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Relating the Rehabilitation of Water Catchment Forest in the Morne Seychellois National Park with the Perspectives and Expectations of Local Communities in a Small Island Nation

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Glossary

broadleaf Broadleaf trees are any trees within the diverse botanical group of angiosperms that have flat leaves. In the rehabilitation specific context in this thesis, we consider them as a distinct group from endemic palms.. 50

evenness Species evenness refers to how close in numbers each species in a given community is and is measured on a scale between 0 and 1. If every species has a similar count of individuals, the community is even and evenness is close to 1. If a community is characterized by a few dominating species with many individuals, species evenness is close to 0. 58

pristine Pristine refers to the condition of a forest which has been unaffected by human activities such as Cinnamon cultivation or logging of timber.. 73

rehabilitation Re-establishing the productivity and some, but not necessarily all, of the plant and animal species originally present. For ecological or economic reasons the new forest may include species not originally present. In time, the original forest's protective function and ecological services may be re-established [Lamb and Gillmour, 2003]. 19

restoration The process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed, to its original state.. 18

sampling strata There are three sampling strata, which are defined by strict rules: Trees - DBH $\geq$ 5cm, Shrubs - DBH $\leq$ 5cm but with a height $\geq$ 0.9m, Ground/herbs - any woody or nonwoody species with a height $\leq$ 0.9m (including ferns). 52

semi-pristine Semi-pristine refers to the condition of a forest which shows some sign of human activities in the past due to which some exotic species are present, and some native elements are missing. However, the forest structure and native regeneration remains largely intact.. 76

set of the future Oldeman's [1990] "set of the future" refers to a subset of only woody species inventoried in the ground/herb layer which will form the trees of the future.. 65

set of the present Oldeman's [1990] "set of the present" refers to a subset of only adult individuals of the vegetation community. Juveniles and seedlings are excluded in the "set of the present".. 65

synusia Synusiae are layers of vegetation which can be regarded as distinct ecological units composed of plants of a similar lifeform e.g. trees, shrubs, herbs, epiphytes etc.. 53

1 Summary

The Mare aux Cochons watershed is one of the most important water sources in Seychelles and falls within the area of the Morne Seychellois National Park. To secure the water regime in the future, especially in the light of climate change, the Ecosystem based Adaptation project aims at rehabilitating parts of the forests in the watershed. However, little is known about the long term development and success of forest rehabilitation in Seychelles. Moreover, development pressure on the Park is likely to increase in the future due to a growing population, an ambitious tourism-based economy, and recently emerged private land-related conflicts. This interdisciplinary thesis aims to support evidence-based sustainable management of the Mare aux Cochons through technical aspects of forest rehabilitation and investigation of public perceptions and expectations. We performed semi-structured interviews with local stakeholders and surveyed a random sample of 395 Mahé residents. In addition, we collected floristic data in two out of ten suggested rehabilitation sites in the National Park, to characterize the current state of the forest regarding community composition, forest structure, and biodiversity. This assessment provided a baseline reference for planned forest rehabilitation activities.

The survey revealed that the majority of people still gather drinking water from forest rivers in the National Park, however, they rarely identified the provision of water or safeguarding the water regime as an important function of the Park. Nevertheless, the majority of people to some degree understood the role of the Park in regulating water runoff. This was more pronounced in people living near the Park, who were more likely to benefit from the Park in terms of it preventing landslides and erosion. Looking at how people benefit from the Park, non-tangible services, such as air purification, aesthetics, and education play the most important role in people's relationship with the National Park. While the majority of locals had visited the Park in the past, only some respondents visit the Park relatively regularly and there seems to be a need to promote less time-consuming trails as a local recreation area. At the same time, people recognize tourism besides the protection of ecosystems and biodiversity as a core function of the Park. Besides, there is local support for the implementation of complementary low-impact infrastructure, as evident from the most preferred future scenario. Subsequently, the desired level of development in the area of the Park has little to no negative impacts on natural resources in the Park, such as the quality of forests and the quality of water. This implies that general local expectations of providing tourism activities within the Park and implementing the necessary facilities can be met without adverse effects on the natural environment.

Historic land use has affected the vast majority of Seychelles' forests from the moment when people settled on the island 250 years ago [Steers and Stoddart, 1985]. As a consequence, the forest canopy in the lower Mare aux Cochons water catchment is nowadays characterized by exotic species such as Cinnamon, Santol, Albizia, and other formerly cultivated woody species, with exotic herbs and shrubs which escaped from historic gardens or residential areas growing in the understorey. Thus, most study sites in the secondary forest are clearly distinct in their composition from the original native lowland forest. However, our forest assessment revealed widespread regeneration of native vegetation in secondary forest, particularly of endemic palms which thrive under the favorable condition provided by the exotic forest canopy. While many exotic species show healthy rejuvenation, the proportion of native vegetation is much higher in younger forest strata, indicating that forests have not reached a stable steady state. These findings highlight dynamic successional

processes with unclear outcomes for the subsequent forest composition. It is, however, likely that in the future more native vegetation will grow alongside exotic old-growth and that secondary forest communities move towards a more original state. Rehabilitation can assist this trend, and thereby raise the conservation value of the forest landscape in the lower Mare aux Cochons water catchment. We developed four indicators to evaluate rehabilitation success and propose two rehabilitation approaches; one based on traditionally used endemic palms, and one based on broadleaf trees which are typical for original lowland forest.

People generally held a positive attitude towards the physical appearance of areas rehabilitated with endemic palm trees. In particular, the presence of native palms went hand-in-hand with increased aesthetics of the rehabilitated area, which was perceived as more green, open, and clear. The EbA program might apply these findings as an argument in favor of forest rehabilitation with traditionally used endemic palms. While attitude towards rehabilitated areas was mostly positive, two arguments stood out for diminishing the value of the rehabilitated areas. First, the lower number of trees after rehabilitation was perceived negatively, and second, people did not like the interference with the natural environment. These arguments might be the root cause of future conflicts. We suggest that the negative attitude towards the physical appearance of restored areas can be conquered with effective and transparent communication, for example, by implementing information boards next to rehabilitated areas.

Our study emphasizes the importance and the opportunities of a transdisciplinary approach in addressing complex challenges in ecosystem management. We show that forest rehabilitation activities and the provision of tourism in the Park can be complementary to people's expectations. Furthermore, the identified mismatches between forest rehabilitation and peoples' perceptions can be used to guide further management decisions and help secure conservation goals in the long term.

2 Introduction

2.1 The Morne Seychellois National Park in context

The earliest records of Seychelles date back to the year 1609 [Steers and Stoddart, 1985]. For over a century, only some explorations reached the uninhabited archipelago until the first french settlers established themselves by the end of the 18th century, marking the start of human settlement. For the first 200 years of its history, Seychelles's economy was built on agricultural products and exploitation of forest products [Pickersgill and Sauer, 1968]. While the agriculture-dominated era came to an end in the 1970s, the government of Seychelles began to assess the possibility of developing a tourism industry [Procter, 1973]. It was realized early that a successful shift to a tourism-based economy can only be achieved if Nature Reserves and National Parks are established [Procter, 1973]. The necessity to protect the natural heritage from further exploitation and to link conservation with successful tourism were the leading motives to declare a series of protected areas in Seychelles [Steers and Stoddart, 1985, Curry-Lindahl, 1974, Procter, 1973, Procter, 1970]. Since the onset of the environmental protection movement in the '70s and significant support by international organizations, 47% of Seychelles' landmass has been put under some form of legal protection [Government of Seychelles, 2014]. An already significant commitment to conservation was taken even further when, in 2011, the Seychelles government announced that it will declare more protected areas in the archipelago, resulting in half (50.6%) of all Seychelles land becoming protected by law [IUCN, 2011, Clifton et al., 2019].

The long history of the granitic micro-continent of Seychelles separating from other continental landmasses allowed the flora and fauna to evolve in multiple isolations which resulted in high levels of endemism of both the fauna and flora [Steers and Stoddart, 1985, Senterre et al., 2013]. On Mahé, the largest of the granitic islands and home to around 79 000 inhabitants [National Bureau of Statistics, 2010], the terrestrial natural heritage of some of the last remaining sanctuaries of original native flora and fauna [Carlström et al., 1996, Senterre et al., 2013] is safeguarded by law within their largest terrestrial National Park. The Morne Seychellois National Park (hereafter called "the Park") was one out of many protected areas designated in 1979 under the National Parks and Nature Conservancy Act [Government of Seychelles, 1973, Clifton et al., 2019] with a specific objective to preserve the scenic beauty and to protect its wildlife [Nevill et al., 2014]. One of the most important watersheds of the island is located within the Park: the Mare aux Cochons – the source of which was declared as a Ramsar site in 2010 [Murugaiyan, 2009].

Safeguarding the water regime under the conditions of climate change is one of the key objectives of the ecosystem based adaptation (EbA) project implemented by the GOS-UNDP-GEF Programme Coordination Unit (PCU) of the Ministry of Environment, Energy, and Climate Change (MEECC) [UNDP, 2012]. An increase in irregular rainfall patterns, which can induce water scarcity and watershed flooding, is predicted for Seychelles. Strengthening the integrity and functionality of water catchments such as the Mare aux Cochons, and enhancing the resilience of surrounding forest resources and coastal areas are therefore crucial components of the EbA project to reduce the vulnerability of Seychelles to future projected climate change.

Besides this Ramsar wetland, the Park entails mainly secondary forests, impressive cliffs, and the highest peak of the island state (Morne Seychellois, 905 m). The secondary forests are the results of 250 years of timber harvesting and agricultural activities [Pickersgill and Sauer, 1968, Procter, 1973, Steers and Stoddart, 1985]. Nevertheless, the Park is the largest reservoir of Seychelles' endemic biodiversity with extensive areas of high conservation values and small scattered patches of original vegetation [Government of Seychelles, 2014, Senterre et al., 2013, Senterre and Henriette, 2015]. The Park is managed by the Seychelles National Parks Authority (SNPA), a governmental institution within the Ministry of Environment, Energy, and Climate Change, which is mandated to manage several terrestrial and marine protected areas in Seychelles. The current mandate of the SNPA for 2017-2021 is to primarily protect and effectively manage the ecosystems and biodiversity, but also to provide and facilitate tourism, recreational activities, research, education, and sustainable forestry practices [SNPA, 2017].

The water catchment Mare aux Cochons, as well as the wider area of the National Park, play a crucial role in the local hydrological cycle and protecting residential areas from erosion and floods: water availability and water quality of public water supply, as well as direct drawing from forests streams, relates directly to protection and management of the watershed [UNDP, 2012]. This highlights the importance of the EbA project's focus on provisioning capacities of catchments and their protection from erosion and floods. The coexistence of the Park with an ambitious and growing economy, however, might challenge the balanced trade-off between conservation and use of the Park and pose a risk to the provision of water-related ecosystem services.

The area of the Park, and specifically the Mare aux Cochons watershed, encompassing parts or whole areas of privately owned properties, which have been managed by the government (SNPA) for the last 40+ years (Figure 1). Some owners of private properties are now coming forward to develop their land [Millett J., personal communication, December 2019] which recently provoked private land-related conflicts. With almost 40% of the Park is privately owned, it has been mentioned as one of the major difficulties encountered by SNPA in its management efforts [Government of Seychelles, 2018]. The root of the conflict lies in the Constitution of Seychelles (Chapter I, Part I, Article 26) which states that "Every person has a right to the property... and the right to acquire, own, peacefully enjoy and dispose of property..." [Constitution of Seychelles, 1993]. It is therefore not clear what "peaceful enjoyment" of private property entails, which leads to conflicts on how private properties in the Park can be used and to what development intensity. There is currently no legislation in place that addresses such issues. On the other hand, the Constitution (Chapter I, Part I, Article 26) also states that "The exercise of the right ...may be subject to such limitations... in the public interest" [Constitution of Seychelles, 1993]. Therefore, public interest and opinions can, to some extent, play a role in governing how private land in the Park is used.

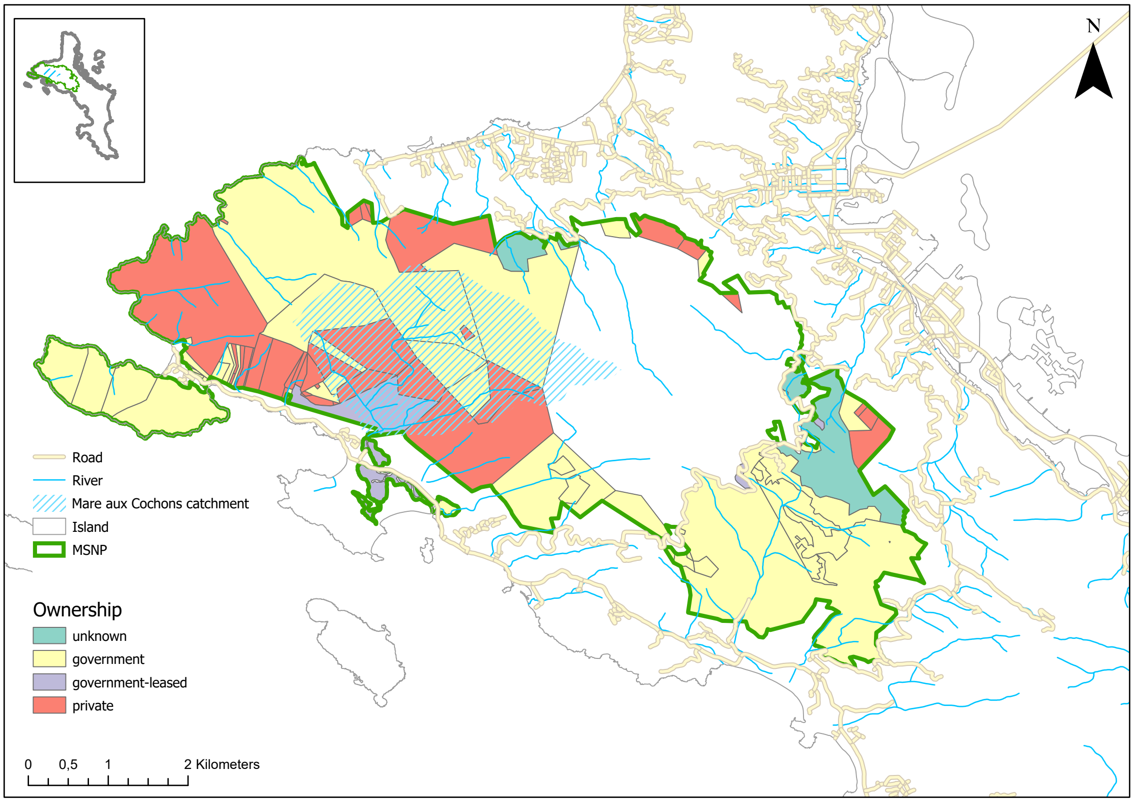


Figure 1: **Map of the Morne Seychellois National Park.**
Raw data retrieved from Web Feature Service (WFS) (data as of May, 2020) (https://www.webgis.gov.sc/cgi-bin/wfs) of the Ministry of Habitat, Infrastructure and Land Transport (MHILT). WFS was accessed through ArcGIS Pro version 2.4.0. White parts inside the National Park lack ownership data.

Similar to many small island economies, tourism plays an important role in contributing to the Seychelles economy [Government of Seychelles, 2018]. The importance of preserving natural resources for tourism has been recognized since the shift to a tourism-based economy in Seychelles [Procter, 1970] and is still prominent in the vision of the Seychelles Tourism Master Plan, which emphasizes sustainable development of tourism and the importance of environmental protection. The provision and facilitation of tourism is a core objective of SNPA along with the protection of biodiversity [SNPA, 2017]. However, sources suggest SNPA has limited management powers due to being underfunded by the government [Clifton et al., 2019] and is having additional difficulties realizing revenue from its assets, despite its central location at the very heart of national tourism [Government of Seychelles, 2014]. Establishing and raising visitor fees in the Park to a level of management costs is a potential solution to improve this situation [Clifton et al., 2019] and is currently being assessed by the SNPA (SNPA, personal communication, February 2020). Hence, provision and maintenance of basic infrastructures, such as entrance kiosks, parking premises, toilets, and other facilities, is needed or at least expected in the area of the Park. While the majority of accommodation and tourist activity is currently concentrated around coastal areas on lower attitudes, Mahé is a relatively small island and provides limited space. Especially in face of climate change, sea level rises [Gerlach, 2008], and a steadily growing population [National Bureau of Statistics, 2020], could make development pressure on the National Park more prominent in the future.

The above-mentioned trends indicate that the touristic function of the Park will be more prominent in the future, together with increased pressure on the area due to a growing population and private land-related issues. By law, economic development can take place in the area of a National Park, mostly through recreation, sustainable agriculture, and tourism, as long as it does not have a significantly negative impact on other objectives [Ministry of Environment & Energy, 2013]. However, it does not make explicit which activities and facilities are acceptable in the area of the Park, which is an area of discussion and has seen some opposing views between the government and interested individuals [Dias A., personal communication, December 2019]. The question arises, which activities should be allowed, and under what circumstances, so that they do not compromise conservation and natural resources objectives and can contribute to the local economy and benefit local communities [Ministry of Environment & Energy, 2013].

That the majority of Seychelles' forests are far from their original state, however, cannot be attributed to mismanagement and lack of funding. Encroachment by non-native species is a major ecological issue particularly in island ecosystems – including the Seychelles [Van Kleunen et al., 2015, Baret et al., 2013]. Most of Mahé's original forests, however, were cut down by the year 1819 and historic land use activities altered terrestrial ecosystems long before the National Park was created [Pickersgill and Sauer, 1968]. Two historical land-use phases can be distinguished, the first phase, which occurred at the beginning of colonization, includes major deforestation for timber and to create land for agricultural purposes. The second phase is related to the cinnamon industry which started around 1900; the distillation of oil in cinnamon distilleries required fuelwood which was obtained from the surrounding vegetation. The shift from an agricultural dominated industry to a tourism-based economy after the opening of the international airport in 1972 with still limited biosecurity added additional new exotic elements to the flora of Seychelles [Carlström et al., 1996].

Seychelles has a long history of rehabilitating the original state of disturbed habitats [Kueffer and Vos, 2004, Beaver and Mougal, 2009] - or as such systems have been described by many authors; novel ecosystems [Hobbs et al., 2006, Kueffer and Vos, 2004, Radeloff et al., 2015, Hobbs et al., 2013, Hobbs et al., 2009, Hobbs et al., 2014]. The key characteristics of a novel ecosystem, defined by Hobbs et al. [2006], are novel species compositions derived from human activities with the potential for functional changes in the ecosystem. Most importantly, in this definition, these human activities do not have to be maintained to let novelty persist. A new state, or a hybrid-state, can be reached and irreversible ecological thresholds may have been crossed. This raises the question, to what extent such novel systems should be managed given the irreversibility to their original state. There is an ongoing debate between two fronts of restoration ecologists, whether we should try to keep as much undisturbed nature as we can, or whether we should accept "the new" as an inconvenient and inevitable reality. Important considerations in the debate are if these new systems are after all persistent and if species composition will change again in the future. The "more modern" front argues that around 30% of the earth may be constituted by novel ecosystems [Hobbs et al., 2013] and that novelty is the "new normal". However, the concept itself and the necessity of the novel ecosystem concept have been challenged by the other front of restoration ecologists. This more "classical front" argues that the concept of novel ecosystems is an unnecessary label based on "theoretical musings" without empirical foundation and with potentially damaging implications for nature conservation [Aronson et al., 2014, Murcia et al., 2014]. Critics of the novel ecosystem concept argue that if altered habitats are in a new steady state is ultimately a testable hypothesis and a matter of temporal perspective [Radeloff et al., 2015].

There are some examples where habitats were altered to an extent that their original state cannot be restored (e.g. large scale mining) [Hobbs et al., 2006]. Secondary forests in Seychelles were previously labeled as novel ecosystems [Kueffer et al., 2010], which implies by its definition that novelty persists [Hobbs et al., 2013, Hobbs et al., 2006]. However, the successional trajectory of forest in the Park is practically unexplored and whether the novel composition of secondary forests in Seychelles has reached a steady-state or not, is therefore unanswered.

Despite the non-consensus among restoration ecologists on how to manage (novel) ecosystems effectively, if such systems even exist, many scientists, governments, and NGOs have called for increasing restoration and management efforts. In Seychelles, component 1 of the Ecosystem based Adaptation (EbA) project aims to "maintain and enhance wetlands in Mare aux Cochons and strengthen the integrity of the surrounding forest landscapes and its water provisioning services, retain and improve water holding capacity and biodiversity features of the watersheds, and promote local stewardship of watersheds" [UNDP, 2012]. This includes reforestation and re-establishing native plants and the removal of exotic alien species. While the goals of reforestation can be articulated and defined unambiguously, little is known about long term development and success of forest *restoration* or *rehabilitation* in Seychelles and the world [Boelsums Barreto Sansevero and Luȷs Garbin, 2015]. Most rehabilitation programs, with a few exceptions, have been poorly recorded and no quantitative data was collected before the project start [Beaver and Mougal, 2009]. Within this study, we provide a robust baseline of present forest vegetation in the lower Mare aux Cochons water catchment to guide forest rehabilitation, implemented soon as part of component 1 of the EbA project. In addition to the baseline inventory of secondary forest, we characterize the vegetation in a newly discovered piece of relict palm forest as a reference for planned rehabilitation.

Within this thesis, we primarily use the term "rehabilitation" instead of "restoration", because it is less deterministic in the outcome of the activity and acknowledges that vegetation may be permanently altered [Lamb and Gillmour, 2003]. However, both terms have the same intention to return ecosystems to its former condition.

In the attempt to restore degraded ecosystems, it is in practice often natural scientists, more specifically ecologists, who answer the question of what is right and wrong. While being crucial in successful ecological restoration [Ruiz-Jaen and Aide, 2005, Boelsums Barreto Sansevero and Luȷs Garbin, 2015], ecological knowledge cannot ensure human participation and commitment necessary for maintaining restoration projects. Here we quote Swart [2001] who concludes the following:

> "To be successful in nature management, especially in restoration, one should not pass over the positions and views of ordinary people who are involved" [Swart et al., 2001] (pg. 237).

Today, including local communities as much as possible in nature conservation is a much more common practice and ensures conservation success in the long run. The EbA project has actively engaged a wide set of stakeholders and also initiated the establishment of "Watershed committees" [UNDP, 2018]. Watershed committees are local community groups established under the project to become actively involved in the protection, rehabilitation, and management of their respective watersheds. However, it was noted during a Mid-term Validation Workshop that stakeholders had a limited understanding of the concept of EbA and that more emphasis is needed on actively engaging with stakeholders. From a Park's perspective, scarce resources and financial constraints are forcing SNPA to prioritize its management and therefore put other educational objectives, such as costly communication and knowledge incentives, as a low priority [SNPA 2017, pers. comm in Clifton, 2019].

To summarize, the sustainable management of water resources in the area of the National Park might be compromised due to trade-offs between conservation and future use of the Park. Here expectations and opinions of local communities can play an important role in preventing undesired development in the Park due to land-related conflicts. Moreover, local support for sustainable forest management, including forest rehabilitation, is crucial in avoiding conflicts, securing long term commitment, and reaching conservation goals. On the other hand, public support by itself is incapable of ensuring the success of rehabilitation, without the technical- and ecological understanding of underlying systems and processes.

To support the EbA project in reducing the vulnerability of Seychelles to climate change through strengthening the integrity of the forest landscape around water catchments, this thesis aims to answer the following overarching research question:

> How can we support the evidence-based sustainable management of the Mare aux Cochons watershed through the technical aspect of forest rehabilitation and investigation of public perceptions and expectations?

In Part I, we answer the following operational questions: (i) What are the most important perceived functions of the Park?; (ii) How do people use and benefit from the Park in terms of visiting and ecosystem services?; (iii) What is the local attitude towards potential future scenarios of the Park, including development intensity?; (iv) Which perceptions are associated with positive and negative attitudes towards the physical outcome of forest rehabilitation?; (v) Do people support forest rehabilitation and how can they benefit from it?

In Part II, we answer the following forest rehabilitation specific questions: (vi) What is the current state of the forest in the lower Mare aux Cochons water catchment regarding species composition (exotic vs. native) and biodiversity? (vii) What is the likely forest succession of rehabilitated- and natural secondary forests? (viii) Is a traditional rehabilitation approach (based on endemic palms) or an approach using diverse native broadleaf trees more successful and how can success be measured?

Together, Part I and Part II, focus on investigating three main entities, namely the residents of Mahé, the Morne Seychellois National Park, and forest rehabilitation activities.

2.2 Connecting the three entities in a harmonized research design

In order to guide this transdisciplinary thesis we designed a framework (Figure 2) to help us investigate the relationship between three main entities of our interests in a structured way, that is (1) local people; (2) the Morne Seychellois National Park; and (3) forest rehabilitation activities. The proposed framework incorporates several state-of-the-art methods from social and natural sciences and forms a harmonized research design.

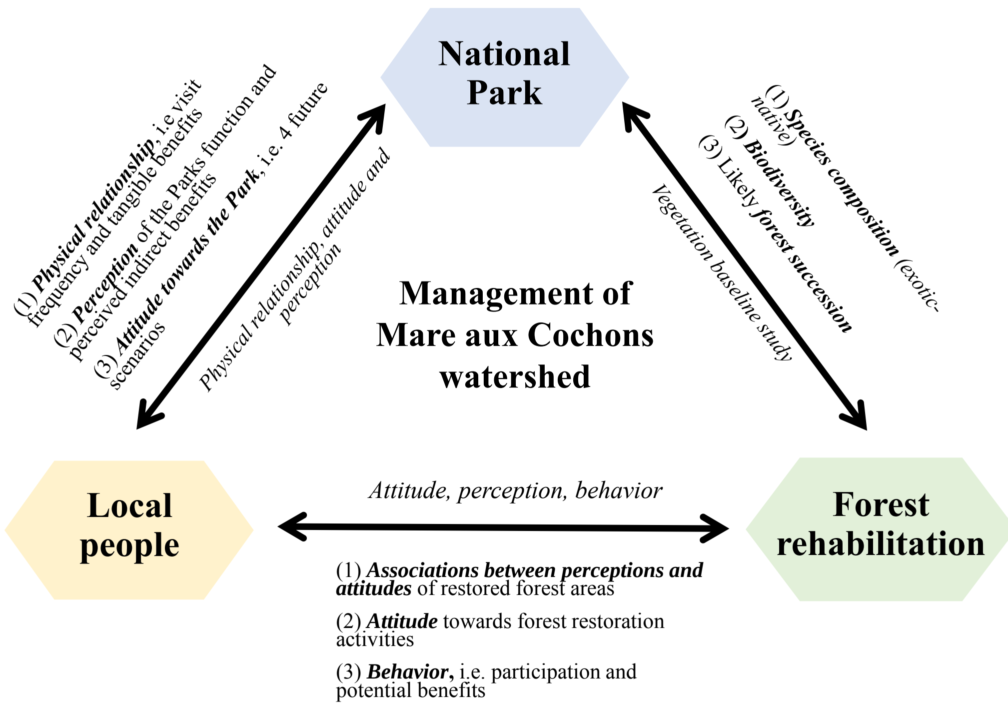


Figure 2: **Operational framework for the management of the Mare aux Cochons watershed.** Framework that captures the relationships between local people, the Morne Seychellois National Park, and forest rehabilitation.

2.2.1 Local people - National Park relationship

Since the establishment of the Morne Seychellois National Park in 1979, there have been numerous reports and scientific articles published focusing on the ecological values of flora and fauna in protected areas [Carlström, 1996, Senterre and Henriette, 2015, Gerlach, 2008, Procter, 1970, Edgar, 2003]. On the other hand, the inclusion of the social dimension in ecosystem management has been rare and few studies have focused on investigating how locals value protected areas. A literature review revealed two studies which explored the perceptions of fishermen in Seychelles about displacement, spillover, and overall impacts of local marine reserves on their livelihoods, respectively, the differing perception in the number of fish caught to improve the legitimacy of fisheries governance [Cinner et al., 2014, Daw et al., 2011]. Even though these studies looked at marine ecosystems, both pointed out a lack of empirical social research in managing nature reserves. Besides published literature, a project carried out by the Seychelles National Parks Authority performed socio-economic monitoring in a marine protected area in Seychelles to improve Parks legislation [Seychelles National Parks Authority, 2009]. Specifically relating to the management of the Morne Seychellois National Park, one master thesis surveyed tourists to investigate the potential of eco-tourism as an economically suitable and ecologically harmless project [Frey and Kruetli, 2000]. Another master thesis project worked with local stakeholders to evaluate ecosystem services and future scenarios in the Val d'Endor watershed [Massy and Schmutz, 2017].

Investigating relationships between the protected area and local people has been, otherwise, a common approach to mitigate conflicts, especially in developing countries where conservation of protected areas often prohibits people from accessing resources they depend on for their daily needs [Bennett and Dearden, 2014]. While there seems to be no universal approach to assess the people-park relationship, researchers tend to describe such relationships in terms of different aspects, such as the resident's resource use of a protected area, attitudes toward the particular area, perception of conservation and development projects, and social context of residents living adjacent to protected areas [Allendorf, 2010]. Based on several people-park studies in Nepal and Myanmar, Allendorf [2010] proposed a simple framework to study such relationships, that consists of people's physical relationship with the protected area; their attitudes and perceptions toward the protected area; and the linkage of the relationship to the broader social, political, and economic context. This framework was used as an inspiration to propose a framework to answer our specific research questions.

Here, we investigate the relationship of local people with the Park, focusing on their physical use of the Park, perception of benefits, and preferred future development scenarios. Thereby, we aim at providing a more comprehensive view of the value of the Park. Specifically, we investigate: (1) *people's physical relationship with the Park*, e.i. how they "use" the area, which consists of visit frequency and tangible benefits from the Park, such as recreation and collection of forest services; (2) *perception of the Park's function and perceived indirect benefits*, such as air purification, education and aesthetics; and (3) *attitude towards the Park*, which consists of liking or disliking the four potential future scenarios for the Park (Figure 2). The tangible and indirect services from the Park fall under the term of "ecosystem services", and are commonly defined as "the benefits people obtain from ecosystems", and include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services, such as nutrient cycling, that maintain the conditions for life on Earth [Alcamo and Bennet, 2003].

The physical relationship captures how local people interact with the Park, which can be quantified with visit frequency [Allendorf, 2010], i.e. how often people visit the area. While one study did in a way investigate the use of the Park [Frey and Kruetli, 2000], it focused on tourists, and little is known about the use of the area by local people. An extensive network of hiking trails is in place within the Park, with each trail having its name, and some even being used for religious purposes (Trois Frères). In addition to recreation, local people may visit the Park for other reasons, such as to collect medicinal plants [Matatiken et al., 2011], forest products, or to collect drinking water. While it can be roughly estimated, it is unknown to what extent people rely on the Park for such provisioning services.

Perceptions of the Park's function and perceived indirect benefits can give insight into how people value the Park for functions that are not tangible, such as education, aesthetics, water regulation, and air purification. Besides water catchment functions, the forests of the Park provide climate- and air quality regulation as well as recreational activities that are equally necessary for human well-being. While local communities take use from many of such services, they may not recognize them as inherent benefits of strong environmental protection policies in Seychelles. At the same time, investigating local perceptions of the Parks may reveal aspects of the Park which are not sufficiently addressed under current management policies. A study by [Allendorf et al., 2012] demonstrated that residents' perceptions can be used by management as a starting point to improve people-Park relationships through feasible and targeted interventions that are meaningful to local communities and their relationships with protected areas. Numerous other articles also point out that studying local perceptions is important in socioeconomic systems similar to the Seychelles [Bennett and Dearden, 2014, Iftekhar and Takama, 2008, Marcus, 1999, Hartter et al., 2012, Vodouhê et al., 2010].

Attitudes towards the Park can simply be measured by asking people whether they like or dislike the Park [Mehta and Heinen, 2001] and are usually accompanied by questions investigating why they like or dislike the area. These questions are usually targeted at conflicts in rural communities between the management of the Park and local residents, who are often deprived of their use of the Park which they depend on for their daily needs [Mehta and Heinen, 2001]. In the case of Seychelles, we did not detect any similar conflicts between people and the Park due to restricted resource use, except in case of exploiting plants for medicinal purposes [Matatiken et al., 2011]. However, apparent conflicts are present due to competition for land in the Park, as elaborated in the introduction. This leads us to investigate people's attitudes towards the future scenarios of the Park, specifically, if different development pressure on the area of the Park increases and results in trade-offs between use of the Park and conservation.

2.2.2 Local people - forest rehabilitation relationship

As shown by many practical examples worldwide, the relationship between local people and conservation as a whole, and more specifically with forest rehabilitation, is of primary importance [Evans and Gueriguata, 2008, Webb et al., 2004, Marcus, 1999, Bennett, 2016]. "It is positive perceptions, not just objective scientific evidence of effectiveness, that ultimately ensure the support of local constituents thus enabling the long-term success of conservation." [Bennett, 2016] (pg. 582).

Authors argue that restoration success depends not only on the technical aspects, but needs to also consider social, cultural, and aesthetic aspects [Higgs, 1997, Geist and Galatowitsch, 1999]. Anchored in Component 1 of the EbA project proposal [UNDP, 2012], the project aims to promote local stewardship of watersheds, for example by initiating Watershed Committees, or by actively engaging local residents in rehabilitation activities in coastal areas and water catchments. While such efforts have been relatively successful in involving communities in EbA activities [UNDP, 2018], little scientific knowledge is available on how rehabilitated areas are perceived and valued - not only by participants but as society as a whole.

Here we investigate the societal dimension of forest rehabilitation, by studying: (1) *associations between perceptions and attitudes* of restored forest areas; (2) *attitude* towards forest rehabilitation activities; and (3) *behaviour*, i.e. participation in restoration activities and potential benefits. The framework was inspired by a conceptual design used to understand social perceptions of invasive species [Estévez et al., 2015].

Associating positive and negative attitudes with different perceptions can help us identify which aspects of forest rehabilitation might lead to potential conflicting views or disapproval of such actions [Estévez et al., 2015]. Estévez et al. [2015] conducted a systematic screening of peer-reviewed literature about the social dimension in invasive species management and concluded that most conflicts were attributed to diverging valuations of the species between scientists, managers, and local communities. Less commonly, but still present, some conflicts resulted due to a mismatch in risk perception of the invasive species and its eradication approach [Estévez et al., 2015]. Diverging opinions about restoration may also occur if local people fear that the cultural identity of a region is threatened [Swart et al., 2001] – which is a reasonable concern given the still relatively recent historical use of forest in the cinnamon era. While the EbA project and forest rehabilitation in Mare aux Cochons is not exclusively about "managing invasive species", the mentioned literature points out the importance of aligning values and perceptions in avoiding conflicts in managing ecosystems[Estévez et al., 2015]. Other than some landowner sensitivities [Millett J., personal communication, May 2020], there is currently no major conflict between local communities and rehabilitation activity managers in Seychelles. Nevertheless, to prevent future conflicts and ensure long-term commitment, a crucial element for any rehabilitation program is whether the local community is involved in its development and how it is perceived from the start of the project until the first results are visible.

By assessing attitude towards forest rehabilitation, we simply measure whether there is public support for such activities. Measuring behavior, on the other hand, intends to understand the target group which is more likely to participate in such activities and how communities could benefit from rehabilitation. It has been shown and argued that involving communities in ecological restoration and allowing them to make a personal contribution, creates a feeling of "ownership" and increases people's propensity to actively care for the environment [Petts, 2007, Geist and Galatowitsch, 1999]. This can directly support the EbA project which struggled to identify the target audience for their activities and help them in building local stewardship of watersheds by involving more communities in their projects [UNDP, 2018].

2.2.3 The Park - forest rehabilitation relationship

As most of Mahé's original forests were cut down, secondary forests make up the majority of the forested area in the National Park alongside small remnants of native original forests.

However, from a restoration perspective, former plantation forests provide a much more suitable start for restoration of native forest as compared to e.g. completely deforested areas where ecological thresholds may have been crossed and an irreversible state is reached [Hobbs et al., 2006]. Moreover, the spread of invasive species has been attributed to available niches [Van Kleunen et al., 2015], which is reduced in the well established secondary forest in the Park. The shady canopy of former plantations was shown to assist natural regeneration [Parrotta et al., 1997], reduces invasion by undesired exotic pioneer species, and facilitate growth of native species [Fleischmann, 1999, Kueffer et al., 2010]. In the case of cinnamon dominated secondary forest, below ground competition through the dense root mat was shown to suppress growth of juveniles of invasive but not for juveniles of native tree species [Kueffer, 2006]. Hence, the protected secondary forests in the Park may represent good nurse habitats for the regeneration of native trees.

The presence of microrefugia of native forests in the National Park, most notably the palm forest in close proximity to Port Launay, additionally provides considerable benefits for rehabilitation: abundance of seed material for rehabilitation, natural seedling recruitment and dispersal to rehabilitation sites, and (potentially) an accessible and visible cue for park visitors and local communities involved in rehabilitation. Lastly, the initial composition of the forest plays an important role in the outcome of forest restoration [Lamb and Gillmour, 2003]. As we will show, there is widespread regeneration of native vegetation in the study sites which will facilitate rehabilitation efforts in the Park.

For the above mentioned reason, the Morne Seychellois National Park is a relatively promising ground for partial conversion to natural or semi-natural forest, and also to study natural forest succession in protected secondary forests, and thereby test the hypothesis of novel ecosystems. Several forest areas in the Park have been identified to be suitable for rehabilitation based on their accessibility, their 'naturalness' and species composition [Senterre et al., 2019a].

Here, we provide a detailed assessment of the vegetation present in two out of ten suggested rehabilitation sites as a baseline reference for planned forest rehabilitation. Baseline studies prior to restoration work are inherently necessary to evaluate success of forest restoration [Bull et al., 2014, Blossey, 1999]. We collected floristic data in two different forest area of 1.3 ha in lowland and lowland-submontane forest of the National park to characterize the current state of the forest in regard to community composition, forest structure, and biodiversity as is common practice in restoration ecology [Ruiz-Jaen and Aide, 2005, Lamb and Gillmour, 2003]. In a total of 26 permanent plots of 50x20 m, resulting in a total of 1.3 ha, we described species diversity, -abundance, -density, and relative abundances of exotic vs. native species. Furthermore, we calculated several biodiversity indexes and create four status indicators to evaluate the present state of the forest in the study areas. We inventoried all woody and non-woody plants except for bryophytes and conducted vegetation community analyses based on species composition. The majority of permanent plots are in typical secondary plantations in the Park. To our surprise, our study revealed a patch of almost pristine lowland forest characterized by original vegetation and absent signs of past human disturbance in close vicinity to residential areas in Port Launay. This finding allowed us to include an additional native species community in our analysis. This microrefugia of original native forest serves as a reference for rehabilitation instead of a control treatment in the lowland forest area. Lastly, we provide direct practical support for future rehabilitation work by mapping a recently introduced invasive species, the Cat's claw creeper *(Macfadyena unguis-cati)* [Senterre, 2009] (to be found in Appendix B Chapter 14.1.1).

The rehabilitation baseline study provides theoretical and practical guidance for planned forest rehabilitation in the Mare aux Cochons water catchment in the National Park. It gives us the opportunity to explore succession of (i) restored secondary forest, (ii) non-rehabilitated secondary forests and, (iii) pristine forest surrounded by degraded forest. By continued monitoring of our baseline plots, we can gain strong insights into managing secondary forests in the National Park.

2.3 Structural overview of the thesis

After this common introduction where we outlined the overarching setting and framework of this trans-disciplinary thesis we now describe the methods- and results sections separately. In Part I we first present methods and findings from the Perception study, and in Part II we provide the methods and results of the vegetation baseline study in the lower catchment area. Following the results, at the end in each part, we discuss our findings separately in more discipline-specific details, and then synthesise the two parts in Chapter 12.

Part I
Perception study

3 Methods and procedure

Studies investigating relationships between people and protected areas have commonly relied on a survey questionnaire as the method of choice to study attitudes and perceptions [Mehta and Heinen, 2001, Allendorf et al., 2012, Allendorf et al., 2007, Das, 2017, Vodouhê et al., 2010, Allendorf and Yang, 2013, Marcus, 1999, Abasolo et al., 2008]. In such research designs, the survey was administered by conducting structured face-to-face interviews with local people and recording responses on an appropriate questionnaire. We followed this approach and developed a standardized questionnaire to be administered to a random sample of local residents living on Mahé, Seychelles.

3.1 Questionnaire

The questionnaire was designed in a manner to describe the relationships between the people with the Park and the people with forest rehabilitation. Ratings, multiple-choice and open-ended questions were used in the questionnaire. The ratings were measured on a 5-point Likert scale, which is a well-known tool among social scientists to measure attitudes of people towards a subject. Alternatively, "yes"/"no" questions can also be used to assess attitude. "Do you like the biosphere reserve?" [Xu et al., 2006], or "Do you agree with buffer zone establishment?" [Htun et al., 2012], for example, can be asked in a survey to examine the attitude of local people towards a protected area. For this study, the survey questions were developed together with key stakeholders (Appendix A, Chapter 13.1). Interviews were conducted with the Plant Conservation Action group, the Ministry of Environment, Energy and Climate change, SNPA, the Seychelles Planning Authority (SPA), the tourism department, tour guides, and local business owners. The interviews were semi-structured. Questions about the interviewee's personal and/or professional view on the potential and preferred future of the National Park and on how local people can benefit from the area were accompanied by interviewee specific questions.

The survey questionnaire was clustered in six topic sections: socio-demographic variables; awareness about the Park and visiting of the Park; benefits from the Park; the importance of the Park; future scenarios; and attitudes towards forest rehabilitation and further perceptions and participation. The complete version of the questionnaire can be found in the Appendix, in English (Appendix A, Chapter 13.2.1), and Creole (Appendix A, Chapter 13.2.2).

3.1.1 Socio-demographic variables

There is present empirical evidence that socio-demographic factors, such as education [Vodouhê et al., 2010, Marcus, 1999], and origin play a role in the perception of biodiversity conservation [Vodouhê et al., 2010]. A study in Nepal [Mehta and Heinen, 2001] identified participation in training, benefits from tourism, gender, and education level as significant predictors of the attitudes of local people towards the conservation area. Therefore, correlating people's attitudes and perceptions with their broader socio-demographic context can increase the depth of understanding the underlying factors for attitudes and perceptions expressed by the people. Thus, the first section of the questionnaire used in this study, concerned relevant socio-demographic characteristics, namely gender, age, nationality, education, and work experience in tourism. People who benefit from the protected area in terms of tourism were shown to hold more favorable attitudes towards the Park [Vodouhê et al., 2010].

Besides, attention was given to the participation of respondents in local environmental education programs because it has been shown that such programs improved short- and long-term stewardship behavior, environmental knowledge, and environmental awareness [Stern et al., 2008]. Moreover, a positive relationship between knowledge about the protected area and perception of benefits has been observed in other studies [Htun et al., 2012, Allendorf and Yang, 2013]. The environmental study programs included in our study were Wildlife clubs and Eco-School. Wildlife Clubs of Seychelles were established in 1994 as a non-governmental organization. The objective of the program is to engage children and the youth in conservation action. Wildlife Clubs of Seychelles has clubs in almost all schools in Seychelles and more than 600 members [Wildlife Clubs of Seychelles, 2020]. Seychelles' Eco-School Program, coordinated by the Environmental Education Unit within the Ministry of Educations, is a school program that involves teachers, students, the wider community, and environmental organizations to work together in promoting environmental learning and environmental management practices. Some of the challenges that schools are responding to are climate change, unsustainable management of energy, water, and waste, amongst others. [Ministry of Environment & Energy, 2020].

3.1.2 Awareness about the Park and visit frequency

To explore the physical relationship between people and the Park, we investigated how often people visit the area, in addition to which and how many trails they have visited. People were first asked if they had heard of the National Park on Mahé. For that, an illustration of the geographical location of the National Park (Appendix A, Chapter 13.8, Figure 26) was presented to the respondents and accompanied by an explanation: "This area in green is the Morne Seychellois National Park on Mahe". This enabled us to visually clarify which National Park we are talking about and to avoid confusion with the Marine National Park. We followed with a multiple-choice question, asking which of the trails have they visited and how frequently they visit the Park. Respondents could specify if there was any reason that prevented them from visiting the Park more often.

3.1.3 Importance of the Park

To investigate the people's perception of the importance of the Park, we first asked respondents whether they think the National Park is important and they could answer with "yes"; "no"; and "I don't know". To elicit a list of perceptions, we followed up with asking an open-end question: "Why do you think the National Park is/is not important for Seychelles?". It was of our interest to compare the given answers to the objectives of the Morne Seychellois National Park and assess, how they match. As a reference for "Objectives of the National Park," we used the mandate of the SNPA for the year 2017-2021 [SNPA, 2017].

3.1.4 Benefits from the Park

Assessing, understanding, and taking into account the full range of perceived benefits allows for several management assets including enhanced user experience and encouraging pro-environmental attitudes and behaviors [Asah et al., 2014]. Moreover, there is empirical evidence that people tend to have more positive attitudes towards a protected area if they feel they are benefiting from it [Marcus, 1999]. Studies in locations similar to Seychelles, such as Mauritius, showed that people mostly favor protected areas for picnics, hiking, and collection of berries [Iranah et al., 2018].

This section aimed to assess how the local population uses the Park and perceives the benefits from the Park in terms of ecosystem services. We have listed 12 services potentially offered by the Park and asked respondents "Do you benefit from this service for your well-being?". They responded on a 5-point Likert scale: "Yes, very much", "Yes", "Not sure", "No", and "Not at all". We listed the following benefits: a collection of fruits, flowers or wood; earning money by working in the Park; picking medicinal plants; prevention of landslides and erosion in the area; clean and fresh air; clean drinking water from forest river; PUC (Public Utilities Corporation) tap water from the Park; scenic view and natural beauty; seeing native plants and animal; hiking, walking or running; and learning about nature and environment.

3.1.5 Future scenarios for the Park

Developing and evaluating future scenarios has been a common approach to support environmental decision-making [Mahmoud et al., 2009, Baker et al., 2004]. Rather than predicting the future of the Park, scenarios can be considered as a learning tool to anticipate the potential outcomes of trade-offs between conservation and use of the Park.

To develop scenarios, we firstly performed a literature search (including grey literature, governmental reports, etc) and conducted several interviews with relevant stakeholders, including the board of the National Park, Ministry of Environment, Energy and Climate Change, and the Planning Office (Appendix A, Chapter 13.1.1) to gain insight into the current state of the National Park, planned activities, potential optimistic and pessimistic futures and its implications on the natural environment. Among other questions, we asked the interviewees "How do you see the Morne Seychellois National Park in the future, let's say in 2040?".

Based on the acquired information we developed future scenarios using the 2x2 Matrix Technique [Rhydderch, 2017]. In the 2x2 matrix technique, two to five scenarios are constructed and presented as narratives. They explore how the future could look like in medium to long term perspective, e.g. in 2025 or 2050 if certain trends or events take place. The scenarios are generated along two axes, where each axis represents a factor that will influence the issue of the study. This forms four quadrants that represent four different scenarios.

The goal of the scenario construction was to make explicit the anticipated trade-offs between different development intensities and conservation, all in light of Park's management capacity. The scenarios were build on an assumption that the development pressure on the National Park will increase in the future due to land scarcity in Seychelles, which might lead to a weakening of the current strict protection status of the Park. We identified several scenario variables: (1) Development pressure; (2) Management capacity; (3) Development type; (4) Trails; (5) Forest quality; and (6) Water quality (Table 1) with different values. "Development pressure" served as the y-axis of the 2x2 Matrix, and was either "low", relating to the current state or "high", capturing future pressures from the ambitious tourism industry and land-owners having the full right to develop their land in the Park. "Management capacity" served as the x-axis of the 2x2 Matrix, and referred to the "high" or "low" ability of the managing authorities to cope with the development pressure in favor of trails maintenance, forest, and water quality. "Development type" was the outcome of developmental pressure ad management capacity, resulting in different facilities and infrastructure in the Park. The impact of development pressure and management capacity on trail maintenance was defined to make the implications of each scenario more explicit to the locals. Lastly, the trade-offs between development and conservation for each scenario were described through forest and water quality and were based on consultations with James Millett and Water resource manager representative of PUC, the public water provider in Seychelles. Both assumed a compromised forest and water quality with intensifying development [Millett J., personal communication December 2019; Laurencine G., personal communication December 2019].

Table 1: **Scenario variables.**

Variables	Scenarios 1	Scenario 2	Scenario 3	Scenario 4
	"Stays as it is"	**"Low-impact development"**	**"High-impact development"**	**"Loss of protected areas"**
Development pressure	Low	Low	High	High
Management capacity	Low	High	High	Low
Development type	No additional infrastructural development	Low-impact development in lower biodiversity zones; toilets, a kiosk, a parking lot, a small restaurant and a zip-line	Development not restricted to areas of lower protection; high-impact development with toilets, kiosks, a Zip line, a Cable car, restaurants, Eco-lodges for tourists	Up to 40% of land in the Park loses protection and is open for unplanned and unstructured development for housing, and/or tourist facilities
Trails	Amount and length of trails remains the same, with less frequent maintenance	Regularly maintained to control tourist visit, supported by guided tours	New extensive network of highly maintained trails	Due to decrease in protected areas, intact nature trails remain only in higher areas that are still under protection
Forest quality	Not compromised and gradually improving in some areas due to natural regeneration with native plants	Not compromised and improving in some areas due to natural regeneration with native plants on rehabilitated areas	The quality is not improving due to disturbance; forest cover decreases and is in danger of being further invaded by invasive alien species	Forest cover decreases in areas of development, quality forest remains only on higher altitudes
Water quality	Not compromised and water quality is maintained	Not compromised and water quality is maintained	Slightly compromised due to development in the water catchment	Negatively impacted with pollution of the water catchment due to development

We developed four future scenarios for the National Park and evaluated them with the local population to measure attitude, which is a positive or negative opinion the local population holds towards the potential future of the Park.

In the questionnaire, the four scenarios: (1) "Stays as it is"; (2) "Low-impact development"; (3) "High-impact development"; and (4) "Loss of protected areas" were presented as narratives (See Appendix A, Chapter 13.2. We confronted respondents with four different scenarios how the Park could look like in 2040 and asked them to rate each of them on a 5-point answer scale: "I like very much", "I like", "I am neutral", "I don't like", and "I don't like at all". As a visual aid, we handed out an illustration of all four scenarios (3 that captured the main points of the scenario description, which was read out by the surveyor.

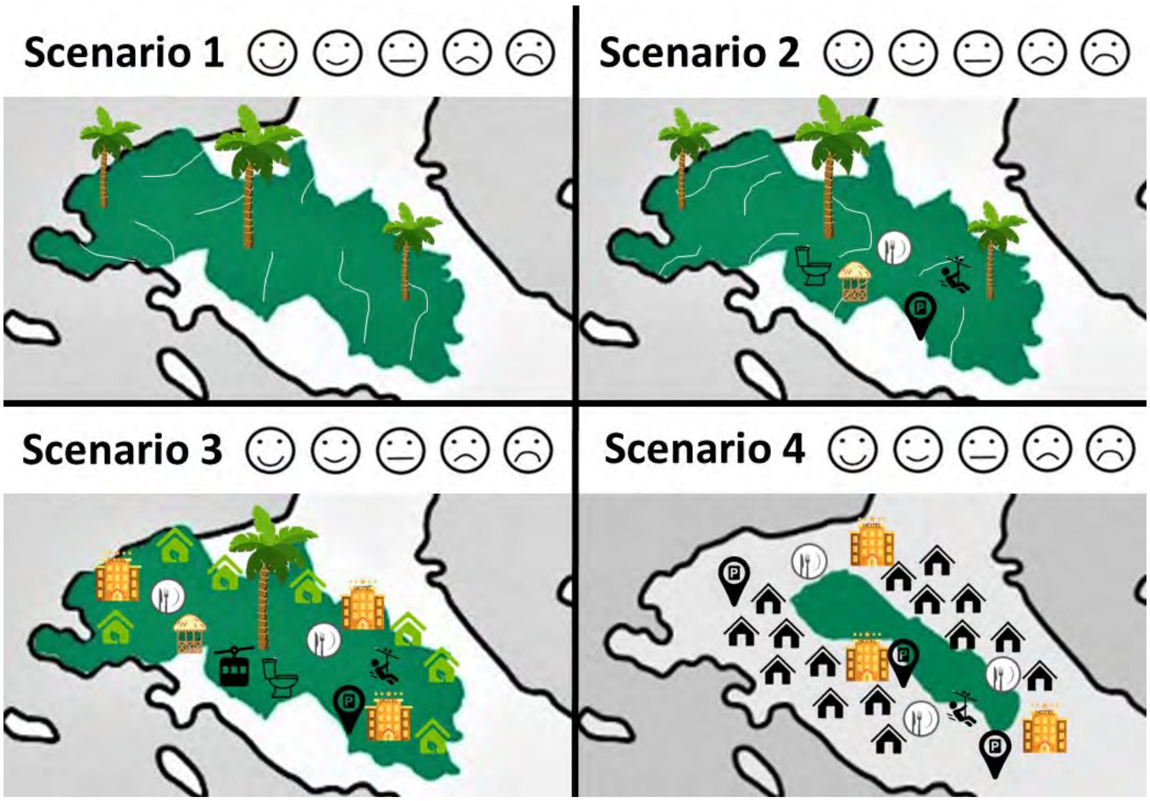


Figure 3: **Potential future scenarios for the Morne Seychellois National Park.** Illustrations for four potential scenarios: scenario 1 or "Stays as it is", scenario 2 or "Low-impact development", scenario 3 or "High-impact development" and scenario 4 or "Loss of protected areas".

On January 24th, 2020, and in the middle of survey data collection, preliminary results of scenario ratings were discussed in a half-day stakeholder workshop. The workshop included a presentation of preliminary results of this master thesis and aimed to further elaborate on the most preferred future scenario. Specifically, we used brainstorming activities to identify potential activities that could take place in the Morne Seychellois National Park under the most preferred future scenario. We invited several stakeholders from the community, government, and other organizations. The agenda, poster, and report on the workshop can be found in Appendix A (Chapter

13.1.2).

3.1.6 Forest rehabilitation attitudes, perceptions and participation

We assessed the relationship between people and forest rehabilitation activities in terms of attitudes, perceptions, and behavior, to involve communities and support evidence-based forest rehabilitation activities [Bennett, 2016]. The attitude towards restored areas was assessed through the evaluation of two photos of before and after of forest rehabilitation activity in the Park (Figure 4a and Figure 4b, followed by a question "Do you think the area improved in quality"? Respondents could answer on a 5-point Likert scale: "I agree", "I slightly agree", "I am neutral", "I slightly disagree", "I disagree". Due to lack of authentic before-after photographic material of restored areas, we took a picture of the current state of a previously restored area by Kueffer et al. [2010] to depict the "after" state and took a photograph of a typical secondary forest close by with high abundance of exotic species (e.g. *Chrysobalanos icaco ssp. atacorensis, Dicranopteris linearis, Cinnamonum verum, Psidium cattleianum*) which represents the "before" state. We followed up with an open-ended question asking "Why?" to elicit positive and negative perceptions people have about rehabilitated areas. Using qualitative methods on social perceptions of invasive species was shown more successful in identifying factors determining the perception of invasive species, compared to otherwise disproportionately used quantitative methods[Kapitza et al., 2019].

(a) "Before" rehabilitation (b) "After" rehabilitation

Figure 4: **Photos depicting an area "before" and "after" rehabilitation.**
Two photos used in the questionnaire as a visual aid to depict an area "before" rehabilitation of mainly secondary forest with abundant exotic species (a) and an area "after" rehabilitation where some exotic species were removed and endemic palms were planted (b).

After, we briefly explained what forest rehabilitation activities are, accompanied by a picture of activity (See Appendix A, Figure 27). Respondents were asked if they had ever heard of such activities and if they support them, which provided a measure of their attitude (I support/I do not support) towards rehabilitation activities. We followed up investigating their behavior and intention of action by asking if they had ever participated and if they would be interested to participate in the future. Respondents' willingness to participate in forest rehabilitation activities for different reasons was further investigated for several listed reasons (i.e. to do exercise, to socialize and meet the community, to learn about plants and environment, to have free drinks and lunch, to plant a tree with their name, to receive a hat and a t-shirt with logo and certificate of participation, to help remove creepers, to help plant more native plants in the forest and to be on TV) and under location constraints, i.e. if the activity location is accessible by car, 30 min walk or 1-hour walk. Lastly, people were asked whether they think a plant nursery is acceptable in the Park, which is a piece of crucial information for planning future rehabilitation activities.

3.2 Sampling and data collection

The sampling was carried out by the Bureau of Statistics. The sample design used for the survey was stratified two-stage sampling. All districts on the main island (Mahé) were selected. The first stage of sampling consisted of selecting primary sampling units, or in our case, enumeration areas (EAs) within districts. The EAs were selected with probability proportional to size (i.e. the number of EAs in the respective district is proportional to the size of the district). A total of 22 EAs were selected from 10 districts. At the third stage, households were selected from each selected EA and two districts near the Park were oversampled, which is Port Glaud and Bel Ombre. Overall, 440 households were selected from all districts, 118 from Port Glaud, 104 from Bel Ombre, and 218 from remaining districts (Table 2).

Table 2: **Households sampled.**

Total number of sampled households in each districts by Bureau of Statistics and the final number of respondents reached and interviewed.

District	Total sampled households	Respondents reached and interviewed (aim was 2 respondents per household)
Port Glaud	107	118
Pointe Laure	33	30
Roche Caiman	32	36
Saint Louis	29	28
Mont Fleuri	26	14
Mont Buxton	30	29
Bel Ombre	104	71
Baie Lazarre	27	22
Anse Royale	30	32
Anse Etoile	22	15
TOTAL	440	395

Bel Ombre and Port Glaud were oversampled to allow for comparison between residents living in areas within or near Mare aux Cochons water catchment and the Park in general. The Mare aux Cochons water catchment, including the open water marshes and part of the Cascade River system, falls within the boundaries of the Port Glaud district with the lower stretches of the river also in Bel Ombre district [Murugaiyan, 2009]. Moreover, Bel Ombre and Port Glaud are the only two districts partly falling under the Morne Seychellois National Park (Figure 5). Direct provision of freshwater and proximity to the Park could have an impact on local people's perception of benefits from the Park and its function, especially in terms of provisioning and regulating ecosystem services, such as the provision of freshwater, prevention of landslides and erosion, air purification, provision of forest products, etc. For this purpose, we distinguished between people residing near the Park (Bel

Ombre and Port Glaud) and compared them in the upcoming analysis as districts "near" and "far" from the Park.

Data was collected in January and February 2020. At each household we aimed to interview 2 persons older than 16 years, preferably of different sexes or different generations, to capture different age and gender groups. If we could not reach a person in a selected household for different reasons, we moved to the next neighboring household. Interviews were conducted face-to-face, where all questions were read out to the respondent and filled in by the surveyor on the questionnaire. We decided on this approach to give an equal opportunity to participate in the survey to respondents that cannot see well and were not willing to independently fill in the questionnaire. The respondents were always given the option to be interviewed in English or Creole by a local assistant, who was provided with a Creole version of the questionnaire. Several times during the interview photographs/illustrations were given to respondents as a visual aid to better understand the questions.

The questionnaire was pretested with 20 respondents and significantly modified, especially in terms of length and expected completion time. A second test with 7 respondents was conducted in households in Bel Ombre and later included in the final sample, as there seemed to be no need to further adapt the questionnaire.

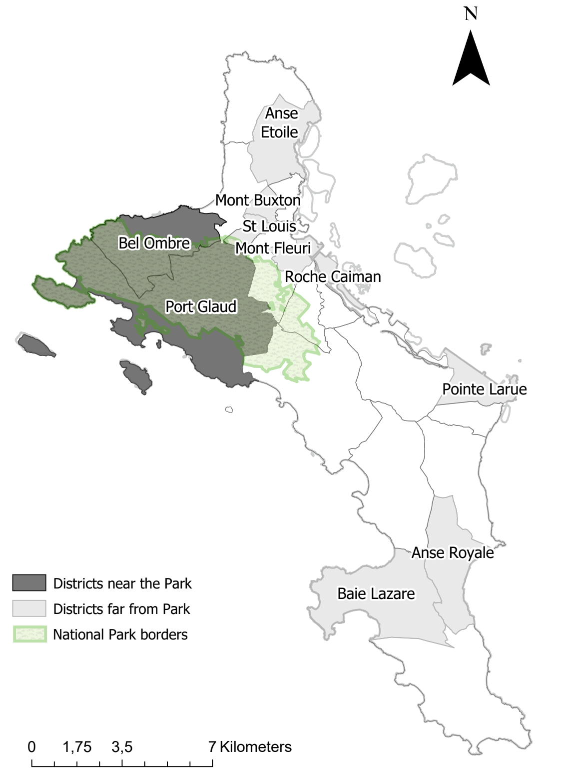


Figure 5: **Map of the Morne Seychellois National Park.**
Map showing the area of the Morne Seychellois National Park, sampled districts, and the distinction between districts near and far from the Park. Raw data retrieved from Web Feature Service (WFS) (data as of May, 2020) (https://www.webgis.gov.sc/cgi-bin/wfs) of the Ministry of Habitat, Infrastructure and Land Transport (MHILT). WFS was accessed through ArcGIS Pro version 2.4.0.

3.3 Sample characteristics

A total sample of 395 respondents was achieved (Table 2), with a 45% response rate. 17 minutes was the average time needed to complete the interview ($SD = 6.24$). 58% were male and 42% were female. 46.5 years was the average respondents age ($SD = 16.6$) from 16 to 94 years. In the education category, the majority had post-secondary education (50.1%), followed by secondary school (28.1%). Respondents had most work experience in tourism sector (38.5%) (See Appendix A, Chapter 13.3, Table 14). Only a few respondents participated in Wildlife club (12.9%) or Eco-school (7.1%) (See Appendix A, Chapter 13.3, Table 15).

Sample distribution was compared to the population of Mahe, using Seychelles census data [National Bureau of Statistics, 2010] (See Appendix A, Chapter 13.4). Distribution of all socio-demographic was significantly different from the population and all reported differences are significant with $p < 0.05$. In our sample males were underrepresented by about 10% and women were over-represented. Age-wise, younger people aged 16-44 were under by about 7%, while older respondents, especially those aged 55-64, were over-represented. Regarding the highest completed education level, respondents who completed primary or secondary school were underrepresented for about 5% and 7%, respectively. Location wise, respondents residing in Central and East/South region were underrepresented for about 7% and 13%, respectively, and the West region was over-represented for about 18%. This is, however, a direct consequence of intentionally over-sampling districts near the Park, which is Port Glaud and Bel Ombre.

3.4 Data analysis

Questionnaire answers were analyzed using IBM SPSS Version 26. Close-ended questions, Likert-scale questions, and multiple-choice questions were recorded as single variables. Open-ended questions were analyzed by coding them into categories for each open-ended question after consideration of the responses gathered in the survey. This approach allowed us to capture very specific and surprising perceptions, which could not have been identified before survey collection while categorizing them at a level that allowed for further analysis and a meaningful discussion. Categories of open-ended questions were defined as "multiple-sets" in SPSS.

Descriptive statistics, such as frequency tables, measures of central tendency (means), and measures of variability (standard deviation), were applied to analyze a single variable at a time. To analyze relationships between two variables we relied on recommendations by Bryman [Bryman, 2012], which are summarized in Appendix A (Chapter 13.6).

Modeling a logistic regression has been a common approach to explain attitudes and perceptions local people hold towards protected areas. For example, logistic regression was used to explain local attitude on conservation area with socio-demographic variables, participation in training benefits from tourism, wildlife depredation issue [Mehta and Heinen, 2001]; test whether socio-economic variables and use of the area influence people's perception of ecosystem services [Allendorf and Yang, 2013]; assess the relative importance of socio-demographic variables in influencing local knowledge about PA and perceived benefits and losses from the PA [Xu et al., 2006], and to assess the influence of socio-demographic variables and local knowledge on perception of benefits and attitudes towards management [Htun et al., 2012].

We used logistic regression to test the influence of socio-economic variables, proximity to the Park, environmental education, and work experience in tourism on the visit frequency, perceived benefits, attitudes toward future scenarios, and attitudes toward and perception of forest rehabilitation activities. Logistic regression in its basic form uses a logistic function to model a binary dependent variable, meaning that the dependant can be categorical [Schreiber-Gregory and Foundation, 2018]. However, the logistic regression assumes that the dependant variable has a binary outcome, 0 and 1 [Schreiber-Gregory and Foundation, 2018]. For this purpose the rating scales of dependant variables, e.i. scenarios benefits from the Park and visit frequency were merged into two categories. For the overall models we reported χ^2, p-value, Nagelkerke R-squared (R^2) and % of correctly classified cases. For each independent variable, we reported the odds ration or OR or Exp(B) in a separate table and elaborated only on significant variables with $p < 0.05$. Absence of multicollinearity between predicting, independent variables is a basis for performing a logistic regression [Schreiber-Gregory and Foundation, 2018]. For this purpose, we assessed correlations between variables and calculated variance inflation factor (VIF) for each independent variable. This analysis enabled us to exclude some variables from the analysis, as they were highly correlated with others, and merge some (see Appendix A, Chapter 13.5).

4 Results

4.1 Awareness about the Park and visit frequency

84.8% of respondents have heard of the National Park and 45.1% claimed to have visited the area before (Table 3). When specifically asked to answer a multiple-choice question on which trails in the National Park respondents have visited, 85.1% visited at least one trail and 14.9% did not visit any of the listed trails. On average, people visited 3 trails out of 11 (M = 3.35, SD = 2.64). Most popular trails, visited by majority of respondents were Anse Major (57.5%) and Mare aux Cochons (49.9%). Above a quarter of respondents visited trails such as Trois Freres, Copolia, Morne Blanc and Mission Lodge. The trails Dan Galas, Salazie, and Casse Dant were less popular. Regarding frequency of visit, most respondents reported to have visited the Park less than once a year (47.3%), followed by once a year (20.8%), several times per year (9.9%), several times per month (4.3%) and several times per week (2.8%). 14.9% never visited the Park. Interestingly, majority of respondents who initially claimed to have never visited the Park or were not sure, ended up reporting to have visited at least one trail in the Park.

Table 3: **Summary of questionnaire answers (*N* = 395) on awareness about the Park and visiting of the area.**

	N	%		*N*	%		*N*	%
Have you heard of the National Park?			Which trails in the National Park have you visited?[a]			How often do you visit the National Park?		
Yes	335	84.8	Trois Freres	146	37.0	Several times per week	11	2.8
No	28	7.1	Copolia	130	32.9	Several times per month	17	4.3
Not sure	29	7.3	Anse Major	227	57.5	Several times per year	39	9.9
			Mare aux Cochons	197	49.9	Once a year	82	20.8
Have you visited the National Park?			Dan Galas	87	22.0	Less than once a year	187	47.3
Yes	178	45.1	Morne Blanc	160	40.5	Never	59	14.9
No	206	52.2	Salazie	81	20.5			
Not sure	8	2.0	Casse Dant	95	24.1			
			Other[b]	176	44.6			
			Mission Lodge[c]	133	33.7			
			Morne Seychellois[c]	17	4.3			
			Other[c]	51	12.9			
			None of the above	59	14.9			

[a] Multiple-choice question. Respondents could specify other visited places under "other".
[b] Respondents could specify other places visited in the National Park. Most common answers, Mission Lodge and Morne Seychellois, were distinguished.
[c] N=395

We identified several reasons why people do not visit the Park more often through an open question. While the most common reason was "I don't have time/I am busy/I work" (46.4%, N = 176), the other reasons were: lack of interest (13.5%, $N = 51$), health issues and/or old age (14.5%, $N = 55$), lack of companion (8.7%, $N = 33$), accessibility, lack of transport and distance (5.5%, N = 21), and lack of information, organized activities, and knowledge about trails (3.2%, $N = 12$). Some said there is no reason (14.8%, $N = 56$) or gave other reasons (5.5%, $N = 21$).

A logistic regression revealed that people living in districts located far from the Park were less likely to visit the Park more often than people living near the Park. Males were almost twice as likely to visit the Park more regularly compared to females. Increasing age was associated with decreased likelihood to visit the Park more often, whereas environmental education was associated with an increased likelihood to visit the Park more often (Table 4). The model was statistically significant, $\chi2$ (8) = 67.371, $p < 0.05$. The model explained 22% (Nagelkerke R^2) of the variance in visit frequency and correctly classified 66% of cases.

Table 4: **Odds ratios of local people's visit frequency of the Morne Seychellois National Park as assessed with a logistic regression.**

Odds ratios with 95% CI	Proximity to Park	Gender	Age	Level of education[a]			Work experience in tourism	Environmental education
	Far from Park	Male	Years	Secondary school	Post-secondary school	University and higher	Yes	Yes
Visit frequency[b]	**0.53 (0.33-0.83)**	**1.91 (1.21-3.03)**	**0.97 (0.96-0.99)**	0.53 (0.18-1.58)	0.65 (0.28-1.51)	1.07 (0.49-2.35)	0.98 (0.62-1.56)	**3.12 (1.65-5.90)**

[a] Reference category is "Primary school".
[b] Categories: (1) "Once a year or more", (0) "Less than once a year or never".
All odds ratios with significant $p < 0.05$ are marked in bold.

4.2 Perception of the Parks importance

All respondents (100%, $N = 395$) regarded the National Park as important for Seychelles, when given the option to answer with "Yes", "No" and "I don't know" (Figure 6). More than half of the respondents found the Park important for "Protection of the ecosystem and biodiversity" ($N = 221$) and many respondents for "Tourism and economy" ($N = 164$). Less respondents classified the Park as important for "Recreation" ($N = 37$), "For future generations" ($N = 33$), "Education" ($N = 24$), to "Protect from human impact" ($N = 17$) and for "Research" ($N = 2$). The question was open-end and coding categories were based on the objectives of the Park. Only four respondents specifically mentioned "water" in their answers, referring to the function of the Park as a provider and source of clean drinking water. One respondent gave an especially insightful answer:" Most water for Seychelles comes from here (National Park). When there was drought, people collected water in Le Niol (an area in the National Park)."

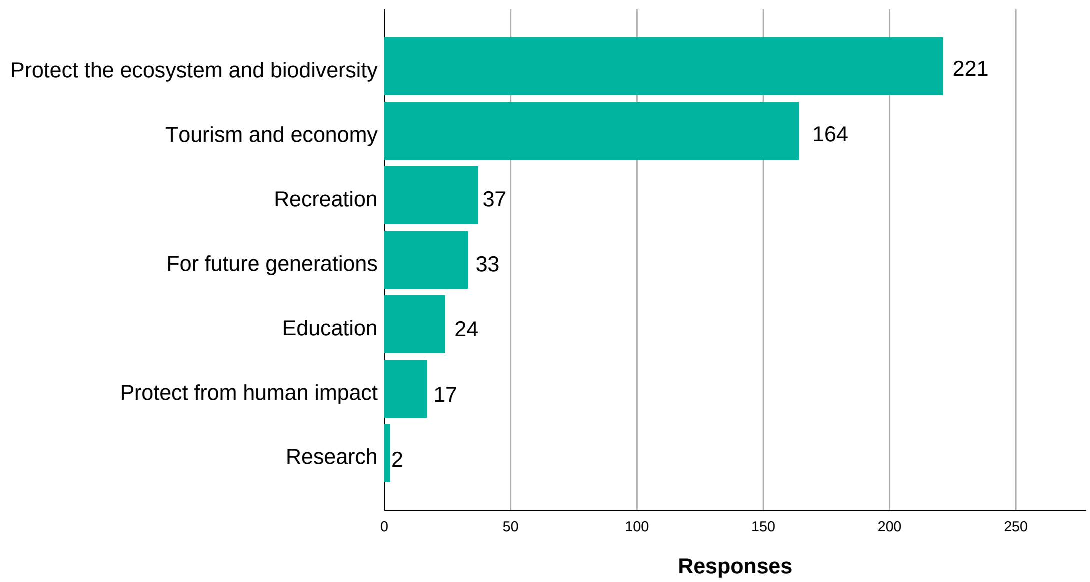


Figure 6: **Importance of the Morne Seychellois National Park for the local people.** Main categories of reasons why respondents found the Park important for Seychelles and number of answers. The question was open-ended and answers were clustered into categories. ($N = 395$).

4.3 Perceived benefits from the Park

People perceived to benefit the most from: clean and fresh air (94.6%, $N = 371$), scenic view and natural beauty (93.1%, $N = 366$), learning about nature and environment (88.0%, $N = 346$) and seeing native plants and animals (85.8%, $N = 337$) (Figure 7). The majority perceived to benefit from clean drinking water from forest river (73.3%, $N = 288$) and hiking, walking or running (65.0%, $N = 256$). Less than half benefited from prevention of landslide and erosion (50.4%, $N = 197$), PUC tap water (44.5%, $N = 175$), and Good Friday walk to Trois Freres (36.1%, $N = 141$). Less than a third benefited from picking medicinal plants (27.7%, $N = 109$), collecting fruits, flowers or wood (23.7%, $N = 93$) or earning money by working in the Park (12.0%, $N = 47$). Respondents were most unsure regarding their answer whether they benefit from PUC tap water from the Park (25.4%, $N = 100$) and if they benefit from protection against landslides and erosion (10.2%, $N = 40$).

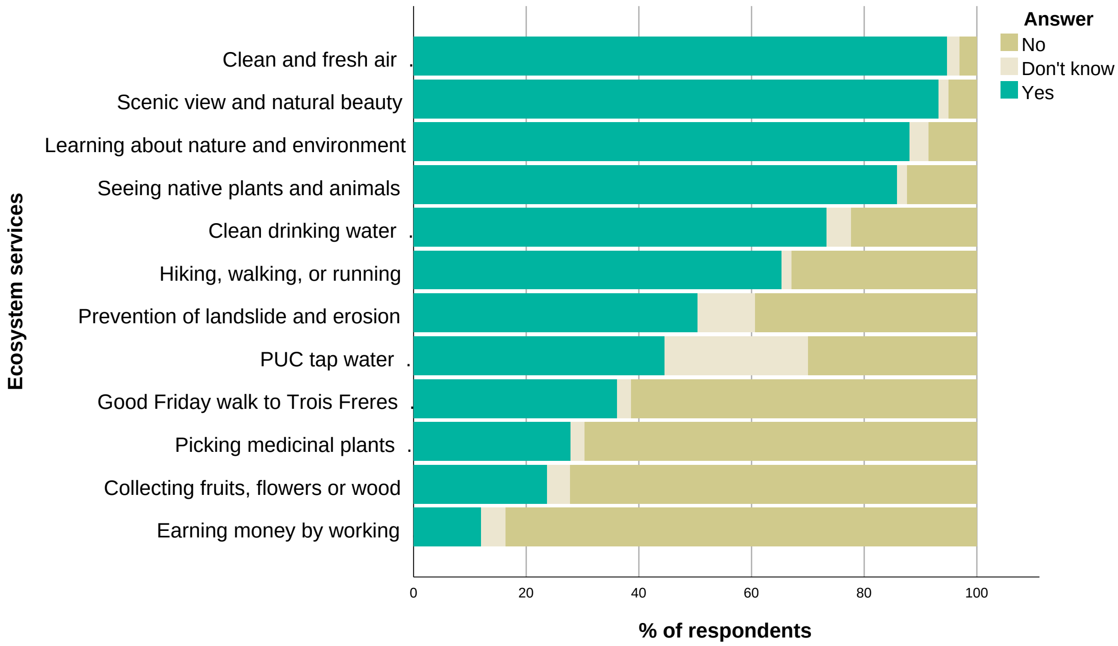


Figure 7: **Perceived benefits from the Morne Seychellois National Park by the local people.** Percentages of respondents ($N = 395$) perceiving to benefit from a certain service offered by the Morne Seychellois National Park.

A logistic regression revealed that some groups of respondents were more likely to benefit from certain services than others (Table 5). People living near the Park were more likely to benefit from landslide and erosion protection. Environmental education was associated with an increased likelihood to benefit from hiking, walking or running in the Park. Younger people were more likely to benefit from: hiking, walking or running in the Park and picking medicinal plants, the younger they were. Males compared to females, were more likely to benefit from: collecting fruits, flowers or wood; earning money by working; clean drinking water; hiking, walking or running; and Good Friday walk to Trois Freres. The binary dependent variable scale for all benefits consisted of (1) Yes and (0) No, excluding the neutral answers. For details on each model see Appendix A, Chapter 13.7.

Table 5: **Odds ratios of local people's perception of benefits provided by the Morne Seychellois National Park as assessed with a logistic regression.**

Odds ratios with 95% CI	Proximity to Park	Gender	Age	Level of education[a]			Work experience in tourism	Environmental education
	Far from Park	Male	Years	Secondary school	Post-Secondary school	University and higher	Yes	Yes
Collecting fruits, flowers or wood[b]	0.64 (0.39-1.05)	**1.94 (1.18-3.19)**	1.00 (0.98-1.01)	2.15 (0.72-6.39)	0.78 (0.29-1.98)	1.06 (0.44-2.59)	0.75 (0.45-1.27)	1.57 (0.79-3.09)
Earning money by working[b]	0.87 (0.46-1.65)	**2.90 (1.49-5.61)**	0.99 (0.97-1.02)	2.50 (0.42-14.89)	1.93 (0.40-9.26)	2.27 (0.50-10.34)	1.90 (0.99-3.65)	0.86 (0.33-2.21)
Picking medicinal plants[b]	0.77 (0.49-1.22)	1.13 (0.71-1.80)	**0.98 (0.97-1.00)**	2.03 (.0.66-6.21)	1.08 (0.41-2.85)	2.04 (0.83-5.039	0.69 (0.42-1-12)	0.58 (0.29-1.15)
Preventing landslide and erosion[b]	**0.40 (0.26-0.63)**	0.95 (0.61-1.48)	0.99 (0.98-1.01)	1.52 (0.55-4.22)	1.37 (0.59-3.16)	0.91 (0.42-2.00)	1.34 (0.85-2.14)	1.38 (0.72-2.65)
Clean and fresh air[b]	0.34 (0.09-1.31)	1.10 (0.32-3.70)	0.96 (0.92-1.01)	3.56 (0.37-34-02)	5.61 (0.67-45.60)	1.69 (0.39-9.56)	0.76 (0.22-2.60)	45438826.35 (0.00-0.00)
Clean drinking water[b]	0.64 (0.39-1-06)	**2.35 (1.36-4.06)**	0.99 (0.98-1.01)	0.92 (0.30-1.85)	0.59 (0.23-1.52)	1.56 (0.62-3.94)	0.96 (0.57-1.62)	0.49 (0.24-1.01)
PUC tap water[b]	0.67 (0.41-1.08)	1.16 (0.71-1.87)	1.0 (0.99-1.02)	1.16 (0.37-3.70)	1.58 (0.56-3.90)	0.92 (0.37-2.33)	1.26 (0.76-2.10)	0.84 (0.41-1.71)
Scenic view and natural beauty[b]	0.66 (0.26-1.69)	2.38 (0.82-6.85)	0.99 (0.96-1.03)	1.04 (0.08-13.37)	0.40 (0.05-3.40)	0.76 (0.09-6.38)	0.72 (0.28-1.82)	3.52 (0.43-28.89)
Seeing native plants and animals[b]	0.61 (0.32-1.15)	1.44 (0.75-2.79)	1.00 (0.98-1.02)	0.50 (0.09-2.76)	0.29 (0.06-1.24)	0.66 (0.14-3.05)	0.76 (0.40-1.45)	3.99 (0.89-17.81)
Hiking, walking or running[b]	0.77 (0.47-1.25)	**2.76 (1.65-4.61)**	**0.97 (0.95-0.99)**	0.35 (0.12-1.08)	0.42 (0.16-1.10)	1.01 (0.39-2.63)	1.01 (0.61-1.68)	**4.06 (1.50-11.01)**
Good Friday walk to Trois Freres[b]	1.24 (0.80-1.92)	**2.22 (1.43-3.45)**	0.99 (0.97-1.00)	2.09 (0.77-5.69)	0.84 (0.36-1.97)	1.37 (0.61-3.06)	0.93 (0.59-1.47)	1.14 (0.61-2.14)
Learning about nature and environment[b]	1.31 (0.62-2.73)	1.37 (0.63-2.99)	0.99 (0.97-	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	1.99 (0.85-4.66)	4.48 (0.56-35.95)

[a] Reference category is "Primary school".
[b]Categories of dependent variables: (1) Yes, (0) I don't know and no".
All odds ratios with significant $p < 0.05$ are marked in bold.

4.4 Attitude towards future scenarios

"Low impact development" was the most preferred future scenario (M = 1.24, SD = 0.97, SE = 0.05) followed by "Stays as it is" (M = 1.07, SD = 1.03, SE = 0.05) (Figure 8). "High impact development" scenario (M = -0.59, SD = 1.30, SE = 0.07) and "Loss of protected areas" scenario (M = -1.58, SD = 1.04, SE = 0.05) were both on average rated negatively. The standard deviations revealed only marginal deviations from the mean for most scenarios, except for "High impact development" scenario, where opinions were slightly more polarizing than for other scenarios. The analyzed ratio scale from -2 to +2 was converted from a 5-point Likert scale.

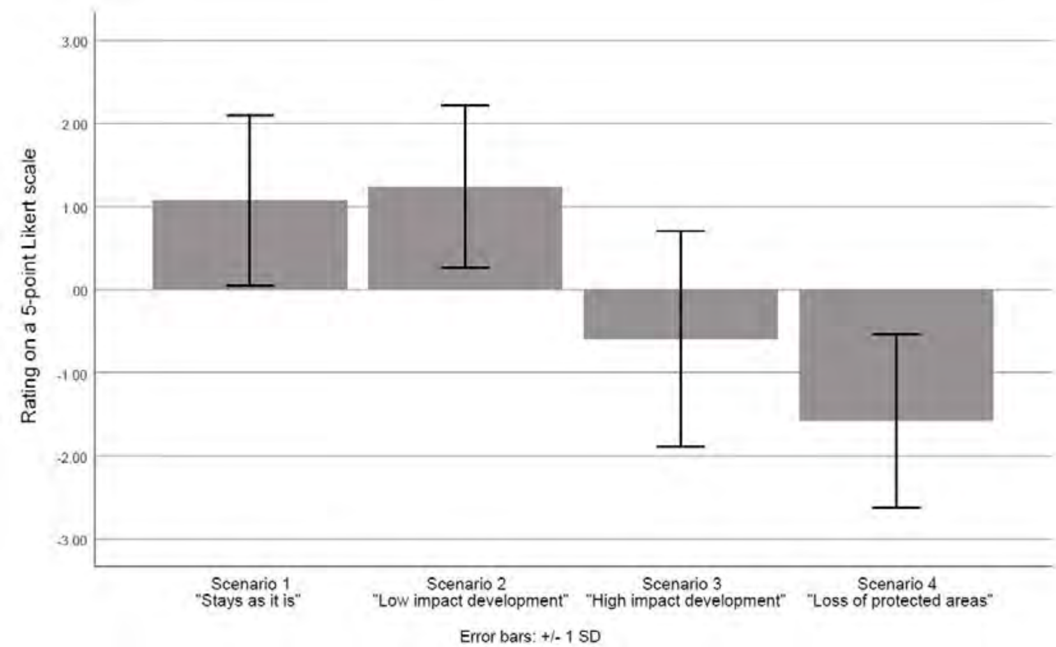


Figure 8: **Potential future scenarios for the Morne Seychellois National Park rated on a 5-point Likert scale.**
Mean and standard deviation for each future scenario for the Morne Seychellois National Park. Data was analyzed by transposing the 5-point answer scale to numeric data: 2 = "I like very much", 1 = "I like", 0 = "Neutral", -1 = "I don't like", -2 = "I don't like at all".

Taking frequencies into account, provides a more detailed insight into how respondents rated the scenarios without assuming equal distances between the rating items. The "Low-impact development" scenario was the most preferred future scenario, based on the observation that 83.4% of respondents had a positive opinion about it, with 50.0% rating it with "I like very much" and 33.4% rating it with "I like" (Figure 9). Only 6.9% respondents had a negative opinion, 4.3% "I don't like" and 2.6% "I don't like at all", and 9.7% remained neutral. "Stays as it is" is the second most preferred scenario, with 76.2% respondents having positive opinion; 41.8% rated it with "I like very much" and 34.4% rated it with "I like". Again, only a small proportion of 7.9% had negative opinion about this scenario, whereas slightly more respondents (15.8%) remained neutral.

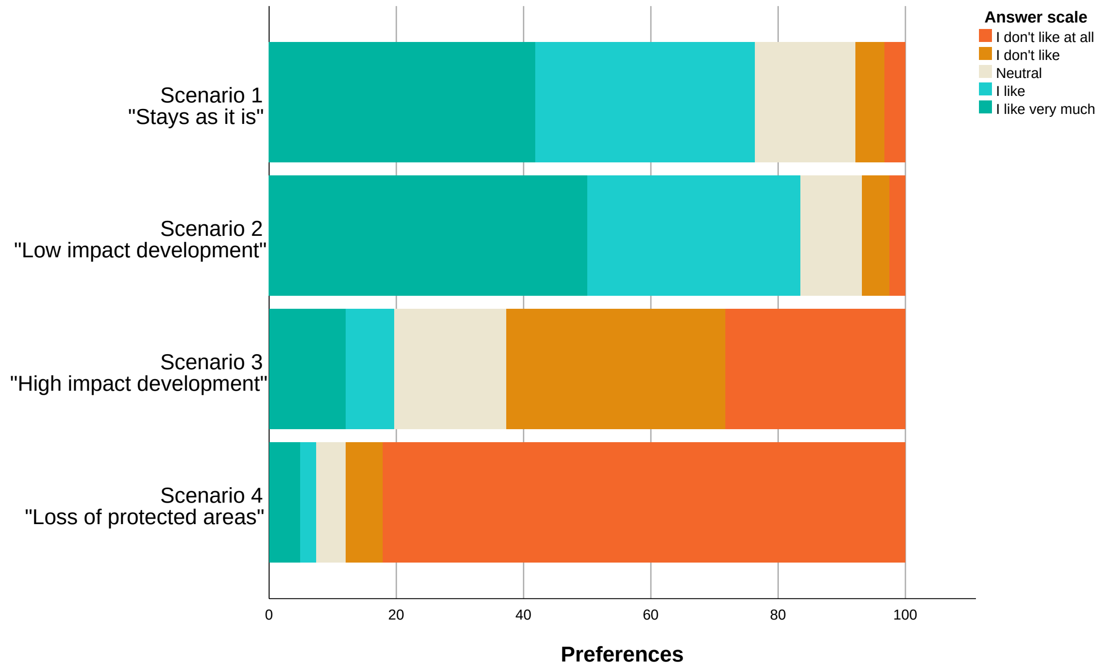


Figure 9: **Preferences for future scenarios for the Morne Seychellois National Park.** The preferences of the local people for the respective future scenarios, color coded for each rating category on a 5-point Likert scale in percent.

"High-impact development" is the second least preferred scenario, with 62.7% respondents having a negative opinion about it, with 34.4% rating it with "I don't like" and 28.3% with "I don't like at all". This scenario received the most diverse response among all scenarios, implying respondents had most diverging opinions about high-impact development in the Park. "Loss of protected areas" was the least preferred scenario, with 82.1% respondents rating it with "I don't like at all" and 5.9% with "I don't like". Overall, 88.0% respondents had a negative opinion about this scenario.

A logistic model for each scenario revealed that people with work experience in tourism sector were associated with an increased likelihood to have positive opinion about scenario 1 "Stays as it is". Respondents with environmental education were less likely to have positive opinion about scenario 3 "High impact development". For "Low-impact development" and "Loss of protected area" scenario, no associations were found. (Figure 6). The scenario rating scale was divided into into: (1) Positive opinion ("I like very much", "I like") and (0) "Other" ("Neutral", "I don't like", "I don't like at all"). The division was based on an assumption that a neutral response could indicate a potentially negative attitude [Xu et al., 2006].

Table 6: **Odds ratios of local people's attitude towards future scenario for the Morne Seychellois National Park as assessed with a logistic regression.**

Odds ratios with 95% CI	Proximity to Park	Gender	Age	Level of education[a]			Work experience in tourism	Env. education
	Far from Park	Male	Years	Secondary school	Post-secondary school	University and higher	Yes	Yes
Scenario 1 "Stays as it is"	0.77 (0.48-1.24)	0.86 (0.53-1.39)	1.00 (0.99-1.02)	1.38 (0.49-3.87)	1.35 (0.57-3.17)	1.50 (0.67-3.41)	**2.38 (1.40-4.06)**	1.60 (0.75-3.39)
Scenario 2 "Low impact development"	0.85 (0.50-1.45)	0.84 (0.47-1.44)	0.99 (0.97-1.01)	0.50 (0.12-2.11)	0.45 (0.13-1.64)	0.46 (0-13-1.62)	0.91 (0.53-1.59)	1.19 (0.51-2.79)
Scenario 3 "High impact development"	0.99 (0.59-1.66)	0.70 (0.41-1.19)	0.99 (0.96-1.01)	3.54 (0.87-14.43)	3.22 (0.90-11.59)	1.92 (0.54-6.829)	0.71 (0.41-1.239)	**0.12 (0.03-0.53)**
Scenario 4 "Loss of protected area"	0.80 (0.36-1.79)	0.69 (0.29-1.63)	1.01 (0.98-1.04)	5.26 (0.58-48.00)	2.95 (0.36-24.29)	0.99 (0.11-8.58)	1.27 (0.56-2.91)	0.39 (0.05-3.19)

[a] Reference category is "Primary school".
Categories of the dependent variable: (1) Positive opinion (I like, I like very much) and (0) Other (Neutral, I don't like, I don't like at all)
All odds ratios with significant $p < 0.05$ are marked in bold.

The logistic regression for scenario 1 was statistically significant $\chi^2(8) = 17.068$, $p = 0.029$. The model explained 6% (Nagelkerke R^2) of the variance and correctly classified 75% of cases. The logistic regression for scenario 2 was not statistically significant, $\chi^2(8) = 4.959$, $p= 0.762$. The model explained 2% (Nagelkerke R^2) of the variance in visit frequency and correctly classified 82% of cases. The logistic regression for scenario 3 was statistically significant, $\chi^2(8) = 26.016$, $p = 0.001$. The model explained 10% (Nagelkerke R^2) of the variance in visit frequency and correctly classified 81% of cases. The logistic regression for scenario 4 was statistically significant, $\chi^2(8) = 20.821$, $p= 0.008$. The model explained 13% (Nagelkerke R^2) of the variance in visit frequency and correctly classified 93% of cases.

4.5 Attitude towards and perception of forest rehabilitation

The majority of respondents expressed a positive attitude towards the physical appearance of restored areas (Figure 10). Based on the photographs of before and after rehabilitation and no additional explanation, 66.6% of respondents agreed the area "after" improved in quality, whereas 17.7% slightly agreed, 3.8% did not know/were not sure, 4.1% slightly disagreed and 7.6% disagreed.

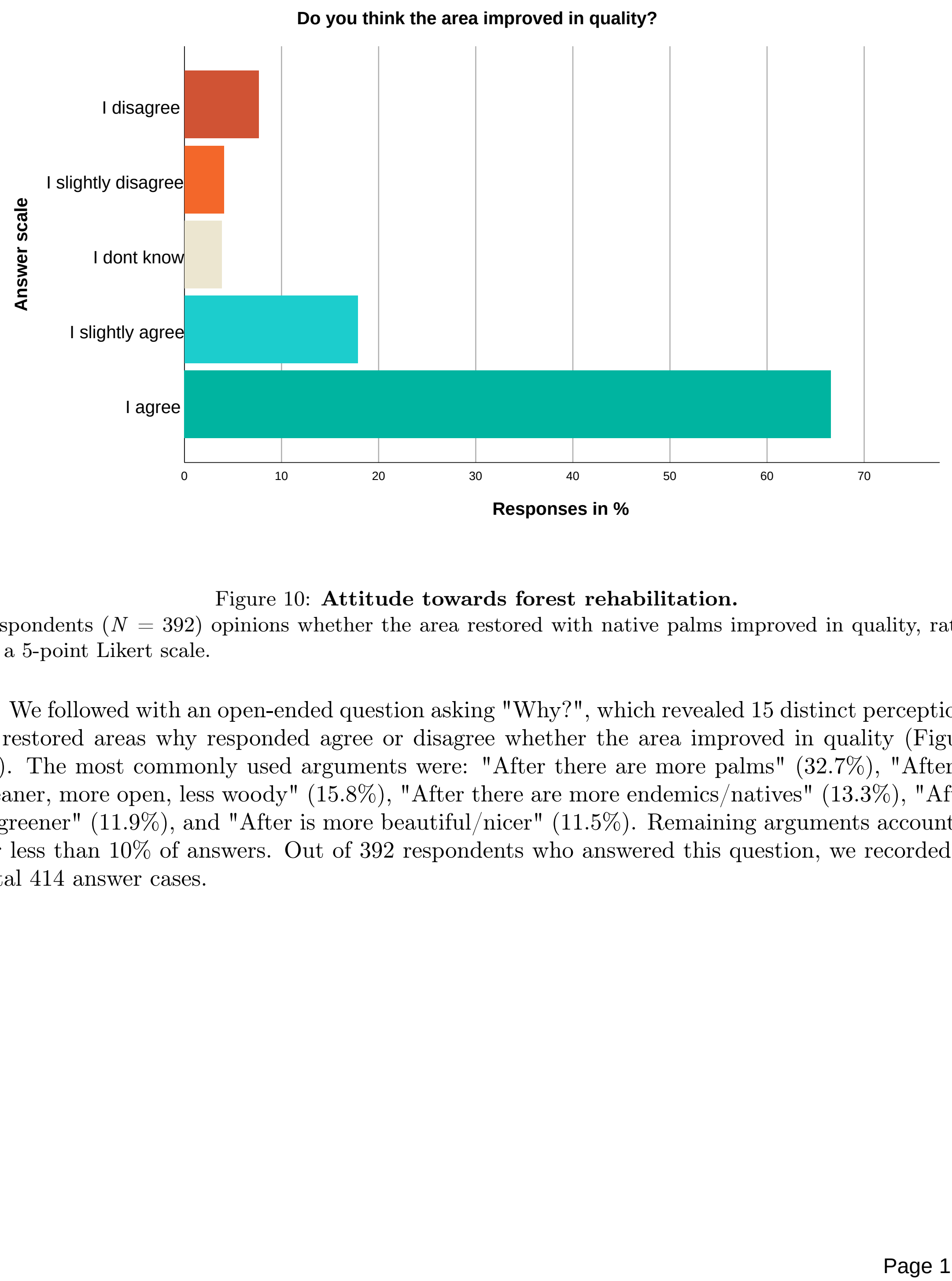


Figure 10: **Attitude towards forest rehabilitation.**
Respondents ($N = 392$) opinions whether the area restored with native palms improved in quality, rated on a 5-point Likert scale.

We followed with an open-ended question asking "Why?", which revealed 15 distinct perceptions of restored areas why responded agree or disagree whether the area improved in quality (Figure 11). The most commonly used arguments were: "After there are more palms" (32.7%), "After is cleaner, more open, less woody" (15.8%), "After there are more endemics/natives" (13.3%), "After is greener" (11.9%), and "After is more beautiful/nicer" (11.5%). Remaining arguments accounted for less than 10% of answers. Out of 392 respondents who answered this question, we recorded in total 414 answer cases.

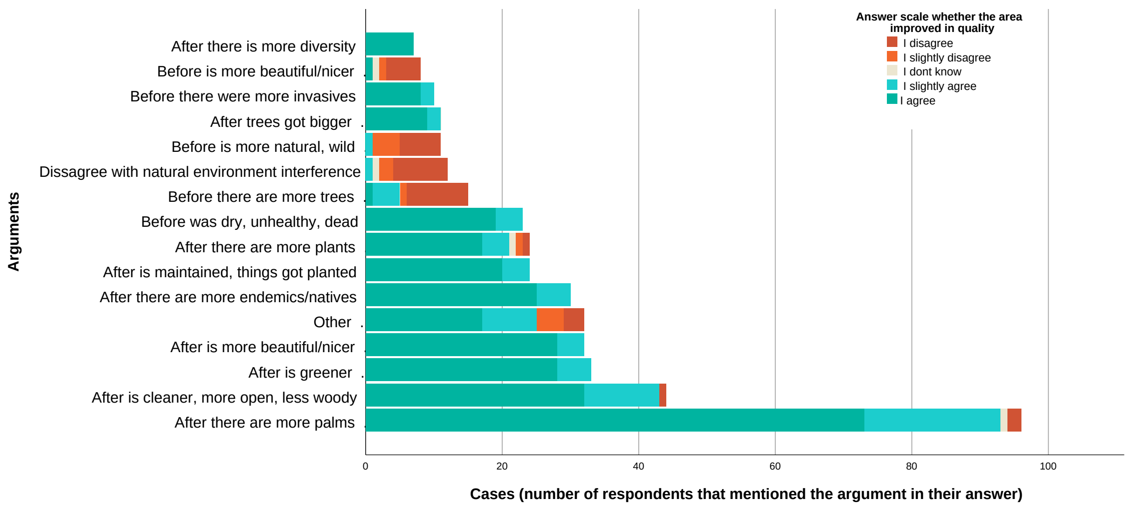


Figure 11: **Associations between attitudes and perceptions of rehabilitated areas.** Associations between two questions: Rating of the restoration area on a 5-point Likert scale and associated answers with the open-ended question "Why". Bars show the number of respondents ($N = 392$) that mentioned an argument and how that associates with their previous rating of the area. Number of answer cases ($N = 414$).

There was an apparent association of some perceptions with either positive or negative attitude towards the quality of restored areas. Perception mostly associated with the negative attitude "I disagree the area improved in quality" and "I slightly disagree the area improved in quality" were: "Before is more natural wild", "I disagree with interference into the natural environment", "Before is more beautiful/nicer", and "Before there are more trees". On the other hand, perceptions such as "After there is more diversity", "After is more beautiful/nicer", "After is greener", "After is maintained, things got planted", "Before was dry, unhealthy, dead", "After threes got bigger", "After there are more endemics/natives/Latanier", "Before there were more invasives", "After there are more palms", "After is cleaner, more open, less woody", and "After there are more plants" were mostly associated positive attitudes "I agree the area improved in quality" and " I slightly agree the area improved in quality".

4.6 Community participation in rehabilitation activities

71.4% of respondents agreed to have heard of forest rehabilitation activities where local communities assisted with planting trees and 94.7% support that such activities take place. 23% of respondents said they have participated at such tree planting activities in the past. A logistic regression model revealed that males and respondents with environmental education were more likely to have participated at a rehabilitation activity in the past (Table 7). However, people with primary or secondary education were less likely to have participated at such activities in the past. A cross-tabulation revealed a clear trend in increased proportion of people that had participated in the past with an increasing level of education. While only 48.0% with primary education had participated, 62.4% with secondary education, 79.1% with post secondary education, and 79.4% with university education or higher.

Table 7: **Odds ratio for previous participation at rehabilitation activities for explanatory variables for logistic regression model.**

Odds ratios with 95% CI	Proximity to Park	Gender	Age	Level of education[a]			Work experience in tourism	Environmental education
	Far from Park	Male	Years	Secondary school	Post-secondary school	University and higher	Yes	Yes
Previous participation at restoration activity[b]	1.01 (0.61-1.67)	**1.98 (1.19-3.30)**	1.00 (0.99-1.02)	0.32 (0.10-1.01)	**0.30 (0.12-0.74)**	0.56 (0.25-1.23)	1.06 (1.71-6.21)	**3.26 (0.63-1.78)**

[a] Reference category is "Primary school".
[b] Categories of the dependent variable: (1) Participated, (0) Did not participate.
All odds ratios with significant $p < 0.05$ are marked in bold.

70.6% of respondents expressed interest to participate in such activities again in the future and have therefore answered several more multiple-choice questions regarding incentives for participation ($N = 303$ out of total N=395). Most favoured incentives why respondents would participate at such tree-planting activities were: to plant more endemic plants in the forest (97.4%), to learn about nature and environment (93.7%), to remove creepers (92.1%), to socialize and meet the community (97.5%), plant a tree with their name (81.2%), to do exercise (69.9%), to receive a hat, t-shirt and certificate of participation (66.0%), to get free drinks and lunch (30.0%), and to be on the television (28.4%). 88.8% of respondents said they would participate at this activity even if it would be far from their neighborhood, and 89.4% said they would not mind walking half an hour to reach the site, whereas 80.5% said they would not mind walking one hour. Respondents were also asked about a plant nursery, whether they find it acceptable in the area of the Park or not. 33.6 % of respondents had an opinion that a plant nursery is not acceptable in the area of the Park and the remaining 66.4% said the nursery is acceptable in the area of the Park.

5 Discussion

The main objective of Part I "Perception Study" was to investigate local attitudes and perceptions towards forest rehabilitation and the Park in light of supporting the sustainable management of the Mare aux Cochons water catchment within the EbA project [UNDP, 2012]. Specifically, the research questions were: (i) Which are the most important perceived functions of the Park?; (ii) How do people use and benefit from the Park in terms of visiting and ecosystem services?; (iii) What is the local attitude towards potential future scenarios of the Park, including development intensity?; (iv) Which perceptions are associated with positive and negative attitudes towards the physical outcome of forest rehabilitation?; (v) Do people support forest rehabilitation and how can they benefit from it? We expected differences in perceived benefits between people living near the Park in Port Glaud and Bel Ombre, compared to other districts. We also investigated whether participation in local environmental education programs played a role in explaining people's perceptions and behavior.

5.1 Recognition of Park's function in safeguarding the water regime

The key strategy of the EbA project is "enhancing ecosystem resilience and sustaining watershed and coastal processes in order to secure critical water provisioning and flood attenuation ecosystem services from watersheds and coastal areas" [UNDP, 2018]. The project reports that if water availability and water quality increase as expected, the following forest rehabilitation will likely result in a beneficial outcome for most of the residents of Mahé. It is however unclear to what extent people recognize the projected benefits of resilient ecosystems, such as the forest in Mare aux Cochons and Park, in general, and with special emphasis on safeguarding the water regime. Our results of perceived benefits (Figure 7) show that people do rely on the Park as a source of clean drinking water, but rarely recognize that as a major function of the Park.

The Park is a water source and provides drinking water. This was recognized by a majority of respondents (73.3%) by perceiving to benefit from "clean drinking water from forest river in the Park". However, the provision of PUC tap water from the Park was not perceived as beneficial by the majority but only (44.5%) of the respondents. From observations during survey collection, it has been uncovered that the perceived benefit is associated with the collection of drinking water, mostly in springs in two areas of the Park, Le Niol and Casse Dent. One respondent gave an especially insightful answer: "Most water for Seychelles comes from here (the Park). When there was drought, people collected water in Le Niol (an area in the Park)."

As expected, the living distance from the Park played a role in explaining that people living near the Park were more likely to recognize and benefit from the Park's function in terms of preventing landslide and erosion in the area. Yet, no differences in perception of water provision were found between residents living near the Park and closer to the water source compared to those living far from the Park. Only 4 respondents specifically referred to the Park's function as safeguarding the water regime. This is in line with the EbA mid-term reports from 2018, where it was noted that involved stakeholders showed a limited understanding of the concept of the EbA project [UNDP, 2018].

Looking into the future, it is of utmost importance to find a common ground between the formulation of the EbA project goals with the local perception of the Park. Since that majority of people to some degree understand the role of the Park in regulating water runoff. This can be used as a starting point for initiating discussions with communities about the role of functioning ecosystems for their well being.

5.2 Perceived function of the Park and what role it play in people's lives

The specific function of the Park to safeguard the water regime went largely unrecognized during our study, as discussed in the previous section. However, respondents identified a rich spectrum of other reasons why they find the National Park important for Seychelles. We found an apparent agreement on tourism and protection of the ecosystem and biodiversity as the main functions of the Park (Figure 6). This is complementary to the initial reasoning behind the creation of protected areas in Seychelles, i.e. to protect and preserve the natural environment for a tourism-based economy [Procter, 1973]. This perception is also in line with the current mandate of the SNPA, which aims at protecting and effectively managing the ecosystems and biodiversity, but also to provide and facilitate tourism [SNPA, 2017]. Other objectives of the Park, such as recreational activities, research, education, and sustainable forestry practices, were less commonly mentioned as a function of the Park. Sustainable forestry including timber plantations, IAS eradication, and rehabilitation, management of a plant nursery, among other activities, were not mentioned in any of the respondent's answers.

In terms of benefits for personal well-being, people recognized a diverse set of ecosystem services from the Park, particularly the less tangible and non-material services, such as air purification, aesthetics, and education, i.e. learning about nature and environment and seeing native plants and animals (Figure 7). In contrast to other developing countries or developing areas within countries, it appears local residents do not depend much on the Park for their daily needs in terms of resources such as fruits, flowers, wood, medicinal plants, and direct source of income. This is in contrast with protected areas in Szechuan, China [Xu et al., 2006], and Benin [Vodouhê et al., 2010], where people still rely heavily on the protected area for survival. On the other hand, the situation we observed on Seychelles is very similar to Mauritius, a small island state near Seychelles with a similar socio-cultural context, where locals now days do not rely on the forest for survival. But Mauritians do favor some areas of the protected area for picnics, hiking, and collection of berries [Iranah et al., 2018]. Meanwhile, our results show that some residents still rely on the unique local flora from the Park for medicinal purposes. The practice of utilizing local plants as medicines to treat various diseases and ailments has been a practice used long before the introduction of modern medicine to Seychelles. People that use plants for medicinal purposes are recognized in Seychelles and locally known as "herbalists". However, there seems to be a fear of over-exploitation of these natural resources by this user group, leading to efforts to educate and train practitioners on sustainable plant harvesting methods [Matatiken et al., 2011].

While the National Park was not explicitly identified by respondents as an important area for local recreation, recreations appear to be the main reason why people enter the Park, together with visiting the Park for spiritual/religious services. 36.1% of respondents had embarked on a hike to Trois Frères, which takes place once a year on the Good Friday, an annual Easter holiday and ritual celebrated by Roman Catholics in Seychelles. The majority of Seychellois also perceived to benefit from recreation in the Park (65%), such as hiking, walking, or running. However, the majority visits the Park less than once a year or never, and only some respondents visit the Park relatively regularly (7.1%). The major reasons why residents do not visit the area more often lie in general disinterest in such endeavors and perception that visiting the Park is a very time-consuming activity. While some trails in the Park are longer and require more time, i.e. Mare aux Cochons, trails such as Copolia, and particularly Mission lodge, Tea tavern, are relatively quick to access from the capital and require less time. The fact that Mare aux Cochons and Anse Major were by far the most popular trails among locals, points out an opportunity to promote other trails to the people. Especially, promoting easily accessible and shorter trails to the locals as less time consuming could attract more people and strengthen the physical relationship between the people and the Park.

This lead to the conclusion that non-tangible services such as air purification, aesthetics, and education play the most important role in people's relationship with the National Park, which appears to be more of a physically distant nature. On the other hand, the promotion of less time-consuming trails as a local recreation area could help to strengthen the physical relationship between locals and the Park.

5.3 Do locals support forest rehabilitation and see value in rehabilitated areas?

Our results showed a generally positive attitude of respondents towards the physical appearance of areas rehabilitated with endemic palm trees (Figure 10). Based on the two photos (Figure 4a, 4b) shown during the survey interviews, most people agreed that the area with endemic palm trees improved in quality, compared to the photo of a typical secondary forest with a high abundance of exotic species. The photos were not a before-after photo set of a restored area, as such photographic material is lacking for rehabilitation activities in Seychelles. Nevertheless, the photos were considered representative of areas rehabilitated under the EbA project, which are typically characterized by canopy-forming cinnamon trees with juvenile endemic palms in the understorey [Millett J., personal communication, May 2020]. This leads us to conclude, that people generally see more value in areas restored with endemic palms, compared to secondary forests with exotic species.

Our results provide an insight into why people might see value in rehabilitated areas (Figure 11), where the positive attitude was associated with: (1) presence of palms, native endemic species and absence of invasive species; (2) more and a higher diversity of plants in general; (3) aesthetics of the area, i.e. the restored area was more beautiful, greener, cleaner, more open, less woody, compared to before which was dry, unhealthy, dead; (4) maintenance, i.e. the restored area appears maintained, in a positive sense; and (5) trees appear bigger in the restored area. From the identified perceptions we observed that the presence of juvenile palms goes hand-in-hand with increased aesthetics of the area, i.e. the area was perceived as a greener, more open, and more clear. The "biophilic values of nature" [Kellert, 2009] are suitable to describe aesthetic value as a human appreciation of nature for its physical attraction and beauty. In line with our observations, there is typically an aesthetic preference for natural features that "enhance sight and mobility, that possess bright and flowering colors, and other features which over time have proven instrumental in human survival" [Kellert, 2009]. We concluded that the presence of endemic palms in forest rehabilitation might be a crucial factor in increasing the aesthetic value of the area and therefore its value to the society. The EbA program might apply this finding as an argument in favor of forest rehabilitation which includes the planting of endemic palm trees.

The majority of locals valued restored areas due to the abundance of endemic palms. This implies, that people might see less value in rehabilitation schemes using other species than endemic palms but could also have other reasons. As elaborated in more detail in Chapter 8.2, the rehabilitation in the lower water catchment includes two treatments: One based on endemic palms and one based on diverse native broadleaf trees. Accumulation of endemic palms results in a different visual outcome compared to native broadleaf forest. Integrating endemic palms into a native broadleaf forest using *Planchonella obovata* [Bwa mon per], *Calophyllum inophyllum* [Takamaka], or *Mimusops seychellarum* [Bwa-d-nat]is possible, since the palms naturally regenerate in the understorey. However, the aesthetic value of the forest might still be impacted and the perception of the locals on the outcomes of primarily broadleaf tree-based rehabilitation remains unknown and has the potential to be evaluated in further research.

Negative associations can give insights into why people might disapprove of forest rehabilitation and pin-point to potential starters of conflicts. Our results show some contradictions regarding the value which people appoint to rehabilitated areas in terms of aesthetics. While the majority did see aesthetic value in the rehabilitated area, some respondents saw it in the secondary forest with exotic species. This is not a surprise, as people's perceptions are a personal and subjective construct. Perceptions that there was a decrease in the number of trees in the before-after photo set and perception that there was interference into the natural environment, were the main arguments why people did not see value in restored areas, and might be a root cause for future conflict. It is noteworthy, that more people supported forest rehabilitation activities after an explanation of the subject (94.7%) compared to when only provided photographs (66.6%). This implies that negative attitudes towards the physical appearance of restored areas can be conquered with effective communication and transparency. For example, the negative perception "disagreement with interference into the natural environment" could be prevented with a signboard next to the restored area, explaining the reasons why trees were removed and palms were planted.

5.4 How local communities can benefit from forest rehabilitation

Besides the valuation of areas rehabilitated with palms, we further investigated how local communities can benefit from forest rehabilitation, such as active participation at tree-planting activities. People who benefit from certain activities are more likely to have a positive attitude towards it; for example, a study on attitudes and perceptions towards mangroves conservation concluded that people should have more direct benefits from the ecosystem to facilitate positive attitudes towards the ecosystem [Kaippilly et al., 2018].

Our results show a general awareness of community tree planting activities (71.4%), and a noteworthy proportion of respondents that participated in the past (23%). Taking into account that the results also capture rehabilitation of mangrove forests and rehabilitation activities on Praslin, among others (see Limitations, Chapter 6), prevents us from drawing any conclusions for activities specifically for the rehabilitation of forests in Mare aux Cochons. On the other hand, our results indicate there is potential in increasing the overall awareness about such activities and great potential in including more participants in the future, as 70.6% expressed their interest to participate in the future. The observation that people would like to participate in tree planting activities, but never had done so in the past, implies a potential lack in the communication of such event to the general public. While not recorded in the survey, respondents did explain to us that they would like to participate but they never heard of such activities or they were never personally invited. While the EbA project is not the only organization conducting community activities in Seychelles, conclusions of the EbA mid-term report [UNDP, 2018] provides a potential root cause: outreach and communication to enhance public and stakeholder awareness about project activities were identified as a project weakness. Our results and field observations suggest that investing more effort into personally inviting community members to rehabilitation activities, either in person or per post, could increase overall participation and enhance the communication of the EbA project to the public.

People with higher education, those who participated in Wildlife-club or Eco-school, and males, were more likely to have participated in such activities in the past. These results might help with the identification of the target audience that is most likely to participate in rehabilitation activities, which may support the EbA project and their communication strategy [UNDP, 2018]. On the other hand, focusing exclusively on community members that are already more likely to participate could miss the general point of including the broader society into EbA activities.

We identified several ways of how communities can benefit from rehabilitation activities. Considering the effects of biases (See Limitations, Chapter 6), our results show the most potential in benefits connected to personal well-being, i.e. to socialize and meet the community, and feeling of ownership, i.e. to plant a tree with their name. This means that people could benefit more from tree planting activities if they are framed more like a community gathering event and include activities that enable participants to "own a piece of the result", such as the ability to plant a tree with their name. Enabling people to benefit more from such activities does not only affect the likelihood to have a more positive attitude [Kaippilly et al., 2018], but also helps to endure long term community involvement and local stewardship of the area [Geist and Galatowitsch, 1999, Petts, 2007]. However, there are other benefits of EbA project interventions to communities, such as reduced flooding risks, water quality, and water availability [UNDP, 2018], which can only be perceived and understood by locals if effectively communicated.

5.5 Trade offs between conservation and use of the Park

By definition [IUCN, 2020], a National Park's primary objective is to protect natural biodiversity along with its underlying ecological structure and supporting environmental processes and to promote education and recreation. Contribution to local economies through tourism can be a complementary objective, as long as the visitor use for inspirational, educational, cultural, and recreational purposes is managed at a level that will not cause significant biological or ecological degradation to the natural resources.

In the present study, locals recognized tourism as the second most important function of the Park, right after the protection of the ecosystem and biodiversity. These results show that locals have high expectations from the Park, to support the local economy through tourism, while at the same time protecting the natural heritage and resources. These expectations are complementary to scenario rating, where the low-impact scenario was the most preferred and received the most positive feedback. Specifically, the evaluation of the scenarios showed that people seem to positively perceive little to no development in the area of the Park including facilities such as toilets, a kiosk, a parking lot, a small low-impact restaurant, and a zip-line. A slight preference for adding a few facilities over no development at all, highlights the idea and conclusion of a study in Mauritius [Iranah et al., 2018], stating that enjoyment of natural areas increases with the provision of low-impact facilities such as toilets, parking lots, tables, and signs containing educational information. This implies that locals see value in low-impact infrastructure, it is however not evident whether they see the value to increase their enjoyment of the area or as an investment to facilitate foreign visitor satisfaction and tourism activity.

In conclusion, people recognize tourism besides conservation as a core function of the Park and support the implementation of complementary low-impact infrastructure. The preferred level of development in the area of the Park has little to no expected negative impacts on natural resources in the Park, such as the quality of forests and the quality of water. This implies that general local expectations of providing tourism activities within the Park and implementing the necessary facilities can be met without adverse effects on the natural environment. Such type of development allows for minimal trade-offs between conservation and use of the area, and is commonly captured under the term "Ecotourism" [Fennell and Weaver, 2005].

People negatively perceived a more building-oriented development, including an introduction of a cable car, restaurants, some hotels and eco-lodges for tourists. The idea of private housing and larger tourism infrastructure with a consequent loss of protection status received extremely negative feedback. However, it should be emphasized that our results do not entail the expectations of private-land owners, who could have different perceptions of the issue since they own land in the area and have a higher opportunity cost of conservation [Walpole and Goodwin, 2001]. Moreover, our results do not directly indicate people's attitude towards infrastructure in the Park, but rather indicate their attitude towards the trade-offs with the quality of the environment in which different development levels would cause. For example, in our study, the introduction of private housing in the Park implied loss of protected areas and compromised forest and water quality. This is important since people might have different attitudes towards development in the Park if not presented along a potential negative impact gradient regarding natural resources. We conclude that there are signs of public objection towards using the Park intensively, including private housing and tourist accommodation, that results in a compromised forest and water quality, or in the worst-case - loss of protected areas.

6 Limitations

There are points in the methodology and study design applied here which potentially influenced the interpretation of our findings and therefore need to be acknowledged.

1. **Population sample and generalization**
   Using a stratified probability sampling technique in choosing our sample is considered sufficient to assume a representative sample and generalize our findings to the population [Acharya et al., 2013]. However, it should be acknowledged that there were significant differences between our sample and the population (see Appendix, Chapter 13.4), with groups such as males, younger people, and less educated, respectively, being marginally underrepresented (not over 7%). This could have had an impact on variables where significant differences in groups were shown. For example, males were more likely to have participated in rehabilitation activities in the past, however, they were under-represented in our sample. From this we can assume that the proportion of people who participated in restoration activities is bigger in the population, similarly to visit frequency and perceived provisioning services. In light of this limitation conclusions for population were drawn based on major trends only.

2. **Social desirability bias**
   Validity of some results might have been affected due to social desirability bias, a tendency of the respondents to say or claim things that are socially desirable and which put them in a favourable light [Nederhof, 1985, Louise and Alison, 1994]. This bias can be minimized by asking neutral questions and/or self-administration of a questionnaire where and interviewer is not present [Nederhof, 1985]. The latter method was not adopted due to several other drawbacks that out weighted the social-desirability bias, such as costs of sending questionnaires per post and difficulty of attaining a random sample. However, there was an effort to ask neutral, non suggestive questions. This was not completely achieved regarding attitude

towards rehabilitated areas, where asking "Do you agree the area after improved in quality" could be improved by instead asking "Which area do you prefer in regard to quality". Additionally, incentives why to participate at restoration activities were most probably biased because respondents did not want to admit, e.g. "free drinks and lunch" were a reason why they would participate. This was taken into account and incentives most vulnerable to social desirability biases were not considered in our conclusions.

3. **Measures used to collect the data**
   The investigation of people-Park relationship, including perception of importance and perceived benefits was potentially suggestive and did not allow respondents to express their negative perceptions towards the area. For example, 100% of respondents said they think the Park is important on a answer scale "yes", "no", "I don't know". Measuring the importance on a Likert-scale could help us attain more reliable data.

   Moreover, we were not completely successful in measuring people's awareness, support and past participation, specifically for rehabilitation activities in the area of the National Park which included removal of "invasive" species and planting of native flora. Respondents associated and generalized the question to other rehabilitation activities as well, including activities such as mangrove rehabilitation, forest rehabilitation on Praslin, etc. While not all respondents misinterpreted the question, the results were not reliable and were therefore interpreted in a broader sense, such as as community awareness, support and past participation of rehabilitation activities in scope of Seychelles.

4. **Data collection consistency**
   While conducting structured interviews proved to be very effective in gaining complete data from respondents and control for reliability of their answers, this resulted in potential biases how the interview was conducted, and in what language. We always offered the possibility to be interviews in Creole, however, in some cases respondents agreed to English but showed poor language skills. This might have affected their understanding of the questions and given answers. Moreover, lack of investing time in properly training the team that collected the interviews results in potential biases caused by how questions were read, explained and recorded. For example, during the survey we noticed inconsistencies in how answers for perception of benefits were recorded. This bias was eliminated by merging the rating scale into "Yes", "Not sure" and "No" for the analysis.

5. **Environmental education**
   Only several people had previously participated in Wild-life club or Eco-school, and these programs only exists for the last 25 years, meaning that only younger respondents were most probable recipients of such education. To better study the effects environmental education plays, a different research design could attain more reliable results, potentially consisting of people that participated in environmental education and a control group.

Part II
Forest analysis

7 Background

In Part I we studied attitudes and perception of local people towards the Morne Seychellois National Park, and to what level of development they would accept – given that some level of development inside the Park is likely to happen in the future [Government of Seychelles, 2018, Seychelles Planning Authority, 2015]. Projected increases in international tourism and landowners making use of their constitutional right to enjoy their property pose a meaningful risk to the Park. Moreover, as we discuss in Part I, a large fraction of the local population is in favour of low-impact development in the park. At the same time, safeguarding natural ecosystem processes is of crucial importance in face of climate change. In particular, sustaining the integrity of the water regime is essential as more irregular rainfall patterns leading to water scarcity and flooding are predicted in Seychelles [UNDP, 2012]. Maintaining ecological functions and processes of watersheds, such as Mare aux Cochons, is therefore key. Forests surrounding the lower catchment area of Mare aux Cochons are mainly secondary and characterized by high abundance of exotic species – either remains of historic land use, or recently introduced species which invaded the area naturally. The premise is that rehabilitation of these secondary forest will improve rainfall detention and infiltration, reduce runoff and sedimentation from forest landscapes, and have an overall positive effect on the hydrological regime [UNDP, 2012, UNDP, 2018]. Indirectly, facilitating native regeneration and removing exotic species will raise the conservation value of the forest landscapes and thereby support the protection of the whole catchment area in times of development pressure.

In the second part of our thesis, we characterize the vegetation in the lower Mare aux Cochons water catchment area where rehabilitation work will take place under the EbA mandate. By describing the present state of secondary- and a small patch of pristine forest in the lower water catchment, we provide a baseline to evaluate planned forest rehabilitation, and to study the natural forest succession of surrounding secondary forests.

7.1 Forest rehabilitation in Seychelles - knowns and unknowns

Globalization has reached almost every corner of the world and humans have breached biogeographical boundaries and thereby facilitated the spread of species into regions that naturally they may never have reached under normal conditions [Hobbs et al., 2006]. In this light, it is not surprising that there is an entire field of science which studies biological characteristics of invading species, habitat characteristics of the invaded sites, and various aspects of underlying mechanisms such as dispersal, competitive advantages against native flora, and light availability. As many other oceanic islands, Seychelles are strongly affected by species invasions and numerous eradication and management programs were carried out [Rocamora and Henriette, 2015, Baret et al., 2013, Beaver and Mougal, 2009]. However, the spread (or mere presence) of many exotic woody and non-woody plants in Seychelles was inadvertently facilitated by deliberate introduction for agricultural and forestry-related reasons (e.g. *Falctaria mollucana, Sandoricum koetjape, Cinnamomum verum, Psidium cattleianum, Syzygium jambos, Alstonia macrophylla, Pentadesma butyracea, Chrysobalanus icaco ssp. atacorensis*), or ornamental reasons (e.g. *Ardisia crenata, Clidemia hirta, Dillenia suffruticosa, Memecylon caeruleum*) [Steers and Stoddart, 1985, Kueffer and Vos, 2004], and was further promoted by available niches created by forest destruction. Some of the most meaningful insights into managing exotic species dominated secondary forests were achieved by studies conducted around the millennial shift [Fleischmann, 1997, Fleischmann, 1999], followed by two doctoral thesis by Christoph Küffer and Eva Schumacher [Kueffer et al., 2007, Schumacher, 2007], and several publications in respected scientific journals [Kueffer et al., 2010, Kueffer et al., 2008, Kaiser-Bunbury et al., 2015, Kaiser-Bunbury et al., 2011, Kaiser-Bunbury et al., 2014, Kaiser-Bunbury et al., 2017]. In a key publication, Fleischman [1997] developed a method to evaluate the invasion status of a habitat using trails transects. In this procedure, he records woody species along trails and calculates several indicators from which ecological status matrices for the evaluation of conservation value of a landscape can be derived. This method has been repeatedly used in Seychelles to describe patterns of species invasion, e.g. in the Val dEndor watershed area[Massy and Schmutz, 2017], in Praslin's palm forests [Fleischmann et al., 2005]. Already in their work, the outstanding potential of two endemic palms, *Phoenicophorum borsigianum* and *Nephrospermum vanhoutteana*, to establish themselves even under harsh environmental conditions were emphasized. This has resulted in widespread use of endemic palms in rehabilitation in Seychelles, whereas experimental trials using other native species are scarce – with one exception by Senterre et al. [2012] on fire degraded land in Praslin. Furthermore, Fleischman [1999] found that low light intensity plays a key role in the competitive relationship between cinnamon and endemic palms as the establishment of cinnamon was suppressed under lower light conditions. Findings from Fleischmann [1997, 1999] had important implications for practical rehabilitation work and were further investigated in work by Christoph Küffer and Eva Schumacher in two doctoral theses. Kueffer et al. [2010] studied the growth of several exotic vs. native species seedlings in artificially created canopy openings. They found that both native- and exotic species benefit from larger openings, while some exotic species particularly prosper from more light availability. Under lower light conditions in smaller gaps, juveniles of several native species survived well but grew slowly. Reduced regeneration of exotic species in understorey conditions was attributed to less light availability and below-ground competition through a the dense root mat of cinnamon which provide rather high resistance to colonization by invasive species [Kueffer, 2006, Kueffer et al., 2010, Kueffer et al., 2007]. Based on their findings, they suggested a strategy for restoring native vegetation using smaller gaps to replant forests with native seedlings, whilst benefiting from the native species-friendly climate provided by adult cinnamon trees. It is noteworthy that leaving the cinnamon canopy intact for the benefit of the "second-storey" of native rejuvenation is not a new idea and was already suggested by Vesey-Fitzgerald [1940]. Another study in Seychelles by Brandis [2012] endeavoured to develop an experimental rehabilitation method for abandoned coconut plantations on D'Arros Island. Similar to Kueffer et al. 2010, this study recommended to preserve the canopy to maintain the shady environment during planting of native trees followed by gradual removal of the coconut palm canopy [von Brandis, 2012]. While explicitly mentioned in the EbA project proposal [UNDP, 2012, UNDP, 2018], measurable impacts of exotic species communities on functional properties of ecosystems were absent in scientific literature in Seychelles until Kaiser-Bunbury et al. [2015] demonstrated positive effects on pollinator networks in rehabilitated inselberg (Glacis) communities. However, regarding high water usage of non-native species, there is weak scientific support on an ecosystem scale for systems with the same growth form (i.e. not comparing grassland with forest). Suspicions on high water uptake of *Falcataria mollucana* [Albizia], *Bambusa arundinacea* [Bambou], and non-native species in general, have so far not been empirically tested in Seychelles. Positive soil feedbacks, where invasive species alter soil properties to their own advantage as known for example in Hawaii [Ostertag and Verville, 2002, Hughes and Denslow, 2005], could not be replicated in Seychelles

[Kueffer, 2010].

Here, we only presented the most important findings related to rehabilitation in the study areas. In summary, there has been a focus on examining factors that influence non-native plant invasion/regeneration and the recovery of native species with many practical applications, while there is still a lack of knowledge about functional properties of secondary forests dominated by exotic species.

What is also vastly unknown, and matter of an ongoing debate, is how ecosystems with new species compositions develop in the long run (cf. Chapter 2.1). The comeback of native vegetation in the understorey in Seychelles is described by almost every scientist cited above, and yet, it is unclear to what extent secondary forests are capable to recover given consistent propagule pressure from exotic species. Fleischmann [2005] presented the first and only re-evaluation of a previously assessed native palm forest in Praslin [Fleischmann et al., 2005]. Long-term studies on forest succession are otherwise lacking, which is partly also due to it being a relatively young problem. At the same time, long-term effects of rehabilitation are of considerable interest, given that not all exotic tree species present are showing natural regeneration (e.g. *Falcataria mollucana, Pterocarpus indicus*) [Fleischmann, 1997] (and this study) and part of the exotic canopies may collapse due to the natural lifespan of adult exotic canopy trees. This is where rehabilitated areas may prevent further biological invasion in the future and detailed descriptions of the floral composition prior to rehabilitation become valuable scientific resources.

As it comes to practical rehabilitation work in Seychelles, traditionally Latannier fey (*Phoenicophorium borsigianum*) and other endemic palms have been widely advocated restoration species due to their robust nature [Fleischmann, 1997], popularity, and availability of seeds. Here, we group our 26 study sites into six treatment areas (two of which are control/reference treatments) in a long-term experimental setting using different main restoration species. This will provide clear guidelines for planned rehabilitation work in the water catchment Mare aux Cochons and give insights in the effectiveness of two different rehabilitation approaches: a traditional one based on endemic palms and an alternative method based on broadleaf species.

8 Methods

8.1 Study areas

Out of ten suggested sites suggested for rehabilitation [Senterre et al., 2019a], we selected two areas based on accessibility and ownership rights; forest Area 5 and Area 10 (Figure 12). Area 5 lays in submontane forest in the cadastral parcel J935 and has an area of 9.3 ha (detailed map in Appendix C Figure 49). The land parcel is government owned and suitable for rehabilitation work. The area is located at the end of a bouldery slope. Remaining house ruins tell us about the historical use of the area. The vegetation is characterized by cinnamon dominated canopies and other historical plantation- and garden species e.g. vanilla, prune, *Sandoricum koetjape, Falcataria moluccana, Camilia sinensis, Dieffenbachia seguine.* There are many endemic palms and other native vegetation growing in the understorey. However, it may be less suitable for the type of rehabilitation work which includes residents because of its distance from Port Launay (around 1h walk). Area 10, which is in a government leased parcel J1364, has very easy access from Port Launay and is 6.1 ha (detailed map in Appendix C Figure 48). Most of the area is dominated by cinnamon and *Tabebuia heterophylla* [Kalis dipap] but Area 10 also contains around 1-2 hectare of semi-pristine or even practically undisturbed lowland rainforest with some rare species. The area is adjacent to residential areas and mangroves swamps. Moreover, there is a small freshwater swamp and several glacis habitats within the semi-pristine forest. In total, we assessed 13 plots in both areas five and ten resulting in a total of 26 permanent plots which we also refer to as study sites[1].

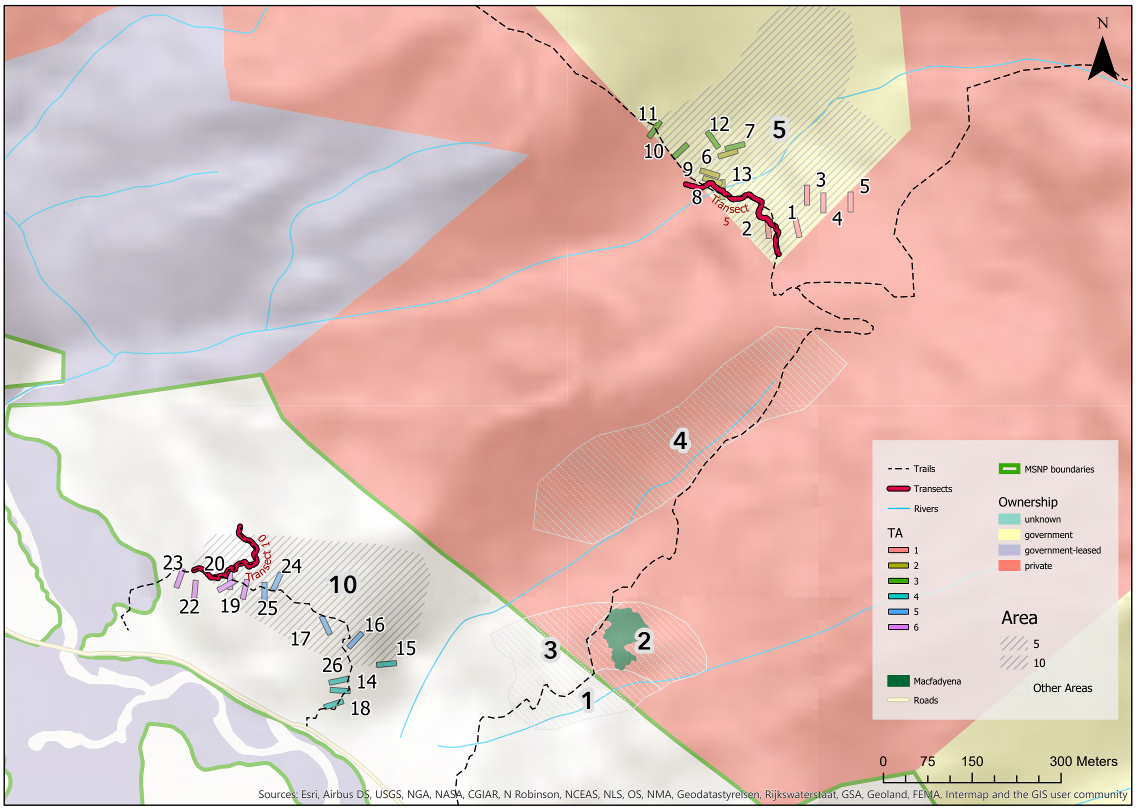


Figure 12: **Overview map of rehabilitation areas**
Area 5 and ten are subdivided in three treatment areas (TA) - each containing four to five plots enumerated from 1 to 26.

8.2 Treatment areas and experimental rehabilitation approach in detail

Using this baseline study, the EbA project is currently establishing a rehabilitation plan for the lower Mare aux Cochons water catchment [Monthy et al., unpublished]. The rehabilitation scheme consists of two treatments. The fist treatment is traditionally based on the endemic palms *Phoenicophorium borsigianum* [Latanier fey], and *Nephrospermum vanhoutteana* [Latanier millepat]. This is the most commonly used rehabilitation approach in Seychelles as seeding material and plants are widely available. The robust nature of *Phoenicophorium borsigianum* and the ability to withstand

[1]In analysis of vegetation community data, commonly matrices with sites or samples as rows, and with species as columns are used [Gauch, 1982]

harsh environmental conditions and eroded soils was noted early [Steers and Stoddart, 1985, Fleischmann, 1997] and has been confirmed in practical rehabilitation (pers. communication James Millett). Moreover, their ability to establish in a wide range of light climates and to quickly cover ground on an horizontal space facilitates the suppression of competing plant growth. However, palms of Seychelles are not typical canopy components but rather under-canopy elements. They can rapidly cover the ground but they do not reach great height very quickly. It might be that broad leaved trees will considerably help rehabilitation by rebuilding better the canopy and faster, while palms will only help covering the understorey; which is useful to limit the recruitment of exotic species, but not to rebuild a canopy that resembles the original state. Forest canopies in Seychelles were likely composed of broadleaf tree species such as Bwa de fer *Vateriopsis seychellarum*, Bwa de natte (*Mimusops sechellarum*), Bwa rouz (*Dillenia ferruginea*), or Bwa mon per (*Pouteria obovata*) before these hardwood trees were cut down for their excellent timber quality or burnt in distillation furnaces [Vesey-Fitzgerald, 1940, Jeffrey, 1963, Steers and Stoddart, 1985]. Therefore, the second treatment is mainly based on broadleaf tree species. Diversifying species will be planted in concordance with native species communities of Seychelles. In addition to the pristine forest described in this study, historical records of Procter [1970], Sauer Pickesgill [1986], and Fitzgerald [1940], as well as the recent studies by Senterre Baguette [2020] and Senterre et al. [2019] were used as a guidance to identify suitable rehabilitation species.

To test these two rehabilitation approaches in the long run, we group the 26 study sites into six treatment areas (TA1-6) (Appendix B Figure 20). In both forest areas we suggest to use two control treatment areas which should not be interfered with. By having a control treatment areas, our baseline study allows for studying individual tree growth and natural forest succession without human interventions.

Every treatment area is comprised of four to five permanent plots with similar species composition. From an experimental perspective, a randomized assignment of plots to treatment areas would be ideal, however, in regard of practical implementation we grouped plots in close proximity together. TA1-3 are in Area 5 (submontane-lowland forest), and TA4-6 are in Area 10 (lowland forest) (Figure 12). TA5 forms an exception as it contains two semi-pristine plots 16 and 17 and two pristine plots 24 and 25 with original native lowland palm forest (Figure 14). Which TA is rehabilitated with broadleaf areas and which ones with palms is discussed in Chapter 10.

8.3 Sampling

We recorded species with a smartphone application developed by Senterre et al. [2019b] as part of the "Bio Holistic Database" database [Senterre et al., 2019b], using Open Foris collect, an FAO-led initiative available in open source format. It provides digital field based inventory tools to implement multi-purpose forest inventories. We used nested plot intensive inventories (NPII) [Senterre et al., 2012b], which are an adopted version of Gentry plots [Gentry, 1982]. This method is widely used to study tree diversity in tropical forest ecosystems and provides accurate estimates of tree diversity [Valencia et al., 2013]. This method subdivides every plot into three separate sampling strata/ inventories: trees in the main plot and both ground/herbs cover and shrubs separately, in nested smaller subplots (Figure 16). The use of smaller subplots within the main plots for shrubs and ground cover is of practical and analytical importance for two reasons: (i) Smaller subplots enabled us to keep track of counts of seedlings, herbs, and shrubs which would otherwise reach uncountable numbers, and (ii) the separation of vegetation growing in different sampling strata allows to make

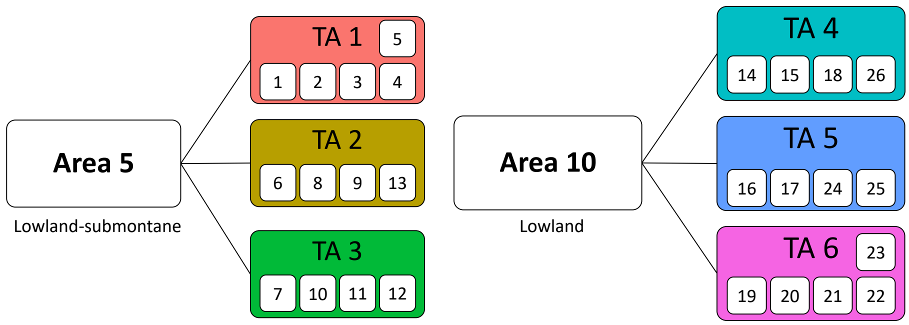


Figure 13: **Plot assignment to treatment areas**
Area 5 and 10 are subdivided in three treatment areas each (lowland-submontane: TA1-3, lowland: TA4-6) - each containing four to five permanent forest plots.

estimates of forest succession. On the other hand, it results in several entries per species which grow in more than one sampling strata. For analysis regarding the whole species composition of a study site, we only used the count of adult individuals in their typical synusia or eco-unit [Oldeman, 1990]. We define this set as the "set of the present" defined by Oldeman [1990]. By subsetting for adult individuals only, we avoid a mix-up and redundant entries of tree species in other strata (e.g. counts of Albizia in the shrub layer are excluded). At the same time, the three separate inventories enabled us to analyse the species composition of all forest strata separately and to construct Oldeman's [1990] "set of the future" by only looking at woody species in the ground/herb inventory.

(a) TA1

(b) TA2

(c) TA3

(d) TA4

(e) TA5

(f) TA6

Figure 14: **Representative images of treatment area 1-6.**

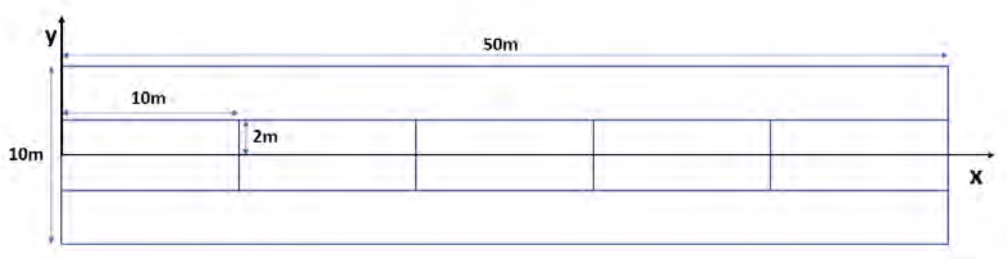


Figure 15: **Sketch of permanent forest plots**
Trees were given x- and y-coordinates based on position in the plot. The main plot is subdivided in subplots along the centre line, we inventoried shrubs and ground vegetation herbs.

Twenty six plots as depicted in Figure 15 were established and inventoried. Species accumulation curves demonstrate adequate sampling effort (Appendix B Figure 31). Permanent plots are 50 m long and 10 m wide with a centre line, which is marked with white PVC tubes at x = 0, 25, and 50 m. We tagged every PVC tube with an aluminum tag and a red ribbon according to position and plot number.

In the big 10 m x 50 m plot boundaries, we identified and counted all trees with a diameter at breast height (DBH) $\geq$ 5 cm. We measured DBH at 1.3 m above ground at the higher side of the stem if on a slope, and additionally marked where DBH was measured with waterproof yellow spray paint. We estimated tree height above ground by eye and if the canopy was exposed or not. Each tree received X and Y coordinates in the plot based on position on the center line (x) and distance from it (y) (Figure 15). We recorded the GPS coordinates of point (0/0) as well as the plot's orientation.

In the ten nested 2 m x 10 m shrub-subplots, juvenile trees and shrubs with DBH $\leq$ 5 cm but with a height $\geq$ 0.9 m were recorded.

For all woody species $\leq$ 0.9 m and herbs (including ferns) in the ground/herb subplots, we estimated van der Maarel values [Van Der Maarel, 1979], which are semi-quantitative cover-abundance value; Each van der Maarel value class (rare [1-2 individuals], occasional [less than 5%], almost frequent [5-10%], frequent [10-15%], very frequent [15-25%], common [25-50%], abundant [50-75%], very abundant [more than 75%]) is be based on numbers of individuals respectively surface covered by creeping or densely growing species, as well as their prominence in every 2x10 m subplot. The shrub- and ground/herb inventory was recorded in the same ten subplots. All three sampling layers are visualized in Figure 16.

8.3.1 Trail-transects

We follow the exact methods of Fleischmann [1997] and [Massy and Schmutz, 2016] to characterize the landscape of area 5 and 10. We placed one trail transects along the main hiking trail in area 5 and one transect along the trail to access the permanent plots in TA6 in area 10 which ends close to the swamp and the small glacis habitat to the north of area 10 (Figure 12, cf. Appendix C Figure 49 and Figure 48). Every 2.2 m, we recorded the closest adult tree and the closest juvenile tree standing in a 90 degree angle to the observer's position on the trail-transect alternating between left- and right side of the trail. Both transects have a length of 220 m and are marked with white PVC tubes with aluminum tags. We used the same definition of tree and juvenile as Fleischmann [1997] where a tree has a real DBH $\geq$ 3 cm, and a juvenile (referred to as "sapling" in [Massy and Schmutz, 2016]) has a DBH $\leq$ 3 cm and height $\geq$ 0.5 m.

8.4 Data analysis

The main goal of this baseline study is not to compare between different forest sites today but to provide solid data to assess changes in the future. Therefore, the analysis does not include statistical tests for significant variance between sites and treatment areas for the current state. To support technical understanding and reproduction of the analysis, we here use different fonts for R **packages** and R `codes`.

We analysed the extracted data from Open Foris in R using the **vegan** [Oksanen et al., 2013] for community analysis and `ggplot2` for illustrations. For rehabilitation purposes, we are not only interested in comparing univariate descriptors of communities, like diversity of trees or density of shrubs, but also in how the overall composition differs between pristine and non-pristine study sites. Therefore, we used two different ordination techniques to collapse multivariate data (species abundance in different study sites) into just two dimensions so that community data can be visualized and interpreted. Two common tools used in vegetation ecology are a correspondance analysis (also called reciprocal averaging) and non-metric multidimensional scaling (NMDS) [Hill and Gauch, 1980, Lane and Texler, 2009]. In the late 1970s, detrended correspondence analyses (DCA) became the method of choice for ordination in vegetation science. The ordination in a DCA

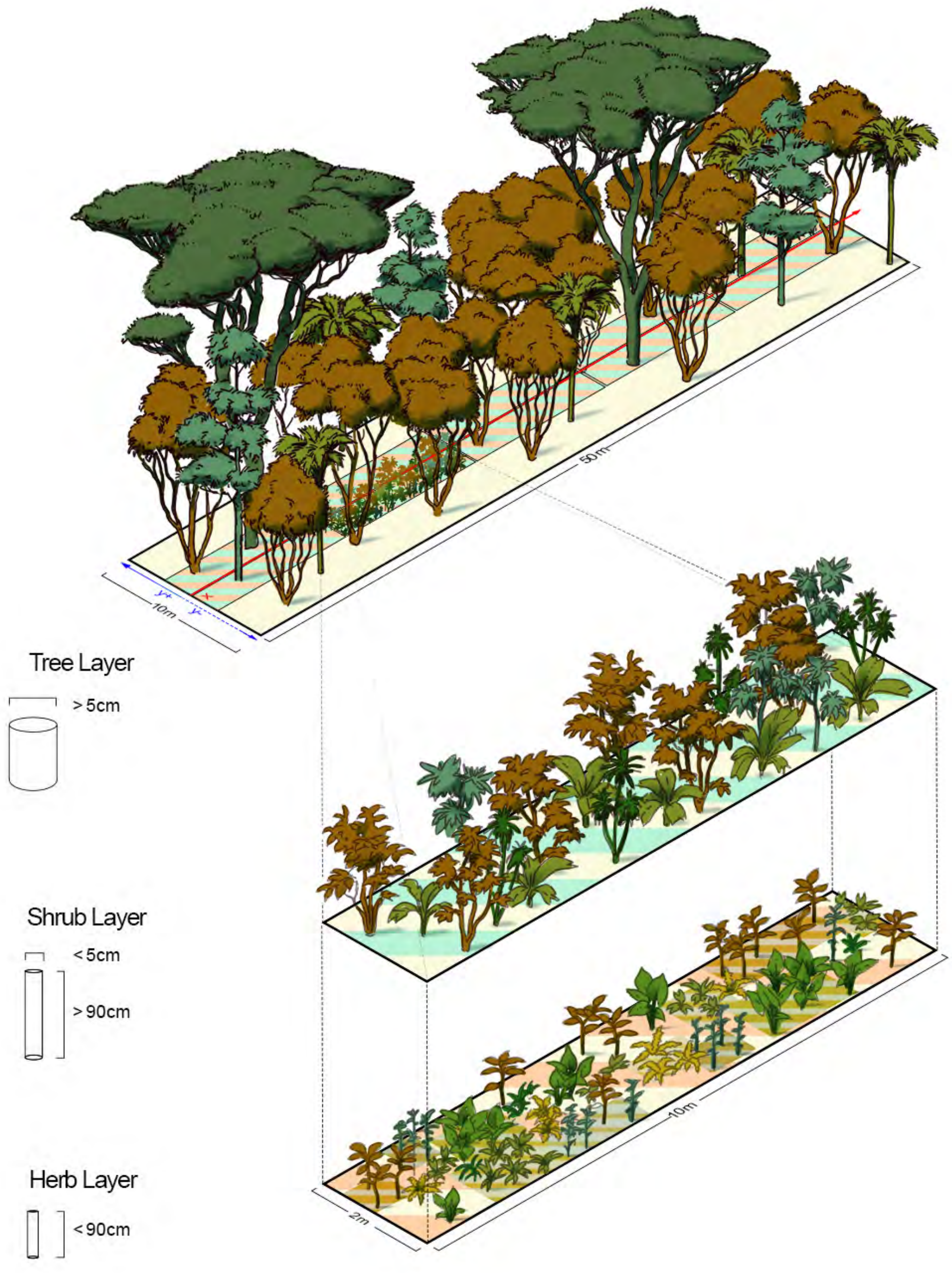


Figure 16: **Visualisation of three sampling layers.**
Credits: Joshua Binswanger

is based on absolute- or relative abundance of all species within one site. If ecological communities are characterized by a few common species with many individuals and many rare species with only few individuals, these rare species are given less importance in the relative community compositions based on counts of individuals. Consequently, the ordination will be strongly influenced by the most abundant species. Non-metric multidimensional scaling, on the other hand, uses rank orders (the most abundant species receives rank 1, the second most abundant rank 2, etc.) and the ordination is then computed using species ranks instead of abundance counts. We visualize and compare species composition of all study sites using both ordination techniques using `decorana` and `metaMDS` of the **vegan** package.

While herbs or epiphytes grow in very defined ecological niches throughout their lifespan, many woody species can occur in different ecological units (synusia) of an ecosystem depending on their age. Juveniles of trees all develop in the ground/herb layer and are therefore also recorded in the ground/herb inventory. For overall species composition analyses, we subset the data for adults growing in their typical synusia (Oldeman's [1990] "set of the present"). Entries for juveniles, e.g. cinnamon seedlings and saplings occurring in the shrub or ground/herb layer, were omitted. This resulted in three community matrices for trees (including palms), shrubs, and herbs (Appendix B). To merge these three matrices for an overall representation of the composition of every study site we performed the following normalization steps: we first corrected abundance of shrubs and trees independently for sampling areas (sampling area per plot: trees; 0.05 ha, shrubs; 0.02 ha) resulting in nr. of individuals/ha – or "density". We then merged tree- and shrub community matrices by study site[2], and transformed density into relative density ranging from 0-1 . For the herb matrix, we converted van der Maarel values to mid-class values (e.g. frequent [10-15%] -> 12.5) and similarly transformed them into relative mid-class values ranging form 0 to 1. Lastly, we merged the normalized shrub-tree matrix with the ground/herb matrix by study site resulting in the final community matrix. Summing up relative values of the final community matrix within one site results in a maximum of 2 (or 200%), as relative values from herbs in one site are merged with relative values of trees/shrubs. However, we refrained from an additional transformation step to maintain a certain degree of separation between herbaceous and woody species. The function `decostand` in **vegan** transforms absolute values in community matrices into relative values f_{sp} with:

$$f_{sp} = \frac{n_{sp}}{n_p}$$

where n_{sp} is the number of recordings of species s in site p, and n_p the total number of species recordings in site p.

We used this overall community matrix for all analyses where the whole species community of adults (Oldeman's "set of the present" [Oldeman, 1990]) of the forest is important; this is the case for the calculation of biodiversity indexes, Ordination plots (DCA and NMDS) and rank-abundance plots.

For rehabilitation specific analyses, we grouped the vegetation data in canopy-, understorey-, and ground/herb layer which we did for the most part by recording trees, shrubs, and ground/herbs

[2]As there are only a few real shrubs growing in the the two forest areas, we combined entries from the tree-plot and the shrub subplots using density instead of abundance to correct for the different sampling area. If relative abundances were taken within the shrub synusia separately, shrubs would have been overrepresented in the final community matrix as there are, in some cases, only a few shrub individuals per plot. This would result in relative abundances for shrub species close to 0.5 and consequently lead to a skewed weighting of species.

separately in the data collection. However, to additionally distinguish between shadowing canopy trees and understorey vegetation, we combined densities of all trees (including palms) with non-exposed canopy (roughly one third of all recorded trees) with shrub densities. We used this grouping to calculate relative composition of native vs. exotic species in all three forest strata.

To estimate likely forest succession, we subset the ground/herb layer for all woody species (Oldeman's "set of the future"), and herbs were omitted. Within this subset as well as for the "set of the present", native:exotic ratio was calculated on the level of individuals. For forest succession estimation of the near future of juveniles, We plotted relative mid-class van der Maarel values of all seedlings and saplings in the ground/herb layer (height ≤ 0.9 m) against their corresponding relative abundances of juveniles in the shrub layer. We applied the same concept to relative abundances of juvenile trees growing currently in the shrub layer (DBH ≤ 5 cm but with a height ≥ 0.9 m) against adult trees in the tree layer (DBH ≥ 5 cm) (Oldeman's set of the present).

Moreover, we created true-to-scale maps of the visually dominating vegetation, trees, by their recorded position in the study site and DBH as well as their origin; native/exotic and species. This supports relocating of trees in the permanent plots for future assessment.

It is a challenging endeavor to represent biodiversity of a multifaceted ecosystem like tropical rainforest in a single number [Duelli and Obrist, 2003]. To characterize the current state of biodiversity of the study sites, we therefore calculated several indexes. The Shannon Weaver diversity index H' is a widely used index to asses diversity with origin in information science [Shannon, 1948]. We calculated diversity of communities with `diversity` (function: "shannon") in **vegan** where:

$$H' = -\sum_{i=1}^{s} p_i \ln p_i$$

where s equals the number of species and p_i equals the ratio of individuals, of species s divided by all individuals of all species [Oksanen, 2017]. We additionally calculated Pielou's evenness, which indicates evenness of a community. Pielou's evenness ranges from 0 (no evenness, one species dominates) to 1 (complete evenness, all species are equally abundant). Moreover, we fitted models to rank-abundance curves or Whittaker plots [Whittaker, 1965] using (`radfit` [Oksanen et al., 2013] - an informative way to illustrate species richness and evenness together in one graph. A combination of indicators is highly supportive to interpret commonly used biodiversity indexes like H' [Duelli and Obrist, 2003].

We calculated diversity indexes for Oldeman's [1990] "set of the present" which includes only adult individuals. We refer to these indexes as the static diversity indexes. To get a better understanding of temporal and spatial variations in species diversity, we calculated diversity indexes separate for all forest strata (trees, shrubs, and herbs). Additionally, we distinguish between native biodiversity and exotic biodiversity. To this type of diversity indexes we refer to as "dynamic diversity indexes".We calculate native species richness N_n, exotic species richness N_{ex}, Shannon Weaver index of native species H'_n, Pielou's evenness of native species J_n, and the ratio of H' for native and exotic species $\frac{H'_n}{H'_{ex}}$. We also include Oldeman's [1990] "set of the future" in a separate analysis where we calculated the same indexes for a subset of woody species in the ground/herb layer.

Prominence values PV of juvenile and adult woody species are calculated using the same approach[3] as in Fleischmann [1997]:

$$PV_{ij} = f_{ij} + \frac{a_{ij}}{\sum_i a_{ij}}$$

where a_{ij} represent abundance class, and f_{ij} relative frequency of species i in transect j. Abundance classes a are defined by number of individuals i in transect j as:

abundance classes							
a	**1**	**2**	**3**	**4**	**5**	**6**	**7**
number individual i	1	2-4	5-8	9-16	17-32	33-64	>64

8.5 Calculation of status indicators

To represent the complex state of the forest in more accessible numbers, we calculate four status indicators derived from the findings of the baseline study. They are tailored to evaluate success of rehabilitation by focusing on understorey characteristics, rejuvenation of woody species in contrast to adult woody species and diversity indexes taking into account all vertical layers of the forest.

The first two, Understorey Nativeness USN and Native Regeneration NR, capture compositional properties within different forest layers (canopy, understorey, ground/herb and Oldeman's [1990] "set of the future") in respect to species origin. Understorey Nativeness is composed of two terms: summed up density ratio of native- and exotic species in the understorey, and summed up ratio of mid-class-van der Maarel values in the ground/herb layer. For the treatment area i, Understorey Nativeness USN is defined as:

$$USN_i = \frac{\sum_{p_i} D_{n_{p_i}}}{\sum_{p_i} D_{ex_{p_i}}}_{US} + \frac{\sum_{p_i} V_{n_{p_i}}}{\sum_{p_i} V_{ex_{p_i}}}_{GH}$$

where $D_{n_{p_i}}$ is density of natives species, and $D_{ex_{p_i}}$ the density of exotic species in plot p_i of treatment area i for all trees and shrubs growing in the understorey US. $V_{n_{p_i}}$ is the mid-class van der Maarel value recorded for all native and exotic species in the ground/herb layer GH.

Native Regeneration NR is defined as:

$$NR_i = \frac{\sum_{p_i} V_{n_{p_i}}}{\sum_{p_i} V_{ex_{p_i}}}_{SOF}$$

where $V_{n_{p_i}}$ is the mid-class van der Maarel value recorded for all native and exotic woody seedlings/saplings, which form Oldman's [1990] "set of the future" SOF, recorded in the ground/herb layer.

The second two status indicators are an overall Richness Index RI and an overall Diversity Index DI. These two diversity indicators collapse several diversity indexes from all forest strata

[3] As we only have one "sampling unit k" (i.e. there is only one transect unit per area), we did not sum in terms of sampling unit k. Therefore, the equation is slightly different as in Fleischmann [1997]

inventories (tree stratum, shrub stratum and ground/herb stratum) into two indicators per TA. The Richness Index is a measure of species richness calculated on the basis of native- N_n and exotic species richness N_{ex} from all forest layers where:

$$RI_i = \frac{\sum_S N_{n_{S_i}}}{\sum_S (N_{n_{S_i}} + N_{ex_{S_i}})}$$

where $N_{n_{S_i}}$ is native species richness and $N_{ex_{S_i}}$ being exotic species richness in stratum S in treatment area i.

Similarly, DI stands for the ratios between Shannon Weaver index of native and exotic species – summed up by sampling strata where:

$$DI_i = \sum_s \frac{H'_{n_{s_i}}}{H'_{ex_{s_i}}}$$

where $H'_{n_{s_i}}$ stands for the Shannon Weaver index for native- and $H'_{ex_{s_i}}$ for exotic species in stratum s of treatment area i.

9 Results

9.1 General vegetation characterization of the study sites

Ordination of species communities based on relative species composition of adults results in several clusters of similar study sites (Figure 17). Along the first DCA axis, there are three distinguishable clusters separating secondary- from pristine and semi-pristine sites. From left to right we observe

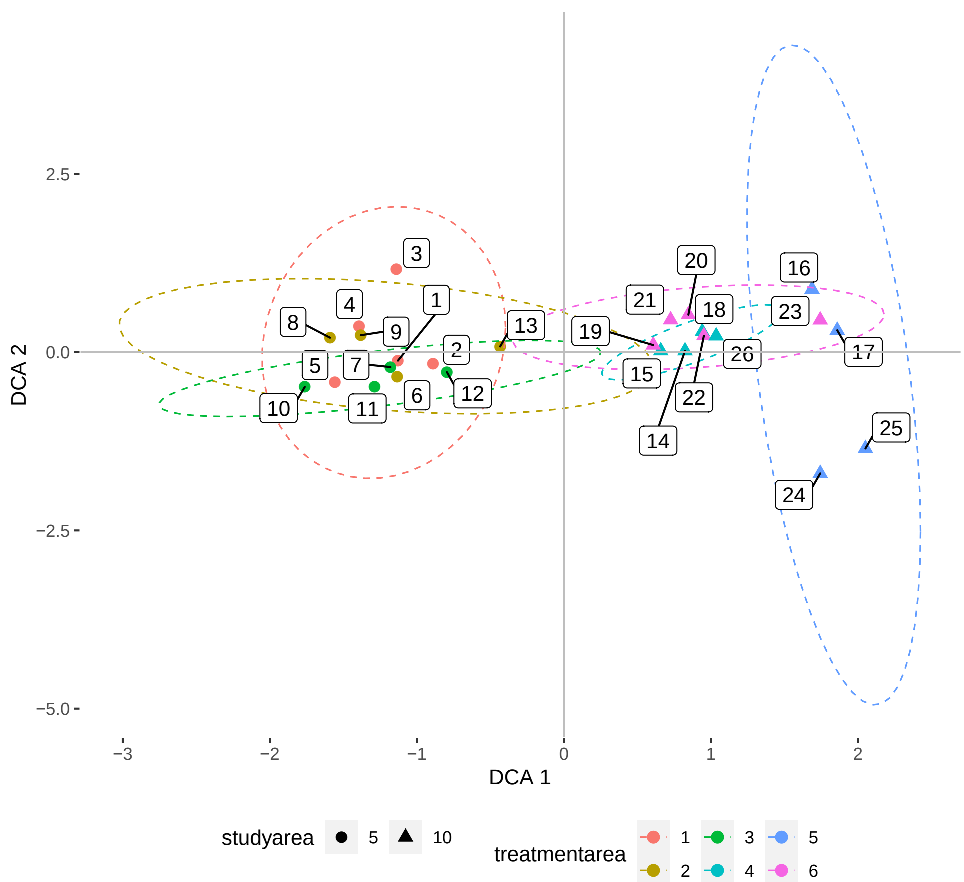


Figure 17: **Ordination of the floristic data**
DCA (detrended correspondance analysis) using `decorana` of the **vegan** package) of all study sites based on species composition using relative abundance resp. coverage of adult individuals in their typical synusia. The first DCA axis separates all permanent plots into three distinct groups: Sites 1-13 are in lowland-submontane forest in Area 5 (round symbols), sites 14-26 are located in lowland forest in Area 10 (triangular symbols). Colors indicate rehabilitation treatment area.

the following groupings: all lowland-submontane sites (Area 10), all lowland sites (Area 5), and both pristine (24,25) sites as well as semi-pristine sites (16,17) position on the far right of the DCA. Site 23 clusters together with the semi-pristine sites. Lowland study sites (triangular symbols on the right) form a more compact cluster when compared to the lowland-submontane sites (round symbols on the left) which cluster less densely i.e. show more variation in their community composition. For more detailed information about species effects on the clustering see Appendix B Figure 41. Ordination based on species ranks (NMDS) shows the same clustering as the DCA (Appendix B Figure 32).

9.1.1 Comparison of exotic- and native vegetation in all forest strata

In both forest areas combined, 30 exotic- and 49 native species were observed. In Area 10 (lowland), 34 native species and 20 exotic species were recorded. In Area 5 (lowland-submontane), 33 native species and 23 exotic species were recorded (Appendix B Table 19). In our all our study areas, cinnamon accounts for 48% of all trees (canopy and understorey), respectively 38% of canopy trees, in secondary forest (pristine and semi-pristine sites excluded). The vast majority of the canopy in all TA except for the semi-pristine and pristine study sites in TA5, currently consists of exotic species (Figure 18). The exotic canopy is dominated by cinnamon, followed by *Hevea brasiliensis* [Kaoutsou] and *Falcataria mollucana* [Albizia] in TA1 and TA3. A significant share of the canopy in TA2 consists of *Sandoricum koetjape* [Santol], followed by Kaoutsou and Albizia. For TA4 and TA6 in the lowland forest, the canopy is dominated by cinnamon, followed by *Tabebuia heterophylla* [Kalis Dipap], and by *Nephrosperma vanhoutteanum* [Latannier milpat] (Appendix B Figure 37). High abundance of the latter results in the relatively high proportion of native species in the canopy stratum in the lowland forest (TA4-6) (Figure 18). TA5 forms the exception with the majority of the canopy consisting of native species - predominantly *N. vanhoutteanum* but also *Phoenicophorium borsigianum, Adenanthera pavonina* and *M. elaeagni* (Appendix B Figure 37). Despite the dominance of native canopy trees in TA5, the second most abundant tree species is still cinnamon. However, cinnamon occurs mainly in the semi-pristine study sites 16 and 17, and is less present in the pristine sites where it is outnumbered by *N. vanhoutteanum* (Appendix B Figure 39)

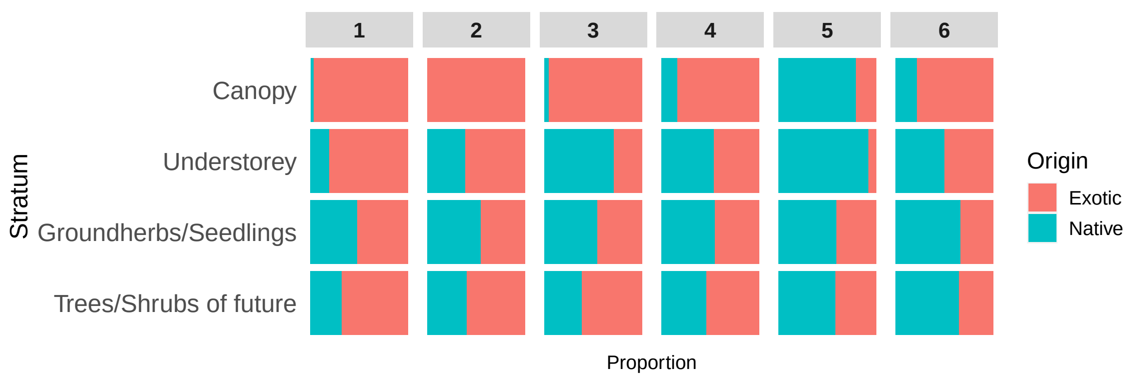


Figure 18: **Proportions of individuals with exotic vs. native origins in all forest strata by treatment area**
Canopy layer shows adult trees with exposed canopy. Understorey shows juvenile trees combined with shrubs corrected for sampling area. Ground/herb seedlings include non-woody species. Trees/shrubs of the future shows only woody species in the ground/herb layer; Oldeman's [1990] set of the present.

We observe a general trend of increasing proportion of native species towards the groundherb/seedlings layer. Compared with the canopy stratum, most TA show a relatively equal proportion of native and exotic vegetation in the ground herb layer. For trees/shrubs of the future (only woody plants in the groundherb/seedlings layer), the proportion of native species is slightly less compared to if non-woody species are included. Special note should be given to TA6's "set of the future" of woody species, which shows a much higher proportion of native trees than the current set of adult trees in the canopy (Figure 18).

9.1.2 Density of exotic and native woody species in canopy- and understorey

Mean overall density (red asterisks) of canopy trees was much lower than density in the understorey in all TA except for TA5, where the difference is only marginal (Figure 19). The canopy tree density of exotic trees was, in all TA except for TA5, higher than canopy tree density of native trees. However, looking at the understorey, in all TA except for TA1, native species show a higher- or at least a similar density compared with exotics. TA6 shows a notably high density of exotic understorey. The density of native trees reaches exceptionally high values in TA5.

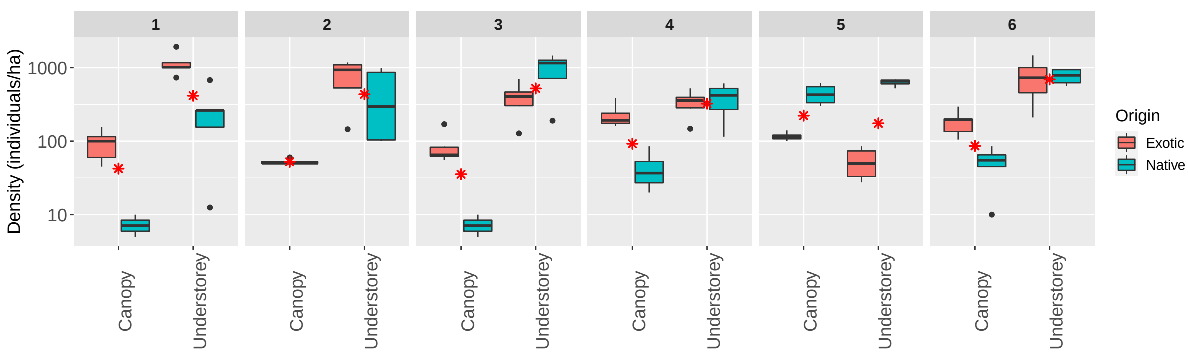


Figure 19: **Canopy- and understorey density (log-transformed) of exotic and native woody species.**
Red asterisks stand for mean density including all individuals regardless of exotic or native origin. TA 3 contains no native species in the canopy, i.e. the red bar is absent.

9.1.3 Coverage in the ground/herb layer

The ground/herb layer is generally the most species rich stratum of the forest with consistently high native species richness (Table 9), including many native ferns (Appendix B Figure 40). This is also reflected in the relatively equal mid-class van der Maarel values of native and exotic species in all TA (Figure 20). Only in TA6, native species show a significantly higher total coverage, as well as the highest ratio of natives vs. exotic species in the ground/herb layer (Figure 18).

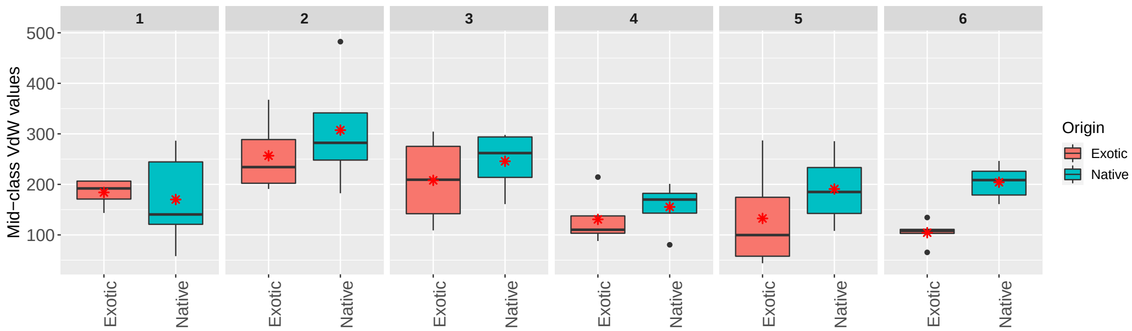


Figure 20: **Percentage of ground cover of native vs. exotic vegetation.**

9.2 Characterizing biodiversity

9.2.1 Biodiversity – a static view

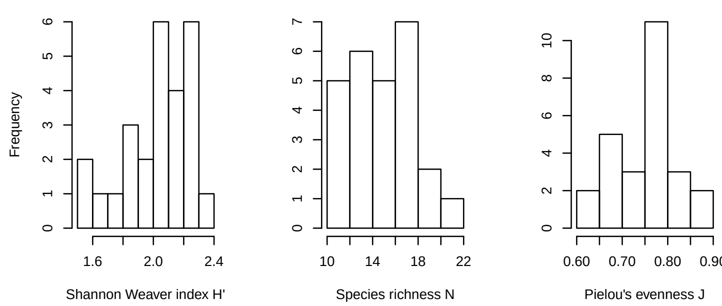
Looking at the composition of adult individuals in all plots (Oldeman's [1990] set of the present), species richness varies from 12 to 21 species in all study sites with most sites containing less than 17 species. Shannon-weaver diversity H' calculated using only adult individuals tends to be higher in lowland-submontane plots but is, in most cases, between 2 and 2.2. The majority of plots show a high evenness around 0.8 (Figure 8b). Semi-pristine study site 15 shows the highest H'. On the other hand, pristine sites 24 and 25 do not show high values for H' (Figure 8a). Many study sites from lowland-submontane forest show high values for H', thus, there is no clear pattern when we look at the species composition of all study sites of adult individuals as a whole.

Table 8: **Static diversity indexes: "Set of the present".**

a) Shannon-Weaver diversity index H', Pielou's evenness J, and total species richness N_{n+e} of all plots based on adult individuals. b) Histogram showing the distribution and variation of diversity indexes.

	Site	H'	J_n	N_{n+e}
low-submontane	1	2.03	0.73	16
	2	2.00	0.78	13
	3	2.03	0.69	19
	4	2.23	0.79	17
	5	2.29	0.83	16
	6	1.87	0.78	11
	7	2.06	0.78	14
	8	2.13	0.83	13
	9	2.29	0.87	14
	10	1.94	0.78	12
	11	2.20	0.78	17
	12	2.15	0.76	17
	13	2.16	0.78	16
submontane	14	1.78	0.69	13
	15	2.39	0.81	19
	16	1.58	0.69	10
	17	2.29	0.87	14
	18	1.57	0.63	12
	19	2.11	0.76	16
	20	2.00	0.66	21
	21	1.80	0.64	17
	22	2.26	0.80	17
	23	1.69	0.73	10
	24	2.01	0.71	17
	25	1.89	0.67	17
	26	2.05	0.76	15

(a)



(b)

9.2.2 Biodiversity – a dynamic view

Looking at diversity of all sampling strata, including juveniles, we observe more differences in respect to species diversity than when looking at Oldeman's [1990] "set of the present". We observe the highest native species richness N_n in the ground/herb stratum. N_n and H'_n is consistently high in all TA in the ground/herb stratum. Besides numerous native pteridophytes (cf. Table 19, which do not occur in other strata, there is widespread regeneration of native woody species (Figure 18) in the ground/herb stratum. However, $\frac{H'_n}{H'_{ex}}$ of the ground/herb layer shows some variation between TA and is significantly higher in TA4 and 5 than in all other plots. Note the low $\frac{H'_n}{H'_{ex}}$ and low evenness in TA6 for the ground/layer.

Table 9: **Dynamic diversity indexes: All forest strata.**

High numbers of native species richness N_n, low numbers of exotic species richness N_{ex}, high H'_n and a high H' ratio of native vs. exotic species diversity are indicate high native biodiversity. Pielou's evenness of native species J_n is added as an indicator of species evenness if J_n is high, respectively, of dominance if J_n is low.

		Tree stratum					Shrub stratum					Ground/herb stratum				
Area	TA	N_n	N_{ex}	H'_n	J_n	$\frac{H'_n}{H'_{ex}}$	N_n	N_{ex}	H'_n	J_n	$\frac{H'_n}{H'_{ex}}$	N_n	N_{ex}	H'_n	J_n	$\frac{H'_n}{H'_{ex}}$
height 5	1	4	9	1.29	0.93	1.40	5	12	0.84	0.52	0.71	19	17	2.30	0.78	1.61
	2	4	6	1.28	0.92	1.17	5	4	0.70	0.44	0.83	17	11	2.02	0.71	1.80
	3	3	10	1.06	0.97	0.84	8	12	1.32	0.64	0.70	24	16	2.43	0.76	1.45
	4	9	6	1.82	0.83	1.81	8	4	1.41	0.68	1.25	19	8	2.04	0.69	2.46
10	5	15	3	1.32	0.49	2.18	9	2	1.19	0.54	3.41	17	8	1.74	0.61	2.38
	6	11	11	1.43	0.59	1.36	8	9	1.20	0.57	2.21	22	11	1.78	0.57	1.29

In the tree stratum, the lowland forest in Area 10 generally shows a higher overall species richness than Area 5 (Table 9, cf. Appendix B Figure 36), with TA5 reaching 15 native tree species. Despite the high number of native trees in TA5, H'_n is relatively low. This is explained by exceptionally high abundance of endemic palms in pristine and semi-pristine study sites (Appendix B Figure 37), which is additionally reflected in low evenness J_n in TA5 (Table 9). However, $\frac{H'_n}{H'_{ex}}$ in TA5 shows yet the highest value of all TA in the tree stratum. The shrub stratum shows consistently low J_n and relatively low H'_n. TA5 stands out with the highest $\frac{H'_n}{H'_{ex}}$ value and only two exotic species. On the other hand, we recorded high numbers of exotic species in the shrub sampling strum of TA1, 3 and 6.

Looking at the biodiversity of woody species in the ground/herb layer, we observe higher native species richness N_n in Area 5 compared to the current set of adult trees 10. TA3 shows much higher species richness in its understorey and ground/herb layer. For the lowland forest, this trend is in the opposite direction: N_n is currently higher in the current tree stratum in all TA of Area 10 as compared with the next set of trees in the ground/herb layer. Species richness of exotic trees N_{ex} of set of trees of the future is notably higher in all TA except for TA4 and 6, where the difference is marginal 10. Notably the "set of the future" in TA4 shows very similar indexes as TA5.

Table 10: **Diversity of the set of the future.**

Diversity indexes calculated only for all woody species in the ground/herb stratum.

		Woody species of the future)				
Area	TA	N_n	N_{ex}	H'_n	J_n	$\frac{H'_n}{H'_{ex}}$
	1	5	14	1.03	0.64	0.86
5	2	7	9	1.14	0.58	1.08
	3	9	12	1.39	0.63	1.16
	4	9	7	1.57	0.71	2.07
10	5	9	6	1.46	0.66	2.40
	6	13	10	1.40	0.54	1.18

9.3 Forest succession

Relative mid-class van der Maarel values of woody species as seedlings in the herb layer against the corresponding relative abundances as saplings/juveniles in the shrub layer are depicted in Figure 43. We applied the same concept to saplings/juveniles in the shrub layer vs. adults in the tree layer 23 to visualize the future composition of adult trees. Species more frequent in the younger layer are assumed to become a more dominating part of the vegetation in the future as they currently are.

We observe that in TA3, TA5, and TA6 there are a few exotic species, which are clearly more frequent in the herb layer (Figure 43). However, regarding TA6, it needs to be noted that the mean coverage of exotic species in the ground herb layer is the lowest of all TA (Figure 20). In TA1 we can see that most native species, (*Nephrosperma vanhoutteanum [Nv]*, *Deckenia nobilis* [Dn] *Pterocarpus indicus* [Pi]), *Adenanthera pavonina* [Ap] and *Phoenicophorium borsigianum* [Phb]) show higher frequencies in the ground/herb layer while the majority of exotic species, except for cinnamon and a few exceptions, are less represented in the ground/herb layer than in the shrub layer. We observe similar trend in TA6, where most native plants are more frequent in their seedling stage with six of them being only present in the herb layer. Lastly, TA5 shows high frequencies of endemic palms *Phoenicophorium borsigianum, Nephrosperma vanhoutteanum* in both layers, while in the shrub layer endemic palms are more frequent than in the herb layer. Both of the two exotic species recorded in TA5 are more frequent in the herb layer, indicating some exotic rejuvenation in pristine and semi-pristine forest.

Looking at relative tree vs. shrub frequencies, we observe that most (except *Verschaffeltia splendida*) of the few native species are more frequent in the shrub layer, while exotic species are less frequent in the layer of juveniles. Cinnamon [Cv], *Hevea brasiliensis* [Hb] and *Falcataria moluccana* are the most abundant trees in all lowland-submontane plots (TA1-3) (cf. Figure 39) but clearly underrepresented in the shrub layer (Appendix B Figure 23. For the two forest areas with clear signs of former agricultural use (TA4 and 6) in the lowland forest, we see a similar pattern for endemic palms, which are more frequent in their juvenile stage. *Memecylon eleagni* is also a candidate native species, which shows healthy regeneration. TA5 shows relatively equally distributed frequencies, with *Draceana floribunda* as the only exception with clearly higher frequency in its juvenile stage.

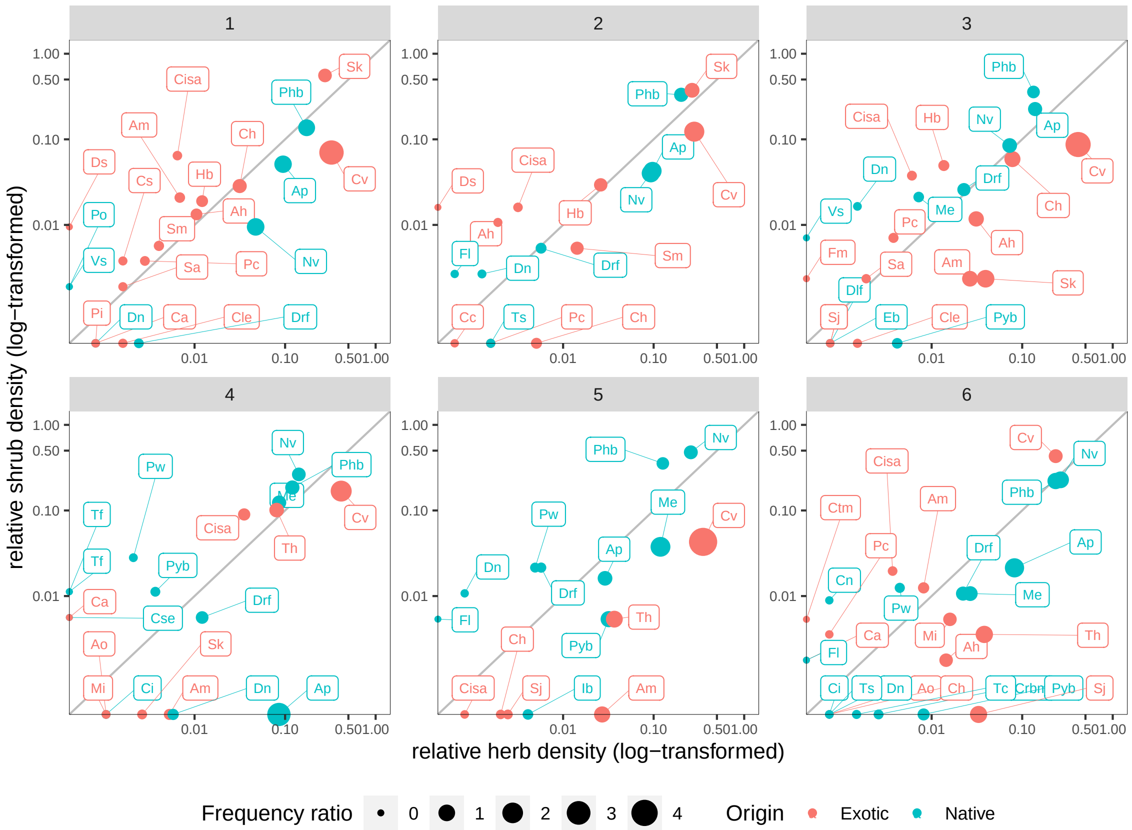


Figure 21: **Forest succession 1: juvenile trees of the future**
Relative densities of woody species in the herb layer vs. shrub layer. Any species below the diagonal is relatively more frequent in the younger layer than in the more adult layer. On the diagonal relative abundances in both sampling layers are the exact same. The point size indicates the density ratio. The bigger the point, the higher the divergence of frequency in herb- vs. shrub layer is. Axes are log-scaled as most species are rare. For species abbreviations see Appendix B Figure 21

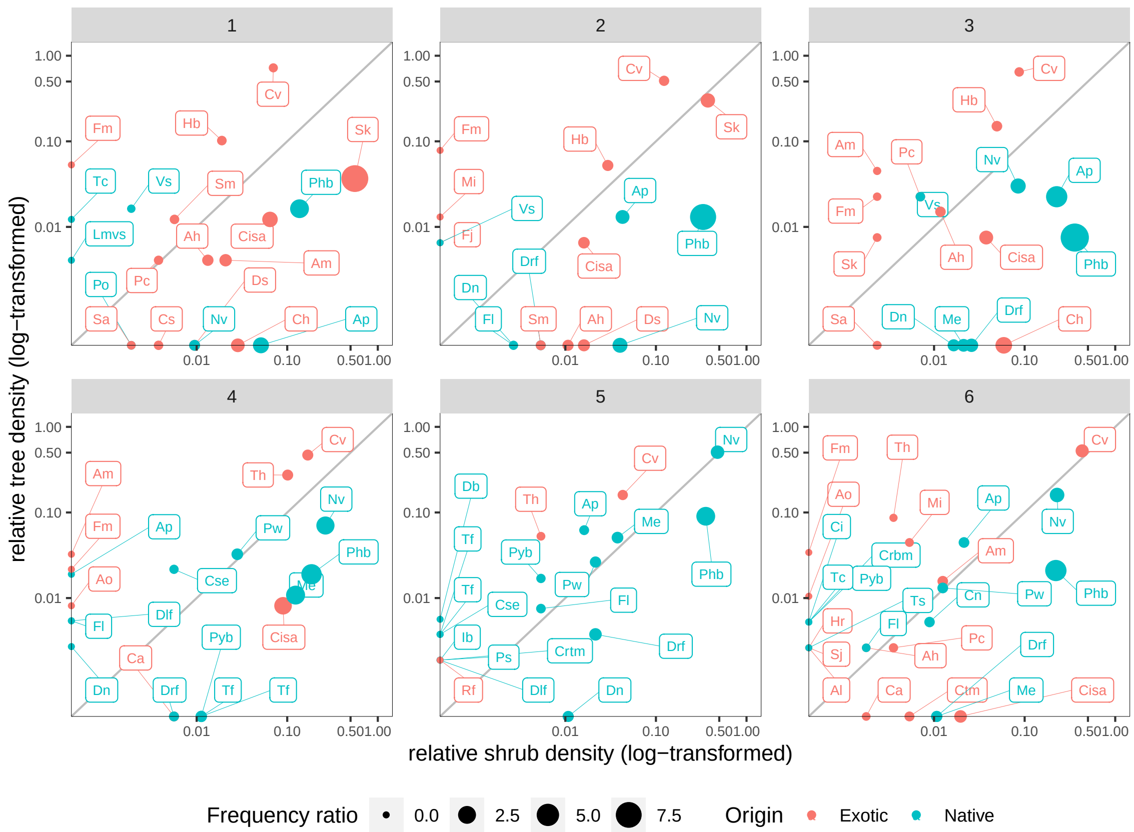


Figure 22: **Forest succession 2: adult trees of the future.**
Relative densities of woody species in the shrub layer vs. tree layer.

9.4 Trail-transects – the assessing the landscape of area 5 and 10

In both areas, most species show low prominence values. Cinnamon, *Sandoricum koetjape* [Santol] and the endemic palms (*Nephrosperma vanhoutteana* [Latanier milpat] and *Phoenicophorium borsigianum* [Latanier fey]) form exceptions and show high divergence between juvenile and adult layer. Cinnamon is more prominent as an adult tree whereas endemic palms (Nv and PhB) are more prominent in the juvenile layer. Santol is very prominent in area 5 as a juvenile. Endemic palms are much more prominent in the juvenile layer of both areas. While native species are slightly more prominent in the juvenile layer in area 5, general patterns regarding species origin are absent. However, in area 5, more species group below the diagonal, indicating higher species richness in the juvenile layer of the landscape in the lowland-submontane forest. In the lowland forest of area 10, numbers of species above- and below the diagonal are more equal.

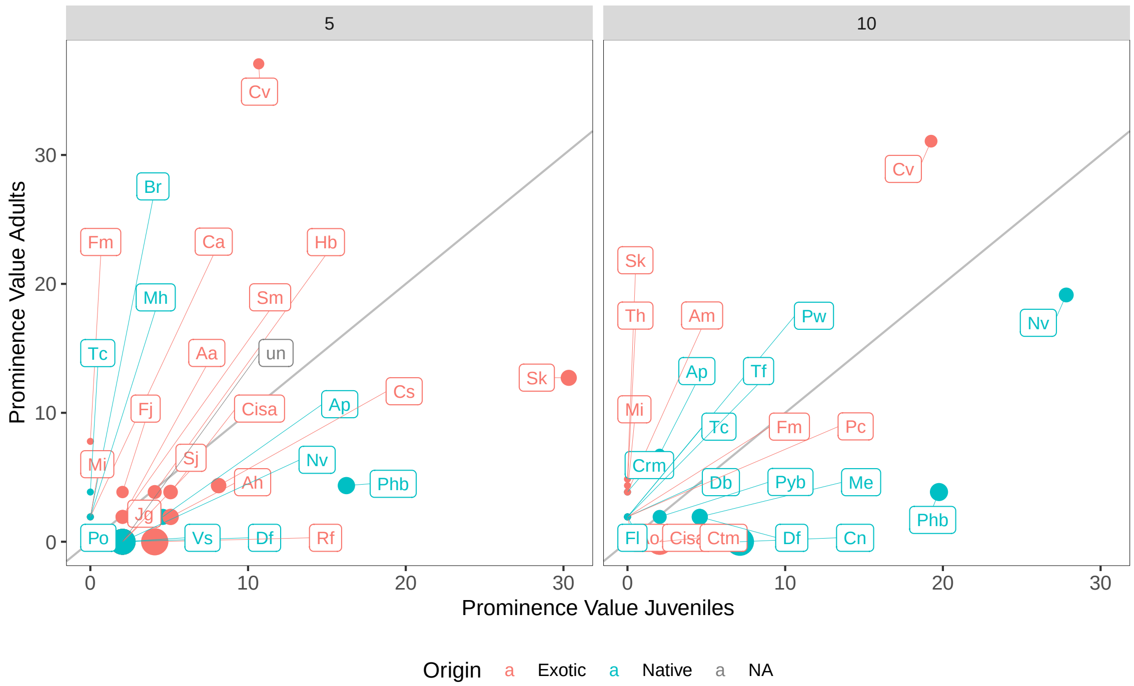


Figure 23: **Prominence values of juveniles vs. adults in trail transects.** Any species below the diagonal is relatively more prominent in the juvenile life stage than in the adult life stage. On the diagonal, prominence in of juveniles and adults are the same. For species abbreviations see Appendix B Figure 21

10 Treatment assignment for rehabilitation

In order to later discuss the results from the baseline study, we here specify which treatments will be used for the six treatment areas (TA) in the rehabilitation areas. These decisions have been made based on the results of this baseline inventory in correspondence with Bruno Senterre, James Millett and Maria Monthy. A detailed rehabilitation plan for the water catchment is currently being designed by Maria Monthy, and is in line with the assignment of treatments presented below.

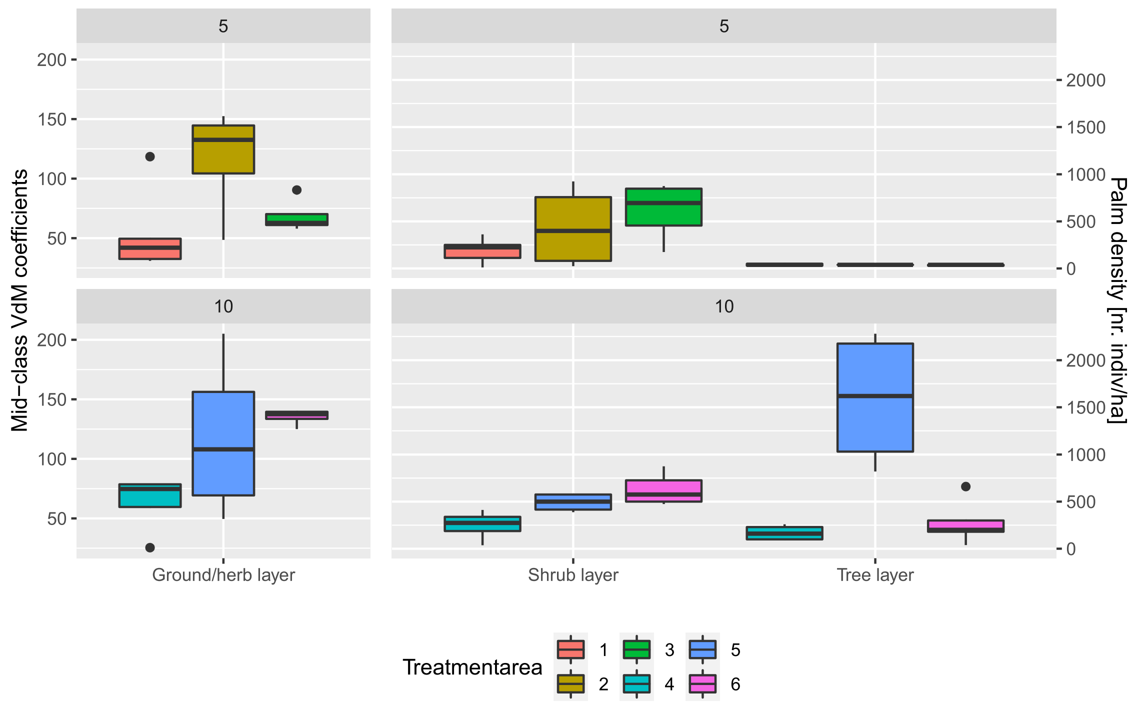


Figure 24: **Palm occurrence in all TA.**

Densities and mid-class van der Maarel (VdM) coefficients were summed up in all layer by plot and averages for all plots in every TA were taken for both study sites (5=lowland-submontane, 10=lowland).

Average density of palms in the tree and shrub layer is currently the lowest in TA1 and TA4 (Figure 25). The same pattern is reflected for the ground/herb layer, where mid-class VdM coefficients for palms are lower for TA1 and TA4. Palms are practically missing in the tree layer of all TA in the lowland-submontane forest, whereas in the lowland forest they grow very densely in TA5 and also occur in the tree layer of the other two TA. We therefore decided to use endemic palms as the main restoration species in TA1 and TA4. We recommend to use broadleaf species in TA2 and TA6 where there are already more palms in the understorey.

Regarding the assignment of the control areas, we considered the following: currently, there is no noticeable difference in the native:exotic ratio of woody species in the ground/herb layer (Oldeman's [1990] "set of the future") between all TA of the forest Area 5 (Figure 18), and the biodiversity indexes only show some minor differences between TA1-3 (Figure 10). However, mean abundance of palms in the shrub layer of the TA3 is currently even higher than in the pristine/semi-pristine TA5, resulting in a higher ratio of native species in the understorey in TA3 (Figure 18). Additionally, TA3 is located further up the slope in the lowland-submontane forest (Figure 48) and therefore, harder to reach. This makes TA3 a suitable control treatment area to follow natural succession of the native understorey in the lowland-submontane Area 5. Yet the overall floristic composition is not different from the other two TA, providing a good experimental baseline to test the use of broad leaf vs. endemic palms in planned rehabilitation (Figure 17).

For the lowland forest Area 10, there is no need for rehabilitation in TA5 as it is already in an exceptionally original state. This means that there is no real control treatment in forest Area 10. Especially site 24 and 25 in TA5 serve rather as a reference point for rehabilitation than as a control. Native species richness is slightly lower compared to natural lowland forests on Silhouette (cf. [Senterre and Baguette, 2020]) with a few species missing in our study sites (e.g. *Allophyllus pervillei, Allophyllus sechellensis, Psychotria pervillei, Mimusops sechellarum, Pandanus balfouri, Jasminum fluminense ssp. mauritianum*), while we recorded one more tree species which was not found during the recent Silhouette survey (*Craterispermum microdon* [Bwa doux]). However, TA5 still serves as a good proxy for original lowland forest. We point out the presence of at least three adult individuals of *C. microdon* within and surrounding the pristine forest sites - another species suitable for rehabilitation with seed material in close proximity. (*Craterispermum microdon*) is known to be used by herbalists, and has nowadays only a narrow distribution because of overharvesting in the past [Matatiken et al., 2011]. We found, however, no natural regeneration of *C. microdon* in the study sites [Senterre et al., 2012a].

Table 11: **Summary of rehabilitation treatments.**

Diversifying restoration species are suggested to use in broad leaf tree treatment areas.

TA	Type	Main rehabilitation sp.	Diversifying rehabilitation sp.
1	Palms	*Phoenicophorium borsigianum* [Latanier fey], *Nephrosperma vanhoutteana* [Latanier milpat] (+ *Deckenia nobilis* [Palmist])	-
2	Broadleaf	*Planchonella obovata* [Bwa mon per], *Dillenia ferruginea* [Bwa rouz]	*Mimpusops seychellarum* [Bwa-d-nat], *Terminalia catappa* [Bodanmyen], *Calophyllum inophyllum* [Takamaka], *Diospyros boiviniana* [Bwa Sagay], *Memecylon eleagni* [Bwa kalou], *Tarenna sechellensis* [Bwa dir ble], *Pyrostria bibracteata* [Bwa dir rouz], *Craterispermum microdon* [Bwa doux], *Paragenia wrightii* [Kafe maron gran fey], *Timonius flavescens* [Bwa kasan-d-montanny], *Brexia microcarpa* [Bwa kato], *Northea hornei* [Kapisen], *Syzygium wrightii* [Bwa-d-ponm], *Vateriopsis sechellarum* [Bwa-d-fer], *Campnosperma seychellarum* [Kapisen blan], *Drypetes riseleyi* [Bwa mare pti fey] (+ in ravines: *Verschaffeltia splendida* [Latanier lat] and *Martellidendron hornei* [Vakwa parasol]) (+ along water streams *Barringtonia racemosa* [Bonnen kare-d-larivyer] and *Martellidendron hornei* [Vakwa parasol])
3	Control	-	-
4	Palms	*Phoenicophorium borsigianum* [Latanier fey], *Nephrosperma vanhoutteana* [Latanier milpat] (+ *Deckenia nobilis* [Palmist])	-
5	Control	-	-
6	Broadleaf	*Calophyllum inophyllum* [Takamaka], *Dillenia ferruginea* [Bwa rouz]	*Terminalia catappa* [Bodanmyen], *Planchonella obovata* [Bwa mon per], *Mimusops seychellarum* [Bwa-d-nat], *Intsia bijuga* [Gayak], *Premna serratifolia* [Bwa siro], *Memecylon eleagni* [Bwa kalou], *Ludia mauritiana var. sechellensis* [Pti prin], *Diospyros boiviniana* [Bwa Sagay], *Adenanthera pavonina* [Lagati], *Phoenicophorium borsigianum* [Latanier fey], *Nephrosperma vanhoutteana* [Latanier milpat], *Deckenia nobilis* [Palmist], *Trilepisium gymnandrum* [Bouskiya], *Psychotria pervillei* [Bwa koulev]

Regarding the choice of broadleaf tree species for rehabilitation, it is important to consider that lowland and lowland-submontane areas have different characters; Since Area 10 is in lowland forest and Area 5 is at the transition to submontane forest, the choice of the restoration species will not be the same. We recommend *Planchonella obovata* [Bwa mon per] as the main broadleaf species used in Area 5 together with *(Dillenia ferruginea)* [Bwa rouz]. In the lowland forest in Area 10, mainly *(Calophyllum inophyllum)* [Takamaka], and *(Dillenia ferruginea)* [Bwa rouz] will be used (Table 11). The selection of other diversifying species is guided by the composition of TA5 of this study as well as previous recommendations for rehabilitation in the water catchment and the characterizing species of lowland forest on Silhouette [Senterre and Baguette, 2020].

11 Discussion

The key objective of Part II is to provide a baseline study of the present vegetation in the lower Mare aux Cochons water catchment for future rehabilitation as part of the EbA project [UNDP, 2012]. We characterized the current forest composition in 26 permanent forest plots with a focus on species origin (exotic vs. native) and biodiversity. This baseline additionally allows for the study of natural forest succession in secondary lowland and lowland - submontane rainforest typical for the Morne Seychellois National Park. As we located around 1 ha of pristine forest inside the area designated for rehabilitation, we also studied the vegetation in one of the rare remaining remnants of original forest in Seychelles. Besides the main purpose to evaluate rehabilitation success in the Park in the future, this study provides a foundation to test the novel ecosystem hypothesis, i.e. if a new steady state with an entirely new species composition has been reached in Seychelles, or if secondary forests, characterized by an exotic canopy but noteworthy regeneration of native and endemic species, are still part of a dynamic successional progression with unknown outcome.

11.1 Reflections on historic land use

Before discussing our findings, we consider it important to place our research within the short historical background of the study area and Mahé as a whole. Sauer and Pickersgill [1968] and John Procter in chapter 33 of Stoddart [1986, p. 641] give detailed insights into the social- and floral history of Seychelles:

The vegetation on Mahé had already caught the attention of the first sailors, who set foot on the island. Trees were described as "fine timber suitable for great masts" or "straight as a an arrow" [Pickersgill and Sauer, 1968] - potentially referring to massive stands of *Vateriopsis seychellarum* [Bwa de fer] [Steers and Stoddart, 1985]. Descriptions of *Mimusops sechellarum* [Bwa-d-nat] and *Calophyllum inophyllum* [Takamaka] in lower elevations with heights over 20 m and around 1.5 m diameters can unmistakably be identified from journals of early explorers in the eighteenth century [Vesey-Fitzgerald, 1940]. However, this type of forest disappeared soon after colonisation started: in the late eighteenth century, the French colonists started growing spices and crops, and for a long time they lived from agriculture and exploiting forest products. First botanists who visited the island by the end of the 18th century wrote "it was only in a few spots near the summits of the hills that he could perceive any remains of the ancient flora" and further note how bamboo and particularly "...pineapple growing almost to the top, killing native flowers" [Procter, 1973]. Important components of the agricultural economy of Seychelles were coconut plantations (*Cocos nucifera*), which expanded in the mid-nineteenth century, followed by vanilla cultivation (*Vanilla planifolia*) which peaked in the later nineteenth century. While cinnamon was introduced early by the first colonists and became progressively naturalized in open spaces, it was not heavily utilised until the start of the 20th century. The start of the cinnamon era marked a second wave of deforestation, as firewood was needed in the distillation process of cinnamon oil. In 1938, 82 cinnamon-leaf-oil distilleries existed throughout the forests in Mahé alone, consuming an "enormous amounts" of firewood. Eventually, a shortage of firewood, and then a price drop in cinnamon oil dawned the end of the cinnamon era [Vesey-Fitzgerald, 1940, Steers and Stoddart, 1985]. Starting in 1950, active reforestation and erosion control of exotic species such as *Tabebuia heterophylla* [Kalis dipap], *Sandoricum koetjape* [Santol], *Chrysobalanos icaco ssp. atacorensis* [Cocoplum] but also with *Calophyllum inophyllum* [Takamaka] were carried out [Steers and Stoddart, 1985].

Within two centuries, logging, clearing, fire, cultivation, and secondary succession replaced original forest with a mosaic of diverse communities. Undoubtedly, forests have undergone profound modification in Seychelles since its discovery. Nevertheless, today forests cover 66.7%[4] of Seychelles – which is high for small island developing countries [Wilkie et al., 2004]. The EbA project aims to strengthen the integrity of secondary forest landscapes surrounding the water catchment Mare aux Cochons by removing exotic species and re-colonize with native plants. Thereby native habitats can be reestablished, and at the same time the conservation value of the whole forest landscape in the catchment is increased, which (indirectly) supports conservation efforts of the whole water catchment in times of development pressure (cf. Chapter 2.1).

Here, we discuss the outcome of our baseline vegetation study conducted in two components of this diverse mosaic of forests in Seychelles[5]; pristine lowland palm forest, and secondary plantation- or former agricultural forest. Both are located in the lower Mare aux Cochons water catchment.

11.2 Rehabilitation - where and how can we measure success

What the best indicators and variables are to measure rehabilitation success is not conclusively answered. Validating the reliability and accuracy of indicators requires long term monitoring and reassessments, which are only scarcely available in the relatively young discipline of restoration ecology [Boelsums Barreto Sansevero and Luȷs Garbin, 2015], resulting in a wide range of indicators in "trial phase". In an attempt to structure this unorganised variety of indexes, the Society of Ecological Restoration International (SER) recommended three major ecosystem attributes to measure restoration success: vegetation structure, forest diversity, and ecological processes [Ruiz-Jaen and Aide, 2005]. Moreover, community compositional changes are commonly used as reference for restoration and as descriptors for success [Lane and Texler, 2009]. Here, we present two of three proposed ecosystem attributes by SER (vegetation structure and diversity), from which we derive four status indicators presented in detail in Chapter 8.5 (Understorey nativeness USN, Native regeneration NR, richness index RI, and diversity index DI by which forest rehabilitation in the lower Mare aux Cochons catchment can be evaluated. Furthermore, we describe the community change approach and how plant community descriptions can be used to assess rehabilitation success.

[4]The estimate by Seychelles forest management in 1993 estimates forest cover with 90% [Kueffer and Vos, 2004]

[5]Elzein [2011], Senterre [2009], Senterre et al. [2009], and Senterre & Baguette [2020], previously conducted similar assessments in low- and upper montane forest on Mahé, respectively on Silhouette.

11.2.1 Structural changes

Vegetation structure can be characterized by the dominance of different ecological groups (in our case exotic- and native species), at different layers (ground/herbs, shrubs, trees) [Boelsums Barreto Sansevero and Luȷs Garbin, 2015]. Our results show high densities of exotic understorey in all TA, except for the two control treatments (Figure 19), and clear differences in ratio between exotic and native species in all forest strata (Figure 18). The change in the absolute density of exotic understorey vegetation can be used to evaluate effective removal of exotic species because rehabilitation primarily tackles exotic species in the understorey to avoid openings of the cinnamon canopy in order to maintain a shady understorey[6]. Moreover, exotic regeneration in the ground/herb should be suppressed in the case of successful rehabilitation, while the planting of native broadleaf or endemic palm species will enrich Oldeman's [1990] "set of the future" with native woody species. We capture this structural component in the first two status indicators Understorey Nativeness USN and Native Regeneration NR (Table 8.5).

11.2.2 Changes in diversity

Regarding the second ecosystem attribute to evaluate restoration suggested by SER, diversity, we first need to point out some differences in the suitability of our biodiversity indexes to accurately measure rehabilitation success. Our biodiversity indexes can be grouped into two categories: static, using Oldeman's [1990] "set of the present" species as inputs (Table 8), and dynamic, which separates the flora data into forest strata (Table 9) – additionally including Oldeman's [1990] "set of the future" (Table 10). The dynamic biodiversity indexes are more useful for evaluation of rehabilitation as we describe below; the main reasons are that there are no major differences in biodiversity within the static "set of the present". Therefore, we used dynamic biodiversity indexes to derive the second two status indicators; Richness Index RI and Diversity Index DI in Table 8.5.

Even though we do not include static diversity indexes in status indicators to evaluate rehabilitation success, does not meant they are not informative. However, there are several considerations that first need to be discussed in regard to interpreting static indexes from Tab.8. Table 8 is calculated based on Oldeman's [1990] set of the present (i.e. only looking at adult species in their typical synusia). This allowed us to quantify the present state of diversity in a complex ecosystem in simple numbers and answer the second part of research question (vi), which had the goal of describing the present biodiversity of the forest. Currently, diversity of the forest composition as a whole, based on adult individuals, does not show any clear differences (Figure 9). Values of Shannon Weaver diversity H' around 2, as reached in numerous sites, are lower compared with other tropical rainforests which may reach values up to 5 [Tchouto et al., 2006] and tropical secondary forests [Capers et al., 2005, Onyekwelu et al., 2008]. Seychelles' native flora is indeed relatively species poor with only 376 vascular plant species described in the whole habitat range, out of which over 24% are endemic [Senterre et al., 2013] (cf. Amazonian or Cameroonian rainforest where several hundreds of species occur in one vegetation type [Gentry, 1982, Tchouto et al., 2006]). Our forest sites in the lowland forests of the MSNP in the lower water catchment revealed 79 different species in both forest areas out of which 49 are native (indigenous or endemic). However, maximum species richness per study site only exceeded 20 species once (site 20) (Figure 8a), demonstrating the difference in local vs landscape levels, i.e. the beta-diversity. Interestingly, using the metric of H' for the set of the present, there are many forest sites with higher diversity than the two pristine forest sites 24 and

[6] More reasons are explained in Chapter 7.1

25, indicating that the diversity of secondary rainforest does not necessarily need to be lower than in pristine forest.

The above methods only represent a static picture of the vegetation in the lower water catchment and ignores juveniles of woody species and species origin. In this way, however, we lose a lot of information. Moreover, the interpretation of H' as a stand-alone value can be misleading [Duelli and Obrist, 2003, Kim et al., 2017]. H' is an inverse measure of entropy and therefore this metric is strongly affected by uneven community compositions - in other words, the highest H' values are achieved if every species has the same number of individuals (=unordered, low entropy). As forests in Seychelles are dominated by either cinnamon or by palms (TA5), they are highly uneven (=very ordered, high entropy) and all forest types receive relatively low values for H'. As long as there is a dominating species, every additionally recorded species only has a marginal effect on H'. Particularly both pristine study sites 24 and 25 naturally show high densities of endemic palms and are among the most uneven sites (Table 8). Consequently, the few additionally recorded individuals of very rare species, such as *Intsia bijuga* [Gayak] or *Craterispermum microdon* [Bwa doux], are not adequately reflected in H' of pristine sites and both forest types receive an average value around 2 for H'. Therefore, in near future reassessments of biodiversity, H' of all study sites is unlikely to change as high abundance of cinnamon in the canopy will inhibit significant increases in H' when merely looking at adult species (Table 8). Only in a scenario where adult cinnamon trees are replaced by native adult trees, will H' overall serve as a useful metric to measure increases in biodiversity.

Dynamic biodiversity indexes, on the other hand, reveal more differences between forest areas and TA because they consider every forest as distinct, and include juveniles as well as the set of "woody species of the future". Additionally, Tab.9 and Tab. 10 separate diversity indexes for native- and exotic species, which is useful because rehabilitation aims to increase diversity of native species, and not diversity of exotic species.

Unlike when looking at adult species alone (cf. Table 8), (semi-)pristine TA5 now stands out from all other TA with a higher native species richness N_n and a higher values for $\frac{H'_n}{H'_{ex}}$, while showing low exotic species richness $H'_{ex}x$ in all strata. Table 10 additionally displays diversity indexes for the "set of the future" – the subset of all woody species in the ground/herb layer. A comparison with diversity indexes of adult trees in the tree stratum allows some interesting conclusions; Secondary forests in the lower water catchment will likely show higher native- *and* higher exotic species richness in the future. As exotic species in the understorey are removed in TA that are rehabilitated, this predicted increase in species richness will be interesting to monitor and compare between control- and rehabilitated TA after rehabilitation. It is noteworthy though that $N_e x$ in TA5 is relatively high indicating some level of invasion of juvenile exotic woody species. However, this can be explained mostly by the mere fact that two semi-pristine plots are included in TA5. Because Table 9 provides a more detailed insight into patterns of diversity between TA, we derived the second two status indicators from species richness and $\frac{H'_n}{H'_{ex}}$ resulting in the Richness index RI and diversity index DI respectively. We suggest to use these two status indicators as they summarize all essential information from calculated biodiversity indexes.

11.2.3 Community changes towards reference original remnant community

To our knowledge, the only published study conducted in Seychelles, which assessed the state of forest prior to rehabilitation, used such community changes as a metric to evaluate the outcome of different treatments for removal of exotic species [Kaiser-Bunbury et al., 2015]. They analysed the outcome of different treatments using the same ordination method to test for changes in community composition as we used (Figure 17, Appendix Figure 32) (non-metric multidimensional scaling with the `NMDS`-function of the vegan package). Therefore, our baseline study allows for the same approach to assess rehabilitation success in the four treatment areas in the water catchment. However, unlike Kaiser-Bunbury et al. [2015], we include a reference of an original forest remnants which is clearly distinct in its composition from secondary forest (Figure 17) and shows no visible signs of past human interference. Pristine, undisturbed ecosystems are the key component in the definition of restoration. Thus, TA5 provides a reference for in which direction species communities should change in order to successfully re-establish native forest. A reassessment of the community composition (with a focus on juvenile trees) after rehabilitation can reveal how the forest community changes; if the composition of lowland study sites shifts closer to the pristine and semi-pristine sites in the DCA (Figure 17) (or compare NMDS; Appendix Figure 32), rehabilitating native forest can be considered successful.

11.2.4 Summary of Indexes for reassessment in the future

We summarized our findings represented in the result section in four status indicators tailored to measure rehabilitation success in simple numbers (Table 8.5. The first two status indicators, Understorey Nativeness USN and Native Regeneration NR, capture compositional properties within different forest layers (canopy, understorey, ground/herb, as well as Oldeman's [1990] "set of the future") in respect to species origin. USN and NR are calculated based on data visualized in Figure 18 (cf. Appendix B Figure 35). The second two status indicators, Richness Index RI and Diversity Index DI are based on data from Table 9 and collapse several diversity indexes across forest strata inventories into two status indicators per TA. The Richness Index is a measure of species richness and DI is summing up Shannon Weaver diversity index-ratios between native- and exotic species over all forest strata. Detailed calculation of all indicators can be found in Chapter 8.5

Table 12: **Summary of all treatment areas and indexes:**

TA	Area	Treatment	State	USN	NR	RI	DI
1	5	Palms	secondary	1.16	0.43	42.42	3.72
2	5	Broadleaf	secondary	1.83	0.62	50.00	3.22
3	5	Control	secondary	3.60	0.61	50.79	3.89
4	10	Palms	secondary	2.33	0.83	66.67	5.53
5	10	Control	(semi-) pristine	12.97	1.34	75.93	7.97
6	10	Broadleaf	secondary	2.96	1.68	56.94	4.86

We refrained from further simplification of indicators into "quality" groups (cf.[Fleischmann, 1997]) because not enough comparisons of native "high quality" forest are included in this baseline. However, we see a clear differentiation of (semi-) pristine TA5 in all four status indicators, indicating "high quality" features desirable to reach in rehabilitated forest.

Finally we conclude that a combination of a quantitative assessment of the vegetation community shift towards the original reference TA5 and a reassessment of the four status indicators provided in the baseline should allow for a solid evaluation of rehabilitation success in the lower catchment area.

11.3 How novel are compositions, and how novel will they remain?

Pristine study sites 24 and 25 are highly dominated by palms. Being surrounded by secondary forest, the palm forest may have been left untouched due to its very nature when the area was deforested; palm wood was not considered valuable for timber products as compared to hard woods [Pickersgill and Sauer, 1968]. The complete absence of adult native hardwoods in semi-pristine sites 16 and 17 may, on the other hand, be a sign of timber harvesting in the past. However, no cinnamon coppices are present in any of the semi-pristine and pristine sites, indicating no active cinnamon cultivation in TA5. It is therefore very likely that the forest in TA5 has never been clear-cut or actively managed while the surrounding forest shows clear signs of agroforestry and cinnamon plantations. The species composition, particularly in the pristine sites 25 and 24 is unique among all study sites (Figure 17) with some rare adult hard woods (e.g. *Intsia bijuga* [Gayak] and *Craterispermum microdon* [Bwa doux]).

Figure 25: **Original lowland palm forest in permanent plot 24 of TA5.**
Plot 24 and 25 show practically no signs of human disturbance and present an example of relict native lowland forest on Mahé.

According to the most up to date GIS resources access through the web feature service of the Ministry of Habitat, Infrastructure, and Land Transport (MHILT), the whole study Area 10 is not included in the National Park. However, protecting these last relict native forest communities around TA5 is crucial as they feature the last remnants of practically undisturbed native lowland flora on Mahé, which could also be useful for rehabilitating other forest areas on Mahé. The importance of intact original forest remnants for conservation of biodiversity and successful restoration has been extensively discussed [Wintle et al., 2019, Parrotta et al., 1997]. The close proximity of a small patch of original native vegetation can facilitate rehabilitation work by providing seeding material, analytical reference as described in Chapter 11.2, and within education use as discussed in Chapter 12.

However, we recorded exotic species in the undergrowth of both pristine study sites (Figure 17), indicating a low level of invasion by exotic species. Species invasion is currently mostly limited to the ground herb layer and adult trees, while there are virtually no recording of exotic species in the shrub layer of the pristine forest. On the other hand, in all other treatment areas besides TA5, the ratio of native juvenile trees (set of the future) is higher than the present set of adult trees (Figure 18), with many native species being more abundant in the understorey compared to their adult counterparts in the tree layer (Figure 23, cf. general linear model included in Appendix B Figure 44 for general trends). This could indicate a shift towards more native composition in secondary forests in the future. Most notably, the control area TA3 shows exceptional ratio differences between shrub- and tree layer for endemic palms and almost all other native species (Figure 44) and high Understorey Native Richness USN (12). Similarly, TA6 shows the highest Native Regeneration RI status indicator of all TA. This trend is mainly due to high abundance of endemic palms in the younger forest strata. The promising prospects of Phoenicophorium borsigianum [Latanier fey] and *Nephrospermum vanhoutteanum* [Latanier milpat] thriving below the cinnamon dominated canopy [7] were already pointed out in pioneering work of Fleischmann [1997]. A look at the younger two layers and their relative native:exotic ratio, however, shows that this trend is not consistent in the herb/shrub layer comparison, where most native woody species are (relatively) less frequent in the younger layer than exotic species (Figure 43). Likewise, the absolute coverage in the ground/herb layer shows high coverage of exotic species in TA3. This inconsistency may have to do with unequal growth rates from seedling to saplings between different species due to limited light availability. It needs to be noted that our succession visualizations are valid under the assumption that all species have the same likelihood to grow into adults and grow at the same speed. Differences in growth strategies and survival probabilities are inherent species characteristics and therefore, our extrapolations need to be interpreted carefully. Therefore, it is impossible to predict a clear and consistent future trend across all strata for the control areas TA5 an TA3 at this point of time.

Monitoring whether the exotic woody species of the future in TA5 (Figure 18) will grow into juvenile exotic trees, and if the dominating native flora in control TA3 can outnumber exotic regrowth in the future, will help to understand dynamics of species invasion in Seychelles and give quantitative insights in natural forest succession. What we can conclude from our data, even if the assumption of equal growth rates for all woody species is made, is that a steady state has likely not yet been reached, and secondary forests in the lower Mare aux Cochons water catchment are still in a transient mode.

It has been argued that simply not enough time has passed to predict outcomes of recent species invasions. In most studies, the time of invasion dates back less than a hundred years, or is not even mentioned [Strayer et al., 2006]. Similarly, many exotic species (e.g. *Clidemia hirta* [Fo watouk], *Alstonia macrophylla* [Bwa zom], *Tabebuia heterophylla* [Kalis dipap], *Sandoricum koetjape* [San-

[7] Our results reveal that the canopy of the lower catchment is currently dominated by exotic species in all TA (except for TA5). 48% of all trees and 52% of all trees with exposed canopies (excluding pristine and semi pristine forest sites) are cinnamon trees. This significantly less as the previously mentioned 80%, respectively 70-90%, [Kueffer, 2010, Kueffer et al., 2010].

tol], *Chrysobalanos icaco ssp. atacorensis* [Cocoplum]) were very recently introduced in Seychelles [Kueffer and Vos, 2004, Steers and Stoddart, 1985]. Therefore, evolutionary and ecological processes are in an early phase and it may be too early to draw general conclusions about the fate of Seychelles' secondary forests. There may be examples where ecological thresholds were crossed resulting in irreversible novel states. As we show, the present state of the lower Mare aux Cochons water catchment cannot be compared to commonly named examples of novel ecosystems (e.g. rain shadow tussocks in New Zealand, kelp forest in the Northern Pacific or recolonized grassland where former mining activities have restructured the landscape from scratch [Hobbs et al., 2006]). Undeniably, historic land use and more recent introductions of non-native species leave exotic imprints that characterize secondary forests in the lower water catchment. The historical fact that Seychelles' forest were once almost completely deforested and cultivated with species and other agricultural crops, and the extent of the come-back of native vegetation hardly justifies a steady-state label of novel ecosystems. Already John Procter, who made vegetation surveys in 1970 resulting in recommendations for the establishment of the Morne Seychellois National Park [Procter, 1973], discussed the resilience of native flora to withstand two centuries of human exploitation in Seychelles [Steers and Stoddart, 1985]. Similarly, our results show notable regeneration of native and endemic species which coexist alongside mostly exotic species that dominate the canopy. Notably the herb layer, which was described to be unusual or absent under closed cinnamon coppices in the middle of the 20th century [Vesey-Fitzgerald, 1940], is characterized by regeneration of native herbs, as well as native woody species. Therefore, we argue that forest in Seychelles do not fall under the category of "hopeless quest to 'fix' this systems" [Hobbs et al., 2006], but are currently still in a dynamic state with many relatively recent introductions and unforeseeable ecological shifts in the future. How the forests will change over the long term needs yet to be tested, for which our baseline study can be used.

11.4 Limitations, Opinions, and future research questions

Provided indicators are conceptually similar to parameters used in Fleischman [1997]; diversity of natives, singularity, total abundance of invaders, total abundance of natives, and rejuvenation [Fleischmann, 1997]. However, the most significant methodological difference is that our approach is based on forest stands in defined plots laying inside ecological boundaries of a habitat [Senterre et al., 2012b]. Fleischman's [1997] parameters are, on the other hand, derived from observations along trail-transects. Forest trails may include different ecological habitats within a larger landscape and observations are subject to the picking of the 'closest' individual at each recording. Our transect in Area 5 for instance went through the garden of an old distillery, a tree-fall gap, and typical cinnamon dominated secondary forest, and even crossed a river 12. Similarly the trail in Area 10 goes through TA6, where many juvenile endemic palms are present, through a former fruit tree plantation with *Mangifera indica* [Mango], *Citrus mitis* [Bigarad] and *Hibiscus rosa-sinensis* Hibiscus, and then passes by the pristine forest of TA5 – while not one single rare tree was picked as the closest tree to the transect. Given a sufficient length of transect, a trail-transect approach and derived indexes (e.g. protection value) are a practical and original way to characterize and compare landscapes to inform rehabilitation needs. However, they may fail to capture important compositional and structural properties that describe a habitat. Additionally, in tropical forests, many species are rare [Gentry, 1988] and are likely to be missed in a landscape approach while exactly these rare species are important as a reference for rehabilitation of native forests and for the characterization of the species community.

A shortcoming within our methodological approach is that we assume equal likelihood of juveniles growing into adult trees. Light intensity reaching the ground affects some native and exotic species differently [Kueffer et al., 2010, Kueffer, 2006], resulting in unequal growth. An inclusion of hemispherical photographs as used by Fleischman [2005], or simply a sensor that measures light intensity, could provide useful modelling variables to increase the resolution of forest succession estimates.

One more useful parameter of Fleischman [1997] is also not included in our status indicators: the IUCN Red List status of threatened species, which is captured in Fleischman's [1997] as a "singularity" index. Fleischman [1997] further simplified all parameters by classifying them into 5-point scales and created ecological matrices with transformed parameters. This step could be additionally done for our status indicators of all TA in the lower water catchment presented in this study (Table 12). However, more sites would first need to be evaluated to design appropriate scales for USN, NR, RI and DI. This may be done by placing and evaluating additional permanent plots in undisturbed submontane forest in the upper Mare aux Cochons catchment. More importantly, additional permanent plots in undisturbed submontane forest could assist rehabilitation in Area 5 by providing an analytical reference and improve the resolution in the ordination of the present vegetation community (Figure 17). The floristic composition of relatively undisturbed submontane forest on Silhouette was previously described in a comparable way. This opens opportunities to combine data sets and describe the lowland-submontane vegetation including more "high quality" forest, which is a component that is missing in this baseline.

Within this thesis we intentionally did not assign explicit quality values to forest communities based on patterns of "invasion" by "invasive species". Presence of many exotic species is, as we outlined in many cases, related to historical land use and not due to active biological invasion. Some species termed "invasive" only show weak regeneration (e.g. *Albizia* or *Pterocarpus*) and there is unclarity how about future trajectories of many introduced species. Moreover, cinnamon is the best example of an exotic species with a very ambivalent nature. While often termed an invasive species and even "rigorous spreader", cinnamon is, at the same time (and by the same authors), praised as a provider of a native species friendly microclimate by offering a shadowing canopy and below ground root competition that hampers growth of other exotic species. Likewise, exotic Mango trees in Area 5 are completely covered with native ferns and provide habitat for birds, frogs and other organisms. On the other hand, the origin status of species, exotic vs. native (endemic or indigenous), is based on [Senterre et al., 2013] in almost all cases not controversial. [8] Therefore, we instead used the concept of species origin and grouped species into two categories exotic and native. This division is still subject to the observer's temporal scale as initially every lifeform was once introduced to a certain geographic location. However, it allows for a simplistic distinction in line with goals of rehabilitation work. While we thereby avoid conflicting interpretations of the term "invasive" (cf. [Senterre, 2009, Humair et al., 2014] we point out the non-differentiation between species which may indeed show higher invasive character and are potentially undermining regeneration of native species. Additionally, statements such as "eradicating invasive species" may help to form policies and communicate project progress in a catchier way. However, the limitations of separating species by their origin (i.e. native or exotic) outweighs the potential misuse of the term "invasive" due to

[8] The origin of *Adenanthera pavonina* [Lagati] was described as "introduced" in other literature [Vesey-Fitzgerald, 1940, Friedmann, 2011, Fleischmann, 1997, Massy and Schmutz, 2017]. However, the cryptogenic origin of *A. pavonina* is currently being discussed and there is now reasonable evidence that it is native to Seychelles (Senterre Baguett, unpublished). Therefore, we listed it here as native.

insufficient ecological knowledge. Regardless of the debate about terminology and ecology of exotic or invasive species, it is not a justifiable distinction in regard to functional properties of a forest ecosystem (cf. [Mascaro et al., 2012]).

Not including the third parameter suggested by SER, ecological functionality, is a considerable shortcoming of the baseline study. We focused on vegetation structure and diversity and, under some limitations, the temporal dimension of forest succession. An additional more process oriented metric which includes functionality of nutrient cycles, hydrology and carbon cycles, would be a more holistic and complete approach. Including key invertebrate species can also also inform rehabilitation success as they play an important role in nutrient cycling [Jansen, 1997] or pollination networks [Kaiser-Bunbury et al., 2017].

It is a general problem in restoration ecology that indicators to measure restoration success require years, if not decades, to be validated. Nevertheless there is an extensive effort to rehabilitate degraded ecosystems around the world – some of which may include ecological baseline studies, some may not. Given the detailed assessment of vegetation within this study, we emphasize the scientific opportunities to not only reassess the outcome of the experimental rehabilitation scheme, but also to gain insights into natural forest succession of secondary forests.

Lastly, we want to emphasize again that the obvious anthropological influence on the vegetation of Seychelles during only two centuries cannot be neglected. Numerous authors attribute the loss of native species to invasion by exotic species. While this is justified and true in the right context, this may as well proceed the other way around in the Seychelles; given that the vast majority of original forests where gone by the early 19th century, native species rather "invaded" back into the plantation- and secondary forests. The latter is by no means a factual statement but it shows that historic context matters. Regardless in which direction the story is framed, the presented baseline study provides solid ground for future scientific exertion with dynamic forest ecosystems in Seychelles.

12 Synthesis: Reconciling the rehabilitation of water catchment forest in the Park with perception of local communities

In this interdisciplinary thesis we diversified research in the Morne Seychellois National Park protected area with insights into local social perception of protected areas and forest rehabilitation. In this section, we finally conclude and synthesise the findings from both parts and provide an outlook into the future.

The relationship between humans and the environment is reciprocal. How people perceive their environment affects the way they respond to it. How people make use of natural resources or to what extent land is altered in the National Park affects ecosystem services we receive from it. Forest areas can be selected based on their observed state/value/services according to which, we then decide which forest areas are suitable for rehabilitation. The outcome of forest rehabilitation affects the conservation value of the landscape, which then again affects how people perceive it, and which new values they attend to it.

This superficial descriptions cannot capture the full complexity in interactions between the three entities but they demonstrate the interconnectivity of the environment and humans in the case study of Mare aux Cochons, and the wider Park area. Understanding these connections may not only directly support planned rehabilitation activities in the lower catchment area, but it also addresses important social aspects of conservation which were only scarcely addressed in previous research in Seychelles. Untangling these complexities can begin with how humans perceive and interact with their environment.

We found that a positive perception of rehabilitated areas often came along with statements of "green and lush palms", but also with a positive remark on big trees (cinnamon) being present after restoration. This may be in favour of not only using endemic palms in forest rehabilitation, but also broad leaf species which will grow into impressive canopy trees. How successful the use of broad leaf trees vs. traditionally used endemic palms in forest rehabilitation will be in the long run can be evaluated with the baseline study provided in PartII. Re-introduction of broad leaf canopy trees such as *Planchonella obovata* [Bwa mon per], *Mimusops seychellarum* [Bwa-d-nat], *(Dillenia ferruginea)* [Bwa rouz] and *(Calophyllum inophyllum)* [Takamaka] may, as we have shown, not only be justified from an ecological and historical point of view, but by engaging in the concerns and perceptions of community members in rehabilitation approaches. Moreover, our results showed that approval of physical appearance of rehabilitation increased after and explanation of what the activity is. This is an argument why there needs to be transparency and effective communication of activities in regard to planned forest rehabilitation in the lower water catchment, especially those that involve interference (justified or not justified) with the natural environment, such as removing exotic species or planting native species. The same is valid for the creation of a nursery, which was generally perceived as an acceptable activity in the area of the Park.

Moreover, the positive association between participation in Wildlife-clubs and Eco-schools with previous participation in restoration activities indicates that involving the community in a wide range of environmental activities is mutually beneficial. Similarly, emphasizing the "community gathering" aspect of participatory rehabilitation events and facilitating the feeling of "ownership" of restored areas (e.g. by allowing participants to plant a tree with their name to own a part of the result), could increase participation and contribute to a stronger local stewardship of watersheds in times of forest rehabilitation.

The weak physical relationship between local people and the National Park calls for an effort to try to bring more locals to the Park and the water catchment area. By definition, a National Park (IUCN II) is designated to protect and preserve the natural environment, as well as for for the benefit, advantage, and enjoyment of the general public [Ministry of Environment & Energy, 2013], including tourists and local communities. While emphasizing the local use of the Park in terms of collecting forest products might not be the best way to strengthen this relationship, investing into portraying the Park as an area for local recreation and education may be more fruitful. Because the majority of local residents visit less demanding trails such as Anse Major, Trois Frères and Copolia more often, including more shorter and less physically demanding trails might be the best option to improve the physical relationship. For example, this is were a potential trail in the lower water catchment, which could also serve as an educational trail to learn native diversity in pristine forest to visualize the goal of rehabilitation, becomes a valuable option. Careful consideration should be given, however, to the exact placement of the trail, as the newly discovered pristine forest patch in Area 10 includes control permanent plots. Human interference should be avoided so that the study of natural succession as part of the experimental rehabilitation scheme is possible. Secondly, a trail through the middle of the pristine remnants of forest may impose significant threat to a, so far, practically undisturbed original lowland forest. However, given that most biodiversity hotspots are in remote areas [Senterre and Henriette, 2015] due to historical reasons, and are therefore hardly accessible (with good reason) for the wider public, restored areas through semi-pristine forests (plot 16 and 17; cf. Figure 12) in walking distance could provide not only potential sources of financial income for the national park but also offer many opportunities for environmental education for the average park visitor. Additionally, local awareness about the ecological issues addressed in rehabilitation focuses primarily on the invasive creeper problem, which is very well known in the country due to information campaigns of the government [Senterre, 2009], however, awareness of other non-native species and the historic reasons behind their widespread presence in the Park is low. Thus, there is high potential to include more educational aspects within planned rehabilitation and visitor trail to rehabilitated areas.

Intact water regimes will become more relevant in face of climate change-induced water shortages or flash floods, which are predicted for Seychelles [UNDP, 2012]. We identified how, among all perceived benefits of the park, water provisioning, in terms of collecting clean drinking water from springs in the Park, still plays a significant role in the physical relationship between people and the area. Their recognition of water provisioning as an important function of the Park, however, went largely unnoticed and was overshadowed by other functions of the park, such as protection of biodiversity, ecosystems, and tourism. Thus showing that more emphasis on communicating the importance of protected areas in regulating the water regime is needed, as it is an ecosystem services people depend on for their own well being. However, people indirectly showed how they recognize value of clean drinking water and undisturbed forests, as scenarios with no- and low impact development with minimum impact on the natural environment were preferred and generally positively perceived. Moreover, scenarios where the quality of water and forests were compromised, due to extensive use of the park through housing and accommodation development, generally received negative feedback. People might also recognize additional value in forest rehabilitation activities if they are framed and communicated in ways that people perceived as important, e.g. how rehabilitation contributes to tourism and protection of biodiversity and ecosystems in general, besides indirectly securing the integrity of the water regime. Through our baseline study we found widespread rejuvenation of native vegetation in younger forest strata of the water catchment, indicating a likely increase of the fraction of native canopy- and undercanopy elements in the future. Such trends can be facilitated through forest rehabilitation and thereby raise the conservation value of secondary forest. This may relieve development pressure in the water catchment Mare aux Cochons and contribute to securing the integrity of the water regime, which is, as we showed, also the preferred future trajectory of the Park from the perspective of local communities.

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Part III
Supporting information

13 Appendix A: Perception study

13.1 Stakeholder consultations

13.1.1 Interviews

In order to better understand the overall setting, major issues, conflicts, underlying causes and general developmental trends in the future, several stakeholders were interviewed (Table 13). The interviews were semi-structured. Except for interviews with tour guides and local bussinesses, we tried to follow the guidelines of [?] as much as possible. This means for interviews we prepared a set of specific questions, sent them in advance to the interviewee, performed the interview, took notes and recorded the conversation. However, interviews were not transcribed and notes were consolidated only. We also contacted several tour guides and local businesses to identify in what way people can benefit from the National Park. With those who agreed, we arranged a short conversation based on a few question, either in person or over the phone. We chose to talk to tour guides as we assumed they have extensive knowledge about the National Park and potential benefits it offers.

Table 13: **List of persons interviewed.**

Organization	Person interviewed	Date
Plant Conservation Action group (PCA)	Katy Beaver and Lindsay Chong	21st November 2019
Government (MEECC)	Ashley Dias	28th November 2019
SNPA	James Mougal and Jason Jacquelin	3rd December 2019
Seychelles Planning Authoriy	Joseph Francois	6th December 2019
Tourism department	Philomena Hollanda	17th December 2019
PUC	Ginnie Laurencine	16th December 2019
Tour guides	Mervin and Padmini Mathieu	6th December 2019
Tour guide	Mr. Ryan	6th December 2019
Tourist accomodation	Cashew Nut Grove Chalets	4th December 2019

13.1.2 Stakeholder workshop

The Seminar and workshop for local stakeholders, titled: “Morne Seychellois National Park, as seen through the eyes of local communities”, took place on Friday, 24th of January 2020 at University of Seychelles. The aim of the workshop was to present the research of two master’s students from ETH and two students from UniSey, preliminary results, and to further elaborate on future scenarios of the Morne Seychellois National Park with the stakeholders.

The event started at 8.30 am with registration and ended at 12.00. Betty Victor (EbA) started with a welcome to the participants, followed by a brief presentation from James Millet (EbA) on the EbA project, and Dr. Pius Krütli (ETH Zürich) on the collaboration between UniSey and ETH Zürich. We continued with student presentations of their research. Sara Cerar (ETH Zürich) introduced the research and presented the social science part of the research. Michael Zehnder (ETH Zürich) presented the forest work in Mare aux Cochons, and Heather Lafleur (UniSey) briefly presented her research focus.

After a short, twenty minute break, we began with the workshop. We kicked off with a warm up, followed by a brainstorming activity, where participants had to write down activities acceptable in the MSNP under the low-impact development scenario. We clustered the activities and formed groups, that later worked on implementing one activity. The workshop finished with short 2 minute pitches, where groups presented their ideas. At the very end we collected feedback and closed the event with an Ápero.

25 participants registered at the event, representing several organizations: S4S, SNPA, EBA, PCA, PCU, ETH Zürich, UniSey, Watershed committee, mcss, GCCAT and the National Assembly. The event was covered by the Seychelles Broadcasting Coorporation.

Workshop outcome: Participants identified several creative and interesting activities that could take place in the MSNP under the low-impact development scenario. In just 15 minutes they developed some very interesting concepts and ideas that could be introduced in the Morne Seychellois National Park.

The ideas were gathered from post-its:

• Meditate, silent zone! • Bwa mediz search • Yoga • Bwa doux search • Trekking • Organic honey • Entrance fee • Team building for CEO's • Bwa marbay hunt • Study of Boulder flora • Trailing; cleaning, upgrading, hiking, • Remove all invasive alien species • Frogs of Seychelles • Clean the trail frequently • Toilet • EBA gabion • Swim area (gabion reservoir) along the trail • Toilet • Water buttlings pay SNPA for water abstraction • Fresh drinking water gabion reservoir • Kiosk • Camping nudist area • Restore to almost original • More side trails to view points • Marked and mainained hiking challenges (3rd of May) • Nature Park heroes recognized • Sign boards with species information • Guided tours only • Campsite • Nice trails with small signs • Boardwalks in sensitive areas (recycled plasti lumber) • Forest yoga • Fines for littering • No plastic • Get serios, remove invasives and replant • Remove fowatonk • Extend park boundary (more KBA) • Intensive IAS control • More viewpoints and platforms • Remove invasive • Pitcher plant tours • Games • Hiking (mapping to the trail) • Visitor centre encorporated to nature • Sing • School visits • Educational activities • Aviant avery zoo • Canopy walk//bridge • Small research centers • Paint • Talk • Bird watching • Water bottle (no plastic) with a title Morne Seychellois • Team building activities • Educational awareness programs • Rebuilding historical structures • Restoration • Grow natives • Tree planting, restorations, community involvement • Buy and maintain it • Remove all invasives and replant natives • More local documentary on Seychelles environment and also interactive • Coloring books for kids featuring native species • Bird watching • Art classical projects • Environmental boot camp, learn about environment related topics • Nature film/movies. Inform the masses • Small museum on traditional uses of area • Intensive EbA program • Yoga • Camping, Eco camp=reconnect with nature • Camping sites and facilities.

To learn and appreciate the nature. • Pray • Mysticism, gratitude, concrete answer, discover • Organize owl prowl • Wild swimming, cascade jumping • Yoga • Hiking • Hiking • Exploration • North-south ridge walk • Mountain biking • Planting herbs • Pay entrance local and tourist (Sey 10), free under 15 years • Compost toilet • Canopy walk, small group at a time and make no noise • Small kiosk at trail start, local sell juice • Camping without fire, collect fee for conservation, facilities in the process • Fitness camp • Viewing platform • Controlled campsited in forest • Restricted access

Feedback: We received overwhelmingly positive feedback! Participants liked the interactive, relaxed, and positive spirit of the event. They learned about our research, importance of involving communities in decision making, different ways ecosystems can be restored, new survey techniques, perception of the locals, and different ideas of activities that could take place in the National Park. In the future, participants suggested to extend the workshop, provide more food, explain a bit more about the history of the National Park, and to "keep up the good work".

13.1.3 Poster for the Stakeholder workshop


MORNE SEYCHELLOIS NATIONAL PARK
As seen through the eyes of local communities
Half-day seminar and workshop
24th January at UniSey, room A1/4
ETH zürich
ADAPTATION FUND
UNIVERSITY OF SEYCHELLES

WHAT?

Four students from ETH Zürich and UniSey will present their research project in Mare aux Cochons. They are investigating the local perception of the Morne Seychellois National Park and forest restoration in Mare aux Cochons.

WHY?

The project is taking place to provide evidence from social and natural science perspective for future management of the Mare aux Cochons and potentially for wider area of the Morne Seychellois National Park.

HOW?

At the seminar students will present the methodology and preliminary results of their study, allowing for a discussion. After the presentation, a group activity will take place with the stakeholders.

ETH zürich

UNIVERSITY OF SEYCHELLES

FRIDAY 24th January

8.30 – 8.45	**REGISTRATION**
8.45 – 9.00	**WELCOME**
9.00 – 10.00	**PRESENTATIONS** EbA project, Forest research and perception study
10.00 – 10.15	**COFFEE BREAK**
10.15 – 10.45	**ACTIVITY I** Future scenario – acceptable activities
10.45 – 11.00	**BREAK**
11.00 – 11.45	**ACTIVITY II** Future scenario - implementation
11.45 – 12.00	**END** Apero

13.2 Questionnaire

13.2.1 English version

Date:
Location:
Household ID:

Survey ID:
Start time:
End time:

QUESTIONNAIRE:
The Morne Seychellois National Park, as seen through the eyes of local communities

We are two students from ETH Zürich and we are currently doing our master's thesis in Environmental Science. We are collaborating closely with students from the UniSey and the Ministry of Environment, Energy, and Climate Change. With this survey we try to understand how the National Park is perceived by the local population and tourists. We would like to inform the future management of the Mare aux Cochons watershed area. Your participation is very important to us. Your data will be treated anonymously and confidentially.

BLOCK I.
Socio-demographic questions

1. Gender: ☐ male ☐ female

2. Nationality: ☐ Seychellois
☐ other:____________

3. Age: ______

4. Highest level of education:
☐ primary school
☐ secondary school
☐ post-secondary school
☐ University degree and higher

5. I participate/ed in the following environmental activities:
☐ Environmental NGO
☐ Wildlife club
☐ Eco-school
☐ environmental workshop
☐ other ______________________
☐ none of the above

6. Do you work or have ever worked in:

Tourism sector	☐ yes ☐ no ☐ not sure
Marine protected areas	☐ yes ☐ no ☐ not sure
Terrestrial protected areas	☐ yes ☐ no ☐ not sure
Education	☐ yes ☐ no ☐ not sure

BLOCK II.
Here we would like to learn how you relate to the National Park.

7. Have you heard there is a National Park on Mahe?
☐ yes
☐ no
☐ not sure

GIVE MAP OF MSNP TO THE RESPONDANT AND EXPLAIN "The area in green is the MSNP on Mahe"

8. Have you visited this National Park on Mahe?
☐ yes
☐ no
☐ not sure

9. Which of the following trails have you visited in the National Park?
☐ Trois Frères
☐ Copolia
☐ Anse Major
☐ Mare aux Cochons
☐ Dan Gala
☐ Morne Blanc
☐ Salazie
☐ Casse Dent
☐ other; specify: ________________
☐ none of the above

Date: ID:
Place: Time start/finish:

10. How often do you visit the National Park?
    ☐ several times per week
    ☐ several times per month
    ☐ several times per year
    ☐ once a year
    ☐ less than once a year.

11. Is there any reason that prevents you from visiting the park more often?
    ____
    ____
    ____
    ____

12. Do you think the National Park is important for Seychelles?
    ☐ yes
    ☐ no

13. If yes/no, why do you think the National Park is/not important for Seychelles?
    ____
    ____
    ____
    ____

Date: ID:
Place: Time start/finish:

BLOCK III.

We cannot predict the future, but we can imagine how it could look like. We created four possible future scenarios how National Park could look like in 2040, that is in 20 years. Please look at the illustrations. We will read the scenario descriptions to you. In the end you will have to rate each scenario based on how much you like it.

14. Please rate all of the scenarios based on how much you like it by coloring the corresponding emoji.

<table>
<tr>
<td>SCENARIO I.

It's 2040. The park has not changed much.

• There are still eight official hiking trails, that are maintained to a basic standard
• Unmanaged trails cause erosion and are more difficult to walk.
• There are no facilities or development.
• The natural environment remains in good condition.</td>
<td>SCENARIO II.

It is 2040. A very strict management plan allows for low-impact development in some areas of the park.

• Hiking trails are improved, which makes them more accessible.
• There is a new access point to the park with parking, toilets and a kiosk, offering trail information and hiking tours.
• At a scenic point there is a small low-impact restaurant and a zip-line.
• The natural environment is improved by management activities.</td>
</tr>
<tr>
<td>Rate scenario I.
☺ ☺ 😐 ☹ ☹
Like very much – like – neutral – don't like – don't like at all</td>
<td>Rate scenario II.
☺ ☺ 😐 ☹ ☹
Like very much – like – neutral – don't like – don't like at all</td>
</tr>
<tr>
<td>SCENARIO III.

It is 2040. A less strict management plan allows for high impact development in some areas of the park.

• There is a parking lot, toilets, kiosks, a zip-line, a small restaurant, a cable-car, eco-lodges for tourists, and new hotels.
• There are several new hiking trails in the park, which are regularly maintained.
• The natural environment is at risk to be damaged and water is polluted.</td>
<td>SCENARIO IV.

It is 2040. Almost half of the park's area loses protection status and is opened for uncontrolled development.

• The National Park is now much smaller.
• In the developed areas there is now new housing, tourist accommodation and other activities, such as a zip-line, cable car, parks, gardens, restaurants, and clubs.
• The natural environment is very damaged and water is very polluted.</td>
</tr>
<tr>
<td>Rate scenario III.
☺ ☺ 😐 ☹ ☹
Like very much – like – neutral – don't like – don't like at all</td>
<td>Rate scenario IV.
☺ ☺ 😐 ☹ ☹
Like very much – like – neutral – don't like – don't like at all</td>
</tr>
</table>

Date: ID:
Place: Time start/finish:

BLOCK IV.

Here we would like to learn in what way do you benefit from the park.

15. Please read the questions and answer how much you agree.

	Do you benefit from (service 1-n) in the National Park?				
Service:	Yes, very much	Yes	I don't know	No	No, not at all
Collecting fruits, flowers, wood	□	□	□	□	□
Earning money by working in the National Park	□	□	□	□	□
Picking medicinal plants	□	□	□	□	□
National park preventing land-slides and erosion in your area	□	□	□	□	□
Clean and fresh air	□	□	□	□	□
Clean drinking water from forest river	□	□	□	□	□
PUC Tap water from	□	□	□	□	□
Scenic view, natural beauty	□	□	□	□	□
Seeing native plants and animals	□	□	□	□	□
Hiking and walking and running	□	□	□	□	□
Good Friday walk to Trois Frères	□	□	□	□	□
Learning about nature and environment	□	□	□	□	□
Other: ___________________	□	□	□	□	□

Date: ID:
Place: Time start/finish:

BLOCK VI.

This is a before and this is an after picture. (SHOW THE PICTURES). Please take a good look at it and let us know if:

16. Do you think, this area improved in quality?

☐I agree ☐I slightly agree ☐I don't know ☐I slightly disagree ☐I disagree

Comments:
____
____
____
____

The above picture showed before and after of a restoration activity in National Park. (SHOW PICTURE). This was part of an activity, where invasive plants were remove and native plants were planted. Also communities participated in planting trees.

17. Have you heard of such activities taking place in the National Park?
☐ Yes ☐ No ☐ I don't know

18. Have you ever participated at any such activities in the past?
☐ Yes ☐ No ☐ I don't know

19. Do you support that activity take place in the National Park?
☐ Yes ☐ No ☐ I don't know

20. Would you be interested in participating in such activities (again) in the future?
☐ Yes ☐ No ☐ I don't know

21. If yes, please tell us the most important reason why would you participate at such event:
____
____
____

22. We would like to know why would you participate at such activities and how would you like to benefit from them.

Would you go to such activity in the National park to:	Yes	No	I don't know
Exercise	☐	☐	☐
Socialize and meet the community	☐	☐	☐
Learn about plants and environment	☐	☐	☐
Have free drinks and lunch	☐	☐	☐
Plant a tree with my name	☐	☐	☐

Date: ID:
Place: Time start/finish:

Receive a Hat and a T-shirt with a logo and certificate of participation	□	□	□
Help remove creepers	□	□	□
Help plant more native plants in the forest	□	□	□
To be on the TV	□	□	□
Other :	□	□	□

23. Would you participate at a tree planting activity in the National park, if:

Would you participate at such activity in the National Park if:	Yes	No	I don't know
The site would be near road but far from your neighborhood?	□	□	□
You would have to walk half an hour from the road to reach the site?	□	□	□
You would have to walk one hour from the road to reach the site?	□	□	□

THANK YOU VERY MUCH FOR YOUR TIME!

Sara, Michael, Heather and Maria

Time needed: _____ min

Notes and comments:

13.2.2 Creole version

Date: ID:
Place: Time start/finish:

KESTYONNER:
Park Nasyonal Morn Seselwa, a traver perspektiv lakominote Seselwa

Nou de zelev sorti ETH Zurich e nou an se moman pe fer nou master's thesis dan Lasyans Lanvironman. Nou pe kolabor avek zelev sorti UniSey e osi avek Minister Lanvironnman, Lenerzi e Sanzman Klima. Nou ti a voudre ede pou amelyor plan zesyon Park Nasyonal Morn Seselwa par konpran kimanyer sa Park I ganny apersevwar par popilasyon Mae ansanm avek touris. Ou partisipasyon I vreman enportan pou nou. Leformasyon ki ou donnen pou konfidansyel e annonim.

BLOCK I.
Socio-demographic questions

1. Seks: ☐ mal ☐ femel

2. Nasyonalite: ☐ Seselwa
   ☐ lezot:____________

3. Laz: ______

4. Nivo ledikasyon pli o:
   ☐ lekol primer
   ☐ lekol segonder
   ☐ lekol pos-segonder
   ☐ degree liniversite e pli o

5. Mon partisip/deza partisip dan bann aktivite lanvironnman an swivan:
   ☐ Environmental NGO
   ☐ Wildlife club
   ☐ Eco-school
   ☐ environmental workshop
   ☐ lezot ______________________
   ☐ ni enn dan sa lalis

6. Eski ou travay oubyen deza travay dan:

Sekter tourizm	☐ wi ☐ non ☐ pa asire
Bann park maren	☐ wi ☐ non ☐ pa asire
Bann park lo later	☐ wi ☐ non ☐ pa asire
Ledikasyon	☐ wi ☐ non ☐ pa asire

BLOCK II.
Dan sa seksyon, nou ti a voudre aprann ki ou relasyon avek Park Nasyonal

7. Eski ou'n deza tande I annan en Park Nasyonal lo Mae?
   ☐ wi
   ☐ non
   ☐ pa asire

   SHOW MAP AND EXPLAIN

8. Eksi ou'n deza visit sa Park Nasyonal lo Mae?
   ☐ wi
   ☐ non
   ☐ pa asire

9. Lekel trail a swivan ki ou'n deza vizite dan Park Nasyonal?
   ☐ Trois Frères
   ☐ Copolia
   ☐ Anse Major
   ☐ Mare aux Cochons
   ☐ Dan Gala
   ☐ Morne Blanc
   ☐ Salazie
   ☐ Casse Dent
   ☐ lezot, spesifye: ________________
   ☐ ni enn dan sa lalis

Date: ID:
Place: Time start/finish:

10. Ki degre souvan ki ou vizit Park Nasyonal?
    ☐ de-trwa fwa pa semenn
    ☐ de-trwa fwa par mwan
    ☐ de-trwa fwa par lannen
    ☐ en fwa par lannen
    ☐ pli mwens ki en fwa par lannen

11. Eksi I annan okenn rezon ki anpes ou pou vizit sa park pli souvan?
    ____
    ____
    ____
    ____

12. Eksi ou kwar sa Park Nasyonal I enportan?
    ☐ wi
    ☐ non

13. Si wi/non, akoz ou kwar sa Park Nasyonal I enportan/pa enportan?
    ____
    ____
    ____

Date: ID:
Place: Time start/finish:

BLOCK III.

Nou pa kapab predir le fitir, me nou kapab mazinnen kimanyer I kapab ete. Nou'n kre 4 senaryo ki kapab arive dan le fitir pou Morn Seselwa ki dekrir kimanyer sa park I kapab ete dan 20an- lannen 2040. Silvouple regard sa bann senaryo. Nou pou lir tou bann deskripsyon pou sak e ou pou 'rate' sak senaryo baze lo ki kantite ou kontan.

14. Silvouple rate tou senaryo par swazir en emoji ki reflekte ki kantite ou kontan sak senaryo.

SCENARIO I.

Lannen 2040. **Park pa'n sanz sa kantite**

- I ankor annan zis 8 hiking trail ofisyel ki ganny zesye lo standar normal.
- Trail ki pa byen ganny zesye I fer lerozyon e kree difikilte pou marse.
- Napa okenn fasilite oubyen devlopman.
- Lanvironnman natirel I reste an bon kondisyon.

Rate scenario I.

Kontan bokou – Kontan – Neutral – Pa kontan – Pa kontan ditou

SCENARIO II.

Lannen 2040. En zesyon vreman sever I permet **devlopman avek mwens lenpak** dan serten landwa dan park.

- Hiking trails in amelyore, ki fer trail pli aksesib.
- I annan en nouvo larantre dan park avek parking, toilet e en kyos ki ofer lenformasyon lo trail avek hiking tours.
- Kot en 'scenic point' I annan en pti restoran ki fer mwens lenpak e osi en zip-line.
- Lanvironnman natirel in amelyore avek bann aktivite zesye.

Rate scenario II.

Kontan bokou – Kontan – Neutral – Pa kontan – Pa kontan ditou

SCENARIO III.

Lannen 2040. En plan zesye mwen sever I permet **devlopman avek plis lenpak** dan serten landwa dan park.

- In annan landwa parking, de-trwa toilet, kyos, en zip-line, en pti restoran, en cable car, eco-lodges e lotel pou touris.
- I annan de-trwa nouvo hiking trails dan park ki ganny zesye regilyerman.
- Lanvironnman natirel I dandomaze e delo in ganny polye.

Rate scenario III.

Kontan bokou – Kontan – Neutral – Pa kontan – Pa kontan ditou

SCENARIO IV.

Lannen 2040. Apepre **lanmwatye park in perdi proteksyon** ki'n ganny servi pou **nenport ki kalite devlopman**.

- Park nasyonal I pli pti.
- Dan landwa devlopman, I annan lakaz, akomodasyon tourizm, zip-line, cable car, park rekreasyonnel, zarden, restoran avek diskotek.
- Lanvironnman natirel I vreman andomaze e delo I vreman polye.

Rate scenario IV.

Kontan bokou – Kontan – Neutral – Pa kontan – Pa kontan ditou

Date: ID:
Place: Time start/finish:

BLOCK IV.

Dan sa seksyon nou ti a voudre aprann kwa ki ou benefisye avek dan park.

15. Please read the questions and answer how much you agree.

	Eksi ou benefisye avek (servis 1-n) dan Park Nasyonal?				
Servis:	Wi, bokou	Wi	Mon pa konnen	Non	No, pa ditou
Koleksyon fri, fler e dibwa	□	□	□	□	□
Larzan par travay dan Park Nasyonal	□	□	□	□	□
Anmas plant medisinal	□	□	□	□	□
Prevansyon deboulir later e lerozyon dan ou rezyon	□	□	□	□	□
Ler prop e fre	□	□	□	□	□
Delo prop pou bwar sorti direkteman dan larivyer dan lafore	□	□	□	□	□
Delo tio PUC ki sorti	□	□	□	□	□
Scenic view e labote natirel	□	□	□	□	□
War plan e zanimo nativ	□	□	□	□	□
Hiking, marse e taye	□	□	□	□	□
Lamars Vandredi sen pou al Trois Frères	□	□	□	□	□
Aprann lo la natir e lanvironnman	□	□	□	□	□
Lezot: ___________________	□	□	□	□	□

Date: ID:
Place: Time start/finish:

BLOCK VI.

Sa I en portre en landwa avan e apre. (SHOW THE PICTURES). Silvouple regarde e les nou konnen si:

16. Ou war okenn amelyorasyon dan leta fizik?

☐I agree ☐I slightly agree ☐I don't know ☐I slightly disagree ☐I disagree

Comments:
____
____
____

Sa de portre I montre en landwa avan e apre en aktivite restorasyon dan Park Nasyonal. (SHOW PICTURE). Sa ti en aktivite ki ti tir bann lalyann anvaisan e plant bann plan nativ. E lakominote ki ti partisip dan sa aktivite.

17. Eski oun antann/konnen si sa bann aktivite pe pran plas dan Park Nasyonal?
☐ Wi ☐ Non ☐ Mon pa konnen

18. Eski oun deza partisipe dan sa bann aktivite dan le pase?
☐ Wi ☐ Non ☐ Mon pa konnen

19. Eski ou siporte sa bann akitivte pou pran plas dan Park Nasyonal?
☐ Wi ☐ Non ☐ Mon pa konnen

20. Ou ti pou enterese pou partisip dan sa bann aktivite (ankor) dan le fitir?
☐ Wi ☐ Non ☐ Mon pa konnen

21. Si wi, silvouple donn ou en/de rezon ki pou pli motiv ou pou partisip dan sa bann aktivite:
____
____

22. Nou ti a voudre konnen akoz ou ti pou partisip dan sa bann aktivite e kimanyer ou ti a voudre benefisye avek sa bann aktivite.

Ou ti pou al sa bann aktivite dan Park Nasyonal pou: ?	Wi	Non	Mon pa konnen
Fer legzersis	◻	◻	◻
Sosyalize e zwenn lakominote	◻	◻	◻
Aprann bann plant e lanvironnman	◻	◻	◻
Labwason e dezennen gratwit	◻	◻	◻
Plant en plan avek m non	◻	◻	◻
Resevwar en sapo ek triko avek en logo e en sertifika	◻	◻	◻
Ede tir bann lalyann anvaisan	◻	◻	◻
Ede plant plis plan nativ dan lafore	◻	◻	◻
Pou vwar ou lo TV	◻	◻	◻
Lezot :	◻	◻	◻

Date: ID:
Place: Time start/finish:

23. Ou ti pou partisip dan tree planting activity dan Park Nasyonal, si:

Ou ti pou partisip dan sa aktivite si:	Wi	Non	Mon pa konnen
Sa landwa ti pres avek semen me lwen avek kot ou reste?	□	□	□
Ou ti pou bezwen mars en demi er-d-tan an sortan lo semen pou ariv dan sa landwa?	□	□	□
Ou ti pou bezwen mars pou 1er-d-tan pou ariv dan sa landwa?	□	□	□

Date: ID:
Place: Time start/finish:

THANK YOU VERY MUCH FOR YOUR TIME!

Sara, Michael, Heather and Maria

Who surveyed:

Time needed: _____ min

Notes and comments:

13.3 Sample characteristics

Table 14: **Sample characteristics**

District of residence, residence area (proximity to Park), gender, age, level of education and work experience in related fields, $N = 395$.

District	%	Residence area	%	Gender	%	Age	%	Education	%	Work experience[a]	%[b]
Anse Etoile	3.8	Near the Park	47.8	Male	42.0	16-24	12.7	No school	2.8	Tourism sector	38.5
Anse Royale	8.1	Far from Park	52.2	Female	58.0	25-34	14.5	Primary school	9.9	Marine PA[c]	9.1
Baie Lazare	5.6					35-44	14.8	Secondary school	28.1	Terrestrial PA[c]	10.4
Bel Ombre	18.0					45-54	24.2	Post-secondary school	50.1	Education	20.8
Mont Buxton	7.3					55-64	19.1	University and higher	8.6		
Mont Fleuri	3.5					65+	14.8	No answer	0.6		
Point Larue	7.6					No answer	0.5				
Port Glaud	29.9										
Roche Caiman	9.1										
Saint Louis	7.1										

[a] Respondents were asked, if they had work experience, for each category separately.
[b] Percent of positive answers, $N = 395$.
[c] Protected areas.

Table 15: **Reported participation in environmental activities, N=393.**

	N	%
Have you participated in any of the following environmental activities?[a]		
Wildlife club	51	12.9
Eco-school	28	7.1
Environmental NGO	16	4.1
Environmental Workshop	21	5.3
Other environmental activities[b]	109	27.6
None of the above	248	62.8
Total	395	100.0

[a] Multiple choice question.
[b] Respondents could specify the activity, all were considered.

13.4 Representativeness of the sample

To check whether the distribution of socio-demographic variables, such as gender, age, nationality, level of education and residence indeed matched the total population, we conducted a $\chi 2$ goodness of fit test. Data for comparison was sourced from the Population and Housing Census 2010 Report[National Bureau of Statistics, 2010] and Household Budget Survey 2013 [Bureau of Statistics, 2013] and adapted to fit our categories. For the purpose of this test we formulated the null and the alternative hypothesis:

H0: The distribution of the socio-demographic characteristics of our sample is the same as its distribution within the total population of Mahe.

H1: The distribution of socio-demographic characteristics of our sample differs from its distribution within the total population of Mahe.

$p < 0.05$

For all tested variables, gender ($\chi 2$ (1) = 15.745, $p < 0.000$), age ($\chi 2$ (5) = 95.447, $p < 0.000$), level of education ($\chi 2$ (4) =25.987, $p < 0.000$) and residence ($\chi 2$ (3) = 108.281, $p < 0.000$), we rejected the null hypothesis, implying the distribution of these variables differs from the total population of Mahe.

In our sample males were underrepresented by about 10%, despite our efforts to keep a balanced gender ration. Age wise, younger people aged 16-44 were under represented in our sample by about 7%, while older respondents, especially those aged 55-64, were over represented. Regarding highest completed education level, respondents who completed primary or secondary school were underrepresented for about 5% and 7%, respectively. Location wise, respondents residing in Central and East/South region were underrepresented for about 7% and 13%, respectively, and the West region was over represented for about 18%. This is, however, a direct consequence of intentionally over-sampling districts near the Park, that is Port Glaud and Belombre.

13.5 Multicollinearity

In order to check for multicollinearity and correctly interpret results, relationships between predictor variables were analysed. For this purpose we assessed correlations between variables and also calculated variance inflation factor (VIF) for each independent variable. VIFs greater than 5 represent critical levels of multicollinearity where the coefficients are poorly estimated, and the p-values are questionable [?]. We analyzed the following variables: proximity to park, age, gender, level of education, participation in Wildlife-club, participation in Eco-school, participation in at least one environmental activity, work experience in tourism sector, number of trails visited and visit frequency.

First results showed significant weak to moderate correlations between majority of variables. In order to reduce the amount of multicollinearity between our variables and satisfy assumption of absence of multicollinearity, which is a basis for performing a logistic regression (cite the article), we removed and merged some variables. We merged "participation in Wildlife club" and "participation in Eco school" into "Environmental education". We excluded the variable "participation in at least one environmental activity" and "number of trails visited", which is directly correlated with "Visit frequency". Our final selection of predictor variables included: proximity to park, age, gender, level of education, work experience in tourism sector, visit frequency and environmental education (Table 16). We can conclude that multicollinearity between our final set of predictor variables is still present but acceptable as the VIF remains low <5 (Table 17). This conclusion enables us to include these variable in logistic regression.

Table 16: **Correlations between predictor variables.**

Correlations

			Proximity to park	Age	Gender	Level of education	Work experience in tourism sector	Visit frequency	Environemnta l education
Spearman's rho	Proximity to park	Correlation Coefficient	1.000	-.013	.066	.018	-.047	**-.133****	.017
		Sig. (2-tailed)	.	.797	.191	.718	.355	.008	.741
		N	395	393	395	393	394	395	395
	Age	Correlation Coefficient	-.013	1.000	**.106***	**-.425****	.090	**.299****	**.331****
		Sig. (2-tailed)	.797	.	.036	.000	.075	.000	.000
		N	393	393	393	391	392	393	393
	Gender	Correlation Coefficient	.066	.106*	1.000	-.019	-.017	**.131****	-.080
		Sig. (2-tailed)	.191	.036	.	.711	.729	.009	.112
		N	395	393	395	393	394	395	395
	Level of education	Correlation Coefficient	.018	-.425**	-.019	1.000	-.096	**-.221****	**-.229****
		Sig. (2-tailed)	.718	.000	.711	.	.056	.000	.000
		N	393	391	393	393	392	393	393
	Work experience in tourism sector	Correlation Coefficient	-.047	.090	-.017	-.096	1.000	.042	.036
		Sig. (2-tailed)	.355	.075	.729	.056	.	.405	.482
		N	394	392	394	392	394	394	394
	Visit frequency	Correlation Coefficient	-.133**	.299**	.131**	-.221**	.042	1.000	**.260****
		Sig. (2-tailed)	.008	.000	.009	.000	.405	.	.000
		N	395	393	395	393	394	395	395
	Environemntal education	Correlation Coefficient	.017	.331**	-.080	-.229**	.036	.260**	1.000
		Sig. (2-tailed)	.741	.000	.112	.000	.482	.000	.
		N	395	393	395	393	394	395	395

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 17: **Variance inflation factors (VIF) for predictor variables.**

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Collinearity Statistics Tolerance	Collinearity Statistics VIF
1	(Constant)	29.289	6.727		4.354	.000		
	Proximity to park	.413	1.462	.012	.283	.778	.972	1.029
	Environmental education	9.660	2.107	.211	4.584	.000	.885	1.129
	Work experience in tourism sector	1.410	1.484	.041	.950	.343	.990	1.010
	Visit frequency	5.396	1.595	.157	3.383	.001	.866	1.155
	Gender	3.535	1.490	.105	2.373	.018	.961	1.041
	Level of education with merged no education to primary school	-7.020	.914	-.347	-7.677	.000	.914	1.094

a. Dependent Variable: Age

13.6 Methods for analyzing variables

Table 18: **Methods of bivariate analysis as suggested by [Bryman, 2012]**

	Nominal	Ordinal	Interval/ration	Dichotomous
Nominal	Contingency table + $\chi2$ + Cramér's V	Contingency table + $\chi2$ + Cramér's V	Contingency table + $\chi2$ + Cramér's V If the interval/ratio variable can be identified as the dependent variable, compare means + eta	Contingency table + $\chi2$ + Cramér's V
Ordinal	Contingency table + $\chi2$ + Cramér's V	Spearman's rho ()	Spearman's rho ()	Spearman's rho ()
Interval/ratio	Contingency table + $\chi2$ + Cramér's V If the interval/ratio variable can be identified as the dependent-variable, compare means + eta	Spearman's rho ()	Pearson's r	Spearman's rho ()
Dichotomous	Contingency table + $\chi2$ + Cramér's V	Spearman's rho ()	Spearman's rho ()	phi ()

13.7 Logistic regressions for perceived benefits

Significance and explained variance of each logistic model for "benefits offered by the Park".

- *Learning about nature and environment*
  The model was statistically significant, $\chi2$ (8) =20.764, p=0.008. The model explained 10% (Nagelkerke R^2) of the variance in visit frequency and correctly classified 88% of cases.

- *Good Friday walk to Trois Freres*
  The model was statistically significant, $\chi2$ (8) = 41.840, $p < 0.000$. The model explained 14% (Nagelkerke R2) of the variance in visit frequency and correctly classified 68% of cases.

- *Hiking, walking or running*
  The model was statistically significant, $\chi2$ (8) =120.785, p<0.000. The model explained 37% (Nagelkerke R^2) of the variance in visit frequency and correctly classified 77% of cases.

- *Seeing native plants and animals*
  The model was statistically significant, $\chi2$ (8) =24.376, p= 0.002. The model explained 11% (Nagelkerke R^2) of the variance in visit frequency and correctly classified 85% of cases.

- *Scenic view an natural beauty*
  The model was statistically significant, $\chi2$ (8) = 22.146, p = 0.005. The model explained 14% (Nagelkerke R^2) of the variance in visit frequency and correctly classified 93% of cases.

- *PUC tap water*
  The model was not statistically significant, $\chi2(8)$ = 14.009, p = 0.082. The model explained

5% (Nagelkerke R2) of the variance in visit frequency and correctly classified 60% of cases.

- *Clean drinking water*
  The model was statistically significant, $\chi 2(8) = 33.665$, $p < 0.000$. The model explained 12% (Nagelkerke R^2) of the variance in visit frequency and correctly classified 73% of cases.

- *Clean and fresh air*
  The model was not statistically significant, $\chi 2$ $(8) = 13.128$, $p = 0.108$. The model explained 9% (Nagelkerke R^2) of the variance in visit frequency and correctly classified 94% of cases.

- *Preventing landslide and erosion*
  The model was not statistically significant, $\chi 2$ $(8) = 15.014$, $p = 0.059$. The model explained 5% (Nagelkerke R^2) of the variance in visit frequency and correctly classified 59% of cases.

- *Earning money by working*
  The model was statistically significant, $\chi 2$ $(8) = 16.520$, $p = 0.036$. The model explained 8% (Nagelkerke R^2) of the variance in visit frequency and correctly classified 88% of cases.

- *Picking medicinal plants*
  The model was not statistically significant, $\chi 2(8) = 14.344$, $p = 0.073$. The model explained 5% (Nagelkerke R^2) of the variance in visit frequency and correctly classified 73% of cases.

- *Collecting fruits, flowers and wood*
  The model was statistically significant, $\chi 2$ $(8) = 18.657$, $p = 0.017$. The model explained 7% (Nagelkerke R^2) of the variance in visit frequency and correctly classified 76% of cases.

13.8 Visual aids

Figure 26: **Illustration depicting the Morne Seychellois National Park.**
Source: seychelles.co.za

Figure 27: **Photo of community participating at a tree planting activity.**
Source: EbA project

14 Appendix B: Forest analysis

14.0.1 Ordination and clustering of study sites

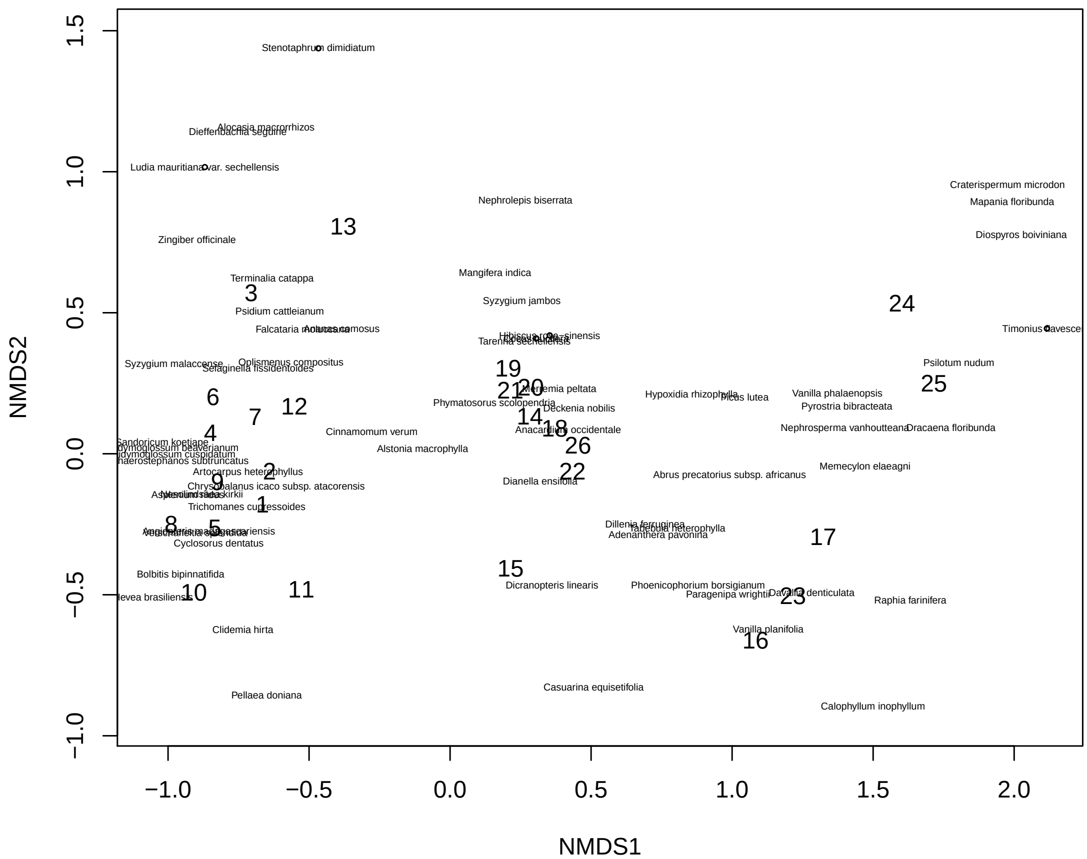

Figure 28: **Ordination of floristic data with NMDS.**
Non-metric multidimensional scaling (NMDS) of the "set of the present" using `metaMDS` of the **vegan** package). Function used is Bray–Curtis dissimilarities.

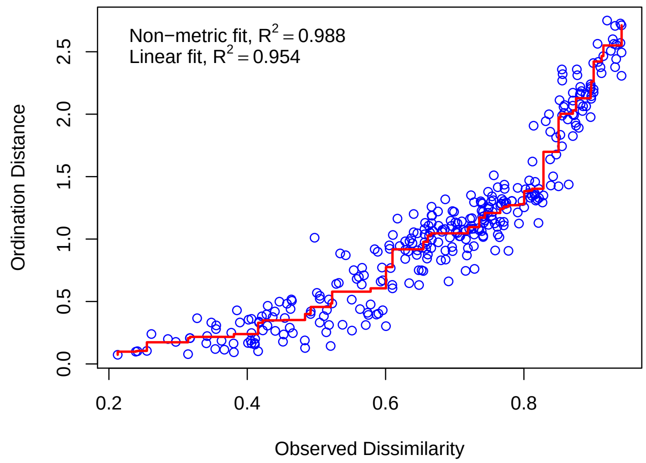

Figure 29: **Stressplot of the NMDS.**

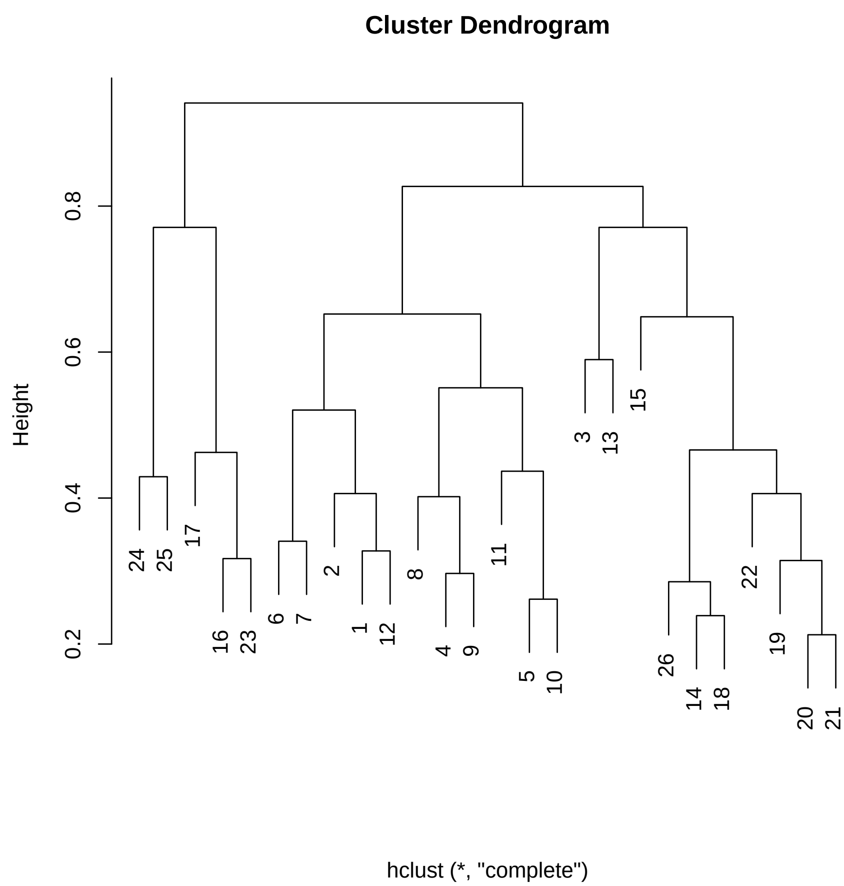

Figure 30: **Hierarchical clustering of study sites.**
Calculated based "set of present". Created with the **vegan** R package using `vegdist` and `hclust`.
Dissimilarity index used to detect underlying ecological gradient is Bray–Curtis distance.

Table 19: **All species recordings in both areas by origin.**

	Area 10 (Lowland)		Area 5 (lowland/submontane)	
	Native	Exotic	Native	Exotic
1	Abrus precatorius subsp. africanus	Albizia lebbeck	Adenanthera pavonina	Alocasia macrorrhizos
2	Adenanthera pavonina	Alstonia macrophylla	Angiopteris madagascariensis	Alstonia macrophylla
3	Calophyllum inophyllum	Anacardium occidentale	Asplenium nidus	Ananas comosus
4	Casuarina equisetifolia	Ananas comosus	Bolbitis bipinnatifida	Artocarpus heterophyllus
5	Cerbera manghas	Artocarpus heterophyllus	Cyclosorus dentatus	Camellia sinensis
6	Cocos nucifera	Chrysobalanus icaco subsp. atacorensis	Davallia denticulata	Chrysobalanus icaco subsp. atacorensis
7	Craterispermum microdon	Cinnamomum verum	Deckenia nobilis	Cinnamomum verum
8	Davallia denticulata	Citrus aurantium	Didymoglossum beaverianum	Citrus aurantium
9	Deckenia nobilis	Citrus mitis	Didymoglossum cuspidatum	Clausena excavata
10	Dianella ensifolia	Clidemia hirta	Dillenia ferruginea	Clidemia hirta
11	Dicranopteris linearis	Falcataria moluccana	Dracaena floribunda	Coffea canephora
12	Dillenia ferruginea	Hibiscus rosa-sinensis	Excoecaria benthamiana	Dieffenbachia seguine
13	Diospyros boiviniana	Mangifera indica	Ficus lutea	Falcataria moluccana
14	Dracaena floribunda	Psidium cattleianum	Hypoxidia rhizophylla	Flacourtia jangomas
15	Ficus lutea	Raphia farinifera	Ludia mauritiana var. sechellensis	Hevea brasiliensis
16	Hypoxidia rhizophylla	Sandoricum koetjape	Memecylon elaeagni	Mangifera indica
17	Intsia bijuga	Syzygium jambos	Merremia peltata	Psidium cattleianum
18	Mapania floribunda	Tabebuia heterophylla	Nephrolepis biserrata	Pterocarpus indicus
19	Memecylon elaeagni	Vanilla planifolia	Nephrosperma vanhoutteana	Sandoricum koetjape
20	Merremia peltata	Zingiber officinale	Nesolindsaea kirkii	Syzygium aromaticum
21	Nephrolepis biserrata		Oplismenus compositus	Syzygium jambos
22	Nephrosperma vanhoutteana		Pellaea doniana	Syzygium malaccense
23	Oplismenus compositus		Phoenicophorium borsigianum	Zingiber officinale
24	Paragenipa wrightii		Phymatosorus scolopendria	
25	Phoenicophorium borsigianum		Planchonella obovata	
26	Phymatosorus scolopendria		Pyrostria bibracteata	
27	Premna serratifolia		Selaginella fissidentoides	
28	Psilotum nudum		Sphaerostephanos subtruncatus	
29	Pyrostria bibracteata		Stenotaphrum dimidiatum	
30	Tarenna sechellensis		Tarenna sechellensis	
31	Terminalia catappa		Terminalia catappa	
32	Timonius flavescens		Trichomanes cupressoides	
33	Trichomanes cupressoides		Verschaffeltia splendida	
34	Vanilla phalaenopsis			

14.0.2 Species occurrence in both study areas

Table 20: **Summary of study site and location.**

Plot number	Forest state	TA	forest area
1	Secondary plantation	1	5. (Submontane/lowland)
2	Secondary plantation	1	5. (Submontane/lowland)
3	Secondary plantation	1	5. (Submontane/lowland)
4	Secondary plantation	1	5. (Submontane/lowland)
5	Secondary plantation	1	5. (Submontane/lowland)
6	Secondary plantation	2	5. (Submontane/lowland)
7	Secondary plantation	3	5. (Submontane/lowland)
8	Secondary plantation	2	5. (Submontane/lowland)
9	Secondary plantation	2	5. (Submontane/lowland)
10	Secondary plantation	3	5. (Submontane/lowland)
11	Secondary plantation	3	5. (Submontane/lowland)
12	Secondary plantation	3	5. (Submontane/lowland)
13	Old distillery garden	2	5. (Submontane/lowland
14	Secondary plantation	4	10. (Lowland)
15	Secondary plantation	4	10. (Lowland)
16	Semi-pristine	5(SP)	10. (Lowland)
17	Semi-pristine	5(SP)	10. (Lowland)
18	Secondary plantation	4	10. (Lowland)
19	Secondary plantation	6	10. (Lowland)
20	Secondary plantation	6	10. (Lowland)
21	Secondary plantation	6	10. (Lowland)
22	Secondary plantation	6	10. (Lowland)
23	Secondary plantation	4	10.(Lowland)
24	Pristine	5(P)	10. (Lowland)
25	Pristine	5(P)	10. (Lowland)
26	Secondary plantation	4	10. (Lowland)

14.0.3 Sampling effort

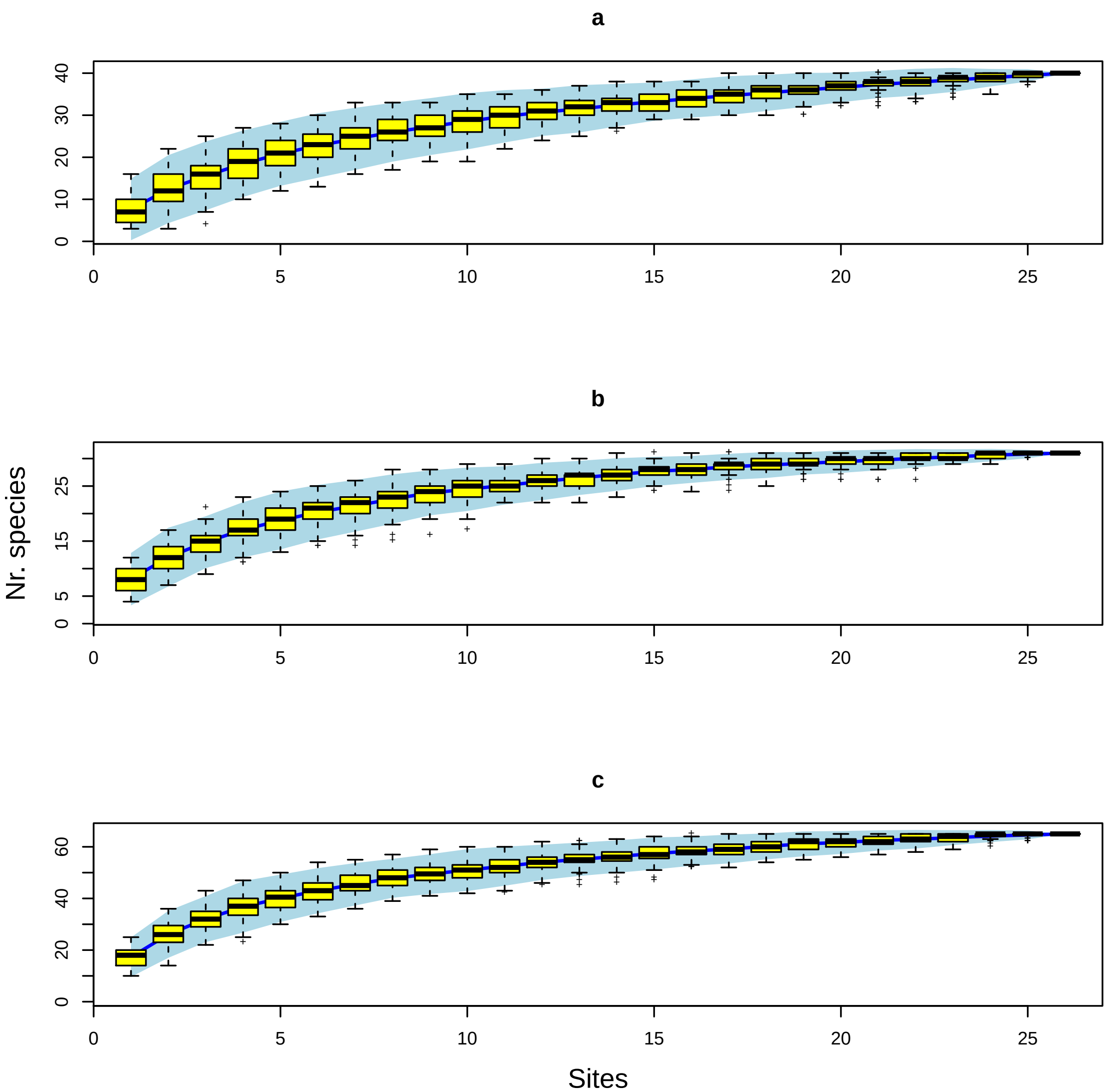

Figure 31: **Species accumulation curves.**
Accumulated number of discovered species for increasing number of sites sampled for a) tree layer, b) shrub layer, c) ground/herb layer. A flattening curve that approaches an equilibrium indicates adequate sampling effort with no additional species being discovered if more sites were surveyed. All sampling strata show adequate sampling effort. Judging from the slope of all layers, it would be the tree layer where chances to discover more species in additional plots would be the highest.

14.0.4 Ordination and clustering of study sites

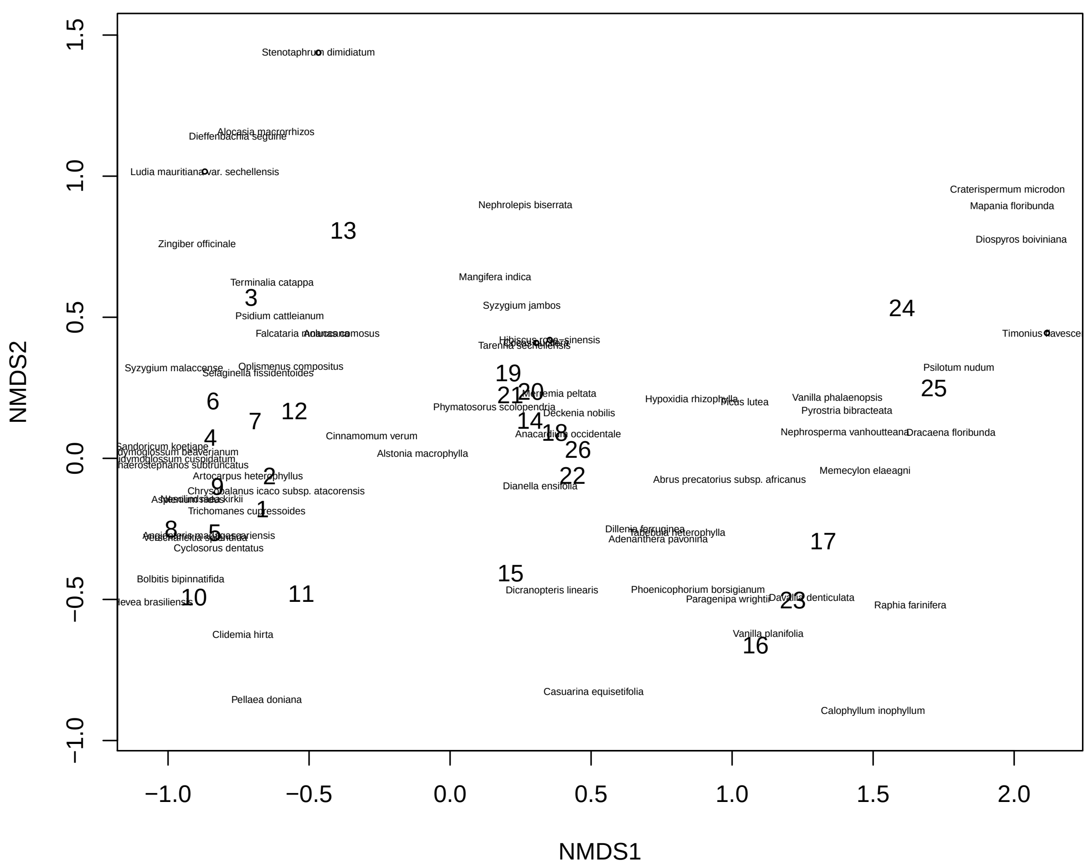

Figure 32: **Ordination of floristic data with NMDS.**
Non-metric multidimensional scaling (NMDS) of the "set of the present" using `metaMDS` of the **vegan** package). Function used is Bray–Curtis dissimilarities.

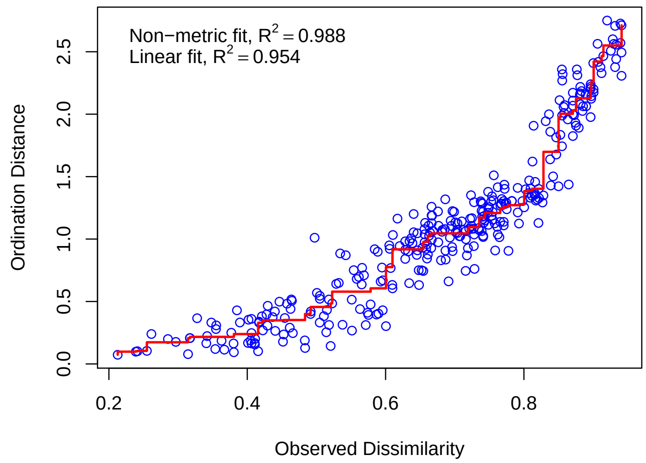

Figure 33: **Stressplot of the NMDS.**

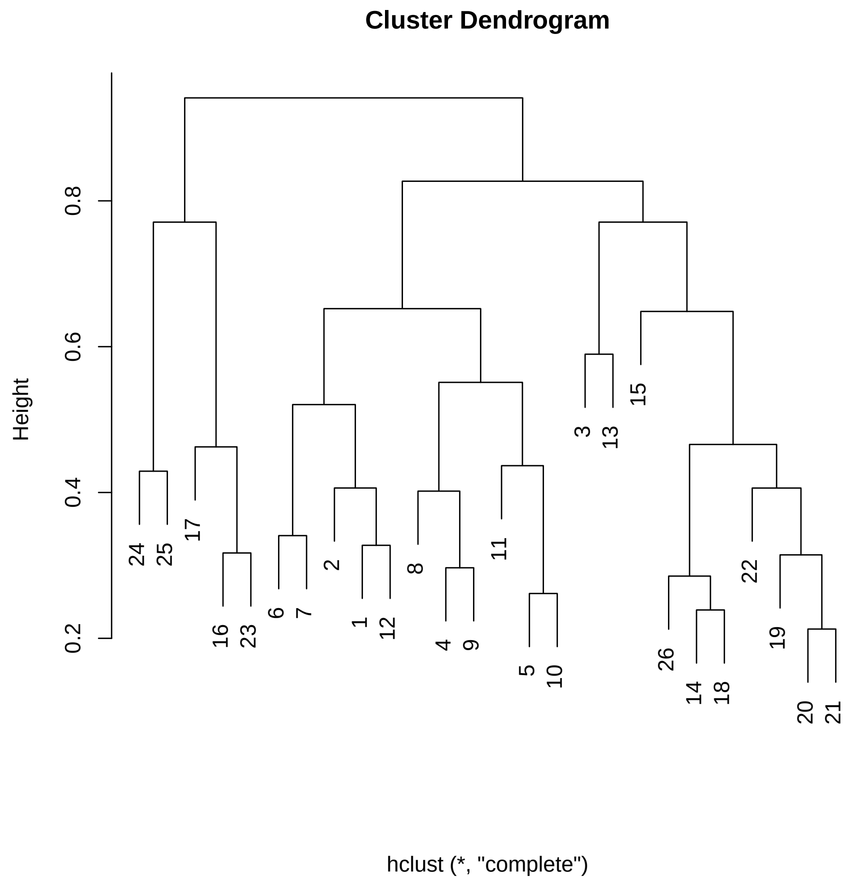

Figure 34: **Hierarchical clustering of study sites.**
Calculated based "set of present". Created with the **vegan** R package using `vegdist` and `hclust`. Dissimilarity index used to detect underlying ecological gradient is Bray–Curtis distance.

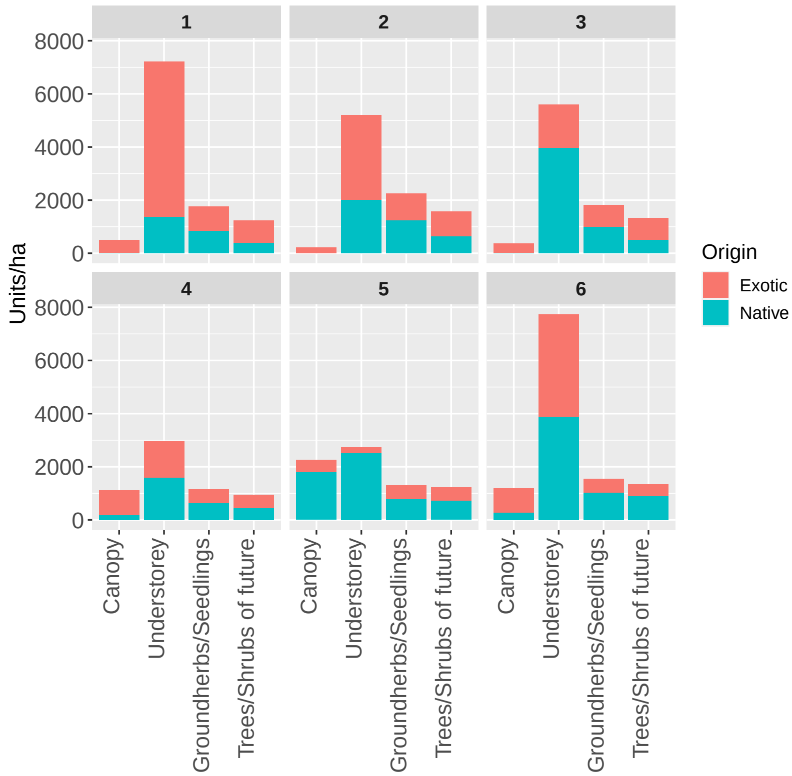

Figure 35: **Absolute densities in all strata by origin.**
Densities in all forest strata including Oldeman's [1990] "set of the future". As compared to Figure 18 which is showing proportions, this figure is showing absolute values for the densities of all exotic and native individuals in all strata. For the ground/herb and "set of the future" layer, mid class van der Maarel coefficients are used. The data displayed serves as the input for the calculation of the two structural status indicators USN and NR.

Figure 36: **Tree diversity map of all study sites.**
Colors indicate species, white circles indicate exotic origin (For species labels see Appendix B Figure 36).

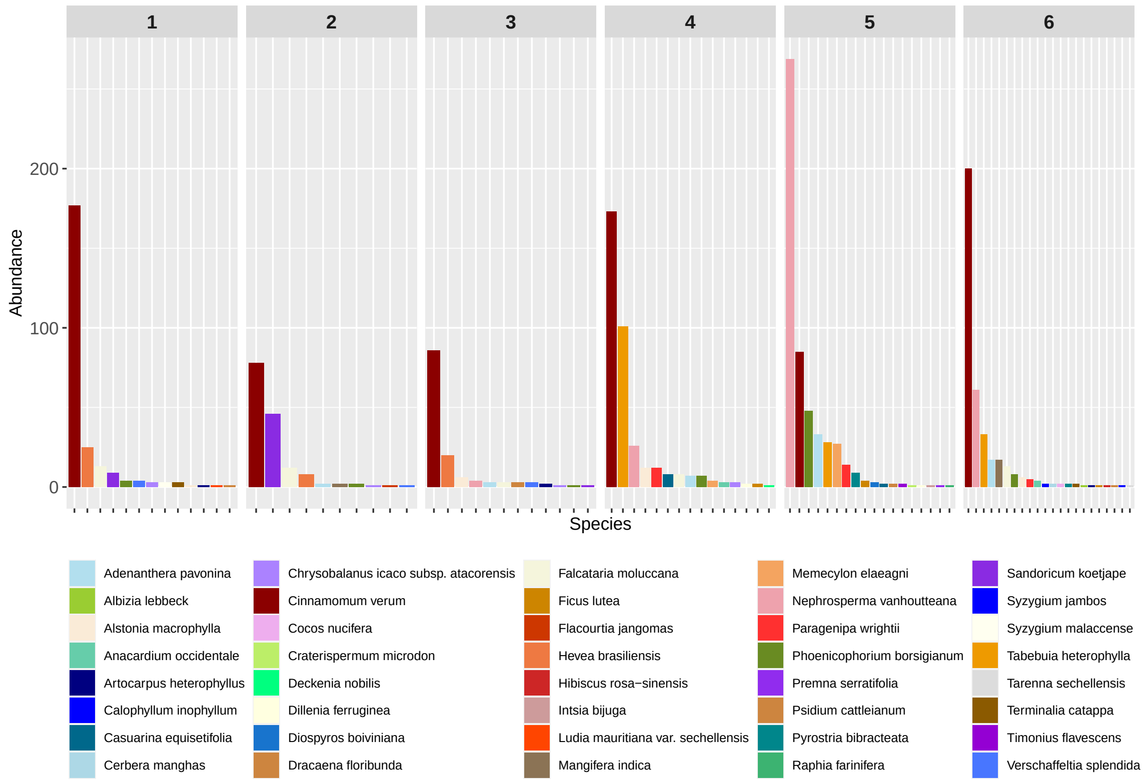

Figure 37: **Tree abundance in all treatment areas.**

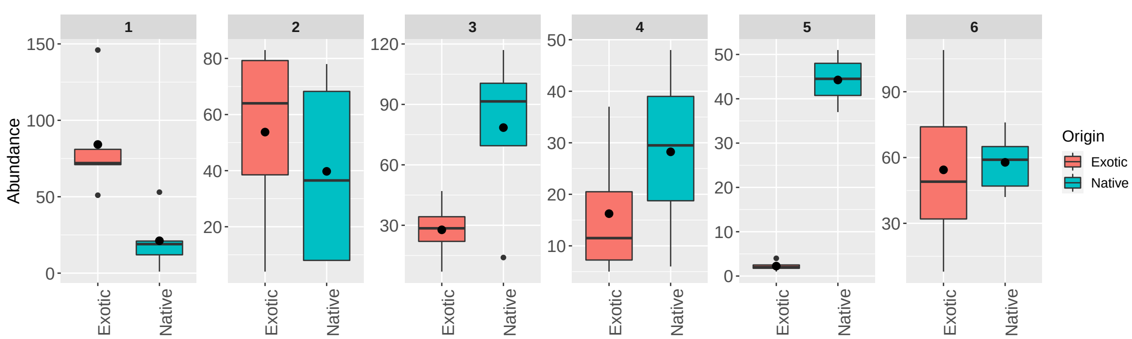

Figure 38: **Mean abundance of shrubs by TA.**

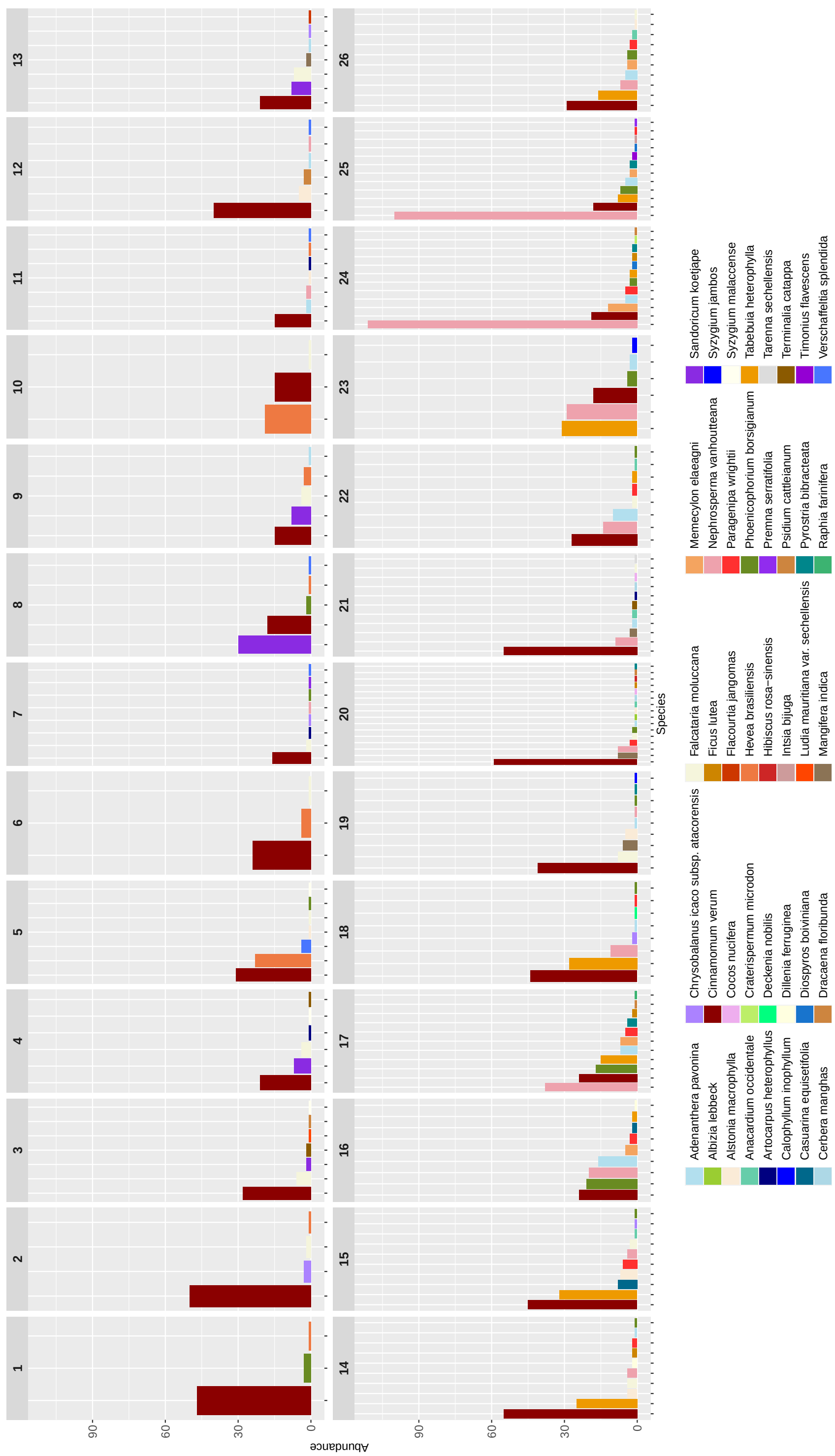

Figure 39: **Tree abundance in all study sites.**

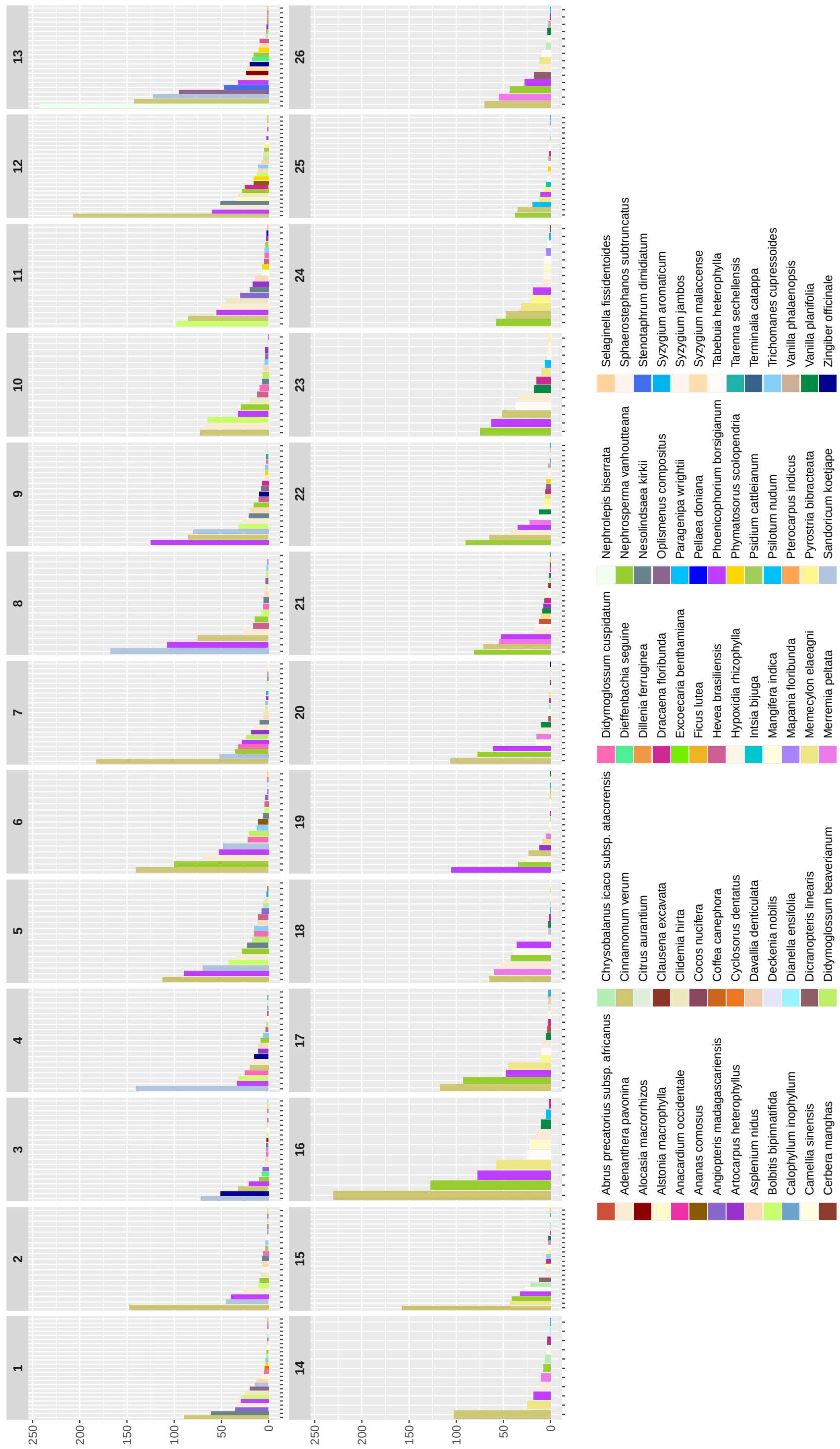

Figure 40: **Herb cover in all study sites.**
Cover value stands for summed up mid class van der Maarel values.

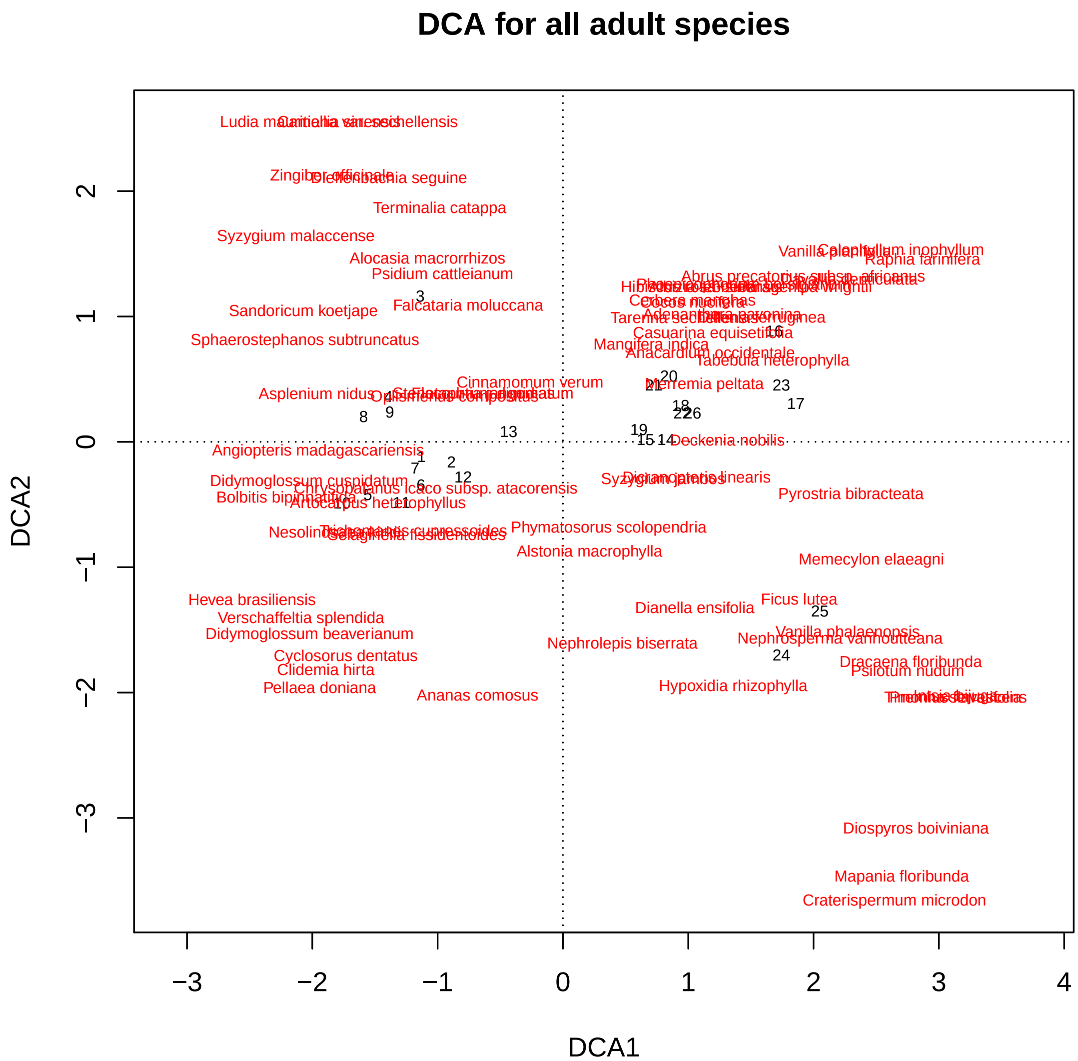

Figure 41: **DCA showing both sites and species effects.**

14.0.5 Rank-abundance plots

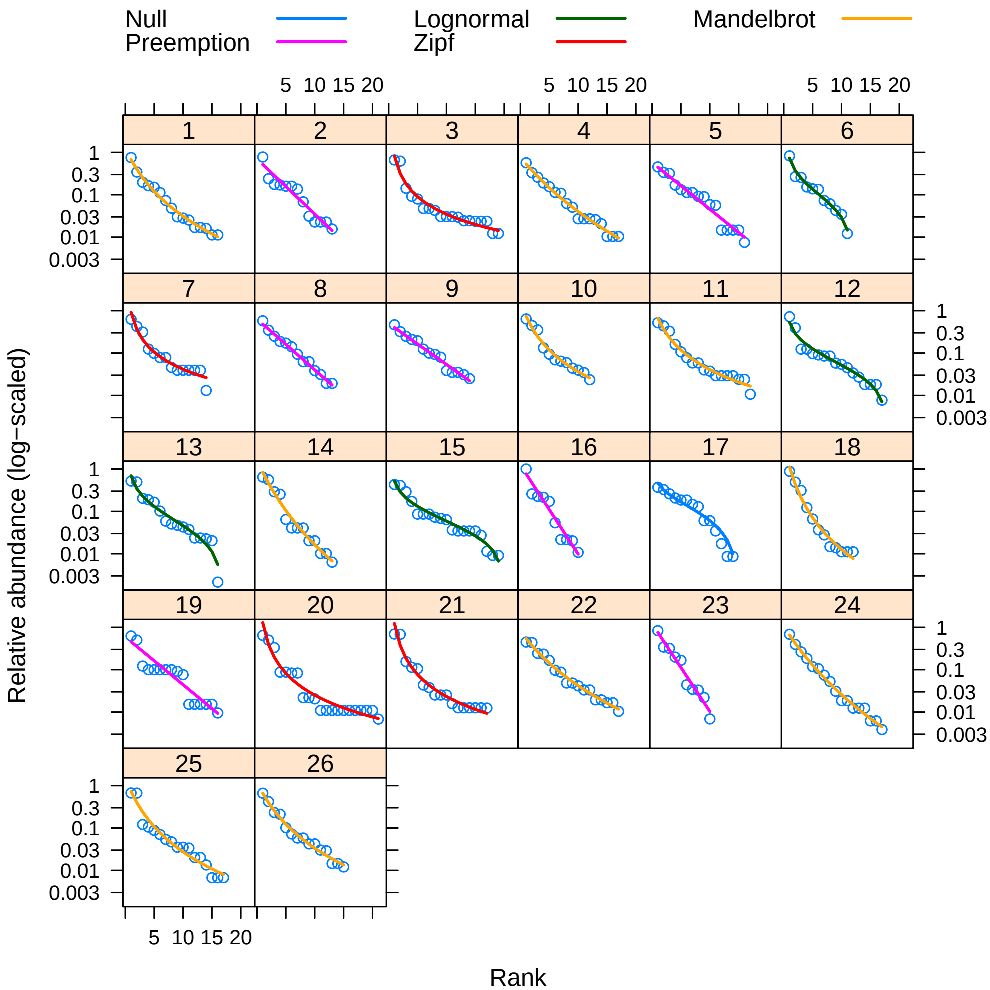

Figure 42: **Rank-abundance plots.**
Rank-abundance plots for all study sites based on species composition of adults [Whittaker, 1965].

14.0.6 Forest succession - Additional material

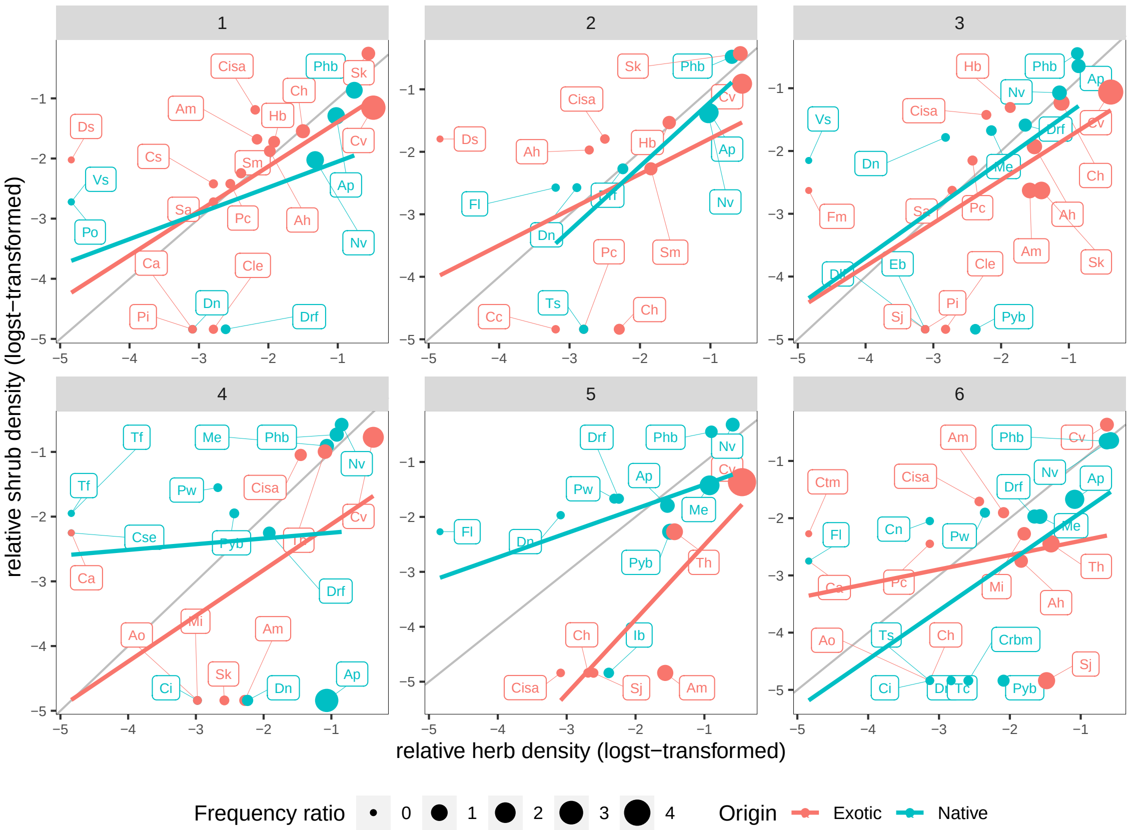

Figure 43: **Forest succession 1 including linear regressions.**
Relative densities of woody species in the herb layer vs. shrub layer. A linear model is fitted to exotic- and native species separately indicating trends. If the blue line lays below the red line, native species are more likely to increase in relative density in the future. The angle of the line indicates if this trend is stronger for abundant of for rare species. The point size indicates the density ratio. The bigger the point, the higher the divergence of density in herb- vs. shrub layer is. Axes are log-scaled as most species are rare. For species abbreviations see Appendix B Figure 21.

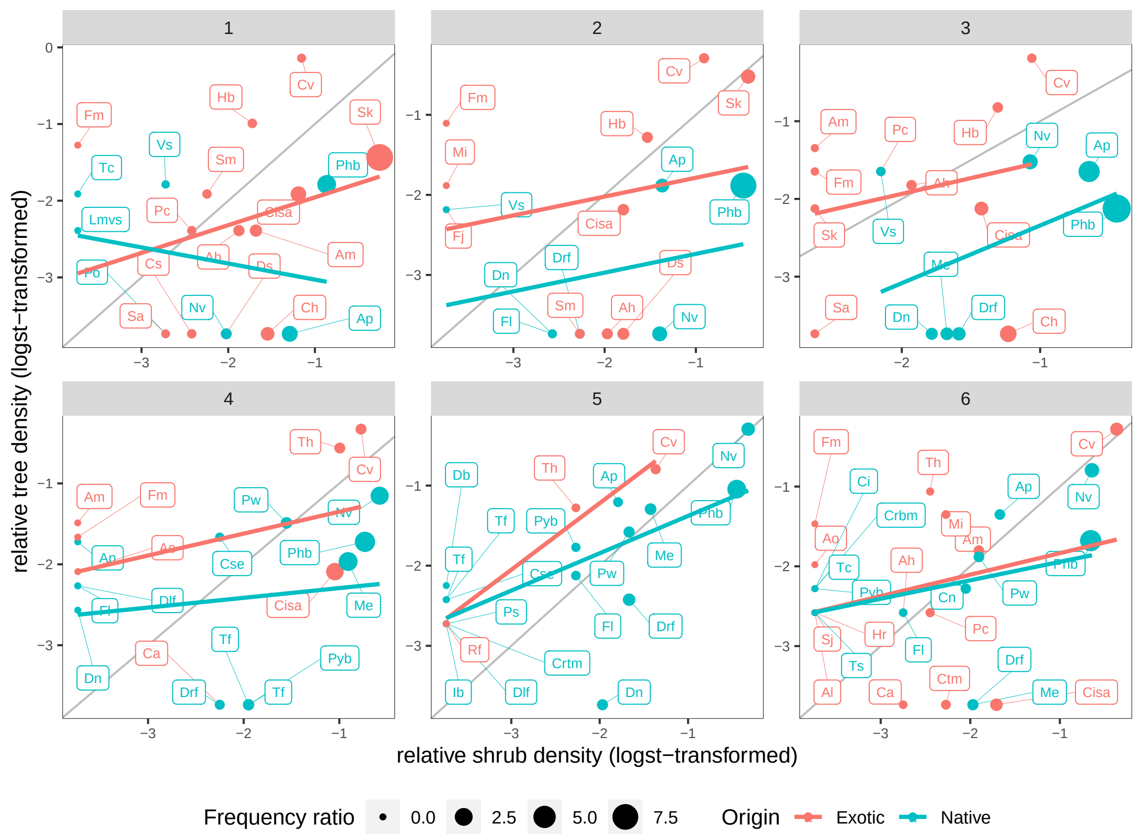

Figure 44: **Forest succession 2 including linear regressions.**
Relative densities of woody species in the shrub layer vs. tree layer. The point size indicates the density ratio. The bigger the point, the higher the divergence of density in tree- vs. shrub layer is. Axes are log-scaled as most species are rare. For species abbreviations see Appendix B Figure 21.

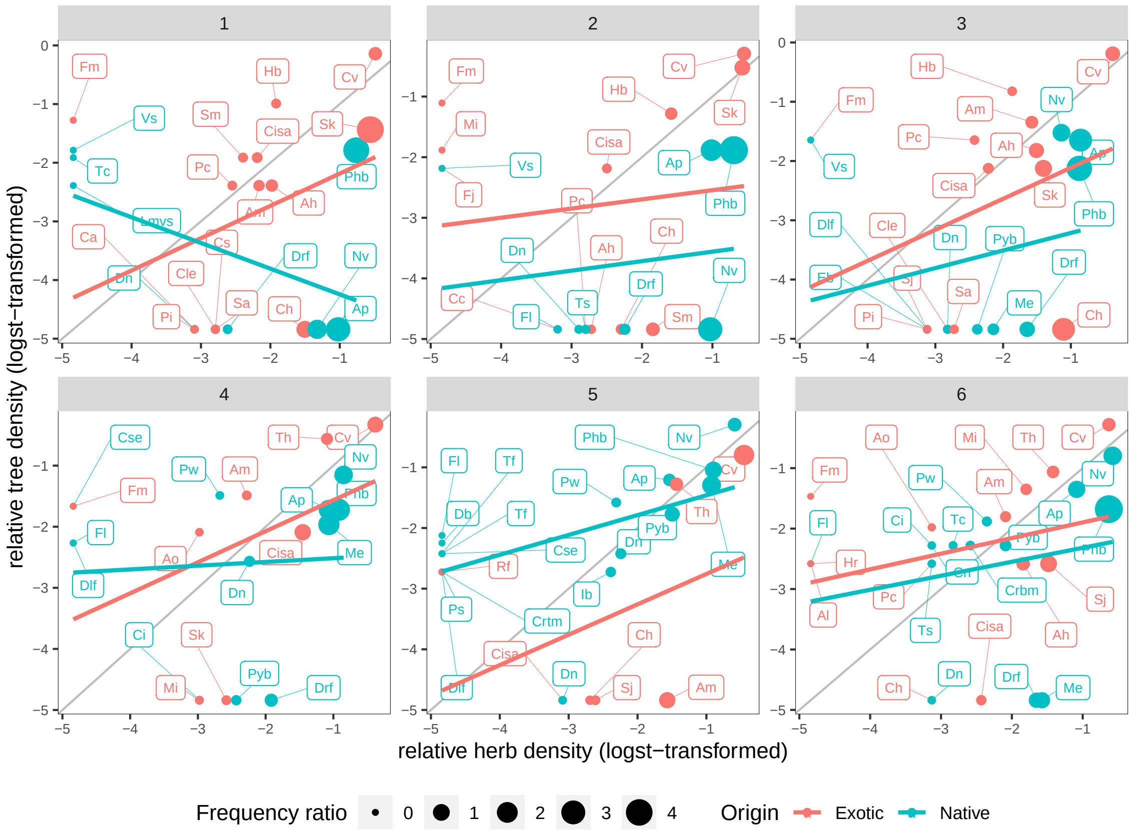

Figure 45: **Forest succession 3 including linear regressions.**
Relative densities of woody species in the herb layer vs. tree layer. The point size indicates the density ratio. This can be understood as the "set of the future" on the x axis against the "set of the present" on the y axis. The bigger the point, the higher the divergence of density in herb- vs. herb layer is. Axes are log-scaled as most species are rare.

Table 21: **Species abbreviations**

	ab	sp
1	Ap	Adenanthera pavonina
2	Al	Albizia lebbeck
3	Am	Alstonia macrophylla
4	Ao	Anacardium occidentale
5	Ah	Artocarpus heterophyllus
6	Ci	Calophyllum inophyllum
7	Cs	Camellia sinensis
8	Cse	Casuarina equisetifolia
9	Crbm	Cerbera manghas
10	Cisa	Chrysobalanus icaco subsp. atacorensis
11	Cv	Cinnamomum verum
12	Ca	Citrus aurantium
13	Ctm	Citrus mitis
14	Cle	Clausena excavata
15	Ch	Clidemia hirta
16	Cn	Cocos nucifera
17	Cc	Coffea canephora
18	Crtm	Craterispermum microdon
19	Dn	Deckenia nobilis
20	Ds	Dieffenbachia seguine
21	Dlf	Dillenia ferruginea
22	Db	Diospyros boiviniana
23	Drf	Dracaena floribunda
24	Eb	Excoecaria benthamiana
25	Fm	Falcataria moluccana
26	Fl	Ficus lutea
27	Fj	Flacourtia jangomas
28	Hb	Hevea brasiliensis
29	Hr	Hibiscus rosa-sinensis
30	Ib	Intsia bijuga
31	Lmvs	Ludia mauritiana var. sechellensis
32	Mi	Mangifera indica
33	Me	Memecylon elaeagni
34	Nv	Nephrosperma vanhoutteana
35	Pw	Paragenipa wrightii
36	Phb	Phoenicophorium borsigianum
37	Po	Planchonella obovata
38	Ps	Premna serratifolia
39	Pc	Psidium cattleianum
40	Pi	Pterocarpus indicus
41	Pyb	Pyrostria bibracteata
42	Rf	Raphia farinifera
43	Sk	Sandoricum koetjape
44	Sa	Syzygium aromaticum
45	Sj	Syzygium jambos
46	Sm	Syzygium malaccense
47	Th	Tabebuia heterophylla
48	Ts	Tarenna sechellensis
49	Tc	Terminalia catappa
50	Tf	Timonius flavescens
51	Vs	Verschaffeltia splendida
55	Aa	Artocarpus altilis
57	Br	Barringtonia racemosa
59	Crm	Cerbera manghas
64	Ca	Coffea arabica
66	Df	Dracaena floribunda
71	Jg	Justicia gendarussa
73	Mh	Martellidendron hornei
75	Nv	Nephrosperma vanhoutteanum
88	un	unknown

14.1 Additional Material for rehabilitation plan

14.1.1 Mapping of Catsclaw creeper

The cat's claw creeper *(Macfadyena unguis-cati* was originally introduced as an ornamental plant in many places. It has since become a major invasive creeper in several tropical countries including northern Australia, South Africa, India, Mauritius, China, USA (Hawaii and Florida) and New Caledonia, where it poses a significant threat to biodiversity in rainforest communities [Prentis et al., 2009]. The cat claw creeper has recently been introduced to the Seychelles. Chemical control options exists, however, as it grows in sensitive areas (water catchment and riparian forests), mechanical control of above ground growth and biological control targeting seed-production using specialist pod-and seed- feeding insects is recommended [Osunkoya et al., 2009]. Currently, the vine grows only in a few locations on Mahe but no mapping has been done. It is of major interest to prevent further spread of this serious environmental weed as long as it is possible to control it. We produced a map of the current distribution between the main trail from Port Launay to Mare aux Cochons (Figure 47). *(Macfadyena unguis-cati* occupies an approximate area of X. The origin appears to be an old ruin (not visible from the trail), where *(M. unguis-cati* grows along the walls and from there invaded the surrounding forest landscape (Figure 46).

(a)

(b)

Figure 46: **Habitat of *Macfadyena unguis-cati*.**
The Distribution of *(Macfadyena unguis-cati* is limited to a small area next to the trail from Port Launay to Mare aux Cochons where spread from (a) the walls of an old ruin (not visible to the trail) to (b) the forest surrounding the ruin.

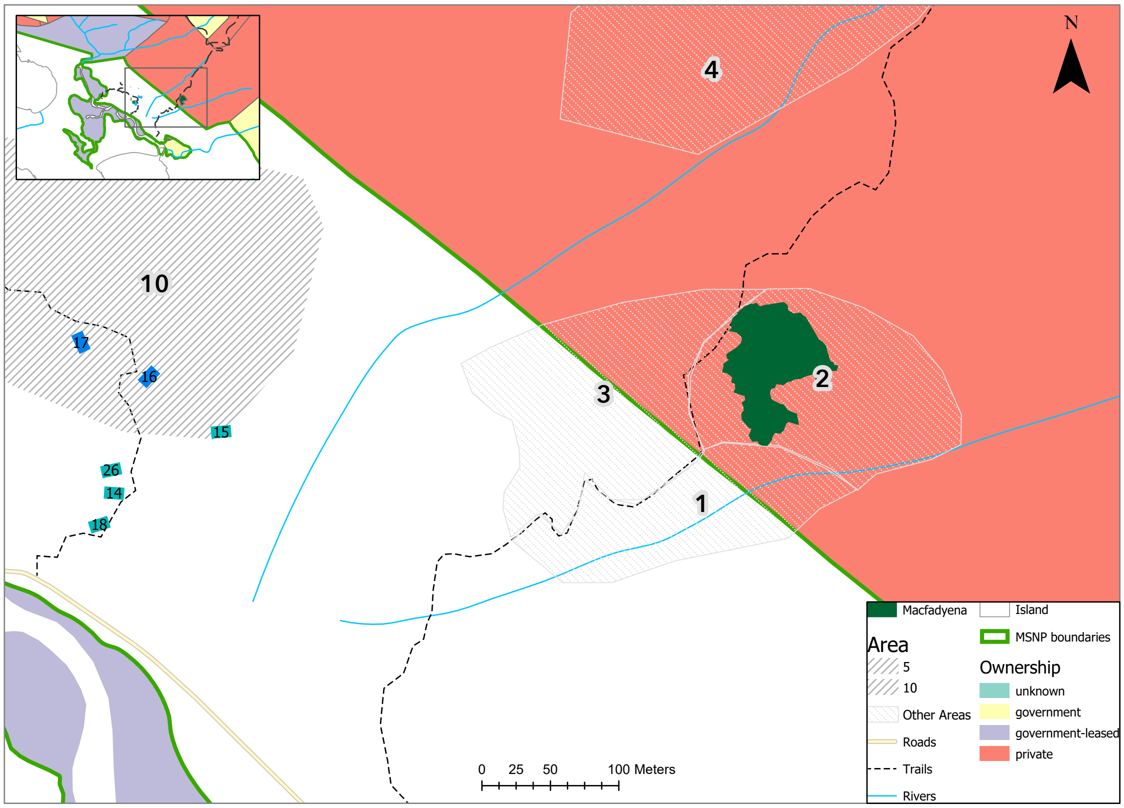

Figure 47: **Map of area invaded with *M. unguis-cati*.**

15 Appendix C) File deposits

15.0.1 Picture of permanent plots and transects

Pictures of permanent plots prior to rehabilitation are deposited under the following link:

https://www.flickr.com/gp/142521267@N04/7DWS3e. The album is only accessible with this link. If the link is broken, contact the authors. We took pictures of at least the three PVC tubes marking starting-, mid-, and end point of every permanent plot. For more pictures, and video footage of the area (including trail transects) contact the authors by email.

The R code used in this analyses (and all vegetation data) is deposited below: https://polybox.ethz.ch/index.php/s/XDYe5CYuVwbTgEy ; as long as data is collected the same way using the FAO OpenForis app, all key analyses should run automatically and reproduce same graphical outputs and indexes as presented in this thesis[9].

[9]The R code needs manual changes in a few flagged places in the code (e.g. names of treatment areas, and of course, corrections for mistakes in data entries within OpenForis if not earlier corrected)

15.1 Additional Maps

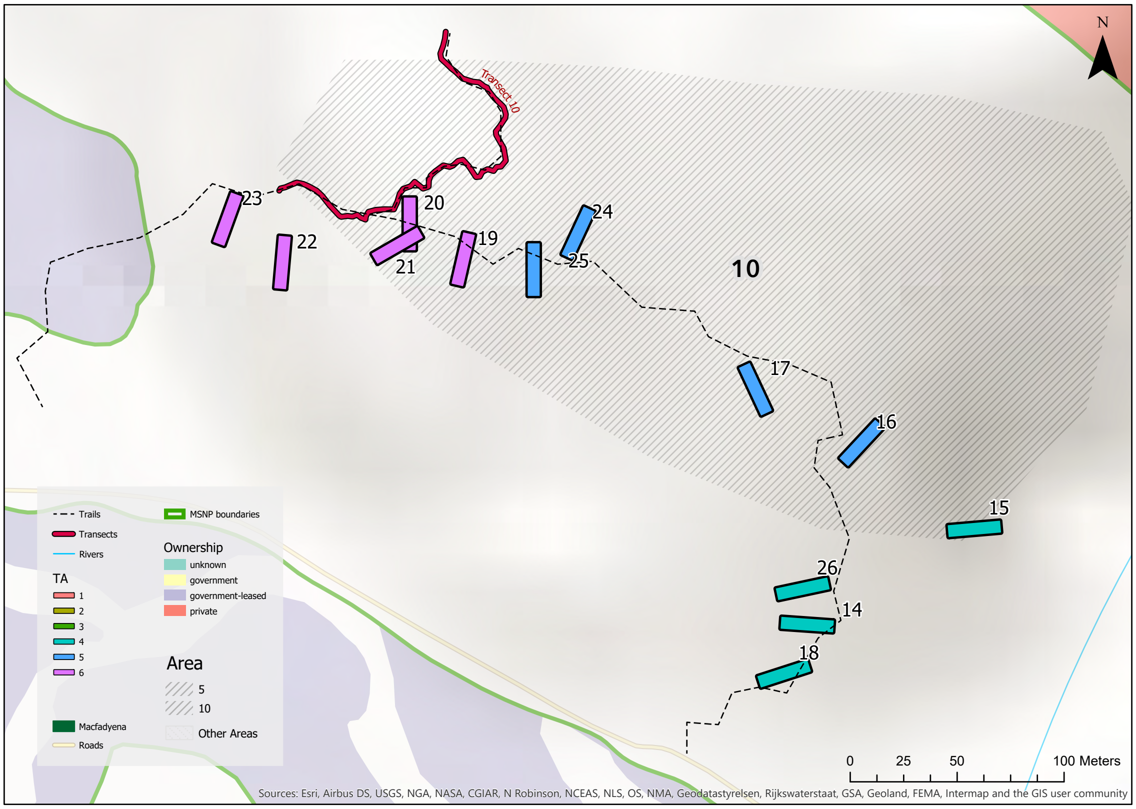

Figure 48: **Detailed map of Area 10.**

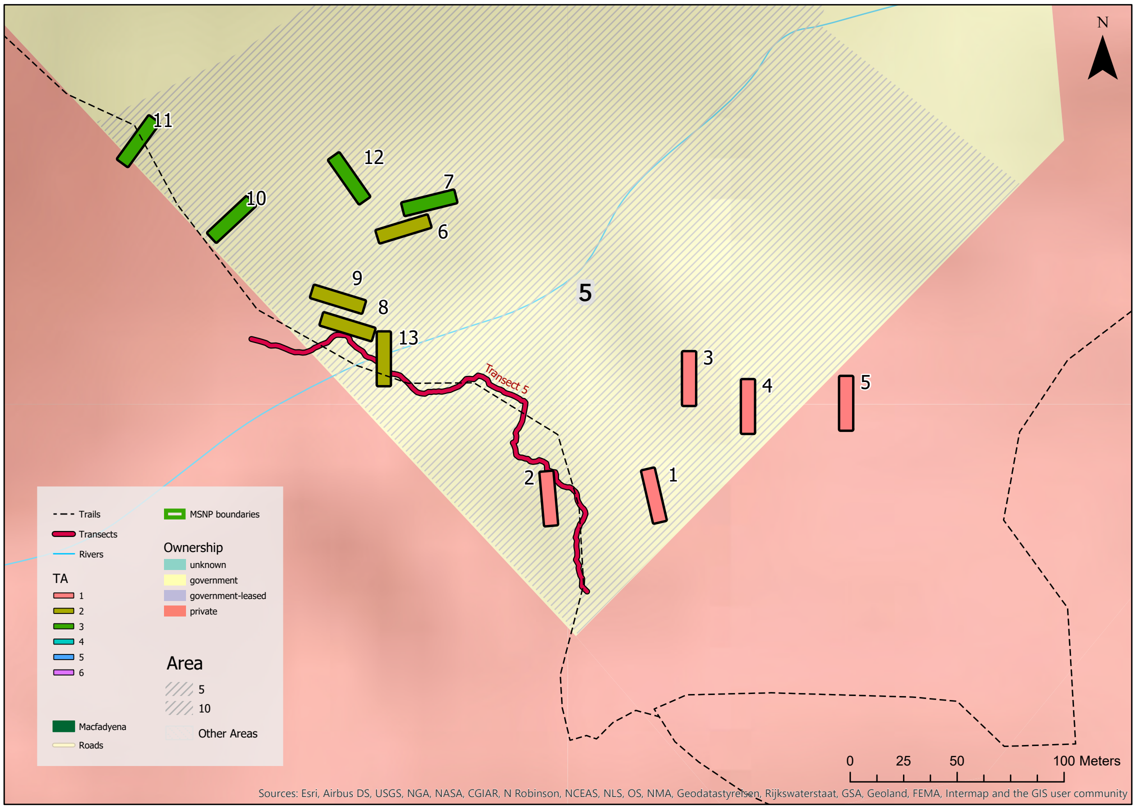

Figure 49: **Detailed map of area 5.**

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