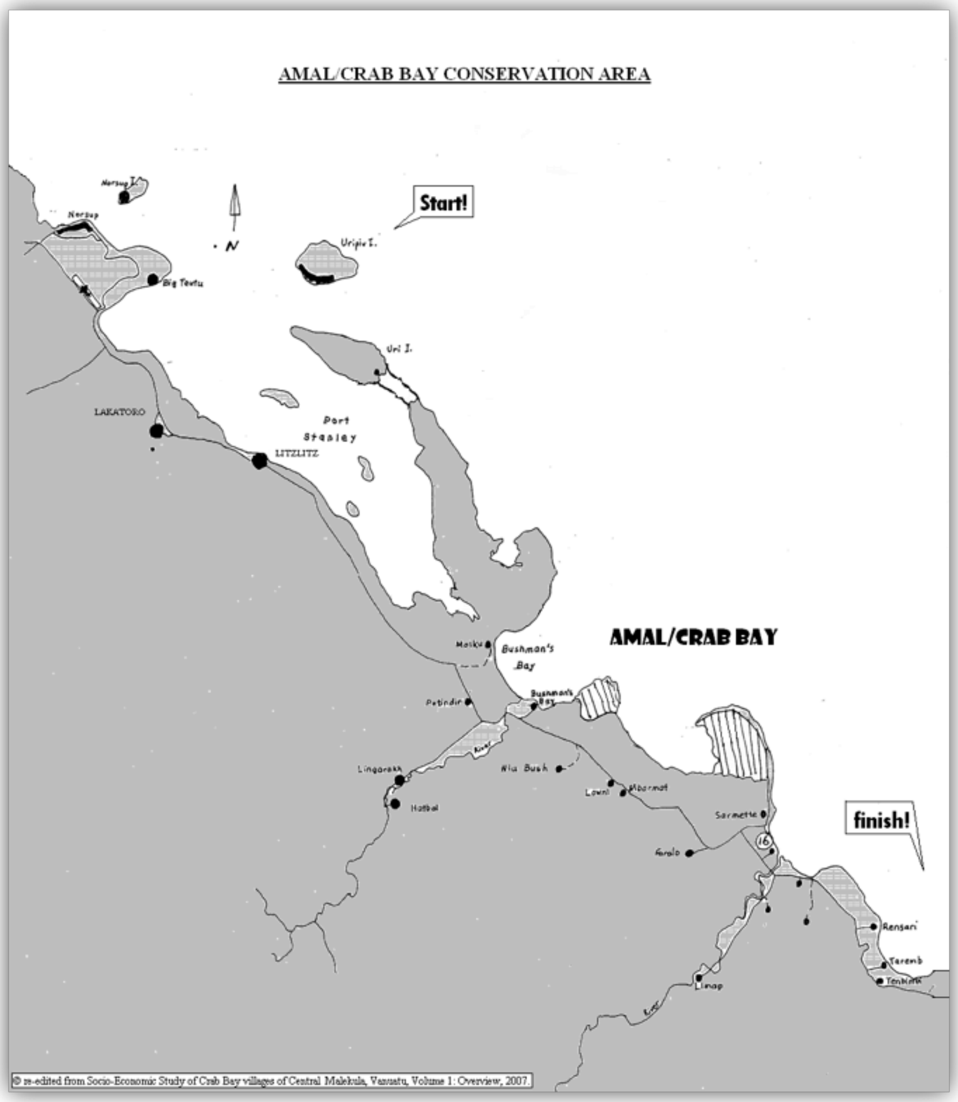

Figure 12: Crab bay fishing ground areas (dashed zones)

ERATAP FISHING ZONES

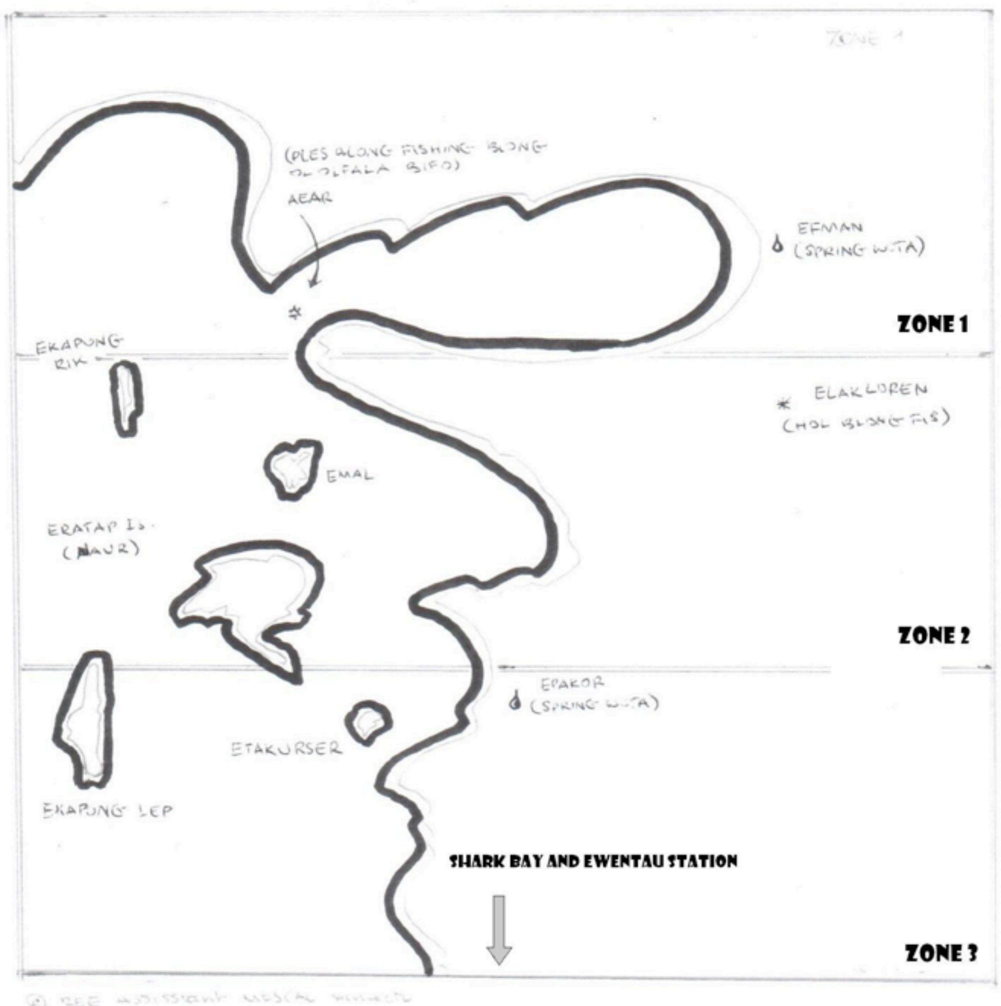

Figure 13: Eratap fishing ground areas

RECREATIVE FISHERY (ES3)

No significant recreational fishery (commercial and non commercial) was observed in Eratap . Most of sport fishermen and sport fishery private businesses (based in Port Vila) usually go fishing to the North area for different reasons (currents, wind protection and proximity).

For sport fishery, only one activity was reported in 2012 in the Eratap area. It is one of the sets of activities proposed by one of the resorts. Most activities are realised on the outside of the barrier reef and main targets are pelagic fishes (*Scombridae sp.* and *Coryphaena sp.)*. In 2012, less than 60 fishing trips have been reported for a total fee of Vt 360k. A similar contributing factor for mangrove was applied to this figure to reflect the role of ecosystem processes of mangroves.

WOOD EXTRACTION (ES4):

DESCRIPTION:

The mangrove trees can be useful in a lot of different ways. The trunks are mainly used for house posts, fencing, firewood[16] and in some places as a gardening tool. The branches are also used for firewood and small hooks that some people cut and use to capture mud crabs. The leaves are used as bait for serwok (small pointy shells) and crabs, and also for medicinal purposes as indicated by the villagers[17]. Traditional medicine practices seems however to be rapidly dying out.

Majority of these villages use the big stems for housing posts and rails (i.e. supports crossing each other and/or running parallel to and from the main frames of the constructed roof) more than any of the other uses. The wood is really strong and long lasting and doesn't have to be changed for a long time.

The surveys conducted in Crab bay have revealed (question 3, 6 and 7 of mangrove survey) the following results:

On average, for all the villages, mangrove dry wood for firewood is collected by most of the households. Nonetheless the frequency is quite low with trips to mangrove to collect dry wood once every 150 days (results vary from 1 fortnight to 1 year depending on the villages). On average, 5 bundles of wood are

[16] Mangrove wood's clean burning properties make it suitable for cooking in wet weather

[17] Communication about these practices are taboo and cannot be revealed to just anyone

collected per trip. Uri, Uripiv, Lowni and Hatbol villages show the highest use of firewood but the volumes, on an annual scale, are still reduced (equivalent to 6 bundles per month per household). Elsewhere it was used occasionally or not at all.

For other uses (house and fencing posts, gardening and marking), we observed a widespread use amongst households of the following villages: Uri, Uripiv, Lingaharak, Tevisi (TFC), Portindir, Losarsar and Hatbo. Nonetheless, as explained before, the longevity of the wood contributes to low frequency of collection. In average the last trip to mangroves for house post was 400 days before, 930 days before for fencing posts and 380 days for gardening posts. Mean number of bundles in each trip is around 13. For villages implicated in these uses, we calculated an average trip to mangrove of 0.6 bundles per month per household.

In Eratap, the mangroves are hardly used for housing or firewood because the people have alternative, much better resources. For firewood, the settlements of Etpup, Etas, Elak and Elan are the only villages reporting a regular use of mangrove wood (every 2 months on average for 2 or 3 bundles per household). The other use reported is for house posts in Etpup and Nanru (every 450 days for 8 bundles per household or 6.4 bundle per month per household).

One other use that is rapidly dying out is the traditional medicine practices derived from the mangroves. Which part of the tree they use is a mystery as that information is sacred to the tribe and only a few people in some of the villages have knowledge of it while others can only remember stories being told of their elders using it long ago.

The relative low use of mangrove wood in Crab bay differed from another study conducted in the same area in 2004 (Vanuatu Environment Unit, 2007). This may be explained by the progressive introduction of alternative sources of cooking in the last 8 years (gas), changes in the family behaviour and different survey protocols.

Social importance and economic value:

With an average equivalent price and added value of 200 Vt per bundle of mangrove firewood and a replacement cost of 850 Vt per bundle of house and fence posts[18], the ES4 was calculated.

In Crab bay, we estimated that 150 households received benefits with some regularity of mangrove wood for fire with an annual value equivalent to Vt 2.1 M. 240 households have used mangrove wood or other

[18] Based on market price of construction material retailers for equivalent posts in cement or other material.

uses (house and fence posts mainly) for an annual value of Vt 1.4M. In total for 2012, we estimated a value for ES 4 comprised between Vt 2.5M and 4.6 M ($US 28 k and $US 51k).

In Eratap, we estimated that 45 households received benefits with some regularity of mangrove wood for fire with an annual value equivalent to Vt 160k. Less than 25 households have used mangrove wood for other uses (house and fence posts mainly) for an annual value of Vt 1.3M. In total for 2012, we estimated a value for ES 4 in Eratap comprised between Vt 1M and 1.9 M ($US 12 k and $US 22k).

TOURISM ACTIVITIES (ES 5)

DESCRIPTION

In Crab bay, no rural tourism activities have been observed in the villages. Apart from some scientific tourism (in 2009 and 2010), the usual tourism activities (day tours, snorkel tours, guesthouses) are not developed in the villages. In Malekula this may be explained by the fact that neither tour operators, nor tourism resort is present in the zone. Scientific tourism represents the visits from researchers, NGOs members or other professionals. It takes usually the form of payment for food and accommodation on sporadic visits. Some of the visits implicate long-term residence in a village or in a research station (e.g. Crab bay).

2 resorts are present in the Eratap bay. The Eratap Beach Resort and the Aquana Beach Resort (opened in 2011). They comprise 19 and 40 beds respectively.

The main guests are from Australia and the average length of visit is 4 to 6 days. Local residents (mainly from the expatriate community) visit the restaurant and the beach during the weekends. The observed occupancy rate are within the tourism standard (between 55 and 65%) equivalent to a total of 10 300 guests in the 2 resorts in 2012. If we add residents coming to the restaurant and spend the day on the beach we get a total of 11 500 visitors in 2012.

The main attractions are the beach, natural environment, relaxation and the restaurant. Some activities are directly related to the coral reefs (snorkelling tour, boating, kayaking) and mangroves (kayaking). No guided tours in the mangroves have been observed. In Eratap, some day tour activities occur. They correspond to visitors coming from the neighbouring resorts to spend part of the day in the village.

All the scuba diving clubs (3) are based in or near Port-Vila city. The most frequented scuba diving sites are close to the capital (time to access less than 1 hour by boat) and none of them is close to Eratap zone.

Social importance and economic value:

Based on interviews with resort managers and neighbouring villages, we estimated that 5 to 10% of the guests have visited the mangrove during their stay in 2012 (equivalent to 800 persons and 1100 visits in the mangrove).

To determine the proportion of expenses of these visitors that may be attributed to mangroves, we need to evaluate the role of mangroves as a marketing argument in the communication strategy of the resorts.

As confirmed by resort managers, the presence of mangroves is not one of the decisive reasons why visitors have chosen the resorts. In the same way, the analysis of advertising images and description of the resorts highlight that very few references are made to mangrove ecosystems. Even if differences exist between both resorts (e.g. one mentions more the "nature environment" than the other) the main marketing strategy is based mainly on comfort, tranquillity, beaches, coral reef and village tours.

Based on other studies about coral reef tourism (Brander et al., 2007; Ghermandi and Nunes, 2011; Hampton, 1998; McElroy, 2003) and mangrove tourism (Bann, 1997; Brander et al., 2012; Conservation International, 2008; Sathirathai and Barbier., 2001), we considered that 3% to 5% of the associated expenses of the mangrove visitors would be attributable to the mangrove ecosystems (mangrove_contributing factor described in the annex). In 2012, this added value was estimated between Vt 3.2M and 5.3M.

Vanuatu has a tourism market niche[19] that may correspond to the Eratap site. Therefore a potential development of rural tourism would be possible if certain conditions are met (access, infrastructures, business capacities, etc) (VTO pers. comm.). In the same way, the number of visitors in Eratap was expected to increase after the improvement of the main road and access to all the villages in the study zone. This huge public work through the Millennium Challenge Account was completed in mid 2010 but effects have not been visible in our research (2012).

[19] The main attractions of Vanuatu rural tourism (VTO pers. Comm..) consist of : (i) nature (volcanoes, sites of natural beauty such as volcanoes, cascades, forests, beaches, coral reef and sites with specific attributes: turtle spawning places, fish biodiversity, emblematic species presence…) (ii) culture: the different lifestyles and languages constitute one important asset for tourism (iii) adventure: bushwalking, treks, discovery of custom sites, dancing grounds, volcanoes, scuba diving, etc.

COASTAL PROTECTION AGAINST FLOOD (ES 6)

Implicated ecosystem processes:

The mangroves are natural barriers against coastal flooding. They limit the phenomenon of coastal flooding by absorbing wave energy and lessening the damage in case of severe weather events (hurricanes, tropical storms, etc.). An extended description of the implicated processes is given in the corresponding annex of the method for coastal protection.

Economic value:

As a reminder, the method to estimate avoided damages provided by mangroves is based on the following steps:

A. Identify coastal areas potentially at risk against the regime of coastal flooding events.

B. Determine the contribution of mangroves and other ecosystems in the coastal protection of the vulnerable areas.

C. Quantify and value the potential damage repair costs with a method of damage avoided costs:

   C.1. Characterization of the assets exposed to risk (3 categories of land use)

   C.2. Valuation of the total repair costs of direct and indirect tangible damages based on approximate values per land use category (object oriented data) and as a function of inundation depth (relative depth-damage function)

   C.3. Estimation of the probability of flood event per impact category.

A. ZONES AT RISK IN STUDY SITES.

In both sites, the GIS analysis of the sites has permitted to delineate the perimeter under risk of coastal flooding (next maps). Most of the villages in both sites present a similar pattern of people from villages living relatively high above the sea level. Due to the topography of the islands (volcanic with mountains), the villages are situated in the hills or quite far from the sea (see following maps). Neither village house nor infrastructure was found in the risk perimeter of Crab bay and Eratap.

Some crop plantations (coconuts) in the bay were identified as a potential flooding zone and represent 300 ha.

When analysing Eratap resorts, the situation is different. Due to market demand of beach access and sea-view, the 2 resorts are placed at sea level and in the 5m flooding zone.

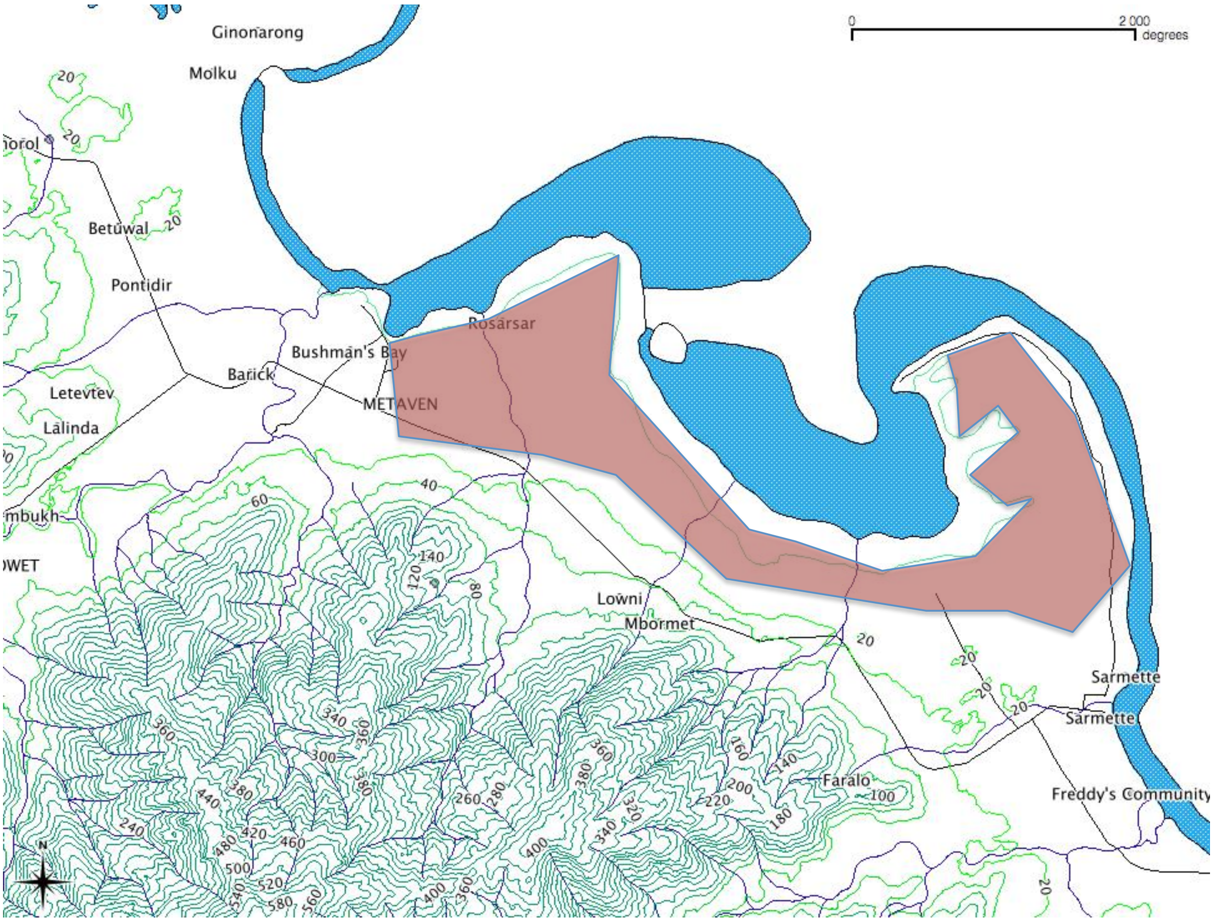

Figure 14: Crab bay, zone at risk for coastal flooding (red area).

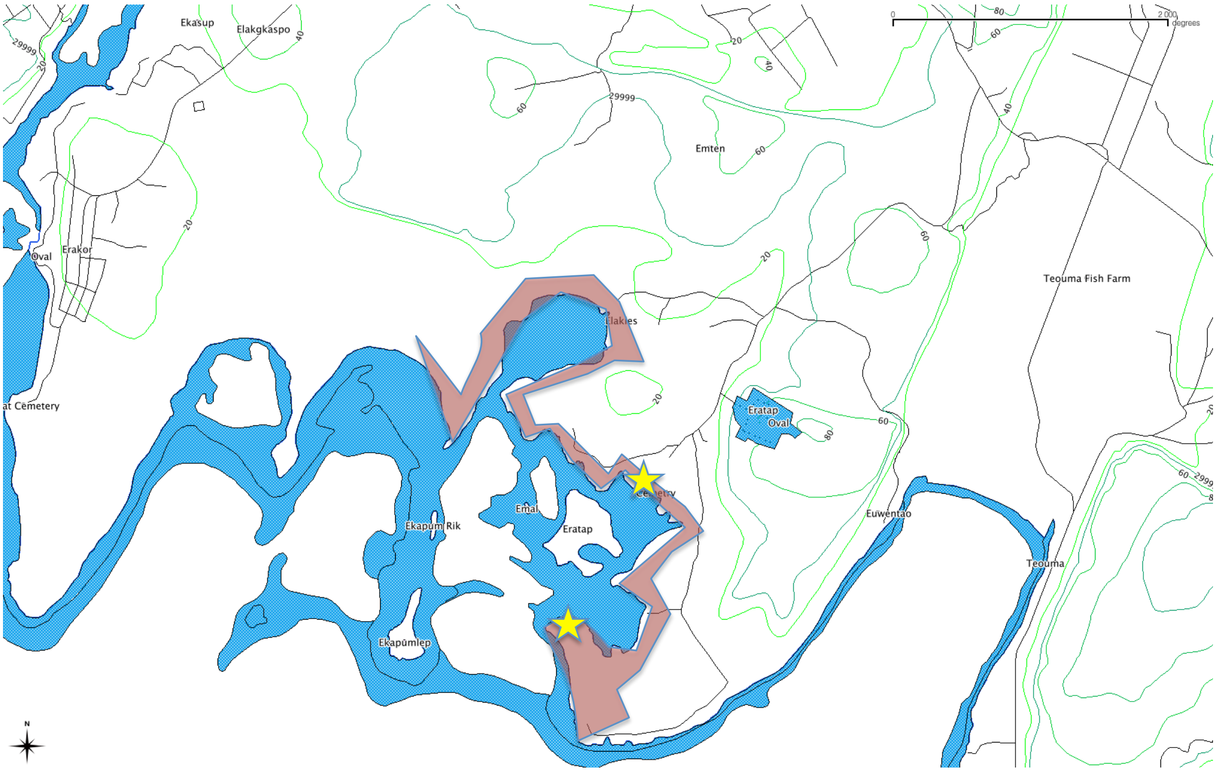

Figure 15: Eratap, zone at risk of coastal flooding (red area). Resorts are identified with a yellow star.

CONTRIBUTION OF MANGROVES AND OTHER ECOSYSTEMS IN THE COASTAL PROTECTION OF THE VULNERABLE AREAS.

The contribution of the mangrove in the coastal protection index of the areas has been estimated in Crab bay and Eratap. Based on several mapping sources of coastal geomorphology and bathymetry, the level of protection provided by different factors were categorized through GIS analysis (details in the method in annex, the sum-up table is recorded hereafter). In Eratap, we focused the analysis on 2 zones, each one containing one of the resorts (see previous figure). Eratap 1 is placed inside the bay with the resort1 (Aquana) and Eratap 2 is located in the entrance of the bay with resort 2 (Eratap Beach Resort)

	Very strong	Strong	Medium	Low	None
	5	4	3	2	1
Geomorphology	Rocky shore	Mix of rocks/sediments/mangroves	Mangroves	Sediments	Beaches
Coastal exposure	Protected bay	Semi-protected bay	Artificial reefs	Low protected bay or coast	No protection
Reef morphology, area and distance to the coast	Continuous barrier (>80%) close to the coast (<1km)	Continuous barrier (>50%) , patch reef, close to the coast (<1km)	Fringing reef (width >100 m)	Coral formation discontinuous	No reef
Inner slope, crest width	Very favorable conditions (gentle slope, large crest width)	Favorable conditions (slope, large crest width)	Favorable conditions (at least one component: slope, crest width)	Reduced favorable conditions (strong slope, reduced crest width)	None
Platform slope	6-10%	2.5-6%	1.1-2.5%	0.4-1.1%	< 0.4%
Mean depth (<1 km from the coastline)	> 30m	> 10 m	> 5m	< 5m	< 5m
Other ecosystems	mangroves, seagrass > 75% coastline	mangroves, seagrass > 50% coastline	mangroves, seagrass > 25% coastline	mangroves, seagrass <25% coastline, sand extraction areas	None

Table 5: The calculation of the CPI (Coastal Protection Index) based on characteristics of the coastline (developed by Allenbach and Pascal).

We observed in the next table that Crab bay and Eratap1 have a relatively high coastal protection index (CPI>2.5) due mainly to being located in a protected bay providing natural barriers against winds and extreme climatic events. The presence of an extended barrier reef in Crab bay coupled with an inner slope and shallow depth are the other main contributing factors. For Eratap 2, the low CPI reflects that the resort is exposed to coastal flooding and has low natural protection (mainly the platfom slope, the barrier reef and the shallow depth). The weight of the reef in the CPI varies from 30 to 40%. The weight of the mangrove is 24% and 10% for Crab bay and Eratap 1. Its value is very low for Eratap 2 (5%). It reflects that the mangroves are only present in a backward zone (inside the bay) that provides a very low barrier against coastal flooding for the resort.

	Crab bay	Eratap 1	Eratap 2
Geomorphology	3	1	1
Coastal exposure	5	5	2
Reef morphology, area and distance to the coast	5	4	3
Inner slope, crest width	5	2	2
Platform slope	3	2	3
Mean depth (<1 km from the coastline)	2	1	4
Other ecosystems	5	3	1
Coastal protection index	4,00	2,57	2,29
Reef contribution to coastal protection	40%	30%	30%
Mangrove contribution to coastal protection	30%	20%	10%
Relative importance of the mangrove in the costal protection index	**24%**	**10%**	**5%**

Table 6: Coastal protection index and relative contribution of mangroves

CHARACTERISATION OF DAMAGES AND ECONOMIC VALUATION (C1 AND C2 IN THE METHODOLOGY)

The results of the economic valuation are based on the determination of the exposure to risk factor of buildings and crops, the estimates of repairing costs or production loss from damage functions and the probability of the hazard.

In Crab bay, avoided damages from flooding come from crop protection. They are estimated to be approx. Vt 5M in total. When applying annual probability of hazard as well as the mangrove-contributing index, this value is approx. Vt 0.5 M per year.

In Eratap, the total avoided damages are estimated at a value of Vt 133M for the 2 resorts present in the bay. When applying annual probability of hazard as well as the mangrove-contributing index, this value is approx. Vt 4.5 M per year. This result represents the value of avoided damages from coastal flooding because of the presence of mangroves.

	Crab bay	*Eratap 1*	*Eratap 2*
Total annual value (ES 6)	534 600	3 243 240	1 235 520
Coastal protection index	4,0	2,6	2,3
Mangrove contribution to coastal protection	24%	10%	5%
Average damage costs	Vt 7100 per ha of coconut plantation	Vt 25000 per m2 of construction	
Probability of hazard event	44%	44%	44%

Table 7: Details of economic valuation of avoided damages from coastal flooding

BIO REMEDIATION OF WASTE WATER (ES 7)

Mangroves are genuine filters of wastewater and prevent the dispersion of pollutants into deeper waters before recirculation offshore (Herteman, 2010; Tam and Wong, 1993). The mangrove can therefore play the role of purifier and treatment of domestic wastewater under precise conditions (a more detail description is given in the annex).

In Crab bay and Eratap, all the village houses use individual septic tank without any connection to waste water pipes. Septic tanks are used for all formal developments along with ventilated improved pit and water seal type pit latrines. Therefore, no wastewater treatment (such as a decanter or buffer tank) is present in the villages.

Based on direct observations, no direct discharges of wastewater from villages or crops plantations have been observed in the mangroves or in the rivers. Nonetheless, the presence of plantations (coconuts, cacao) may be a source of additional input of nutrients (through fertilizers) via water runoff and phreatic connection.

Both resorts dispose of their own water treatment plant effluent. They have invested in well-dimensioned modern water treatment units that seem efficient in terms of nutrient recycling before discharging water in the environment (in the mangrove for one of the resorts and in the sea for the other one).

In Vanuatu, there is still no direct legislation or regulations governing sanitation. No government authority takes direct responsibility on sanitation facilities. So far, the potential role of mangroves as replacement of water treatment units is therefore very reduced.

In Crab bay, the low density of people living close to the mangroves involve a low discharge volume of wastewaters in the mangroves. The situation is different in Eratap with a higher density of people. The proximity to the streams discharging in the mangroves (see next figures in ES8) may increase the potential level of wastewater and contaminated waters flowing to the mangroves.

Precise data about stream flows and water quality were not available and we relied only on direct observations to assess the bio-remediation ES. In this sense, the quantification of the service was too approximate to be communicated and valued through replacement costs.

Nonetheless, we can conclude with the following statements:

- The ecosystem service of bioremediation seems very low in Crab bay due to the low input of nutrients.
- In Eratap, we consider that mangroves play a potential role as bioremediation for an unknown volume of nutrients.

- The reduced width and area of Eratap mangroves, 2 critical factors in the bioremediation processes, moderates the potential importance of this service.

SEDIMENT TRAP (ES 8)

Implicated ecosystem processes:

Mangroves provide a mechanism for trapping sediments and are an important sink of suspended sediment (Furukawa et al., 1997; Walters et al., 2008). The mangrove trees trap sediments by their complex root structure, thus functioning as land builders. In numerous cases, there has been proof of annual sedimentation rate in mangrove areas, ranging between 1 and 8 mm (Bird and Barson., 1977). They reduce tidal flows and induce sedimentation of soil particles at low tide, probably due to friction force.

The suspended sediment is introduced into coastal areas by river discharge, dumping of dredged material and re-suspension of bottom sediment by waves and ships.

The efficiency of sediment trapping varies with mangrove zones and species (Kathiresan, 2003; Wolanski, 1995). In some estuaries mangroves have been found to trap up to 40% of the riverine fine sediment (Furukawa et al., 1997; Victor et al., 2004) and play an important role in protecting fringing coral reefs from sedimentation.

A more detailed description of implicated ecosystem processes is given in the annex.

Description of the ES:

In Crab bay and Eratap, the ES8 is present due to the existence of streams discharging in the mangrove (see following maps). In Eratap, 3 streams and 1 river (Teouma) are identified by the Land department GIS data. In Crab Bay, 3 streams have been observed from the same data source. 2 of the streams were field verified in Crab bay and one in Eratap.

More precise data about stream flows and sediment charges was unavailable and we relied only on local community knowledge to assess the role of ecosystem process in sediment trap.

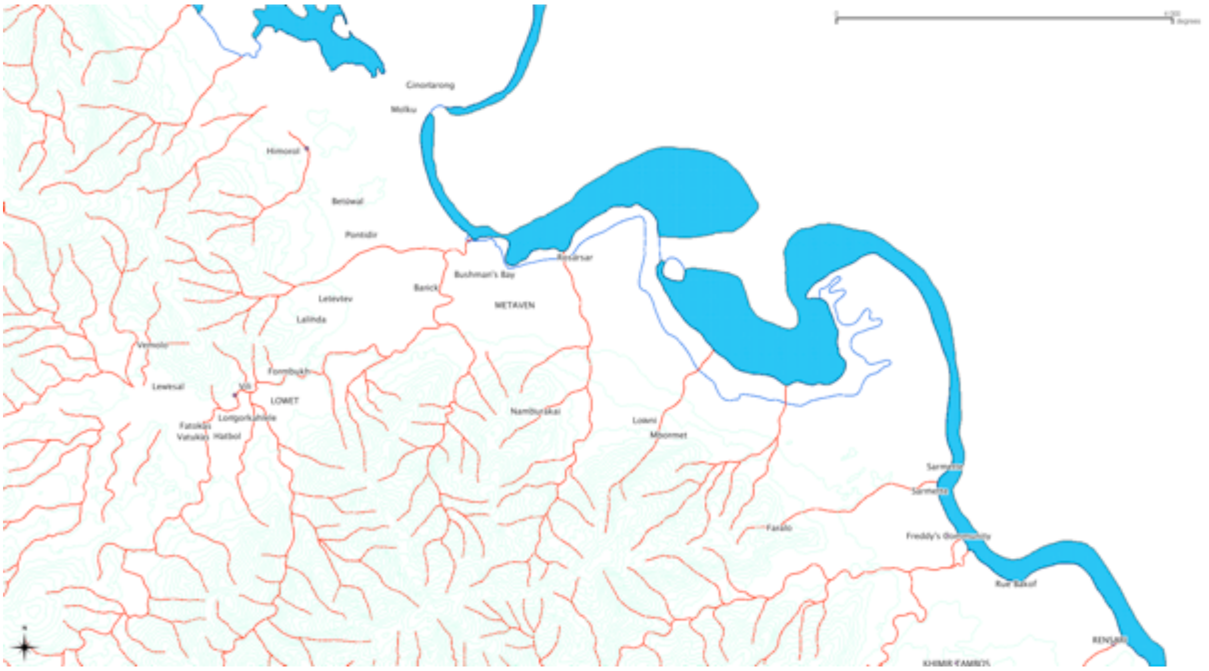

Figure 16: Streams and rivers in the Crab bay zone (in red).

Figure 17: Streams and rivers in the Eratap zone (in red).

All opinions confirm that the streams and the river carry a lot of sediments during heavy rains and summer season. For the streams it was not possible to identify the direction of the sediment plume. For the river, which represents the main source of sediment in the Eratap bay, the flow is parallel to the western coast and usually penetrates in the Eratap bay (see map).

In Crab Bay it was not possible to identify direct beneficiaries of this ecosystem service. In Eratap the 2 resorts are potential beneficiaries through trapping of sediments that allows recreational use by tourists (water clarification).

Economic value:

The 2 resorts have already been described in the ES5 chapter.

For Eratap beach resort, the sediments coming from the Teouma River are firstly trapped by the beaches and then by the mangroves placed back from the beaches.

For Aquana, the mangroves should play their role retaining a major part of the sediment before they came inside the bay, where the hotel beach and some marine activities take place. Nonetheless, since its creation in 2011, the hotel suffers from turbid waters in their bay independently of sediments carried by the river after rainfall.

We concluded, with data available and relying on community knowledge that the service of sediment trap is almost inexistent in Crab bay and has to be more isolated and quantified in Eratap.

CARBON SEQUESTRATION (ES 9):

Implicated ecosystem processes:

Seagrass and mangrove ecosystems remove CO_2 from the atmosphere via photosynthesis, returns some to the atmosphere through respiration and oxidation and, store remaining carbon in two stocks: the living biomass (which includes both above ground and underground vegetation) and soil organic carbon (Knowlton, 2000; Walters et al., 2008).

Based on recent publications and the blue carbon database (Bouillon et al., 2009; Murray et al., 2010; Nicholas Institute for Environmental Policy Solutions, 2011; Sifleet et al., 2011), the average ranges of carbon sequestration by mangroves have been estimated. Mangroves vary from 6 to 8 t. $CO_2e.ha^{-1} y^{-1}$. Soil carbon is however the main carbon stock (approx. 2000 tCO2 $e.ha^{-1}$ for mangroves) since between 20 and 40% of the carbon is stored in living biomass (Murray et al., 2010).

Mangrove carbon pools are among the highest of any forest type (Figure 1). For example, ecosystem carbon pools of mangroves are more than twice those of most upland tropical and temperate forests. A great proportion of this pool is belowground in organic-rich soils, which are susceptible to release significant volumes of greenhouse gases if disturbed by land-use or climate change (Page et al. 2010, Hooijer et al. 2006).

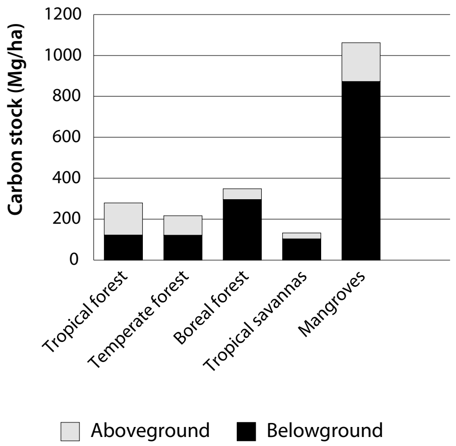

Figure 18: Total ecosystem carbon pools (aboveground and belowground) for some major land cover types of the world (Kauffman and Donato, 2012)

The valuations have used two processes to quantify carbon volumes: the sequestration in living biomass and the carbon pools in the soils. The result will be the annual amount of CO_2e **avoided** of being released into the atmosphere by maintaining ecosystems in their current state. The parameters estimated are:

a. Annual rate of absorption of carbon by the ecosystem in its current state.

b. Carbon stocks in biomass and the basement (at a maximum depth of 1 m even if, generally, carbon pools vulnerable to anthropogenic changes are aboveground biomass and belowground pools up to 30 cm). Data will be based on estimates of tier 1 and tier 2 IPCC categories [20].

c. The amount of potential emissions due to the destruction of the ecosystems. This evaluates how much soil carbon may potentially be exposed to atmosphere and thereby emitted in the form of CO_2. Although meters of carbon-rich organic soils may underlie the coastal habitats, that carbon may persist if the habitat conversion only affects the top layers and the deeper layers remain inundated.

d. The time required for the release of emissions into the atmosphere. In theory, following conversion, carbon in biomass is emitted to the atmosphere in the first few years. Soil organic carbon will take longer than biomass and the deeper the soil carbon the slower its rate of release. In each case, high emission rates would be expected in the years immediately after disturbance, then dropping to lower rates later. A decay function may approximate this physical process, and we will use the concept of half-life that denotes the time required for the carbon pool to fall to one half of its initial value. It is assumed that stocks will have a half-life of 5 years (Murray et al., 2010).

ECONOMIC VALUE

For Crab bay, we estimated a rate of deforestation comprised between 0.1% and 0.3% of the total surface per year. This ratio is based on expert opinion and analysis of the existing literature about mangroves in crab bay (Vanuatu Environment Unit, 2007). It reflects a relatively low pressure on mangroves as well as an efficient management of habitat.

For a total area recently estimated at 136.5 ha (source: Vanuatu Department of Environment and Conservation), the estimation of volumes of CO_2e. in the soil and the biomass ranged from 33,170 and 70,025 t of CO_2e . Following the carbon price estimate described in the annex, these volumes are equivalent to an economic value between Vt 24M and Vt 50M ($US 265k and $US 563k).

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[20] The IPCC (Intergovernmental Panel on Climate Change) has established a tier system reflecting the degrees of certainty or accuracy of the carbon stock assessment. Tier 1 uses IPCC default values (i.e. biomass in different forest biomes, etc.) and simplified assumptions; it may have an error range of +/- 50% for aboveground pools and +/- 90% for the variable soil carbon pool. Tier 2 requires country-specific carbon data for key factors. Tier 3 requires highly specific inventory-type data on carbon stocks in different pools, and repeated measurements of key carbon stocks through time, which may also be supported by modelling.

	Habitat area (Ha)	Annual rate of deforestation (% of total area/y)	t CO2eq. y^{-1} ha^{-1}		Soil and biomass stocks (t CO2eq. ha^{-1})		Potentially released (% stock)	Annual rate of decay of releasable stock (%/y)	Annual volumes of Co2eq. not released (t Co2 eq./y)		Value of the service of carbon sequestration ($US/y)	
			min	max	min	max			min	max	min	max
Mangrove	135,5	100,0%	0,12	23,98	900	1 900	60%	45%	33 170	70 025	265 487	563 338

Table 8: Details and results of the valuation of the carbon sequestration service in Crab bay.

For Eratap, we estimated a rate of deforestation comprised between 0.3% and 0.5% of the total surface per year. This ratio is based on expert's opinion (Vanuatu Fishery Department and village stakeholders) as well as analysis of the present MESCAL studies on mangroves in Eratap. It reflects a relatively low pressure on mangroves. For a total area recently estimated at 31.2 ha (source: Vanuatu Department of Environment and Conservation), assessments of CO_2e stocked ranged from 7,655 to 16,160 t of CO_2e. Following the same carbon price estimate, these volumes are equivalent to an economic value between Vt6.2M and Vt 11.7M per year ($ US 69k and $US 130k).

	Habitat area (Ha)	Annual rate of deforestation (% of total area/y)	t CO2eq. y^{-1} ha^{-1}		Soil and biomass stocks (t CO2eq. ha^{-1})		Potentially released (% stock)	Annual rate of decay of releasable stock (%/y)	Annual volumes of Co2eq. not released (t Co2 eq./y)		Value of the service of carbon sequestration ($US/y)	
			min	max	min	max			min	max	min	max
Mangrove	31,2	100,0%	0,12	23,98	900	1 900	60%	45%	7 655	16 160	68 921	130 001

Table 9: Details and results of the valuation of the carbon sequestration service in Eratap.

METHODOLOGY

ECOSYSTEM SERVICES OF MANGROVES

The most common definition of ecosystem services are "services that human populations derive, directly or indirectly from ecosystem functions" (Costanza et al., 1997) or more simply as "services that people obtain from ecosystems" (Boyd and Banzhaf, 2007) (MEA, 2003). Ecosystem is defined by the Millennium Ecosystem Assessment as "a dynamic complex of plant, animal, and micro-organism communities, and the non-living environment interacting as a functional unit" (MEA, 2003).

SELECTION OF ECOSYTEM SERVICES FOR VANUATU MANGROVES

9 ecosystem services have been identified and analysed: the subsistence fishery (ES1), the commercial fishery (ES2) including professional and non professional fishery as well as coastal and mangrove linked pelagic fishery, the recreational or sport fishing (ES3), the other extractive uses such as wood, medicine (ES4), the tourism activities linked to mangroves (ES5), the coastal protection against flood (ES6), the bio remediation of waste waters (ES7), the service of sediment trap to reduce coastal erosion (ES8) and the carbon sequestration (ES9).

THE TOTAL ECONOMIC VALUE (TEV)

The total economic value is defined as the sum of consumer surplus and producer surplus of all the services of direct, indirect use and non-use. The model of the TEV is explained in many books (Abaza, 2004; Beukering et al., 2007; Defra, 2008; Pagiola, 2004a) and we will present the underlying theory.

The neoclassical theories of "value" introduce the concepts of producer and consumer surplus at the micro economic level (Azqueta and Sotelsek, 2007; Diaz-Balteiro and Romero, 2008; Dimand, 2007). The "producer surplus" is here calculated in the same way as the added value used in national accountancy systems[21] (Defra, 2008; Farber et al., 2002). It can be estimated as the sum of profits and Ricardian rents going to factors of production (e.g. value of a productive marine zone). Some authors also call it the financial value when estimations concentrate on the cash flows with multiplier effects that are linked to the use values of the ecosystem good or service (Beukering et al., 2006).

[21] Added Value is defined as the difference between the sale price and the intermediate costs of a product (which consist of the total goods and services consumed as inputs in production).

The "consumer surplus", defined as the difference between the maximum price a consumer is willing to pay and the actual price they do pay is more complex to obtain and requires either the existence of a demand curve obtained from data (historical prices and quantities sold in the market) or the application of revealed-preference analysis (e.g. travel costs) or stated-preference survey (e.g. choice experiment), (TEEB, 2010). For recreative use, for example, consumer surplus is the value of an activity beyond what must be paid to enjoy it.

There are two prominent types of consumer surplus estimated using slightly different definitions of the demand function: Marshallian consumer surplus based on an ordinary demand function, and Hicksian consumer surplus based on either a compensated demand function or elicited directly using hypothetical market techniques. The difference between these measures is due to the income effect. Since outdoor recreation expenditures are a relatively small percentage of total expenditures (income), differences between the two measures are expected to be negligible

VALUATION METHODS

MAIN METHODS

As described by various authors (Farber et al., 2002; Groot et al., 2010; Pagiola, 2004a; Remoundou et al., 2009) three main methods can be identified for valuing absolute or marginal values of ecosystem services (Figure below).

The method of production inputs is based on evaluation of physical volumes generated by the ecosystem (biomass, tourism attributes, etc.) and considered as an input in the production of services. This is particularly well adapted to determine the direct and indirect values but has rarely been applied in coral reef and mangrove valuations. Cesar (1996), Cesar et al. (2003) and Beukering (2006 and 2007) have used this method, estimating the "effect on production" through the difference in producers' output (fishermen, tourism businesses) from a change in the ecosystem. The technique can be used to calculate marginal changes in production or absolute values of production. When data are based on market data added values we refer to it as producer surplus or financial analysis. When direct market data is not available, another approach is to measure production inputs through (i) the replacement cost method which estimates the costs of replacing ecosystem services with man-made services (e.g. artificial reef to provide costal protection) or, (ii) the cost of avoided damages method that estimates damages avoided due to ecosystem services (e.g. costs of avoided flood due to wave energy absorption by coral reefs).

The revealed preference method is based on observation of individual behaviours, since they are supposed to translate the preferences and thus the value people place on the environment. The most common methods are the travel costs, the hedonic pricing and the averting behaviour. In the first one, the travel costs to access a site are assumed to indicate the value people place on this resource. The second method estimates the influence of ES and environment characteristics on price of marketed goods such as real estate or touristic services. The third one begins with the assumption that people make choices in order to maximize their level of well being when faced with increased health risks. Averting behaviour requires expenditures that would not be made if not faced with the environmental health risk (e.g. the purchase of bottled water when faced with the risk of contaminated drinking water).

The stated preference method uses surveys with users to get statements about their practices and preferences. The techniques place the consumer in an hypothetical market context but realistic, and asked him to make choices between alternatives with different characteristics. It is then possible to deduce the value people place on a specific ecosystem service. This value is called willingness to pay (WTP). It is interpreted as the change in consumer surplus of the individual resulting from the change in the quality of services provided by an ecosystem. It is therefore a method for valuing both use and non-use values. Conjoint analysis (or method of choice experiments and experimental choices or choice modelling) and contingent valuation methods are the two most commonly used stated preference in environmental economics.

All methods are complementary to each other with their own biases (Balmford et al. 2002; Beukering et al. 2007).

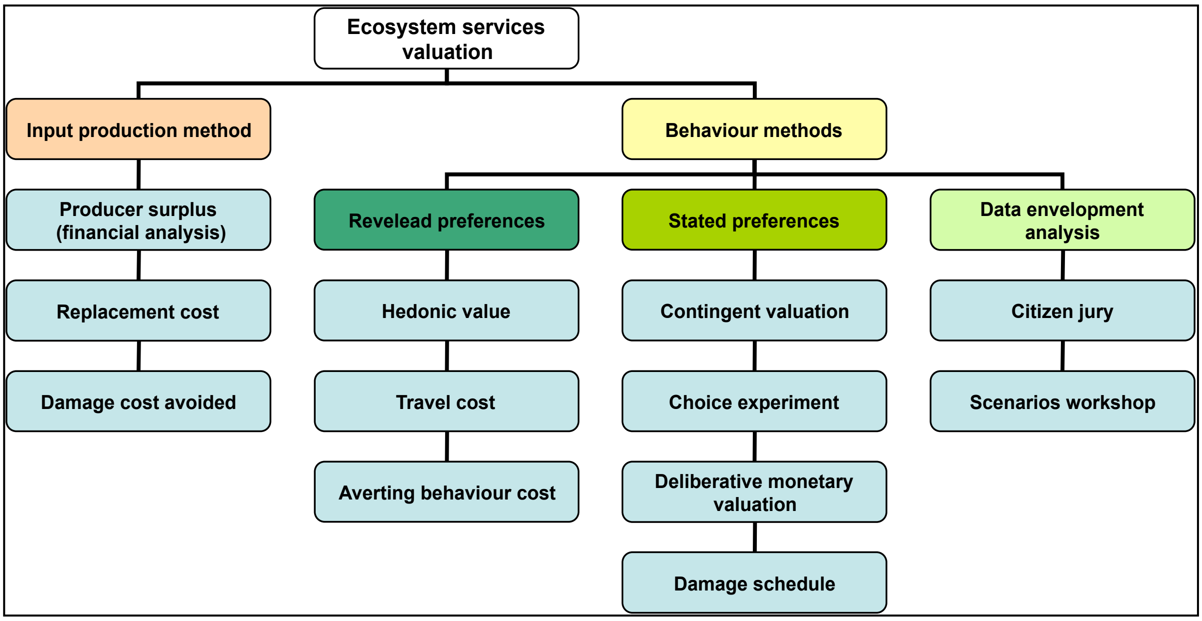


Figure 19: Methods of economic valuation

POTENTIAL AND SUSTAINABLE LEVELS

A question that is legitimate to ask is the sustainability of uses and the meaning of the calculated values. The estimation of a single monetary value to characterize an ecosystem service must then be "contextualized" with information about environmental sustainability and the potential of ecosystem service evaluated.

The report of the Centre d'Analyse Stratégique from the French Prime Minister office (Chevassus-au-Louis et al., 2009) on economic valuation refers to the "maximum plausible use" that it may be possible to determine qualitatively (e.g. based on expert opinions) or quantitatively from production functions for certain ecosystem services.

As recommended by the economic taskforce of the IFRECOR (the French Initiative for Coral Reef), the potential values should be calculated for the following services: fishing, underwater tourism, coastal protection and wastewater treatment (direct and indirect values). The maximum plausible values may be categorized as option values of current uses.

Reef and mangrove fish populations are very sensitive to fishing effort and overfishing is rapidly reached in these ecosystems. Nonetheless, coral reef and mangrove valuations rarely take into account the ecological sustainability of the fishery, when calculating an ecosystem service based on fisheries. Defining the value based on the total fish population is inadequate since this would be equivalent to a capital value and not a sustainable revenue. In order to calculate the potential fishery ES or to project future ES flows it is necessary to define a maximum annual productivity.

In a similar way, the Sheraton paradox (Mirault, 2006) describes how the valuation of coastal ecosystem services linked to tourism will provide big numbers depending mainly on the tourism capacity. Results are independent of future effects on the ecosystem through wastewater, overcrowding of sites, etc. This involves defining the limits of ecological and sociological changes that could cause some degradation but that will be allowed on site (Stankey et al., 1985).

Additional methodological questions include how potential values should be calculated when trade-off between ecosystem services exist. Fish harvest is of concern, particularly when tourism is a potential non-consumptive use of the fish stock. Defining the trade-offs of a yield that values the diversity of fish species for tourism relative to selective fishing for consumption is a further challenge.

SPATIAL DISTRIBUTION

Many challenges remain in defining the spatial dimension of the valuation of the ecosystem services. The first question addresses the choice of what is being assessed: the place of the ecosystem processes, the place where the human activity takes place, or the place where benefits will be transformed into money. Other challenges concern important knowledge gaps in the marine ecological processes (e.g. larval dispersion and trophic migrations) and their spatial distribution (Kendall and Picquelle, 2003; Leis, 2002; Sale et al., 2005).

The practical identification of the study perimeter for each service being valued is not necessarily straightforward and can impact substantially the outcome of the analysis (Mumby and Steneck, 2008a). It seems to be also a key variable for policy-makers when evaluating policy choices usually influenced by the identification of the spatial extension of beneficiaries or losers.

Considering the complexity of these processes (variability and importance) and the technical challenge to identify the flows of dispersion of some services, especially marine species, we will rely on the most recent scientific results to reflect this aspect in the mangrove economic valuation.

COMMUNITY CONTEXT

The contexts of community and traditional economy pose a challenge to the neo-classical approach of individual maximization of welfare. Although no published studies exist to our knowledge, it is possible that customary tenure arrangements in the Pacific significantly skew the influence of community in individual choice (constrains or enables), clan, family, village, resource allocation decisions (Cinner et al., 2007). This could question the appropriate scale of economic valuation analysis from the individual or individual household level to some broader scale (group of families, clan, villages, etc.)

Many of the natural resources in PICTs are communally owned, often with boundaries, which are not clearly defined or formally recorded, creating unique challenges in the use and management of natural resources in a modern world.

In many Pacific islands and mainly in Melanesia (Fiji, New Caledonia, Papua New Guinea, Solomon Islands and Vanuatu), the cash economy is still under-developed. Therefore, the value that local communities attribute to money, and its function in life, differs widely from common economic assumptions. Island societies assign value to things that lack exchange equivalents, or relative prices, and which therefore cannot be included in TEV. Three can be mentioned here (Laurans et al., 2013):

- The degree of familiarity of islanders with the mangrove, which is measured by the number of place names and the number of fishes named locally. These two metrics are a proxy for both the non-use value of the mangrove and its use value (Pacific islanders name only what they use).

- The role of the mangrove in the identity of the village community. The highest values are attached in the place where the canoe of the founding ancestor of the island population first landed.

- The role of the mangrove in the social and political positioning of the community towards other island communities. The highest values are found among reef fishing clans as in New Caledonia (Leblic, 1999) and among communities where the alliance relationships are built on sharing of fishery products, including turtles, as in Tanna island, Vanuatu (Bonnemaison, 1986).

To our knowledge, only one study has addressed the non-use value of coastal ecosystems for local populations in PICTs. The study was conducted in Fiji with several communities to identify the bequest value attached to the reef (O'Garra, 2012). O'Garra's results highlight that local communities were willing to contribute 3 hours of their time per week towards conservation mainly for future generations (bequest value). In this study several challenging issues were raised such as time allocation conflict between communal and personal obligations, gender influence in decision-making and common property resource management by villagers. All the other works addressing non-use values through contingent valuation or choice experiment have been estimated for high-income groups from Australia or developed Pacific islands (Ahmed et al., 2007; Beukering et al., 2006; Cesar et al., 2003a; Whitten and Bennett, 2004).

TIME PERIMETER

Ecosystem services valuations of direct and indirect uses will focus on financial flows or economic values from the previous year of study. No time projection (e.g. no discount rate) is realized (except for carbon credit based on avoided CO_2 emissions during 30 years).

The direct and indirect impacts of ecosystem services on the local GDP will be estimated through multipliers depending on data availability.

The calculated values for use values are compared, where possible, with the last five years to identify potential biases and unrepresentative exceptional situations.

UNCERTAINTIES AND CONFIDENCE INTERVALS

The degree of uncertainty associated with calculations will be highlighted by the presentation of the lowest and highest estimates in the results. Confidence intervals of the results and other mathematical models (production functions) will be specified (and presented with the results). This also applies to information on sustainability practices that should be underlined and highlighted.

ECOSYSTEM PROCESSES AND SERVICES

As noted by Balmford et al (2008), it is important to distinguish clearly the processes and ecosystem services. Processes are physical, chemical or biological and contribute to the maintenance of the ecosystem, while services are the end goods and services that directly affect the human welfare. In this classification, core ecosystem processes and beneficial ecosystem processes are identified. The core processes such as biogeochemical cycles and processes of the water cycle act as support to beneficiaries' processes. Beneficiaries' processes such as biomass production or purification of water are directly involved in the production of ecosystem services to humans.

ECOSYSTEMS CONNECTIVITY

Coastal habitats (coral reef, mangroves, seagrass, saltmarshes) are linked biologically. Many fish and shellfish species utilize mangroves and seagrass beds as nursery grounds, and eventually migrate to coral reefs as adults, only to return to the mangroves and seagrasses to spawn (Mumby and Steneck, 2008b; Ruitenbeek, 1994). In addition, the high biological productivity of mangroves, marshes, and seagrasses also produce significant amounts of organic matter that is used directly or indirectly by marine fishes, shrimps, crabs, and other species (Barbier et al., 2011). The consequence is that interconnected seascapes contribute significantly to supporting fisheries via a number of ecosystem functions including nursery and breeding habitat, trophic interactions, and predator-free habitat.

Allowing for the connectivity of habitats may have important implications for assessing the ecological functions underling key ecosystems services, such as coastal protection, control of erosion, and habitat–fishery linkages. Only recently have studies begun to assess the cumulative implications for these services, or to model this connectivity (Barbier et al., 2011).

DETAILED METHODS FOR MONETARY VALUATION OF ECOSYSTEM SERVICES

The following table summarizes the different methods used for the monetary valuation of the different ecosystem services. 9 ecosystem services have been identified: the subsistence fishery (ES1), the commercial fishery (ES2) including professional and non professional fishery as well as coastal and mangrove linked pelagic fishery, the recreational or sport fishing (ES3), the other extractive uses such as wood, medicine (ES4), the tourism activities linked to mangroves (ES5), the coastal protection against flood (ES6), the bio remediation of waste waters (ES7), the service of sediment trap to reduce coastal erosion (ES8) and the carbon sequestration (ES9).

Services	Evaluation method	Service quantification	Spatial perimeter	Turn over	Intermediary costs	Multiplier
Subsistence fishery (ES 1)	Producer surplus	Catch volumes (kg) of coastal species	Catch in mangroves and ontogenic migration (spillover area around the mangroves)	Replacement price of protein equivalent	Intermediary costs of fishery and distribution circuit	Weighting factor
Coastal fishery (ES 2) (professional and non professional)	Business Expenditure Survey (BES) with fishermen			Final consumer prices		Fishery sector and distribution
	Producer surplus	Catch volumes (kg) of coastal species			Intermediary costs of fishery	
Recreational coastal fishery (ES3)	Producer surplus	Catch volumes (kg) of coastal species		Final consumer prices + elasticity factor	Intermediary costs of fishery and distribution circuit	Fishery sector and distribution
Wood extraction (ES4)	Producer surplus	Volumes of wood extracted per type of use	Mangrove zone	Market price		
Medicine use (ES4)	Producer surplus	Volumes of active ingredient extracted per type of use	Mangrove zone	Replacement cost		
Mangrove tourism (day tours, guided visits) (ES5)	Producer surplus	Visits	Mangrove zone	Price of services	Intermediary costs of activity	Tourism sector
	Business Expenditure Survey (BES) with tourism operators					
Associated expenses linked to activities in mangroves (ES 5)	Producer surplus	Quantification and segmentation of tourists per category of use	Tourism zones	Local expenses (accommodation, food, local transport) + international transport	Intermediary costs of activity	Tourism sector
	BES and surveys with users					
	Advertising Image Analysis					
Coastal protection (ES6)	Biophysical and oceanographic model	Coastal zone in potential flooding zone (probability)	Coastal protection zone (back of mangroves)	Real estate values		
	Damage costs avoided	Contribution of mangroves to coastal protection				
		Urbanized area and damage valuation				
Bio-remediation (ES7)	Biophysical model	Quantification of nutrient charge and water treatment	Mangrove zone	Replacement costs of water treatment unit		
	Replacement costs					
Sediment trap (ES 8)	Biophysical and oceanographic model	Quantification of sediment charge and spatial dispersion	Mangrove zone and sea current regime	Replacement costs or damage costs avoided on tourism activities		
	Replacement costs or damage costs avoided on tourism activities					
Carbon sequestration (ES 9)	Market price	Quantification of carbon annual sequestration and CO2 eq. trapped in soil	Mangrove zone	Market Price or OTC for mangrove CER		
Biodiversity credits (ES 10)	Market option price	Specific biodiversity indicators	Mangrove zone	Due diligence agreement for mangrove		
Non use value (existence) (ES 11)	Willingness to Pay		Villages closed to mangroves, tourists, urban inhabitants			

Table 10: Details of valuation methods for mangrove

ANNEXES

CLASSIFICATION OF ECOSYSTEM SERVICES

Several classifications of ecosystem services generated by mangroves have been proposed (Balmford et al., 2008; Beukering et al., 2007; Cesar et al., 2003b; MEA, 2003; Moberg and Folke, 1999; Pascal, 2010). The two most common classifications used are those of the Millennium Ecosystem Assessment and that of the Total Economic Value.

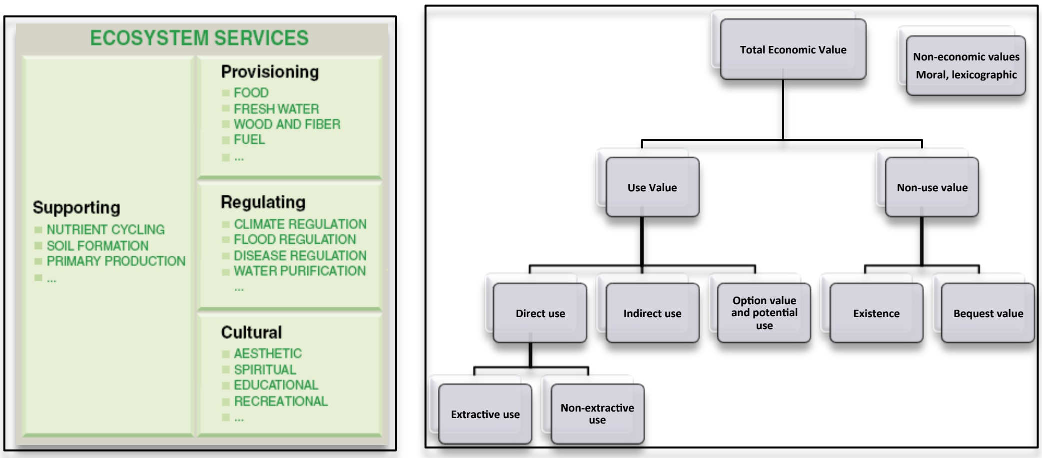


Figure 20: Classification of ecosystem services.

On the left: the Millennium Ecosystem Assessment (MEA 2005). On the right: the Total Economic Value framework (adapted from Balmford et al (2008) and Spash (2000))

The Millennium Ecosystem Assessment (MEA) defines four main classes of ecosystem services. These are the provisioning, regulating, supporting and cultural services. These services manifest in a variety of forms, from concrete harvestable goods such as fish or shells to more abstract regulating services such as water treatment, wave protection for flood control and maintenance of biodiversity.

Even if the previous categorization has been adopted by both the Convention on Biological Diversity and the MA, it was chosen to apply the TEV classification to our case studies. As pointed out by some economists since its publication, the MEA seems not to fit adequately for the purpose of economic evaluation (Balmford et al., 2008). By mixing processes (means) and benefits (ends) it is particularly prone to double counting.

Following Balmford et al (2008) and Harborne et al. (2006), it is important to make a clear distinction between ecosystem processes and ecosystem services. Processes are biophysical functions, while services are the end services that directly affect the human welfare. Two types of ecological processes are considered: 'core' ecosystem processes, the basic ecosystem functions (e.g., nutrient cycling, biochemical processes) supporting the processes that provide benefits to humankind; and 'beneficial' ecosystem processes, the specific ecosystem processes that directly underpin services for humankind (e.g. waste assimilation, biomass production).

The ecosystem services are the end products of these beneficial ecosystem processes (e.g., fishing). Figure 2 describes the classification of the different coral reef ecosystem services to be used throughout this document.

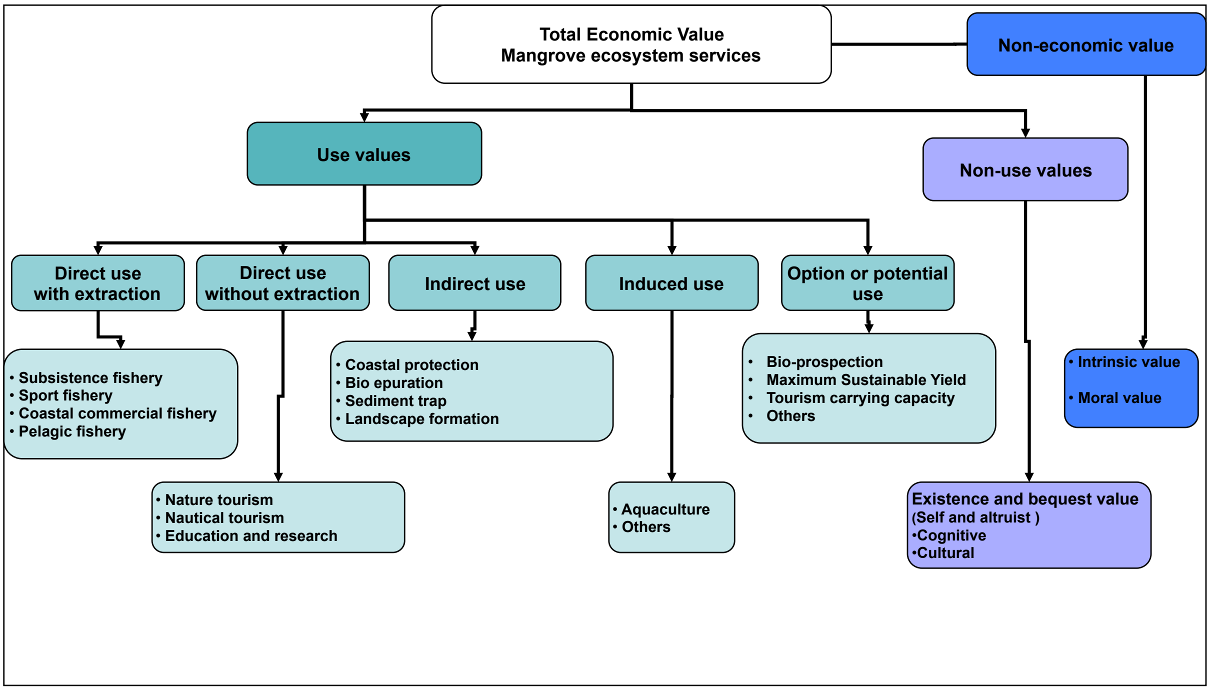


Figure 21: Mangrove ecosystem services classification through Total Economic Valuation (details in the text).

Use values include ecosystem services from direct uses with and without extraction, indirect uses and potential uses (Groot et al., 2002). Direct uses refer to activities where the individual enjoy directly from the resource whether by extracting it (e.g. fisheries) or by taking a non-extractive satisfaction (e.g. underwater tourism). They can be market-type if the service goes through a market that sets the price (e.g. fish or a tourism service) or non-market (e.g. subsistence fishing or unorganized snorkelling activities). Other direct uses include aquaculture and pearling industry that incorporate ecosystem processes as inputs such as water, nutrients, etc. (Moberg and Folke, 1999).

Indirect uses include ecosystem services that exist without the intervention of man (Defra, 2008). For example, mangroves can provide physical protection against waves and can contribute to wastewater treatment (UNEP-WCMC, 2006).

The option values refer to future use (direct or indirect) of coral reef ecosystems, which can be assimilated also to potential values (e.g. not all known marine fish stocks need to be exploited today (even sustainably). One possibility is that some stocks may be exploited immediately and some left untouched as options for the future. (Turner et al., 2003).

The non-use values, also called passive use values, correspond to all the economic values that are not related to the use of the ecosystem (Krutilla, 1967). They often include multiple values for the composite nature of the motivations of the individuals (Manoka, 2003). Usually, non-use values focus only on the existence value and bequest value. All the other ones (such as the intrinsic value of nature, the moral value, etc.) are categorized as non-economic or lexicographic values (Spash, 2000). The existence value is the value given to the mere existence of mangroves independently from its use (Rudd, 2009). Bequest value is associated with the preservation of mangroves for future generations (Nijkampa et al., 2008). Lexicographic values refer to values for which "all or nothing" decisions take place. They go beyond consequentialist (utilitarian) and deontological (rights-based) values (David et al., 2007; Spash, 2007) and ignore the compensation choices underlying the Hicksian economic theory. Therefore they cannot be valued in a monetary way.

Recent works about economic valuation of coastal ecosystems ((Daily et al., 2009; Goldman and Tallis, 2009; Laurans et al., 2013) agreed that it is important to concentrate mainly valuation efforts on the three following ES:

(i) Food production: coastal associated fisheries provide an important source of food and basis for livelihoods
(ii) Recreation&tourism: coastal recreation and tourism activities generate significant economic value depending on the quality and availability of specific marine ecosystem attributes.
(iii) Coastal protection: marine ecosystems (coral reefs, mangroves, seagrass) can buffer coastlines from storm-induced erosion and inundation. They also can help to regulate natural processes of erosion and sedimentation that are critical to maintaining beaches.

In the case of mangroves, we will add the services of carbon sequestration and bioremediation of wastewater.

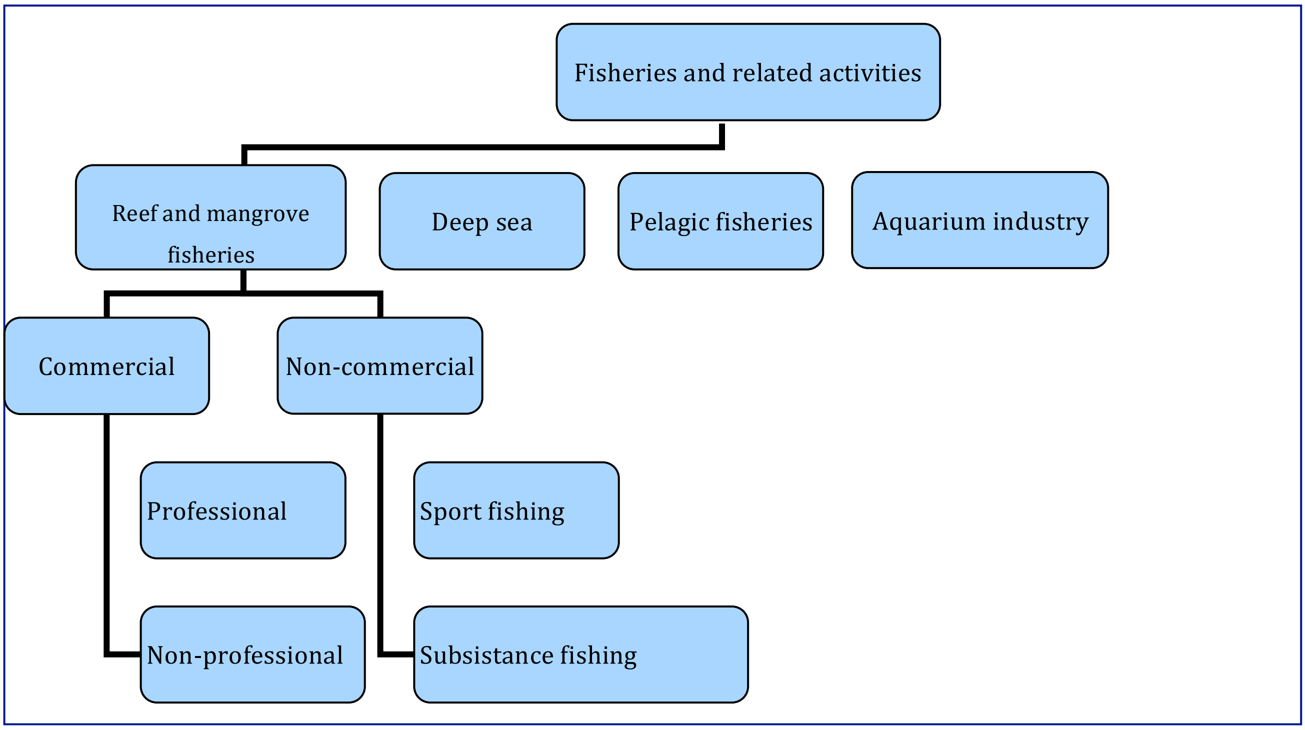
VALUATION OF DIRECT EXTRACTIVE USES (ES1, ES2, ES3 AND ES4)

This section discusses the methods of economic evaluation of ecosystem services included in the category of direct extractive, non-extractive and induced uses. Direct uses refer to activities where the individual can enjoy the resource directly or by consuming (e.g. fishing), or through non-extractive satisfaction (e.g. Tourism, underwater).

They can be market-based services if a transaction goes through a market that sets the price (e.g. fish or tourist service) or non-market (e.g. subsistence fishing activities or snorkelling without payment).

Induced uses correspond to uses that incorporate ecosystem processes such as water, nutrient etc. as inputs for the production of non-ecosystem services. Aquaculture and pearling are examples.

There are different types of extractive uses mainly related to fishing. Distinctions can be made according to whether the fishing takes place in the reef and mangrove area or not, if fishing is for commercial, recreational or subsistence use and if it is performed by professionals or not.



IMPLICATED ECOSYSTEM PROCESSES

Several processes are identified in the production of the service of coastal fishery. We distinguish mainly the process of biomass production and the maintenance of habitat complexity, nursery role and ecosystems connectivity.

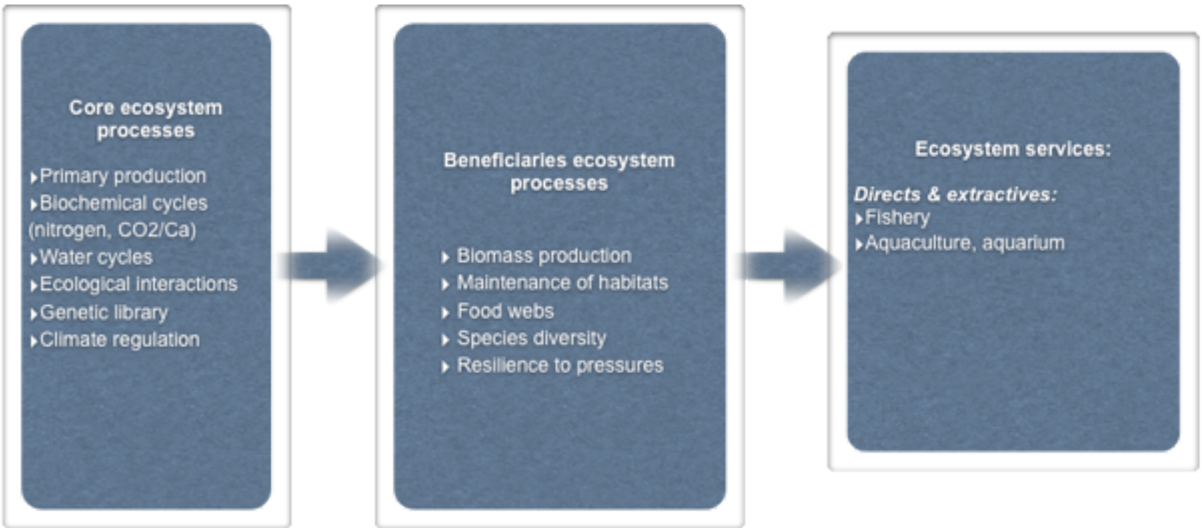


Figure 22: Description of main ecosystem processes associated to reef and mangrove fisheries

BIOMASS PRODUCTION

The description of this process is based on the work of Done et al. (1996) and Pollnac (2007). A coral reef ecosystem and healthy mangrove are a diverse community of marine organisms in a highly productive marine environment low in nutrients. Productivity refers here to the large volume of carbon fixation that occurs in these ecosystems.

Productivity measurements have shown that coral reefs and mangroves are among the most productive marine ecosystems (Done et al. 1996 Barnaud and Fustec 2007).

Ecosystem	**Primary production (g d.m. $m^{-2}.y^{-1}$) average values**
Mangroves	2000
Coral reefs	2500
Open ocean	125
Continental platform	360
Upwelling zones	500
Estuaries	1500

Lakes and rivers	250
Tropical forests	2200
Template forests (coniferous)	1300
Agroecosystems	650

Table 11: Primary production of the ecosystem (in g of dry matter per m² per year). Adapted from (Barnaud and Fustec 2007)

Moreover, this productivity is obtained with the relative absence of dissolved nutrients (N and P) in oligotrophic waters surrounding. For reefs, the secret to this success is an important recycling of nitrogen levels in the system of symbiosis between algae and coral polyps. They function as a nitrogen fixer in nutrient-poor environments, such as legumes in agricultural ecosystems. Algae and phytoplankton also ensure the transformation of nutrients in marine environments (oxygen, nitrogen, ...), into biomass available for other plant and animal species (Harborne et al. 2006). They have the distinction of being autotrophs since they ensure the production of organic matter from inorganic substances (water, CO2, minerals), in the environment. Mangroves produce a large amount of organic material, due to its structure of vegetation. This production is, the basis of the complex food web in these tropical coastal environments. Therefore, mangroves have abundant marine life and often serve as spawning grounds. They also provide organic carbon to coral reefs. If nutrient-recycling chain is interrupted by the removal of mangroves, coral reefs would be deprived of this important provision (Ruitenbeek 1994).

HABITAT COMPLEXITY

Science has recently given higher interest to the relationship between coral reef, mangroves and abundance of fish stocks (Worm et al 2006. Mumby and Steneck 2008).

Two meta-analyses concluded that half or more of the reef species of herbivores (including commercial species of Scaridae sp., And Acanthuridae sp.), note a significant decrease in abundance after a bleaching event (Wilson and others, 2006; Mumby and Steneck 2008)

This impact on the abundance and diversity of fish and invertebrates is partly explained by the dependence on habitats provided by all coral reefs or mangroves for the settlement phase or larval feeding (Wilson et al 2006). Some studies have shown that over 60% of the fish disappear within three years following a reduction of more than 10% live coral cover (Jones et al 2004).

The loss of habitat complexity may increase the effectiveness of predators and thus influence the density of small fish (Hixon and Beets 1993). It also influences the diversity of invertebrate species (Idjadi and Edmunds 2006). Even the recruitment of fish that do not depend on live coral cover decline in degraded areas.

There's a pretty unique mix between fish species of reef, mangroves and the lagoon. Indeed almost half run between these ecosystems for ontogenetic trophic reasons. For mangroves, nesting aerial roots supports the fauna and flora of the tropical coasts: algae, sponges, molluscs (oyster). The fish take shelter among the roots, and in the calm waters rich in nutrients. It is not uncommon to find schools of fry that attract predators. Further evidence for interconnectivity of habitats, is that juvenile fish migrate form mangroves to nearby reefs as they grow (Harborne et al. 2006). Recent studies (Barbier, 2012) have shown that average fish density for 10 families that inhabit the mangroves, is significantly lower for mangroves located 30 to 50 m or more inshore than the mangroves on the seaward edge. No fish were found more than 50 m inshore from the sea.

NURSERY HABITATS

Nursery habitats are areas providing critical living space for eggs, larvae, juveniles, and sub-adults of the vast majority of coastal and pelagic marine species. The features of nursery areas that make them critical for fish populations and other marine species include providing food, shelter, space, and pathways to and from the site to other adult habitats of the species.

A nursery habitat is valuable to a species only insofar as it is accessible. Eggs, larvae, and young rely largely on currents to deposit them in nursery areas. Current flows facilitate dispersal to and from the nursery site while at the same time boundary currents allow for larval retention. Once there, they need to be able to stay and grow - thus nurseries are relatively static areas able to retain larvae and young until they grow large enough to leave the site on their own. Fish, sea turtles, marine mammals, and invertebrates that have grown in nursery areas must be able to successfully access adult habitats (or other nursery habitats for other, non-adult life stages), from these sites.

Nursery sites provide food through nutrient loading and prey availability. In order for a nursery habitat to increase the survival of young organisms, sufficient food must be available on hand. For primary consumers, this food takes the form of plant life: phytoplankton, algae, and macroalgae. For carnivorous and omnivorous species, nursery habitat must supply prey. As explained before, estuaries, seagrass beds, mangroves, and other kinds of marine nurseries are notable for their productivity. Nutrients come from outside the site via rivers, run-off, currents, and upwelling. Nursery habitats that are also able to produce food on site retain many nutrients through efficient recycling. The wide availability of nutrients in turn fosters blooms of copepods and other prey species.

Nursery habitats are physically complex places, with much spatial heterogeneity. Simply stated, nursery areas provide many hiding places that make them suitable as refuges from predators. Survivorship is significantly higher in areas with reduced predation than it would be in the open ocean. Some nurseries simply provide a different habitat that predators do not generally venture into (e.g. areas with shallow, calm waters or low salinity).

Nurseries provide also the space needed for maintaining optimal densities of individuals. Most marine organisms are highly fecund – producing a lot of young to offset the natural mortality caused by predation, including human fishing pressure. Vast numbers of eggs and young from many different species find their way to nursery areas, and once there they need space to grow. Thus, the most valuable nursery areas are those that provide all the functions above with sufficient space to support large numbers of growing organisms.

This way marine nurseries provide refuge and food to a wide array of species, and in so doing, contribute important ecosystem services.

There are many types of nursery areas. They include estuaries, shallow banks, mangroves, coastal forests and wetlands, seagrass beds, coral and rock reefs, seamounts, and even static portions of the oceans such as the Sargasso Sea.

CONNECTIVITY

In the marine environment, all habitats are ultimately connected – and water is the great connector. Currents and mobile organisms themselves provide the linkages between habitats such as coral reefs, nursery areas, and places where organisms move to feed or breed.

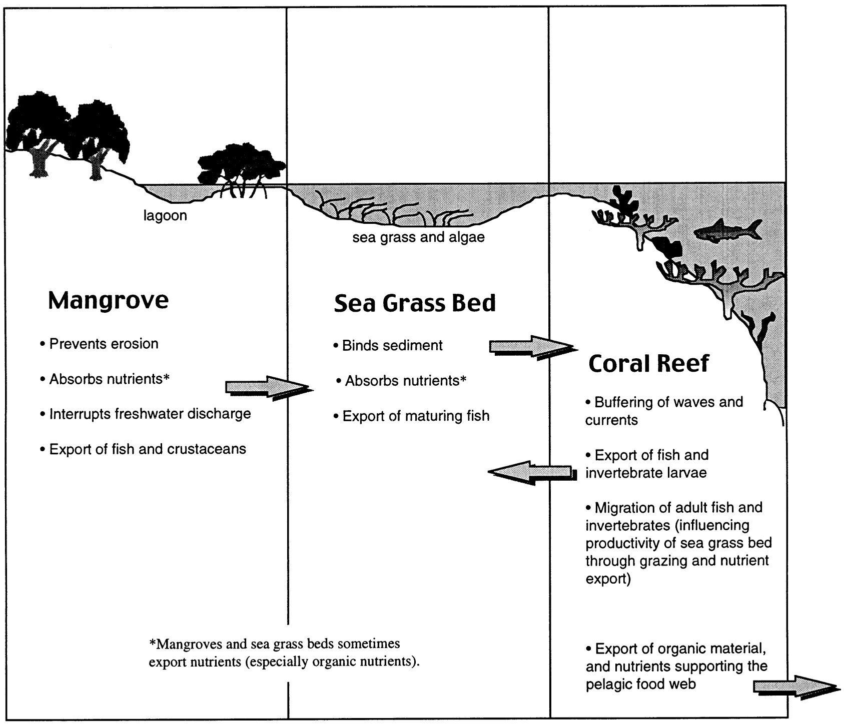


Figure 23 : Interactions in the tropical seascape, showing the connections between mangroves, sea-grass beds and coral reefs (Moberg et al., 1999).

In the scientific literature, connectivity for fishery is estimated through production function (PF) in terms of the resulting changes in consumer and producer surpluses from the marketed catch. The standard approach adopted in coastal habitat-fishery PF models is to allow the wetland area to serve as a proxy for the productivity contribution of the nursery and habitat function. It is necessary to model how changes in the stock or biological population may affect the future flow of benefits. If the natural resource stock effects are not considered significant, then the environmental changes can be modelled as impacting only current harvest, prices and consumer and producer surpluses. If the stock effects are significant, then a change in an ecological service will impact not only current but also future harvest and market outcomes. In the PF valuation literature, the first approach is referred to as a 'static model' of environmental change on a natural resource production system, whereas the second approach is referred to as a 'dynamic model' because it takes into account the intertemporal stock effects of the environmental change. Both PF have their own demands in terms of ecological and economic data that usually overpass the available data. For example, the dynamic model relies on a logistic function for biological growth and a Schaefer production process for harvesting requiring the estimates of many variables and coefficients.

For the study, we have considered that all reef, seagrass and mangrove associated species caught by the coastal fisheries have received in different degree benefit of at least one of those two important ecosystem processes (habitat complexity and nursery habitats).

SUBSISTENCE FISHING (ES1)

DEFINITION

The subsistence fishery (Ecosystem Service 1) corresponds to the non-commercial fishery where all catches are auto consumed, given or exchanged but no monetary transaction takes place. This definition applies also to the recreational fishery (ES 3) but it was non-existent in the studied sites. The fishery ceremonies for specific events or celebrations form part of the subsistence fishery. Even if monetary transaction may occur, fish sold in the village during fund raising activities have been included in this category due to their low price of fish (less than 10% of the normal commercial price).

FORMULA

The estimates of catch volumes are based on :

$$A_{ie} = (\sum_{ie} f_i * cpue_i)$$

With:

f_i : Fishing effort per fishing métier in hours of activity

$cpue_i$: catch per unit of effort per fishing métier (i)

The valuation of subsistence fishery added value ($VA_{f\,mpa}$) is based on :

$$VA_{f\,mpa} = ((A_{ie} * s * Pr_e * p) - \sum_i CI_i) * b$$

With:

s: proportion of catches for subsistence fishery.

Pr_e : Protein equivalent content per family

p = Price of basic replacement protein (euro/g)

CI_i : Intermediary costs per fishing métiers (i)

b: Weight factor to correct resource dependency

PROTEIN CONVERSION

The monetary valuation for ES1 was realized in two steps. First the protein equivalent of catches for the most representative species of fish was estimated. The database developed by Ramseyer (Ramseyer, 2000) was used to convert the catch of fish in protein weight. The weight of the catch of the principal families is converted into protein weight (Pr_e), which is then transformed into the equivalent weight of a basic food. Canned tuna (in oil) was chosen as a very common and affordable product. The Vanuatu Statistics Office uses its market price as a reference in regular macroeconomic indicators. The price was relatively stable during the observed period and converted in Euros/g of protein (p).

DATA COLLECTION METHODS

Several methods are applied in the collection of fishery effort data: (i) logbooks auto-filled by fishermen to determine fishing effort, (ii) interviews with fishermen (selected individuals or with group) to complete the previous data, (iii) regular monitoring of fish commercialization (with transporters) and (iv) analysis of the results about non-monetary incomes produced by recent HIES (Household Incomes and Expenses Survey conducted by the statistics office)

FISHING EFFORT

Fishing effort (f_i) per métier will be estimated through semi-structured questionnaires (annex xxx) with a sample of active fishermen and completed by direct observations. The sample comes from the most active fishermen and was updated regularly to reflect the variability of the subsistence fishing (Hickey, 2008). The surveys depended on recent memory to improve the reliability of answers and had a very reduced number of questions. The number of trips, the approximate duration of trips during the last month (no fishing on Sunday) for crab collecting, gillnet and spear fishing and the destination of their catches (sold or consumed), were recorded. Data from direct observations (number of boats, fishing nets, spearguns…) completed the surveys

ANNUAL CATCHES ESTIMATES

The estimates of annual catches are the product of the fishing effort per métier (e.g. number of trips p.a. of net fishing) by the average CPUEs (e.g. average number of fish catch in a fishing trip). Catches for reef fish and crabs are estimated for every village. The number of fish is converted to its equivalent weight based on the results of previous fishery monitoring (Amos, 2007; Kronen, 2007; Pascal, 2011). They provide a range of average weight of reef catches per fishing metier[22]. Average weight is comprised between 0,2 and 0,35 k per fish for net fishing and handline. For speargun, the mean weight is higher (comprised between 0,3 and 0,5kg per fish).

ADDED VALUE

The intermediary costs (CI_i) associated with the 3 main fishing métiers are estimated through interviews with fishermen. The methods described by several authors (Gillett and Lightfoot, 2001; Kronen, 2003; Kronen, 2007) have been used to take into account all cost categories for the coastal fishery métiers (motorized or not).

CORRECTING FACTOR FOR SUBSISTENCE FISHERY

One of the problems of the economic approach is that it considers replaceable, all the benefits withdrawn from subsistence fishing activities . In this case it was chosen to measure the benefit in protein weight leaving aside many aspects of the subsistence fishing. For example the following benefits are not reflected in the valuation: (i) the fishing activity needs low requirement of investment and training (Sprep, 2007), (ii) it can be a factor of social cohesion in villages because it contributes to maintain the women in the villages instead of seeking a cash income outside (Bensa and Freyss, 1994), (iii) for some households the part of the protein obtained from fishing in the total diet is non-replaceable (Pollnac et al., 2000), (iv) fishing is a stable food source against future uncertainties and a way to spread alimentary risks (Johannes, 2002). To reflect these benefits of the subsistence fishery, a weight-correcting factor (b) of 1.3 is applied to the results of added value (Seidl et al., 2011)

COASTAL COMMERCIAL FISHING (ES2)

DEFINITION

Ecosystem service of commercial fishery (ES2) includes all captures of reef and mangrove fish and invertebrates sold for food or for shells. Food can be sold as fresh or prepared.

Fish include all species that spend at least one ontogenic life stage or trophic migration in the reefs and mangrove ecosystems.

[22] For fishermen, a metier is an activity characterised either by the use of a specific gear, or by targeting a specific species, or within a specific fishing zone.

FORMULA

The same method as that used for subsistence fishery was applied to calculate the financial value of commercial fishery. First a quantification of the annual catches was estimated and then economic valuation was applied on this result.

For the valuation, the formula is:

$VA_{fc\ mpa} = ((A_{ie}*(1-s) * pm) - \sum_i CI_i)$

With:

Pm : average market price for commercial catches

CI_i : Intermediary goods per fishing métiers and other related businesses (i)

A_{ie}: Fishery catch volume (same as for subsistence fishery)

s: proportion of catches for subsistence fishery .

FISHING EFFORT

The data collection methods are the same ones as for subsistence fishery. No difference exists between both fisheries in the target species or in the métiers except for trochus fishery (*Trochus sp.*), which are collected specifically to be sold for their shells in the capital.

PRICE

Finfish and invertebrates are sold fresh or processed as either a main dish or as a complement. Commercialized fresh or prepared foods are valued based on their market price. This allows covering all the added value generated by reef fishery sector. The price of reef finfish is species independent and does not seem to fluctuate according to criteria of supply or demand. The price for crabs has been collected with intermediaries.

When used as a complement in prepared food, the commercial value is based on the final consumer price converted with the estimated weight of fish in the preparation.

ADDED VALUE

The commercial circuit for fresh fish is short. The fishermen have 2 options: sell directly to consumers (in the village or in the city) or to an intermediary who will sell in the city. Sales in the city can be made informally in some neighbourhoods or through the market place. No direct sales of reef fish or crabs have been observed with consumers such as restaurants or fish retailers.

In the studied villages, all the intermediaries belong to the same village as fishermen. The distribution of the fishery benefits per actor is then limited to the village level.

Intermediary costs per fishing métiers are the same ones as for the subsistence fishing. The costs related to commercialization such as ice, transport, market place and labour costs were collected.

DETAILS OF METHOD COMMON TO BOTH FISHERIES

ANNUAL EXTRAPOLATIONS

The extrapolation of observed results to an annual base has needed some corrections. The hot and wet season lasts from November to April and is characterized by higher temperatures. The period has an impact on the fishing effort as fishermen can stay longer in the water or more fishing trips can be made. As described by Amos (2007), fishing activity is often correlated to the agriculture calendar and the wet season corresponds to a weaker crop activity. These 2 potential sources of bias are taken into account in the extrapolations through the application of a factor of 1.3 on the catches from spear gun and 1.2 for gillnets. Factors were deduced from a previous study (Mees and Anderson, 1999) which surveyed a full year of fishing effort for the same gears.

MAXIMUM SUSTAINABLE YIELD CORRECTOR

The obtained catches were aggregated and reported to the fishing grounds area (in $t.y^{-1}.km^{-2}$) and compared to a reference of Maximum Sustainable Yield (MSY) value for reef fisheries. The value of 5 $t.\ y^{-1}.km^{-2}$ of reef is proposed as an indicator of sustainability for coral reef fisheries (Armada et al., 2009; Jennings and Polunin, 1995; Mumby and Steneck, 2008b; Munro, 1984; Newton et al., 2007). For mud crabs, a maximum catch of 5 000 individuals for the whole zone is taken as a very approximate and almost arbitrary reference (Villasmil and Mendoza, 2001). In the case of villages with yields surpassing the MSY, only the yields under this level were taken into account. The underlying idea is to limit the valuation to sustainable activities only.

PELAGIC AND DEEP SEA FISHERY

Regarding effects on pelagic and deep-sea fisheries it was decided not to include them in the valuation. MPA has very little effect on the benthic species of the continental shelf and offshore pelagic species. The only demonstrated effects would be the trophic exchange through export of reef fish species larvae from MPA. These reef fish species larvae make up part of the diet of some non-coastal fish species. However, studies analysing stomach contents show that the contribution is relatively low (between 5-10% of the total diet) (Allain, 2009).

SPORT FISHING (ES3)

DEFINITION

The ecosystem service of sport fishing or recreative activity (ES3) corresponds to the non-commercial fishery where all catches are auto consumed, given or exchanged but no monetary transaction takes place.

Two types of fisheries are distinguished: the food or subsistence fishing and recreational fishing. As described before, the subsistence fishery (ES1) has a different valuation approach and it is necessary to identify the volumes and fishing effort of each one.

Apart from the two extremes between fishing as an important source of nutritious food and a 100% recreational fishing (quasi-non-dependent on catches), there are several intermediate levels making the distinction between the two types of fishing sometimes difficult.

Recent studies (Virly, 2002) show a continuum between these two types of fishing rather than classes with distinct boundaries. Gradients can be characterized by different variables.

Low number of sources of food _______________ High number of food sources

Peri-urban ______________________________ urban, rural

Large boat, motor ___________________ reef gleaning, foot

Research effort will be made to identify and categorize these groups in order to quantify them.

The estimate of recreational fishing involves assessing the notion of leisure. Recreational fishing differs from other commercial fisheries or subsistence insofar as satisfaction of fisherman is not based only on a catch or a financial benefit but on well being generated by a leisure activity. Uncles (1997) demonstrated this fact in a relevant way by presenting results in the state of Victoria (Australia), where the average cost of fish caught by sport fishers is around $US 120 per kg (Uncles 1997) against a purchase price $US 5 per kg on average.

For the calculation of producer surplus, two aspects are considered: (i) the value of fish catches if they were to be replaced by purchases on the commercial circuit (estimates of demand substitutability), and (ii) the added value generated by the boating industry connected to recreational fishing.

However, this choice implies that all recreational catches should be substituted by purchases of similar fish on different outlets of the community. Of course, it is not possible to consider a total replaceability between the catch of recreational fishing to commercial fishing. The factor elasticity of demand is estimated for recreational fishermen who have access to a regular market of reef fish. This factor corresponds to the proportion of catches from recreational fishing, which would disappear if these people had to buy their catch. This factor will be estimated from meetings with various experts as well as interviews with recreational fishermen.

The added value levels are the same as those of the commercial fishery.

NAUTICAL SECTOR LINKED TO RECREATIONAL FISHING

The approach follows the method exposed below:

VA = (number of boats registered in year n * the purchase price - intermediate costs) + (number of fishing trips * Annual average expenditure per trip – intermediate costs involved).

The recreational boating industry corresponds to a "coherent set of activities articulated in a productive system" that meets the principle of the concept of industry, as defined by economists. The industry can be divided into (i) the business of the boat, motor and equipment and (ii) the expenditures related to boats.

Calculations of boat / motor / equipment industry are based on the determination of an average purchase price per ship type (size and power) and equipment.

The quantification of the number of annual registrations, import (or manufacture) hardware and the number of annual trips are estimated from various sources (Merchant Navy, Customs statistics, surveys with existing users, ...). The study launched in 2007 by the French Ministry of Agriculture and Fisheries on recreational fishing (recreational and sports) at sea will be adapted to the local context based on Purchasing Power Parity (Heston et al., 2009) and based on the price of port fees, marinas and insurance.

The added value of the two sectors is then calculated.

OTHER EXTRACTIVE USES (ES4)

For other ecosystem services provided by other extractive uses (wood, aquarium industry, souvenirs) the idea is to use methods via the producer surplus.

For example, another type of extractive use is the aquarium industry. The methodology to calculate the added value of the industry follows a classic way :

VA = Volume collected * Final Price - Intermediate costs

VALUATION OF TOURISM ECOSYSTEM SERVICE (ES 5)

IMPLICATED ECOSYSTEM PROCESSES

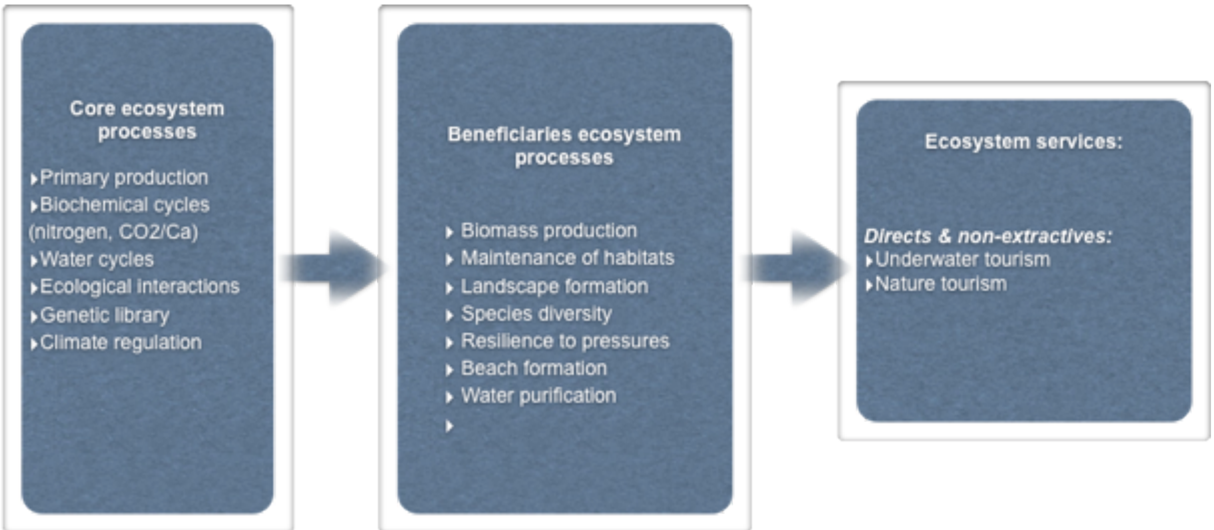


Figure 24: Key ecosystem processes involved in tourism services.

For tourism activities, 2 valuation methods are used:

(i) industry producer surplus for market tourism activities related to the ecosystem processes, and,

(ii) (ii)???

TOURISM PRODUCER SURPLUS

The method followed is firstly to valuate the direct uses related to mangrove (with or without service providers).

In a second step, the valuation of indirect costs (accommodation, transportation, food, etc.) associated to the previous activities will be done applying a calculated ecosystem-contributing factor.

Methods of Business Expenditure Survey (BES) with key informers are used for surplus producers estimates.

COMMERCIAL ACTIVITIES:

It is assessed by the value associated with commercial activities of recreational mangrove activities: the user pays a fee for the realisation of the activity.

The idea is to quantify all tourism activities that use one or more of coral reef and mangrove ecosystem processes. Quantification of results will be expressed in terms of number of visitors while monetary valuation is based on the calculation of surplus producers of the business activities.

The methodology is therefore :

*Added value (by activity) = price * tourism frequentation - intermediate costs*

Nautical tourism includes activities related to reefs and mangroves. The following uses are listed: water taxis, day charters, mangrove-guided tours, fishing charter and boat/kayak rentals by the day or week.

Knowledge of the motivations of users and their practices will be based on interviews with business providers. They will identify the intensity of use of ecosystems in their activities.

Uses that do not involve observations of mangrove associated animals or habitats will be eliminated.

ASSOCIATED TOURISM EXPENSES

The formula is as follows:

*VA = contributing factor of ecosystems *associated tourism local expenditure - intermediate costs*

Three types of users can be identified for associated tourism local expenditures: non-resident tourists, residents and cruise passengers

NON-RESIDENT TOURISTS

Expenses assessed include:

(i) the international transport and
(ii) local expenditures.

The direct tourism expenditures described previously (kayaking, guided tours, etc.) will not be taken into account to avoid double counting.

For international transport and to meet the objective of the study to isolate the creation of wealth for the country only, we should remove all non-resident companies. Thus, only the international airlines with the parent company based locally will be taken into account.

For local expenditures, we contemplate :

- accommodation (hotels, cottages, ...)
- restaurants, cafés and food
- local transportation (sea, air and land)
- souvenirs, gifts and other expenses (fuel, services connection etc.).

The proposed method for estimating expenditures per person will be done:

a) using survey responses to estimate the average expenditure of the users (sampling protocol defined according to the context, but to ensure a 90 and 95% confidence interval according to the homogeneity of the target population)

Respondents will be asked to indicate the approximate amount they spent on different categories.

The midpoint of each category will be compared to the average values in order to estimate the total expenditure on all categories and avoid bias in the final estimates.

b) using the results of existing studies investigated the departure at the airport (exit surveys). Protocols and sampling will be checked to ensure the robustness of the data used.

RESIDENT USERS

Aside from non-resident tourists, residents of the community who exhibit uses associated with reefs or mangroves may incur expenses related to accommodation meals and transportation that must be taken into account.

The main objective is to know the precise use of reefs by residents and especially the costs associated with them. Hotel occupancy studies can complement this approach and quantify the annual number of users. In case of data unavailability, surveys with resident users will be used to estimate some parameters.

ECOSYSTEM CONTRIBUTING FACTOR

If we want to estimate the economic impact of an ecosystem on tourism-associated expenditures, we must be able to determine the share of tourism expenditures directly attributable to the ecosystem. We called it the contributing factor and reflect the importance of ecosystems in the choice of the tourism destination. However, it is not always possible to isolate a factor in the selection process of the destination by tourists because many trips are inherently due to multi-attributes. Almost thirty factors involved in the selection of a site are identified by different authors (Parry and McElroy, 2009; Tourism and Transport Consult, 2005). As an illustration, we can mention: accessibility, price, infrastructure, security, cultural atmosphere, hospitality, recreational activities proposed, etc.

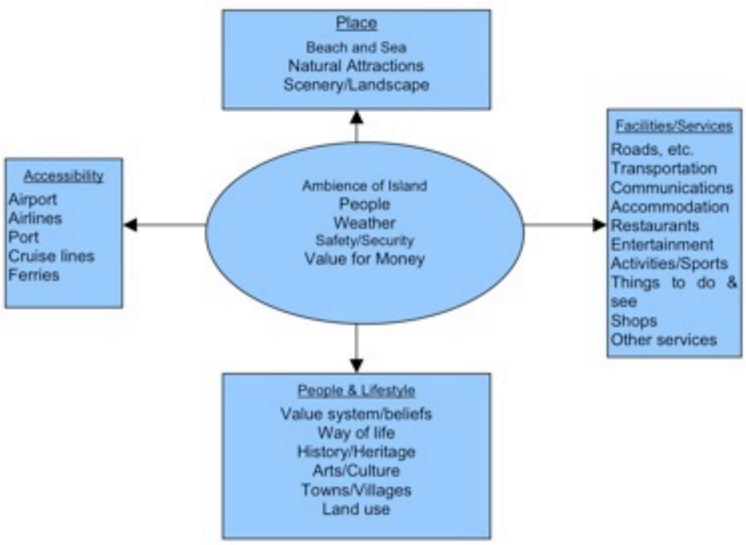


Figure 25 : Factors influencing tourism satisfactions

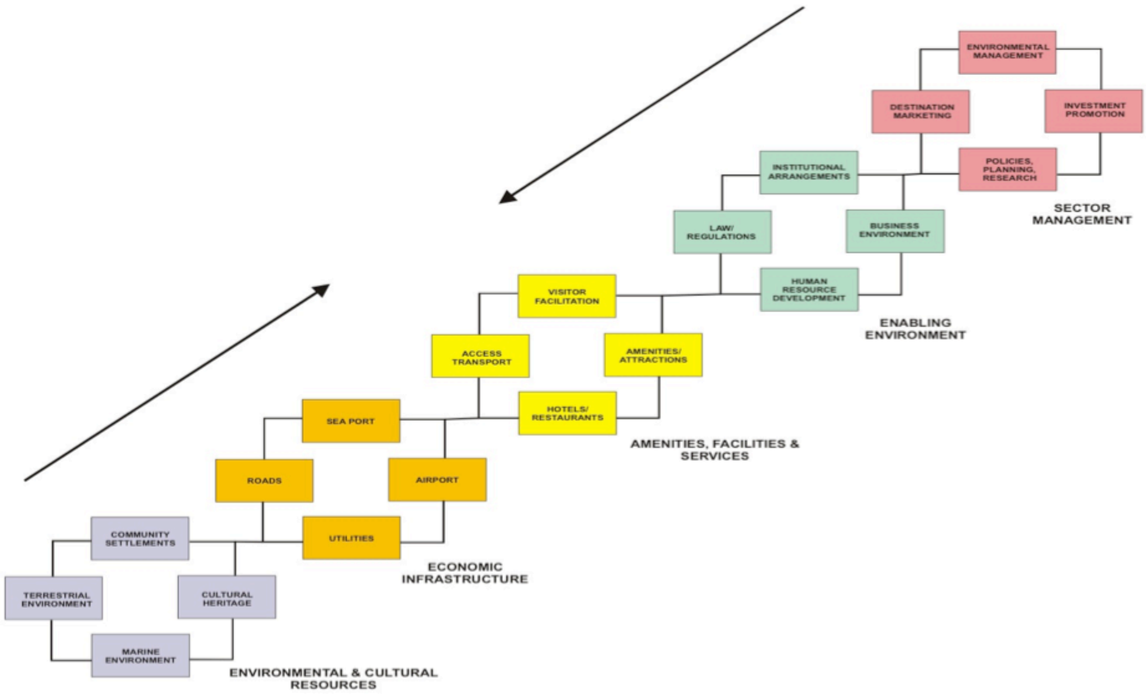


Figure 26 : Factors influencing the tourism choice of destination

The contributing factor will be calculated through:

a) The Analysis of Advertising Images (AIA)

The method of analysis of advertising images is first described by Hajkowicz et al (2005). It is based on the existing tourism advertising media (mainly print and online) that have been known by tourists before their arrival. The underlying theory is that advertisements are based on a communication strategy. They are designed with a specific target and aim to arouse the recipient's desire to acquire the service promoted. In our case it will be used as a proxy on the choice made by tourists in their destination.

The media supports will be quantitatively analysed to determine the proportion of images and keywords related to certain attributes.

The selected attributes are:

- Images related to culture and people

• Images related to ecosystems and landscapes

• Images related to beaches

• Images related to recreational underwater coral and marine biodiversity

• Images related to other forms of entertainment

A minimum of 200 images (when available) will be classified to determine the importance of the attributes analysed. These images are available to tourists before their arrival and proceed from different sources (internet and print mostly).

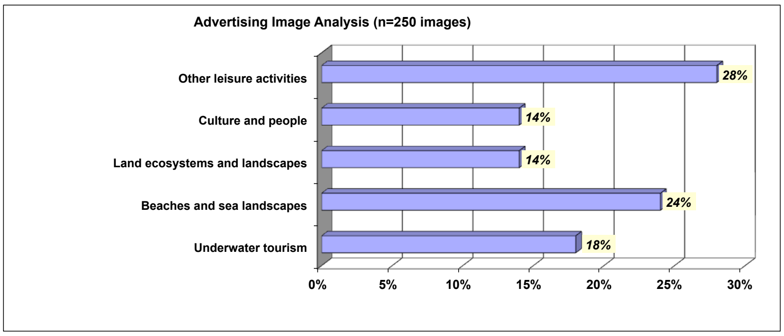


Figure 27: Illustration of the technique of analysis of advertising images for coral reefs

FINAL RESULTS

Based on annual figures, visitors will be segmented following the criteria set out below. The goal is to produce populations as homogeneous as possible in order to ensure the best application of contributing factors. Matrix variables of mangrove_contribution from the analysis of advertising images are then applied on the expenditure structure of different categories of users or tourists.

Category 1:It corresponds to visitors (all groups combined) that would not have come into the community if ecosystems were not in their current state (mangrove_contribution variable is equal to 1). It may be specialized nature trips, hunting or photography, for example. Total associated expenditures are accounted at 100%.

Category 2: These are the visitors who came to the site for several reasons and realize any of the following activities related to the mangrove ecosystems.

Category 3: Spending by visitors who do not realize any mangrove related activities described above will be excluded from this monetization.

VALUATION OF COASTAL PROTECTION AGAINST FLOOD (ES 6)

ECOSYSTEM PROCESSES

WAVE ENERGY ABSORPTION

The coral reefs and mangroves are natural barriers to coastal protection. They limit the phenomenon of coastal erosion by absorbing 70-90% of the energy waves (Kench and Brander, 2009) and lessen the damage in case of severe weather events (hurricanes, tropical storms, ...) (UNEP-WCMC, 2006).

Storm systems such as tropical cyclones and mid-latitude storms and their associated cold fronts are the main cause of storm surges. Storm surges can interact with other ocean processes such as tides and waves to further increase coastal sea levels and flooding. A storm surge will have maximum impact if it coincides with high tide. Breaking waves at the coast can also produce an increase in coastal sea levels, known as wave setup. Storm surges occurring on higher mean sea levels will enable inundation and damaging waves to penetrate further inland. This would increase flooding, erosion and damage to built infrastructure and natural ecosystems.

The shape of the sea floor and the proximity to bays, headlands and islands also affect the storm surge height. Wide and gently sloping continental shelves amplify the storm surge, and bays and channels can funnel and increase the storm surge height.

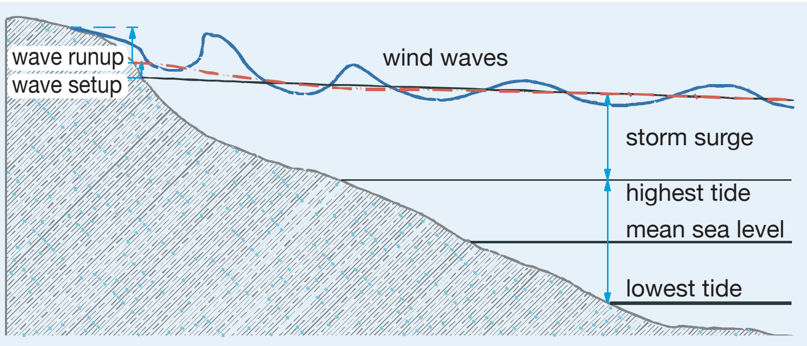


Figure 28 : Storm surges occurring on higher mean sea levels will enable inundation and damaging waves to penetrate further inland increasing flooding, erosion and damage to built infrastructure and natural ecosystems (extracted from (CSIRO and Australian Bureau of Meteorology, 2007)

The climate change effect of rising mean sea levels will be felt most profoundly during extreme storm conditions.

Coral reefs and mangroves create protection against waves forming barriers along the costal line. Similarly, lagoon areas protected by barrier reefs are generally quiet areas that promote the multiple uses described previously. Several studies (Brander et al., 2004; Kench and Brander, 2009; Lugo-Fernandez et al., 1998) show that the reefs act similarly to wave breakers or shallow coast. They impose strong constraints on the swell of the ocean resulting in transformations on wave characteristics and a rapid attenuation of wave energy. The waves formed by the wind have a large part of their energy in the surface. The fringing reef and the reef crest can absorb a large part of this force, sometimes up to 90% at low tide (Lugo-Fernandez et al., 1998). The following figures show different results for the reefs of the Caribbean. There is a high variability depending on the type of reef, the depth and the waves (Kench and Brander, 2009). In addition, the role of coral reefs and mangroves in coastal protection is difficult to isolate from other variables. In fact, a combination of factors comes into the process. The main ones are: (i) bathymetry (ii) geomorphology (iii) topography and (iv) the biological cover (Burke, 2004). Few studies have focused on isolating the contributory role of the reef in this combination of factors (Barbier et al., 2008).

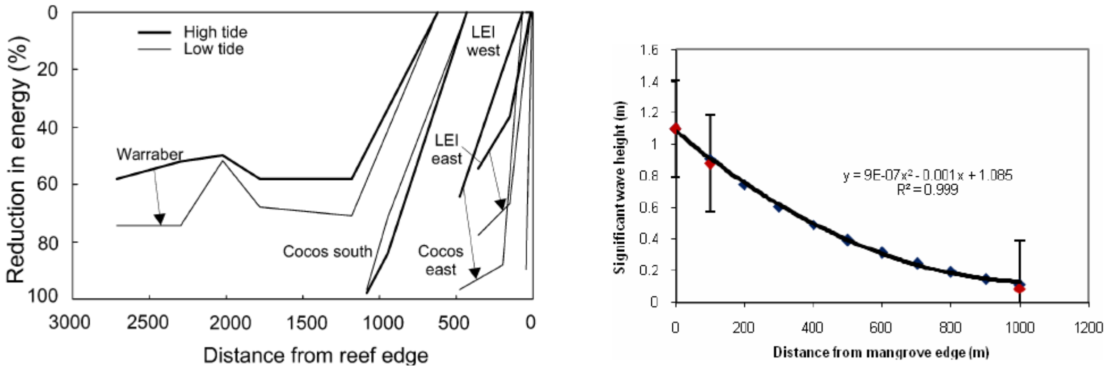


Figure 29 : (left) Reef as wave energy absorber (Extracted from Kench et Brander (2009)) (right) Effects of mangroves on wave height (extracted from Barbier et al. (2008)

In the same way, an analysis by Barbier et al. (2008) found that the relationship between reef area and this absorption process is nonlinear. This adds an additional complexity in the evaluation of this ecosystem service. To illustrate the non-linearity effects, the same analysis on the effect of mangroves on the wave height shows that waves of 1.1 m in the sea are reduced to 0.91 m along the mangrove forest if the forest has an extension of 100 m. The wave continues to decline, albeit at a slower rate, for each additional 100 m of mangroves inland. For a forest extending 1000 m inland, the waves would be reduced to a negligible 0.12 m).

Seagrasses, composed of four major families of plants (Zosteraceae, Posidoniaceae, and Cymodoceaceae, Hydrocharitacea), play a major role in coastal areas they colonize, forming extensive meadows, more or less diversified and expanded. Their presence is an important factor in the stability of sedimentary substrates they colonize. The leaves of these plants slow currents by increasing the viscosity of water and they decrease the energy dissipated by the waves (up to - 40% of erosive energy when seagrasses are dense (Barbier et al., 2011). They also contribute to increase the sedimentation rates (Pearson, 2001). The roots and rhizomes fix the material in which they grow. As such, seagrass effectively contributes to the protection against mechanical waves and limit coastal erosion.

A study by Das and Vincent (Das and Vincent, 2009) assesses the storm protection role of mangroves, based on data on human casualties, damages to houses and livestock losses suffered in the Kendrapada district in Orissa state during the super cyclone of October 1999. The analysis incorporates meteorological, geo-physical and socio-economic factors to separate out the impact of mangrove vegetation on cyclone damage. The results indicate that the mangroves significantly reduced human death and seemed more effective in saving lives (both human as well as animals) than in reducing damage to static property (Vishwanathan et al., 2004). Factors like land elevation, immovable asset holdings, etc, too, had decisive effects on human casualties in the storm surge affected areas. Further analysis by Das (2009) on the storm protection role of mangroves revealed that if the mangrove cover had remained at the level that it had been in the 1950s, the area would not have suffered any fully collapsed houses at all. The study suggests that mangrove forests provided protection benefits to houses to the extent of USD 23 233 per km width of forests.

Barbier (Barbier, 2007b) through a count data model[23] based on EM-DAT (2005) data showed that a change in mangrove area had a significant influence on the incidence of coastal natural disasters in Thailand, and with the predicted sign. Results indicate that a decline in mangrove area increases the expected number of disasters. The analysis for Thailand over 1979–96 shows also that loss of mangrove area in Thailand increases the expected number of economically damaging natural disasters affecting coastal provinces. It suggests that the marginal effect of a one-km2 loss of mangrove area increased expected storm damages of about US$585 000 per km2.

As a reference, average annual direct loss caused by tropical cyclones in 15 South Pacific countries was calculated to vary from US$ 2 to 80 million (2009 prices) with 60% of damages coming from loss on buildings, 30% on cash crops and 10% on infrastructure (PCRAFI, 2011b).

[23] In economics, count data models have been used to explain a variety of phenomenon, such as explaining successful patents derived from firm R&D expenditures, accident rates, disease incidence, crime rates and recreational visits (see (Barbier, 2007b) for more details). Count data models could be used to estimate whether the presence of an ecosystem affects the expected incidence of economically damaging storm events.

ROLE AGAINST TSUNAMI WAVES

Some studies have suggested the role of reefs and mangroves against tsunami waves (Das and Vincent, 2009; UNEP-WCMC, 2006). Thus, studies show that, historically, tsunamis waves have been through the Great Barrier Reef only through the channels (Knott, 1997). Similarly, for the mangrove, tree density seems to explain some of the effects reducing tsunami threats. The effects of coral reefs against the tsunami waves, however, are different from those facing wind-originated waves. A tsunami wave is much larger and its energy is distributed throughout the water column. Evidence from the 12 Indian Ocean countries affected by the tsunami disaster, including Thailand, suggests that those coastal areas that had dense and healthy mangrove forests suffered fewer losses and less damage to property than those areas in which mangroves had been degraded or converted to other land uses. See (Barbier, 2007a) for a selection of studies highlighting this role[24].

Nonetheless, other studies seeking correlations between mangrove cover and tsunami risk reduction (Done et al., 1996; Pérez-Maqueo et al., 2007; SOPAC, 2008) have not been able to show clear results. In many cases, where the mangroves were supposed to have reduce the tsunami wave, they were off the main path of the wave or were close to deep zones that already greatly reduce the effect of the tsunami. What emerges from these studies is that the extension of the reef or mangrove may be not the main factor influencing the reduction of damage on the coast. Coastal bathymetry and geomorphic profile of the coast are probably other key explanatory factors (Burke, 2004). Tsunami effects are amplified on the coasts with gradual depth.

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[24] With the overwhelming evidence of the storm protection service provided by intact and healthy mangrove systems, since the tsunami disaster increased emphasis has been placed on replanting degraded and deforested mangrove areas in Asia as a means to bolstering coastal protection. For example, the Indonesian Minister for Forestry has announced plans to reforest 600 000 hectares of depleted mangrove forest throughout the nation over the next 5 years. The governments of Sri Lanka and Thailand have also stated publicly intentions to rehabilitate and replant man- grove areas (UNEP, 2005; Harakunarak and Aksornkoae, 2005).

METHOD

The first step of the avoided damages method[25] is to quantify the coastal protection ecosystem service in terms of land protected. The second one is to apply the coral reef and associated ecosystems contributing factor and the third one is to value this ecosystem service in terms of avoided damages. Similar methodology to value this coral reef ecosystem service has been tested by Burke (Burke et al., 2008) and (Pascal, 2010) to Caribbean and New Caledonian reef respectively.

One of the main challenges is that coastal protection against waves is a complex process implicating many factors such as geomorphologic patterns of the coast, the presence of other ecosystems, etc. The identification of the contributing role of each of the different factors is a challenging task and is out of the scope of this study.

The general model is:

A. **Identify coastal areas potentially at risk against the regime of coastal flooding events.**

B. **Determine the contribution of coral reefs, mangroves and seagrass in the coastal protection of the vulnerable areas.**

C. **Quantify and value the potential damage repair costs with a method of damage avoided costs:**

C.1. Characterization of the assets exposed to risk (3 categories of land use)
C.2. Valuation of the total repair costs of direct and indirect tangible damages based on approximate values per land use category (object oriented data) and as a function of inundation depth (relative depth-damage function)
C.3. Estimation of the probability of flood event per impact category.

[25] it assesses the damage costs avoided by the presence of the ecosystems. This is a special category of 'valuing' the environment as 'input'; it assumes that the value of an asset that yields a benefit in terms of reducing the probability and severity of some economic damage is measured by the reduction in the expected damage (Barbier, 2007b).

IDENTIFY COASTAL AREAS POTENTIALLY AT FLOOD RISK AGAINST THE REGIME OF OCEAN WAVES

Coastal flooding can occur during severe weather conditions. They are related to "storm surge" (elevation in sea level in low pressure situations (hurricanes)) and the onslaught of cyclone swells (DEAL, 2012).

Directive 2007/60/EC on the assessment and management of flood risks, more commonly known as Directive "Floods" is the first European directive in the field of risk prevention. It is transposed into French law with Article 212 of the Law of 12 July 2010 on the National Commitment to the Environment (known as Grenelle II). Decree No. 2011-227 of 2 March 2011 on the assessment and management of flood risks complements these provisions.

Estimates will be realized on the coastal land zone comprised between an altitude of 0 and 5 m upper the high tide sea level (a storm surge will have maximum impact if it coincides with high tide). This level comes from the historic maximum height of non-tsunami waves during the last 25 years in the tropical regions (source: NOAA, Meteo France and Vanuatu Meteorological Office).

A projection of this height will be made with GIS topographic data to project potential impacts of flood events. Several sources of data are used:

- SOPAC Vanuatu and Fiji maps of infrastructure and buildings
- Government of Vanuatu 1:50,000 cartographic maps for coral reefs, mangroves, bathymetry, topography
- Vanuatu National Statement on Vulnerability and Adaptation, Rarua J. Nelson, Mawa Patricia, Nari, Russell & Smith M. Atchinson, 1998.
- Aerial photography: PlanetObserver (satellite images), Institut national de l'information géographique et forestière, Centre national d'études spatiales (CNES), Astrium
- SHOM maps (Service hydrographique et océanographique de la marine). Marine maps from 1:8 000 to 1:8 725 000) with bathymetry.

The areas vulnerable to the flood impacts of waves and swell are all areas that have less elevation than the maximum height relative to the sea level at low tide and up to 1 km inland (Kench and Brander, 2009)(Das and Vincent, 2009).

The area and depth of inundation are the most important information to be sampled in flood risk evaluation (Torterotot, 1993). Inundation depth is generally the most important or at least most frequently used inundation parameter in damage evaluation. Based on the assumption that inundation depth has the strongest influence on damage magnitude, nearly all damage functions are solely depth-damage functions (see chapter C.3.). Nevertheless it should be noticed that analyses of empirical damage data showed that the variability of damages can only be explained to a rather small extent by the depth of flooding experienced (Messner et al., 2007). The duration, time of occurrence, velocity or the toxicological load of flooding water could have also a significant influence on damage. Other flood characteristics than depth are not recorded, so that it is difficult to quantify their influence.

Due to the macro-scale of the study and the knowledge gaps, only depth and area will be taken in account.

Inundation characteristics	Relevance
Area	Determines which elements at risk will be affected
Depth	Has perhaps the strongest influence on the amount of damage
Duration	Special influence on damages to building fabric
Velocity	Only high velocities will lead to increased damages; therefore mainly relevant in flash flood areas or areas near dike breaches
Rise rate	Influence on damage reducing effects of warnings and evacuation
Time of occurrence	Especially important for agricultural products
Contaminations	Contaminations and loads may increase damages significantly
Salt-/freshwater	Saltwater may increase damages; relevant in coastal areas

Table 12 : Damages influencing flood characteristics (Messner et al., 2007)

B. CONTRIBUTING FACTOR OF ECOSYSTEMS IN COASTAL PROTECTION.

CONTRIBUTING FACTOR OF CORAL REEFS IN COASTAL PROTECTION.

Different working groups from the Institute of Marine Affairs (IMA) and the University of New Caledonia (UNC) have developed models of factors that categorize the level of coastal protection (Burke et al., 2008) according to various contexts.

Coastal stability is defined as an index of coastal protection that incorporates ten physical characteristics. The index estimates the erosion resistance of each segment of coastline. Physical characteristics included in the index of coastal protection are:

- coastal geomorphology (a limestone cliff, beach, etc.) and coastal geology (igneous, metamorphic, etc..)
- exposure of the coast (protected by a breakwater or riprap or exposed)
- characteristics of coral reefs (reef type, area and distance to the coast)
- slope of the platform (m)
- inner slope and crest width (m)
- mean depth between the reef and the coast
- presence of activities causing erosion, such as sand extraction.
- coastal vegetation (mangroves, wetlands, etc..)

These physical characteristics are converted to a value between 1 and 5 and the average is calculated to produce a unique index value for each shore: the Coastal Protection Index (CPI). The relative contribution of reefs in the CPI is then calculated.

This method will be adapted to the context of each geomorphological sites and available data. The UNC considers that at least five factors must be filled in (Allenbach pers. Comm.) to ensure robustness in the results. In cases where local data are not available, it will be chosen to simplify the model to assess the contribution of reefs.

	Very strong	Strong	Medium	Low	None
	5	4	3	2	1
Geomorphology	Rocky shore	Mix of rocks/sediments/mangroves	Mangroves	Sediments	Beaches
Coastal exposure	Protected bay	Semi-protected bay	Artificial reefs	Low protected bay or coast	No protection
Reef morphology, area and distance to the coast	Continuous barrier (>80%) close to the coast (<1km)	Continuous barrier (>50%) , patch reef, close to the coast (<1km)	Fringing reef (width >100 m)	Coral formation discontinuous	No reef
Inner slope, crest width	Very favorable conditions (gentle slope, large crest width)	Favorable conditions (slope, large crest width)	Favorable conditions (at least one component: slope, crest width)	Reduced favorable conditions (strong slope, reduced crest width)	None
Platform slope	6-10%	2.5-6%	1.1-2.5%	0.4-1.1%	< 0.4%
Mean depth (<1 km from the coastline)	> 30m	> 10 m	> 5m	< 5m	< 5m
Other ecosystems	mangroves, seagrass > 75% coastline	mangroves, seagrass > 50% coastline	mangroves, seagrass > 25% coastline	mangroves, seagrass <25% coastline, sand extraction areas	None

Table 13 : The calculation of the CPI (Coastal Protection Index) based on characteristics of the coastline (developed by Allenbach and Pascal).

CONTRIBUTING FACTOR OF MANGROVES IN COASTAL PROTECTION.

The mangrove is a unique ecosystem of the intertidal zone, having developed the capacity to adapt to extreme conditions (Walters et al., 2008). In cases where no coral reef are present, we will measure a small number of settings, accessible and quantifiable from cartographic and imagery usually available to assess the role of mangroves.

a. Coastline concerned;

b. Mangrove area and species cover;

c. Width of the coastal zone concerned;

d. Evolution of colonized areas (stability, gain, reduction).

For the purposes of monetary valuation, the role of mangrove protection against erosion (except from tsunamis that escape from normal quantification) may, schematically, be quantified on the base of the width of the colonized area by mangroves:

a. Less than 100 meters: low,

b. 100 to 500 meters: average,

c. Beyond 500 meters: high level.

Mangroves are effective in reducing storm-induced waves less than 6 m in height, and studies suggest that the wave height decreases nonlinearly for each 100 m that a mangrove forest extends out to sea (Barbier, 2012). In other words, wave attenuation is greatest for the first 100 m of mangroves but declines as more mangroves are added to the seaward edge. Barbier (2012) signals that Gedan et al. (2011) and Koch et al. (2009) find similar nonlinear wave attenuation across other mangrove landscapes, regardless of the mangrove species, the tide level and coastal geology.

When available, other factors will be taken in account such as: width of forest, slope of forest floor, forest density, tree diameter and height, proportion of aboveground biomass in the roots, soil texture, and forest location (open coast vs. lagoon) (Alongi, 2008; Barbier et al., 2011).

On the other side, the role of the other neighbour ecosystems will be taken in account.

MAIN CLIMATE CONTEXT

The Streamlines of Mean Surface Wind (Figure below) shows how the region is dominated by easterly trade winds. In the Southern Hemisphere the Trades blow to the northwest and in the Northern Hemisphere they blow to the southwest. The streamlines converge, or crowd together, along the SPCZ. The Southeast Asian Monsoon also influences much of the Melanesian subregion. (Siméoni and Lebot, 2012)

The strength and timing varies considerably, but at Manus Island (PNG), for example, the NW monsoon season (winds from the northwest) runs from November to March, while the SE monsoon brings wind (also known as the Southeast Trade Winds) from May to October. Unlike many monsoon-dominated areas, the rainfall is distributed evenly throughout the year (in normal years). (SOPAC, 2006)

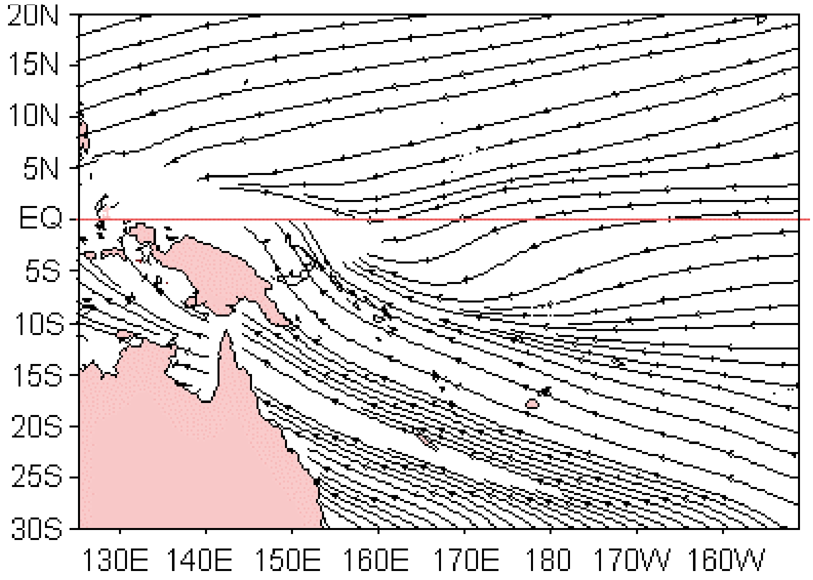

Figure 30: Streamlines of mean surface wind (extracted from SOPAC, 2006)

Vanuatu is located south of the equator in an area known for the frequent occurrence of tropical cyclones with damaging winds, rains and storm surge between the months of October and May. In the South Pacific region from the equator to New Zealand in latitude and from Indonesia to east of Hawaii in longitude, almost 1,000 tropical cyclones with hurricane-force winds spawned in the last 60 years, with an average of about 16 tropical storms per year (PCRAFI, 2011a).

If we quote the last report about natural hazards in the Pacific (PCRAFI, 2011a), we can highlight the following analysis for Vanuatu: "Since 1990, Vanuatu has been subject to at least 20 damaging tropical cyclones. The most significant cyclones in recent years were Uma in 1987 and Ivy in 2004, each affecting nearly 50,000 people and causing destruction that amounted to losses in the tens to hundreds of million USD. Figure below shows the levels of wind speed due to tropical cyclones that have about a 40% chance to be exceeded at least once in the next 50 years (100-year mean return period). These wind speeds, if they were to occur, are capable of generating severe damage to buildings, infrastructure and crops with consequent large economic losses. A number of destructive tropical cyclones have passed near Vanuatu in the last 25 years. Three in particular have come close enough to Port Vila to be recorded as very low pressures. TC Prema, on 29 March 1993, TC Paula (Category 3), on 2 March 2001 and TC Ivy (Category 4) on 26 February 2004 have all caused considerable damage."

Quoting other report, we can figure out the importance of cyclone damages in Vanuatu: "Disaster impact assessments in Vanuatu principally focus on the impacts of cyclones, and related flooding and landslides. The most comprehensive impact assessment in Vanuatu was conducted for Cyclone Ivy, which struck the country in February 2004. The total cost of Cyclone Ivy was estimated at VT 427.6 million. Cyclone Ivy affected 50,000 people, and caused one fatality. In the affected communities 90 per cent of the water sources and water supply systems, 70 per cent of roads, 60 per cent of health infrastructure, 112 schools, and over 80 per cent of food crops were damaged" (McKenzie et al., 2005).

The number of extreme events since 1940 per category is presented in the following table :

Vanuatu

Category	Count
Category 5 (H5)	0
Category 4 (H4)	2
Category 3 (H3)	9
Category 2 (H2)	4
Category 1 (H1)	9
Trop./Sub. Storm (TS/SS)	7
Trop./Sub. Depression (TD/SD)	0
Extratropical (ET)	0
Unknown (N/A)	

Figure 31: Count of extreme climatic events in Fiji and Vanuatu since 1940. Source: National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center , Historical Hurricane Tracks.

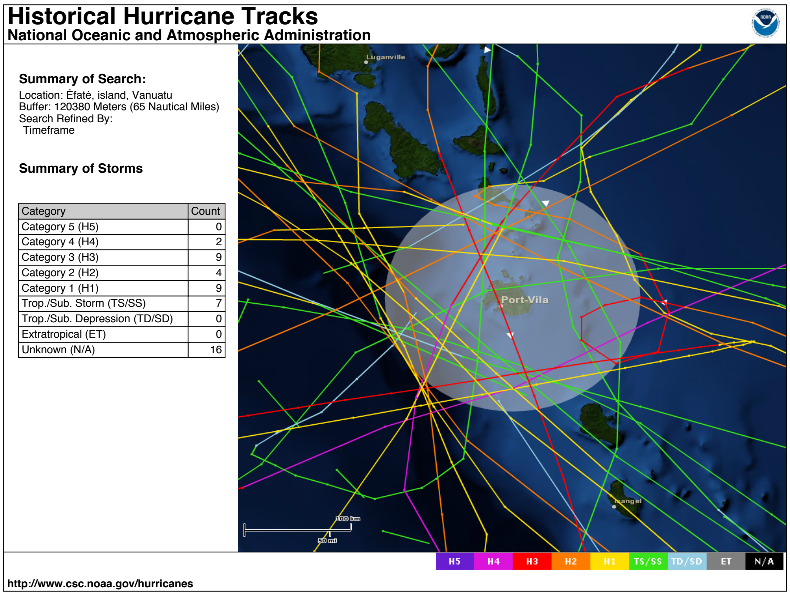

Figure 32: Historical Hurricane Tracks for Efate, Vanuatu – 70 years of data (source: National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center , Historical Hurricane Tracks.)

ECONOMIC VALUATION

After defining the hazard by flood characteristics it is necessary to find out who or what is exposed to this hazard. More precisely, information is needed about the number, location and type of elements at risk as well as their value and their susceptibility against flooding.

Following the methodology developed by several reports ((PCRAFI, 2011b) (Bolt et al., 2005; Messner et al., 2007; Pagiola, 2004a, b), 3 steps are necessary to the economic valuation:

- Characterization of the assets exposed to risk (3 categories of land use)
- Valuation of the total repair costs of direct and indirect tangible damages based on approximate values per land use category
- Apply relative depth-damage function showing the damaged share of the total value as a function of inundation depth.

The approaches are considerably approximated methods, mostly developed for the application in large areas or for quick overviews.

C.1. EXPOSURE TO RISK

The initial step of the process is the characterization of the assets and distribution of population exposed to flood risk[26]. As described in the following table, several categories of damages from flood events are identified.

[26] Direct damage from direct contact with water

		Measurement	
		Tangible	Intangible
Form of damage	Direct	Physical damage to assets: - buildings - contents - infrastructure	- Loss of life - health effects - Loss of ecological goods
	Indirect	- Loss of industrial production - Traffic disruption - emergency costs	- Inconvenience of post-flood recovery - Increased vulnerability of survivors

Table 14 : Typology of flood damages with examples (Messner et al., 2007)

Due to the macro scale of our study and the purpose of reflecting a minima valuation, we will focus our analysis on direct and indirect tangible damages.

For direct ones, we have selected[27]: (i) buildings (ii) infrastructure and (iii) crops. For indirect ones, the emergency costs and the loss of tourism industry revenues have been chosen. Details for direct damages are given below:

(i) The building exposure will include residential, commercial, public, and industrial buildings. A database with building quantification, replacement cost and simplified structural characteristics that affect the vulnerability to natural perils will be created in the zone at risk. It will be assembled at a varying level of resolution and accuracy. The level of detail of land use data is determined by two aspects: the spatial resolution of the data and the level of differentiation of different land use types. Especially regarding urban areas, the spatial resolution of land use information varies considerably. Detailed data contains information about single properties or buildings. This kind of data is called object-oriented data and damage valuation methods based on this data can be called property-by- property approach (Penning-Rowsell et al. 2003). In other data sources properties or buildings are aggregated to areas of more or less homogeneous land use. This type of data is called aggregated land use data. Both land use data are often available from secondary sources. Two different kinds of data can be mentioned here: Address-point data, where each property is represented by a point in a map, and cadastral maps, which also give information on ground floor area of properties (see chapter A for a list of GIS sources used). Data field verification, if planned, will be located in areas that have more variety of building types and usage with more costly structures.

[27] Direct tangible damage can include more categories (inventories, cars, etc.). However, some damage categories – especially buildings – usually dominate the total amount of damage. Therefore, it can be reasonable to include only the most important damage categories to reduce the effort of the study.

(ii) The infrastructure exposure will be assembled using similar techniques as those used for buildings, comprises a detailed and extensive inventory of major assets, such as airports, ports, power plants, dams, major roads, and bridges.

(iii) The spatial distribution of major commercial crops will be derived from medium resolution satellite imagery (see chapter A for a list of GIS sources used). To the extent possible, results will be validated by ground "truthing". Additional validation will be performed using agricultural census data and feedback from local experts.

A GIS-based population database (when available) is analysed in order to geographically identify the population most at risk in each site. This database, which will be compiled from data sets of many sources, such as the bureaus of statistics from the countries' government and other databases (the World Bank), provides population counts within the main administrative boundary.

C.2 REPAIRING COSTS

The costs reflect the construction costs needed to repair or replace the damaged assets. The repair cost values for different buildings and infrastructure will be collected from a variety of sources, including construction cost management firm, governmental reports, interviews with local experts, and historical disaster reports. The potential damages on the constructed areas will be measured with average construction costs to replace damages assets. Average surface per house will be estimated from official and real estate sources. Three types of structures considered are single-story timber, masonry/concrete, and traditional-style buildings. For infrastructures, the construction costs can be either derived from official statistics, special publications or directly from the responsible offices.

The chosen approach through repair costs permits to consider homogenous cost category independent of the site and real estate price fluctuations. When compared to the approach of calculating the costs of losses in assets values, it avoids the issues associated with estimates of assets appraisals. Additionally, using assets values is an overestimation of damage from a broader economic perspective, because it does not include depreciation and assume a replacement with a new asset. Depreciated values should be applied in order to reflect the value of a good at the time when it is damaged by a flood.

For cash crops, the damages will be derived from loss in gross profit from crop production. Data will come from local governments and/or official annual rental costs of croplands. What is lost is the real economic value of the crops minus the variable costs avoided because the crop has been destroyed e.g. harvesting, drying the crop. No permanent reduction in the value of agricultural output will be considered.

All of the assets in the exposure database of buildings, infrastructure assets, and crops will be categorized in groups of similar vulnerability to tropical cyclones.

For population impacts, potential available results from models developed to estimate the number of casualties caused by each type of event will be incorporated. For example, in the South Pacific, the tropical cyclone casualty model predicts the number of casualties as a function of the total economic losses, which are used as a proxy for the number of damaged buildings.

When data is available, indirect tangible damage (e.g. loss of tourism revenues, emergency costs, traffic disruption, etc.) will be estimated.

The emergency costs that local governments may sustain, include debris removal, setting up shelters for those made homeless, or supplying medicine and food (Messner et al., 2007; PCRAFI, 2011b). The emergency losses will be estimated as a fraction of the direct losses. Research on historical tropical cyclones and earthquakes has revealed that an "average" estimate of the emergency losses, as a percentage of the direct losses suffered by residential dwellings, commercial establishments, public buildings, schools, and hospitals, is about 23% for tropical cyclones and flood (Bolt et al., 2005; Pagiola, 2004a; PCRAFI, 2011b).

For impacts on tourism facilities, earnings per room, a common ratio in the hotel industry will be tested as reference value for the damage in terms of loss of earnings during a 2 year period time (in addition to the construction replacement cost).

DAMAGE FUNCTIONS

The vulnerability of different types of buildings, infrastructure assets, and crops will be derived from damage functions. A damage function between storm intensity and expected level of losses (vulnerability) in a typical building will be developed. Damage functions are needed to provide information on the susceptibility of elements at risk against inundation characteristics. They show either the damaged share (referred to as relative damage functions) or the absolute monetary amount of damages per property or square metre (referred to as absolute damage functions) of a certain group of elements at risk as a function of the magnitude of certain inundation characteristics. In the current state-of-the-art the main inundation parameter considered in these damage functions is inundation depth (depth-damage functions). Others, like velocity, duration and time of occurrence are rarely taken into account(Messner et al., 2007). The function will provide the loss that is expected when an asset is subject to different levels of storm intensity and will be usually expressed as a percentage of the replacement cost of the asset.

Two prominent damage databases are used: The damage data from FHRC (UK) and the German HOWAS-database. The data fairly represent the typical damage that might be expected for selected flood events.

Attempts to improve the database of properties in other locations did not noticeably change the weighted distribution function (DEAL, 2012; Eleuterio et al., 2011; Messner et al., 2007).

The valuation of the present study has relied on the following estimates. For houses from the villages an estimate of a 35% damage was used in Vanuatu. This situation represents an average impact of floods on houses with traditional materials and on more modern houses with concrete walls. For resorts a 20% damage on buildings was employed for flood impacts

Costs are calculated on the average costs of a cement and traditional house for a household of 5 persons. An average cost of $US 15 000 and US$19 000 has been applied to cement house in Vanuatu and $US 6000 for traditional house built with local materials (pers. observ.).

C.2. PROBABILITY OF THE HAZARD EVENT

The last step is to calculate the probability of the hazard event (storm, cyclones). Tropical cyclone activity and intensity is variable on the intraseasonal, interannual, interdecadal and multi-decadal timescales. Variations in the number of tropical cyclones from year-to-year are strongly correlated with local sea surface temperature before and near the start of the cyclone season (CSIRO and Australian Bureau of Meteorology, 2007). Tropical cyclone numbers are also correlated with indices of ENSO, indicating a remote effect on tropical cyclone numbers through the Walker Circulation (CSIRO and Australian Bureau of Meteorology, 2007).

There is also substantial evidence from theory and model experiments that the large-scale environment in which tropical cyclones form and evolve is changing as a result of greenhouse warming. Projected changes in tropical cyclones are subject to the sources of uncertainty inherent in climate change projections. These include errors in the modelled tropical cyclone climatology and regional patterns and magnitude of change for various fields and climate patterns such as ENSO (PWA and SAIC, 2009).

Consequently there is large uncertainty in the tropical cyclone frequency projected by climate models. IPCC (2001) concluded, "There is some evidence that regional frequencies of tropical cyclones may change. There is also evidence that the peak intensity may increase by 5% to 10% and precipitation rates may increase by 20% to 30%. There is a need for much more work in this area to provide more robust results."

The probability of events will therefore be calculated from existing models for the study region. A review of models that range from global climate models to higher resolution regional models will be done.

The spatial and temporal occurrence and severity of past events is often used as a guide to predict potential tropical cyclones and earthquakes that may affect the study zone in the future. The simulated events are not necessarily identical to those that occurred in the past but are statistically consistent. For example, in the south Pacific, the catalogue of simulated events, which spans the entire Pacific basin, contains more than 400,000 tropical cyclones, grouped in 10,000 potential realizations of what may happen in the next year. Mathematical models are then used to estimate the intensity of the simulated events in the affected region. These effects are wind speed, precipitation, and coastal surge for tropical cyclones, and ground shaking for earthquakes. If the earthquakes produce a tsunami, wave height and velocity is estimated as well. The models are based on empirical data and on the underlying physics of the phenomena (CSIRO and Australian Bureau of Meteorology, 2007).

When no models are available, the tracks of historical tropical cyclones will be analysed. The catalogue of historical storms is assembled starting from the dataset of the International Best Tracks Archive for Climate Stewardship project, the NOAA Historical Hurricane Tracks, the Joint Typhoon Warning Center (JTWC), the Australia Bureau of Meteorology (BoM), the France Météo and other country Meteorological Service.

The spatial and temporal occurrence and severity of past events will be used as a guide to determine potential tropical cyclones and earthquakes that may affect the study zone in the future. The probability on the occurrence of climatic events, will be applied to annualize the calculations and reflect the potentiality of avoided damages. A probability annual event of 44% in Vanuatu was deduced from historic storm events analysis (70 years).

VALUATION OF THE SERVICE OF BIOREMEDIATION (ES 7)

METHOD

The steps followed for the assessment of this service are:

Step 1: Calculation of the production function

The biophysical production function of water bio-remediation by mangroves and seagrass is based on literature references and field observations.

The variables taken into account to calculate the denitrification capacity and particle deposition of mangroves and seagrasses are:

a. Facies

b. Cover surface of living biomass and density

c. State of nutrient load discharged into water mangroves and seagrass, water residence time, and general hydrodynamic conditions.

Results will be expressed in terms of denitrification capacity (kg N.ha-1.year-1) and particle retention capacity (mg.l-1 of dissolved or suspended solids).

Step 2: Economic valuation of bioremediation

Main approach

There are four potential benefits of using natural systems for wastewater treatment over other conventional methods (Breaux et al., 1995). These benefits are:

1. Reduced costs to attain the same level of treatment as alternative methods.

2. Effluent discharges may enhance the quality and integrity of the receiving wetlands.

3. Levels of treatment by wetlands may exceed levels attainable by other methods.

4. Surface waters previously receiving effluents under prior treatment methods may have water quality improvements.

Wastewater treatment requires both investments and operating costs. Treatment levels are typically specified so that a discharge exhibits certain water quality characteristics, such as biological and chemical oxygen demand, suspended solids, acidity, etc. These levels are met under conventional treatment with physical, chemical, and biological processes, such as settling ponds and aerators, and chemical additives, such as chlorine and lime. These treatments may be avoided, or can be undertaken at reduced rates if mangrove treatment is used for any of these processes. Cost savings can be estimated quite simply (Breaux et al., 1995).

The literature values of water treatment or bio-remediation have mostly been calculated by the method of replacement costs (Bann, 1997; TEEB, 2009). The replacement cost of this service is estimated by comparing the cost of implementation and operation of an artificial system producing the same quality of service (Barbier, 2007; Berland et al., 2001; Duncan, 2003.). More specifically, the value can be estimated from comparing (i) the cost of installing and maintaining a biodisc waste water treatment with (ii) a decanter and a buffer tank with discharge of water in the mangroves (Herteman, 2010; Liénard et al., 2001).

The costs of engineering and annual maintenance serve as a replacement cost for determining the value of this function (Molle et al., 2005; Yang et al., 2008). Initial investment costs will be amortized on the expectancy life of the asset.

It is important to highlight that most experts recognize that the service of domestic water treatment by mangroves seems to be restricted to water discharges equivalent to 200-300 habitants equivalent (Marchand, Riegel, pers. Comm.). This substantially reduces the potential of this ES, which maybe restricted to some specific sites.

Replacement values will be estimated from actual costs in the study area. To this end, interviews with local water treatment industries will be conducted to clarify the costs of this function. If specific values for the study area could not be estimated, data will be derived from literature or other IFRECOR valuation. These values should correspond to similar contexts and be adjusted to the economic environment of the area. Adjustments will be made based on PPP (Purchasing Power Parity) (Heston et al., 2009).

Shabman and Batie (1978) suggested that the replacement cost approach can provide a reliable valuation estimation for this service if the following conditions are met:

(1) the alternative technology provides the same services;

(2) the alternative compared for cost comparison should be the least-cost alternative; and

(3) there should be substantial evidence that the service would be demanded by society if it were provided by that least-cost alternative.

In the same way and following expert recommendations (Riegel, pers. comm.), there are two complications in estimating cost savings. First, cost comparisons must be based on identical treatment standards under mangrove and non-mangrove systems. Second, the alternative against which the mangrove costs must be compared is the least cost alternative. This comparison may be simple when the only alternative is another type of treatment. However, it would be more complicated if discharge standards could be met by more pervasive, but less costly means, such as changes in consumer habits.

OTHER APPROACHES

Other approach to explore is the avoidance of human health and morbidity effects downstream from organic pollutants retained in great quantities by the mangrove system (Bann, 1997). One measure of damage costs avoided would be to estimate the potential loss of earnings from the health effects that would occur if the pollutants were released downstream. Another approach would be to estimate the medical and other preventive expenditures required to compensate for this pollution.

VALUATION OF THE SERVICE OF SEDIMENT TRAP (ES 8)

ECOSYSTEM PROCESSES

One of the important functions of mangroves is to provide a mechanism for trapping sediments and to be an important sink of suspended sediment (Furukawa et al., 1997; Walters et al., 2008). The mangrove trees catch sediment by their complex aerial root structure, thus functioning as land builders. In numerous cases, there has been proof of annual sedimentation rate in mangrove areas, ranging between 1 and 8 mm (Bird and Barson., 1977). They reduce tidal flows and induce sedimentation of soil particles at low tide, probably due to friction force.

The suspended sediment is introduced into coastal areas by river discharge, dumping of dredged material and re-suspension of bottom sediment by waves and ships. Based on bibliographic review made by Kathiresan (Kathiresan, 2003), the mechanisms of sediment transport in mangrove waters are mostly based on the mechanism of hydrodynamic process rather than biological process (Wolanski, 1995). The hydrodynamic processes include the tidal currents, the baroclinic circulation and shear-induced destruction of flocs. The mangroves trap the suspended sediments during their transport based on tidal flows. This enables efficient trapping of suspended and particulate matter, which can lead to land accretion buffering against potential sea level rise in the future (Victor et al., 2004).

The efficiency of sediment trapping varies with mangrove zones and species (Kathiresan, 2003; Wolanski, 1995). The high efficiency of trapping suspended sediment in Avicennia-Rhizophora interphase may be attributed to wide spread occurrence of numerous pneumatophores (aerial respiratory roots) in Avicennia and to compactly arching, stilt roots of Rhizophora (Kathiresan, 2003).

Dune systems and seagrass also play a notable role in trapping sediments (acting as sediment reserves) and stabilizing shorelines (Ruitenbeek, 1994; Victor et al., 2004).

Some estuaries mangroves have been found to trap up to 40% of the riverine fine sediment (Furukawa et al., 1997; Victor et al., 2004) and play an important role in protecting fringing coral reefs from sedimentation. Sediment stabilization by seagrass roots and rhizomes, as well as by their beach-casted debris is important for controlling coastal erosion (Barbier et al., 2011). Some studies suggest that the sediment trapping efficiency of mangroves may be explained as a function of tidal dynamics independent of riverine suspended sediment concentration (Victor et al., 2004).

METHOD

The sediment retention function of mangroves may protect downstream economic activities and property from sedimentation (Walters et al., 2008). Evaluating the effects on slowing downstream sedimentation requires estimating the amount of sediment restrained by the mangroves and determining what economic activities and structures would be affected if this extra sediment had been released downstream. The damage costs avoided (DCA) and replacement cost approaches can be used to value this function (Bann, 1997).

From different case studies in the world, the following situations have been identified (Bann, 1997; Barbier, 2007b; Furukawa et al., 1997; Hussain and Badola, 2008; Kathiresan, 2003; Victor et al., 2004; Wolanski, 1995). Increased sedimentation may require extra dredging to clear for use such as shipping and navigation. The additional dredging expenditure would be one estimate of the value of mangrove sedimentation retention. Another estimate would be the damage costs avoided of extra sedimentation to downstream irrigation, turbines, and dam reservoirs, among others. Finally, the costs of building sediment 'traps' to replace the mangrove function would also indicate the value of this ES.

Specific analysis will be made in each case study to identify potential benefits of sediment trapping service to downstream activities. The biophysical valuation will be made through GIS analysis (river flows, watershed characterization, urbanism, human uses, etc.) and interviews with local experts. The economic valuation will be adapted to the type of service identified and will follow the principle of DCA or replacement costs.

SERVICE OF NUTRIENT ENRICHMENT

ECOSYSTEM PROCESSES

Another approach to explore is the nutrient enrichment for agriculture uses (Hussain and Badola, 2008). These authors examined the nutrient contents in mangrove and non-mangrove soils in and around the Bhitarkanika National Park, India. They assessed whether the local agricultural producers were aware of this contribution of mangrove forests in enhancing agroecosystem productivity. Soil samples from both mangrove and non-mangrove areas were analysed and quantity of organic carbon, total nitrogen, available phosphorus and potassium were derived. The replacement cost method was used to derive the value of nutrients in mangrove soils. They estimated that each hectare of mangrove contains additional nutrients worth US232.49 in comparison to non-mangrove areas. The difference in nutrient content in mangrove versus non-mangrove areas gave the value of US3.37 million for the nutrients in 145 km^2 of mangrove forests. The agricultural producers were aware that mangrove forests act as a source of nutrients and were willing to pay a higher price for the land adjoining mangrove forests.

METHOD

Valuation (if decided to be done) should be based on valuing the increase in crop productivity or through avoided costs (less intensive in artificial fertilizers). Productivity increase data will be found on scientific literature (Jack Snaddon, Oxford Univ. and Alain Rival, CIRAD, pers. comm.) for some specific productions such as palm oil or coconuts. Interviews with local experts should complete the estimates for other crops.

SERVICE OF LAND ACCRETION

ECOSYSTEM PROCESSES

The mangroves trap the suspended sediments during their transport based on tidal flows. This enables efficient trapping of suspended and particulate matter, which can lead to land accretion buffering against potential sea level rise in the future (Victor et al., 2004). Mangroves, by retaining sediment, increase their capacity to continue building riverine habitats downstream. This can lead to reduce erosion and loss of riverine habitats. (Vishwanathan et al., 2004) In the Sundarbans, Bangladesh, the planting of 150,000 ha of mixed mangrove species has enhanced the deposition of sediments to such an extent that the elevation of 60,000 ha is no longer suitable for mangrove, and can be used for agriculture worth US$ 800 ha^{-1} $year^{-1}$ (Saenger and Siddiqi, 1993).

METHOD

The value of the land accretion service requires determining the rate of land accretion and then the value of any extra agricultural production generated annually (Bann, 1997). Land appraisal techniques will be based on local data (lease values, database, etc.) or estimated through interviews with experts.

VALUATION OF THE SERVICE OF CARBON SEQUESTRATION (ES9)

ECOSYSTEM PROCESSES

Seagrass and mangrove ecosystems remove CO_2 from the atmosphere via photosynthesis, returns some to the atmosphere through respiration and oxidation and, store remaining carbon in two stocks: the living biomass (which includes both ground and underground vegetation) and soil organic carbon (Knowlton, 2000; Walters et al., 2008)

The rate of carbon sequestration quantifies the annual amount of carbon that is added to the biomass and carbon pools in the soil. For intact ecosystems, mature vegetation maintains a constant live biomass and almost all sequestration is stocked in the soil. This rate is assumed to be constant over time ((Duarte and Middleburg, 2005; Jennerjahn and Ittekkot, 2002; Suzuki and Kawahata, 2004).

Based on recent publications and the blue carbon database (Bouillon et al., 2009; Murray et al., 2010; Nicholas Institute for Environmental Policy Solutions, 2011; Sifleet et al., 2011), the average ranges of carbon sequestration by mangroves and seagrass ecosystems have been estimated. Mangroves vary from 6 to 8 t. CO_2e.ha^{-1} y^{-1} and seagrass around 4t CO_2 e.ha^{-1} y^{-1}. Soil carbon is however the main carbon stock (500 tCO_2 e.ha^{-1} for seagrasses and approx. 2000 tCO_2 e.ha^{-1} for mangroves) since only 5% of the carbon is stored in living biomass for seagrass and between 20 and 40% for mangroves (Murray et al., 2010).

Mangrove carbon pools are among the highest of any forest type (Figure 1). For example, ecosystem carbon pools of mangroves are more than twice those of most upland tropical and temperate forests. A great proportion of this pool is belowground in organic-rich soils, which are susceptible to release significant volumes of greenhouse gases if disturbed by land-use or climate change (Page et al. 2010, Hooijer et al. 2006).

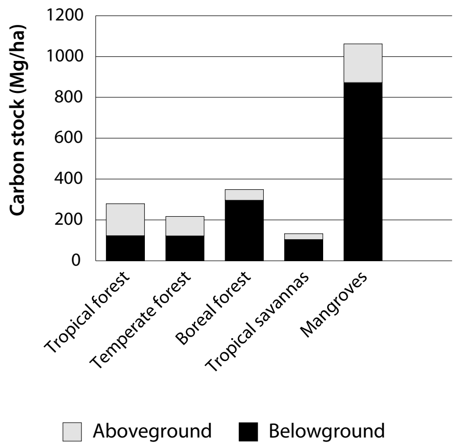

Figure 33 : Total ecosystem carbon pools (aboveground and belowground) for some major land cover types of the world (Kauffman and Donato, 2012)

Mangroves vary greatly in structure and function, largely as a result of topography, substrate, latitude and hydrology (Kauffman and Donato, 2012). Dominants in mature mangroves may range from trees with trunk diameters >1 m to shrub-like stands <1 m in height. Aboveground biomass may range from >500 Mg/ha in riverine and fringe mangroves of the Indo-Pacific region to about 8 Mg/ha for dwarf mangroves.

Mangroves have been classified into four major associations of differing structure, corresponding to physical, climatic and hydrologic features of the environment in which they exist. These are (i) fringe or coastal mangroves; (ii) riverine or estuarine mangroves; (iii) basin mangroves; and (iv) dwarf or scrub (or chaparro) mangroves (Mitch and Gosselink 2007).

METHOD

STEP 1: PRODUCTION FUNCTION

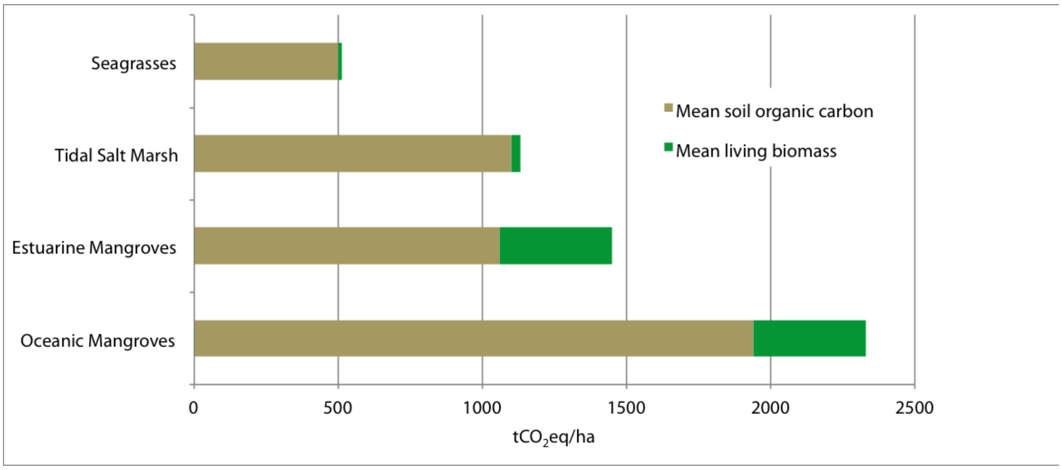

Figure 34 : Global averages for carbon pools (soil organic carbon and living biomass) of focal coastal habitats (Sifleet et al., 2011)

For the production function, we will adapt the method developed by the Nicholas Institute for Environmental Policy Solutions of the Duke University (Murray et al., 2010) to the context of the studies and the availability of data. The approach has benefited from the support of one member of the team of B.C. Murray (L. Pendleton).

The function will use two processes to quantify carbon volumes: the sequestration in living biomass and the carbon pools in the soils. The result will be the annual amount of CO2 eq **avoided** of being released into the atmosphere by maintaining ecosystems in their current state. The parameters estimated are:

a. Annual rate of absorption of carbon by the ecosystem in its current state.

b. Carbon stocks in biomass and the basement (at a maximum depth of 1 m even if, generally, carbon pools vulnerable to anthropogenic changes are aboveground biomass and belowground pools up to 30 cm). Data will be based on estimates of tier 1 and tier 2 IPCC categories [28].

c. The amount of potential emissions due to the destruction of the ecosystems. This evaluates how much soil carbon may potentially be exposed to atmosphere and thereby emitted in the form of CO_2.

[28] The IPCC (Intergovernmental Panel on Climate Change) has established a tier system reflecting the degrees of certainty or accuracy of the carbon stock assessment. Tier 1 uses IPCC default values (i.e. biomass in different forest biomes, etc.) and simplified assumptions; it may have an error range of +/- 50% for aboveground pools and +/- 90% for the variable soil carbon pool. Tier 2 requires country-specific carbon data for key factors. Tier 3 requires highly specific inventory-type data on carbon stocks in different pools, and repeated measurements of key carbon stocks through time, which may also be supported by modelling.

Although meters of carbon-rich organic soils may underlie the coastal habitats, that carbon may persist if the habitat conversion only affects the top layers and the deeper layers remain inundated.

d. The time required for the release of emissions into the atmosphere. In theory, following conversion, carbon in biomass is emitted to the atmosphere in the first few years. Soil organic carbon will take longer than biomass and the deeper the soil carbon the slower its rate of release. In each case, high emission rates would be expected in the years immediately after disturbance, then dropping to lower rates later. A decay function may approximate this physical process, and we will use the concept of half-life that denotes the time required for the carbon pool to fall to one half of its initial value. It is assumed that stocks will have a half-life of 5 years (Murray et al., 2010).

STEP 2: MONETARY VALUATION

CLEAN DEVELOPMENT MECHANISM (CDM) AND THE CARBON PRICE

In order to include an estimate of the price of carbon that can be considered valid for a certain period of time, it is necessary to be clear about how to generate such price and in which market it will be traded.

The Clean Development Mechanism (CDM) is an agreement of the Kyoto Protocol, which allows governments and companies in industrialized countries to engage in emission reduction projects in developing countries to earn Certified Emission Reduction (CER), so they can meet emission targets set in the Protocol. Each certificate, equivalent to 1t CO_2e, can be traded and sold in international financial markets. CER are obtained by driving projects to mitigate greenhouse gases through actions promoting clean energy or reducing consumption (brown credit), afforestation and reforestation (green credits).

The above mechanism is one of the most successful as it has been selected as the model designed by the United Nations Framework Convention on Climate Change (UNFCCC). This convention gave rise to the global carbon market, which currently constitutes one of the most important mechanisms and incentives to mitigate emissions of greenhouse gases, as it becomes the primary tool for protocol countries to meet agreed targets for reducing emissions (Nellemann, et al., 2009a).

Currently there are two types of carbon markets: the compliance regulated ones and voluntary ones. The first type is used by companies and governments that are obliged by law to meet a "quota" of emissions of greenhouse gases for carbon credits through Certified Emission Reductions, which are traded in the market to meet their emission reduction obligations. It will be the base of our price valuation.

The second type can be used by any country, institution or companies wishing to carry out such projects for different reasons (reputation, certifications, etc.). They will receive, in this case, the credits called Verified Emission Reductions (VER)[29] or Verified Carbon Standard (VCS)[30] .

Although credits from initiatives such as REDD+ (Reducing Emissions from Deforestation and Forest Degradation), afforestation[31]/reforestation (A/R) and Improved Forest Management (IFM) are the best suited to the characteristics of the mangrove ecosystems, they have still not have been included in the regulated market as CER (Gordon et al., 2011). Because compliance standards do not yet account for the offsets of these initiatives, mangrove and seagrass carbon finance through verified emissions reductions must come through the voluntary market. Although major voluntary offset creditors such as the Verified Carbon Standard and Climate Action Reserve have yet to approve any blue carbon projects, future projects could occur on the basis of current REDD standards.

Additionally, the most recent version of the VCS Agriculture, Forestry and Other Land Use (AFOLU) requirements include peat land rewetting and conservation (VCS 2011a). Coastal lands with peat soils could be eligible for voluntary credits through these peat land requirements. Moreover, VCS is in the process of approving wetland mitigation standards that will likely include coastal habitats.

The future of coastal habitat protection through the voluntary carbon market will rest, for now, on two factors: (1) the extent to which REDD projects in the voluntary markets can incorporate blue carbon, and

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[29] The most popular type of carbon credit used to offset emissions around the world voluntarily is a VER, a Verified or Voluntary Emission Reduction unit and there are many different types. Before CDM deliver credits used for Compliance purposes such as CERs they can produce VERs. These credits can be verified to a number of specific standards, including the Gold Standard. Not all projects go on to register within the CDM, often due to the size of the project and the inhibitive costs associated with compliance registration, so their choice of one or more of these voluntary standards is made based on it's overall viability and compatibility to them.

[30] VCS credits or Voluntary Carbon Units (VCU) must be real, the abatement must have occurred, they must be additional by going beyond business-as-usual activities, be measurable, permanent, not temporarily displace emissions, the findings need to be independently verified and unique so they cannot be used more than once to offset emissions. The VCS is the most widely known and chosen standards in the voluntary market due to it's Kyoto compatibility as well as it's ability to manage a wide range of project types and methodologies. (www.carbonplanet.com)

[31] Afforestation: The direct human-induced conversion of land that has not been forested for a period of at least 50 years to forested land through planting, seeding and/or human-induced promotion of natural seed sources. Reforestation: The direct human-induced conversion of non-forested land to forested land through planting, seeding and/or the human- induced promotion of natural seed sources, on land that was forested but has been converted to non-forested land (CDM-EB07-A04-GLOS).

(2) the development of blue carbon standards in the voluntary market. According to REDD methodology in the Verified Carbon Standard, project areas may include forested wetlands (including mangroves) as long as these wetlands contain no peat, which is dealt with separately by VCS (VCS 2011b).

Therefore, the REDD+ credits will be used in this study as a proxy for blue carbon credits from mangroves (Gordon et al., 2011).

In the context of existing payments for REDD-related carbon credits, the voluntary market has then been the only player. In 2010, the voluntary market purchased approximately 131.2 Mt CO_2e (Gordon et al., 2011). Of this amount, 30.1 Mt CO_2e stemmed from forest carbon projects for a market value of $178 million. Depending on the study referenced, REDD credits supplied between 17.8 and 19.5 Mt CO_2e to the voluntary market (Idem, 2011). The average price for a REDD credit in 2010 was $5/t CO_2e; the average forest credit price was $5.5, and the average voluntary credit price was $6.9. Nonetheless the price range of all voluntary credits (including forest credits) remains extremely high. Prices in the voluntary market range from $.01 to $136.3/t CO_2e. Forest carbon credits in the voluntary market have a smaller range, with a high price of approximately $34/t CO_2e.

The majority of voluntary credits as a percentage of the total market came from the Verified Carbon Standard (VCS). VCS prices average $4/t CO_2e. Latin America provided almost all (89%) of the REDD voluntary credits (Murray et al., 2010).

However, demand for REDD carbon credits is difficult to predict and remains subject to pending regulations (post-2012 UNFCCC protocol and California's Global Warming Solutions Act (AB32)). Estimates of REDD+ carbon credits future demand for blue carbon credits has been identified by several authors as a highly speculative enterprise (Gordon et al., 2011; Murray et al., 2010; Point Carbon, 2010). In this sense, the comparative analysis of CER should provide useful insights (Sifleet et al., 2011).

When considering the price at which CER´s are traded, it is necessary to note that this price, generated in the financial market, is characterized by volatility in prices and depends on agents' expectations, the success of the projects and the global economic situation, among other features. The cost for biomass carbon credits dropped from $12 to $10 between 2009 and 2010. At the same time, agroforestry carbon credits doubled in value – from $5 in 2009 to $10 in 2010. In terms of geographical location, the most expensive carbon credits in 2010 were those produced by offset projects in Oceania-- $18.1. In Europe, prices in 2010 were a little over $11 per credit. In the same year, U.S.-produced credits were transacted at the lowest value among regions, at $4.9 per credit.

Figure 35 : Price simulations of CER (source : JP Morgan report)

The estimated price per unit of emission reduction is based on the analysis of historical transactions of EUA (European Union Allowances) on the European marketplace ECX (European Climate Exchange). These transactions as EU ETS (EU Emissions Trading System) or Kyoto-CER (Certified Emission Reduction) in 2010 represented more than 80% of transactions in global carbon markets (12 000 Mt CO_2e since 2006).

An average price for the study period will be estimated based on the results of different surveys ((Gordon et al., 2011; Point Carbon, 2010; Sifleet et al., 2011)).

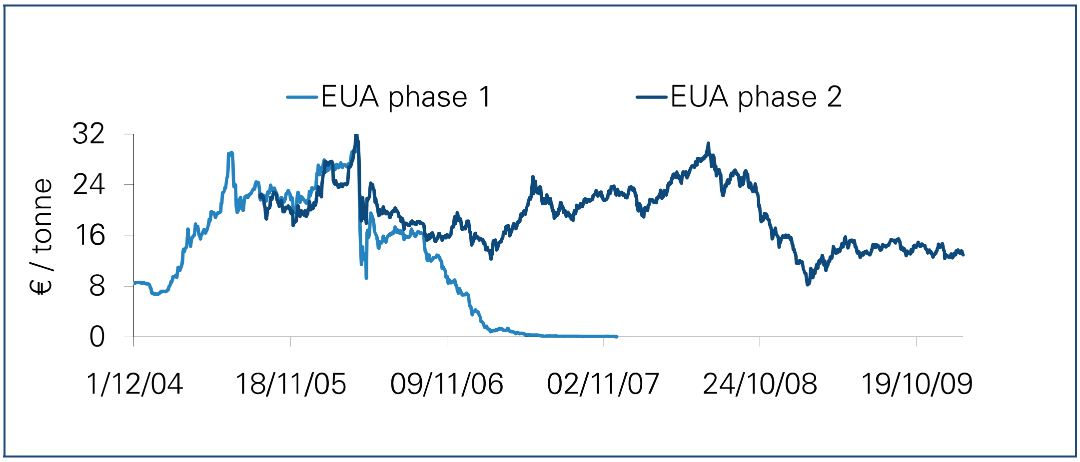

Figure 36 : market prices EU—ETS , 2004-2009. Price at 30/12/11: 6,70€/t

Source: Point Carbon

FORMULA

The formula will be :

$SC_e = \sum_{e,t} \left((T_e + Q_{e,t}) * Prix_t\ (tCo_2eq) \right)$

With

SC_e : Annual value of carbon sequestration (t CO_2 eq) per ecosystem (e)

Te : Annual absorption rate per ecosystem (e)

$Q_{e,t}$: Quantity of potential release of pool stocks of CO_2 per ecosystem (e) per year (t) with decay rate.

Prixt (tCo_2eq): Price projection of avoided t CO_2 eq

The carbon flows are monetized by multiplying the annual avoided carbon quantities during the year of the valuation by expected carbon prices ($/$tCO_2e$).

DESCRIPTION OF THE SURVEYS

SURVEYS:

There were three separate questionnaires in total that were used in the socioeconomic survey that was conducted in each village. One of them focused on crabs, the other on reef fishes and the last on mangroves.

➢ Survey 1: Household Crabs Survey. The objective was to collect info about:

- General info on interviewee (status, age, gender, marriage, island, religion, household members
- Basic Questions on common type crabs the interviewee catches…preferably species found in the mangroves.
- Language name of the interviewees commonly caught or preferred crab type, info on common area the crabs are caught (zones of the areas devised by the MESCAL team), transport means of getting there, how many people in the household hunts crabs, the quantity caught per person in a week or per trip, harvesting techniques used, how long it takes for a usual crab hunting trip, purpose of catching crabs- consumption or selling?-, number of crabs the family consumes after a catch, quantity of crab sold weekly/ monthly
- Any taboo/ management systems in place in the village that looks at preservation or conservation of any resources or ecosystems, with follow questions as to reasons for there being or not effective

➢ Survey 2: Mangrove Survey. The objective was to collect info about:

- Income earning activities the family does, how much does the household earn monthly in total
- General info on interviewee (status, age, gender, marriage, island, religion, household members
- Does the family use had been/ have or are still using mangroves for anything? State what it is, where its mostly collected, species type of mangrove used
- What are the mangroves used for, how often are they cut (week/ month), how many are cut (posts/bundles), who is the usual mangrove-cutter
- Alternative for firewood and house posts used, firewood is bought or not (sometimes/never)
- Statements about mangrove ecosystems

➢ Survey 2: Reef Fish Resource Survey. The objective was to collect info about:

- Basic background information about the interviewees
- What types of fish does the family normally catch, some common fishing techniques used by the family, fishing trips weekly for the different techniques the family uses, fish caught per trip
- Common fishing grounds, some information on last catch (was it consumed or sold?), market information (buyers, means of selling, transportation, middlemen, price of fish per kilo or rope)
- Number of different fishing gears in the village

SAMPLING DETAILS

The team used random sampling in the villages. Randomly selecting the households for interview took into account issues including looking at houses near the mangroves and those further away, fishermen and non-fishing households, different religious beliefs such as SDA's not eating crab to Presbyterians, etc…the factor that hindered the surveying was the willingness of villagers to be interviewed, i.e. some did not want to be interviewed.

Based on the completed data entries:

Questionnaires	ERATAP	AMAL/CRAB BAY
Household Crab	29	130
Mangroves	29	137
Reef fish	29	128
Total	**87**	**395**

The total number of valid surveys is 482. In Crab bay, surveying began on Tuesday the 4th of September and ended on Thursday the 12th of September 2012 with the help of seven locals, an officer from the department of Environment and a contracted resource environmental assistant. There were in overall 15 villages that hosted the team and its socioeconomic agenda.

Name	Status/*Village*
Molu Hango Bulu	Resource Environmental Economic Assistant
Primrose Malosu	DEPC, Administrative Officer (with first-hand experience in field workshops)

Kalmasing Peter	Hatbol Community Chief - Amal/ Crab Bay Committee member*, Hatbol village*
Numa Fred	Vanuatu Cultural Centre field worker, *Uripiv*
Spetly Jonah	Amal/Crab Bay committee member, *Hatbol village*
Ritson Josen	*Uripiv*
Leonie Mark	*Lingharak village*
Susan Tahi	*Lowni village*
Morry Ruben	*Tautu village*

There were few difficulties that arose in the field including responsible committee members having other commitments on the day we were supposed to visit their village thus causing hindrance in the program, there were also slight program changes that had to be done in the field due to some overlooked issues also in one case, there was one person who recently built his home using mangroves who "side-stepped" the interview and the team could not locate him due to the tight schedule. Overall the survey was successful and the villagers were very helpful. There were in overall 15 villages that hosted the team and its socioeconomic agenda.

In Eratap surveying commenced on the 24th of September and ended on the 10th of October 2012. Collecting data here was lengthy due to the community's many issues.

QUALITATIVE ANALYSIS OF SURVEYS (BY MOLU BULU)

AMAL/CRAB BAY:

All 15 villages are original members of the conservation area committee of Amal/Crab Bay. Although only a few of them are located within a reasonable walking distance, with the nearest at a rough 5 minutes' walk away and the latter 15-20 minutes, they are members due to land related issues. These villages are diverse in both their cultures and people. Most of these villages have people from other villages and/or islands. *Tevaiout* and *Niu Bush* for instance, were for Paamese people and have been for decades, ever since the tribal landowners in the olden days granted their ancestors the right to make a settlement for their people. Malekula has a very varied range of cultural practices and customs, all so different yet they have that feel of similarity between then. For instance, in the central alone, among the member villages of the conservation area, there are four different languages.

Agriculture has been the sole back bone in these parts for centuries and the people still carry on that tradition to this day. However with the rising economy it can be difficult to cope at times, there are some families fortunate enough to have family members with a good job (Lakatoro, Luganville and/or Port Vila) or have access to education, some even with successful youths continuing on to University that makes life a bit easier. Manoa of *Lowni* for example works at the Public Works department in Lakatoro but his family still depends on resources from the gardens and conservation area for food and other necessities.

As you can see in *figure 1,* the urban centre of Malakula, Lakatoro is quite far, about an hour thirty minutes drive to the conservation area of Amal/Crab Bay. The START and FINISH labels below show the span of villages that are members of the conservation area committee.

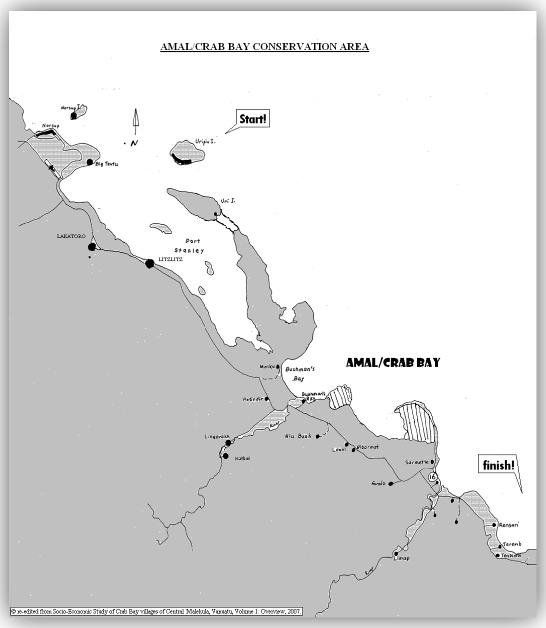

Figure 37: AMAL CRAB BAY

CRABS EXTRACTION:

Not all villages are located within walking distance to the conservation area as can be seen clearly from *figure 1* above. Despite the distance, results show that one out of every three household in every village has crab hunters. With a variety of trip-frequencies however for every family member, average travel range falls within 0.2 to 3.0 and less mostly for these villages.

Consumption levels for each village vary too. Annually, according to the surveys done, young girls in the house have the most recorded crab catch than any other family member, with average numbers of 55 in the crab season and 30 when it's not the crab season.

Easily more than 80% of households interviewed collected crabs for subsistence use only, a mere 15% for both sale and consumption and 5% that only caught crabs to sell for income. This difference in consumption patterns comes back to two factors, distance from the village to the mangroves and alternate resources available. Patterns show that those living nearby the mangroves are the ones who collect more crabs than the other villages, drawing the conclusion that these villages have few alternative resources and they are dependent on the mangrove ecosystems resources to meet immediate needs.

Annually, an average crab hunt catch can add up to an estimated amount of 363,000 for these villages. Estimated number of catch in total annually has reached up to 363,129 crabs. More than 50% of annual crab catch is consumed in the homes while a smaller percentage is sold for money at the main market, roadside markets, or shops in Lakatoro.

Each village has its own allocated access area provided by the conservation area committee in the bay area, and you are not allowed to go into the other village's access areas but your own.

WOOD EXTRACTION

Apart he mangrove tree is useful to the locals in a lot of different ways. The trunks can be used for house posts, fencing, and firewood and in some places as a gardening tool. The branches are also used for firewood and small hooks that some people cut and use to capture mud crabs. Leaves are used as bait for *serwok* (small pointy shells) and crabs, and also for medicinal purposes as indicated by the villagers although specifics as to these practices are taboo and cannot be revealed to just anyone. Traditional medicine practices are however rapidly dying out.

Majority of these villages use the big stems for housing posts and rails (i.e. supports crossing each other and/or running parallel to and from the main frames of the constructed roof) more than any of the other uses. Unlike other trees, these works are not done occasionally because the wood is really strong and long lasting. For instance, a man builds his house using the mangrove trees for posts and roof railings; he won't have to cut some more mangroves for at least 10 or so more years because the wood is very strong and long lasting, this is the case for one house in Mapbest Plantation.

One other use that is rapidly dying out is the traditional medicine practices derived from the mangroves. Which part of the tree they use is a mystery as that information is sacred to the tribe and only a few people in some of the villages have knowledge of it while others have faint recollections from old stories.

FISHERY

Among the many fishing techniques used by the locals there, the two most common ones are the handline and the reef net, followed then by the cast net and other techniques. The capability of nets to reap a large number of fish in a short time is very beneficial to the local fishermen. In fact, reef nets are used more than 90% of the time on overall fishing trips.

On a weekly basis, the average number of fishing trips a household takes is 1. More trips happen but only on occasion and never more than a month in a row. Usually occasions that call for a huge stock of fish to be caught are normal activities such as village fundraisings, big village meetings, and sometimes community held workshops such as the MESCAL socioeconomic visit. For some villages, the young men had gone fishing the night before the team arrived so as to have the catch for lunch.

Average number of fish caught on each trip is fairly around 15 – 20 per fisherman or fisherwoman. As normal, not all the fishing is done around the mangrove areas. Some people go deep-sea fishing, outside the conservation areas towards the reefs. Zones and maps showing the fishing grounds in the area can be seen in *figure 1* above and *figure 2* below.

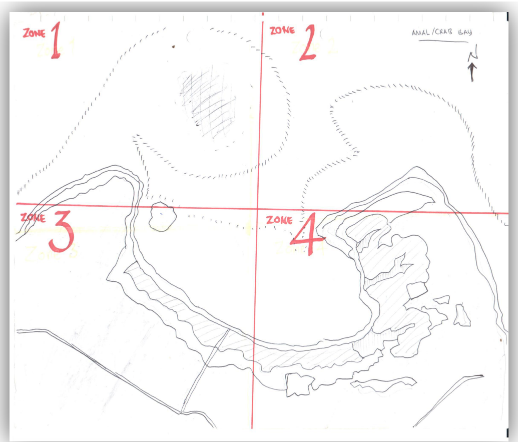

Figure 38: Amal fishing zones

Each village has an access area allocated to them by the conservation area's committee that only they can extract resources from. Fishing however is a different thing and is open only in areas inside the bay and outside, away from the two headlands (Amal/Crab Bay).

Of the total amount of fishes caught, majority is consumed in the village and the lesser sold for income purposes. Distribution of fish to be sold follows a fairly similar yet simple pattern among fishers. The caught fish are immediately taken to the Lakatoro market, fish market, or Rina store in Litzlitz using any available means of transport or they are sold in the village. Pricing is fluctuant between everyone but 1kg is normally around 300vt. The men are normally the ones who fish in big stocks and they are the ones who go selling in the semi urban centre while the women usually help to sell in the village.

The number of fish caught per household a year as seen from the survey ranged from 74 for *Tevif* to 2174 for *Barrick*, clearly showing a massive gap which can be the result of a lot of issues for example, availability of alternate resources, time, means of fishing, distance to fishing grounds and reasons for fishing for instance, for school fees, a feast, to pay for groceries, etc...there are a lot of reasons that can account for such a gap.

In a year, estimated total money value for fish caught for both subsistence and commercial purposes can range between VT6, 875,645 and VT10, 239,424 for all the villages. As usual, fishing is not a constant or certain profession but faces countless issues that determine the outcome at the end of the day.

PERCEPTION OF TABOO AND MANAGEMENT

Managing the area is a big problem even with the management plans set up by the conservation area committee and the respective stakeholders. Even though there are terms to accessing the access areas and its resources, a very few do not abide by them causing frustration for the villages creating frustration and tension between neighbours who follow the rules and depend on the resources more than others. An example comes from a committee member himself (whose name and village will not be revealed in this report) suspected some people in his own village and was quietly conducting an investigation on his own during our stay in his village.

The villages understand what the *taboo* aims to achieve for them and their children and they are for it but some issues that make it hard for them to abide by the set rules are that the resources are their main source for food and income, there are some unexpected issues coming up at the last minute that demand food or money for something, and some people do not abide by the set rules.

There is no traditionally set means of managing the mangroves themselves but there have been cases for the fishes and crabs.

ERATAP SURVEYS

Eratap surveying commenced on the 24th of September and ended on the 10th of October 2012. Collecting data here was lengthy due to the community's many issues. The area is much smaller compared to Malekula but activities were dragged on for two weeks more than the one-week intended to complete everything.

Being a multi cultural community with many different beliefs, backgrounds and life goals, organizing a workshop is difficult to get everyone to attend. Some may receive the notice and some may not, some may not want to come just because of personal issues they have with the person conveying the message or where it's coming from. In any case, there is always something there to interrupt and hinder activities or planning for such occasions.

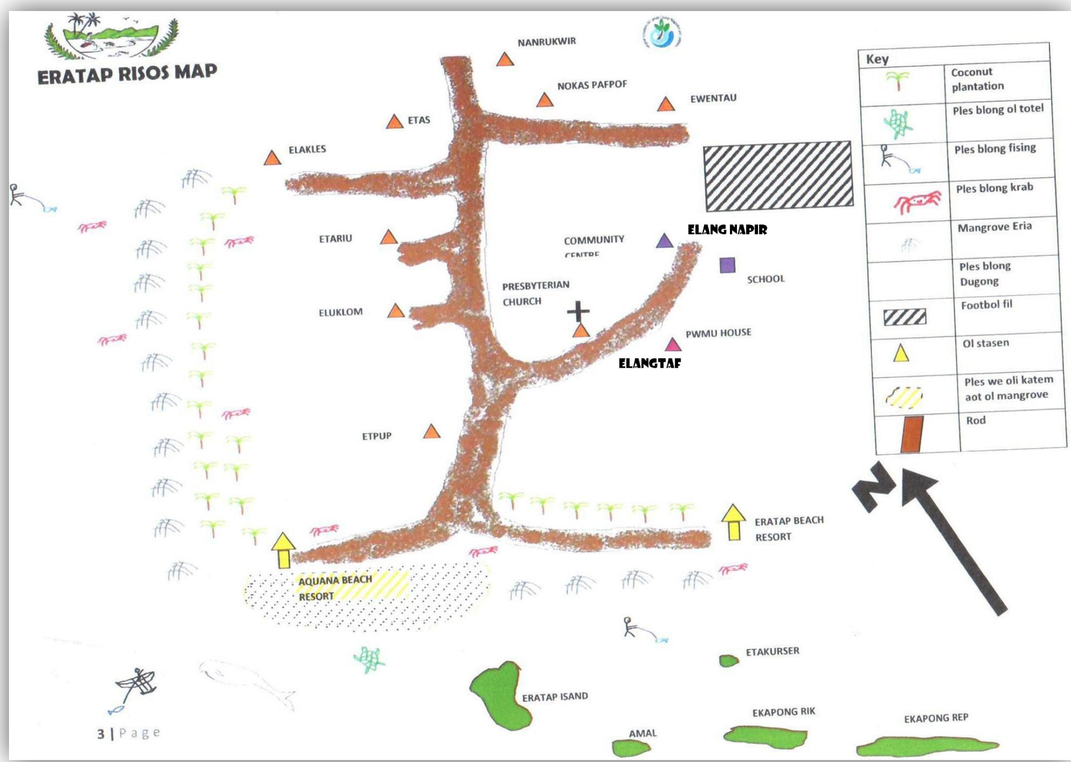

Figure 39: Eratap resource map, ***Re-edited from Eratap Community Consultation Workshop, 2011.***

CRABS EXTRACTION:

Eratap is just one village but is divided into ten small stations. With its population around 50 – 200 and 15-50 households for the small stations and over 300 for the two main stations combined. The smallest station is 50 square meters roughly, and the main village (combining two stations) is 12 soccer fields. The stations are filled with people with different ethnic backgrounds from different islands of Vanuatu that have settled here to be close to the Port Vila, the urban centre. This came around through shady land sales between customary landowners, which have been the basis of dispute for many years.

Results show that the middle-aged male hunts crab more than the other members on Eratap of the household though very few people go nowadays. Not everyone on Eratap goes hunting and the number of crabs per household is usually not more than 50 crabs in a month and it sometimes remain as it is for the whole year. About 50% of the people that were interviewed hunted crabs to feed the family, while 40% do not hunt crabs either because of religious beliefs (SDA), they have other alternate, more easily accessible resources to satisfy their needs, or could have other more stable income generating means.

Eratap has a very diverse population with different ethnic backgrounds and complex issues that poses a lot of problem when it comes to protecting and managing the natural resources in the area.

The lowest number of crabs collected in a household monthly falls below ten while on a good catch can go up to 50 crabs. This is only for mangrove *white* crabs, mud crabs are rarely hunted nowadays because of the unlikely chances of catching any. There is no one station that collects more because they hunt on occasion and mostly only in the crab season.

The estimated number of crabs caught annually can reach up to (*Nicolas to input figure from calculations)* while the most of them are purposely for household consumption. More than 90% of the crabs caught annually are not sold but eaten at home with families and friends, this including mud crabs that are rarely seen anymore on hunting trips.

The areas of mangroves on Eratap are not managed properly in any way and it is not a conservation area thus the people freely use the resources and without a management mechanism in place the resources are being depleted and destroyed without any care for future generations.

WOOD EXTRACTION

The mangroves here are hardly used for housing or firewood because the people have alternative and more easily accessible sources for these things. Using mangroves here for anything is a very rare activity. The last time that the people of Eratap used mangroves was from 2-3 months prior to the surveying done which is roughly around June or July of 2012. Meaning their use of the mangrove tree is only on very rare occasions and not frequent.

There are a few people who know how important mangroves are and its value to the community and environment are trying to preserve its ecosystem but it is hard to do so with the villagers finding it hard to work together.

FISHERY

With a variety of fishing equipments available to the people the handline however has been the most commonly used fishing tool for a long time. The stations near the sea and river go fishing more often than the others and it makes sense that they have more fishing equipments, like for instance the station of

Ewentau has a rough estimate of 120 people but there are only 8 canoes which though may seem small in number in comparison to its population, it is more than that of the other stations.

Fishing occurs a few times monthly but not all the time. Average number of fish caught begins around 15 in and can reach up to around 30 fishes per trip. Fishing areas vary from shorelines to around the mangroves as well as outwards on the reefs, below in *figure 4* is a map of Eratap which was used in the surveys to roughly help the locals to identify their fishing 'hot spots'.

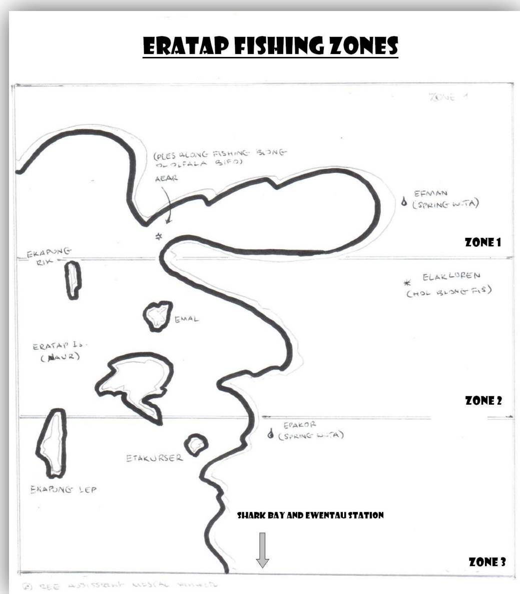

Figure 40: Eratap fishing zones

The people fish in various locations along the coast and out on the reefs meaning there are no patterns to their trips, they are simply random decisions made according to various issues such as the willingness to go out on the reef to fish. For instance a fisherman may start on Eratap point that can follow the coast all the way past the resort, back the other end towards the river and Shark Bay or borrow a canoe to go out. There are no motorboats in the villages, the only motorboats are owned by the two resorts, Aquana and Eratap beach resort.

Fish caught for consumption at home is more common at Eratap, but people do also go fishing every so often as a recreational activity and/or to earn some money. Fish is only sold in nakamals at Eratap, to a few relatives and friends outside that have made arrangements. Each arrangement is different from each other. They are not sold in kilo but on ropes, the prices range from 300 to 500vatu for a rope of fish depending on the person who caught them.

A typical household on Eratap annually may have caught no more than 200 fishes for both home consumption and selling.

The community of Eratap has no existing taboo or traditional management system in place whatsoever for the mangrove ecosystems. There were previous taboos on fishing and crabs but are at current no longer working. Coming from different multi-cultural backgrounds, it is very difficult for the Eratap community to set up and maintain a good traditional management system when there are a lot of different traditions in the area struggling to co-exist, continuous land disputes, tribal differences and personal issues go on between the people.

GENERAL OBSERVATION

Hindering issues faced in the field included transportation difficulties between villages because of the long distances (for Malekula), attendance in group discussions and cooperation in interviews was very poorly organized by the responsible locals (Eratap) and there were trouble with finances. Most villages or stations that were visited did not believe entirely on learning about the importance of mangroves but were expecting good in return for helping the team, especially for accommodation and lunch which put pressure on the limited budget the team had.

Socioeconomic observations have shown that for Malekula, the majority of income earnings are agricultural products, fish and handicrafts. The resources found in the mangroves provide for a majority of services such as food security, shelter and housing means, and financial support. For Eratap, there is very little income generated from the mangroves because the urban centre of Port Vila is on the same island and thus has a lot of other income generating means. Majority of the resources are used for consumption residentially while a lesser percentage is sold for income.

The people are dependent on the mangrove ecosystem to ensure a certain percent of sustainable livelihood, its resources are abundant and satisfy the most basic needs like food and shelter.

Figure 41: Laplap Taro on the island of URI 1

The abundance of crabs, shells and fishes supplied by the ecosystem ensures food security for the villages, especially those without stable salary paid jobs, which actually is the majority of villages. With market prices fluctuating unreliably, this ecosystem service of supplying free food gives them an advantage. With the majority of the people depending on agricultural produces for income, these types of activities being seasonal in nature, is not too reliably consistent at times in terms of income. Thus, the ecosystem serves as a back up for food, housing materials, gardening tool, etc...and also as a means of earning some income.

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