UNDERSTANDING SOCIAL ECOLOGICAL CHANGE THROUGH PALM USE AND MANAGEMENT

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ABSTRACT

As people change their livelihood preferences, they change the way they relate to the natural resources around them. Anticipating and managing these changes, where possible, is a major challenge for sustainable land-use planning and natural resource management. This is most evident in the Amazon, a region of immense biological and cultural diversity but also a region of rapid change and transformation, quickly integrating through transportation infrastructure (roads, harbors, airports, etc.) with other South American regions and the rest of the world. This project analyzes social and ecological change taking place in indigenous settlements of the Amazon region, as they transform their subsistence economies to fit into a western model of living. It uses social ecological systems as a framework to identify and explore the linkages between changes in these two domains, and aims at understanding natural resource management from the perspective of the user and the utilized resource. This, we argue, requires an understanding of collective decision making (governance) of the variations in land and resource use in a community governed in a specific way, and of the response of forests to small-scale human intervention. The way decisions are taken and the way a group of people structure their governance system will affect the ecological system in different ways. We observed fast transformation and diversification of formerly indigenous communities and fast-track integration into western systems of organization resulting in hybrid governance systems with different combinations of traditional and western ways of social organization and resource management. Palms are an ideal study group because their use and ecology is well documented throughout the region and have more recently become an important source of income for many Amazonian populations. Changes in the management of three utilized palm species served as indicators of change in the social ecological system. We investigated palm abundance and management in the three land-use categories: cultivation areas, moderately disturbed forest, and low disturbance forest. Palms are not sown from seed or transplanted into cultivation areas rather they are passively cultivated (protected from fire, weeds, pests, falling branches, etc.). Although palm species are appreciated either for commercial or domestic purposes, seldom did we observe or document active cultivation taking place. In forested areas the most abundant of the three, *Socratea exorrhiza*, recognized as a generalist or oligarchic species, showed a positive response to moderate levels of human intervention. The second most abundant species, *Astrocaryum chambira*, is a near generalist, with more restrictions for its dispersion and establishment than *S. exorrhiza*, and therefore a less favorable response to moderate levels of intervention. Abundance of *Phytelephas macrocarpa* was the lowest; as a soil specialist its distribution is uneven and its overall response to intervention most difficult to assess. Changes in palm management betrayed a general shift from a view of cultivation areas as the community's pantry to a view of cultivation areas as the sum of individually owned plots where only commercially valued species are harvested. The distinction between the three zones was blurred in the community with greater access to the west, there was a pressure towards privatization, to erase the traditional zoning regulations, since both palms and land are seen as a commodity. Indiscriminate extraction is taking place in forested areas and in cultivation areas pressure and conflicts are increasing and leading to formalization of property rights and new forms of representation, thus pushing integration further. Transportation infrastructure will continue its expansion, the pressure for oil and mineral extraction will increase in the Amazon and it will be necessary to accept and understand these paths of change in order to minimize the negative consequences that they might have for the social ecological system as a whole.

Understanding ecological change through palm use and management
ZUSAMMENFASSUNG

Gesellschaftliche Lebensmuster ändern sich – dies hat Einfluss auf Tier- und Pflanzenpopulationen, die als natürliche Ressourcen angesehen werden. Die Vorwegnahme und Bewältigung der sich ändernden Lebensmuster gehört zu den größten Herausforderungen für eine nachhaltige Landnutzungsplanung und ein langfristig erfolgreiches Ressourcenmanagement. Exemplarisch hierfür ist die Amazonasregion – ein Gebiet von immenser biologischer und kultureller Diversität. Es ist ebenso eine Region, die sich extrem schnell verändert – vor allem durch die Anbindung zu anderen südamerikanischen Regionen und der restlichen Welt durch Transportinfrastruktur (Straßen, Häfen etc.). Dieses Projekt analysiert den sozialen und ökologischen Wandel in Siedlungen von Eingeborenen, der in der Amazonasregion stattfindet. Die Eingeborenen ändern ihre Subsistenzwirtschaft und traditionellen Regelungen in Richtung des westlichen Lebensstils. Das Projekt nutzt sozial-ökologische Systeme als Rahmen zur Identifizierung und Untersuchung der wechselseitigen Beziehung zwischen den Veränderungen innerhalb dieser zwei Domänen, um das Ressourcenmanagment sowohl aus der Perspektive des Nutzes als auch der genutzten Ressource zu beleuchten. Dies erfordert unserer Meinung nach ein Verständnis über ein System der kollektiven Entscheidungsfindung (Governance) der unterschiedlichen Land- und Ressourcennutzung innerhalb dieser speziellen Gesellschaftsform, genauso wie ein Verständnis über die Reaktion der dortigen Wälder auf kleinflächige menschliche Eingriffe. Die Art und Weise, wie Entscheidungen getroffen werden und das Verfahren, wie Menschen ihr Steuerungssystem organisieren, beeinflusst das ökologische System in unterschiedlicher Weise. Wir konnten eine rasche Transformation und Veränderung von einst indigenen Gemeinschaften und eine beschleunigte Einbindung in westliche Organisationsformen feststellen. Dies führte zu gemischten Steuerungssystemen mit traditionellen und westlichen Ausprägungen der gesellschaftliche Organisation und des Ressourcenmanagements. Palmen stellen eine ideale Untersuchungsgruppe dar, weil ihre Nutzung in der Region gut dokumentiert ist. In letzter Zeit sind sie zudem zu einer wichtigen Einkommensquelle vieler Amazonasbewohner geworden. Die Änderungen im Management dreier genutzter Palmenarten dienten als Indikator für die Änderung im sozial-ökologischen System. Die Häufigkeit der Palmen und deren Management wurden in drei Landnutzungskategorien untersucht: Anbaufläche, leicht gestörter Wald und gering gestörter Wald. Auch wenn Palmen entweder wegen kommerzieller oder heimischer Zwecke geschätzt wurden, konnten wir selten aktiven Anbau beobachten oder dokumentieren. D.h.sie wurden nicht gesät oder in die Anbaufläche verpflanzt sondern vielmehr passiv kultiviert (Schutz vor Feuer, Unkraut, Schädlingen, heruntergerfallenen Ästen etc.). In bewaldeten Gebieten hat die am häufigsten vorkommende der drei Arten, *Socratea exorrhiza,* positiv auf das mäßige Eingriffslevel reagiert, die als Generalist oder oligarchische Art bekannt ist. Die am zweithäufigste Art, *Astrocaryum chambira,* ist ebenfalls Generalist, hat aber mehr ökologische Einschränkungen in Bezug auf ihre Verbreitung und Etablierung als *S. exorrhiza*. Dadurch reagiert sie etwas empfindlicher auf mäßige Störungen. *Phytelephas macrocarpa,* die dritte Art, verzeichnet das geringste Vorkommen; als ein Bodenspezialist ist ihre Verbreitung ungleichmäßig und ihre allgemeine Reaktion auf Störung am schwierigsten zu beurteilen. Die Änderungen des Palmenmanagements wurde verzerrt durch eine generell verschobene Ansicht, Anbauflächen als die Summe individuell genutzter Parzellen zu sehen, wo alleinig

kommerziell genutzte Arten angebaut werden, statt diese als ”gemeinschaftlich genutzte Speisekammer” anzuerkennen. Die Unterteilung der drei Kategorien war in der westlich orientierten Gemeinschaft verschwommen: der Druck in Richtung Privatisierung ist ebenso ein Druck auf die Abschaffung der traditionellen Zonierungsregelungen, da beides, Palmen und Land, als Ware gesehen werden. Willkürliche Entnahme findet in den Waldgebieten statt. In Anbaugebieten steigt der Druck und die Konflikte, was zur Formalisierung von Eigentumsrechten und neuen Repräsentationsformen führt und somit die Integration in westliche Systeme vorantreibt. Die Verkehrsinfrastruktur wird sich weiter ausbreiten und der Druck auf den Amazonas durch Öl- und Mineralgewinnung zunehmen. Es wird notwendig sein, die damit einhergehenden Veränderungen zu akzeptieren und zu verstehen, um die möglichen negativen Auswirkungen auf sozio-ökologische Systeme als Ganzes zu minimieren

EXECUTIVE SUMMARY

Changes in livelihood strategies have an impact on populations of species considered a natural resource. Anticipating and managing these changes, where possible, is a major challenge for sustainable land-use planning and natural resource management. As people change their livelihood preferences, they change the way they relate to the natural resources around them. The definition, use and value of natural resources will change together with changing livelihoods. This is most evident in forest communities like those in the Amazon, a region of immense biological and cultural diversity with a prominent role in stabilizing the global climate and an immeasurable number of potentially useful species. It is also a region of rapid change and transformation, quickly integrating through transportation infrastructure (roads, harbors, airports, etc.) with other South American regions and the rest of the world. Countries in South America are committed to ambitious plans for economic development, relying to a high degree on resource extraction, thus creating an increasing need for effective management of natural resources. In this context, high priority is given to oil and mineral exploitation and regional infrastructure development plans.

This project analyzes social and ecological change taking place in indigenous settlements of the Amazon region, as they transform their subsistence economies and traditional politics to fit into a more western model of living. It uses social ecological systems as a framework to identify and explore the linkages between changes in these two domains, and aims at understanding natural resource management from the perspective of the user and the utilized resource. This, we argue, requires an understanding of collective decision making (governance) of the variations in land and resource use in a community governed in a specific way, and of the response of forests to small-scale human intervention. Similar work, initiated from different disciplines, has evidenced the challenge and the need of seeing ourselves as “part and parcel of nature” and of “harnessing complexity instead of trying to eliminate it”.

The study of natural resource governance can be understood as the study of linkages between social and ecological systems. Thus, by evidencing changes in governance it is possible to observe changes in the social ecological system as a whole. The way decisions are taken and the way a group of people structure their governance

system will affect the ecological system in different ways. We reconstructed the evolution of governance in two settlements. Analyzing and comparing the governance paths of the two communities against the background of a third, more traditional and more isolated settlement in the area it was possible to gain a better understanding of the ongoing transformations on collective decision making in these communities. We observed fast transformation and diversification of formerly indigenous communities and fast-track integration into western systems of organization resulting in hybrid governance systems with different combinations of traditional and western ways of social organization and resource management.

Palms are an ideal study group because their use and ecology is well documented throughout the region. Most importantly, they have an extended history of use and a great number of uses, and have more recently become an important source of income for many Amazonian populations. Changes in the management of three utilized palm species served as indicators of change in the social ecological system, i.e., *Astrocaryum chambira*, *Socratea exorrhiza* and *Phytelephas macrocarpa*. These palm species, as many others, are intricately woven in the lives of indigenous people in the Amazon. *Astrocaryum chambira* is an important source of fiber from which a different variety of handicraft products are made and sold in local and sometimes national markets. *Socratea exorrhiza* is used as a source of timber from which construction material like thatch, walls and floors are made; more recently it has also entered the handicraft market. *Phytelephas macrocarpa* is used in the region almost exclusively for thatching material, although in other parts of the Amazon its seeds are carved into buttons and small figurines.

The use and management of these three palm species was documented in two indigenous communities of the Ticuna ethnic group. The largest community lies on the Amazon River, is the easiest of the two to access and has established a reputation as handicraft market in the area. The second community is smaller and more difficult to access, and its people rely mostly on agriculture for a living but also hunt and fish as part of their subsistence needs. Through household interviews and participant observation during visits to the two communities, information on the use and management of palms in the areas surrounding the communities was collected.

We distinguished three land-use categories: cultivation areas, moderately disturbed forest, and low disturbance forest. We investigated palm abundance and management in the three zones. Cultivation areas are in the immediate surroundings of the human settlements, have the lowest soil humidity and vegetation cover and are considered to be a female domain by the Ticuna. Moderately disturbed areas, ca. 2 km from the core settlements, have a higher soil humidity and vegetation cover and are places where most of the timber and non-timber forest products are extracted. Low disturbance forest areas have the highest humidity and vegetation cover and are known to a few elders and experienced hunters in the community. In the cultivation areas, the differences and changes in economic activities are most evident, and the linkages between governance change and management change can be closely observed. This is where social and ecological systems are closely tied and thus where effects in the two directions are triggered.

Comparing the abundance of palm individuals in both low and moderately disturbed areas around each settlement allowed a general overview of the condition of the three palm species populations. Disturbance here is defined here as human intervention. In addition to this general assessment, abundances of large individuals and harvesting practices in cultivated areas allowed a more comprehensive understanding of palm management in these settlements. It was possible to distinguish three broad management actions in this land-use category: *active cultivation, passive cultivation and tolerance*. None of the three palm species, and probably no other palms, are actively cultivated, i.e., they are not sown from seed or transplanted into cultivation areas. Palms are passively cultivated (protected from fire, weeds, pests, falling branches, etc.) in the case of *A. chambira* for its commercial appreciation and *P. macrocarpa* for its domestic importance. *Socratea exorrhiza* is mostly tolerated, although some people might cultivate it passively from time to time. Although palm species are appreciated either for commercial or domestic purposes, seldom did we observe or document active cultivation taking place.

Each of the palm species studied belonged to different ecological categories conditioning their response to moderate levels of intervention. The most abundant of the three, *S. exorrhiza*, has been recognized as a generalist or oligarchic species, and has shown a positive response to moderate levels of human intervention. The second most

abundant species, *A. chambira*, is a near generalist, known from other studies as having more ecological restrictions for its dispersion and establishment than *S. exorrhiza,* and therefore had a less favorable response to moderate levels of intervention. Abundance of *P. macrocarpa*, the third species, was the lowest; as a soil specialist its distribution is uneven and therefore its overall response to intervention most difficult to assess.

Changes in palm management betrayed a general shift from a view of cultivation areas as the community's pantry to a view of cultivation areas as the sum of individually owned plots where only commercially valued species are harvested. The distinction between the three zones was blurred in the same process: a pressure towards privatization is also a pressure to erase the traditional zoning regulations, since both palms and land are seen as a commodity. Indiscriminate extraction is taking place in areas of moderate as well as low disturbance. In cultivation areas pressure and conflicts are increasing and leading to formalization of property rights and new forms of representation, thus pushing integration further.

Viewing changes taking place in both social and ecological systems will improve the way conservation, social development and economic planning is taking place at local and regional levels.

Transportation infrastructure will continue its expansion, and the pressure for oil and mineral extraction will increase in the Amazon. Human communities in the region will continue to pursue stable sources of monetary income and thus their integration into western forms of social organization. Whatever direction the development takes, it will be necessary to accept and understand these paths of change. Policies need to be drawn to prepare for these changes and to minimize the negative consequences that they might have for the social ecological system as a whole.

Understanding ecological change through palm use and management

ÜBERBLICK

Gesellschaftliche Lebensmuster ändern sich – dies hat Einfluss auf Tier-und Pflanzenpopulationen, die als natürliche Ressourcen angesehen werden. Die Vorwegnahme und Bewältigung der sich ändernden Lebensmuster gehört zu den größten Herausforderungen für eine nachhaltige Landnutzungsplanung und ein langfristig erfolgreiches Ressourcenmanagement. Änderungen der menschlichen Muster und Verhaltensweisen beeinflussen das Verhältnis zu den natürlichen Ressourcen, die sie umgeben. Die Bedeutung, Nutzung und der Wert der natürlichen Ressourcen wandeln sich. Exemplarisch hierfür sind Waldgemeinschaften wie z.B. in der Amazonasregion – ein Gebiet von immenser biologischer und kultureller Diversität, dem eine bedeutsame Rolle in der Stabilisierung des globalen Klimas zukommt und welches eine unermessliche Zahl an potenziell nutzbaren Arten vorzuweisen hat. Es ist ebenso eine Region, die sich – vor allem durch Transportinfrastruktur (Straßen, Häfen, Flughäfen etc.) mit anderen südamerikanischen Regionen und der restlichen Welt – extrem schnell verändert und transformiert. Südamerikanische Länder verfolgen ehrgeizige Pläne in Bezug auf ihre ökonomische Entwicklung, die meist zu einem hohen Grad auf Ressourcenabbau beruhen und dadurch einen wachsenden Bedarf an ein effektives natürliches Ressourcenmanagement stellen. Dies betrifft vor allem den Öl- und Rohstoffabbau wie auch die regionale Infrastrukturentwicklung.

Dieses Projekt analysiert den sozialen und ökologischen Wandel in Siedlungen von Eingeborenen, der in der Amazonasregion stattfindet. Die Ureinwohner ändern ihre Subsistenzwirtschaft und traditionellen Regelungen in Richtung des westlichen Lebensstils. Das Projekt nutzt sozial-ökologische Systeme als Rahmen zur Identifizierung und Untersuchung der wechselseitigen Beziehung zwischen den Veränderungen innerhalb dieser zwei Domänen, um das Ressourcenmanagment sowohl aus der Perspektive des Nutzes als auch der genutzten Ressource zu beleuchten. Dies erfordert unserer Meinung nach ein Verständnis über ein System der kollektiven Entscheidungsfindung (Governance) der unterschiedlichen Land- und Ressourcennutzung innerhalb dieser speziellen Gesellschaftsform, genauso wie ein Verständnis über die Reaktion der dortigen Wälder auf kleinflächige menschliche Eingriffe. Ähnliche Arbeiten aus unterschiedlichen Disziplinen

belegen die Herausforderung und Notwendigkeit uns selbst als „Teil und Parzelle der Natur“ zu sehen und „Komplexität zu nutzen statt zu beseitigen“.

Die Untersuchung einer erfolgreichen Steuerung des Ressourcenmanegements ist im Prinzip eine Untersuchung der Verknüpfungen zwischen sozialen und ökologischen Systemen. Änderungen in dieser Steuerung bedeuten Veränderungen im ganzen sozial-ökologischen System. Die Art und Weise, wie Entscheidungen getroffen werden und das Verfahren, wie Menschen ihr Steuerungssystem organisieren, beeinflusst das ökologische System in unterschiedlicher Weise. Hierzu haben wir die Entwicklung des Steuerungssystems zweier Siedlungen rekonstruiert. Indem die Steuerungswege der zwei Siedlungen mit einer dritten, isolierteren und traditionelleren, Siedlung in der Region analysiert und verglichen wurden, war es möglich, ein besseres Verständnis für die laufenden Veränderungen kollektiver Entscheidungsfindung in diesen Siedlungen zu erlangen. Wir konnten eine rasche Transformation und Veränderung von einst indigenen Gemeinschaften und eine beschleunigte Einbindung in westliche Organisationsformen feststellen. Dies führte zu gemischten Steuerungssystemen mit einer Mischung aus traditionellen und westlichen Ausprägungen der gesellschaftliche Organisation und des Ressourcenmanagements.

Palmen stellen eine ideale Untersuchungsgruppe dar, weil ihre Nutzung in der Region gut dokumentiert ist. Weiterhin besitzen sie eine lange Nutzungshistorie und eine Vielzahl an Nutzungsarten. In letzter Zeit sind sie zudem zu einer wichtigen Einkommensquelle vieler Amazonasbewohner geworden. Die Änderungen im Management dreier genutzter Palmenarten, *Astrocaryum chambira*, *Socratea exorrhiza* and *Phytelephas macrocarpa,* dienten als Indikator für die Änderung im sozial-ökologischen System. Wie viele andere Palmenarten sind diese auf komplexe Weise in das Leben der indigenen Menschen des Amazonas eingebunden. *Astrocaryum chambira* ist eine wichtige Quelle für Fasern, aus denen verschiedenes Kunsthandwerk hergestellt und auf lokalen und z.T. nationalen Märkten verkauft wird. *Socratea exorrhiza* wird als Holzquelle genutzt, aus der Baumaterial wie Strohdächer, Wände und Fußböden hergestellt wird; seit kurzem ist es auch im Bereich des Kunsthandwerks zu finden. *Phytelephas macrocarpa* wird in der Region fast ausschließlich als Material für Strohdächer verwendet, auch wenn in anderen Amazonasregionen die Samen zu Knöpfen und kleine Figuren verarbeitet werden.

Die Nutzung und das Management dieser drei Palmenarten wurde in zwei der indigenen Gemeinschaften dokumentiert, die ethnisch der Ticuna-Gruppe angehören. Eine Gemeinschaft, die direkt am Amazonas liegt, einfach zu erreichen ist und Anerkennung als Kunsthandwerksmarkt in der Region erlangte. Die zweite Gemeinschaft ist kleiner und schwieriger zu erreichen. Deren Bewohner sind größtenteils auf Landwirtschaft als Lebensgrundlage angewiesen, aber auch Jagd und Fischerei sind Teil ihrer Subsistenzwirtschaft. Während des Aufenthalts in den zwei Gemeinschaften konnten durch Haushaltsbefragungen und Beobachtung der Verhaltensweisen Informationen zur Nutzung und des Managements der Palmen in der Umgebung der Siedlungen gesammelt werden.

Es wurden drei Landnutzungskategorien definiert: Anbaufläche, leicht gestörter Wald und gering gestörter Wald. In diesen drei Kategorien wurden die Häufigkeit der Palmen und deren Management untersucht. Die Anbauflächen befinden sich in den direkten Umgebung der Siedlungen und weisen die niedrigste Bodenfeuchtigkeit und Bodenbedeckung auf. Der Anbau wird von den Ticuna als weibliche Domäne gesehen. Die mäßig gestörten Gebiete sind ca. 2 km von den Kernsiedlungen entfernt, haben eine höhere Bodenfeuchtigkeit und Bodenbedeckung, und sind die Orte, wo die meisten Holzprodukte und andere forstwirtschaftlichen Erzeugnisse entnommen werden. Gering gestörte Waldgebiete haben die höchste Bodenfeuchtigkeit und Bodenbedeckung und sind nur ein paar älteren Menschen und erfahrenen Jägern in der Gemeinschaft bekannt. In den Anbauflächen machen sich die veränderten ökonomischen Aktivitäten am meisten bemerkbar. Hier werden die Zusammenhänge zwischen dem sozialen und ökologischen System besonders deutlich. Beide Systeme sind hier eng miteinander verknüpft, daher haben Veränderungen starke Auswirkungen in beide Richtungen.

Indem die Anzahl der Palmenindividuen sowohl in gering gestörten als auch mäßig gestörten Waldgebieten nahe der Siedlungen verglichen wurde, konnte ein genereller Überblick über den Zustand der drei Palmartenpopulationen geschaffen werden. Störung ist hier als menschlicher Eingriff definiert. Zusätzlich zu dieser generellen Beurteilung wurde durch die Untersuchung des Vorkommen größerer Individuen und Erntemethoden in Anbauflächen ein umfassenderes Verständnis vom Palmenmanagement in diesen Siedlungen erworben. Drei größere Bewirtschaftungsmaßnahmen konnten in dieser Kategorie definiert werden: *aktiver Anbau, passiver Anbau,* und *Duldung.* Keine der drei untersuchten Palmenarten, und wahrscheinlich auch keine anderen Palmenarten, sind aktiv

kultiviert worden, d.h.sie wurden nicht gesät oder in die Anbaufläche verpflanzt. Die Palmen wurden passiv kultiviert (Schutz vor Feuer, Unkraut, Schädlingen, heruntergerfallenen Ästen usw.) - im Falle von *A. Chambira* wegen ihres ökonomischen Wertes und *P. Macrocarpa* wegen ihrer Wichtigkeit in der heimischen Nutzung. *Socratea exorrhiza* wurde meistens nur toleriert, auch wenn einige Menschen sie passiv von Zeit zu Zeit kultiviert haben. Auch wenn Palmen entweder wegen kommerzieller oder heimischer Zwecke geschätzt wurden, konnten wir selten aktiven Anbau beobachten oder dokumentieren.

Jede der untersuchten Palmenarten lässt sich unterschiedlichen ökologischen Kategorien zuordnen, wodurch ihre Reaktion auf mäßige Eingriffe bestimmt wird. Die am häufigsten vorkommende der drei Arten, *S. exorrhiza,* wurde als Generalist oder oligarchische Art eingestuft und hat positiv auf das mäßige Eingriffslevel reagiert. Die am zweithäufigste Art, *A. chambira,* ist ebenfalls Generalist, ist jedoch durch andere Studien bekannt dafür, mehr ökologische Einschränkungen in Bezug auf ihre Verbreitung und Etablierung zu haben. Dadurch reagiert sie etwas empfindlicher auf mäßige Störungen. *P. macrocarpa,* die dritte Art, verzeichnet als ein Bodenspezialist das geringste Vorkommen. Durch ihre ungleichmäßige Verbreitung ist die allgemeine Reaktion auf Störung am schwierigsten zu beurteilen.

Die Bestimmung der Veränderungen des Palmenmanagements wurde verzerrt durch einen generell verschobenen Blickwinkel auf Anbauflächen als die Summe individuell genutzter Parzellen, wo alleinig kommerziell genutzte Arten geerntet werden, statt diese als ”gemeinschaftlich genutzte Speisekammer” zu sehen. Die Unterscheidung der drei Zonen war ebenso verschwommen: der Druck in Richtung Privatisierung ist ebenso ein Druck auf die Abschaffung der traditionellen Zonierungsregelungen, da beides, Palmen und Land, als Ware gesehen werden. Willkürliche Entnahme findet in mäßig als auch gering gestörten Gebieten statt. In Anbaugebieten steigt der Druck und die Konflikte, was zur Formalisierung von Eigentumsrechten und neuen Repräsentationsformen führt und somit die Integration in westliche Systeme vorantreibt.

Die Beobachtung der Veränderungen sowohl in sozialen als auch ökologischen Systemen wird die Weise, wie Schutz, soziale Entwicklung und ökonomische Planung auf Lokal- und Regionalebene stattfinden, verbessern. Die Verkehrsinfrastruktur wird sich weiter ausbreiten und der Druck auf den Amazonas durch Öl- und Mineralgewinnung zunehmen. Gemeinschaften in der Region werden weiterhin ein sicheres finanzielles

Einkommen und damit ihre Einbindung in westliche soziale Organisationsformen anstreben. In welche Richtung auch immer die Entwicklung ihren Lauf nimmt - es wird notwendig sein, die damit einhergehenden Veränderungen zu akzeptieren und zu verstehen. Richtlinen müssen geschaffen werden, um sich diesen Änderungen entsprechend zu begegnen und die möglichen negativen Auswirkungen auf sozio-ökologische Systeme als Ganzes zu minimieren.

RESUMEN EJECUTIVO

Los cambios en las estrategias de vida conllevan cambios en las poblaciones de lo que los grupos humanos consideran un recurso natural. Cambios en las preferencias de vida transformaran la manera en la que los usuarios se relacionan con los recursos naturales. Poder anticipar y manejar en la medida de lo posible estos cambios es uno de los grandes retos al generar planes para el uso y la planeación sostenible de los recursos naturales. La definición, el uso y el valor de los recursos naturales cambia al mismo tiempo que cambia la forma de vida de las personas. Esto es evidente sobretodo en las poblaciones humanas dependientes del bosque como aquellas en la region Amazonica, una region de inmensa diversidad biológica y cultural, con un gran potencial de especies útiles y un importante papel en la estabilización del clima global. También es una region que rápidamente se integra con el resto del continente a través de infraestructura de transporte como carreteras, puertos y aeropuertos. Los gobiernos suramericanos se han comprometido a desarrollar ambiciosos planes para el crecimiento económico de la region en gran parte dependientes de la extracción de recursos naturales. Estos planes le dan prioridad a la extracción de hidrocarburos y minerales aumentando la necesidad de implementar de planes que integren el manejo de recursos naturales con el contexto politico, económico y social.

Este proyecto intenta analizar los cambios sociales y ecológicos que se están dando en comunidades indígenas del amazonas a medida que transforman sus actividades de subsistencia y sus modos tradicionales de vida por actividades orientadas de mercado y formas de vida mas occidentales. Haciendo referencia a la teoría de sistemas socio-ecologicos este trabajo identifica y explora las conexiones entre los sistemas sociales y ecológicos para llegar a un mejor entendimiento del manejo de recursos naturales desde la perspectiva del usuario y el recurso. Para esto es necesario entender el proceso colectivo de toma de decisiones o governanza ambiental, de las variaciones en el uso de la tierra y los recursos en una comunidad especifica y de la manera como los recursos forestales responden a intervenciones humanas de pequeña escala. Distintas disciplinas se han encaminado a desarrollar propuestas similares evidenciando los retos y la necesidad de verse como parte y parcela de la naturaleza y de reconocer la complejidad socio-ecologica en vez de tratar de eliminarla o ignorarla.

El estudio del manejo de recursos naturales se puede entender como el estudio de las interacciones entre el sistema social y el ecológico y al estudiar los cambios en la governanza es

posible observar cambios en el sistema socio-ecologico como tal. La manera en que se toman decisiones y la forma en la que un grupo de personas estructura la manera de gobernarse afecta el ecosistema de diferentes maneras. Al reconstruir la manera en que dos comunidades indígenas amazónicas se han organizado la manera de toma de decisiones colectivas en el tiempo y al compararlas con una tercera comunidad mas tradicional y aislada es posible entender la manera en que se transforma el sistema de gobernanza. Observamos como estas comunidades indígenas que rápidamente se integran en un sistema de organización y governanza mas occidental se transforman rápidamente , son llevadas a diversificar la manera en que toman decisiones trayendo como resultado la creación de sistemas híbridos de toma de decisiones colectiva que combinan formas tradicionales y occidentales de organización social y manejo de recurso naturales.

Un grupo de plantas ideal para analizar interacciones socio-ecologicas son las palmas (Arecaceae). La documentación acerca de la ecología, la historia de uso y la diversidad de usos (incluyendo usos comerciales) de las palmas en esta region del amazonas es amplia. Los cambios en el uso y manejo de tres especies de palmas *Astrocaryum chambira*, *Socratea exorrhiza* and *Phytelephas macrocarpa* sirvieron como indicadores de cambios sociales en dos comunidades indígenas al sur de la Amazonia Colombiana. Estas tres especies de palmas como muchas otras están íntimamente ligadas a la vida de los indígenas amazónicos. *Astrocaryum chambira* es una importante fuente de fibra, antiguamente utilizada a nivel domestico, hoy en día empleada en la elaboración de productos artesanales comercializados a nivel local y nacional. Los troncos de *Socratea exorrhiza* son utilizados como material de construcción; pisos, paredes, soporte para techos y recientemente los troncos se utilizan también para la elaboración de artesanías. En esta region las hojas de *Phytelephas macrocarpa* son utilizadas para techar mientras que en otras regiones de la Amazonia esta especie es valorada por sus semillas a partir de las que se producen figuras artesanales y botones para el mercado internacional.

El uso y manejo de estas tres especies de palma se documento en dos comunidades indígenas de la etnia Ticuna. La mas grande de estas comunidades esta ubicada sobre la rivera del Rio Amazonas, es la de mas fácil acceso y es reconocida en la region por su mercado de artesanías. La segunda comunidad es la mas pequeña de las dos, su acceso mas restringido y sus habitantes dependen de la agricultura para su subsistencia. A través de entrevistas y estadías en estas comunidades fue posible recoger información acerca del uso y manejo de palmas en los

asentamientos y las areas aldeañas.

Se distinguieron tres areas de uso de la tierra en donde se estimo la abundancia y el manejo de palmas; areas de cultivo, bosques moderadamente intervenidos y bosques con bajos niveles de intervención. Las areas de cultivo están en las inmediaciones del asentamiento humano, los suelos tienen bajos niveles de humedad y cobertura vegetal y se consideran areas de dominio femenino por los Ticuna. Las areas de intervención moderada están aproximadamente a 2 kilometros del núcleo de los asentamientos, los suelos contienen una mayor humedad, la cobertura vegetal es también mayor que en las areas de cultivo y son areas utilizadas para la extracción de productos maderables y no maderables. Las areas con bajos niveles de intervención son aquellas en donde la humedad del suelo es la mas alta, la cobertura vegetal es mayor y donde pocas personas transitan. Estas son areas conocidas por tan solo un selecto grupo de cazadores o hombres mayores. Es en las areas de cultivo, las mas utilizadas por los habitantes locales, en donde los cambios y diferencias en actividades económicas son mas evidentes y las conexiones entre cambios de governanza y cambios en el manejo se pueden observar con mas detenimiento. Es en las areas de cultivo en donde los sistemas sociales y ecológicos están fuertemente ligados y por lo tanto donde se desencadenan efectos en ambas direcciones.

Al comparar la abundancia de palmas entre areas con bajos y moderados niveles de intervención (definida en términos de distintas actividades humanas) se pudo hacer una evaluación general de la condición de las poblaciones de las tres especies alrededor de cada asentamiento. Ademas de esta evaluación general, al estimar las abundancias de individuos adultos en areas de cultivo y documentar las practicas de manejo en estos lugares se pudo llegar a un entendimiento mas comprensivo del uso de estas especies en ambas comunidades. Se distinguen tres tipos de actividades relacionadas con el manejo de palmas; cultivo activo, cultivo pasivo y tolerancia. Ninguna especie de palma es cultivada activamente, es decir ninguna especie es sembrada de semilla o rebrote en las areas de cultivo. Las palmas llegan a estos lugares por medio de dispersion natural y en algunos casos su presencia es tolerada mientras que en otros casos los individuos pequeños son resguardados del fuego y protegidos de pestes o parasitos facilitándoles así su permanencia (cultivo pasivo). En el caso de *A. chambira* el cultivo pasivo es motivado por su valor comercial mientras que en el caso de *P. macrocarpa* su valor domestico motiva su cultivo pasivo. En la mayoría de los casos *S. exorrhiza* es tolerada aunque algunos artesanos reportaron cultivarla de forma pasiva. Aunque estas palmas son

apreciadas bien sea por motivos comerciales o domésticos en ningún caso se observo que fueran cultivadas de manera activa.

Las tres especies de palmas pertenecen a distintas categorías ecológicas condicionando su respuesta a niveles de intervención moderada. La mas abundante de las tres especies *S. exorrhiza* es reconocida como una especie generalista o oligarca y demostró una respuesta positiva en abundancia en areas de intervención moderada. La segunda especie mas abundante, *A. chambira,* es considerada como una especie cuasi-generalista y en comparación con *S. exorrhiza* su dispersión dependiente de roedores hace que su abundancia en niveles de intervención moderados sea restringida. La limitada abundancia de *P. macrocarpa* una especie considerada especialista en suelos con altos niveles de nutrientes y con una distribución natural restringida distribución, dificulto la posibilidad de evaluar su respuesta a bajos niveles de intervención humana.

Al observar cambios en el manejo de estas especies de palmas en las areas de cultivo se pudo observar un cambio en la percepción de las personas. Mientras que en la comunidad menos accesible perpetuaba una vision de los lugares de cultivo como despensas en la comunidad mas accesible y orientada hacia actividades comerciales, las areas de cultivo se empiezan a ver cada vez mas como parcelas privadas para la producción de productos comercialmente rentables. La distinción entre las tres areas se disipa en este proceso, la presión por privatizar las areas de cultivo hace que las formas tradicionales de repartición de la tierra desaparezcan y tanto las palmas como la tierra comienzan con el proceso de comodificacion. La extracción indiscriminada de recursos naturales se lleva a cabo tanto en areas de moderada intervención como en areas de baja intervención. En areas de cultivo los conflictos sobre la repartición de la tierra aumentan incrementando la necesidad de formalizar títulos de propiedad y formas de representación, en otras palabras estimulando la integración entre los sistemas occidentales y tradicionales cada vez mas.

Al analizar los cambios entre los sistemas sociales y ecológicos de forma integrada se contribuye a una planeación ambiental, económica y del desarrollo en general mas acorde a la realidad local y regional permitiendo encontrar soluciones mas efectivas. El crecimiento de la infraestructura de transporte continuara su expansion de igual forma la presión por extraer hidrocarburos y minerales sera mayor en toda la Amazonia. Las comunidades indígenas en la region seguirán buscando formas de diversificar sus ingresos monetarios acelerando su integración al mundo occidental y sus formas de organización social. Cualquiera sea el camino

que tomen sera necesario aceptar y entender estos senderos de integración. Es necesario generar políticas que acompañen estos cambios y permitan a estas comunidades integrarse de la mejor manera minimizando las consecuencias negativas que esta integración pueda tener para el sistema socio-ecologico en general.

Table of Content

1. General Introduction

Indigenous groups in the Amazon, just like all human societies, developed capacities, knowledge, rules and regulations that enabled them to live under particular environmental conditions. In other words, throughout the Amazon region we find different examples of social ecological systems that have evolved over hundreds of years. More than 20 linguistic families exist in this region, and approximately 1.6 million km2 or 21% of the Amazon corresponds to officially recognized indigenous territories (RAISG 2012). These indigenous groups live in a region with more than 600 different types of terrestrial and freshwater habitats, and where one can find one of every ten species on the planet (C. Thompson 2010). From a simple utilitarian perspective, the Amazon provides a series of goods and services (carbon storage, water flow and climate regulation, etc.) that grant the region an invaluable importance for the continent and the world (Foley et al. 2007; Costa and Foley 1999; Laurance and Fearnside 2002).

Some of the first encounters of indigenous people of the Amazon with westerners during colonial times were with European explorers (around the 1540´s). The missionaries, slave traders, rubber tappers, pelt hunters, drug lords, loggers, etc., who came later catalyzed transformations that have reshaped traditions and practices throughout the region. For some societies, changes have brought instability and weakening of traditional practices and impoverished livelihoods (Sirén 2007; Sierra, Rodriguez, and Losos 1999; O. Coomes and Burt 1997). Others have been able to adapt to change and look forward to improving their livelihoods (Toledo 2003; Reyes-García et al. 2007; Vadez et al. 2004; Godoy et al. 2007; Freire 2007). Conservationist fear that western integration and further degradation of traditional knowledge and practices will further detach indigenous societies from their role as forest stewards (Fikret Berkes 2009; Watson, Alessa, and Glaspell 2003; Rerkasem, Yimyam, and Rerkasem 2009; Grenier 1998; Folke 2004) placing them and the natural resources they manage in vulnerable conditions.

We are interested in exploring these rapid changes, particularly changes in the transformation of the human nature linkages within social ecological systems common throughout the Amazon. As an indicator of social ecological change, in this study we selected palms (Arecacea) because of the close connections of these species with

indigenous people. We chose three palm species that are seen as a resource and that are deeply entwined with the daily life of indigenous communities in an area where change is rapid and dramatic, and where development and conservation priorities come face to face, i.e., in the southern Colombian Amazon region. We hope to contribute to a better understanding of social ecological systems through the study of changing palm use and palm abundance. Through our analysis, we expect to refine, develop and provide insights on existing theories of socio-ecological change.

A large amount of information exists on the diverse types of ecological characteristics as well as on uses of palm species throughout the region, which makes them an ideal study group. Palms are probably the group of plants that has the greatest participation in the life of Amazon people. Approximately 130 species of palms with nearly 2000 different uses have been reported for the Amazon region (Macía et al. 2011; Paniagua-Zambrana et al. 2007). A single palm species or part of a plant can have a number of different uses. Palms are part of people's homes, eating habits and cultural traditions (O. T. Coomes 2004; Paniagua-Zambrana et al. 2007; Cámara-Leret et al. 2014). Many species are now also an important source of income, as palm products are increasingly being commercialized in local as well as international markets (Balslev 2011; Brokamp et al. 2011). The long history of palm use by indigenous people provides yet another advantage to study the consequences of the rapidly changing lifestyles of these people on the use of this group of plants.

Some palm species are commonly found in the Amazon forests, and have been seen to adapt to different environmental conditions, while others have been observed to have contrasting characteristics, namely habitat specialists adapted to specific environments (Balslev 2011; Kristiansen et al. 2011; Ruokolainen and Vormisto 2000). The connection between people and palms together with the interconnectedness of palms with the ecosystem is already contributing to the understanding of tropical forest dynamics as well as of social ecological interactions in this region. A recent review on palms revealed determining factors influencing palm species distribution, community composition and diversity at different spatial scales that can probably be extrapolated to other species in this biome (Bernal et al. 2011; Eiserhardt et al. 2011; Kristiansen et al. 2009; Montúfar et al. 2011).

We believe that once a community defines an element of the natural system as a resource, such as palms, that the element and the natural system it is part of will be affected by its governance system, and by the way collective and binding decisions in the community are made. Studying natural resource management therefore allows us to investigate human-nature linkages, which leads to a better understanding of the social ecological system. When economic, political, legal and social structures in a community change, the definition and use of resources is also likely to change. In addition, the way the ecosystem is being affected is also likely to change. Studying the results of shifting management and use patterns on a resource can certainly provide insights not only on the way an ecosystem is affected but also on the processes of social change.

Because we were interested in the linkages and outcomes of social and ecological systems, we placed our study within the broad framework of social ecological systems, which have been largely influenced by ecology but which have also been modified and expanded to include knowledge and concerns stemming from social sciences and from local experiences of communities across the world. Our observations are in line with those of other researchers, who agree that disciplinary knowledge targeted at a specific aspect of the social or ecological system can help uncovering crucial aspects that contribute to the understanding of the whole system (Epstein et al. 2013; Mascia et al. 2003; Binder et al. 2013; Fox et al. 2006). We argue that the social ecological system framework in its present state is not yet inclusive enough to provide insights in the evolution of social systems, so we therefore attempt to contribute to its further development by giving governance a central role. Governance is already featured prominently in social ecological systems and natural resource management literature (Folke et al. 2005; Lebel et al. 2006; Ostrom 2007a). The way decisions are taken, the way governance is structured, and the way a natural resource is perceived by a group of people will affect the ecological system in different ways. We believe that studying natural resource governance is studying the linkages in social ecological systems, and that looking at changes in governance is looking at changes in social ecological systems.

In the following sections of the introduction, we present a brief overview of the genesis and key concepts of social ecological systems. We will also provide an overview of the social political setting of indigenous people in Colombia, since they are entitled with a unique legislation and policies within the national government dealing with indigenous

issues. Because this is also an area where development and conservation priorities are high and discussions make part of people's daily life, we will also briefly point out key conservation issues in the region. Finally, we provide a summary of each chapter of this thesis.

1.1. Study of change and the notion of social ecological systems

A series of frameworks aimed at studying human-nature interactions, like those of indigenous people in the Amazon, have emerged as scholars from different disciplines challenge ideas of ecosystem stability, command and control management approaches and try to understand both human and ecological dimensions as co-developing (Holling 2001; Fikret Berkes and Folke 1998; Walters and Holling 1990; Ostrom and Nagendra 2006; F Berkes and Folke 2002). They have paved an alternative to blueprint approaches in the study of human-nature interactions and emphasized the need for interdisciplinary reasoning.

The study of ecosystem dynamics is a discipline that has developed several influential concepts for the understanding of human-nature interactions. Already in 1916, Frederic Clements presented the idea of natural populations reaching a single climax as a result of succession, and years later scientists like Tansley (1939) argued in favor of several climaxes. By the 1950's, the difficulty in identifying a stable climax condition began to question the whole idea (Whittaker 1953; Begon, Townsend, and Harper 2006). In the 1970's, ecologists focused on the idea of stability, where a community could be described in terms of its ability to return to its former condition after disturbance or in terms of its ability to resist being disturbed. Models describing a community in terms of its resilience or resistance to change emerged from studies on food web interactions (i.e., May and Mac Arthur 1972; De Angelis 1975; Pimm 1979). Based on similar discussions, Holling (1973) presented ideas on which the concept of resilience was developed further. Resilience was originally defined to describe the possibility of a system to have numerous different stages of equilibrium where disturbance, if strong enough, could push the system from one state to another. This is probably one of the most influential concepts in the conception of social ecological systems.

The idea of resilience was taken up as a core concept for the development of adaptive forms of natural resource management. When an ecosystem is perceived to be in

continuous change with no one unique point of stability, effective management cannot attempt to narrow down uncertainty with traditional scientific approaches. It should rather integrate different types of information to be able to identify gaps, come up with alternatives, and weigh different management options (Walters and Holling 1990). Resource management and the search for sustainable practices needs to be viewed in a holistic manner considering both social and ecological entities as parts of the same system (F Berkes and Folke 2002). Adaptive management practices should be tested, monitored and reevaluated within a learning environment that allows the promotion of leadership skills and eventually influences the policies of management organizations (Folke et al. 2005).

Resilience has also been extended to explain how social systems respond to change, basically through further developing concepts of adaptive management. The idea of adaptive governance emerges as an extension of the adaptive management framework into the social dimension (Folke et al. 2005). Adaptive governance relies on adaptive management practices to build ecological knowledge that allows a resilient social ecological system. It requires the collaboration of different stakeholders, multilevel social networks and the support of flexible institutions to be able to deal with uncertainty and change, making the system less vulnerable to external perturbations (Folke et al. 2005; Fikret Berkes and Folke 2002). In both adaptative governance and management, knowledge and expertise play a crucial role in building resilience and enabling social ecological systems to overcome crisis.

In a comprehensive comparison between different frameworks used to study social and ecological interactions, Binder et al. (2013) conclude that partly because of the variation in theoretical and disciplinary backgrounds and the way social ecological systems are conceptualized there is no one single framework that can be applicable for all case studies. Some of the frameworks included in their review like the Earth System Analysis (Schellnhuber 1999; Schellnhuber and Wenzel 1998), Ecosystem Services (Costanza 1998; De Groot, Wilson, and Boumans 2002) and Natural Step (Burns and Katz 1997; Upham 2000) emphasize the influence of human interactions on the ecological system. Others, like the Sustainable Livelihood Approach (Ashley, Carney, and Britain 1999; Scoones 1998) and the Vulnerability Framework (Billie L Turner et al. 2003; Billie Lee Turner et al. 2003), place more attention on the way the ecosystem interacts with the social system. According to the authors, the dynamic condition of the social ecological system in these frameworks still

needs to be conceptualized better. They indicate that the Social Ecological System framework (Ostrom 2007b; Folke et al. 2007) is the only one among the sixteen different frameworks they analyzed that treats both the social and ecological systems at equal depths and at the same time allows several degrees of specificity within different levels (Binder et al. 2013).

The social ecological system framework builds largely on the idea of resilience and adaptive management (Holling 1973; Fikret Berkes and Folke 1998; Folke 2006) as well as on the distinction of several property rights regimes (Poteete, Janssen, and Ostrom 2009; Ostrom and Nagendra 2006; Schlager and Ostrom 1992). It presents a muti-leveled hierarchy of variables relevant for the analysis of human-nature interactions (Ostrom 2009). The popular scheme introduced by Ostrom (2009) depicts variables that can describe interactions (harvesting, networking, etc.) and outcomes (both social and ecological) between natural resource users who are part of a governance system and natural resource units that are part of a resource system (ecosystem) (Ostrom 2009).The social system is therefore composed of users-actors within a governance system through which action, e.g., rules, monitoring and sanction mechanisms, influence resources within an ecological system.

So the concept of resilience has inspired new approaches to perceive natural resource management and ecosystem change as well as the way they respond to human-induced change. Discussions on resilience, ecosystem dynamics and natural resource management have opened crossroads between disciplines evidencing the complexities of social and ecological systems. This has enabled the construction of frameworks like the social ecological system framework and concepts that can help explain regime shifts in either social, ecological or both types of systems.

One concept that has received increasing attention is that of critical transitions (Scheffer et al. 2009) which, based on mathematical and biological models and empirical findings, describes tipping points in complex systems. These tipping points are mostly predictable points in time where the system slows down and then shifts to a different condition. Many examples drawn from shallow water lakes, fisheries, etc., provide the empirical basis for this phenomenon, which described in mathematical terms, makes feasible the prediction of critical transitions. The promoters of this concept believe it can

also be transposed and applied to social systems in order to understand and predict social transformations (Levin et al. 2013; Scheffer et al. 2012).

Scholars in the field of economics studying the way societies organize themselves and their resources and interact with each other as well as with their surroundings have come up with concepts that can also explain social transformations. For example, theories of economic change and property rights schemes have contributed to the development of a (sub) discipline in the field of economics, and have also influenced the understanding of social ecological systems. In a similar line of arguments presented by ecologists in the development of adaptive management concepts, Duglass North (2005) coins the term adaptive efficiency to explain the dependence of economic changes on a society's effectiveness to create stable, fair and productive institutions that are flexible enough to change in response to political and economic circumstances. In his work, he emphasizes the importance of the type and quality of institutions in the economic performance of societies (North 2005). In addition to North's work, the description of different property rights schemes, particularly those dealing with common pool resources (i.e., Elenor Ostrom's principles for common pool resource institutions) have contributed in the further understanding of human nature relationships.

The study of social ecological systems attempting to understand particularities and things in common has become a challenge that scholars from many different disciplines are undertaking. Their work evidences the difficulty but also the need of seeing ourselves as "part and parcel of nature". All seem to agree that the ecological challenges in our world are linked to social transformations and vice versa.

We frame our approach within the social ecological system framework as described by Berkes and Folke (1998) and Ostrom (2009), and draw from some of the above-mentioned different theoretical developments to complete the understanding of changes taking place either from an ecological or a social perspective. As a linking element, we use a group of species substantially important for both humans and ecosystems, i.e., palms. Through the study of palm use and management we attempt to understand the way different degrees of access to western institutions are influencing the way two indigenous communities are managing natural resources. We hope to gain insights on the type of changes caused by increased access to small and relatively isolated human settlements and the forest resources they depend on.

We share Ostrom's (2009) idea that "we must learn to dissect and harness complexity rather than eliminate it…" to state that development problems in general should be tackled with a broader understanding of social ecological systems as a whole. Theoretical and empirical progress made within the fields of institutional economics, conservation biology, and environmental governance allows us to observe, analyze and better understand social ecological transformations by combining and creating different concepts like resilience, adaptative management, critical transitions, evolutionary governance, property rights, etc.

We draw on concepts of social ecological change as studied by Olson et al. (2001); Folke et al. 2005; Duit and Galaz 2008; Berkes 2009; Voß and Bornemann 2011 among others. By taking a detailed look at the changes in the management of a widely used natural resource, we will be able to provide further insights in the couplings between governance dimensions (Greif 2006) and at the same time also bring into focus the linkage between the governance system (social system) and the ecological system.

We use concepts from disturbance ecology, population dynamics and general information on species life history traits to interpret our findings on palm abundance and distribution in the forests surrounding the communities. When attempting to understand the effects of human interventions in a natural system, it is important to bear in mind the spatial and temporal dimensions of the actions and their interactions with the life history, physiology and behavior of the species (Denslow, Pickett, and White 1985). Human activities can alter, suppress or enforce natural processes like dispersion and seed establishment (White 2001). Deforestation, for example, can have negative demographic effects by reducing the density and diversity of pollinators and seed dispersers, while harvesting will depend on the life stage harvested (Montúfar et al. 2011).

The social ecological system framework will help us delineate the human-nature interactions and outcomes we are interested in studying. Theories and concepts from institutional economics and population ecology will help us analyze and interpret independently the social and ecological dynamics. It is necessary, however, to provide details on the socio-political setting in which this system is embedded. By doing this, we will be able to elaborate on the complexities and challenges surrounding the social and environmental situation we have studied.

1.2. Legal situation of indigenous people in Colombia: the social-political setting

As a result of long-sought political recognition, indigenous groups in many Latin American countries now have been granted the right of self-government and the possibility to design their own education, health and administrative frameworks. Although there are differences from one country to the next, several countries in the region redrafted their constitutions giving indigenous people specific rights and responsibilities within the nation they are a part of. In this way, indigenous lands are for the collective use and benefit of indigenous people and activities of non-indigenous people (from the public or private sector) carried out within these territories require collective approval.

One of the first constitutions that explicitly recognized indigenous right to self-determination was that of Colombia (1991). Approximately 25% of national territory has been assigned indigenous territory or resguardo, most of it in the Amazon and Orinoco regions (Van der Hammen 2003). Reforms in the political constitutions of Peru (1993), Bolivia (1994), Ecuador (1998) and Venezuela (1999) followed, thus opening a new chapter on indigenous legislation and property rights in the region. The right of indigenous people to govern themselves and their territories according to their law was recognized, granting them the possibility to define the rules and norms to organize their societies and the way they use and manage their territories.

These legal changes that took place in the early 1990's have allowed some indigenous groups to reorganize themselves in such a way that they have been able to profit from markets, government agencies and services (health, education, subsidies, etc.). Some indigenous groups, like the Tsimani in Bolivia (Reyes-García et al. 2007; Godoy et al. 2007), the Piaroa in Venezuela (Freire 2007) and several indigenous communities in Mexico (Toledo 2003) have been able to combine their traditions with new western practices as a response to the interaction with markets and other western institutions. In other areas, like the western and central Amazon region, indigenous groups still struggle to understand and integrate into western life. Traditional chiefs have been replaced by democratically elected representatives, traditional medicine has been replaced by western doctors, and subsistence livelihoods are losing importance to market-based activities (Balee 1993; Wood 1995; Rodrigues et al. 2009). Amazonian groups continue integrating into regional/national political and economic systems. As a result, we see traditional systems of organization weakening and an increasingly predominant role of western ideals, institutions and

management systems. In addition, as national policies and institutions meet indigenous traditions many conflicts also begin to emerge. A well-documented example is the conflict between indigenous people and oil and mineral extraction.

In the northern Amazon region of Ecuador, roads built by oil companies promoted the expansion of local markets, while local populations of forest products like wild game have shrunk to dangerous limits (Suárez et al. 2009). In the same region, the government promoted the creation of a monetary scheme in which large areas of oil rich forest within Yasuni National Park would be spared from oil extraction as long as the international community was willing to pay the country compensation for not extracting; some years later this proved to be not a viable alternative. Similar conflicts have arisen in Peru, where oil and gas concessions spread across the entire northern Amazon, completely overlapping indigenous territories and national parks (Finer et al. 2008). In Colombia, some indigenous groups have opted to establish so-called Protected Areas overlapping their territory (i.e., Alto Fragua Indiwasi and Yaigoje Apaporis National Parks) as a way of safeguarding their lands from the oil and mineral extraction but at the same time creating an overlap of administrative authorities often with contradictory forms of land use.

1.3. Development and conservation debates in the Amazon

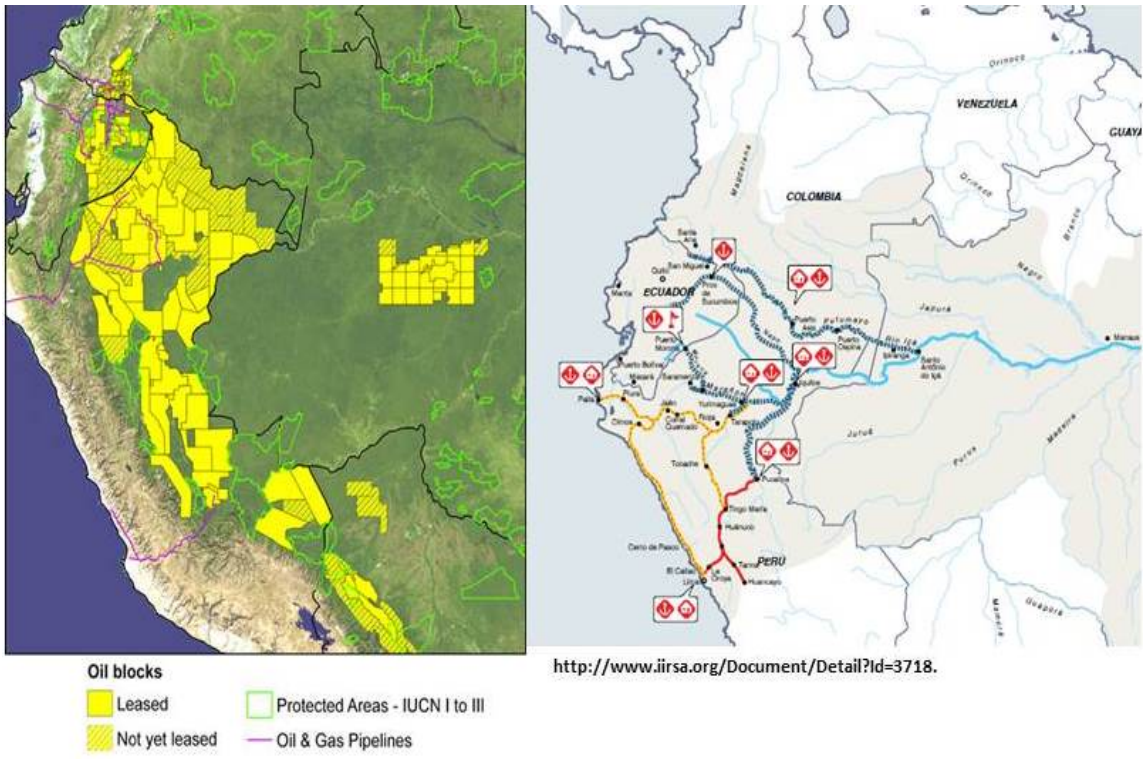
A rapid transformation of land use taking place in the Amazon and often related to oil and mineral extraction is the expansion of transportation infrastructure, namely road development. The most prominent example is the Initiative for the Integration of Regional Infrastructure in South America (IIRSA), which aims at connecting the continent from east to west. In 2011, the last stretch of the Interoceanica Sur highway was completed, giving Brazil terrestrial access to Peru and its Pacific Ocean ports. By investing in river channelization, port and road construction, the IIRSA aims to strengthen commercial activities within the region and with international markets. These projects are well underway and will increase accessibility to the Amazon region through the creation of two major connection routes between the Atlantic and Pacific Ocean (IIRSA 2012).

Negative consequences of road construction are well known in the region, i.e., forest fragmentation, expansion of the agricultural frontier, migration, shifting settlement patterns, etc. (Almeyda Zambrano et al. 2010; Rodrigues et al. 2009; Etter et al. 2006; Perz et al. 2012). In Brazil, the conversion of forests to cattle ranching pastures and large-scale

agricultural fields has been seen to initially relatively increase standards of living, which later decline as the deforestation frontier evolves (Rodrigues et al. 2009). In Ecuador, for example, the construction of roads to oil wells has been correlated with the decline of game species like tapirs and peccaries (Finer et al. 2008; Suárez et al. 2009). In the pursuit of economic development, increased access to markets and commodities is transforming communities and natural resources throughout the Amazon region (Carvalho et al. 2001; Geist and Lambin 2002; Perz et al. 2007). In addition to these socio economic changes, predicted changes in precipitation patterns and temperature will affect the vegetation in the Amazon region in terms of increased aridity or in terms of raised water levels, which may lead to barriers for seed dispersers and pollinators thus affecting the distribution of single species (Feeley and Rehm 2012; S. Thompson et al. 2010). These changes may also impact the success of seedling recruitment of certain species due to an increase in pathogen infections (S. Thompson et al. 2010).

Although governments in the region are optimistic about the improvement of education and extension services through an integrated transportation and communication infrastructure (IIRSA 2012), we can expect that social and ecological systems in the region will continue to go through difficult transformations.

Efforts to reconcile development and conservation goals have led to the promotion of Integrated Conservation and Development Projects (ICDPs), community-based development projects, and economic compensation mechanisms to name a few popular examples. All of these have in common the idea of bringing change or development to forest communities without sacrificing ecological and human welfare. The underlying motivation is that forest dwellers should profit from a fair participation in markets and economic activities. Although these are well-intentioned initiatives, they have sprouted long debates on their effectiveness (Brandon and Wells 1992; Hughes and Flintan 2001; Börner et al. 2010; Pearce, Putz, and Vanclay 2003).



Economic and infrastructrucure development plans for the study region. Right: oil and mining concessions in Peru. Left: harbors and road connections from Brazil to Peru.

These types of "win-win" initiatives assume western forms of participation, steering, monitoring and enforcement, which are not entirely familiar to many forest communities. As a result, local systems of organization are overlooked and many forest communities struggle to understand and adopt concepts and forms of organization required for the implementation of conservation initiatives. For indigenous communities in the Amazon, integrating in a broader western society has often been a frustrating process in which their traditional ways of governance have partially or completely given way to western elements resulting in a large array of hybrid governance systems.

Sustainable use initiatives have been given much support particularly since they were coupled with poverty alleviation. This has given rise to a series of mechanisms which promote sustainable use as a solution to both poverty and nature degradation (Miller, Minteer, and Malan 2010). However, the long debate among conservationists on whether promoting sustainable use (social conservationists) in order to achieve nature conservation is more effective than policies strictly limiting human intervention (nature protectionists) is often revived in the light of the development projects being promoted in the region and the

expected consequences of climate change. In an evaluation of this debate, several authors agree with the idea of promoting a new discussion, which they refer to as a new conservation debate (Minteer and Miller 2010; McShane et al. 2011). Here, conservationists are urged to identify hard choices and look for trade-offs in the development of conservation actions in a given place taking into account the interactions between different scales (political, social, ecological) in space and time. They also advocate respecting the co-evolution of natural and human histories and considering the different points of view and complexities that might exist (McShane et al. 2011).

As mentioned above, the South American countries, including the Amazon basin, have established ambitious economic development plans to strengthen and encourage economic growth. They have placed oil and mineral exploitation as a high priority in their agenda, and are committed to support regional integration as a strategic element of their development plans. For the people in the Amazon, most of which belong to indigenous communities, this means fast-track integration into western systems of organization and governance which we believe will result in hybrid systems, and different combinations of traditional and western ways of organizing their societies and managing their resources. How are these changes being played out at a local level? What shape does this integration process take within an indigenous community? What consequences do these changes bring for these forest communities, which are highly dependent on natural resources and the land, and which changes in a particular natural resource of high local importance can be expected?

These are questions in the background of our study. However, we do not expect to find far-reaching solutions to conservation conflicts but would rather like to view these conflicts from an integrated perspective. We hope that from a different viewpoint we will be able to indicate patterns, trajectories, and paths that could help us understand the transformations that are taking place and their consequences to both humans and natural resources. We believe that by understanding the expected changes in both social and ecological systems in the region, planning, i.e., conservation, social, development, economics, etc., at local and regional levels can be improved.

We recognize that the Amazon will continue its development path, that transportation infrastructure will continue to expand, and that pressure for oil and mineral extraction will continue to increase. Human communities in the region will continue to

pursue stable sources of monetary income and thus their integration into western forms of social organization. Whatever position we take in the debate, we will need to accept and understand these paths of change. Policies need to be drawn to prepare for these changes and to minimize the negative consequences that they might bring to the social ecological system as a whole.

1.4. Outline of the thesis

In Chapter 2, we present the different layers (or triers) of the social ecological system we have studied. We introduce the resource units and three commonly used palm species, and present an analysis of the effects of the different livelihood strategies of two indigenous communities on palm populations. We categorize the ecological setting where these palm populations exist, i.e., low and moderately disturbed forests around the human settlements based on satellite image analysis and details provided by local people

In the Chapter 3, we refer to the challenge of foreseeing the implications different livelihood strategies have on natural resource populations for conservation and sustainable land use planning. We focus on the differences in the condition of palm populations around the two settlements, and associate differences in use and management to the communities' accessibility.

In Chapter 4, we explore in more depth the social reorganization taking place in the two indigenous communities, and take a third settlement as a reference of an even less accessible, more traditional community. We then investigate the governance in these three indigenous communities. The less accessible communities represent earlier steps in governance evolution. We develop an evolutionary governance model in which governance dimensions can emerge as relevant in a community. We focus on the changing management of the three selected palm species and illustrate how detailed studies of natural resource management add detail to the image of governance change and insight in the coupling between social and ecological change.

In Chapter 5, we summarize the main and findings and conclusions, and provide policy recommendations for this particular study case. Using sophisticated disciplinary ideas, concepts and theories we investigate in detail the situations we observed from a social and from an ecological perspective.

2. Palm management in a transforming landscape; the case of *Astrocaryum chambira, Socratea exorrhiza* and *Phytelephas macrocarpa* in the North-western Amazon

2.1. Introduction

Crucial to conservation is the role of human actions on the ecosystem and species response to these actions. Finding a balanced solution to both conservation and human welfare problems has been at the core of the long contested debate on whether to include or exclude humans from the conservation equation, crystallized in the well-known parks versus people debate (see e.g., Terborgh 1999; Terborgh 2000; Schwartzman, Moreira, and Nepstad 2000; Brockington 2002; Brandon, Redford, and Sanderson 1998; Adams and Hutton 2007; Sanderson and Redford 2003; Sanderson and Redford 2004; Roe and Elliott 2004). Strict conservation approaches that attempt to minimize human impact require resource users to act in accordance with conservation aims and often make reference to "win-win" situations where conservation and human development problems are dealt with at the same time (Hayes 2006; West et al. 2006; Kenward et al. 2011; Pokorny et al. 2012). Some popular examples include community based conservation, integrated conservation and development projects, payment for ecosystem services, etc.

Recent academic discussions however encourage the debate in a new direction by urging conservationist to consider interactions at political, social and ecological scales and to recognize the co-evolution of natural and human histories (Minteer and Miller 2010; Sarkar and Montoya 2010; Kenward et al. 2011; McShane et al. 2011). Recognizing trade-offs among the different points of view and complexities that exist in social-ecological systems requires a comprehensive view of the different levels of interaction, links and changes that are taking place in the system as a whole; one cannot expect "win-win" situations at all levels and scales of interaction. However fundamental it is for conservationist to have a better understanding of the social ecological system in which socio-political context in which their actions are embedded, it is also important to have a fundamental understanding on the impact of human activities on surrounding natural resource populations.

In regions with high levels of biodiversity and growing human populations like the Amazon, attempts to reconcile conservation and use of natural resources is both relevant

and urgent, particularly considering the development plans which are unfolding in the region. Mayor road and transportation infrastructure being built to improve South Americas East-West connectivity will continue to increase access to inaccessible well conserved areas(Killeen 2007; Perz et al. 2012). Increasing accessibility has enabled the establishment of markets and commercialization of forest products across the Amazon (Finer et al. 2008; Suárez et al. 2009) stimulating overexploitation and the adoption of unsustainable livelihood strategies (Carvalho et al. 2001; Geist and Lambin 2002; Perz et al. 2007). Increasing accessibility is modifying local livelihoods in the Amazon, changing the way people use and manage resources and the forest around them (Etter et al. 2006; Schmitt and Kramer 2009; Perz et al. 2012; Salonen et al. 2012; Van Vliet et al. 2012).

Forest response to human activities in many ways resembles that of certain types of disturbance and depends on spatial and temporal scales of observation, frequency and intensity of intervention (Connell 1978; Condit et al. 2000; Wills et al. 2006; Hubbell et al. 2008),influx of alien species (Catford et al. 2012) and site history in geological but also human terms (Bush et al. 2000). The response of species to changing forest conditions will of course depend on life history traits; weather they are common or rare(Wills et al. 2006) and on the functional group they belong to (light demanding or shade tolerant for example)(Hubbell et al. 1999; White 2001; Bongers et al. 2009). Within a plant population human intervention just as natural disturbances can affect life stages differently and depend on old growth forest remnants, high levels of seed dispersal and high levels of generalist species (Norden et al. 2009). All these factors have an influence on the way human intervention is analyzed and conservation approaches should be designed.

Although large scale disturbances without a doubt are a major threat to Amazonian ecosystems, it is human intervention taking place around non-urban settlements, which is fundamental to the conservation versus use/development debate mentioned earlier. Moderate levels of disturbance have been found to provide conditions for higher diversity (Connell 1978; Molino and Sabatier 2001; Condit et al. 2002; Wills et al. 2006; Bongers et al. 2009; Montúfar et al. 2011; Catford et al. 2012) however disturbances for prolonged periods of time are thought to restrict forest composition to heliophilic species (Hubbell et al. 1999). Many studies have focused on the large scale effects of human intervention in the Amazon(Krebs 2001; Egler 2002; Hargrave and Kis-Katos 2011; Mon et al. 2012)but few

examples can be found for the consequences of small scale progressive changes in human activities in the region. Human settlements sharing similar conditions and different levels of integration in the western scene provide a suitable context for comparing the effect of human intervention on utilized forest resources (Kramer et al. 2009; Schmitt and Kramer 2009; Salonen et al. 2012).

Differences in physical accessibility and economic activities between human settlements will influence the way people use and manage forest resources and we therefore assume the condition of natural resources around settlements with different degrees of physical accessibility should be different (Scatena et al. 1996; Etter et al. 2006; Perz et al. 2007, 2008; Rodrigues et al. 2009; Schmitt and Kramer 2009; Salonen et al. 2012). We took a look at two human settlements typical for the Amazon region which are just a few kilometers apart but different in their economic orientation and degree of physical access (and therefore interaction with national markets and other western institutions). One of the settlements, Macedonia, is easily accessible from larger urban centers; it has an established market place for non-timber forest products and a reputation as an artisan center. The other settlement, San Martin, has a restricted accessibility, no marketplace and limited commercialization experience. Differences in economic orientation and physical accessibility modify the types of activities developed in the surrounding forests; the more accessible market oriented community increasingly relies on cash while in the less accessible community there is a less dependence on cash, people rely on agriculture, hunting and fishing for their subsistence. There are also historic reasons that have shaped the social organization of these settlements for the purpose of this paper however we will focus on the ecological consequences of human activities around these communities understanding that management and conservation recommendations will need to consider the social ecological system as a whole.

Considering that species with different ecological traits respond differently to disturbance we are interested in studying how small-scale human intervention affects species with different ecological characteristics. By choosing species with different ecological traits we are able to carry out a more comprehensive comparison on the way human intervention in these kind of settlements are influencing the surrounding forests (Coomes and Burt 1997; Anderson and Putz 2002; Manzi and Coomes 2009; Balslev 2011;

Navarro et al. 2011; Vedel-Sørensen et al. 2013). In broad terms we would like to explore the influence of moderate levels of human intervention on populations of commonly utilized resources. We would like to know if human intervention can tip the balance in favor of certain species, for example common or light demanding species. We believe that a better understanding of the consequences of human intervention in forests surrounding these types of settlements provide enriching elements for the conservation versus development debate and hopefully help understanding the consequences of the development patterns unrolling in the Amazon.

We chose palm trees (Arecaceae) as an ideal working group for this comparison since palms are probably the group of plants that has the largest participation in the life of Amazon people. Approximately 130 species of palms with nearly 2000 different uses have been reported for the Amazon region (Paniagua-Zambrana et al. 2007; Bernal et al. 2011; Macía et al. 2011; Isaza et al. 2013). Palms are appreciated by men and women as well as children, they are part of their homes, eating habits and cultural traditions (Coomes and Ban 2004; Bernal et al. 2011; Isaza et al. 2013). Many species are now also an important source of income as palm products are increasingly being commercialized in local as well as international markets (Balslev 2011; Brokamp et al. 2011). The wide spread use of palms facilitates comparisons between human settlements with different types of socio-economic and political characteristics. We will take a look at the abundance and distribution of three utilized palm species as a proxy to evaluate the condition of their populations around the two human settlements.

Astrocaryum chambira handcraft.

Socratea exorrhiza stem-splits.

Phytelephas macrocarpa thatching units.

The first palm species *Astrocaryum chambira* is considered to be a light demanding near generalist species (Ruokolainen and Vormisto 2000; Beck and Terborgh 2002; Potvin et al. 2003; Ramirez et al. 2009; Jansen et al. 2010) and is used almost exclusively for commercial purposes in both communities, *Socratea exorrhiza* is one of the most common canopy species in the Amazon referred to as an oligarch (sensu Pitman et al. 2001) or generalist species (Ruokolainen and Vormisto 2000; Potvin et al. 2003; Balslev et al. 2012) and is used for a combination of domestic and commercial purposes, the third, *Phytelephas macrocarpa*, is referred to as a specialist because of its edaphic preferences (Ruokolainen and Vormisto 2000) and is used almost exclusively for domestic purposes.

As a first step we will determine land use categories around the settlements based on satellite image analysis and ground information in order to better define disturbed areas and refine the comparison. In comparing the abundance and distribution of palm populations between land use categories we expect to find differences between the two settlements as a result of differences in physical accessibility and economic activities. We also expect species to have different responses to disturbance as a result of their life histories and the type of use/management. We hope this comparison is able to provide useful insights on the way utilized species are responding to human intervention in areas that are gradually integrating into western lifestyles.

2.2. Materials and methods

2.2.1. Study region

The study was conducted between September 2011 and March 2012 in the southern part of the Colombian Amazon region, approximately 70 km to the northwest of Leticia (capital of the Amazonas department). Field work was conducted within and around the area of Amacayacu National Park in the two indigenous communities of San Martin (03°46'39.44"S, 070°18'13.10"W) and Macedonia (03°50'46.68"S, 070°13'18.88"W) (Figure 2.1). San Martin is the smaller of the two communities with a population of about 505 people while Macedonia is one of the largest rural settlements in the Amazonas department with around 730 inhabitants (Alcaldia de Leticia 2012). Although both communities are accessible by speed boat from Leticia, San Martin lies about 5 km up the Amacayacu River, making it somewhat more remote than Macedonia, which lies directly by the Amazon River.

These indigenous settlements, as most in the Amazon region, rely on agricultural production as basis of their livelihood. However within settlements households vary in their degree of dependence on agriculture; some rely entirely on agricultural production (subsistence based livelihoods) and others on the provision of some services like tourist guide and teacher (non-subsistence based livelihood).

Both communities are located on fine-texture soils of the Pebas geological formation which presumably have an Andean origin (Hoorn 1994; Duivenvoorden et al. 2002). Mean annual temperature in the region is 25 °C and annual average relative humidity ca. 86% with approximately 3400 mm of annual rainfall in Leticia(Rudas and Prieto 1998).

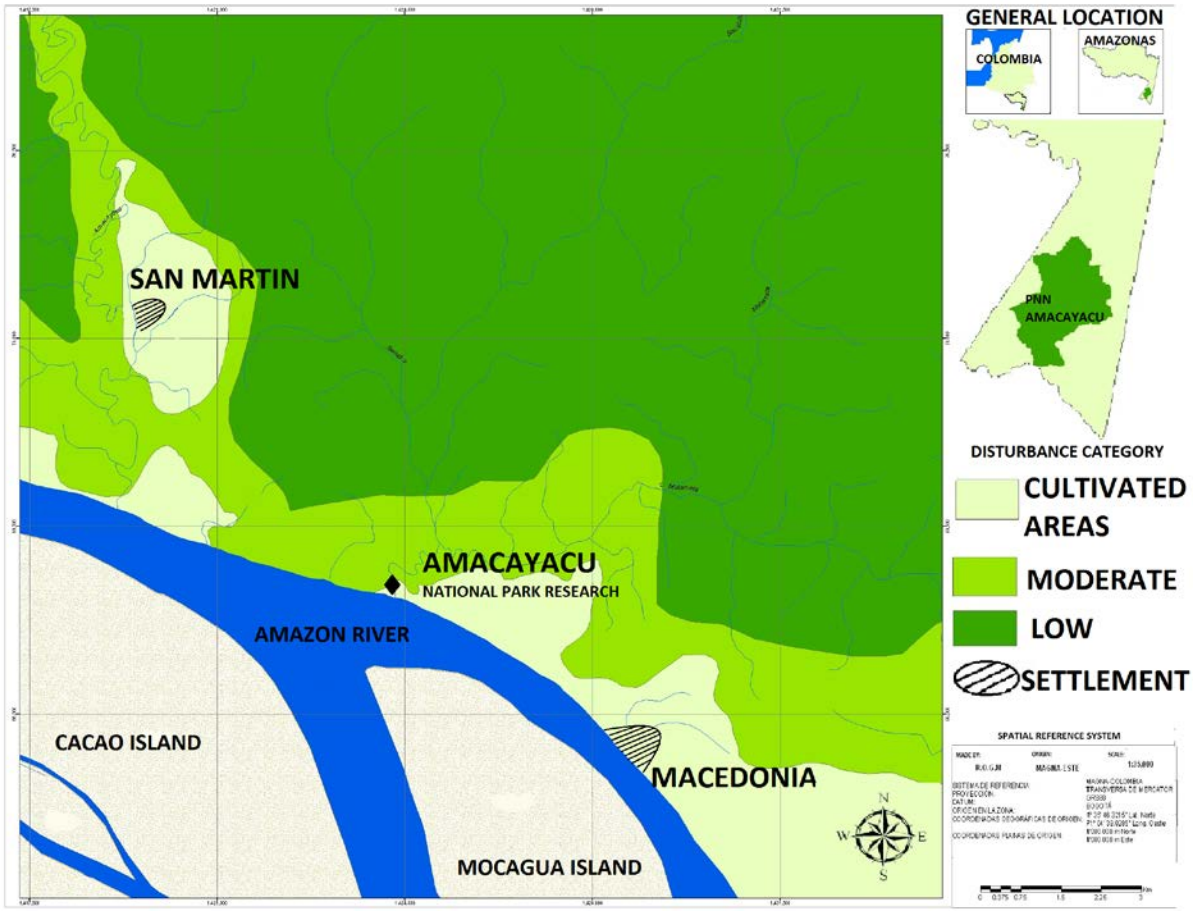


Figure 2.1. Detail of study site.

The study site is situated at the southeastern border of the Solimoes-Japura (Amazon-Caquetá) ecoregion, which is characterized by a high edaphic and topographic variability and nutrient-poor soils (oxisols and ultisols) with high content of aluminum and iron (Olson et al. 2001; Quesada et al. 2009).Abiotic and biotic differences have been used to distinguish this ecoregion from the Jurua-Purus and the southwestern Amazon ecoregions as distinct

units with major rivers such as the Amazon, Japura (Caquetá), Pastaza and Ucayali as borders between them. These rivers are dispersal barriers for many species and represent vital connectivity and commercial routes for many human settlements.

2.2.2. Data Collection

Information on land use (provided by community members) as well as data on vegetation cover and humidity spectral responses (obtained from Landsat image63-15112009) were analyzed and the results used to assign land use-categories to the areas around San Martin and Macedonia.

Three land use-categories were identified according to the satellite image analysis and the information provided by local people on activities developed there: (I.) cultivation areas are in the immediate surroundings of the human settlement, have the lowest humidity and vegetation cover and are considered to be a female domain; (II.) moderate disturbed (MD) areas are approximately two kilometers from the settlement area, have a higher soil humidity and vegetation cover than cultivated areas and (III.) low disturbed (LD) forest areas have the highest humidity and vegetation cover and known to a few elders and experienced hunters in the community (Figure 2.1). Because we are interested in the consequences of moderate levels of human intervention around these settlements we will base our comparisons on palm populations in moderate (MD) and low disturbed areas (LD).

For LD and MD forests in each community, two transects were installed following the point quadrant method (Mueller-Dombois and Ellenberg 2002) and 10 points (every 10 m) within each transect were sampled. At every sampling point, for all present trees with a stem diameter at breast height (DBH) ≥ 10 cm the stem height was estimated and DBH was measured. Additionally, whenever possible a sample was taken along with pictures and the vernacular name of the tree. Identification of individuals to the generic level was carried out by Andres Barona/Fundacion Entropica and Juan Sebastian Barreto/Sinchi Institute.

The study presented here focuses on three palm species, which are commonly used in both of the communities under study. Information on the size and number of individuals of all palm individuals was collected in a total 6 ha. of forest in each community. An area of 3 ha. was sampled in LD and MD forests with two 1 ha. plots installed for collecting information on palm species' distribution and four 0.25 ha. plots installed to incorporate

landscape variability. Plots were distributed as widespread as possible throughout each land-use category.

Size-class categories were defined post hoc for each species based on leaf size and division, stem size and overall height; seedlings, saplings, young adults and adults. Only in the case of *Phytelephas* we used three size-class categories; seedlings, young adults and adults (annex).

Information on household activities and characteristics and palm use and management was collected through semi-structured interviews and participant observation during weekly stays in each community and visits to cultivation areas. A complete census of each community was attempted and detailed information on approximately 60% of the households was collected (48 houses in San Martin and 80 houses in Macedonia). Households not included were empty or not willing to participate.

2.2.3. Data Analysis

We calculated vegetation similarity at genus level using Sørensen species similarity indexes calculated by EstimateS (Colwell 2013). To compare individuals' height and DBH we used box plots from IBM SPSS Statistics 20.

Since early life stages are useful in understanding dispersal events (Hubbell 2001; Norden et al. 2009), by comparing early life stages between forests with different levels of disturbance it could be possible to understand how these processes are being affected by human activities. The effects of harvesting large size individuals can be plainly understood by comparing the attributes like abundance, size and distribution of individuals in forests with different levels of human activity.

We therefore evaluated the condition of palm populations around the settlements by testing for differences in the abundance or number of individuals per unit area (hectares). We used species cover as an estimate of species' distribution by calculating the percentage of 10m x 10m plots where individuals of all sizes were found.

For this situation the experimental design is comparable to a retrospective cohort study it is therefore possible to calculate the prevalence of individuals of each size category in LD and MD forests through logistic regressions. Further linear hypothesis tests were carried out to test for interactions between groups. Significant relationships between

frequencies in different categories were tested with Fisher's exact test due to the low frequencies of large size individuals. Statistical tests were done using STATA 12.

2.2.4. Palm species

Astrocaryum chambira Burret is a common, tall, and single-stemmed palm found in non-flooded low land forests of the western Amazon region (Balslev 2011). It is associated to secondary forests and prefers non-flooded non-inundated, nutrient-poor soils (Ruokolainen and Vormisto 2000). In spite of its association to secondary forests, some studies have found that seed infestation by beetles was higher in disturbed areas (Ramirez et al. 2009). Abundance of *Astrocaryum* might be limited by low success of seed dispersal and germination, as evidenced by experiments with palms of the same genus (Potvin et al. 2003; Klinger and Rejmanek 2010). *Astrocaryum* species are reported to show low resilience to disturbance, probably due to limitations in dispersal and seedling recruitment (Montúfar et al. 2011).

Socratea exorrhiza (Mart.) H.Wendl is a tall, single-stemmed palm which is wide-spread throughout the neotropics (Balslev 2011). It has been associated with gaps in non-flooded lowland forests (Svenning 1999ab) but is also found in old-growth vegetation as well as in seasonal swamps or on alluvial soils (Balslev 2011). *Socratea* has been identified as a generalistic (Vormisto et al. 2004a) or oligarchic species (Pitman et al. 2001) because of its high abundance in both nutrient rich and nutrient poor soils as well as due to its occurrence in different types of forests (Pitman et al. 2001; Vormisto et al. 2004a). It also is considered to be a highly resilient species due to its positive response to disturbance (Montúfar et al. 2011). The reasons for its high abundance and low habitat requirements remain indistinct however some factors that might contribute to its success are its open stilt root cone(Potvin et al. 2003), its germination success (Potvin et al. 2003; Avalo et al. 2005) and high survival rate (Montúfar et al. 2011).

Phytelephas macrocarpa Ruiz and Pav. is a dioecious, single-stemmed understory palm (Balslev 2011). It has a marked preference for nutrient rich soils of both flooded and non-flooded areas and therefore has been classified as a specialist species (Ruokolainen and Vormisto 2000). *Phytelephas* species have been assigned to a medium resilience level, i.e., they showed an only slightly negative response to disturbance (Montúfar et al. 2011) which

might partly be explained by a limited recruitment due to long seed dormancy periods and low germination success (Jordan 1970; Bernal 1998).

Phytelephas macrocarpa seedling.

Socratea exorrhiza seedling.

2.3. Results

2.3.1. Land use categories; structure, composition and use

Based on satellite image analysis, vegetation transects and the information provided by local people we are able to delimit three distinct land use categories. In both communities low disturbed areas were approximately three kilometers from the main settlement. We observed that in both communities LD forests shared the highest number of genera (Sørensen Index 0.4 and 0.5 in San Martin and Macedonia respectively) and MD forests tended to have a more heterogeneous composition (Sørensen Index 0.2 in both San Martin and Macedonia). In Macedonia MD areas extend over a greater area than in San Martin where, inspite having a smaller population, cultivation areas were much larger. With regards to forest structure (height and DBH) the only differences were observed in MD forests of Macedonia where large size individuals (≥ 20 m and ≥ 30 cm DBH) were scarcely found (figure 2.2).

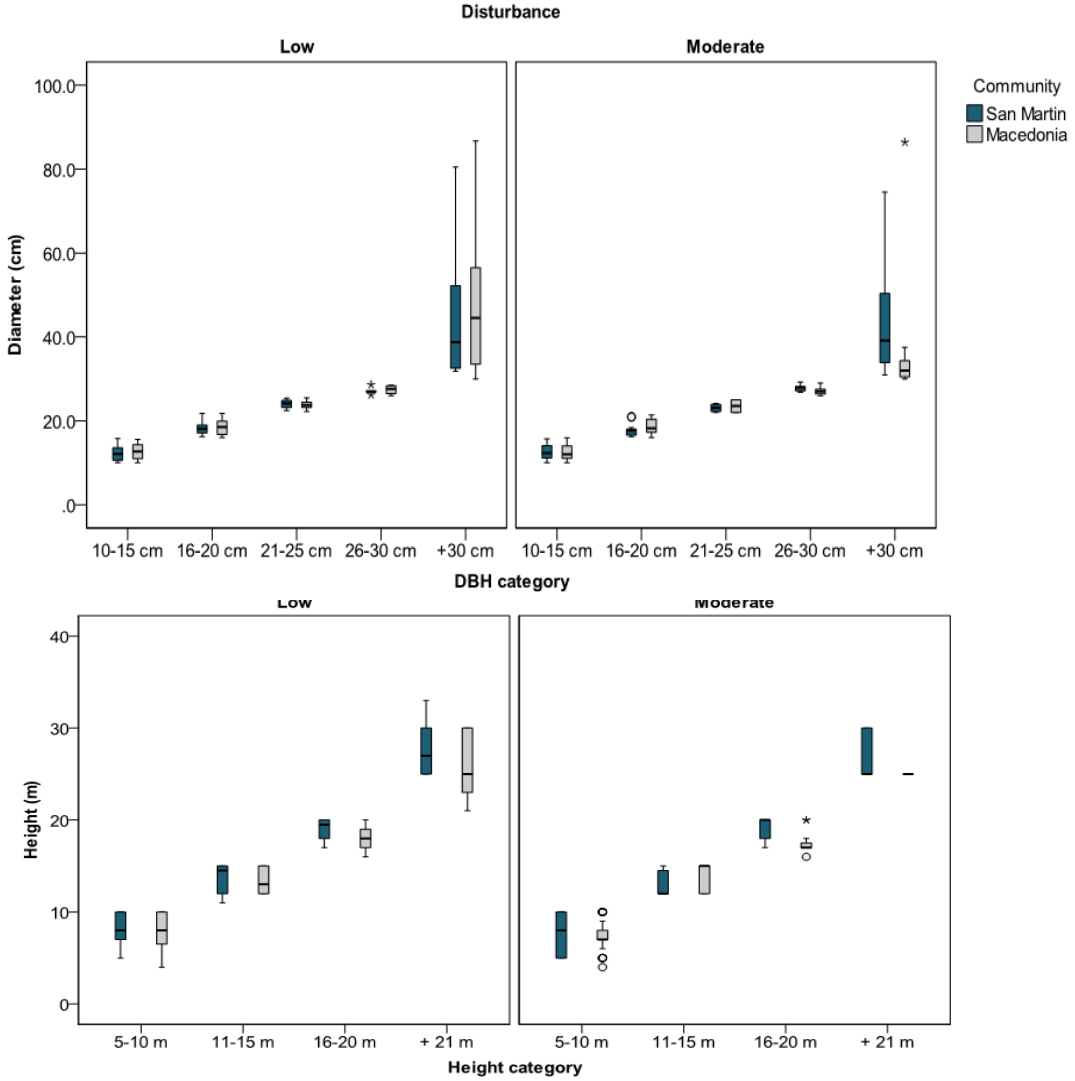


Figure 2.2. Structure of vegetation in low and moderately disturbed forests around human settlement with low (San Martin) and high (Macedonia) accessibility; a)tree diameter at breast height (DBH) and b tree) height.

2.3.2. Palm use, extraction and commercialization

Although the three palm species are used in both communities, few households in either community used all three (10% in San Martin and 7% in Macedonia). In San Martin close to half of the interviewees (45%) use two of the three species while in Macedonia 47% of the households reported using only one of the three. The commercially valuable *Astrocaryum* is the palm with the highest proportion of users while domestically valued species ranked second; *Socratea* in San Martin and *Phytelephas* in Macedonia (table 2.1).

Most of the households claim to extract *Astrocaryum* fibers directly from the forest or cultivation areas although in Macedonia about 27% of the households claimed buying fiber from other members of the community or from other communities. Elder women

claim that properly managed *Astrocaryum* individuals should be harvested approximately every four months so that the individual has time to develop a new leaf between each harvest. Extraction of raw material is done mostly by women in their gardens and fallows, although sometimes men assist in the extraction when the palm is too high or when they journey beyond the cultivation areas into moderate and low disturbed forests in search of game. Several of the men admitted to cut down the entire palm when the youngest leaf is out of reach. While in Macedonia marketplaces are visited every day, in San Martin there is no constant demand for *Astrocaryum* handcrafts; women stock them in their houses for weeks or even months until a group of tourists comes to visit the community.

Table 2.1.General description of the use of three palm species in two indigenous settlements which differ in their degree of accessibility; Macedonia more accessible and San Martin less accessible.

Species	Use characteristics	Community	
		Macedonia	San Martin
Astrocaryum chambira	Main use	Commercial: Handcraft production	Commercial: Handcraft production
	User households	67%	71%
Socratea exorrhiza	Main use	Commercial: Handcraft production	Subsistence: House construction
	User households	22%	43%
Phytelephas macrocarpa	Main use	Subsistence: thatching	Subsistence: Thatching
	User households	50%	36%

Socratea timber is used in the construction of houses (flooring, walls and as stem-splits for thatching units). In San Martin, the stem splits are mainly used together with leaves of Lepidocaryum tenue (carana) in the production of thatch while in Macedonia, 22% of households reported using the timber in handicraft production ei: carvings and cutlery add-ins (table 2.1). In both communities extraction of *Socratea* timber is done directly by the users, in Macedonia however, *Socratea* stems can also be purchased from other community members. The harvest procedure is simple: *Socratea* individuals of at least 8

meters high are cut down with an ax and the stem splits are transported to the community. Usually this activity takes one or two days depending on how far the palm is from the main settlement. Harvesting is a planned in advance, is physically demanding and therefore is done exclusively by men.

Phytelephas is used as thatch for both houses and/or kitchens in 50% of the house-holds of Macedonia while in San Martin a smaller proportion of house-holds (36%) are using it mostly in combination with other palm species like carana (*L.tenue*) and chapaja (*Attalea c.f. phalerata*) for thatching kitchen roofs. Palm leafs are directly extracted by users from gardens and fallows. Extraction of leaves usually is a planned activity that requires the assistance of several people. An adult plant can yield approximately six leafs according to local informants and can be harvested once a year. This species in not usually commercialized however at the time of the study more than 5000 thatching units, each of three to four meters long and consisting of three to four leafs, were requested for roofing tourist accommodations in an area a few kilometers down the river from Macedonia.

2.3.3. Condition of palm populations in forested areas

Astrocaryum chambira.

Astrocaryum is the second most abundant species (83 individuals/ha.). About 70% of individuals are found in LD forests and of these 84% are seedlings (table 2.2). Differences in prevalence of individuals between low and moderate disturbed forests are significant only for small size individuals (seedlings and saplings) ($P<0.05$), particularly in San Martin although differences in Macedonia were also significant (figure 2.3a).

In both communities young adult and adult individuals tend to be most abundant in LD forests. The lowest abundance is observed in LD forest of Macedonia where no young adults (with a height between 1.5 and 4.5 meters) were found. *Astrocaryum* seems to be most abundant in LD of San Martin however it is also in this community where the difference in abundance between LD and MD forests was greater (table 2.2 and Figure 2.3).

In both communities *Astrocaryum* covered more than 40% of low disturbed plots with one exception where cover was of 30%. Few adult individuals were observed in moderate disturbed forests in general (0.6 ind./ha. in Macedonia and 0.3 ind./ha. in San

Martin) (table 2.3).Cover in moderate disturbed areas was below 20% in all sampling units with the exception of one plot where it covered 30% of the area (annex).

Table 2.2.Comparison of information found in the literature with empirical findings. [San Martin:SM and Macedonia:M]. * (Henderson et al 1997) w(Kristiansen et al 2009) Ψ(Vormisto 2002) v(Vormisto 2004)

Species	**Lifehistory traits**	**Comparison**			
		Literature reports		Empirical data in forest disturbance	
				Low [SM/M]	Moderate[SM/M]
Astrocaryum chambira	Near-generalist, Large seeds, Rodent dispersed, Dormancy period, Difficult germination, Low resilience	Height (m)	≤ 30 *	19.6 (±4)	19 (±4)
		Ind./ha.	50 w	127[115/139]	40[28/52]
		Adult/ha.	0 >10mΨ	1.6[2.3/1]	0.5[0.3/0.6]
		% seedlings	FewΨ	84[83/85]	72[62/78]
Socratea exorrhiza	Generalist Small seeds Bird dispersed Successful germination, Resilient	Height (m)	≤ 20 *	15 (±5)	17.1 (±8)
		Ind./ha.	165 w	132[132/133]	487[494/349]
		Adult/ha.	1.5 – 8 Ψ	2.3[2.6/2]	5.5[6/5]
		% seedlings	58-70 Ψ	88[89/88]	94[94/93]
Phytelephas macrocarpa	Specialist, Large seeds, Rodent dispersed Long seed dormancy period	Height (m)	n.a.	-	-
		Ind./ha.	≈ 43 v	5[0/10]	2.5[2.3/2.6]
		Adult/ha.	n.a.	1[0/2]	1[1.6/0.3]
		% seedlings	Few v	22.5[0/22]	12.5[0/12]

Socratea exorrhiza.

Out of the three species studied, *Socratea* is the overall most abundant (277 individuals/ha.). In both communities more than 70% of the individuals are found in MD forests and 77% of these are seedlings (table 2.2). Just as for *Astrocaryum*, significant differences in the prevalence of individuals between low and moderate disturbed forests was observed only for small size individuals (seedlings and saplings) ($P<0.05$). Abundance of small size individuals is significantly different between LD and MD forests in both community but was similar within the same land use area (Figure 2.3 c and d).

Number of large size individuals (young adults and adults) was not large enough to perform significance tests however number of individuals per hectare tended to be greater in MD than in LD areas (table 2.3).

Individuals were more or less evenly spread between LD and MD forests. In Macedonia *Socratea* covered 66 and 36% of the plots while in San Martin it covered 30 and 40%. Moderate disturbed areas in Macedonia were covered 43 and 59% while in San Martin one plot had a 31% cover and in the other eleven adult individuals were found and the species covered 87% of the sampling unit (appendix).

Phytelephas macrocarpa fruits in a garden of San Martin

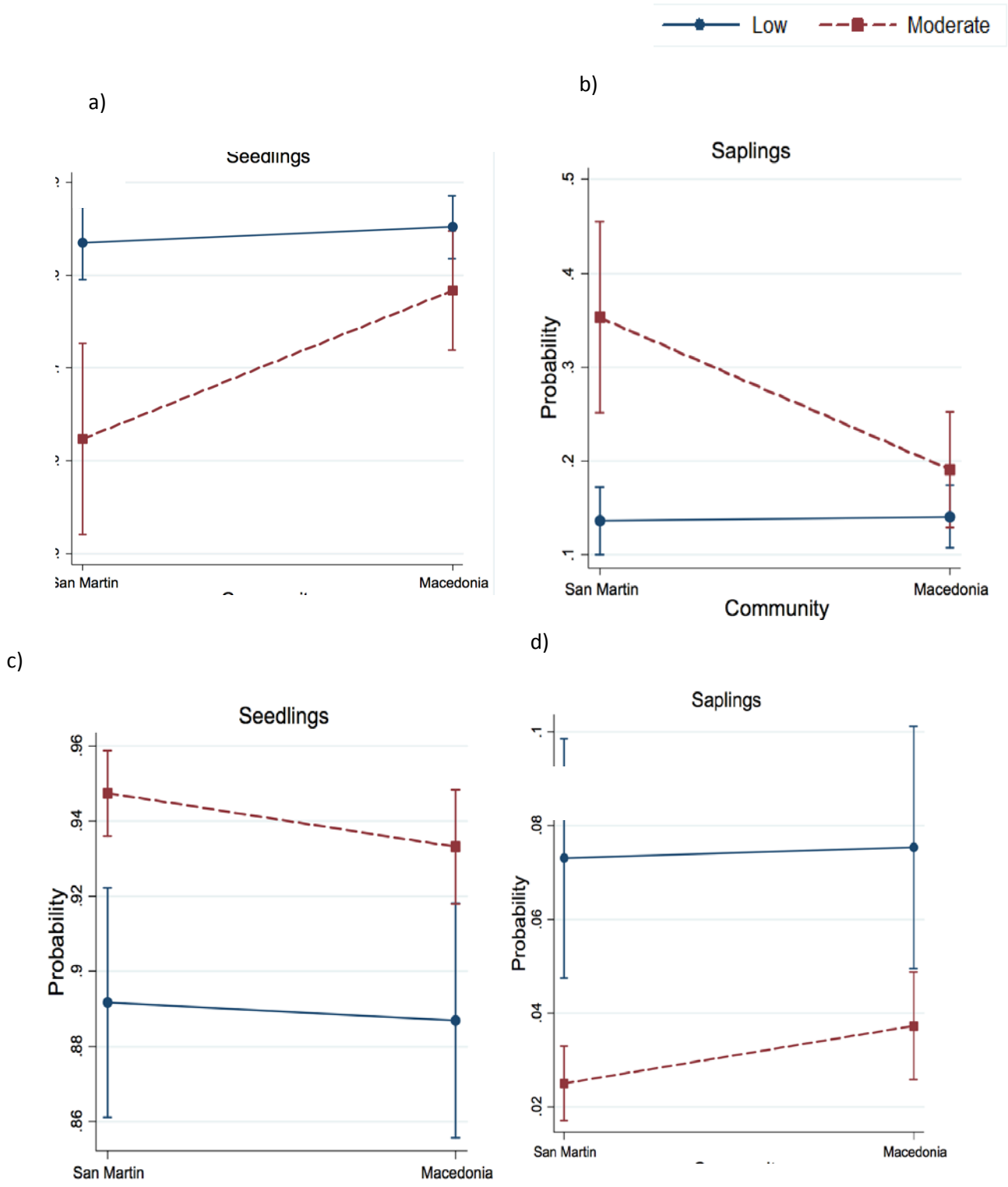


Figure 2.3. Prevalence of finding *Astrocaryum chambira* a) seedlings and b) saplings and *Socratea exorrhiza* c) seedlings and d) saplings in low and moderate disturbed forests in a less accessible (San Martin) and a more accessible (Macedonia) indigenous settlement.

Table 2.3. Response of large size individuals (young adults and adults) of three palm species to low and moderate levels of human intervention in a less (S.M) and a more (M) accessible community measured by the number (n) and average height (h) of individuals in meters in 3 hectares of forest per category in each community.

Species	**Size class category**	**Community**	**Disturbed Forest Category**			
			Low		Moderate	
			n	h (m)	n	h (m)
Astrocaryum chambira	Young adults	S.M	3	4 ±0.7	1	4
		M	0	-	2	2.2±1.1
	Adults	S.M	7	20.5±4.6	1	25
		M	3	17.6±2.5	2	16±1.4
Socratea exorrhiza	Young adults	S.M	6	4.8±2	23	3.5±2
		M	9	2.6±1.5	16	3.5±1.7
	Adults	S.M	8	16.2±4.9	18	17.9±9.5
		M	6	13.4±6.5	15	15.9±5.7
Phytelephas macrocarpa	Young adults	S.M	0	-	2	-
		M	18	-	6	-
	Adults	S.M	0	-	5	-
		M	6	-	1	-

Phytelephas macrocarpa.

Phytelephas is the least abundant of the three species in the forests surrounding the communities (3.8 individuals/ha.). Most of the individuals are found in one LD forest plot in Macedonia while in San Martin no individuals are found in low disturbed areas. Unlike the other two species, most of the individuals found are large sized (young adults and adults) and seven of the eight seedlings observed were found in one LD forest plot in Macedonia (table 2.3). *Phytelephas* covered about 5% of plots were it was found.

In general individuals found in this area have an average height similar to that referenced in the literature. The overall number of adults per hectare in low and moderate forests was within the range reported in other studies however the percentage of seedlings was higher than that found in other areas (Ruokolainen and Vormisto 2000; Vormisto 2002; Vormisto et al. 2004b; Kristiansen et al. 2009) (table 2.2).

2.4. Discussion

The land use categories we established seem to properly reflect the two broad levels of intervention in forested areas around the human settlements. Low disturbed areas are at approximately the same distance from the settlement and share roughly the same number of tree species in both communities. We observed no variation in tree size between the two locations. Although Macedonia has almost twice as many inhabitants as San Martin, walking distance seems to be the main factor limiting human activities in these areas. Moderate disturbed forests on the other hand are more intensively used and we observed a greater variation in tree composition between sampling units. Selective logging and extraction of non-timber forest products are probably the responsible for maintaining intermediate levels of disturbance and allowing a greater number of species to coexist in these areas (Connell 1978; White 2001; Wills et al. 2006; Hubbell et al. 2008; Bongers et al. 2009).

When taking a look at the response of particular palm species to moderate and low levels of intervention we observe how *Socratea*, a generalist oligarchic palm was abundant under both low and moderate levels of intervention. Its small bird dispersed seeds allow it to be widely dispersed (Potvin et al. 2003; Balslev 2011) while its fast growth mechanism using a wide spread stilt root system favors its early establishment (Avalo et al. 2005; Endress et al. 2013). Although it is similarly distributed in both low and moderate disturbed areas it also suffered the highest levels of mortality in the transition from seedlings to sapling growth stages (Wills et al. 2006). This generalist species like others in the Amazon is able to establish under contrasting environmental conditions and although it also suffered from higher mortality than less common or rare species (Ruokolainen and Vormisto 2000; Wills et al. 2006; Kristiansen et al. 2009) abundance of large size individuals was relatively high and its response to moderate levels of human intervention could be cataloged as positive.

Astrocaryum, a less common species, contrary to what has been observed in other areas (see Kahn and de Granville, 1992; Vormisto, 2002), had a higher abundance and even distribution in low disturbed forests. The contrasting abundance of small size individuals between moderate disturbed areas of San Martin and Macedonia could be an indicator of differences in human activities between the two settlements. We believe these differences can be attributed to the low abundances of larger size individuals in this same land use

category although an alternative or complementary explanation could have to do with the negative impact of human activities on disperser populations (rodent species like agouties) (Potvin et al. 2003; Ramirez et al. 2009), which are also locally valued game species (Wright and Duber 2001; Potvin et al. 2003; Murray K.G. et al. 2008; Klinger and Rejmanek 2010). While moderate levels of intervention seem to have a stronger effect on *Astrocaryum* populations in San Martin, high extraction pressure in Macedonia extends beyond moderate disturbed areas where detrimental extraction practices are taking place. For this species overall response to moderate levels of human intervention seem to be unfavorable (Coomes and Ban 2004; Montúfar et al. 2011), the high extraction pressure is stimulating overexploitation and urges for an effective regulation mechanism.

Phytelephas, a specialist species, is naturally restricted to nutrient rich soils (Ruokolainen and Vormisto 2000) and periodically flooded forests (Balslev 2011). In our study site it was found it was found in moderate disturbed areas of both communities but only in low disturbed areas of Macedonia. The low number of individuals and the uneven distribution among size classes make comparisons between communities difficult for this species; nonetheless we believe human activities around San Martin might be having a positive effect on *Phytelephas* populations. The low density of individuals found in areas of moderate intervention could not provide enough thatching material for the relatively high number of users (36% of the households). Thatching material is extracted from cultivation areas where we were able to observe several gardens and fallows where the species was growing. Slash and burn agricultural practices could be providing *Phytelephas* the necessary soil fertility required for its establishment in these areas where rodents are common and perhaps responsible for the dispersion of seeds into moderate disturbed areas. In Macedonia, nonetheless, highest abundance was observed in low disturbed areas and it was in these areas where the largest number of seedlings was observed. Further research will need to specifically target this situation in order to support this idea.

Human activity in the areas surrounding the settlements affects species and their different size categories differently; the smaller size classes could be linked to dispersion and establishment events while larger individuals can easily be associated with extraction practices. For a generalist like *Socratea*, dispersion and establishment in this case might be positively affected by moderate levels of human activities while the opposite is true for a

less generalist species like *Astrocaryum* (perhaps *Phytelephas* as well). Initial observations of palm abundance appear to confirm that specialized species are more likely to be negatively affected by moderate levels of human intervention; forest use and extraction of palm material.

We also observed differences in the extraction of larger size individuals between low and moderate disturbed areas. In Macedonia for example, no young adults of *Astrocaryum* were found in low disturbed areas, most probably as a result of cutting down the entire palm instead of extracting only the youngest leaf. The low commercial pressure and the higher extraction effort for *Phytelephas* and probably also for *Socratea* provide further away populations a temporary safeguard. In addition to life history traits the negative impact on wild populations will also be determined by the easiness to extract raw material.

It is the combination of life history traits and type of use that conditions the response of these species in forested areas around human settlements and at the same time we observed how an increased degree of physical access can condition the way these natural resources are being used. Commercialization is stimulating detrimental extraction practices further from the settlement as is the case in Macedonia while intensive use of forested areas in San Martin having an influence on dispersion events resulting in a negative balance for *Astrocaryum* populations. In the case of *Phytelephas*, life history traits like its specialized soil preferences and long germination periods could be disadvantageous for populations around human settlements however it seems that in this case cultivation practices and domestic appreciation might be favoring the establishment of populations in areas of moderate intervention.

2.5. Conclusions

Moderate levels of intervention around these two settlements were characterized by the same conditions inspite the differences in economic activities between the communities. The main difference was in the overall size of moderately disturbed areas; in the more accessible market oriented community, area of moderate intervention was larger than in the less accessible subsistence oriented community. Human activities in these areas are reflected by differences in utilized palm species abundance and cover. Abundance of

different size classes was notably different among these two land use categories and different as well for species with different life histories.

Socratea populations seem to find moderate disturbed areas as ideal nurseries while *Astrocaryum* individuals preferred less intervened areas for their establishment. Lower abundance of small size individuals of this species in areas of moderate disturbance might be a result of both hunting and pressure on larger sized individuals tipping the balance towards unfavorable conditions for these populations.

While small size individuals of *Phytelephas* were rare throughout the study site, the presence of medium sized and large individuals in moderate disturbed forests seem to indicate that dispersion and establishment in these areas is feasible and probably even favoured by management practices in cultivated areas as we assume from observations made in San Martin.

Extraction of palm material from larger size individuals of *Astrocaryum* seems to be intensive in moderate disturbed areas of San Martin where low abundances might be responsible for the sharp difference of small size individuals with areas of low intervention. Increase hunting of dispersers in these areas might also be responsible for this pattern. In Macedonia detrimental extraction of larger size individuals is evidenced by their absence in low disturbed areas and low numbers in areas of moderate disturbance. In both communities the overall balance for this species in forested areas of moderate disturbance tends to be negative although the underlining reasons might be different.

Moderate levels of human intervention can be clearly identified around these Amazonian settlements. Information captured through satellite images was corroborated by rapid vegetation sampling as well as by local informants. Palm populations also responded to differences in land use confirming that moderate levels of intervention through selective logging, hunting, etc. are tipping the balance in favor of certain species; however these are not necessarily the most resilient ones. Although the most resilient of the three palm species we studied, *Socratea*, was indeed favored by moderate levels of disturbance we believe the least resilient of the species, *Phytelephas*, can profit from the combination of management in cultivated areas and seed dispersal into moderate disturbed forests. The third of the species we studied, *Astrocaryum*, warns us that changes in livelihood activities taking place in these communities as they increase their proximity to the western scene (eg

replace subsistence with market based activities) will increase pressure to extract disregarding sustainable practices (Coomes 1995; Salisbury and Schmink 2007; Kramer et al. 2009; Perz et al. 2012, 2013; Salonen et al. 2012). Differences in the abundance and structure of used palm species populations reflect changes in livelihood strategies, in this case subsitance and market oriented activities. A basic understanding of the interactions, outcomes and unique evolutions of social and ecological systems (Berkes and Folke 1998; Folke et al. 2005; Ostrom 2007; Perz et al. 2012) can contribute to the formulation of effective sustainable use and conservation practices by embracing complexity and avoiding blue-print solutions.

3. Can appreciation encourage conservation practices? Use and management of three palm species in the North-western Amazon

3.1. Introduction

Infrastructure expansion driven by economic incentives has been identified as one of the proximate causes of tropical forest degradation around the world (Boucher et al. 2011; Geist and Lambin 2002; Hosonuma et al. 2012; Laurance et al. 2006). In the Amazon for example, road construction, oil exploitation and the expansion of the agricultural frontier represent the main factors associated with the degradation of natural resources (Egler 2002; Hargrave and Kis-Katos 2011; Krebs 2001; Mon et al. 2012) and in some cases of human well-being (Etter et al. 2006; Peres et al. 2010; Suárez et al. 2009). In Brazil, the conversion of forests to pastures and large scale agriculture has led to an initially raised standard of living, which declined with further deforestation (Rodrigues et al. 2009). In Ecuador for example, the construction of roads to oil wells resulted in a decline of game species such as tapirs and peccaries (Finer et al. 2008; Suárez et al. 2009). In the pursue of economic development, increased access to markets and commodities is transforming communities and availability/condition of natural resources throughout the Amazon region (Carvalho et al. 2001; Geist and Lambin 2002; Perz et al. 2007).

These development plans for the region are expected to rapidly change the small sparsely distributed human settlements, like the indigenous communities that characterize the Amazonian landscape. With increase accessibility these small indigenous communities tend to adopt new livelihood interests through a process some anthropologists refer to as acculturation (Balee 1993; Henrich 1997) in which traditional practices and knowledge fade away as people adopt western life-styles. From these examples it is easy to draw associations between traditional lifestyles and sustainable management and western lifestyles with detrimental use of natural resources often leading conservation practitioners to encourage local knowledge and community-based management as effective conservation approaches in attempt to stall acculturation (Henrich 1997; Oyuela-Caycedo and Vieco Albarracin 1999; Van de Sandt 2003). Outcomes of these approaches however have been praised by some but questioned by others (Berkes, 2004; Gockel and Gray, 2009; Igoe, 2006). Considering these situations an interesting question to explore is whether natural

resources appreciated in a traditional context continue to be appreciated as western practices and preferences begin to predominate?

Benefits of "acculturation" are less often document (Godoy et al. 2007; Heckenberger et al. 2007; Sirén 2007). In some cases increased market access has been observed to have little influence on subsistence activities (Sierra et al. 1999) and traditional ecological knowledge (Reyes-García et al. 2007). Increased access to western culture has also provided some indigenous communities with the opportunity to seek modern health care, education facilities and western commodities. If traditional appreciation for natural resources can persist under western influence could it be the catalyzer of sustainable management practices? The response to increase accessibility and interaction with western markets could be less straightforward than expected.

The Initiative for the Integration of Regional Infrastructure in South America (IIRSA) which aims at connecting the Peruvian coast, Andean and rainforest regions with the city of Manaus and with the Atlantic Ocean (Kileen 2007) will soon connect Pacific and Atlantic Oceans through the middle of the Amazon. Considering increasing connectivity in this region is expected in the near future we are interested in studying changes brought to two indigenous communities, particularly changes brought to commonly used and traditionally appreciated natural resources, in the southern Colombian Amazon as they become more integrated into regional and global networks. We use physical access as a proxy for increase western interaction. By comparing the condition of a specific resource in indigenous communities which are at different levels of integration into western networks we expect to find clues about conditions triggering beneficial or detrimental outcomes on human populations and natural resources. These are some of the general questions that motivated this study; Are land use changes associated with increase accessibility unavoidably linked to natural resource degradation? In the face of change could local/traditional appreciation inspire sustainable management practices?

We chose palms (Arecaceae) to help us compare natural resource use and management between two indigenous settlements with different degrees of connectivity to the main urban center in the region. In Amazonia, palms are probably the most important plant group in everyday life of the non-urban population which is mostly recognized as having an indigenous ethnic background. Around 130 palm species have been reported for

the Amazon region offering ca. 2000 different uses (Macía et al. 2011; Paniagua-Zambrana et al. 2007), which reflects the astonishing multi-use character of palms. Palms are appreciated by men and women alike; they are part of their homes, eating habits and cultural traditions (Coomes et al. 2004; Paniagua-Zambrana et al. 2007). To date, many palm species also represent an important source of monetary income as palm products become increasingly commercialized on local to international markets (Balslev 2011; Brokamp et al. 2011). The high diversity of palm uses underlines the relevance of drawing comparisons between human settlements with locally contrasting socio-economic and political characteristics.

The close link between people and palms together with the interconnectedness of palms within their ecosystems is already contributing to the understanding of tropical forest dynamics as well as of social-ecological systems or human-nature relationships in this region. The long history and comprehensive scientific documentation of palm uses in Amazonia represent a perfect background for studying the consequences of the rapidly changing life-style of indigenous people and its impact on this plant group in recent times. Recently published studies and reviews focused on palms report on the main factors influencing palm species distribution, community composition and diversity at different spatial scales that can probably be extrapolated to other species in this biome (Bernal et al. 2011; Eiserhardt et al. 2011; Kristiansen et al. 2009; Montúfar et al. 2011).

We expect that changes to socio-economic conditions brought by increased physical connectivity will be reflected in the way palm species are appreciated and managed. We realize that attempting a detailed understanding of the social and ecological changes linked to increased connectivity with the west requires a longer term effort nonetheless we believe an attempt to jointly investigate the use, management and condition of palm populations can bring forth useful insights on the often disregarded indirect effects of increased access in this region. We expect it will provide a sharper view on the interactions and links between social and ecological changes.

We want to know 1) what is the condition of utilized palm populations around human settlements with different degrees of accessibility? specifically in areas that are more and less intensively used and 2) what are the mayor differences in the social economic organization of these communities that can be linked to changes in palm use and

management practices? In order to answer these questions we characterize both the social and natural environments by collecting information on socio-economic aspects, land use, vegetation and palm abundance and distribution. We hope that by attempting to answer these questions we will be able to more easily discriminate between the type of changes that bring detrimental consequences and those that can stimulate beneficial outcomes.

3.2. Materials and methods

3.2.1. Study region

The study was conducted between September 2011 and March 2012 in the southern part of the Colombian Amazon region, approximately 70 km to the northwest of Leticia (capital of the Amazonas department). Field work was carried out within and around the area of Amacayacu National Park in the two indigenous communities of San Martin (03°46'39.44"S, 070°18'13.10"W) and Macedonia (03°50'46.68"S, 070°13'18.88"W) (Figure 2.1). San Martin is the smaller of the two communities with a population of about 505 people while Macedonia is one of the largest rural settlements in the Amazonas department with around 730 inhabitants (Alcaldia Municipal de Leticia 2012). Both communities are located on fine-texture soils of the Pebas geological formation which presumably have an Andean origin (Duivenvoorden et al. 2002; Hoorn 1994). Mean annual temperature in the region is 25 °C and annual average relative humidity ca. 86% with approximately 3400 mm of annual rainfall in Leticia (Rudas and Prieto 1998).

These indigenous settlements, as most in the Amazon region, rely on agricultural production as basis of their livelihood. However within settlements households vary in their degree of dependence on agriculture having some households that rely entirely on agricultural production (subsistence based livelihoods) and others relying on the provision of some services like tourist guide and teacher (non-subsistence based livelihood). Subsistence agriculture is based on what has often been referred to as slash and burn agriculture where each household works on several agricultural units or gardens, usually one or two harvested at the same time and the others left for fallow. Staple crops like manioc (*Manihot sp.),* plantain (*Musa* sp.), pineapple (*Ananas sp.)* are sowed from stubs or re-growths while others like palms and some timber species are spared during the clearing or burning process.

3.2.2. Accessibility

The Amazon River and the daily commercial flights from Colombia's capital to Leticia connect this region to major urban centers and facilitate the development of touristic activities and commercialization of timber and non-timber forest products. The city is accessible through the Amazon River from the Peruvian city of Iquitos which is 785 km up stream and from the Brazilian city of Manaus which is 1600 km down the river. Most of inhabitants in this region still rely on agriculture, fishing and hunting for their subsistence however commercial activities are increasing.

We will use the term accessibility as a synonym of connectivity to regional and national net-works (Kramer, Urquhart, and Schmitt 2009; Salonen et al. 2012; Schmitt and Kramer 2009). Here, in the absence of road infrastructure connectivity to regional networks depends on how fast and frequent fluvial transportation is. We will therefore define accessibility in terms of its transportation element and the easiness of reaching the settlement from the main urban center of Leticia. Although both communities are accessible by speed boat from Leticia, San Martin lies about 5 km up the Amacayacu River, making it somewhat more remote than Macedonia, which lies directly on the Amazon River. Accessing San Martin requires coordination and previous preparation, sometimes possible through mobile phones but most of the time the settlement is out of the reach of the mobile phone network. Macedonia´s geographical position on the other hand allows for the continuous functioning of several marketplaces within the community and also lies within the reach of mobile phone networks making it easier to coordinate transportation to and fro.

3.2.3. Data Collection

We collected information that could help us delineate an area of influence or land use for each human settlement. Information on land use (provided by community members) as well as data on vegetation cover and humidity spectral responses (obtained from Landsat image 63-15112009) were analyzed and the results used to assign land use-categories to the areas around San Martin and Macedonia.

Three land use categories were identified according to the satellite image analysis and the information provided by local people on activities developed there: (I.) cultivation areas, (II.) moderate disturbed (MD), and (III.) low disturbed (LD) forest areas. The settlement area is at the core of these land three land-use categories and edged by a river (Figure 2.1).

Cultivation areas, in the immediate surroundings of the human settlements, have the lowest humidity and vegetation cover. Beyond cultivated areas, at approximately two kilometers from the settlement areas, are moderate disturbed (MD) forests, the main source of timber, firewood and non-timber forest products like palms. Other activities developed there include hunting and guided walks for tourists. The third category is the area with the highest humidity and vegetation cover, used mainly for hunting and extraction of certain forest products. Due to its distance from the settlements it is subject to lower intensity of use and is therefore termed as an area of low disturbance (LD).

To complete the characterization of the land use categories we installed two transects in LD and MD forests per community following the point quadrant method (Mueller-Dombois and Ellenberg 2002) and 10 points (every 10 m) within each transect were sampled. At every sampling point, for all present trees with a stem diameter at breast height (DBH) ≥ 10 cm the stem height was estimated and DBH was measured. Additionally, whenever possible a sample was taken along with pictures and the vernacular name of the tree. Identification of individuals to the generic level was carried out by Andres Barona/Fundacion Entropica and Juan Sebastian Barreto/Sinchi Institute.

The study presented here focuses on three palm species; *Socratea exorrhiza*, *Astrocaryum chambira* and *Phytelephas macrocarpa*, commonly used in both of the communities under study. Information on the size and abundance of all palm individuals was collected in a total 6 ha. of forest in each community. An area of 3 ha. was sampled in low and moderate disturbed forests with two 1 ha. plots installed for collecting information on palm species' distribution and four 0.25 ha. plots in order to incorporate landscape variability. Plots were distributed as widespread as possible throughout each land-use category.

Size-class categories were defined post hoc for each species based on leaf size and division, stem size and overall height; seedlings, saplings, young adults and adults. Only in

the case of *Phytelephas* we used three size-class categories; seedlings, young adults and adults. For the purpose of this paper we will mostly refer to utilized size classes which for all species are large size individuals; young adults and adults.

Information was collected through semi-structured interviews and participant observation during weekly stays in each community and visits to cultivation areas. Approximately 60% of the households participated in the interviews (48 houses in San Martin and 80 houses in Macedonia) the houses that did not participate in the interviews were either uninhabited at the time of the visits or their inhabitants were not willing to participate in the study. Data on three general topics were collected: household characteristics (ethnic background, household size, number of landholdings, house infrastructure, etc.), activities/occupation of the heads of the household, and management and extraction of palm resources. Management of palm species was defined according to information on the extraction of palm raw material mainly within cultivation areas since these could be directly attributed to specific households while extraction in forested areas (moderate and low disturbed) is difficult to trace and human activities were often difficult to discriminate from natural disturbances.

3.3. Data Analysis

We calculated vegetation similarity at genus level using Sørensen species similarity indexes calculated by EstimateS (Colwell 2013). To compare individuals' height and DBH we used box plots. We also tested for differences in socio-economic variables between communities using univariate analysis of variance. All tests were performed in IBM SPSS Statistics 20.

The condition of palm populations around the settlements was evaluated by testing for dif-ferences in the proportion of individuals between forest categories within each community using Fisher´s exact (Chi2) tests in IBM SPSS Statistics 20. To test for differences in the proportion of individuals between communities we performed test of proportion using large sample statistics with STATA 12.

3.3.1. Palm species

Socratea exorrhiza (Mart.) H.Wendl is a tall, single-stemmed palm which is wide-spread throughout the neotropics (Balslev 2011). It has been associated with gaps in non-flooded

lowland forests (Svenning 1999ab) but is also found in old-growth vegetation as well as in seasonal swamps or on alluvial soils (Balslev 2011). *Socratea* has been identified as a generalistic (Vormisto et al. 2004) or oligarchic species (Pitman et al. 2001) because of its high abundance in both nutrient rich and nutrient poor soils as well as due to its occurrence in different types of forests (Pitman et al. 2001; Vormisto et al. 2004). It also is considered to be a highly resilient species due to its positive response to disturbance (Montúfar et al. 2011). The reasons for its high abundance and low habitat requirements remain indistinct however some factors that might contribute to its success are its open stilt root cone (Potvin et al. 2003), its germination success (Avalo et al. 2005; Potvin et al. 2003) and high survival rate (Montúfar et al. 2011).

Astrocaryum chambira Burret is a common, tall, and single-stemmed palm found in non-flooded low land forests of the western Amazon region (Balslev 2011). It is associated to secondary forests and prefers non-flooded non-inundated, nutrient-poor soils (Ruokolainen and Vormisto 2000). In spite of its association to secondary forests, some studies have found that seed infestation by beetles was higher in disturbed areas (Ramirez et al. 2009). Abundance of *A. chambira* might be limited by low success of seed dispersal and germination, as evidenced by experiments with palms of the same genus(Klinger and Rejmanek 2010; Potvin et al. 2003). *Astrocaryum* species are reported to show low resilience to disturbance, probably due to limitations in dispersal and seedling recruitment (Montúfar et al. 2011).

Phytelephas macrocarpa RuizandPav.is a dioecious, single-stemmed understory palm (Balslev 2011). It has a marked preference for nutrient rich soils of both flooded and non-flooded are-as and therefore has been classified as a specialist species (Ruokolainen and Vormisto 2000). *Phytelephas* species could be considered to have low resilience levels, i.e., they showed an only slightly negative response to disturbance(Montúfar et al. 2011). This might partly be explained by a limited recruitment due to a long seed dormancy period and low germination success (Bernal 1998).

3.4. Results

3.4.1. Vegetation structure and composition of land-use categories

In both communities LD forests shared the highest number of genera (Sørensen Index 0.4 and 0.5 in San Martin and Macedonia respectively) while MD forests tended to have a more heterogeneous composition (Sørensen Index 0.2 in both San Martin and Macedonia). With regards to forest structure (height and DBH) the only differences were observed in Macedonia where large size individuals (≥ 20 m and ≥ 30 cm DBH) were scarcely found in MD forests (Figure 3.1).

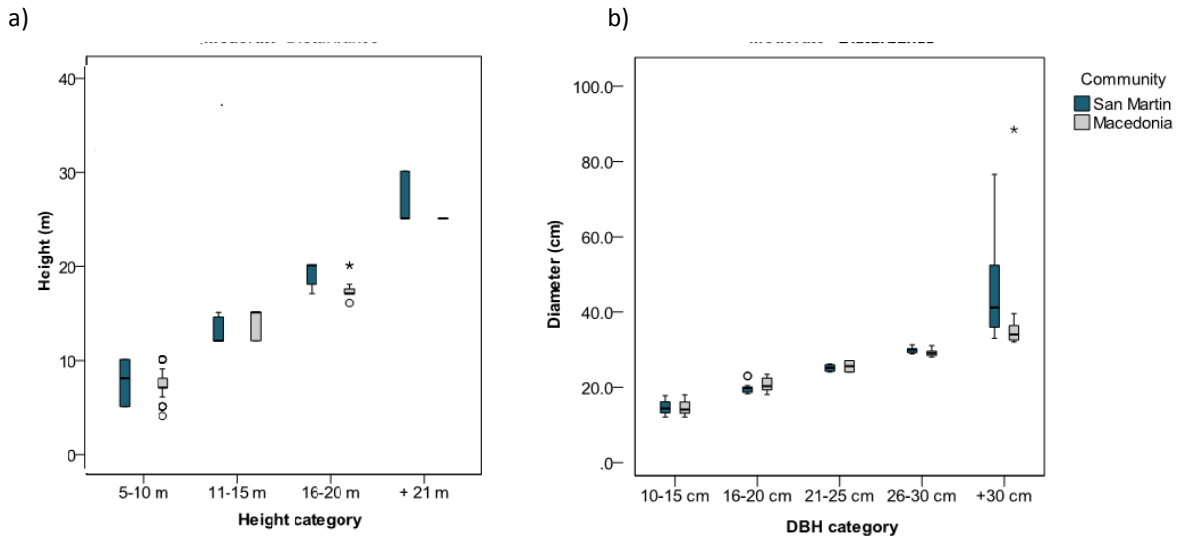


Figure 4. Tree a) height in moderate disturbed forests and b) diameter at breast height (DBH) around a human settlement with low (San Martin) and high (Macedonia) accessibility.

3.4.2. Social-economic change

Principle component analysis extracted two main factors from the group of variables; the first group of variables included ethnic background, palm species cultivated and landholdings. The second group of variables included house-hold size, number of children and livelihood strategy. Analysis indicated that among all the input variables these were the ones with the highest level of interdependence and for that reason we used them to compare the socio-economic situation between communities, the rest of the variables were excluded from the analysis.

Among these variables the greatest differences between settlements are observed for total number of landholdings and ethnic background. While in San Martin, the less accessible community, most of the people are Ticuna (95%) and had an average of 12.3 ±9.2 cultivation units (gardens and fallows) in Macedonia the percentage of Ticuna house-holds is 60% and the average cultivation unit per household is of 2.4 ±2 (table 3.1). In San Martin

most interviewees reported having four to six different palm species in their gardens and fallows while most of their counterparts in Macedonia reported having one to three palm species. Although the three palm species are used in both communities, few households in either community used all three (10% in San Martin and 7% in Macedonia). In San Martin 45% of the households use two of the three species while in Macedonia 47% use only one of the three.

From the second group of variables little difference was observed between communities; households have a similar average size and number of children. Most of the people in both communities combine subsistence with non-subsistence activities as their livelihood strategy nonetheless the percentage of subsistence households in San Martin is higher than in Macedonia (table 3.1).

Table 3.1. General descriptive characteristics of two indigenous settlements with a low (San Martin) and a high (Macedonia) degree of physical accessibility.(1)Fisher exact test (chi square) (2)Univariate Analysis of Variance (3) Partial Eta square (4) 95% confidence intervals.

Community	**Ticuna background P= 0.00(1)**	**Subsistence households P= 0.29(1)**	**House Roofs**		**Household size P= 0.11(1)**	**Number of children P= 0.13(1)**	**Land holdings P=0.00 (2) Eta²= 0.40 (3)**
			zinc	palm			
San Martin	95%	22%	11%	35%	6.0 ±2.7	4.9 ±2.4	[10.5; 13.9](4)
Macedonia	60%	14%	37%	6%	6.2 ±2.3	4.1 ±2.9	[1.1;3.6](4)

3.4.3. Palm populations, management and use

Information collected from interviews and participant observation enabled us to create a typology of the different ways people use and manage palms in cultivated and forested areas around the settlements. We distinguish between active cultivation and passive cultivation. The former is a version of the customary farming practice where the land is prepared for sowing seeds while in what we term passive cultivation crops are not actively sown but arrive to the field through natural dispersion or existing seed banks. In both cases crops are looked after ei: weeds and pests are removed, etc. We noted as well that some crops were tolerated, they were not actively sown or looked after but left standing at the margins of the field. Beyond cultivated areas no care or special management practice is carried out all palm species in forested areas are potentially subject to extraction.

Astrocaryum chambira palm among banana trees in a cultivation plot or garden in San Martin, resulting from passive cultivation

In passive cultivation or management practices palms are spared during the burning of an agricultural plot.

3.4.3.1. *Socratea exorrhiza*

Use, extraction and management. This species is used by inhabitants of both communities, however partly for different purposes: In both communities *Socratea* timber is occasionally used in the construction of houses (flooring and walls). In San Martin, the stem splits are mainly used together with leaves of *Lepidocaryum tenue* (carana) in the production of thatching material. Usually the resulting thatching units are produced for private use only, but when in demand they are also commercialized outside the community. During this study, for example, 3000 thatching units of approximately four meters long were produced in San Martin to be sold as roofing material in tourist facilities; this required the felling of approximately 150 adult *Socratea* individuals. In Macedonia, 22% of households reported to use the timber in handicraft production (table 3.2). Here, a local wood carver reported to carve two masks of 150 cm long each out of one stem; however *Socratea* stem-splits are most commonly used for the production of cutlery handles which are then sold as handcrafts.

In both communities extraction of raw material is mainly performed by the user, in Macedonia however, *Socratea* stems can also be purchased by users from other members of the community. The harvest procedure is simple: *Socratea* individuals of at least 8 meters high are cut down with an ax and the stem segments are transported to the community. Cutting down these palms is a planned activity and is done exclusively by men since it is physically demanding. Usually this process takes one or two days depending on the distance that is covered. Inhabitants of San Martin tend to cut down trees that grow close to the river in order to transport the stems by “floating” them down-stream.

Socratea is frequently observed in cultivation areas; 40% of gardens and fallows in San Mar-tin and 46% in Macedonia (table 3.2) nonetheless in the latter with a higher number of individuals per hectare (table 3.3). In both communities *Socratea* is most often tolerated in cultivated areas; however its commercial appreciation in Macedonia motivates certain artisans to passively cultivate it.

Thatching unit of *Lepidocaryum tenue* using stem-splits of *Socratea exorrhiza*

Condition of natural populations. Out of the three species studied, *Socratea* is the overall most abundant (277 individuals/ha.) and about 90% of these individuals are seedlings (table 3.3). Large size individuals tends to be more abundant in MD areas although distribution is not homogeneous; in both communities more than 50% of large size individuals are found in one sampling plot. In LD forests on the other hand distribution tends to be homogeneous, individuals of all sizes are found in all sampling units.

Table 3.2. Comparison of palm species utilization in a human settlement with low (San Martin) and high (Macedonia) accessibility. Presence in cultivated areas expressed as the percentage of cultivation units (gardens and fallows) where the species was observed. Total cultivation units visited: San Martin (gardens=38 and 64=fallows) and Macedonia (gardens=33 and fallows=42).

Species	Main use		Harvesting effort	No. of user households		Presence in cultivated areas	
	San Martin	Macedonia		San Martin	Macedonia	San Martin	Macedonia
Socratea exorrhiza	Subsistence	Commercial	high	43%	22%	40%	46%
Astrocaryum chambira	Commercial		low	71%	67%	50%	33%
Phytelephas macrocarpa	Subsistence		high	36%	50%	16%	61%

Table 3.3. Comparison of palm individuals per hectare in low and moderate disturbed forests and cultivation areas around indigenous communities with low (San Martin) and high (Macedonia) degrees of physical accessibility. ya: young adult and a: adult. Approximate cultivation areas: San Martin=555 hectares and Macedonia=340 hectares.

Species	Size Category	San Martin			Macedonia		
		Low	Moderate	Cultivated areas	Low	Moderate	Cultivated áreas
S.exorrhiza	Ya	2 ind/ha.	7.6 ind/ha.	-	3 ind/ha.	5.3 ind/ha.	-
	A	2.6 ind/ha.	6 ind/ha.	0.2ind/ha.	2 ind/ha.	5 ind/ha.	0.5ind/ha.
A.chambira	Ya	1 ind/ha.	0.3 ind/ha.	-	0	0.6 ind/ha.	-
	A	2.3 ind/ha.	0.3 ind/ha.	0.2 ind/ha.	1 ind/ha.	0.6 ind/ha.	0.3 ind/ha.
P. macrocarpa	Ya	0	0.6 ind/ha.	-	6 ind/ha.	2 ind/ha.	-
	A	0	1.6 ind/ha.	0.1ind/ha.	2ind/ha.	0.3ind/ha.	0.9ind/ha.

3.4.3.2. *Astrocaryum chambira*

Use, extraction and management. Fibers from the palm´s youngest leaf are used for the elaboration of different assortments of handcrafts. *Astrocaryum* is the palm with the highest numbers of users in both communities (table 3.2). In The less accessible community all of the households claim to extract fibres directly from the forest or cultivation areas. In the more accessible community the extraction is most often done directly, as in the less accessible community, but in some cases the fibres are bought from other members of the community or from other communities. While in the less accessible community all users claim to extract and process the fibres by themselves, in the more accessible community some of the users (about 27%) are paying others for extracting and processing the raw material.

Extraction of raw material is done mostly by women in their gardens and fallows, although sometimes men assist in the extraction when the palm is too high or when they journey beyond the cultivation areas where women do not venture. When asked, some men admitted bringing raw material back home when they encountered individuals during their excursions in the forest. Although sometime women were reluctant to admit taking leafs from the gar-dens of others complains about frequently observing this practice are constant. According to elder women, properly managed palms should be harvested approximately every four months so that the individual has time to develop a new leaf between each harvest. This management is feasible when extraction of the youngest leaf is

done with a machete or a long hooked stick however several men admitted to cut down the entire palm when the youngest leaf is out of reach. When this practice is done in the surrounding common use areas (moderate and low disturbed forests) it is not possible to keep track of harvesting events.

Macedonia receives tourists everyday from 10:00 am to 4:00 pm in their marketplaces while in San Martin there is no constant demand for *Astrocaryum* handcrafts; women stock them in their houses for weeks or even months until a group of tourists comes to visit the commu-nity. Although commercialization is less frequent in San Martin, close to 70% of the house-holds in both communities are using it. The number of large size individuals per hectare in cultivated areas is similar in both communities but more frequent in San Martin (50%) than in Macedonia (33%) (table 3.3). Commercialization in San Martin is not constant but *Astrocaryum* appreciation is high and is stimulating passive cultivation (table 3.2). In Macedonia *Astrocaryum* is also passively cultivated by many people but cannot counteract the high extraction pressure.

Condition of natural populations. *Astrocaryum* is the second most abundant species (83 individuals/ha.) out of which about 80% are seedlings. Low disturbed areas of San Martin have the highest numbers of adult individuals per hectare; 2.3 versus 1 in Macedonia. Few young adults(with a height between 1.5 and 4.5 meters) are found; 0.6 and 0.3 individuals/ha. in Macedonia and San Martin respectively. No individuals were observed in LD forests around Macedonia and only three in LD forests around San Martin. Particularly in Macedonia populations appear to be under greater pressure.

3.4.3.3. *Phytelephas macrocarpa*

Use, extraction and management. This palm is appreciated by both communities as thatching material particularly in Macedonia where half of the houses are using it (table 2.1). Palm leafs are directly extracted by users from gardens and fallows. Thatching with *Phytelephas* is relatively easy compared with other palm leafs because the leaflets do not require weaving nor does the leaf need additional supporting structures as is the case with thatch from *Lepidocaryum tenue*. Extraction of leaves usually is a planned activity that requires the assistance of several people. An adult plant can yield approximately six leafs according to local inform-ants and can be harvested once a year.

Phytelephas is used as thatch for both houses and/or kitchens in 50% of the house-holds of Macedonia while in San Martin a smaller proportion of house-holds (36%) are using it mostly in combination with other palm species like *L. tenue* and *Attalea c.f. phalerata* for thatching kitchen roofs.

Although this species in not usually commercialized at the time of the study more than 5000 thatching units, each of three to four meters long and consisting of three to four leafs, were requested for roofing tourist accommodations in an area a few kilometres down the river from Macedonia.

Of the three palm species, this is the least abundant in cultivated areas of San Martin and although it is used by 36% of the households it is observed in only 16% of the cultivated areas. In contrast *Phytelephas* is used by half of the households in Macedonia and it also was the species with the highest abundance in cultivated areas, it was observed in close to 60% of the gardens and fallows (table 3.2). While people in San Martin tolerate *Phytelephas* individuals in the cultivated areas, in Macedonia people cultivate it passively and perhaps in some cases even actively since other thatching species are not easily available around the settlement.

Condition of natural populations. *Phytelephas* is the least abundant of the three species (3.8 individuals/ha.) with only 17% of all individuals being seedlings however abundance of large size individuals is higher than that of *Astrocaryum* although in San Martin no *Phytelephas* individuals are found in LD areas and abundance in MD areas is of 2.3 individuals/ha. Highest number of *Phytelephas* individuals are found in one LD forest plot in Macedonia (8 individuals/ha.)(table 3.3)

3.5. Discussion

Vegetation sampling and local informants confirmed the differences between land-use categories initially discriminated through satellite image analysis. Low disturbed forests proved to have a similar composition around the two communities while in moderate disturbed forest composition was more heterogeneous. We also observed fewer trees larger than 30 cm DBH and higher than 20 meters in forests that were moderately disturbed around Macedonia confirming that people in this community are selectively extracting timber more often than in San Martin where the number of trees of different sizes was not

noticeably different between low and moderate disturbed areas. Vegetation sampling thus allowed not only to verify differences between disturbed forests but also to evidence differences in the type of activities developed in moderate disturbed areas around each community where consequences of selective logging are more obvious in Macedonia.

By comparing the use and management of three palm species in San Martin and Macedonia we observed how people in these communities are adjusting the way they harvest palms according to their different socio economic contexts. *Astrocaryum* is appreciated in both communities for its commercial value and in both communities was the species with the highest number of users. Although market conditions in San Martin are imperfect and commercialization of *Astrocaryum* products is not frequent, it was in the gardens and fallows of this community where we most frequently observed *Astrocaryum* individuals and although the number of individuals per hectare in moderate disturbed areas was somewhat less than in Macedonia, low disturbed areas in San Martin bared the highest abundance of large size individuals in all of the sampling area. People in Macedonia have turned to destructive ex-traction practices (cutting down the entire individual) in faraway areas and many users are now constantly buying fibres from other communities nearby. In the case of *Astrocaryum* we observed a direct association between efficient market conditions, increasing extraction pressure and deficient resource conditions. It seems that commercial appreciation is not enough to stimulate active cultivation of this species and in addition its life history traits, like dormancy period and rodent dependant dispersion pose a disadvantage for guaranteeing satisfaction of demand.

Local appreciation can stimulate passive cultivation of highly used species like was the case for *Phytelephas*. In both communities this is a domestically appreciated species, with about half of the households in Macedonia using it for thatch and being cultivated in nearly 60% of the cultivation units we observed. In San Martin appreciation stimulated passive cultivation in a less than 20% of the gardens and fallows, nonetheless this production seems to satisfy local demand and probably even facilitating its dispersion to moderate disturbed areas. It seems unlikely that the absence of *Phytelephas* in low disturbed areas of San Martin is a result of overexploitation since the relative high effort required to harvest leafs would motivate people to target individuals in areas closer to the settlement. A more likely explanation is that rodent dispersion is likely to take place

between cultivation and moderate disturbed areas, dispersers being lured by the diverse combination of crops and forest species (Sanchez 2005). Unfortunately we also observed how indiscriminate and massive harvesting took place when people were presented the opportunity to commercialize thatching units.

A similar situation was observed with *Socratea*, where commercialization of thatching units of carana (*L.tenue*) led to massive extraction of both leafs of that species and stem-splits of *Socratea* in San Martin. In this community *Socratea* is used locally for the production of carana thatching units and is passively cultivated in about 40% of the gardens and fallows. To its advantage, *Socratea*'s efficient dispersion, successful germination rate, fast growth and other resilient life history traits allows it to establish and survive better under moderate levels of intervention than in low disturbed areas. In addition to its life history traits, the high extraction effort of palm raw material adds to its advantage in dealing with human intervention this scale. This generalist species is not only successful in overcoming natural disturbances but also seems successful in dealing and overcoming moderate levels of human intervention.

We observed how use and management practices of active/passive cultivation, toleration as well as extraction changed between communities as they move from subsistence to market based activities. In the less accessible settlement people actively cultivate staple crops (cassava, bananas, pineapple, etc) as well as passively cultivate forest species and palms like the commercially valued *Astrocaryum*. In the more accessible Macedonia there is mixture of traditional and western practices coming from more heterogeneous ethnic composition. We were able to perceive how a larger population is creating a higher pressure over the land and cultivation is becoming exclusively active, passive cultivation carried out for the commercially valuable *Astrocaryum*, the irreplaceable *Phytelephas* and in some cases *Socratea* as well. However neither high commercial appreciation nor passive cultivation practices for *Astrocaryum* guaranteed high abundances in cultivation areas of either community and for none of the species we were able to observe intentions of active cultivation.

Active cultivation practices could ensure higher abundances in cultivated areas and although some women admitted considering this as an option for *Astrocaryum* few people have at-tempted to go beyond passively cultivating it. Passive cultivation practices are not

enough to ensure its sustainable use and its high commercial appreciation for chamber handcrafts might be leading to detrimental practices as suggested by the complete absence of young adults in low disturbed forests around Macedonia. In addition, the relative easiness to extract *Astrocaryum* fibres does not discourage its extraction in further away areas as might be the case with *Socratea*.

In these communities increasing access is promoting regional and national integration facilitating social transformations. Economic activities are shifting from subsistence to market oriented, promoting specialization of labor, commodification of agricultural products and changing land use and management practices. We documented how local appreciation might lead to positive management practices of some species for example shifting from toleration to passive cultivation, however active cultivation was rarely considered. We also witnessed how the urge to commercialize overrides local appreciation and none of the actual management practices seem to be able to guarantee species sustainable use.

3.6. Conclusions

We confirmed differences in land use categories discriminated by satellite images through the rapid vegetation sampling and differences in palm use, reflected in abundance of large size individuals in these areas as well as information provided by local informants.

Macedonia, as many settlements that have become increasingly accessible, has contrasting land use practices from those of the less accessible San Martin. Better transportation possibilities have allowed migration of non-Ticuna people with commercial and/or religious interests and the establishment of permanent marketplaces. As a result people combine subsistence and commercial activities, households have fewer land holdings cultivation areas smaller and moderate disturbed areas larger than those of San Martin.

Commercialization of *Astrocaryum* has had a toll on natural populations in both communities with less than one individual per hectare in forested areas closest to the settlement (moderate disturbed forests) and only greater numbers in low disturbed areas in San Martin. In Macedonia raw material is purchased from other communities to satisfy the demand for Astrocaryum fiber but no active cultivation or management was observed. With

high extraction pressure building from commercial activities and life history traits that restrict a widespread dispersion and establishment, populations of this species seem to be under high pressure in Macedonia.

Passive cultivation of *Phytelephas* is ensuring availability of the resource in cultivation areas for domestic demand in both communities however we witnessed how the opportunity to commercialize thatch from *Phytelephas* in Macedonia led to massive extraction frenzies evidencing how immediate monetary returns seem to be more important than guaranteeing a longer term supply. We documented a similar case in San Martin for thatching units made of *Lepidocaryum tenue* (using *Socratea*).

A high domestic appreciation might stimulate people to passively cultivate species increasing their abundance as we observed with *Phytelephas* which was almost exclusively present in cultivated areas around San Martin. Passive cultivation in the case of *Astrocaryum* however is not enough to satisfy demand in Macedonia; extraction takes place at great distances from the settlement and raw material is often bought from other communities. Even under deficient market conditions like those of San Martin, extraction pressure is high. In spite of the high commercial appreciation few people reported actively cultivating *Astrocaryum* palms and no consideration seems to be given to the active cultivation of *Socratea*.

Our simple typology of active and passive cultivation and toleration allowed us to compare palm management in the two communities, further quantification of activities following this categorization could be a useful to track changes in settlements like these and thus assist in the monitoring of land use change.

The case of the three palm species here studied leads us to conclude that local appreciation is not enough to guarantee sustainable use of these species. Used species, whether commercially or domestically appreciated are under pressure in increasingly accessible settlements where cash economies over take subsistence livelihoods and where commercialization overrides local appreciation for a species. It becomes evident from these examples that local appreciation alone will not be enough to guarantee the development or continuance of sustainable practices as indigenous communities access the western world and that sustainable management won't be spontaneously promoted.

Response of these palm species to human activities regardless of whether they are market or subsistence oriented, strongly depends on species life history and stage of development. Near-generalist/specialist species like *Astrocaryum* and *Phytelephas* seem to be at a disadvantage. Resilient species like *Socratea* might have a temporary advantage however it might take populations long time to recover from the consequences of large uncontrolled extraction events.

Traditional practices in these communities will continue to transform as they integrate into a western setting. We don't believe these transformations necessarily imply degradation of natural resources since we did observe that management practices can keep up with local demand for domestic use. We observed how increase connectivity allows for diversified economic activities and at the same time sets off social transformations ei: traditions, knowledge, economic activities, etc. and that in this scenario the lure of economic incentives combined with weak or absent regulations can easily open the way for overexploitation of natural resources. Analyzing social and ecological change in an integrated way can allow a more effective design of conservation policies and strategies ei: considering implementation of different property rights regimes.

We observed how palm species are used and managed differently in agricultural and forested areas around indigenous settlements that develop different economic activities. Integration into cash economy brings commercialization opportunities that can override management regulations and stimulate an uncontrolled extraction placing palm populations in vulnerable situations. Although local appreciation can stimulate passive (and probably also active) cultivation practices that can ensure domestic demand, it cannot counteract uncontrolled extraction frenzies will most likely have negative effects on local populations. Commercialization pressure will probably override local, more sustainable practices which are unlikely to spontaneously arise from local appreciation. Species' safeguard in these settlements seems to depend solely on their life history traits, its resilience and ability to survive in moderate disturbed areas. Sustainable use will require new rules and regulation mechanisms, new ways of taking decisions and enforcing them, as they integrate into regional, national, international scenes.

Community of San Martin. Thatching units of *Lepidocaryum tenue* using *Socratea exorrhiza* by the Amacayacu River waiting to be sold.

4. The evolution of socio-ecological systems: Changing palm species management in the Colombian Amazon as an indicator of ecological and institutional change

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4.1. Introduction

The co-evolution of community governance and surrounding ecology is called social ecological change (cf Berkes 2009; Folke et al. 2005; Olsson, Folke, and Berkes 2004; Duit and Galaz 2008; Voß and Bornemann 2011). We believe social ecological change cannot be purely explained by the way communities integrate or resist integration into markets and therefore attempt to understand the way these changes take place through the way collective decisions (regarding natural resource use and management) are taken (Muro and Jeffrey 2008; Seabright 2010; Booher and Innes 2010).

Changing natural resource management is a response to changing markets and to changing technologies, but understanding the changing use of natural resources requires a broader understanding of social- ecological change (Berkes and Folke, 1998; Coomes, 1995; Folke, Colding, and Berkes, 2003; Folke, Pritchard, Berkes, Colding, and Svedin, 2007; Putsche, 2000; Vadez et al., 2004). As soon as there is some form of coordination of resource use, some form of rule- making and collective decision- making, we can speak of natural resource governance. Natural resource management therefore is always natural resource governance, since what is possible and desirable for one actor is shaped by the organisation of the community and where the community wants to go hinges on the resource use of individuals (Agrawal, Chhatre, and Hardin, 2008; Booher and Innes, 2010; Folke, Hahn, Olsson, and Norberg, 2005; Van Assche, Van Biesebroeck, and Holm, 2013; Voß and Bornemann, 2011). In a normative sense, working on management requires then working on governance, and in an analytic sense, grasping the relations between changes observed in resource use and in other areas of community activity requires a grasp of governance. It is in and through governance that communities try to respond to change in social- ecological systems, and it is in the same way that they cause change. It is in governance that markets are created: these do not exist in a vacuum, rather function on a

structure of political, legal and cultural institutions (Ostrom, 1999; Rerkasem, Yimyam, and Rerkasem, 2009; Sierra, Rodriguez, and Losos, 1999).

The often observed transition (normative and analytic) from natural resource management to natural resource governance fits seamlessly into a social- ecological change perspective. Building on institutional economics, social systems theory and also explicitly on a new perspective called evolutionary governance theory, in turn incorporating elements of the former, we intend to develop the social- ecological change perspective further. We will argue and demonstrate that social- ecological change theory can be fruitfully developed by a more detailed understanding of governance in its several dimensions. Understanding social- ecological change becomes then the understanding of different interrelated governance dimensions, each representing an aspect of internal organisation and at the same time an aspect of the relation between community and surrounding ecology (Van Assche, Beunen, and Duineveld, 2013; Van Assche, Van Biesebroeck, and Holm, 2013).

What are called 'natural resources' are elements of that physical and ecological environment highlighted in and by communities, attributed a value, supported by and restrained by an organizational and institutional structure. Therefore, we expect that a detailed analysis of changes in the use and management of a widely used natural resource can provide additional insights on natural resource governance while also bringing into focus the linkage between the governance system (social system) and the ecological system. When an element of the ecological system becomes a natural resource in a community, it offers a window on the functioning of that community, and on the way the community affects its natural environment (cf Ostrom 2005; Latour 2009).

Each social- ecological system has different entries to study its structure and evolution. We used palm species management in three Amazonian communities in Colombia as an appropriate entry for the area. For the Amazon region, palms (Arecaceae) provide an ideal window to study changes in governance because they have a long documented history of use and are used in a variety of ways throughout the area. Palm management reflects broader processes of socio- economic change (Balslev 2011) and can, for tropical areas, refine and further the analysis of rapid, hybrid and often messy governance evolution in communities entering the orbit of the western world. Palms play an important role in both the life of the people as well as in the ecology of the rainforest

(Coomes and Ban 2004; Paniagua-Zambrana et al. 2007; Salonen et al. 2012, Stevenson 2011, Link 2006). They have been used and managed by human societies in the Americas for many centuries (Morcote-Ríos and Bernal 2001; Bernal, Marmolejo, and Montes 2007) and close to 2000 different uses have been reported for this group (Sanchez 2005; Paniagua-Zambrana et al. 2007; Macía et al. 2011). Palm products become increasingly commercialized on local to international markets (Balslev 2011; Brokamp et al. 2011).

We studied the changing use of three palm species; *Astrocaryum chambira*, *Socratea exorrhiza* and *Phytelephas macrocarpa*, in two communities in the Colombian Amazon belonging to the Ticuna ethnic group, one more isolated than the other. As a third point of comparison we make reference to Ticuna practices still carried out in a cluster of more isolated settlements which we did not directly observe, but which we are able to sketch via interviews, reports and secondary literature. People from the more isolated settlement still have personal connections with the less accessible of our two main communities.

We thus analyse governance change in the Colombian Amazon by comparing three communities with different degrees of (physical) accessibility. We refine the comparison and link governance change to environmental change by studying palm management. We structure our study within the framework of social ecological systems and refine our analysis of social- ecological change by studying the evolution of governance systems. We present an expanded model of governance change that is more sensitive in non- western contexts and for socio-ecological co-evolution. It will be argued that the model of coupled governance dimensions presented can be further tested and developed, yet offers a promise for the analysis of social- ecological change in various parts of the world, albeit through a different choice of resource, and a cautious observation of possibly differing and differently coupled governance dimensions.

In the next section, we further introduce and develop the theoretical perspective on coupled governance dimensions and social- ecological change, after which we present more detail on the empirical case. Then, we analyse more in detail the linkages between social and ecological systems, and between governance dimensions, in the empirical case. Finally, we come back to the broader implications of the perspective presented, and the applicability in other contexts.

4.2. Theoretical framework

A series of frameworks aimed at studying human-nature interactions, like those of indigenous people in the Amazon, have emerged as scholars from different disciplines challenge ideas of ecosystem stability, command and control management approaches and try to understand both human and ecological dimensions as co-developing (F Berkes and Folke, 2002; Fikret Berkes and Folke, 1998; Holling, 2001; Elinor Ostrom and Nagendra, 2006; Walters and Holling, 1990). Resilience is probably one of the most influential concepts in the development of social ecological systems. It has its origins in the study of ecosystem dynamics and was originally defined to describe the possibility of a system to have different, numerous stages of equilibrium, where disturbance-if strong enough-could push the system from one state to another (Holling 1973; Levin et al. 2013). Resilient systems are therefore those that have the ability to maintain their function, structure and identity while undergoing change (Walker Holling Carpenter et al 2004).

When considering ecosystems as in continuous change, with various points of stability, conventional scientific approaches which try to minimize uncertainty and control change will not be enough for effective management. Natural resource management needs to constantly adapt to new conditions by integrating different types of information and coming up with alternatives and different management options; management needs to be adaptive (Walters and Holling, 1990). The main concepts behind adaptive management of ecological systems were further expanded to understand the social sources that shape and react to change. Folke, Hahn, Olsson, and Norberg, (2005) spoke of adaptative governance. Adaptive governance seeks for resilience in social- ecological systems, it aims at understanding the capacity of the social ecological system to reorganize itself after it has been disrupted or gone through a rapid change (Folke, Hahn, Olsson, and Norberg, 2005). In both adaptive governance and management knowledge and expertise play a crucial role in building resilience and enabling social ecological systems to overcome crisis.

In a comprehensive comparison between different frameworks used to study social and ecological interactions, Binder et al 2013 single out the Social Ecological System framework (Berkes and Folke 1998;Folke, Pritchard, Berkes, Colding, and Svedin, 2007; Elinor Ostrom, 2007) as being the only one among the 10 different frameworks analyzed that treats the social and ecological systems as equally important and at the same time

allows for analysis of different aspects of social- ecological systems, from different angles, at different levels of generality (Binder, Hinkel, Bots, and Pahl-Wostl, 2013). The social ecological system framework builds largely on the ideas of resilience and adaptive management (Fikret Berkes and Folke, 1998; Folke, 2006; Holling, 1973) as well as on the description of collective property rights arrangements (Elinor Ostrom and Nagendra, 2006; Poteete, Janssen, and Ostrom, 2009; Schlager and Ostrom, 1992).

Opening up the understanding of property rights, as bundles of use rights, restrictions and obligations, and pertaining not only to individuals but also to groups and communities, broadens the scope, again normatively and analytically, of natural resource management, and places it more firmly into the sphere of governance. Interactions (harvesting, networking, etc) and outcomes between users and natural resources take place within a particular governance system in which management actions (monitoring, sanctions, etc) have a direct influence on the resource system (ecosystem) (Folke, Colding, and Berkes, 2003; Folke et al., 2007; Elinor Ostrom, 2009). Although this framework already implies a strong interaction between social and ecological systems, in order to analyze and compare these interactions we believe we still need additional methods that can allow for a more detailed understanding of social systems, beyond property rights arrangements and environmental policy.

We use social ecological systems as our main working frame and dissect human-nature relationships through the comparison of governance systems. Governance here understood as taking collectively binding decisions in a network of governmental and non-governmental actors (Easterly 2006; Hillier 2002; Ostrom 2005). Institutions are the rules guiding and coordinating interaction, either written or unwritten. What is coordinated can be individuals or organizations.

Based on concepts stemming from biological theories of evolution, social systems theory, post-structuralism and institutional and development economics, Van Assche et al 2013 developed what they call evolutionary governance theory. This perspective explains how governance systems evolve; how they are formed as they build on previous institutions and knowledge and modify their forms of steering and participation. For natural resource governance, many others already observed that governance and its change entails several aspects (Brandon and Wells 1992; Blaikie et al. 1997; Brocklesby and Fisher 2003) and

governance change can be best understood when these aspects are seen as coupled (Berkes 2007; Berkes 2009; Duit and Galaz 2008).

One manner to analyse governance change is to distinguish between the so- called functional domains: law, economy, politics, religion, science as the most important ones. While this set of distinctions remains useful, we would like to complement it by another set of distinctions, between what we call governance dimensions. Governance we understand as the activity of the political domain, broadly understood, that is, without restricting it to paper rules, laws, and formal roles of politicians and administrators. Who becomes an 'actor' in a governance path, cannot be understood without reference to that path; the mafia can be a main actor in governance on an island and so can be the public transportation union in a rural area.

Governance affects the functioning of law, but law still has its internal logic which cannot simply be steered or predicted. Governance can affect the functioning of science, but the same is true for the autonomy of that functional domain. Governance itself, therefore, cannot be understood as either consisting of the other functional domains, or entirely organizing and steering them. For the analysis of aspects of governance itself, we believe it is helpful to distinguish choice dimensions, topics of collective choices that set a community on a path and give its governance system a unique character (North 2005; Duit and Galaz 2008).

We here adopt and modify the evolutionary governance model of Van Assche, Beunen, and Duineveld 2013 (Van Assche, Beunen, and Duineveld 2013; Van Assche, Van Biesebroeck, and Holm 2013) to describe, compare and analyse governance changes. In the analysis of the different dimensions of governance, they demonstrate that choices in one dimension affect positions on others (Thelen 1999; North 2005; Duit and Galaz 2008; Hahn et al. 2008). Four choice dimensions are proposed: knowledge (local vs scientific), steering (central vs network), democracy (participatory vs representative) and institutions (formal vs informal). If, e.g., formal institutions (such as laws) play a minor role in a society, then the development of representative democracy or capitalist market forms is very unlikely (Van Assche, Beunen, and Duineveld 2012), since capitalist markets and representative democracies support and suppose each other to a certain extent (Luhman 1995; Thelen 1999; Easterly 2006) (figure 4.1c). Identifying points of flexibility and inflexibility helps us

understand the system's capacity to respond or to adapt to change and thus provides us with a better idea of its resilience. The differentiation of governance into dimensions coupled to each other within governance systems offered us a straightforward framework to compare and analyse governance changes in social systems in which usually governance has often been studied-exhaustively-from one perspective at a time e.g.: traditional/ecological knowledge, indigenous legislation, etc.

Evolutionary governance theory theoretically leaves open the possibility of other choice dimensions to crystallise as relevant in a governance path. We test its analytic potential in a non- western context and remain open to both the possibility of non-applicability and of different dimension sets.

4.3. Materials and methods

The field study was conducted between the months of September 2011 and March 2012 in the southern part of the Colombian Amazon region, approximately 70 km from the department's capital of Leticia. We directly observed two indigenous communities within and around the area of Amacayacu National Park: San Martin (03°46'39,44"S; 70°18'13,10"W; pop. 505) and Macedonia (03°50'46,68"S; 70°13'18,88"W; pop. 730) (Figure 2.2). Macedonia is located on the Amazon River, well connected to Leticia, facilitating the existence of a marketplace. San Martin lies ca 5 km up the Amacayacu tributary, about 15 km from Macedonia. Public speed boats reach Macedonia three times a day while none travel to San Martin. This seemingly small difference in accessibility has major implications for their economy and governance.

The community of Buenos Aires is situated approximately 100 km north from San Martin and represents a more traditional Ticuna settlement. Buenos Aires can be reached on foot in four to six days from San Martin during drier periods of the year walking. According to anthropologist Jean- Pierre Goulard, Buenos Aires belongs to the Cotuhe river socio- cultural group. We used these accounts in addition to literature, official reports and interviews to reconstruct governance change and palm use in Buenos Aires.

We categorized land use units based on satellite image analysis of spectral responses of vegetation cover and soil humidity using Landsat image 63-15112009 as well as information provided by local people and on site verification. We assigned three land use

categories to the area around the settlements 1.) cultivation areas, 2.) moderate and 3.) low disturbed forest (Figure 2.1).

By means of household interviews and settlement visits, a complete census of each community was attempted and information on approximately 60% of the houses was collected (48 of 75 houses in San Martin and 80 of 130 houses in Macedonia). The houses not included in the census were either uninhabited not willing to participate at the time when the visits took place. Further information on Ticuna traditions was gathered from journal articles, official government reports, personal communications and field reports

Information was collected through semi-structured interviews and participant observation during weekly stays in each community and walks through cultivated areas, which took place throughout a period of five months. Data was collected based on three general topics: household attributes (ethnic background, household size and number of landholdings), agricultural attributes (average number of cultivation units, number of palm species grown) thirdly palm use, cultivation and extraction practices.

The three palm species studied are used in all three communities and were chosen from a list of commonly used palm species in the area. For understanding the management of palms, we focused on the care given to palm species in the cultivation areas but also considered extraction of palm materials beyond cultivation areas, farther away from the settlements. In addition to management and extraction we also looked at the commercialization and production of palm products.

Indigenous people do not actively cultivate palms as they do other crops like manioc, bananas or pineapple, rather they allow them to grow in cultivated areas and might occasionally do weeding around the smaller individuals or protect them from fire during the process of burning areas to prepare them for cultivation. In cultivated areas we distinguish between active cultivation and passive cultivation. The former is a version of the customary farming practice where the land is prepared for sowing seeds while in what we term passive cultivation crops are not actively sown but arrive to the field through natural dispersion or existing seed banks. We noted as well that some crops were tolerated, they were not actively sown or looked after but left standing at the margins of the field. All three require decisions and observation, differ from negligence, and can thus be called management.

Beyond cultivated areas (low and moderate disturbed forests) no care or special management practice is carried out. Extraction of palm material from forested areas (moderate and low disturbed) is difficult to trace and human activities were often difficult to discriminate from natural disturbances. In these places all palm species are potentially subject to extraction particularly in moderate disturbed areas which are closer to the human settlement.

We used descriptive statistical methods for comparing quantitative and qualitative information between communities. Statistical tests were done using IBM SPSS Statistics 20.

The fist selected species, *Socratea exorrhiza*, from now on referred to as *Socratea*, is a large tall to medium-stemmed palm (Balslev 2011). It can be found from Central America to Brazil from lowland to premontane rainforests (Henderson, Galeano, and Bernal 1997). Its hard outer stem is used not only as construction material but also to manufacture handicrafts.

The second species, *Astrocaryum chambira*, from now on *Astrocaryum*, is categorized as a large-tall stemmed palm wide spread in lowland non inundated forests of the Western Amazon (Henderson, Galeano, and Bernal 1997; Balslev 2011). Fibres from the youngest leaf of *Astrocaryum* are used by indigenous communities throughout the Amazon in the manufacture of ropes and threads to weave a wide assortment of handcrafts.

The third species, *Phytelephas macrocarpa*, from now on *Phytelephas*, is a large leaved short-stemmed diocious palm, from the western Amazon whose geographic distribution limits the study area. The leaves of this palm are used for thatching in this region.

4.4. An introduction to the communities: historical and comparative notes

In traditional Ticuna societies, clan interests dictated political and economical decisions, with clan hierarchies based on mythical heroes (Barry and Goulard 1998; Oyuela-Caycedo and Vieco Albarracin 1999). Traditional Ticuna settlements were centered around a large round house or maloca. Each maloca had a chief, member of the dominant clan who took all important political and spiritual decisions in an autocratic system of governance. Four or five roundhouses, usually a couple of days apart, delimited an economic, ritual and marital frontier (J.-P. Goulard and Barry 2012; Barry and Goulard 1998) (Figure 4.1a). The traditional

Ticuna form of politics, just as it was for many traditional indigenous groups throughout the Amazon, was in large part driven by spiritual practices in which places, animals, trees could be endowed with a spiritual significance (Gray 2003; Maria Clara Van der Hammen 1992) and had an influence on governance, on collective decision-making.

During the rubber boom in north west Amazonia (1912-1942), rubber barons (rich and politically influential owners of rubber plantations) split up Ticuna clusters of roundhouses taking away relevance from the actor of the "chief" and clan rules in the new context (Ullán de la Rosa 2000). The traditional rules of coordination, unwritten, yet respected and thus formal, first collapsed as a result of this social atomization and then where replaced by simplified and very local sets of ad hoc rules (a parallel linguistic simplification was observed by J. P. Goulard and Montes 2013). As the government entered the fray in the 1960's and early 70's new rules were written down, in the form of regulations, policies and plans. Following these developments one can thus present a general evolution from formal to informal to formal institutions, but now defined in the frame of the nation state. A democratic system of electing a community leader, local council, treasurer, etc. was established at the beginning of the 1970´s, following national government regulations (Van de Sandt 2003; Ullán de la Rosa 2004).

Many pre-settlement cultural features survive: oral history, language, clan marriages, etc. (Oyuela-Caycedo and ViecoAlbarracin 1999). The contact with western actors and institutions in this still fragmented social landscape (a legacy of the rubber barons intervention) in many cases brings doubt about the rules which apply in particular situations. Old rules and norms have been forgotten or lost and western regulations are unknown or misunderstood.

In San Martin, 95% of people still identified themselves as Ticuna, compared to 60% in Macedonia. Ticuna people are divided into patrilineal groups classified into two broad categories, earth and air, and these are divided in sub-categories or clans. Marriage rules dictate that marriage should take place between people belonging to different clans, e.g., "macaw" and "ant". Clan marriage rules preserve the clan structures and therefore the other rules associated with clan belonging. In Buenos Aires and San Martin, people are well aware of their clan belonging and in some cases clan rules play a role in local governance, eg. people from a certain clan tend to oppose decisions taken by a certain other clan (see

below). One of the clear differences that separate the more traditional communities of Buenos Aires and San Martin from Macedonia is the persistence of clan marriage traditions.

Non-Ticunas in Macedonia identified themselves as belonging to ethnic groups from Peru, coming from other communities or urban areas close-by or having a mixed ethnic background. Macedonia attracts immigrants because of its market place (people hoping to become an artisan) and because of its evangelical Christian community. Immigrants came from faraway places (up to 600 km) for this religious reason, and the evangelical hierarchy locally dominates politics. Another of the most obvious differences between this community and those of Buenos Aires and San Martin is the lower proportion of people dedicated exclusively to subsistence activities in the more accessible Macedonia (14% in Macedonia versus 22% in San Martin).

4.5. Communities in transformation

Macedonia, San Martin and Buenos Aires all changed. None of them purely conforms with the earliest images and descriptions of traditional Ticuna settlements and lifestyles. It is clear that the most accessible one, Macedonia, transformed most, but we do not point at physical access itself as the only driver. In this section, we look more closely at the differences between the communities, and in a next section interpret these differences and changes in terms of the governance model presented above, which can help us to grasp the entangling of several aspects of change. The changes listed below are twofold: as remembered by older members of the community, and as compared to the more traditional communities in the series studied (and as present in the literature on traditional Ticuna society).

a)

Traditional Tikuna Model			
Choice dimensions		**Positions**	
Institutions	formal	⟷	informal
Steering	central	⟷	network
Doctrine	spiritual	⟷	secular
Coercion	authoritarian	⟷	democratic

b)

Transitional Tikuna Model			
Choice dimensions		**Positions**	
Institutions	formal	⟷	informal
Steering	central	⟷	network
Doctrine	spiritual	⟷	secular
Coercion	authoritarian	⟷	democratic

c)

Western Model Reference			
Choice dimensions		**Positions**	
Institutions	formal	⟷	informal
Steering	central	⟷	network
Democracy	representative	⟷	participatory
Knowledge	scientific	⟷	local

Figure 4.1. Collective decision making considering different positions and choice dimensions based on Van Assche, Beunen, and Duineveld (2013) in what can be referred as a) traditional Ticuna governance model (1700's and earlier) and a b) transitional governance model (1800's to 1960's). c) The western governance model that serves as reference for these evolutions.

4.5.1. Occupation changes

In San Martin most households are essentially dependent on subsistence farming with handicraft production and other types of market economy taking a secondary role. Conversely, in Macedonia, greater physical accessibility drove immigration, market integration and specialization: we encountered full-time artisans, shop-keepers, teachers, tourist guides, specialized farming (mono- cultures). People rely and depend less on their gardens and can buy many food products in shops within the community while in San Martin there are no shops. Yet, also in Macedonia most of the people interviewed

recognized the importance of having land for cultivation and admitted it was foolish to rely completely on money for subsistence. In Macedonia changes in occupation and the tendency towards specialization and services does not reduce peoples appreciation for land. Landholdings are an appreciated asset in both communities although economic activities have changed. In Buenos Aires, a market economy seems virtually absent. Social and political life is influenced by institutions associated with clan belonging.

Artisans in Macedonia selling handcrafts at the main marketplace.

4.5.2. Land use changes

Based on satellite images and household counts, we estimate that households in San Martin (#49) have approximately 9.2 ha of land available for cultivation compared to 3.6 ha in Macedonia (#81). On average each household in San Martin has 12.3 ± 9 production units (adding together the reported number of gardens and fallows) compared to 2.4 ± 2 units per household in Macedonia . The decline in agricultural land is one of the most important changes we observed and can be partly explained by a shift from mostly agricultural activities towards more commercial market-oriented activities (compare Ellis 2000). This shift is also visible on satellite images, demonstrated by an increase in moderately disturbed

forest in the surrounding of the more accessible Macedonia in comparison to San Martin (Figure 2.1).

We see how land pressure is increasing in Macedonia, the more accessible community; larger population, less land units per household, etc. One elder inhabitant is starting to delineate private gardens in common use (moderate disturbed) forest further away from the settlement. Another man arrived several years ago from Peru with his wife. They had no family in the community, no access to land and thus had to ask the community leader for him to allocate them a space for cultivation. Since there are no rules to assign land to foreigners, the elected community leader has not yet been able to come up with a solution to this situation. In the meantime, the man and his wife live almost exclusively from handcraft commercialization. A woman, born in Macedonia, stopped working on her land for more than a year to dedicate her time exclusively to the production of *Astrocaryum* handcrafts. Now the business is less profitable (e.g., increasing competition) and she wishes to return to her gardens and fallows but finds people cultivating what used to be her land. She took a risk by leaping into purely market oriented activities which in addition to land-hungry new residents left her landless.

More frequent, comfortable and fast physical access to Macedonia, brings in new people, and alters the landscape of economic opportunity for current residents. It also causes conflicts over land tenure, which cannot be solved by existing institutions. Due to the increasing and varied contact with the outside world, the solution is sought in an increased integration into western-style institutional structures (Putsche 2000; Gray 1994; Freire 2007). Accessibility thus brings both opportunity and conflict, and the solution to the conflicts is sought in greater connectivity and integration. Previous undermining of Ticuna institutional structures (ei: atomization of settlements during the rubber boom) made it easier to move into a “western” direction. Concretely, this means that many of the affected people want the leader to formalise property rights.

4.5.3. Palm use changes

Gardens and fallows (cultivated areas) in San Martin are used for a variety of crops and have a heterogeneous composition, with monocultures seldom observed. This is in line with a community largely dependent on subsistence farming in a traditional way. Conversely,

monocultures of manioc and banana are common in Macedonia. This trend in agricultural homogenization is also reflected in palm cultivation: most of the households in San Martin reported growing four to six different species of palms and only 5% of the people reported not growing any type of palm in their cultivated area. Most of the people in Macedonia reported growing one to three different palm species and about 20% of them cultivated no palms at all. Ticuna households in both communities reported growing a larger number of palm species than non-Ticunas. In Macedonia cultivated areas are not only decreasing in size as mentioned in the previous section, but apparently also in crop diversity. Some anthropological studies of traditional Ticuna society as well as of more traditional and isolated indigenous communities also seem to indicate that several uses have already been lost in this area and therefore in all likelihood (given the wide variety of used species) some cultivated species (Salick, Cellinese, and Knapp 1997; Van der Hammen 1992).

In addition to differences in the perception of agricultural activities, we noted differences in the extraction of palm raw material between communities. In Macedonia palm material was not always extracted by the users themselves nor was it obtained exclusively from cultivated areas. Some users (17 of 72) reported either buying the raw material from other members of the community or receiving it from family members. In the case of *Astrocaryum*, fibers were often bought from people of other indigenous settlements in the region. In San Martin some people (11 of 42) also reported receiving palm raw material from family members, however, these were mostly elder women who had difficulties extracting the fibers, or young women who were learning how to weave *Astrocaryum* fibers. Only one of the palm users in this community reported buying *Astrocaryum* fibers (from a larger settlement in Peru). For Buenos Aires, we did not find narrative traces of commercialization.

In San Martin *Astrocaryum* users directly extract fibers. Most women knew how to process the leaves in order to produce fibers with which to weave hammocks, among other things. In Macedonia where processed fiber is often bought, many women admitted not knowing how to extract the fibers. Often, they also forgot traditional weaving techniques for traditional objects like hammocks, since tourists have no interest in these types of objects. Instead many women in this community had learned how to weave new objects like dream-catchers which seem to be more commercially appealing. Dream-catchers, typical for North

American tribes, were brought to the community by a US woman who taught several local women how to weave them. They became a popular handcraft in the local market places. Skills and knowledge are lost and others gained because economic incentives change and social structures fostering traditions are dissolved. In Buenos Aires, lacking tourism, a market place, and accessibility, our sources claim, as said, that palms, techniques and objects forgotten elsewhere still exist, as does the clan culture where they find a place.

We documented differences in the diversity of palm species cultivated and recognized by people as well as in extraction and processing techniques that can be directly connected to the constant commercialization of palm products in Macedonia. Although these differences might be perceived by some people in San Martin without hesitation most interviewed people in that community would like to have a steady source of income. Some are constantly looking for ways to establish a durable connection to regional or national markets. One family, for example, has established connections with an entrepreneur in the capital who periodically orders *Astrocaryum* handcrafts. When orders are too big they ask a group of women to help them with the production. Usually each of the women obtains her own fibres, but often they also have to buy raw material from a Peruvian community close by.

In both communities women complained that although they grow *Astrocaryum* in their gardens some unscrupulous people take the fibres without asking and although they have complained about the situation with the leader of the community they feel there is no strong authority to develop or enforce rules. We were told by elders that in previous times round house chiefs had the authority to punish people either physically or spiritually (through the use of magic). Nowadays leaders are different, they have not been instructed in traditional ways but rather in western classrooms. Because commercialization in San Martin is sporadic, these conflicts usually do not escalate; in Macedonia the situation is different. Accessibility changes the value of resources, leading to conflicts that cannot be resolved by traditional means and engenders a call for fuller integration in the western institutional structure.

4.6. Analysis of transformation: governance dimensions and their couplings

Increased physical accessibility is rightly often associated with unsustainable use, depletion of natural populations (Krebs 2001; Egler 2002; Hargrave and Kis-Katos 2011; Mon et al. 2012) and the transformation of subsistence-based to market-based communities (Etter et al. 2006; Suárez et al. 2009; Peres et al. 2010; Carvalho et al. 2001; Geist and Lambin 2002). As remote communities become physically more accessible, western models of governance become more influential. This is a step-wise process with examples documented throughout the Amazon (Perz et al. 2007; Perz et al. 2008; Peres et al. 2010; Rodrigues et al. 2009; Soares-Filho et al. 2006; Stoian 2005; Finer et al. 2008; Feeley and Rehm 2012; Davidson et al. 2012; Phillips et al. 2004; Almeyda Zambrano et al. 2010). As western governance dimensions we consider formal vs informal institutions, central vs network steering, local vs expert knowledge, participatory vs representative democracy. We look again at the community transformations studied through the lens of the governance dimensions and try to understand and illustrate their couplings.

In the studied communities, changing economic constraints and opportunities lead to political pressure to change political and legal institutions in a western direction. People want the leader to formalize property rights. This makes simultaneously the leader and property rights more important, the leader appointed according to western rules and property rights defined in the western nation state. A greater pressure for centralized steering is building, with more power delegated to government bureaucrats, extension workers and experts (national and international) (Easterly 2014). They will be called in to assess value, delineate plots, figure out which rules apply where, and determine appropriate or profitable land uses. Formalization of land property triggers formalization of other institutions, brings in courts for decisions on legality and police for enforcement of decisions. Economic activities can become more diversified at the community level and land use can become more flexible, i.e. less governed by traditional rules reproducing one possible pattern.

For individual persons and particular places, the move from traditional regulation to the connected set of western governance dimensions entails both flexibility and the possibility to specialize: people and land can shift more easily to new activities and uses, while they can also be focused more exclusively on one activity/ use. Market integration

allows for non- subsistence activities, for specialization of people and places, but requires a redefinition of rules and roles in a community, with property right of land serving as the basis and battleground triggering further reforms in the direction of western institutional configurations. In the specific context of the Colombian Amazon, this means that some people will specialize and use land only as back-up, while some others specialize and introduce monocultures of cash crops in a manner and in places that defy traditional regulations.

We observed how in Macedonia several cultivated species, including palms are starting to be viewed as commodities, and gardens as production spaces for those, while in San Martin and Buenos Aires gardens are still perceived as a pantry, which provides a range of different products to use by the household, similar to the view of their ancestors and more isolated indigenous communities in the Amazon (Persoon et al. 2004; Sanchez 2005). Forests around San Martin hold palm species that are better for thatching than *Phytelephas* (eg: Lepidocaryum tenue and Attalea cf phalerata) however many people passively cultivate it or favour its growth in their gardens because they believe it might be useful in the future (and they accept that it might never be used). While in San Martin people had different management options (active/passive cultivation and tolerance) in Macedonia there seems to be little space for tolerance, often also passive cultivation and there is a strong tendency to mono cultures (one type of active cultivation).

The diversity of management options can be seen as an adaptation mechanism typical of traditional institutional arrangements. It presents people with the opportunity to decide to easily adapt to socio-economic and ecological circumstances. It can also provide the ecological system with more opportunities to interact with the social system and adapt to it. In the case of Macedonia , reduced management options could be reducing peoples capacity to adapt to sudden changes or shocks like pest attacks or reduction of handcraft demand (e.g.: closure of airport or transportation companies). No new adaptive mechanism seems to be coming in or present yet, in other words the new western institutional arrangement with its own adaptation mechanisms is not fully in place.

We are able to see that there are differences in the way palm products are commercialised and the way the market is being incorporated in these communities. The use of palms is transformed as their value is redefined in new economies (Coomes 1995;

Latour 2009; Ostrom 2005), while the desirable transformation according to market perspective also triggers a series of other changes, hauling in a western governance configuration (Kramer, Urquhart, and Schmitt 2009; Luhmann 1995; Easterly 2006). In our model, this is the case because dimensions of governance are coupled (Van Assche, Beunen, and Duineveld 2013). By becoming commercial products hammocks became handcrafts and thatching tiles are now sold as construction material. A palm species becoming a commodity crop attracts more value, more expertise, more regulation and more conflict, calls for centralization and enforcement, and pushes westernization more rapidly (Seabright 2010). Loss of old land management rules and traditions reduces the variety of crops and palms in the gardens and promotes reliance though the adoption of western institutions and eventually the formalization of property rights (Scott 1998; de Soto 2000). In an attempt to solve conflicts over land, its use tends to be simplified and palm diversity reduced. Old knowledge is lost (J. P. Goulard and Montes 2013) in the new selectivity imposed by the new economic, legal and political rules, while new knowledge is attracted (Latour 2009).

The changes brought by commodification thus go beyond the pressure to cultivate a few profitable palm species for the marketplace in the traditional garden plots: the simplification of socio-ecological space brought about spans other places and species, and potentially affects all people in a community. Places tend to become more 'rationalized', i.e., optimized according to a new rationality (Freire 2007), and this means in our communities the continuous and efficient use of space, of any space, for useful things and the continuous questioning of things (e.g. palm species) for usefulness (Gunder and Hillier 2009; Hillier 2002). People tend to become more specialized in parallel: their roles simplify and their land use can be less diverse (Luhmann 1995; Weber 1905; Van Assche, Beunen, and Duineveld 2013). The simplified role can however only be sustainable if it is also optimized for a narrow goal and this is only possible when others are becoming specialized too, in a new interdependence that is supported by a new network of rules and roles (Greif 2006).

As said, in these Amazonian communities, the transformational pressures came with increased accessibility and became first and foremost visible in land conflicts. Changes in palm management sometimes derived from these land conflicts (e.g. uncertainty over property rights, conflicts with neighbours), while in other cases the market integration

directly affected palm management (e.g. forgetting palm uses or palms replaced by easily available market products).

4.7. Discussion and conclusion

By observing and analysing governance systems in the three Amazonian communities we can distinguish four main periods in governance evolution tending towards the integration into western society in this particular region. We begin with the more traditional Ticuna societies that lived in communal roundhouses, with an autocratic government headed by a male member of the dominant clan who took political decisions based on an extensive accumulation of knowledge of the forest and spiritual beliefs. Clan belonging used to guide the coordination of many decisions including land use, relocation of the round houses, trade, marriage alliances, etc (pushing evolution further) (Figure 4.2 and 4.3).

The traditional governance system encountered its first major disruption at the time of the rubber boom, at the beginning of the 1900´s. This system was kept in place for decades dismantling Ticuna traditions in an extended period of informality that ended in most places in the 1960´s and 70´s with government land policies catalysing new village formation (Ullán de la Rosa 2004) (Figure 4.2).

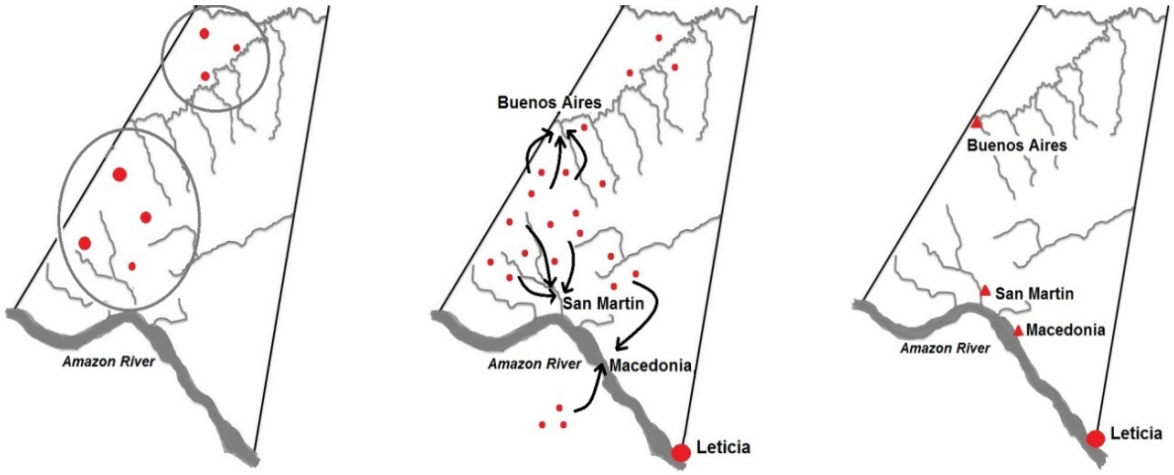

Figure 4.2. Sketch representing the evolution of Ticuna settlements through history in the study area. a) Represents the associations of round houses which during b) the 1800's and early 1900's were split into family units. These scattered families where regrouped in c) the 1960's and early 1970's into the settlements that exist today.

Buenos Aires and San Martin are in a third and Macedonia in a fourth stage of change. We can say that each community represents a different combination of positions on the

governance dimensions presented in the Van Assche, Beunen, and Duineveld (2013) model and that these dimensions themselves changed. After initial atomization, scattered families were persuaded to organize themselves in communities consisting of single family homes following a western type of arrangement. Ticuna communities like San Martin adapted their traditional clan marriage system under this new setup, however in multiethnic communities like Macedonia this system lost significance (Oyuela-Caycedo and ViecoAlbarracin 1999). Democratic systems of organization were set in place in all communities around 45 years ago (Figure 4.3).

Accessibility creates the perception of new value in the old environment, and this value is in our communities associated with new uses of the land. With the lack of traditional systems set in place for the distribution and use of land, a growing number of land use and tenure conflicts remain unsolved in Macedonia, placing pressure on community authorities who now feel they have to look for the formalization of land tenure following a western system of private property as a solution. This in turn is creating the need for specialized or scientific forms of knowledge, legal norms, law enforcement, political representation, creating a series of positive feedback loops in which western governance systems are reinforced. By using an evolutionary governance model we were able to compare the governance systems of communities with different degrees of physical accessibility and evidence how the adoption of one type of western governance arrangement tows-in other types of western institutions demonstrating the interdependence between the different dimensions and the large number of possibilities in governance configurations that can emerge as indigenous communities become more accessible.

We observed how increased physical accessibility allowed the establishment and persistence of markets and how this in turn has contributed in changing income structure/occupation, land and palm use and management. The establishment of a market for handcrafts has pushed aside more traditional institutions and forms of knowledge causing conflicts that require a governance system to be in place and functional. This means a governance system that relies on steering, participation (democracy), knowledge and other types of institutions and that brings in its own adaptive capacities. We observed how older more traditional governance dimensions are weak and often incompatible with the

incoming western dimensions and how at the same time they are begging to be replaced by them.

We summarize the governance evolutions of these communities in a series of diagrams which illustrate the evolutions just described (Figure 4.3).

The study of palms helped us to see the fine-grained detail of the linkages between the different governance dimensions. The palm species we focused on each had their own use and management in traditional economies. Once these societies began to adopt western systems of organization and governance, use of these species was redefined to fit in modern economies and legal- political regimes.

Cultivated plot mostly with banana crops in Macedonia

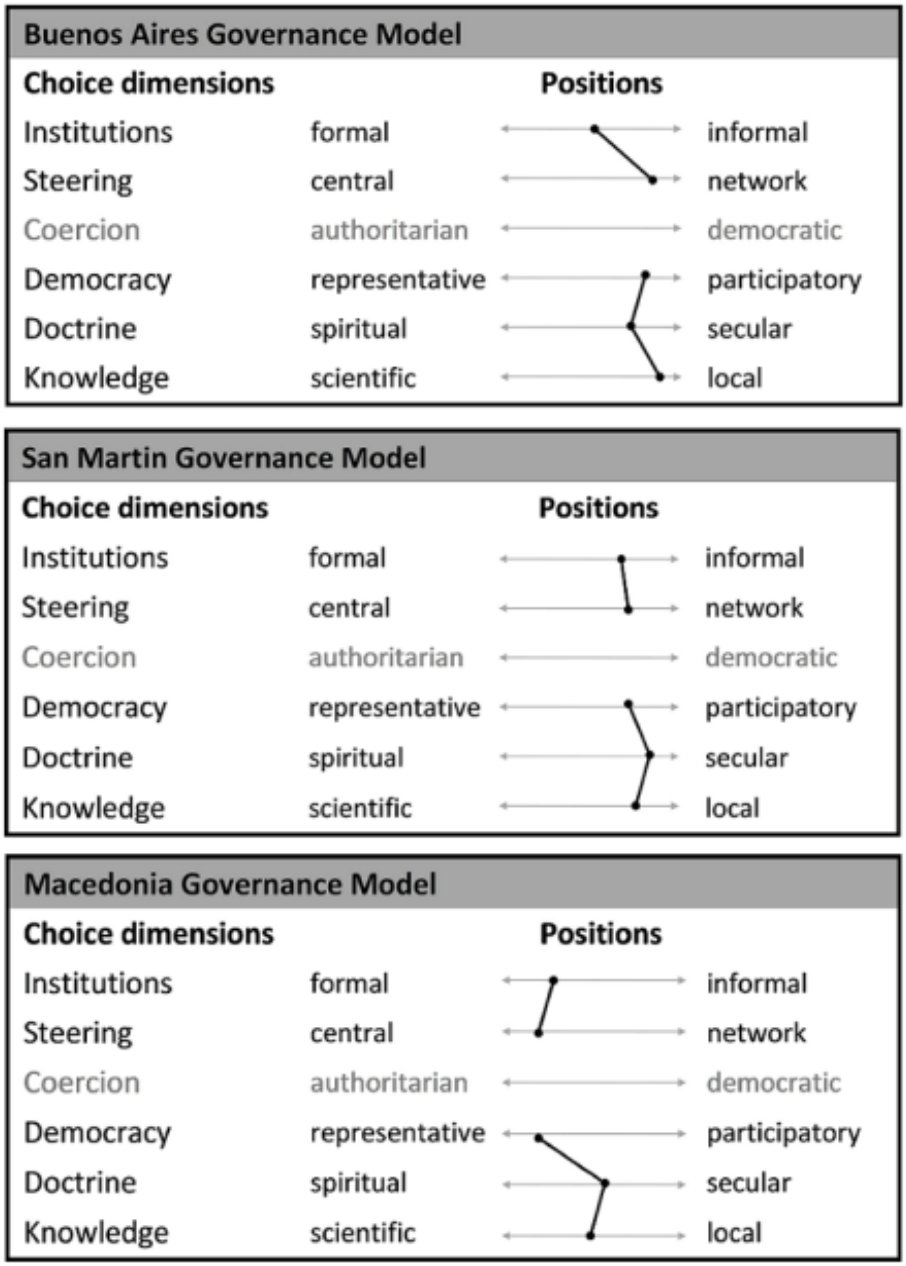

Figure 4.3. Representation of governance models for three indigenous communities with different degrees of physical accessibility in order from least to most accessible: Buenos Aires, San Martin and Macedonia. Secondary information (Buenos Aires) and direct observations (San Martin and Macedonia) enabled the comparison of the positions in the different choice dimensions that play a role in their governance models. Traditional indigenous moved between authoritarian and democratic forms of coercion but in today´s communities democratic forms of government are in place. Dimensions in gray have disappeared.

An increase in physical accessibility accelerated the process by enabling a constant connection to the western world allowing the permanent survival of institutions, actors and associated knowledge. Increased access in the case of Macedonia has facilitated the establishment and persistence of marketplaces and a continuous immigration which has

contributed to the displacement of traditional institutions (eg: clan marriages, clans structures and associated rules) and knowledge (eg: agricultural practices as garden pantries become commodified). As a result conflicts over land tenure have arisen which require solutions from new types of governance arrangements, new forms of steering and new types of institutions. The establishment of markets has triggered changes in a hybrid governance system exposing its weaknesses, in this case the lack of property rights regulations, and eventually pulling-in other western institutions and ways of organization.

The community comparison, deepened by the palm analysis, shows unambiguously that the four governance dimensions identified by Van Assche, Beunen, and Duineveld (2013) are not a timeless structure against which to assess specific situations; just as the positions on the dimensions, they are a product of time and place. In our communities, democracy (participation vs representation) arrived later in history, while doctrine (spiritual vs secular) disappeared for a long time, to reappear in the particular case of Macedonia as a semi- theocratic evangelical regime.

The palm analysis does not allow us to say that local or traditional knowledge in governance would bring a necessarily healthier socio- ecological system, but one can say that it illustrated how the coupling between social and ecological system was weakened by its gradual inclusion in modern institutional arrangements. At the same time rules and regulations which in western societies serve to manage undesirable outcomes are still not in place. This means that during transition from traditional to western systems these societies are left in a void where earlier governance mechanisms lose their functions. As local knowledge is lost the perception of the impact of governance on the environment becomes blurry, incentives for sustainability are undermined and conflict resolution strategies and strategies to envision a common good are not in place. An evolutionary governance perspective allows us to see options and restrictions for adaptive governance and by enabling us to distinguish governance paths this perspective also allows us to see different forms of resilience.

Easterly (2006), Freire (2007) and Kramer, Urquhart and Schmitt (2009) demonstrate that increased access and integration do not necessarily produce the same outcome everywhere. Our expanded governance model leaves space for this kind of variation (configurations of positions) while revealing structural couplings (i.e. coupled governance

dimensions) reducing variation in a globalized world. Considering the varied paths of governance evolution of local communities could render development policies (social, environmental, economic) for the region more effective and less risky for the socio-ecological system.

We acknowledge that the dimension model of governance evolution requires further testing and development in other contexts. We believe it also deserves this. The model is embedded in various stream of literature, establishes new connections between those streams, and adds new insights, in a transparent conceptual architecture which makes comparison of governance paths easier, can guide the interpretation and structuring of very diverse data, and allows for further development, without toppling the construction. The perspective is flexible in two ways: it envisions different sets of positions on the four western dimensions and it allows for new dimensions of choice to emerge while offering an explanation for these forms of flexibility and change.

In contexts where rapid evolution of communities and their governance dimensions is not so easily observable, as in many western polities, one can expect that different dimension sets are most visible in long-range historical studies (as e.g. attested in the tradition of the French annales school, and by historical geographers and sociologists). Also in more stable institutional configurations, however, the positions on these dimensions will change over time, and in multi- level governance, especially with a degree of local autonomy, niches will be carved out where different governance paths remain possible, marked by different positions on the more common dimensions.

5. General Conclusions

We believe that changes in the use and management of palms are able to indicate changes in both the human and natural systems they are a part of. One important social transformation taking place in human settlements in the Amazon is the transition from subsistence to market-oriented lifestyles. As indigenous people adapt to western lifestyles, the relationship with their surrounding resources change. Palm use and management change and, as we expected, natural populations also change. We were able to point out some of these socio-ecological changes by combining observations on both management practices and the condition of palm populations. The large amount of information on palm ecology that already exists allowed us to understand life history traits, dispersion mechanisms, germination success, etc., for each species. A growing number of studies on palm management and use enriched the analysis and helped us to confirm the dependence of Amazonian inhabitants on palm species.

From the three palm species studied, *Astrocaryum* seems to be the species demanding the most urgent conservation action. Pressure to commercialize *Astrocaryum* products is high even under unfavorable market conditions. In places with favorable market conditions, individuals are subject to detrimental harvesting practices, and local appreciation has not motivated active management practices. In addition, the species' strong dependence on rodent dispersal and its near-generalist characteristics, probably also its light requirements at early life stages, make it difficult for the species to establish in moderately disturbed areas like the ones surrounding the settlements in the Amazon.

For a species like *Phytelephas*, also with a strong dependence on rodents for dispersal and nutrient-rich soil, sustainable harvesting is also a challenge. Nonetheless, passive cultivation practices in both communities seem to have ensured domestic demand and might be favoring dispersion into moderately disturbed areas. Unlike *Astrocaryum*, this species does not suffer from a constant commercial pressure and might have a temporary safeguard against over-exploitation. The massive extraction that took place in order to satisfy the demand for a tourist shelter near Macedonia, however, are cause for concern.

A similar extraction crusade took place in San Martin for carana thatch for which *Socratea* stem-splits are required. Massive extraction occurred disregarding local extraction practices. This well-known generalist is dispersed by several animal species, has an effective germination rate and fast growth, and moderate levels of human intervention do not seem to be a major challenge for its establishment. Although it is appreciated for both domestic and commercial purposes, extraction pressure does not seem to be as high as for *Astrocaryum*. Although its distribution in moderately disturbed forest is uneven, populations of this species seem to be able to persist around human settlements. Of the three species studied, it is probably the one with the least conservation concern. However, we observed rapid changes in management decisions that could pose difficulties for sustainable practices in the future.

We observed that indigenous communities are eager to take part in regional and national economic activities, and integrate into a more western lifestyle. This leads to changes to their communities and to the way they are using the land and resources around them. Through satellite images, we were able to discriminate three broad land-use types, i.e., cultivation areas or agricultural land, forest with moderate levels of intervention, and forests with low levels of intervention. The information we gathered enabled us to confirm differences in the activities developed in these areas as well as differences in palm populations. Little disturbed forests further away from the main settlement are areas where few people venture, and intervention is limited by walking distance while moderately disturbed areas are more frequently used; however, intervention is more frequent in the more easily accessible, market-oriented community. In the less accessible subsistence-oriented community, cultivation areas appear to be of greater importance judging from the overall size and also from the amount of land holdings each household in the community owns.

Cultivation areas are the main source of food of most of the population, and also provide a variety of materials for domestic use in which palms play a fundamental role. It is in these areas where actual management takes place, since forested areas (both moderately and less disturbed) are of common use, and monitoring activities there are difficult. We observed only extractive activities in forested areas. Although simple, our management typology enabled us to distinguish between the different decisions made in areas of

intensive use; people actively cultivate staple crops, they support the growth of selected species by weeding and protecting them from pests (passive cultivation), and they tolerate other species by simply letting them grow in the margins of the cultivation plot or fallow. Distinguishing between these types of decisions enabled us to compare palm management practices and helped us understand how transformations are taking place in these communities.

We observed how pressure for land increases in the more easily accessible community, and how people tend to focus on active cultivation and exclude passively cultivated and tolerated species from their gardens or cultivation plots. Passive cultivation and tolerance are associated with a "garden as pantry" view of cultivation as opposed to a more simplistic and commodified perception of cultivated areas. The commodified garden is one of the outcomes of integrating into a more western lifestyle; it allows people to become part of a market economy on a larger scale from which they can access goods and services to improve their quality of life. The risk we highlight in this transition consists of changing the way a species is being used, e.g., from domestic to commercial use, but not its management, e.g., from passive to active.

As communities adapt to western traditions and to western organization systems, management of natural resources transforms and new problems and conflicts arise. We noticed how traditional systems for the distribution and use of the land are disappearing and that the number of land-use and tenure conflicts are increasing. Local authorities are being pressured to find ways of formalizing land tenure within a western system of private property to avoid such conflicts. This requires specialized forms of knowledge, legal norms, law enforcement, political representation, etc., that favor western (over traditional) governance; a positive feedback loop through which these communities are gradually being integrated into modern institutional arrangements. As communities transit from traditional to western governance systems, we observed how traditional couplings between the social and ecological systems weakened, and without western rules and regulations to manage undesirable outcomes yet in place, these societies are left in a governance void and the social ecological system in a vulnerable position.

The use of an evolutionary governance model based on different governance dimensions helped us to compare older and more traditional governance dimensions with

the incoming western dimensions, thus making incompatibilities evident. With this model, we were able to explain how older governance systems are often weak and therefore being replaced by the incoming western way of organization. We recognize that the dimension model of governance evolution requires further testing and development in other contexts, but it allowed us to make comparisons between governance paths easier. We were also able to describe new governance dimensions relevant for the social ecological system we studied, and believe this kind of analysis enriches our understanding of the functioning of social ecological systems.

We used the social ecological systems framework to help us understand how human nature interactions in the context of indigenous communities in the Amazon are being transformed as they integrate into a western context. Approaching social change from a governance perspective allowed us to identify important aspects of collective decision making as well as the different couplings between them. We observed how increased interaction with western governance systems brought changes to a particular aspect of local governance, and this in turn led to changes in other aspects. By analyzing palm use and management in these communities, we were able to fill in details of this transformation process and confirmed the importance of this group in the lives of the indigenous Amazon societies of today. Because the utilized palms species are tightly interwoven with indigenous societies in the Amazon, their use and in turn their natural populations change as social transformation takes place making them important indicators of social-ecological change. We believe that being able to analyze change with such an integrated perspective can help in understanding the implications of conservation strategies as well as public policies and development plans in the region.

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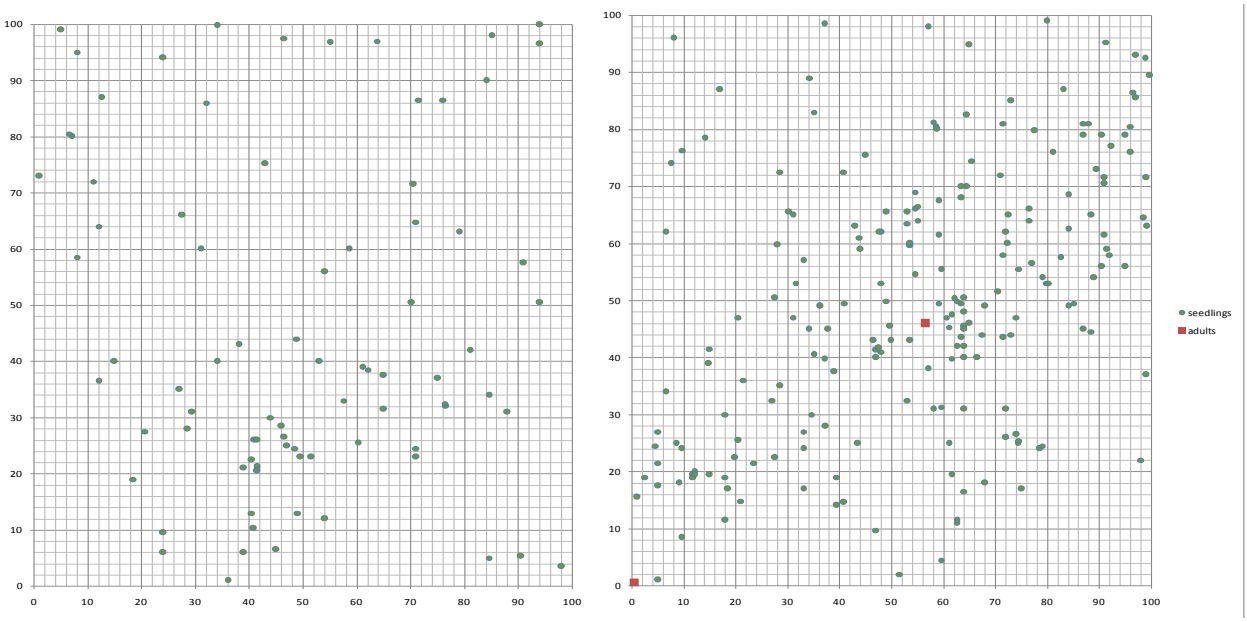
Appendices

1. Parameters used for the definition of size class categories based on field data and literature review.

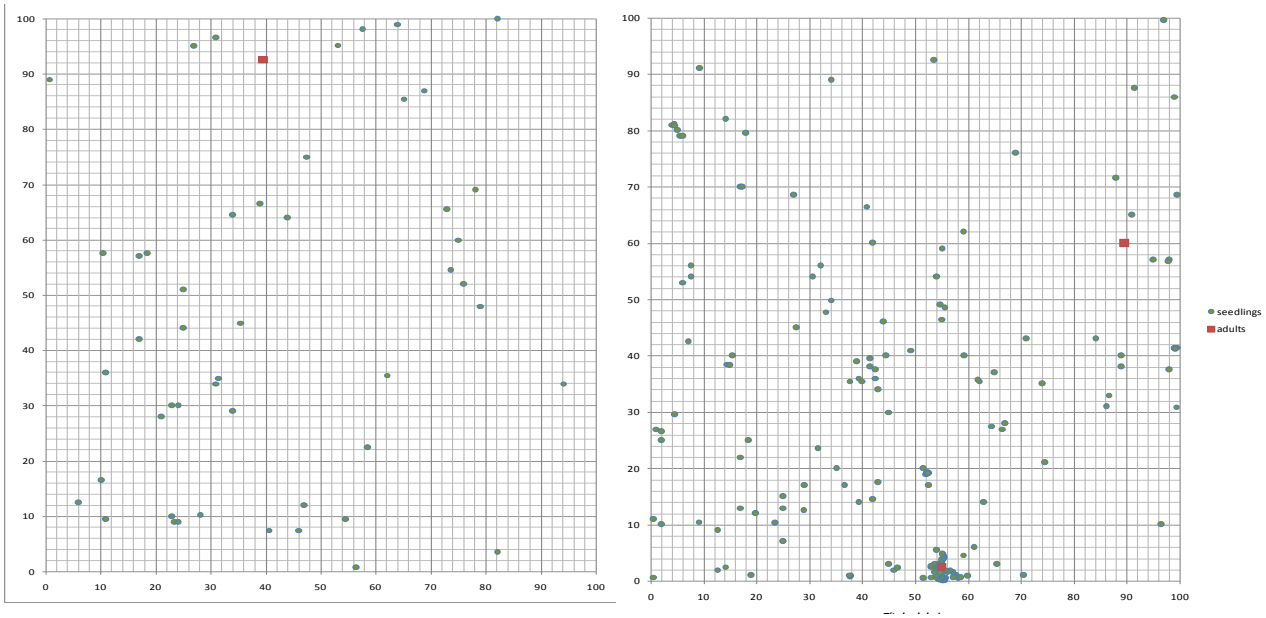
Species	Size class	Min stem height (cm)	Max stem height (cm)	Min leaf no.	Max leaf no.	Min leaf length (cm)	Max leaf length (cm)
Socratea exorrhiza	seedling	0	45	0	21	0.3	221
	sapling	10	114	2	6	8	250
	young adult	67	650	2	9	90	370
	adult	500	3500	4	12	200	600
Astrocaryum chambira	seedling	0	0	1	8	3	150
	sapling	0	96	2	9	155	1100
	young adult	143	450	7	14	500	1100
	adult	1500	2700	8	16	500	900
Phytelephas macrocarpa	seedling	0	0	2	5	49	240
	young adult	0	60	6	10	104	500
	adult	0	76	11	19	300	`

2. Distribution of adult and seedling individuals in low disturbed forests plots (100m x 100m) of Macedonia

Astrocaryum chambira

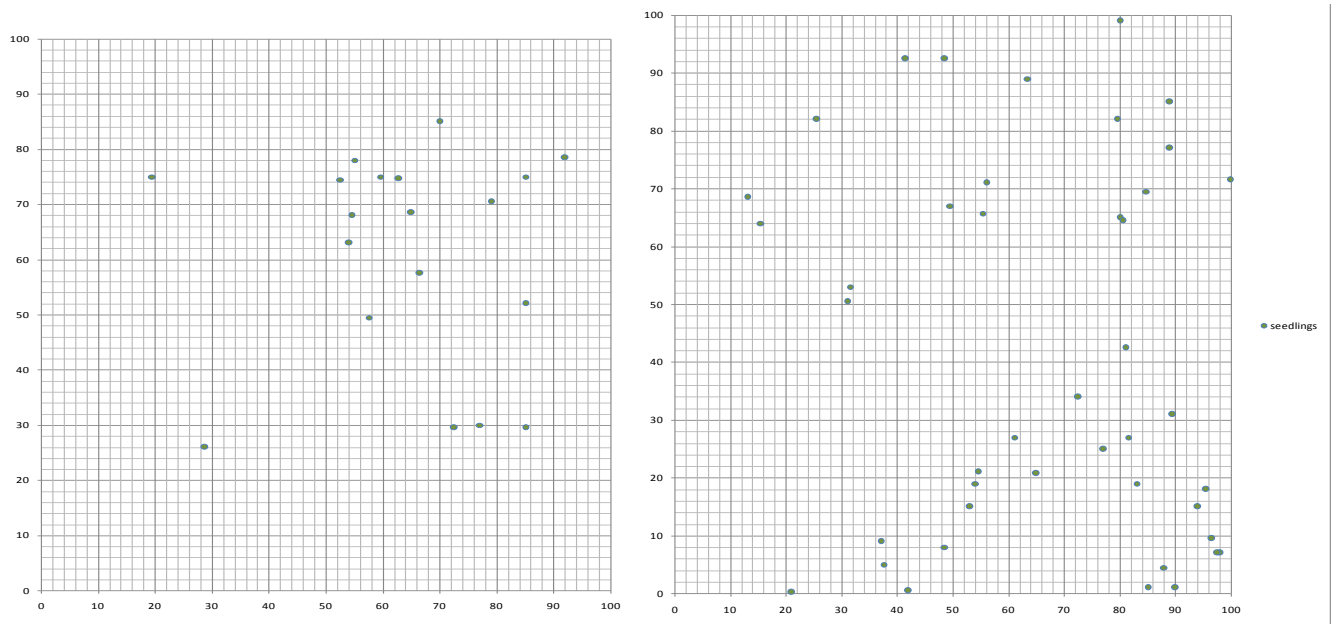


Socratea exorrhiza



3. Distribution of adult and seedling individuals in moderate disturbed forests plots (100m x 100m) of Macedonia

Astrocaryum chambira



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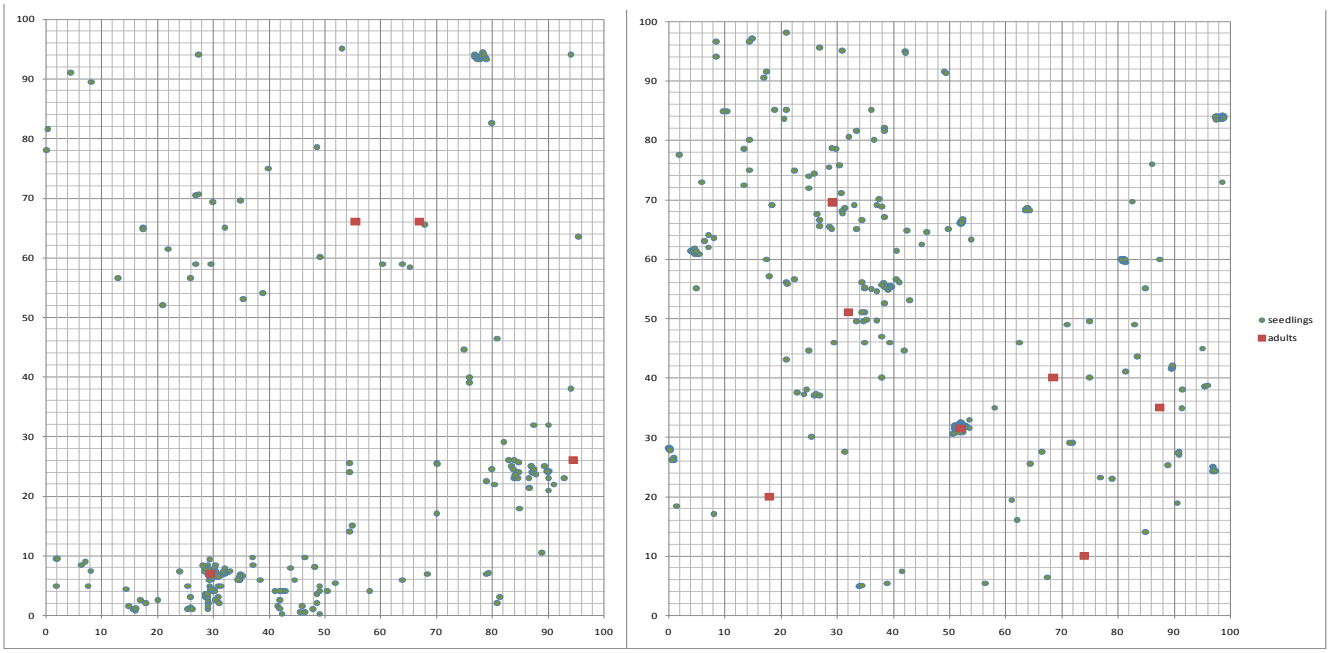
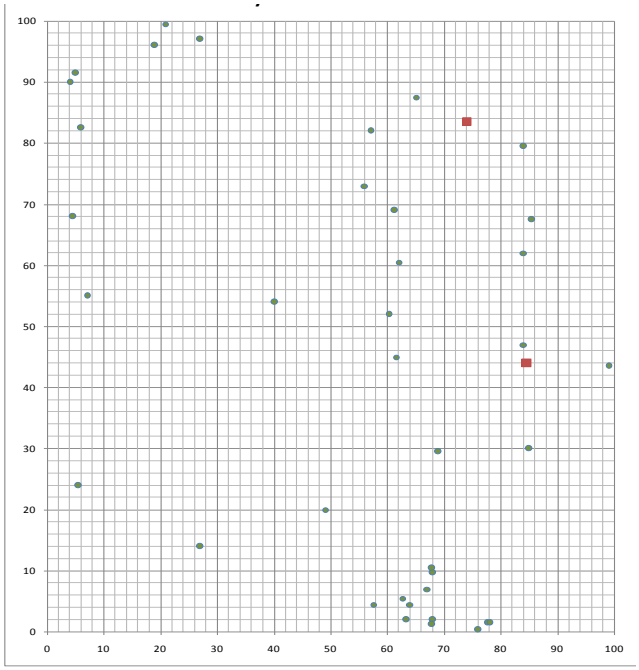
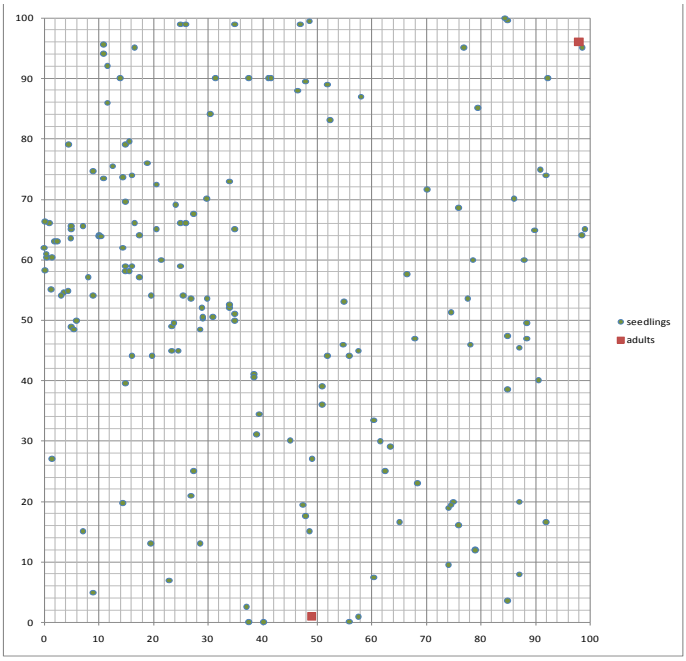


4. Distribution of adult and seedling individuals in low disturbed forests plots (100m x 100m) of San Martin

Astrocaryum chambira





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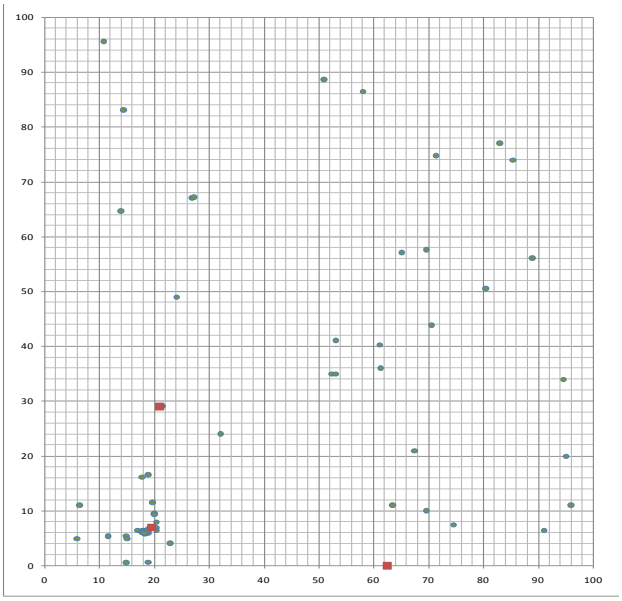
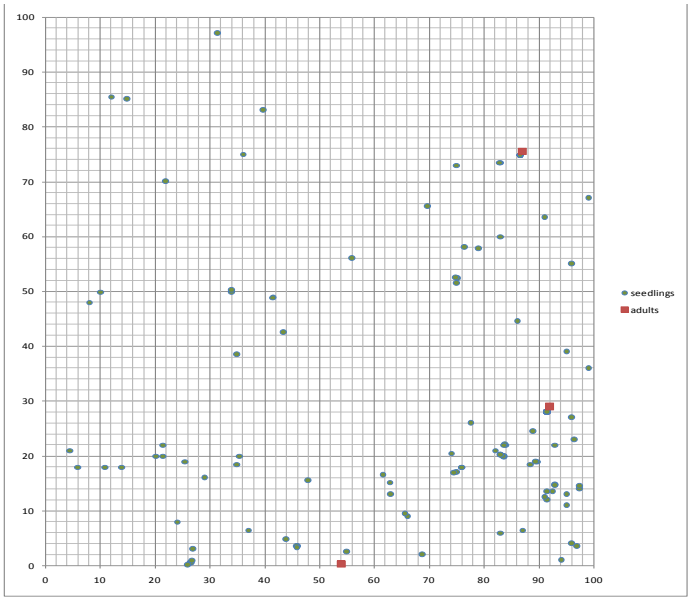
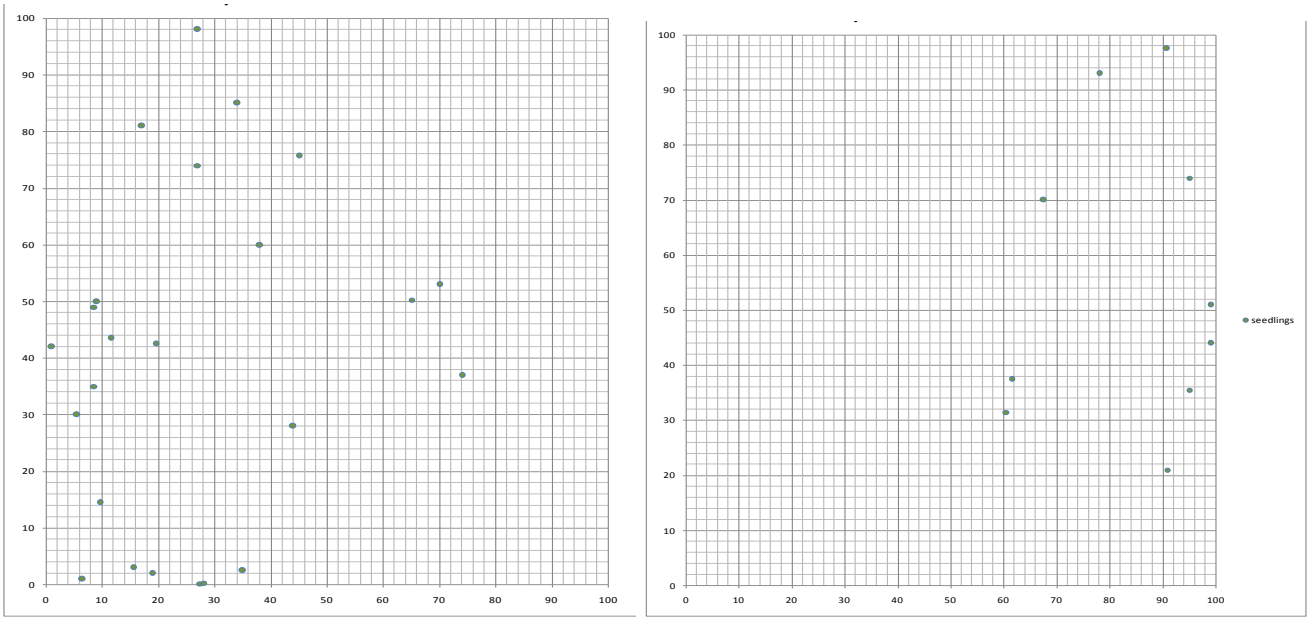


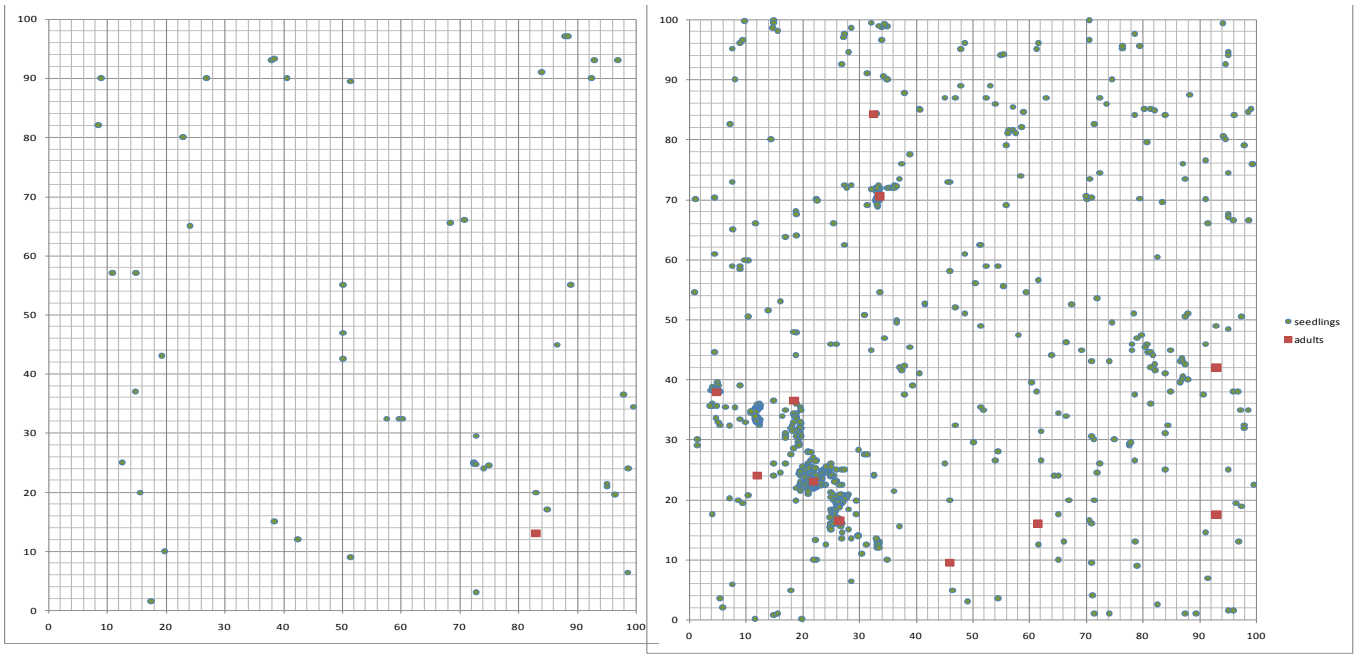


5. Distribution of adult and seedling individuals in moderate disturbed forests plots (100m x 100m) of San Martin

Astrocaryum chambira



Socratea exorrhiza



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