THE POTENTIAL OF FOREST MANAGEMENT BY SMALLHOLDERS IN THE AMAZON

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I dedicate this thesis to my wife Natalia
and my children Amelia y Juan Pablo.
You are my inspiration and happiness

Dedico esta tesis a mi esposa Natalia
y a mis hijos Amelia y Juan Pablo.
Ustedes son mi inspiración y felicidad

Statement of originality

I hereby declare that this thesis has never been submitted to another examination commission in Germany or in another country for a degree in the same or similar form. This thesis contains no material previously published or written by another person except where due acknowledgement is made in the proper manner.

Marco Robles Morillo

Freiburg, 13th November 2017

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Abstract

Smallholders in the Amazon are one of the most important actor groups for achieving long-term maintenance of the remaining forests. They manage vast areas of forestlands based on customary rights, and possess significant local knowledge about their resources. Smallholders have been exploited and marginalized throughout centuries within paternalistic societies ruled by economic and political elites. More recently, in response to pressure from emerging societal movements, many national governments, supported by the international community, have recognized the rights and roles of smallholders living in rural, often still forested landscapes.

During the 1990s, Sustainable Forest Management (SFM) proliferated throughout the Amazon region as a promising approach to halter deforestation and biodiversity loss, as well as to mitigate climate change. While SFM initially focused on the capacities of professionally working timber companies managing public forests in concessions, soon the need became obvious to consider the smallholders living in and from these forests. This gave rise to the concept of community-based forest management that primarily relates to the management of timber by small local forest owners based on legally authorized management plans grounded in the principles of Reduced Impact Logging (RIL). Accordingly, many different governmental and non-governmental organizations, supported by the international donor community, started initiatives to support this new approach.

However, after many years of promotion of community-based forest management, experiences have been rather ambivalent. Despite some impressive success stories of some forest development projects, only very few smallholders adopted the proposed management schemes. This lack of broader success indicated a lack of compatibility between the regulatory and market frameworks for community-based forest management and the capacities and interests of smallholders. This raised the more general question if and to what degree the management of forests for timber under the specific conditions of the Amazon region is a feasible option for smallholders to generate the urgently required income in a sustainable way.

Against this backdrop, this study aimed at analysing the effective potential of timber management for smallholders in the Amazon to provide orientation for the formulation of policies to promote community-based forest management for the benefits of smallholders. The study considered two critical impediments to community-based forest management: the locally absent technical skills and financial means needed to act successfully in timber markets; and a low abundance, unsatisfactory regeneration and productivity of marketable species in natural forests. Related to this, it is often argued that smallholders tend to seriously overexploit and damage their forests if not controlled. Accordingly, the study followed four research questions: i) What possibilities do smallholders have to engage in timber markets?; ii) What is the commercial potential of their primary and secondary forest areas?; iii) What are the effects of smallholders' timber logging on forests?; and, iv) What are the possibilities for long-term management of timber resources?.

As part of the EU-financed international research project "Forest management by small farmers in the Amazon - An opportunity to enhance forest ecosystem stability and rural livelihood", this study addresses these three questions by empirically analysing 21 communities in four forest regions in Bolivia (Riberalta), Ecuador (Macas) and Peru (Pucallpa and Puerto Maldonado)

selected for their relevance and representativeness regarding regional contexts in terms of markets characteristics, smallholder's management strategies, and forest characteristics. The analysis included three studies:

i) A market and value-chain analysis to understand the role of smallholders in contemporary timber markets and to identify the barriers and potentials to make forest management an attractive source of income.
ii) An analysis of the monetary value of timber in smallholders' primary and logged areas.
iii) An assessment of the effects of smallholder's logging activities in primary and secondary forests on forest structure and composition through comparisons between primary and logged farm forests.

In these studies, farm inventories were carried out in primary, secondary, and logged forests. Semi-structured interviews were conducted with smallholders about timber management practices, generated incomes, production costs, and timber marketing. Secondary information and expert interviews complemented information particularly related to the scientific names and ecological characteristics of the inventoried trees, production chains, and relevant legal aspects. Multivariate and univariate approaches were used to analyse farm forests, and to classify smallholders according to their forest management strategies. In a final step, the findings were used to calculate the financial and ecological potential of community-based timber management under consideration of different area size, logging intensity, and productivity scenarios.

The market analysis revealed that the number of species with commercial potential for regional or international markets differed largely between the study areas. Whereas in Riberalta, Bolivia, 15 tree species were regarded as commercial, 22 commercial species were regarded as such in the Pucallpa and Puerto Maldonado regions in Peru, and up to 80 species in the Macas region in Ecuador. Accordingly, the stocking commercial volumes in the analysed forests varied from around 20 m^{-3} in Riberalta, Pucallpa and Puerto Maldonado, to up to 80 m^{-3} ha^{-1} in Macas. The specific numbers strongly varied between the different smallholder forest stands due to previous logging practices and local forest composition. Also, the prices paid by local traders for timber varied strongly. For *Cedrelinga cateniformis,* a timber tree species found in all the study regions, the price varied from only USD$ 3.7 in Riberalta, to USD$ 6.7 in Pucallpa and Puerto Maldonado, up to USD$ 16 m^{-3} of round wood in Macas. Accordingly, the monetary value of stocking timber volume for one hectare varied from USD$ 0 in a logged farm forest located near Riberalta, to USD$ 1,324 in a smallholder forest located in the Macas region.

The analysed households used this potential to different degrees. It is possible to distinguish five general categories of smallholders: (1) Those not dependent on income from timber; (2) those requiring occasional income from timber; (3) smallholders requiring complementary income; (4) those obtaining their principal income from timber; and (5) smallholders specialized in timber harvesting and trade. Depending on market opportunities, forest conditions and the strategy of the smallholder, incomes from timber varied from USD$ 194 yr^{-1} in Pucallpa and Puerto Maldonado, to USD$ 216 in Riberalta, up to USD$ 2,589 in Macas.

Forests previously logged by smallholders showed significant differences to pristine forests regarding basal area, number of trees and DBH distribution of the principal commercial species. Particularly, a large shift towards smaller size classes was observed. In secondary forests, the commercial timber potential depended in particular on the regeneration and dominance of commercial tree species. In some young secondary forests, dense regeneration of pioneer species with a commercial value in local markets dominated the forest composition. In other cases, only few commercially interesting trees were found.

Projections of timber production for the next thirty years resulted in the volumes: between 7.4 m^3 ha^{-1}, 12.2 m^3 ha^{-1}, and 20.9 m^3 ha^{-1} for Bolivia, Peru, and Ecuador respectively, with large variations depending on previous logging practices. These values translate into Annual Allowable Cuts between 0.05 m^3 ha^{-1} yr^{-1} in a stand located in Puerto Maldonado, up to 1 m^3 ha^{-1} yr^{-1} in a still pristine forest in Ecuador. Considering the average forest areas of smallholder farms of 53 ha in Bolivia, 46 ha in Peru, and 31 ha in Ecuador, the yearly harvestable volume per smallholder is around 11.5 m^3 yr^{-1}, 12.5 m^3 yr^{-1}, and 7.2 m^3 yr^{-1} in Bolivia, Peru, and Ecuador, respectively. These translate into potential annual incomes of around USD$ 45 (Bolivia), USD$ 84 (Peru), and USD$ 115 (Ecuador) for the three countries. The potential annual net income also strongly varied depending on transport distance to the nearest road and the availability of horses and chainsaws. Thus, income prospects of forest that were three hours distant from a road were around USD$ 200 yr^{-1} compared to USD$ 1,000 yr^{-1---} for a forest located near a road.

These findings suggest that timber management can be financially attractive for smallholders particularly if value is added through the cutting of planks. However, in practice, this potential depends largely on local marketing possibilities and timber prices, the possibility of integrating into value-added chains, as well as the size, composition and state of the forest. In case of vibrant timber markets that absorb large volumes of a wide range of tree species, the financial attractiveness of timber logging is high. Even under less favourable conditions, smallholders tend to develop strategies to take advantage of an eventually existing potential for generating income from the logging of timber in their forests. The identified timber use strategies employed by smallholders in the study regions, although not under control of the forest authorities, so far have only moderately changed the structure and composition of forests at a level comparable with the one documented for sustainable timber management schemes. Timber growth projections for forests that have been logged by smallholders are comparable to those of logged areas under management plans.

It can be concluded that the management of forests to produce timber can be attractive for smallholders as a complementary source of urgently required income while contributing in parallel to the long-term conservation of significant forest areas in the Amazon. Against this backdrop, it is highly recommended to more intensively support smallholder forestry in the region, above all by the formal recognition of local management schemes and a substantial improvement of local conditions for the commercialization of timber.

Zusammenfassung

Kleinbauern in der Amazonasregion sind eine der wichtigsten Akteursgruppen für den langfristigen Erhalt der noch bestehenden Wälder. Sie managen große Waldflächen auf der Basis althergebrachten Gewohnheitsrechts und besitzen teilweise signifikantes lokales Wissen bezüglich der Bewirtschaftung ihrer Naturressourcen. Über die Jahrhunderte hinweg wurden sie in paternalistischen Gesellschaftsmodellen unter Führung der ökonomischen und politischen Eliten ausgebeutet und marginalisiert, doch gegenwärtig haben viele nationale Regierungen, unterstützt durch die internationale Gemeinschaft und in Folge des durch soziale Bewegungen aufgebauten Drucks, die Rechte und die wichtige Rolle der ländlichen Kleinbauern anerkannt, die meist in waldreichen Gebieten leben.

In den 90iger Jahren wurde das Konzept der nachhaltigen Waldbewirtschaftung als Strategie zum Wald-, Biodiversitäts- und Klimaschutz weit über die Amazonasregion hin verbreitet. Anfangs fokusierte dieser Ansatz die Kapazitätenstärkung von Forstunternehmen, welche durch den Staat vergebene Waldnutzungskonzessionen besaßen. Später wurde das Konzept der Gemeindewaldbewirtschaftung gefördert, welches sich vor allem auf die Holznutzung durch forstliche Kleinproduzenten auf Basis von legal anerkannten Managementplänen und den Prinzipien des Reduced Impact Logging (RIL) konzentrierte. Viele staatliche und nicht-staatliche Stellen, unterstützt durch die internationale Gemeinschaft, begannen mit der Umsetzung von Aktionen zur Anwendung dieses neuen Ansatzes.

Nach jahrelanger Förderung der Gemeindewaldbewirtschaftung sind die erzielten Ergebnisse jedoch moderat. Auch wenn einige wenige Erfolgsgeschichten vorliegen, die normalerweise mit Unterstützung der internationalen Zusammenarbeit erzielt wurden, haben nur wenige kleine Produzenten diesen Managementansatz angenommen. Der diesbezügliche Mangel an Erfolg weist auf eine fehlende Kompatibilität zwischen den rechtlichen Rahmenbedingungen und dem Markt für Gemeindewaldbewirtschaftung hin, was die Kapazitäten und Interessen der kleinen Produzenten miteinschließt. Dies führt zu der generellen Frage ob eine nachhaltige Einkommenserzeugung aus der Waldbewirtschaftung durch Kleinproduzenten in der Amazonasregion mit ihren spezifischen Bedingungen machbar ist.

Vor diesem Hintergrund zielt die vorliegende Studie darauf ab das Bewirtschaftungspotenzial zur Holzproduktion durch Kleinbauern in der Amazonasregion zu untersuchen um auf diese Weise orientierend auf die politische Strategieformulierung zur Förderung einer Gemeindewaldbe-wirtschaftung zu Gunsten kleiner Produzenten einzuwirken. Die Studie berücksichtigt zwei kritische Elemente, welche auf die Gemeindewaldbewirtschaftung einwirken: Mangel an notwendigen technischen und finanziellen Kapazitäten um auf dem Holzmarkt erfolgreich zu sein; sowie niedriger Anteil, fehlende Naturverjüngung und eingeschränkte Produktivität von kommerziellen Holzarten in Naturwäldern. Bezüglich des lezteren Aspektes, bestätigt sich häufig dass kleine Produzenten dazu neigen ihre Waldflächen zu übernutzen und deutlich zu schädigen wenn keine Kontrollaktivitäten stattfinden. Dementsprechend stellt die Studie die folgenden 3 Forschungsfragen: i) Welche Möglichkeiten bieten sich für kleine Produzenten um an den Holzmarkt zu gelangen? ii) Welches Kommerzialisierungspotenzial besitzt das Holz aus Primär- und Sekundärwäldern? iii) Welche Effekte ergeben sich aus der Holznutzung durch kleine Produzenten in den Waldflächen?

Als Teil des EU-finanzierten Forschungsvorhabens “Forest management by small farmers in the Amazon – An opportunity to enhance forest ecosystem stability and rural livelihood“, adressiert die Studie die 3 Forschungsfragen durch eine empirische Analyse in 15 Gemeinden in den vier Regionen Riberalta (Bolivien), Macas (Ecuador), Pucallpa und Puerto Maldonado (Peru), die wegen ihrer regionalen Relevanz und Representativität bezüglich der kleinbäuerlichen Bewirtschaftungsstrategien sowie der Markt- und Waldcharakteristik ausgewählt wurden. Die Analyse umfasst drei Studien:

i) Eine Markt- und Wertschöpfungskettenanalyse zum besseren Verständnis der Rolle von kleinen Produzenten in gegenwärtigen Holzmärkten sowie zur Identifizierung der Barrieren und Potenziale um Waldmanagement zu einer attraktiven Einkommensquelle zu machen;
ii) Eine Analyse des kommerziellen Potenzials und monetären Wertes von Holz aus kleinbäuerlichen Primär.
iii) Eine Untersuchung der Effekte der Holzeinschlagsaktivitäten von kleinen Produzenten auf die Waldstruktur und Artenzusammensetzung durch den Vergleich von Primär- und Sekundärwäldern auf Farmniveau.

In diesen Studien wurden Inventuren in Primärwald, Sekundärwald und eingeschlagenen Wäldern durchgeführt, sowie semi-strukturierte Interviews mit kleinen Produzenten über forstwirtschaftliche Praktiken, erzieltes Einkommen sowie Produktionskosten und Holzkommerzialisierung. Des weiteren ergänzten Sekundärinformationen und Expertenbefragungen die Datenerhebung insbesondere bezüglich wissenschaftlicher Artnamen, ökologischer Charakterisierung der inventarisierten Baumarten, Wertschöpfungsketten und legaler Aspekte der Waldbewirtschaftung. Uni- und multivariate statistische Methoden wurden angewandt um die forstlichen Farmen zu analysieren und die kleinen Produzenten entsprechend ihrer Forstbewirtschaftungsstrategie zu klassifizieren. Abschließend wurden die gefundenen Informationen benutzt um unter Berücksichtigung von Flächengröße, Nutzungsintensität und Produktivitätsszenarien das finanzielle und ökologische Potenzial der Gemeindewaldbewirtschaftung zu bestimmen.

Die Marktanalyse zeigte dass die Anzahl von Arten mit kommerziellem Potenzial auf regionalen oder internationalen Märkten zwischen den Untersuchungsgebieten stark variierte. Während in Riberalta (Bolivien) 15 Arten als kommerziell identifiziert wurden und in Pucallpa und Puerto Maldonado (Peru) 22 Arten, waren es in Macas (Ecuador) 82 Arten. Dementsprechend bewegte sich auch das kommerzielle Volumen in den untersuchten Wäldern von 20 m3 ha-1 in Riberalta, Pucallpa und Puerto Maldonado bis hin zu 80 m3 ha-1 in Macas. Diese Werte zeigten auch eine hohe Variation zwischen den Waldflächen der kleinen Produzenten auf Grund vorheriger Holznutzungsmaßnahmen und der Artenzusammensetzung. Auch die Holzeinkaufspreise der lokalen Händler schwankten stark, beispielsweise für die Baumart Cedrelinga cateniformis, eine geimeinsame und häufige Baumart in den Untersuchungsgebieten, reichte die Preisspanne pro Festmeter Rundholz von USD$ 3.7 in Riberalta und USD$ 6.7 in Pucallpa und Puerto Maldonado bis zu USD$ 16 in Macas. Nach diesen Daten variierte der monetäre Wert des Holzvorrats pro Hektar von USD$ 0 auf einer frisch eingeschlagenen Waldfläche in Riberalta bis hin zu USD$ 1,324 auf einer Waldfläche in Macas.

Die Untersuchten Haushalte nutzen dieses Potenzial in unterschiedlicher Intensität, so dass fünf Kategorien unterschieden werden können: Kleinbauern die (1) von Holzeinkünften unabhängig sind; (2) gelegentlicher Holzeinkünfte bedürfen; (3) ihr Einkommen durch den Holzverkauf vervollständigen; (4) vom Holzverkauf als Haupteinnahmequelle abhängig sind; und (5) auf Holzproduktion und -verkauf spezialisiert sind. Die jährlichen Einkünfte aus dem Holzverkauf variieren, abhängig von den Vermarktungsmöglichkeiten, den Waldbedingungen und der Produktionsstrategie, zwischen USD$ 194 in Pucallpa und Puerto Maldonado, USD$ 216 in Riberalta und bis zu USD$ 2,589 in Macas.

Die von den kleinen Produzenten bereits eingeschlagenen Wälder zeigten signifikante Unterschiede zum Primärwald was Grundfläche, Stammzahl und Durchmesserverteilung der wesentlichen kommerziellen Baumarten betrifft. Insbesondere wurde ein Wandel hin zu kleinen Durchmesserklassen beobachtet. Im Sekundärwald hing das kommerzielle Holzproduktionspotenzial besonders von der Naturverjüngung und Dominanz der kommerziellen Baumarten ab. In einigen jungen Sekundärwäldern konnte eine hohe natürliche Verjüngung von Pionierbaumarten mit kommerziellem Potenzial für den lokalen Markt beobachtet werden, welche die Artenzusammensetzung dominierte. In anderen Fällen fanden sich dagegen nur wenige Individuen mit kommerziellem Potenzial.

Die Projektion der Holzproduktion für die folgenden 30 Jahre weist als Ergebnis ein Volumen von 7.4 m3ha-1 in Bolivien, 12.2 m3ha-1 in Peru und 20.9 m3ha-1 in Ecuador vor, mit hoher Variation entsprechend der zuvor angewandten Praktiken zum Holzeinschlag. Diese Werte lassen sich auf ein erlaubtes jährliches Einschlagsvolumen von 0.05 m3ha-1Jahr-1 in einem Baumbestand in Puerto Maldonado bis hin zu 1 m3ha-1Jahr-1 in einem Primärwaldbestand in Ecuador übertragen. Berücksichtigt man die durchschnittliche Größe der kleinbäuerlichen Waldflächen von 54 ha in Bolivien, 46 ha in Peru und 31 ha in Ecuador, dann ergibt sich ein jährliche Erntevolumen von 11.5 m3año-1 in Bolivien, 12.5 m3año-1 in Peru und 7.2 m3año-1 in Ecuador pro Familie. Diese Werte wurden auf potenzielle jährliche Einkünfte von etwa USD$ 45 (Bolivien), USD$ 84 (Peru) und USD$ 115 (Ecuador) überführt. Der potenzielle jährliche Nettogewinn zeigte zudem eine hohe Variation in Abhängigkeit von der Distanz zum nächstgelegenen Transportweg sowie der Verfügbarkeit von Transportpferden und Motorsägen. So betrug der Schätzwert für einen Hektar Wald der 3 Stunden vom nächsten Weg entfernt liegt etwa USD$ 200 pro Jahr, während er für einen Wald in Wegnähe USD$ 1000 betrug.

Die Ergebnisse weisen darauf hin, dass eine auf die Transformation von Kantholz abzielende Waldbewirtschaftung für kleine Produzenten finanziell attraktiv sein kann. Dennoch ist es in der Praxis so dass dieses Potenzial stark von lokalen Marktbedingungen und -preisen, Möglichkeiten der Wertschöpfung sowie von Größe, Zusammensetzung und Zustand des Waldes abhängt. Im Falle von attraktiven Märkten mit der Kapazität große Holzvolumen aus einem weitgefächerten Artenspektrum abzunehmen, ist auch das finanzielle Potenzial der Waldbewirtschaftung hoch. Doch auch unter ungünstigen Bedingungen tendieren die kleinen Waldbesitzer in den Untersuchungsgebieten dazu Strategien zu entwickeln um ein eventuell vorliegendes Potenzial zur Einkommensgenerierung aus der Holznutzung auszuschöpfen. Obwohl die von den kleinen Produzenten angewandten Holznutzungsstrategien nicht der Kontrolle der forstlichen Aufsichtsbehörde unterlagen, hatten sie dennoch nur einen moderaten Umwandlungseffekt auf die Struktur und Zusammensetzung der Wälder, vergleichbar mit dem nachhaltiger Waldbewirtschaftungspläne. Die Waldwachstumsprojektion in in den von Kleinbauern eingeschlagenen Flächen ist vergleichbar mit der auf Flächen unter solchen Waldbewirtschaftungsplänen.

Abschließend lässt sich folgern, dass die Waldbewirtschaftung zur Holzproduktion eine finanziell attraktive, komplementäre Einkommensquelle für Kleinbauern darstellen kann, während sie gleichzeitig zum langfristigen Erhalt signifikativer Waldflächen im Amazonasgebiet beiträgt. Vor diesem Hintergrund empfiehlt es sich die Waldbewirtschaftungsaktivitäten der kleinen Produzenten in der Region stärker zu unterstützen, was die formelle Anerkennung lokaler Managementschemata und eine erhebliche Verbesserung der lokalen Holzkommerzialisierungsbedingungen miteinschließt.

Resumen

Los pequeños productores en la Amazonia constituyen uno de los más importantes actores para asegurar el mantenimiento de los bosques tropicales. Estos actores administran grandes extensiones de tierras forestales basadas en derechos ancestrales y cuentan con un significativo conocimiento acerca del manejo de sus recursos. Los pequeños productores han sido explotados y marginalizados a lo largo de siglos dentro de sociedades paternalistas regidas por élites económicas y políticas. Recientemente, en respuesta a la presión de movimientos sociales, y apoyados por la comunidad internacional, muchos gobiernos han reconocido los derechos y cultura de los pequeños productores que viven en áreas rurales normalmente cubiertas por grandes extensiones de bosque.

Durante los años 90, el concepto de Manejo Forestal Sustentable (MFS), fue ampliamente difundido a lo largo de la Amazonia con una estrategia para frenar la deforestación y la pérdida de la biodiversidad, así como la mitigación del cambio climático. Inicialmente este enfoque se centró en el fortalecimiento de capacidades de las empresas forestales que fueron beneficiarias de concesiones forestales adjudicadas por el Estado. Posteriormente se promocionó el concepto de Manejo Forestal Comunitario que se centró principalmente en el manejo de la madera por parte de pequeños productores forestales basados en planes de manejo legalmente autorizados y basados en los principios de Aprovechamiento de Impacto Reducido (AIR). Muchas agencias gubernamentales y no gubernamentales con el apoyo de la comunidad internacional iniciaron con acciones para poner en marcha este nuevo enfoque.

Sin embargo, después de varios años de promover iniciativas de Manejo Forestal Comunitario, los resultados han sido modestos. A pesar de pocas historias de éxito normalmente conseguidas con el apoyo de proyectos de cooperación internacional, pocos pequeños productores han adoptado estos esquemas de manejo. Esta falta de éxito indica una falta de compatibilidad entre el marco regulatorio y el mercado para el manejo forestal comunitario, incluyendo las capacidades e intereses de los pequeños productores. Esto a generado una pregunta más general sobre la viabilidad del Manejo Forestal por parte de pequeños productores en la Amazonia y sus condiciones, con el fin de generar ingresos de manera sostenible.

Con este antecedente, este estudio tiene el objetivo de analizar el potencial de manejo de madera por parte de pequeños productores en la Amazonia con el fin de generar orientación para la formulación de políticas para promover el manejo forestal comunitario que permita generar beneficios para los pequeños productores. Este estudio considero dos elementos críticos que limitan el manejo forestal comunitario: La ausencia de capacidades técnicas y financieras necesarias para lograr éxito en los mercados de madera, y la baja abundancia, falta de regeneración y productividad de especies comerciales en los bosques naturales. Con respecto a este último aspecto, frecuentemente se afirma que los pequeños productores tienden seriamente a sobre-explotar y causar daños a sus bosques si no se implementan acciones de control. De esta manera, esta investigación propuso tres preguntas de investigación: i) ¿Qué posibilidades tienen los pequeños productores para ingresar a los mercados de madera?; ii) ¿Cuál es potencial comercial de la madera de los bosques primarios y secundarios?; iii) ¿Cuáles son los efectos del aprovechamiento de madera llevada a cabo por pequeños productores sobre

sus bosques?; y iv) Cuáles son las posibilidades para el manejo a largo plazo de sus recursos madereros?

Este estudio es parte del proyecto de investigación financiado por la Unión Europea “Manejo Forestal por parte de pequeños productores en la Amazonia – Una oportunidad para mejorar la estabilidad del ecosistema natural y los medios de vida rurales”. Específicamente responde a las tres preguntas de investigación planteadas a través de un análisis empírico en 15 comunidades ubicadas en cuatro regiones de estudio en Bolivia (Riberalta), Ecuador (Macas), y Peru (Pucallpa y Puerto Maldonado), seleccionadas por su relevancia y representatividad con respecto a contextos regionales in términos de características de mercado, estrategias de manejo implementadas por pequeños productores y características de los bosques. El análisis se basa en tres estudios:

i) Análisis de mercado y cadenas de valor, para entender el rol de los pequeños productores en los mercados de madera e identificar las barreras y potencialidades para que el manejo forestal sea atractivo como una fuente de ingreso.
ii) Análisis del potencial comercial y monetario de la madera en bosques primarios.
iii) Evaluación de los efectos del aprovechamiento de madera llevada a cabo por parte de pequeños productores sobre la estructura y composición del bosque, a través de comparaciones entre bosques primarios y secundarios.

Inventarios a nivel de finca se llevaron a cabo sobre bosques primarios, secundarios y aprovechados. Entrevistas semi-estructuradas fueron realizadas con pequeños productores acerca de las prácticas del manejo forestal, ingresos generados, costos de producción y comercialización de madera. Información secundaria y entrevistas a expertos complementaron información relacionada principalmente a nombres científicos de especies y características ecológicas de los árboles inventariados, cadenas productivas y aspectos legales sobre el manejo forestal. Métodos estadísticos univariados y multivariados se aplicaron para analizar las fincas forestales y para clasificar a los pequeños productores de acuerdo con sus estrategias de manejo forestal. En una etapa final, los hallazgos fueron utilizados para calcular el potencial financiero y ecológico del manejo forestal comunitario, bajo consideraciones del tamaño del área de manejo, intensidad de aprovechamiento y escenarios de productividad.

El análisis de mercado reveló que el número de especies con potencial comercial para mercados regionales o internacionales fue muy diferente entre las áreas estudiadas. Mientras en Riberalta, Bolivia, hasta 15 especies fueron identificadas como comerciales, 22 especies en Pucallpa y Puerto Maldonado en Perú y 82 especies en la región de Macas en Ecuador. De acuerdo con estos datos, el volumen comercial en los bosques analizados varió desde 20 m^3 ha^{-1} en Riberalta, Pucallpa y Puerto Maldonado, hasta 80 m^3 ha^{-1} en Macas. Los valores tuvieron una alta variación entre las diferentes áreas forestales de los pequeños productores, debido a las acciones previas de aprovechamiento y la composición del bosque. Los precios de la madera pagados por los comerciantes locales también tuvieron una alta variación. La especie *Cedrelinga cateniformis* un árbol común a las regiones analizadas los precios variaron desde USD$ 3.7 en Riberalta, USD$ 6.7 en Pucallpa y Puerto Maldonado, hasta USD$ 16 m^3 en forma rolliza, en Macas. Con esta información, el valor monetario del stock de madera en una hectárea varió desde USD$ 0 en un área de bosque aprovechada en Riberalta, hasta USD$ 1,324, en un área de bosque ubicada en la región de Macas.

Los hogares analizados utilizaron este potencial en diferentes niveles, pudiendo distinguirse cinco categorías de pequeños productores: (1) Aquellos no dependientes de ingresos provenientes de la madera; (2) Aquellos que requieren ingresos ocasionales de la madera; (3) Productores que complementan sus ingresos de la madera; (4) Aquellos que dependen de la madera como fuente principal de ingresos; y (5) Pequeños productores especializados en producción y comercialización de madera. Dependiendo de las oportunidades de mercado, las condiciones del bosque y la estrategia de producción, los ingresos de la madera variaron en promedio desde USD$ 194 por año en Pucallpa y Puerto Maldonado, 216 en Riberalta, hasta 2,589 en Macas.

Los bosques aprovechados previamente por los pequeños productores mostraron diferencias significativas a bosques primarios en relación al área basal, número de árboles y distribución diamétrica de las especies comerciales principales. Particularmente, un cambio hacia pequeñas clases diamétricas fue observado. En bosques secundarios, el potencial comercial de madera dependió en particular de la regeneración y dominancia de árboles comerciales. En algunos bosques secundarios jóvenes, se observó una alta regeneración de especies pioneras con potencial comercial para mercados locales, que dominó la composición del bosque. En otros casos, se encontraron pocos individuos comerciales.

Las proyecciones de la producción de madera para los siguientes treinta años resultaron en volúmenes entre 7.4 m^3ha^{-1}, 12.2 m^3ha^{-1}, y 20.9 m^3ha^{-1} para Bolivia, Perú, and Ecuador respectivamente, con altas variaciones dependiendo de las prácticas de aprovechamiento previas. Estos valores se trasladaron a Corta Permitida Anual que estuvieron entre 0.05 $m^3ha^{-1}año^{-1}$ en un rodal ubicado en Puerto Maldonado, hasta 1 $m^3ha^{-1}año^{-1}$ en un rodal primario ubicado en Ecuador. Considerando el promedio de las áreas de bosque de las fincas, de 54 ha en Bolivia, 46 ha en Perú y 31 ha en Ecuador, el volumen anual de cosecha por pequeño productor fue de 11.5 $m^3año^{-1}$, 12.5 $m^3año^{-1}$, y $m^3año^{-1}$ en Bolivia, Perú y Ecuador respectivamente. Estos valores también se trasladaron a ingresos potenciales anuales de alrededor de USD$ 45 (Bolivia), USD$ 84 (Perú) y USD$ 115 (Ecuador). El valor potencial anual neto también tuvo alta variación dependiendo de la distancia de transporte hacia el camino más cercano y la disponibilidad de caballos para transporte y motosierra. Así el valor estimado de una hectárea de bosque ubicada a tres horas de distancia desde el camino fue de alrededor de USD$ 200 por año comparado con USD$ 1000 para una hectárea ubicada cerca del camino.

Estos hallazgos sugieren que el manejo forestal de madera puede ser atractivo financieramente para pequeños productores a través de la transformación de tablones. Sin embargo, en la práctica, este potencial depende fuertemente de las condiciones de mercado local, las condiciones de generación de valor agregado, así como el tamaño, composición y estado del bosque. En el caso de mercados atractivos que tienen la capacidad de absorber amplios volúmenes de madera de una alta gama de especies, el potencial financiero del aprovechamiento de madera es también alto. Aún bajo condiciones desfavorables los pequeños productores tienden a desarrollar estrategias para tomar ventaja de un eventual potencial existente para la generación de ingresos de las actividades de aprovechamiento de madera en

las regiones de estudio. Aunque las estrategias de aprovechamiento de madera empleadas por los pequeños productores no estuvieron bajo el control de la autoridad forestal, estas han tenido efectos moderados en términos de cambio de la estructura y composición de los bosques en comparación con los planteados en los Planes de Manejo Forestal Sustentable. Los volúmenes de corta proyectados en áreas aprovechadas por pequeños productores fueron comparables con aquellas definidas en los planes de manejo.

Se concluye que el manejo de bosques para producción de madera puede ser atractivo financieramente como una fuente complementaria de ingresos en casos de urgencia económica, mientras se contribuye a la conservación a largo plazo de significativas áreas de bosque en la Amazonia. En relación a estos hallazgos, se recomienda un mayor soporte a las acciones de manejo forestal implementadas por pequeños productores en la región, incluyendo el reconocimiento formal de los esquemas locales de manejo y un mejoramiento substancial de las condiciones locales para la comercialización de madera.

1 INTRODUCTION

1.1 Problem statement

The Amazon forests, with an area of around 5.5 million km^2, are the largest contiguous area of tropical forests in the world and play a major role in water and carbon cycles (UNEP 2009). Of this area, close to 2 million km^2 are formally titled or are in the process of receiving such a land title in connection with local communities or smallholders (RAISG 2009). Deforestation in the Amazon affects around 36,000 km^2 every year (FAO 2010), and smallholders are responsible for around 20-30% of the forest clearing (Fearnside 2008).

Different strategies have been promoted during recent years to contribute to tropical forest conservation and management in smallholders´ forest areas. However, the feasibility of implementing such forest management schemes continues to be debated, as poor organizational capacity, lack of knowledge of forestry techniques, limited access to markets, and compliance with bureaucratic procedures are all limiting factors (Sunderlin et *al.* 2008, Amacher et *al.* 2009, UNEP 2009, Agrawal et *al.* 2013, Sist et *al.* 2014). Market-based development has been identified as the best opportunity to improve smallholders´ livelihoods and to reduce or avoid forest conversion to agricultural lands (Scherr et *al.* 2002). Income generation from forests is stated as one of the major factors that determine the probability for their conservation through management (Merry et *al.* 2009).

Regarding income generation, timber products have a higher potential than non-timber forest products (NTFPs) (Amacheret et *al.* 2009). However, there are several factors that continue to be discussed concerning the viability of timber management to maintain forests on smallholders' plots (Sunderlin et *al.* 2004, Belcher 2005, Galloway et *al.* 2010). The most relevant impediments to the sustained commercial use of forests by smallholders include: i) market control by a few actors that impose prices and product characteristics (Smith et *al* 2006); ii) capital investments needed to transform and transport products to markets (Agrawal et *al* 2013); iii) high variation in abundance of marketable species according to biophysical factors (Chomitz and Kumari 1998, Søren et *al.* 2001, Smith et *al.* 2003, Ruiz Perez et *al.* 2004); iv) limited evidence of possibilities for long-term timber management, especially in small forest areas, considering the lack of regeneration of species logged and long-term horizons to recover forest productivity (Pearce et *al.* 1999). After decades of support of smallholder or community-based forest management by external actors (governmental or non-governmental), it is still not certain how successful this approach really is. In any case, it is important to understand that forest management occurs in complex ways that are related to particular social, economic, environmental, political, and cultural conditions (Galloway et *al.* 2014).

Given this context, there is a need for better information about the conditions under which smallholders can find or develop viable mechanisms to help them benefit from their forest areas and ensure the long-term maintenance of their forests. Three aspects are of crucial importance when evaluating this approach: 1) the way that smallholders participate in timber markets in the Amazon region; 2) the commercial potential of smallholders´ forest areas given the market context; and 3) the practices that smallholders apply to manage their forest areas and their forest productivity.

This research aims to increase knowledge about these factors that define the potential of forest management by smallholders, with the objective of contributing to the sustainable development of the Amazon. Four main research questions are posed:

What possibilities do smallholders have to engage in timber markets?

What is the commercial potential of primary and secondary forest areas?

What are the effects of logging on smallholders' forests?

What are the possibilities for long-term management of timber resources?

To answer these research questions, the following studies were conducted in different regions of the Amazon:

iv) A market and value-added chains analysis, to understand how timber markets and actors function. The role of smallholders was also analysed in relation to the strategies of timber logging and benefits obtained from their forest areas.

v) An analysis of the commercial potential of forests was carried out at the farm level in primary and secondary forests, and a financial assessment of the timber potential was carried out concerning market prices of timber.

vi) A characterization of logging practices and an analysis of their effects on the structure and composition of forests was performed, comparing primary and logged areas forest areas as a basis for assessing the impact of smallholders´ activities.

vii) Finally, an analysis of scenarios for timber management was performed considering forest areas, logging rates, timber productivity, and the potential financial incomes from forest areas under different scenarios of forest management.

This thesis is structured into the following chapters:

i) Chapter one presents a review of the state of knowledge in relation to the Amazon region and the livelihoods of smallholders.

ii) Chapter two presents the analytical framework, methodologies and methods applied to obtain and analyse the information.

iii) Chapter three presents the results obtained in relation to the research questions raised.

iv) Chapter four discusses the results obtained in relation to the possibilities that smallholders have for the adequate management and conservation of their forests.

1.2 The Amazon region.

The Amazon basin, encompassing an area of approximately 8 million km^2, represents the worlds´ largest tropical forest zone. 5,5 million km^2 of that area are covered by natural forests (UNEP 2009, ITTO 2006). This region provides about 15-20% of all the fresh water on the planet (ITTO 2006), and although it only occupies 7% of the earth's land area, it holds more than half of the world's biota and one-third of its tropical forests (ibid). The Amazon basin's territory is distributed between nine countries, with 63% located in Brazil, 10% in Peru, 7% in Colombia, 6% in Bolivia, 6% in Venezuela, 3% in Guyana, 2% in Suriname, 1.5% in Ecuador, and 1.5% in French Guiana (TCA 2007). In 2007, there was an estimated total population of 33.5 million inhabitants living within its boundaries (UNEP 2009). Around 420 ethnic groups survive in this region, maintaining particular socio-economic and cultural characteristics (TCA 2007).

Population development has been highly dynamic in the Amazon region. Mankind's presence in the Amazon began with the first Indian settlements around ten thousand years ago. Their population was estimated to have reached several million by the arrival of the Portuguese and Spanish in the early 16th century. Due to the following period of bloodshed, disease, and cultural destruction, indigenous peoples currently comprise only a small segment of the Amazon's population (Viana 2010). Today's dynamics of human occupation in the Amazon forests started in the 1950s, when most governments began to promote big development projects and colonization programs (Barclay et *al.* 1991, Rudel and Horowitz 1992, UNEP 2009). As part of this process, thousands of kilometres of roads were opened, ancestral rights to indigenous communities were recognized by communal land tenure, and colonists received land titles, commonly for a patch of between 50 to 100 ha per family (TCA 1992, SIISE 2005, D´ Antona and WanVey 2006, Amacher 2009). In addition, large forest areas were given to certain landholders. For instance, in Brazil, around 500,000 families received an average of 100 hectares (Lima et *al.* 2006, Amacher et *al.* 2009). In the case of communal areas mostly in hands of indigenous communities, the extension varied from several thousand to millions of hectares, depending on geographical location (ITTO 2006). However, nowadays certain areas, such as the Ecuadorian Amazon, are more densely populated. Combined with continued population growth, this has caused individual smallholder plots to decrease in size to 5-10 hectares per family (Muzo et *al.* 2013).

Currently, more than 60% of the Amazon population live in urban areas (UNEP 2009). More than 3,000,000 inhabitants live in Manaus and Belém in Brazil (IBGE 2007), while there are 1.5 million in Santa Cruz in Bolivia, and 400,000 in Iquitos, Peru (INEI 2005). Because of the socio-economic dynamics in the Amazon, population growth is higher than in the rest of the overlying country. For instance, in the province of Orellana in Ecuador, located in the Ecuadorian Amazon region, population growth during the period of 2001-2010 was 5.06%, the highest value in the country (Villacís and Carrillo 2012).

Owing to the existence of strategic resources, the integration of the Amazon into national and global economies is part of the political agenda of the nations that share this territory (for example, see the Infrastructure Development Program for the Integration of the Region [IIRSA 2009]). This pressure has generated different effects on the territory. During the last few years, substantial improvements have been made in infrastructural development, such as roads and communication networks. For instance, the road network in the Brazilian Amazon has expanded tenfold in the last thirty years, generating migration processes and important effects on industry development and demand, especially in local markets (UNEP 2009). However, this process has also generated environmental problems, such as deforestation, which have a global impact. Historic information about deforestation indicates that during the period of 1990-2000, 20.550 km^2 of territory yr were transformed, and land value increased up to 27.218 km^2 during the period of 2000-2005 (UNEP 2009). At 0.8%, Ecuador was the country with the highest deforestation rate (MAE 2012), followed by Brazil with a rate of 0.63% (FAO 2005). Regarding the causes of deforestation, various studies identify several drivers: on a macro-economic level, world trends of demand for natural resources such as biofuels and livestock; national government-level policies like agrarian laws or road improvements to inaccessible areas; and even micro-economic dynamics such as smallholders´ livelihood strategies, including slash and burn practices (Stoian 2000).

Different actors are present in the Amazon and have different interests. Each generates different results regarding the status of natural resources and forests. The principal actors present in the forest areas in the Amazon are: i) the State and Governments, which define the rules regarding production, exploitation and conservation, most of which are not compatible with customary or traditional laws; ii) natural resources extractors, including forest concessionaries, agro-industrialists, entrepreneurs, mining and oil concessions; iii) smallholders, who are normally the less powerful actors due to their inherent limitations of capital and political weakness; iv) finally, development organizations, governmental or non-governmental, which commonly promote conservation, sustainable management of natural resources, and poverty reduction (Sunderlin 2005).

1.3 The use of timber from Amazon forests

1.3.1 Commercial potential of tropical Amazon forests

The high biodiversity levels of tropical forests influence their potential to produce commercial products. The Amazon region contains an estimated 10% of the plant species of the entire planet (Prance et *al.* 2000*).* Five general types of vegetation can be found in the Amazon forests: rain forests, seasonal forests, plains, savanna, flood plain forests, and deciduous forests (de Jong et *al*. 2010b).

Timber is the most important forest product of the Amazon. An assessment of the potential timber value in the Brazilian Amazon region estimated that a commercial timber volume of 4.5 ± 1.35 billion m^3, of which 1.2 billion m^3 are currently profitable to harvest, has a potential stumpage value of US 15.4 billion (Merry et *al.* 2009). Given this potential, the logging industry has become very strong in countries like Brazil, Bolivia, and Peru, and continues to wield influence in public policy (de Jong et *al.* 2010a). Timber production differs in intensity between countries. In Brazil, 24.5 million m^3 were produced in 2004, while in Bolivia 500,000 m^3 are produced annually, and in Peru 1.8 million (UNEP 2009); meanwhile, in Ecuador, 400,000 m^3 were reported to be produced in 2010 (MAE 2010a). In Brazil, around 44 million hectares in national forests and smallholder's settlements have the potential to be harvested profitably (Merry et *al.* 2009).

The structure and composition of forests affect their commercial potential. Several factors, such as altitude, slopes, soils, precipitation, micro-climatic characteristics, availability of dispersers, intensity, and time of disturbance (Myerscough et *al.* 1995, Clarke 1999, Kariuki 2004, Dauber et *al.* 2005) cause high levels of variation in terms of presence and abundance of commercial species, which affects commercial volumes and, consequently, potential financial values (Summers et *al.* 2004, Sunderlin et *al.* 2004). For instance, the most valuable species, such as *Swietenia macrophylla* King, *Cedrela odorata* Ruiz & Pav. *and Amburana* cearensis (Ducke) J.F. Macbr., are normally present only in extremely low abundances and only in certain parts of the region. *Swietenia macrophylla* and *Amburana cearensis* were reported at densities of 0.014 and 0.06 trees per hectare respectively near Riberalta, Bolivia (PROMAB-IPHAE 2006).

The main commercial species logged in Amazon forests differ between countries and regions. In Brazil as a whole, more than 100 tree species are logged in forest areas, at intensities of up to 40 m^3ha^{-1} (Verissimo et *al.* 1992, Nepstad et *al.* 1999). Other studies report different numbers of species traded in different regions of the Amazon, depending on local or regional market characteristics. The quantity varies from 32 species in the region of Riberalta, located in the extreme northeast of the Bolivian Amazon, to more than 300 species reported in different regions of Ecuador (See table 1.1). Schulze et *al.* (2008) reported values of 30, 92, 99, and 113 commercial species in four sites of the state of Pará, indicating that markets are most highly developed in the northeast of the Brazilian Amazon. Market evolution also influences commercial potential. Silva et *al.* (1995) reported an increase of 29 tree species for timber markets from 1981 to 1993 in Santarem, Brazil, representing a growth of 18 to 54 m^3 ha^{-1} of commercial volume in forest areas. This aspect has been also highlighted by Mostacedo and Fredericksen (1999) in the sense that when the most valuable species become scarce, new species are used by industry and the market.

Table 1.1 Timber species logged in different regions of the Amazon.

Country	**Region**	**Number of species logged**	**Source**
Brazil	Rondonia	26	Summers et *al.* (2004)
	Manaus	50	Magnusson et *al.* (1999)
	Macapa	43	Sears and Pinedo Vasquez (2004)
	Para (four regions)	30, 92, 99, 113	Schulze et *al.* (2008)
Peru	Pucallpa	53	INRENA (2006)
Ecuador	Whole country	300	MAE (2010a)
Bolivia	Riberalta	32	Superintendencia Forestal (2006)

When timber production of natural forests and timber plantations in the Amazon are compared, the former is less productive, and therefore plantations may be a better option for timber management (Vanclay 1996a). However, certain experiences in the Amazon demonstrate that plantations have not been successful in smallholders´ areas due to several problems, both related to their establishment and management and to inadequate schemes promoted by development organizations (Hoch 2009). In any case, forest plantations established in Amazon countries are very important, and timber production is greater than in natural forests. Hoch (2009) reported that Bolivia holds approximately 20,000 ha of forest plantations, Ecuador 167,000 ha, and Peru 726,000 ha. In Brazil, in 2003, 64 percent of the round wood production came from forest plantations covering around five million ha (Bacha 2006). Meanwhile, in Ecuador forest plantations represent more than 60% of total timber authorized for logging—an average of 3 million m^{-3} between 2007 and 2009 (MAE 2010a). In the same way, timber production that comes from agroforestry systems has grown quickly in the recent years. In the case of Ecuador, a quick authorization of timber permissions from agroforestry systems was reported, rising from 58,000 m^3 in 2007 to 480,000 m^3 in 2010, exceeding the 400,000 m^3 authorized from natural forests in 2010.

Secondary forests are also an important component of the landscape because of their capacity to provide goods and services and the increase of these areas across the decades due to factors such as abandonment of agricultural areas, intensification, migration to urban areas, and market dynamics (FAO 2005, Moran *et al.* 1994). These forests have been recognized for their vital capacity to recover useful forest products and environmental services for society (Smith et *al.* 1997). It has been also recognized that their management may provide many ecological and economic services that were originally provided by primary forests (Brown and Lugo 1990). The importance of their management has been increasingly highlighted, especially for smallholders, 20% of whose lands are covered by these forests (Smith et *al.* 2003). In some cases, their importance lies in their capacity to regenerate important commercial tree species. For instance, Vásquez et *al.* (2000) and Sears and Pinedo-Vásquez (2004) highlighted the importance of the commercial species *Callycopyllum spruceanum* (Benth.) Hook. f. ex K. Schum., a species that has regenerated in high densities in secondary flood plain forests in Peru and Brazil. This species has been reported as having fast growth rates, attaining up to 20 cm DBH in eight years in managed fallows there. Galvan et *al.* (2000) also highlighted the dominance of the commercial species *Guazuma crinita* Mart. in secondary forests of 10 years old and more in the Pucallpa region, as well as its importance in providing monetary incomes for smallholders.

Considering the potential of plantations, agroforestry systems, and secondary forests as timber sources in the context of landscapes managed by smallholders, an integrated approach of timber management should be analysed to increase the potential value of forests. To evaluate the importance of the goods and services that tropical forests provide for human beings, several market and non-market-based methods have been applied (see De Groot et *al.* 2002 for an overview). Many studies about economic assessment of timber and NTFPs from tropical forests have been carried out in different regions and contexts with varying results. In general, these analyses report their assessments in terms of USD$ per hectare yr^{-1} or in terms of USD$ per hectare, assuming timber management scenarios. For instance, in a survey of twenty-four studies in tropical forests, Godoy et *al.* (1993) reported potential financial values ranging from 0.75 to 422 USD$ ha^{-1} $year^{-1}$ with a median of about USD$ 50 using market-based values. Another study by Peters et *al.* (1989) included potential values from 697.8 USD$ ha^{-1} $year^{-1}$ for non-timber forest products and 310 USD$ ha^{-1} $year^{-1}$ for timber in a region near Iquitos in Peru. Tandazo and Gatter (2005) reported potential timber values ranging from USD$ 326.6 to 1,641.6 per hectare under simplified management plans in different sites in tropical forests in Ecuador. Meanwhile, Nebel (2003) reported potential net values ranging from USD$ 500 to 1,000 while logging up to 22 trees per hectare and cutting trees with minimum DBH of 60 cm in flood plain forests in Peru. However, as detailed in section 1.4.1, potential values differ greatly from effective values that smallholders generate from their forest areas.

1.3.2 Possibilities of forest management for timber production

Managing tropical forests for timber is one of the most promising alternatives to forest conservation, considering that around 403 million hectares of tropical forest have been officially designated for this purpose (Blaser et *al.* 2011). However, inherent limitations related to tropical forest characteristics include: high species diversity, slow growth, and lack of regeneration (Vanclay 1996b). For instance, Smith et *al.* (2003) argue that the great variation of timber species results in insufficient timber volumes considered in management plans. In addition, yields may decline to a point where in a second logging cycle after thirty years, only between 3% to 28% of the initial volume can be logged if stands were not treated in the meantime. Still, 9% to 64% might be able to be harvested following treatments like liberation from competition (Keller et *al.* 2007). Modelling scenarios including new marketable species indicate that on average, 54% of the timber volume extracted during the first harvest of a primary forest will be available for the second and third cuts (Putz et *al.* 2012). A recent assessment of an experimental area of timber management in the Tapajós National Forest in Brazil found that after thirty years, where 22 species had been logged (at an average volume of $62m^3$ ha^{-1}) in 1982, there was a recovery of between 19% and 57% of harvestable volume relative to pre-logging levels. When considering an additional group of 30 new commercial species not harvested, the potential volume was enough to support a second harvest of maximum 30 m^3 ha^{-1}, except in a treatment with a high tinning intensity (De Avila *et al.* 2017). In any case, large differences are presented in terms of volume recovery, which depends on factors like logging intensities and techniques (Putz et *al.* 2012), as well as ecological factors like precipitation, soil fertility, vine loads, and disturbances such as fire, wind, and a history of anthropogenic influence (Dauber et *al.* 2005).

Basic information required to identify the potential of timber management of forests is based on inventories in which species are measured according to the parameters of diameter at breast high (DBH) and commercial height. Table 1.2 reports information from inventories in the Peruvian Amazon region in a group of six communities located near Pucallpa in dense flood-plain forests. The parameters of basal area, number of stems, and number of individuals are reported for twelve commercial species. Although these locations are relatively close, there are large differences in terms of basal area, number of stems per hectare, and abundance of commercial species, probably due to specific site characteristics. An important item to highlight is the absence of the species *Swietenia macrophylla*, the most valuable tree species in the Amazon. The number of individuals available above 10 cm DBH vary from 11.7 up to 26.4, which influences the potential commercial volumes of these forests.

Table 1.2 Basal area and number of stems for common commercial species greater than 10 cm DBH, in six communities of the region of Pucallpa, Peru

	Pueblo nuevo	**Junín Pablo**	**Curiaca**	**Puerto Belén**	**Preferida**	**Callería**	**Mean**
Basal area (m^2 ha^{-1})	20.0	22.2	17.1	17.9	19.7	20.1	19.5
Number of stems (N)	282.0	564.0	338.2	302.3	329.2	314.1	355.1
Amburana cearensis (Allemão) A.C. Sm.	0.0	0.0	0.3	0.0	0.8	0.0	0.2
Aniba sp. *Ocotea* sp.	11.4	17.3	7.9	2.2	2.6	9.2	8.4
Aspidosperma macrocarpon Mart.	0.5	0.1	0.8	0.0	0.1	0.0	0.3
Calycophyllum spruceanum (Benth.) Hook. f. ex K. Schum.	0.5	2.2	4.8	3.6	2.6	3.5	2.9
Cedrela odorata Ruiz & Pav.	0.2	0.4	1.3	0.1	0.6	0.1	0.5
Cedrelinga cateniformis Ducke	0.0	3.2	0.0	0.0	1.3	0.0	0.8
Chorisia integrifolia Ulbr.	0.1	0.4	0.4	0.1	0.1	0.6	0.3
Dipteryx alata Vogel.	1.7	0.0	2.4	0.6	0.0	0.1	0.8
Hura crepitans Müll. Arg.	0.1	0.0	0.0	6.6	0.0	3.8	1.8
Manilkara bidentata (A. DC.) A. Chev.	0.7	0.0	0.3	15.3	0.0	7.7	4.0
Ormosia schunkei Rudd.	0.6	0.0	5.1	0.1	1.0	0.1	1.2
Simarouba amara Aubl.	2.8	2.8	1.9	0	2.6	0.0	1.7
Sum of common commercial species	**18.6**	**26.4**	**25.2**	**28.6**	**11.7**	**25.1**	**22.6**

Source: AIDER 2005

The information presented in Table 1.2 was generated through forest inventories, which are the basis for management and harvesting plans. The basic criteria defining volumes to be harvested and cutting cycle lengths as part of the management plans were the following: i) harvestable trees that usually exceeded minimum harvesting diameter[1] (MHD); ii) volume and growth rates of commercial trees; and iii) tree mortality (Fredericksen 2000, Dauber et *al.* 2005). However, one of the major difficulties that forest managers face is the lack of basic information about species description and ecology, including growth rates (Silva et *al.* 1995). Because of this, decisions about forest management are generally based on assumptions about growth rates and minimum harvesting diameters for timber species. Because of the practices implemented in managed areas, one of the key problems in maintaining productivity over the long term is the futility of recovering the initial forest conditions according to the planned cutting cycles (Silva et *al*. 1995, Pearce *et al.* 1999). This aspect has been commonly analysed in forest areas subjected to timber management under technical guidelines, where inventories are carried out and logging blocks to be logged annually are defined in relation to the forest management area. For instance, nearly 80% of commercial timber species were not regenerating at levels sufficient to replace harvested trees in an area subjected to forest management in Bolivia (Mostacedo and Fredericksen 1999). Another instance of timber management in Bolivia painted a similarly pessimistic picture, suggesting that in the absence of silvicultural treatments, cutting cycles of 50 to 60 years may be required to maintain today's already low (5–15 m3/ha) cutting volumes (Fredericksen et *al.* 2003). In the Brazilian Amazon a major concern is the yield of harvested timber species, which may recover to less than 50% between the first and second harvest (Putz

[1]Minimum Harvesting Diameter is the minimum diameter limit to harvest a tree, as part of a management plan. This value is defined according to the ecological characteristics of the timber species, specially related to the reproduction age.

et *al.* 2012). However, it should be considered that for a second cycle, new species will surely be incorporated to increase the potential volumes.

In addition, costs and benefits also influence decisions to manage forest areas. Viable transport distance is a factor that influences the cost structure directly. In this sense, for any given level of demand, logging will expand out to the point where the rent (return) for this type of land use is zero; lower transportation costs through better roads obviously push this point further into the primary forest (Bauch et *al.* 2007). In fact, Zuidema (2000) stated that commercial logging has not been very intensive in the Bolivian Amazon due to the lack of roadway infrastructure. The same logic is applicable to other factors of production, such as logging and milling. Under these scenarios, the quality of timber resources is usually a key factor, since only more valuable species can pay for the higher extraction and transport costs associated with remote locations (Gatter and Romero 2005).

Another aspect of the efficiency of forest operations in timber value-added chains is related to the technologies applied. Obsolete technologies and inefficient production chains affect financial returns, which in turn affect the prices of the raw materials provided for smallholders. For instance, Smith et *al.* (2006) stated that enterprises located in the Pucallpa region have determined that there are a low number of species to harvest with major potential commercial values, which additionally jeopardizes the hopes for a sustainable forest management.

Given the rate of degradation of natural forests, ample possibilities exist for management of secondary forests (Ewel 1980). This is true even though wood properties of typical secondary forests´ species are characterized by lower densities and less natural durability than most species in primary forests. They also usually contain fewer commercially viable trees (Emrich et *al.* 2000). Characteristics such as high rates of productivity and uniform composition of tree species have been isolated as aspects that facilitate their management (Wadsworth 1987, Finegan 1992), as have fast growing timber rates in comparison to tropical timber plantations (Wadsworth 1993). A final factor that influences the economic feasibility for management of secondary forests is the presence of light demanding commercial species (Finegan 1992).

1.3.2.1 Ecological effects of forest logging

Logging practices in the Amazon have commonly been confined to a limited number of species with different impacts on forest structure and composition (Kammesheidt 1998, Mostacedo and Fredericksen 1999, Summers et *al.* 2004, FAO 2005). In most cases, logging started with the more valuable species such as mahogany (*Swietenia macrophylla)*, cedar (*Cedrela odorata)*, and tumi (*Amburana cearensis*). Once these species had been depleted, new species were incorporated into the production systems and timber markets. One practice that aided this process is selective logging, which is defined as the logging of the most important timber species while allowing the remaining forest to naturally regenerate over time (Bawa and Seidler 1998). In this context, it is also important to understand the term degradation, which refers to "the reduction of the capacity of a forest to provide goods and services" (FAO 2003). However, the term should be explicitly defined depending on the context. For instance, modification of forest structure and composition as result of silvicultural interventions is the result of timber management in natural tropical forests (Putz and Romero 2015). Therefore, under this context this practice will not be considered degradation.

The effects of logging on forests depend on several factors, including basal area removed, canopy opened, number, abundance and ecological characteristics of the species logged, site characteristics, and methods of logging and extraction (Kariuki 2004). Timber logging impacts ecosystem services and biodiversity. For instance, an analysis of 22 studies on carbon stocks suggested that, soon after logging, stands retained about 76% of their above-ground live carbon, with a high variation in carbon retention, depending on logging intensities (Putz et *al.* 2012). Impact on biodiversity is also a key analytical aspect in sustainable forest management; however, such analysis is not part of this study. Other studies argue that some practices of selective logging have the potential to cause little disturbance and are suited to regenerate the stock of commercial species (Vanclay 1990, 1996a), or even to increase species richness (Sheil 2001). Others state that selective logging practices provoke the depletion of the species logged, resulting in residual forests without commercial value (Gullison et *al.* 1996, Nepstad et *al.* 1999). Mostacedo and Fredericksen (1999) reported a scarcity of regeneration for many commercial trees species in private concessions. This paucity can be partially explained by the fact that many tree species in tropical forests occur in low densities—normally less than one adult tree per hectare—and by the lack of knowledge of the ecological characteristics and regeneration processes of the species logged (Schulze *et al.* 2008).

One effect of logging practices is a change in forest composition, wherein shade-tolerant species and stimulating light-demanding species are reduced (Oliveira et *al.* 2005). Normally, these species fill the gaps by stems of non-commercial species in approximately two thirds of the population (Fredericksen and Liconia 2000). Silva et *al.* (1995) found a large percentage of the light-demanding *Inga* sp. and the maintenance of the *Ocotea* sp. in forests subjected to experimental logging thirteen years after harvesting. Aguirre (2007) also reported an abundance and dominance of the light-demanding *Aniba* sp. in smallholders´ logged forests in the southern Ecuadorian Amazon, indicating a favourable response to the practices applied by smallholders. Considering the increased dominance of long lived pioneer species in logged areas, subsequent harvests have to deal with a different composition of commercial species.

Regenerating the capacity of forest structure and composition to pre-harvest conditions depends on time, basal area removed, and species logged. A subtropical forest located in northeast New South Wales in Australia was subjected to different logging levels that varied from 33% to 78% of the basal area removed. After thirty-five years, low intensive logged forests have recovered the same levels of basal area and stems as the primary forest, but in the most intensively logged areas, the structure has not recovered its previous logging levels (Kariuki 2003, Smith and Nichols 2005). However, depending on the structure, composition, ecological characteristics of species logged, and management considerations, exploitation may result in the disappearance of the species, as in the case of mahogany, which has been depleted from some regions in the Amazon (Schulze et *al.* 2008).

1.3.2.2 Forest Management approaches

To increase the intelligent use of forests, different actors linked to forest management and conservation have developed and promoted the application of different concepts and systems. The first concepts developed to promote sustainable forest management were sustainable timber management (STM) and sustainable forest management (SFM) (Pearce et *al.* 2003). STM implies a management system that aims for sustained timber yields to ensure the future supply of wood. Investment in regeneration is key. It is also associated with the minimization of damage to residual stands, possible investment in finding uses for non-merchantable species, and accelerated growth of merchantable species in managed stands (Vanclay 1996a, Pearce et *al.* 2003). SFM integrates a system of forest management that aims for sustained yields of multiple products and services from the forest (ibid). The term conventional logging (CL) is defined as the common logging practices that are focused on short-term yield and income and are less concerned with forest regeneration through management. There is usually no government control (ibid).

More recently, new schemes have been devised to minimize the impact of logging on forest structure and composition as part of the application of the concept of sustainable timber management. Reduced impact logging (RIL), for example, refers to a set of pre- and post-logging guidelines designed to protect advanced regeneration from injury, minimize soil damage, prevent unnecessary damage to non-target species, and protect critical ecosystem services (Putz *et al.* 2000). Selective logging refers to the extraction of a limited number of trees in forest areas (Asner et *al.* 2005).

Considering these concepts, several institutions have developed trials, guidelines, and systems for sustainable management of forest resources (ITTO 1992, Sist 2000). Table 1.3 demonstrates data from management plans carried out in different regions of the Amazon according to the different norms and rules of respective countries for sustainable timber management. Information about volume removed, number of trees, and species logged has large variations between different regions and countries, which is related to the commercial species and their abundance. The values of volumes harvested are as low as 12.7 m^3 ha^{-1} in Bolivia and as high as 55.6 m^3 ha^{-1} in Pueblo Nuevo, Peru. There are also large variations between regions in terms of the number of trees removed, ranging from 4 to 16 trees per hectare, as well as in terms of the number of species logged, which vary from 14 to 38.

Timber management in the tropics is a relatively recent activity, considering that second-cutting cycles are only now being assessed in terms of possibilities for long term management (de Avila et *al.* 2017). To reflect on the future of timber management in the tropics, it is important to look back and analyse the results of the two last centuries of timber management in temperate forests. This has mainly consisted of intensive managed operations focused on increased commodity production (mostly of wood) and on favouring the production of even-aged single-species (Puettmann et *al.* 2015). However, in the last three decades some alternative management regimes have been introduced to answer concerns about the ecological consequences of intensive forestry practices. These alternative schemes (e.g. close to nature forestry, ecological forestry, multipurpose forestry) are based primarily on the provision of a broad range of goods and services, including product extraction (see Puettmann et *al.* 2015 and references within).

Table 1.3 Comparison of logging intensities in timber management plans in the Amazon region.

Location	Timber practice	Volume removed (m^3 ha^{-1})	Trees removed (N ha^{-1})	Species logged (N)	Source
Brazil	STM	35.0 – 40.0	--	--	Barreto et *al*. (1998)
Bolivia Different regions	STM	11.8– 18.8	--	--	Dauber et *al.* (2005)
Ecuador – not specified	STM	16.4	--	--	Tandazo and Gatter (2005)
Ecuador – not specified	SMP	14.5	4.0	--	Tandazo and Gatter (2005)
Brazil	STM	21.0	6.0	--	Sist and Ferreira (2007)
Brazil - Mato Grosso Rondonia and Roraima	SL	21.7- 26.6 and 21.4	--	--	Asner et *al.* 2005
Peru (Pueblo Nuevo)*	STM	55.6	10.7	18	AIDER 2004
		19.2	5.4	12	
Peru (Junín Pablo)*	STM	34.7	--	15	AIDER 2004
		39.7	--	11	
Peru (Curiaca del Caco)*	STM	28.7	11.0	14	AIDER 2004
		30.7	9.9	12	
Puerto Belén*	STM	--	3.1	--	AIDER 2004
		--	2.8	--	
		--	3.8	--	
Peru (Callería)*	STM	40.8	9.7	19	AIDER 2004
		41.5	12.2	16	
Peru (Preferida)*	STM	47.6	10.1	14	AIDER 2004
		44.1	8.3	9	
Bolivia Loma Alta*	STM	17.2	--	24	IPHAE 2007
Bolivia 12 de Octubre	STM	12.7	--	38	IPHAE 1999

STM: Sustainable Timber Management, SMP: Simplified Management Plans, SL: Selective Logging, *Proposed in Sustainable Management Plans.

Despite efforts to promote occidental science-based schemes through development projects, to date only a fraction of the total tropical forest area is under sustainable management (Bowles et *al.* 1998, Putz et *al.* 2000). The main reason is probably that conventional logging is still more profitable in the short term (Hammond *et al.* 2000) and that financial incentives to adopt sustainable management practices (for instance certification) are still not sufficient (Pearce et *al.* 1999). For example, unrestricted logging of mahogany may be between two to five times more profitable than logging with sustainable plans (Rice et *al.* 1997).

There is a consensus that smallholders are not able to meet the legally imposed requirements for the management of their forest areas due to aspects related to technical guidelines (principally inventories, management and cut annual plans) and costs for planning and logging operations (Pacheco 2012). In this sense, community forestry has been proposed as an option for smallholders to manage their forests and improve rural welfare as well as mitigate undesired impacts of forest conversion on the environment (de Jong et *al.* 2010a). This scheme is viewed as an alternative for the development of communities that inhabit forest areas where they are expected to form enterprises to harvest, process, and sell timber from their forests in market niches as high-value, preferably certified, timber (Scherr et *al.* 2004, Medina 2008). Nevertheless, to date only a few successful examples from Mexico and Central America have been identified because of strong support of external organizations. These are areas where communal business organizations have been built on existing structures for community and political-legal organization (Stoian 2009).

In recent years, due to the modest success of community forest management initiatives, governments have changed policies to control timber harvesting with the intention of promoting smallholders' participation in timber activity. In the case of Ecuador, a basic scheme was established in 2005 for timber logging based on minimum distances between trees to be logged (inventories are not needed), minimum cut diameters, and allowing the use of chainsaws in the forest to transform round wood into planks (MAE 2010b). More recently, the Brazilian government established norms for small-scale sustainable forest management plans (PMFSPE), a new category for low-intensity management in the state of Amazonas. This category of management plan accounted for 85% of the approved management plans in Amazonas in 2009 and 2010 (Amazonas SDS, 2010). Discussions are underway to make the plans more consistent with the reality of the smallholders whom the plans are intended to serve. To engage smallholders more actively in development and the protection of forests, the need has been stated to implement better policies and a shift in the policy frameworks adapted to their needs and capacities (Pokorny and de Jong 2015).

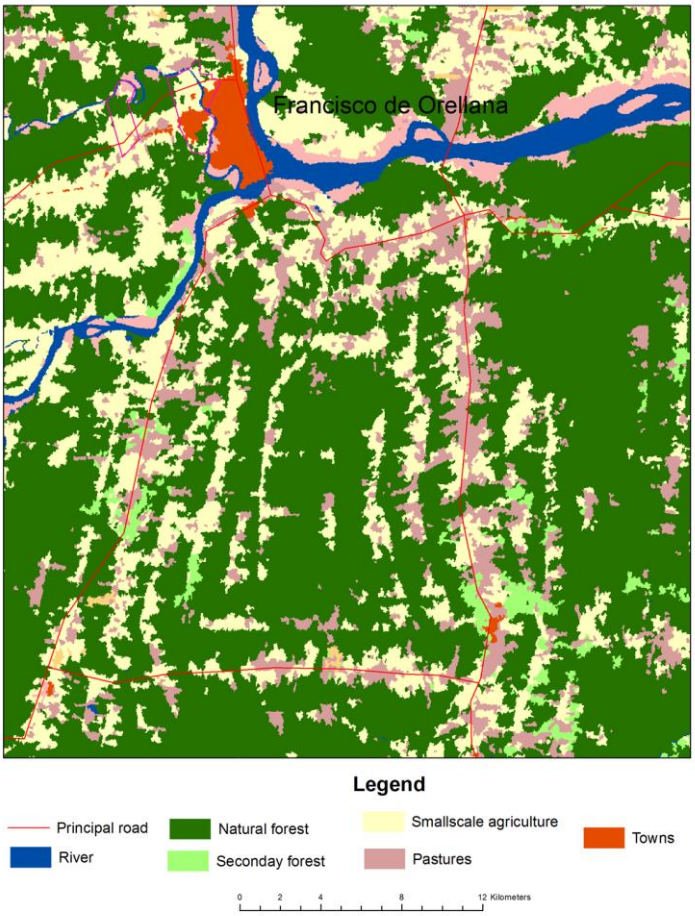
1.4 Smallholders in Amazonian forests

1.4.1 The role of forests in the livelihood systems of smallholders

Smallholders are composed of families or communities whose livelihoods depend principally on natural resources, usually in forests and agriculture. They face limitations on capital investments and specialized manpower for intensive production. Therefore, an important component of their livelihoods is normally based on diversified activities for subsistence. Smallholders include indigenous or quasi-ethnic groups, locally-born non-tribal residents, and recent migrants operating at independent units despite communal rights (Chibnik 1991, Pokorny and de Jong 2015). In tropical forests worldwide, smallholders own around 22% of land areas (White and Martin 2002), and it was expected that by 2015, close to 50% of forests in developing countries will be in their hands (Molnar *et al.* 2004).

Forests and trees are generally an integral part of smallholders´ production systems (Hoch 2009, Pokorny et *al.* 2010). In this way, the forest uses and crop cultivation in smallholders' plots lead to different land use types, from primary, logged, and secondary forests in different successional stages to agro-forestry systems, crops, and pastures (Moran et *al.* 1994, Yasmi and Gritten 2014; De Bruyn et *al.* 2014). The area of each land use unit changes according to different biophysical and socio-economical contexts, resulting in a complex landscape interspersed with patches of different land use units (D´ Antona and WanVey 2006). For instance, Amacher et *al.* (2009) reported that smallholders who obtained their lands through colonization programs continue to maintain more than 50% forest cover on their land. Figure 1.1 presents a typical example of a landscape managed by smallholders. This particular landscape was obtained through an agrarian reform implemented in Ecuador in the 1970s that gave around 50 hectares to each family. The area is in the northeast of Ecuador, next to the Yasuní National Park in the Amazon region. After more than forty years, forest cover represents more than 60% of that area (MAE 2010b).

Figure 1.1. Typical landscape managed by smallholders in the Amazon region dominated by primary, secondary forests, small-scale agriculture and pastures.

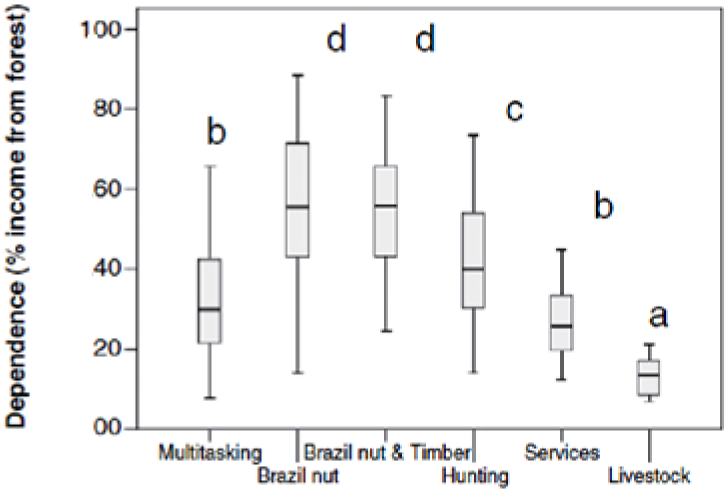


Source: Based on the map of forest use and cover (2008) of the Ministry of Environment of the Ecuador

Smallholders adopt different livelihood strategies according to their assets and other context factors (Ellis 2000, Zenteno et *al.* 2012). Livelihoods based on forest systems are related to the availability of means of production, natural forest area and richness, manpower capacity, and available time for market-based activities. These aspects determine the production capacity for timber or NTFPs. However, other equally important factors include an appreciation of the complexity of social systems in which communities are embedded—not only local culture, institutions, and livelihood systems, but also the broader socio-economic and political forces that determine the viability of forest management (Schmink 2004).

An illustrative case of livelihood strategies was presented by Zenteno et *al.* (2012), who found six different strategies in the region of Riberalta in the northeast of the Bolivian Amazon. Four were based on forest activities, one on livestock, and the last on services (manpower selling) (Figure 1.2). An important unique characteristic of that region is the abundance of the species B*ertholletia excelsa* Bonpl.*,* which produces the "brazil nut", for which there is a high demand in regional and international markets.

Figure 1.2. Degree of forest dependence of communities in the north - eastern of the Bolivian Amazon.



Source: Zenteno et *al.* 2012

In this region, two forest-based strategies (Brazil nut and Brazil nut and timber) are the principal incomes sources, contributing around 60% of household incomes respectively, which confirm that forest products constitute the main source of income (Padoch 1987, Sotian 2000). However, a review of 51 studies from 19 countries suggested that forests may contribute as much as 22% of household incomes (Vedeld 2007). A recent analysis reported that timber incomes in two provinces in the north of Ecuador are around USD$ 400 yr^{-1}, but with large differences between colonists and indigenous people (Mejía et *al.* 2015). Specifically, colonists are generating higher incomes due to better access to means of production. On average, these incomes represent 16% of the total income of at least six income sources. When incomes were reported in terms of USD$ ha^{-1} $year^{-1}$, there were also large variations between different regions and contexts. For instance, Pyhälä *et al.* (2006) reported a value of 1.37 USD$ ha^{-1} $year^{-1}$ as the net income obtained from commercialized forest products in a region close to Iquitos. In the Rondonia region of Brazil, smallholders obtained between USD$ 533 to 667 annually from the palm hearts in their forest areas, USD$ 76.3 from timber, and only USD$ 26 to 35 from the Brazil nut (Summers et *al.* 2004).

There is a consensus that household wealth and distance to markets have significant implications on forest dependency (Stoian and Henkemans 2000, Pyhälä et *al.* 2006). One common view contends that poor people use more natural resources because they depend more heavily on them for income generation, higher discount rates, and shorter time horizons (Pyhälä et *al.* 2006). When employment opportunities are few and labour is poorly paid, selling timber, even under unfavourable conditions, can generate attractive incomes for local households (Medina 2008). In addition, those communities that are closer to cities tend to depend more on cash income, and thus are strongly linked to markets, which has important implications with respect to forest use (Pacheco 2012). When smallholders take advantage of market opportunities in agricultural systems, the importance of forests will be reduced (de Jong 2010a, Zenteno 2012). This demographic also tends to convert their lands to establish crops or livestock due to benefits that are greater than forest activities (de Jong 2010b). A key point in terms of livelihood strategies is that a shift from a subsistence economy to a cash one based on markets will stimulate specialization to maximize economic opportunities (Ruiz-Pérez et *al.* 2004).

1.4.2 Smallholders and timber markets

The potential benefits that smallholders and communities obtain from their forests depend on their capacity to engage with timber markets and the market conditions under which they carry out their forestry operations (Pacheco 2012). Some aspects that favour their engagement are: sufficient and secure resources, access to attractive market schemes, effective collaboration between social and commercial networks, adequate and reliable public support, an adequate regulatory framework, and effective law enforcement, including the protection of rural dwellers against the interests of more powerful actors (Zenteno 2012, Pokorny et *al.* 2012). Other scholars suggest that market integration is not a panacea for improving forest users' livelihoods because many communities are no able to capture the economic benefits from their forests; instead, actors located downstream in the value chain capture most of the benefits (Pokorny and Johnson 2008).

However, in the Amazon in general, there are no reported cases of the integration of communities in market structures, and there are only a few instances where they have been able to trade raw material or semi-finished products directly. Most of them continue to sell their products to local intermediaries with little influence of their own on price formation. In fact, they hardly ever succeed in establishing trusting relationships with non-local market participants and therefore do not manage to receive more attractive prices for their products (de Jong et *al.* 2010a, Galloway et *al.* 2014). In other regions, it is reported that a small number of buyers control prices, putting community-based operations in a disadvantageous situation (Sierra and Negreros-Castillo 2014).

An example of favourable frameworks and attractive markets exists in Ecuador in the form of simplified management plans (section 1.2.3.1) and limited industrial-scale timber extraction. The interaction of these aspects has resulted in small-scale timber logging by smallholders (Messina et *al.* 2006, Mejia et *al.* 2015). In fact, on-site conversion of logs into planks using chainsaws is the main form of timber production by smallholders (Gatter and Romero 2005, Palacios and Malessa 2010, MAE 2010a, Mejia et *al.* 2015). For smallholders, it is usually a component of a diverse livelihood strategy, but for local chainsaw operators it can be a near full-time occupation, representing a substantial proportion of total household income (Wit et *al.* 2010). In this context, engagement in these markets changes the opportunities and strategies of forest-related people (Ruiz-Pérez et *al.* 2004).

However, favourable conditions are not common in other regions of the Amazon, because the timber production chain is a capital-intensive activity and market scenarios are very difficult for smallholders (Agrawal 2013). One restriction is the financial capital needed to engage in the activity; costs of compliance with management plans, logging, and transportation machinery all factor in heavily. These aspects give place to external and capitalized actors that enter their forest areas and capture most of the benefits generated. For instance, the timber industry, which maintains strong links with local sawmill owners and intermediaries, often tends to influence the final prices that are paid to smallholders and communities for their timber. In other cases, the presence of a large number of buyers enhances competition for timber (Pacheco

2012). Given these restrictions, Scherr et *al.* (2004) suggested that even where forest market conditions are favourable for smallholders, the poorest will benefit mainly as labourers for small- or medium-sized forest enterprises or from the employment multiplier effects of local forest development.

To support and promote the participation of smallholders in timber markets, four general strategies have been proposed:

i. The promotion of domestic markets, considering that they may be more important than international ones (Sierra 2001) because they demand a diversity of products, are nearer to forest areas, which allows some easily perishable edible products to reach consumers faster (Sunderlin et *al.* 2008, Molnar et *al.* 2004), are less demanding in terms of quality, and do not face the same level of legal barriers as international markets (IFAD 2003). For instance, Uhl and Guimaraes-Vieira (1989) estimated that less than 20% of the sawmill production centred in the Brazilian Amazon was bound to international markets and 80% was feeding into local or regional markets. In fact, local sales of low-value wood products and NTFPs with stagnant demand can play an important role in the livelihoods of forest dwellers.
ii. The establishment of partnerships between forest companies and smallholders to equitably negotiate access to forest areas (Scherr et *al.* 2004). However, this point depends greatly on business decisions regarding social responsibility, and therefore these decisions should be carefully analysed. Some experiences demonstrate that company-community forestry partnerships work best with government support and when communities have strong claims to their forests (Mayers and Vermeulen 2002).
iii. The involvement of smallholders in value-added chains, since they usually participate only at the bottom of the supply chain, which results in the generation of marginal incomes (Scherr et *al.* 2004*)*.
iv. The participation of niche or ethical markets like fair trade, for which local producers have, or could develop a competitive advantage. In some of these market niches it makes logical business sense for forest industry and investors to work with local producers (Scherr et *al.* 2004). A recommendation to raise incomes significantly is to analyse the value-added chains in the market and establish a competitive position.

1.4.3 Smallholders and timber practices

Several operational characteristics distinguish smallholder timber enterprises from the large-scale commercial timber industry (Rockwell et *al.* 2007). The characteristics and limitations that smallholders face to entering timber markets and timber production chains were described in section 1.3.2. These limitations result in the specific timber operational characteristics highlighted in Table 1.4. In general, there are large differences between the industrial practices normally applied by commercial timber industry and smallholders' timber enterprises. The principal factors differentiating the two groups are the ownership of resources and entrepreneurial capacities. Whereas external industrial actors normally obtain their timber resources via concessions and live off-site, smallholders own the forests and timber resources. In fact, in most cases, they live within their forests, and depending on their livelihood strategies, those forests may be their principal source of income.

Table 1.4 Generalized operational characteristics distinguishing smallholders' timber enterprises from large-scale industrial operations.

Characteristic	Industrial	Community/Smallholder
1. Ownership	Usually buy logging rights via concession May own land, but live offsite	Timber harvesting rights owned or held by local inhabitants
2. Degree of timber focus	Timber sole income-generating activity and management focus	Timber part of integrated livelihood system
3. Scale and intensity	Capital intensive techniques Usually higher harvest volumes Heavy machinery	More reliance on local labour Lower harvest volumes More use of animal traction
4. Added value	Harvested round wood usually transported to offsite-processing sawmill	Often seeks to add value to lumber onsite
5. Start-up capital	Good access to start-up capital	Rarely has access to start-up capital
6. Investment of profits	Profits moved to other localities	Often retained for local reinvestment
7. Management and governance	Management decisions usually not locally-defined Typical have better connections to central power	Traditional, locally defined management Greater awareness of local threats to forest
8. Value of forest to future generations	Long term investment (if any) based on future profit interest	More likely to view silvicultural activities as impacting future regeneration
9. Technical knowledge base	Details for successful management plan often based on outside technical norms and expertise	Traditional ecological knowledge of resources based on daily observations processed through many generations
10. Commitment to forest conservation	Sustained timber yield for next cycle usually primary motivating factor	Practical consideration of livelihood and sometime aesthetic values drive interest in forest conservation

Source: Rockwell et *al.* 2007.

Aspects such as type of practices applied, logging intensities, technologies used, manpower abilities, and investment of benefits are relevant with respect to the capacity to generate financial benefits, the effects on forest structure and composition, and the quality and capacity of the residual forests to recover timber productivity in the long term. Timber logging practices applied by smallholders are normally characterized by the use of local manpower, lower harvested volumes, and the use of animal traction, and normally they are limited to the processing of lumber in dimensioned planks or beams to be transported to accessible areas (Rockwell et *al.* 2007).

The importance of traditional practices and the local knowledge that smallholders apply during their timber activities is also an important aspect. In this sense, smallholders tend to promote regeneration of useful trees and other management practices passed down through generations. Normally, this local knowledge has been integrated with science-based technologies through developing a vertically integrated local industry based on locally developed knowledge and expertise of specific forests and management of ecological processes, individual observation, and experimentation, as well as concepts and practices derived from temporary employment by large-scale industrial timber firms (Sears et *al*. 2007). An example of this type of local experience was provided by Sears et *al.* (2007) in the region of Amapa in Brazil, where local farmers have themselves integrated exogenous technology and knowledge which they gained while working for the large-scale timber industry with their own local knowledge of the environment and their own silvicultural practices. In this case of hybridity, these local farmers have developed a successful local industry based principally on saw-millings of around 24 fast-growing species and management of the timber resources of their forest areas.

1.5 Objectives and research questions

Despite important efforts to find effective mechanisms of forest management according to the needs, opportunities, and constraints of smallholders' livelihoods, the results have been modest. The previous three sections have identified the present state of knowledge of the possibilities that smallholders have to manage their forest areas given the market opportunities that have emerged as result of the development of the region. The most important aspects to highlight are the following: 1) smallholders are one of the most important actors, given the vast areas of forest resources in their hands; 2) new opportunities have been proposed to increase income generation from smallholders´ forest areas, given the growing market opportunities and access to forest resources; 3) timber has been identified as the most important forest product under favourable context factors; 4) the actual technical schemes of forest management have been difficult to apply to smallholders´ livelihoods, given their limitations of capital and technical capacities, which in turn have defined their dependence on external actors, reducing the potential benefits they can obtain from forests; 5) given the different scenarios in different places within the Amazon, comparative analyses are needed to understand more clearly the influence of different factors on the benefits that smallholders obtain from forests. These aspects should guide any research focused on finding real and viable solutions for the sustainable forest management in the Amazon.

The following research aims to contribute to a better understanding of the characteristics of smallholders' logging practices in the Amazon and the potential that forests offer those groups to generate monetary benefits under different contexts. Four research questions were formulated using information collected in four study areas in the Amazon.

What possibilities do smallholders have to engage in timber markets?

What is the commercial potential of primary and secondary forest areas?

What are the effects of smallholders' logging in forest areas?

What are the possibilities for long-term management of timber resources?

2 MATERIAL AND METHODS

2.1 Analytical approach

Despite efforts to find effective mechanisms of forest management according to the needs, opportunities, and constraints of smallholders` livelihoods, results have been modest. An integrative analysis is required to find answers to help smallholders take advantage of their opportunities. This sort of analysis must include market dynamics and trends, commercial potential of forest resources, physical accessibility to forest areas, and smallholders' logging strategies (Scherr et *al.* 2004). However, the complexity of such an extensive analysis that includes too many variables has been highlighted by Ostrom (2010).

Given the different scenarios in various parts of the Amazon, comparative analyses between different study areas are needed to understand the influence of different factors on the benefits that smallholders obtain from forests. For instance, compared to the remote areas of the Amazonian plain, Amazonian highlands in the Andean countries are located relatively close to large cities such as La Paz, Lima, and Quito. These different locations affect the commercial potential of forests because of they create lower transportation costs and better access to markets. Additionally, landscape conditions such as slopes and forest composition also influence the possibilities of commercial potential. For instance, the most valuable tree in the Amazon—mahogany—does not occur in the highlands.

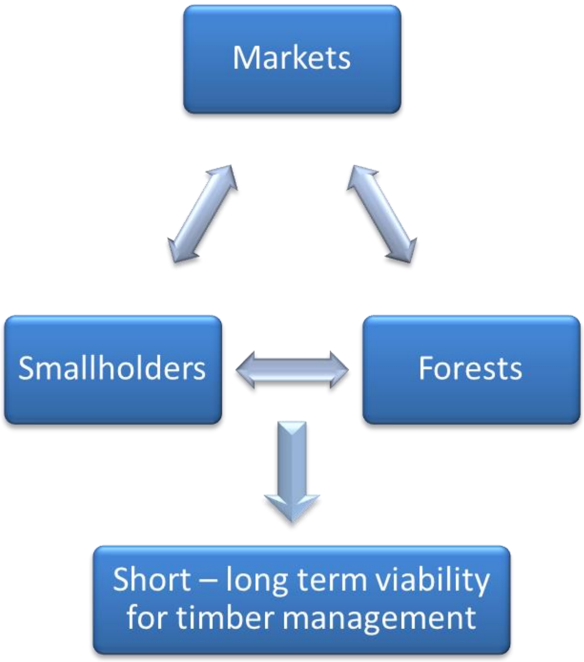
Given these aspects, three countries with four specific study areas were selected for a comparative analysis. This analysis used different contexts and specific factors that included market and forest characteristics and smallholders´ management practices. The role of smallholders in timber markets was assessed through a market and value-added chain analysis. Forest inventories were carried out to assess the commercial potential of forests and also to analyse the effects of logging on smallholders' forests. In addition, projections of timber productivity in differently logged areas were performed using single simulation models to determine the management viability of smallholders´ forests according to their management practices. The potential of secondary forests was also assessed in terms of marketable species that regenerate in these stands.

The following research is focused on endogenous timber management practices in forest areas managed by individual smallholders, since there are no reported cases of forest management at the communal level.

2.1.1 Analytical framework

Given the specific research questions, it was necessary to define an integrative analytical framework. Three fundamental aspects that influence the possibility of managing forests in the long term were considered: markets, smallholders, and forests (Figure 2.1).

Figure 2.1. Analytical framework to analyse smallholders´ timber logging in the Amazon.



A market and value-added chains analysis became the starting point to understand market characteristics, which actors were present, and the role of smallholders. Market characteristics determine the potential commercial of forests, resulting in different logging strategies being applied to smallholder forests. The characterizations of these logging practices include the inputs used for logging, the use of family manpower, and time invested in the activity. A typology of smallholders was performed to understand their strategies regarding the use of their forest areas.

The analysis of the forest resources included a characterization of smallholders´ plots in terms of the size of forest areas (primary and secondary). Through forest inventories and analysis of market prices, commercial volumes were calculated. To better understand the short-term effects of logging on structure and composition of forests, both primary and logged-over forests were compared.

Possibilities for long term management of forests were analysed through an integration and synthesis of the results of market, smallholders, and forest analysis. The analysis of long term possibilities for timber management was performed considering forest areas, logging rates, timber productivity, and potential financial incomes from forest areas under different scenarios of potential commercial volumes, logging intensities, and distance of logging areas to markets.

The analytical framework considered interactions between the different components. In the first instance, markets defined the species demanded and smallholders applied different strategies for timber logging, affecting forest productivity and increasing the scarcity of certain valuable species. As a result, markets responded through price adjustment or by incorporating new species into production systems. These interactions defined the possibilities for short- and long-term viability of timber management.

2.1.2 Study regions

Bolivia, Ecuador, and Peru make up a large part of the western Amazon and contain large swathes of tropical forests. Smallholders in these regions depend to varying degrees on forests to meet their daily livelihood needs and extract forest products, including timber (Pacheco et *al.* 2016). Forests cover 49 million ha in Bolivia, 11 million ha in Ecuador, and 73 million ha in Peru (FAO 2010). Smallholders own a significant amount of forest, but part of their territory usually overlaps with protected areas. The contributions of forestry and smallholder forestry to the national economies in Bolivia, Ecuador, and Peru vary. The formal contribution of forests to total gross domestic product consists mostly of the production and trade of timber and comprises about 3% of the Bolivian GDP, 2% in Ecuador, and 1% in Peru (ITTO 2011).

In Bolivia and Peru, most of the timber supply originates from forests in the Amazon, which are abundant compared to the poorly developed plantations in these countries. In contrast, Ecuador produces much more timber in plantations than Peru or Bolivia. Timber from plantations is complemented by timber from the country's Amazon native forests. A large portion of the timber extracted by smallholders from native forest in the three countries originates from the Amazon. Ecuador has a relatively well-developed industrial sector that sources its raw material for briquettes and plywood from timber plantations located in the highlands and coastal zones. In addition, an important small-scale artisanal sector in the Ecuadorian Amazon involves smallholders who supply timber for construction and furniture manufacturing to the main urban centres (Mejía et *al.* 2016).

In Bolivia, about 41.2 million hectares of forest have been declared as lands for permanent forest production. This area comprises several tenure regimes: Indigenous lands, individual landholdings, public forests under concessions (including concessions assigned to local social groups) and public forestlands without classification. An area of 28.1 million hectares are classified for sustainable forest production without restrictions, 2.4 million hectares are classified as potentially productive but reserved for recreational or other non-timber use, and the remaining 10.7 million hectares are classified as legally protected areas (ITTO 2011). Currently, about 11.4 million hectares of land have formally been granted to Indigenous peoples (National Institute for Agrarian Reform 2010), not all of which is forested. The number of tree species used for timber production has been estimated between 240 and 303 (Dauber 1999).

Ecuador has not defined a Permanent Forest Production and there are not forest concessions, but there is a clear distinction between forests for (potential) production and forests for protection, and the latter are clearly delimited. The Government of Ecuador (in 2009) estimated the total area that is potentially used as production forest at 4.51 million hectares and the total area of protected forests at 6.55 million hectares, but the production forest area that can be considered as permanent forest estate is only about 2 million hectares (ITTO 2011). Most timber harvesting from natural forests is done on Indigenous and small-farmer community lands and private lands. Legal harvesting is carried out principally on two kinds of permit: Simplified Forest Management Plans, which mainly involve non-mechanized extraction, and Sustainable Management Plans, which involve relatively large areas that are suitable for industrial harvesting (Mejia et *al.* 2016).

Peru considers the following categories of forests: production forests (permanent and in reserve); forests on protection land; forests for future use (plantations, secondary and degraded for restoration); natural protected areas; forests in Indigenous and rural communities; and local forests. Permanent production forests are intended for timber and non-timber production and the conservation of forest resources, and an approved forest management plan is required. As of 2010, 33.3 million hectares of permanent production forests had been classified within the PFE. However, only an area of 18.7 million hectares has so far been allocated for production purposes (Kometter 2010). More than 1,354 Indigenous communities are known to make their living in the Peruvian Amazon, occupying about 14.95 million hectares or 17% of the total area of the Peruvian Amazon. Their livelihoods are closely interlinked with forests. An estimated 13.5 million hectares of potentially productive forests are in areas claimed by Indigenous peoples and about 1.75 million hectares are located within Indigenous reserves.

These three countries share large similarities in terms of cultural, economic and biophysical aspects and at the same time show particular conditions regarding their forest sectors. In this sense, four regions in three countries were analysed in this study. These areas presented different contexts in terms of market characteristics, structure of timber production, and accessibility conditions (Figure 2.2). The study regions were located in northeast Bolivia, in the Beni region surrounding Riberalta city; in the south-centre of the Ecuadorian Amazon in the Morona Santiago province, in the surroundings of Macas city; and in the centre and south of the Peruvian Amazon in the Ucayali region close to Pucallpa city, and in the Madre de Dios region and in the surroundings of Puerto Maldonado city respectively (Figure 2.2).

Figure 2.2. Location of the study regions.

2.1.2.1 Riberalta, Bolivia

Biophysical characteristics

The climate in the region is characterized by an average rainfall of 1,700-1,850 mm, an average annual temperature of 26º C, and a pronounced dry season from May to September with <100 mm rain per month (Beekma et *al.* 1996). A considerable number of tree species are deciduous during the dry season. Soils in the non-flooded forests are generally xanthic or haplic ferrasols (DHV 1993). Non-flooded forests in the region have been classified as semi-evergreen tropical forests, although other descriptors have also been used (e.*g.* Amazonian lowland moist forests; CDC - Bolivia). Forest cover in the region is very high, as timber logging and agriculture have not been practiced at a large scale (DHV 1993). Canopy height of forests in the region amounts to 25-35 m, with emergent trees attaining heights of up to 45 m. Tree diversity (trees >10 cm diameter at breast height) in these forests amounts to 80 species per ha., which is relatively low compared to other Western Amazonian forests (Porter et *al.* 2000). *Bertholletia excelsa*, the Brazil nut tree, is an important structural element in Northern Bolivian forests, as it is an abundant emergent that often accounts for a large proportion of total basal area (DHV 1993).

Socio-economic characteristics

Riberalta hosts a significant proportion of forest enterprises of the two departments of north-eastern Bolivian Amazon, Beni and Pando, with 36 forest enterprises registered. In 2006, 46,457 ha of forest were approved for management. Of that, 1,237 ha were covered by annual operative plans with an authorized extraction volume of 63,285 m3 (UOBP 2006).

Commercial logging of timber has not been very intensive in the Bolivian Amazon due to the lack of roads and the low prices of timber. In addition, during the so-called "ecological pause" (*Pausa Ecológica Histórica*) from 1990-1995, no new forest concessions were issued. As a result, timber exploitation has been focused on high-valued species whose logs can be transported by river. Nowadays, there is a tendency to exploit more species for timber, as the road network is gradually expanding and improving. Furthermore, taxes for concessions that were applied under the new forest law of 1996 are paid on an area basis, stimulating the extraction of timber from more species to use the allocated forests more efficiently (Zuidema 2000).

The regional economy depends heavily on forest products. The contribution of forest products to the total monetary income in the Bolivian Amazon is over 60% (Zuidema 2000). The region is inhabited by 130,000 people, of whom 80% live in the three larger towns (Riberalta, Guayaramerín, and Cobija). Most inhabitants derive their income from forest products—mainly Brazil nuts, timber, and palm hearts. The human development index for the region is low (0.50-0.55), reflecting the fact that a large percentage of the population live under the poverty line (UDAPSO/PNUD 1997).

2.1.2.2 Macas, Ecuador

Biophysical characteristics

This study region is located in the highlands of the Amazon basin, in the fluvial valleys between the borders of the Andean and Cutucú mountain chains (Rudel and Horowitz 1996). The altitude varies between 1200 and 1400 m.a.s.l., with an annual precipitation of 2000 to 3000 mm and a dry season that oscillates between one and five months, with 10 to 68 dry days (ECORAE 2001). The annual average temperature ranges from 21 to 25^{o} C. The soils are of volcanic origin and categorized as hydrandepts (ibid). Approximately 67% of the total area is covered by natural vegetation (ECORAE 2001)

According to Sierra (1999), the vegetation type falls under the category of evergreen low-mountain forest, and it covers an undulating landscape of small hills. The ecological characteristics vary, resulting in a fine-scale pattern of species composition and different land use strategies by smallholders. One of the most important climatic characteristics is the absence of a long dry season, which eliminates the possibility for the slash and burn cultivation practices that are otherwise common in the lowlands of the Bolivian and Peruvian Amazon.

Socio-economic characteristics

The population of the Morona Santiago province is approximately 115,000 with a density of 5 inhabitants per km^{-2}. Approximately 41.3% of the population of the Morona Santiago province are indigenous people, mainly of the Shuar ethnic group (INEC 2001).

In this province, there are only small sawmills that process timber for local markets, and therefore most of the timber is commercialized in the regional industry located in the Andean region in the south of Ecuador. In 2011, the Ministerio del Agricultura reported an extracted volume of approximately 5,000 m^3 in the province for the year (MINAG 2011). However, owing to illegal logging practices, the true total extracted timber is likely twice as high as officially reported (Walter Palacios, personal communication). The principal economic activity in the province is cattle ranching for meat production. For that reason, approximately half of the total area in the Ecuadorian Amazon region is covered by pastures (ECORAE 2001). NTFPs for markets are insignificant in the region.

Indigenous inhabitants have practiced shifting cultivation, meaning that they clean small plots to produce a short cycle of crops, principally cassava, corn, and banana. After a period of around 3 years, these are abandoned to restore soil fertility.

2.1.2.3 Pucallpa and Puerto Maldonado, Peru

Biophysical characteristics

Pucallpa and Puerto Maldonado are located in the lowlands of the Amazon region. The geomorphology around these two study regions is principally composed of low river terraces, normally flooded during the rainy season, medium terraces, and small hills (Pizarro 2001). The temperature in the Pucallpa region ranges from 23 to 25^{o} C, with an average precipitation of 1,800 mm $year^{-1}$ (AIDER 2012). The dry season occurs between June and August, and the rainy season between November and March. Meanwhile, in Puerto Maldonado, the temperature ranges from 23 to 26° C, the precipitation varies from 1,900 to 3,000 mm year^{-1}, and the altitude varies from 200 to 300 m.a.s.l. (Lanao et *al.* 2005). The forest type in both zones is categorized as tropical moist forest (AIDER 2012, Lanao et *al.* 2005). The soils in the study region of Puerto Maldonado are deep, extremely acidic, have a clay-like texture, and are classified as inceptisols (Egoavil 1989).

In flood plains, soils are typically fertile with a high content of available nutrients due to the periodic inputs of fluvial deposits (Nebel 2001). Forests in these areas have considerable growth rates and relatively high net primary production, suggesting a large potential for wood production (Nebel 2001).

Socio-economic characteristics

Pucallpa city is the capital of the Ucayali department and is located in the centre of the Peruvian part of the Amazon, about 800 km from Lima. This city has quality road access, especially when compared with regions such as Puerto Maldonado, which is connected with the Andean region only by a dirt road network that is not passable during the rainy season.

The Ucayali region is the main wood provider for Peru, with 30% of the national harvest coming from there. With 40% of processed wood (parquetry and laminates) emanating from this region (INRENA 2005), Pucallpa is also the biggest timber processing centre in the country (Smith et *al.* 2006).

The Ucayali department has around 300,000 inhabitants, a large proportion of whom depend on the forest industry. The people living in forests depend on them as their principal source of income. This dependency ranges from pure commercially-based extraction of marketable products to various subsistence operations such as fishing, hunting, or collecting forest products. The preponderance of uses of natural resources is connected to the high habitat diversification, since different forest types provide possibilities for various activities. This phenomenon is enhanced by the often-high density of the resources (Nebel 2001).

Table 2.1 summarizes particular biophysical and socio-economic characteristics of the regions in the three study countries of the Amazon. Riberalta is the most isolated region when compared to the other regions, in terms of accessibility conditions, socio-economic characteristics and timber markets dynamics. On the other side, Macas is the nearest town of principal timber markets that demands a variety of timber products used principally in construction segment. In addition, other dynamics including colonization programs and population growth dynamics have resulted in the fragmentation of farms up 5 hectares. These aspects influence the dynamics of each region in terms of terms of timber markets and pressures to forest resources.

Table 2.1 Physical and socio-economic characteristics of the study regions in three countries of the Amazon.

	Riberalta, Bolivia	Macas, Ecuador	Pucallpa and Puerto Maldonado, Peru
Market characteristics	Few buyers, principally primary timber enterprises or traders connected with enterprises	Many traders connected with local sawyers or small and medium timber enterprises in regional cities	Few buyers, principally wood enterprises or traders connected with enterprises
Property rights of forest areas	Communal areas in hands of indigenous or traditional inhabitants	Communal areas in hands of indigenous inhabitants	Communal areas in hands of indigenous inhabitants
	Forest concessions to wood enterprises for sustainable forest management	No forest concessions Individual plots assigned to colonists	Two types of forest concessions: less than 1.000 in hands of small producers and greater than 1.000 in hands of medium or big landholders
Individual smallholders` forest areas	40 – 100 hectares. Presently 500 hectares are being delivered to smallholders as part of the agrarian reform	5 to 100 hectares depending on site, and accessibility.	40 – 100 hectares
Accessibility to regional markets	48 hours to La Paz	12 hours to Cuenca and other important markets	Pucallpa: 24 hours to Lima Puerto Maldonado: 72 hours to Lima
Local demand characteristics	80,000 inhabitants isolated from big markets	20,000 inhabitants connected with relatively good roads to big cities of the Andean region	Pucallpa: 300,000 inhabitants, isolated in the central Peruvian Amazon Puerto Maldonado: 100,000 inhabitants
Accessibility to forest areas	Amazon plain: forest areas accessible through navigable rivers and roads	Hilly landscape: access through roads only	Amazon plain: forest areas accessible through navigable rivers and roads

2.1.3 Case studies

Table 2.2 presents the communities selected as part of a Rapid Rural Appraisal (RRA) in the four regions chosen for research. The information gathered was related to the timber products that smallholders harvest from forest areas to sell, sale prices, costs of production, type of processing, participation in the production chains and commercialization strategies, time invested in the timber activity, means of production, present and previous logging intensities, and participation of family manpower in the activities.

Table 2.2. Communities visited for collection of socio-economic information related to commercial forest products through RRA and number of interviews, in Bolivia, Ecuador, and Peru.

Bolivia	**Ecuador**	**Peru**	
		Pucallpa	**Puerto Maldonado**
12 de Octubre*	Wachmas*	Callería*	Alto Loero*
Palmira*	Quinta Cooperativa*	Patria Nueva	San Agustín*
Campo Central	Octava Cooperativa*	Nuevo	
Santa María*	Pajanak	San	
26 de Octubre*	Chinimbimi	Alejandro*	
El Hondo*	Edén*	7 de Junio	
Santa Rosa*		El Porvenir*	
		San Alejandro	

* Communities selected for intensive research.

In Riberalta, the communities were selected with the participation of stakeholders of each community. Of the communities visited, 12 de Octubre, Palmira, Santa María, and 26 de Octubre were selected for a more intensive analysis. In the region of Macas, the communities selected for the research were located in the surroundings of Macas city at a maximum distance of two hours by car. From the communities visited, the communities Wachmas, Quinta Cooperativa, Octava Cooperativa and Edén were selected for an intensive analysis. In the regions of Pucallpa and Puerto Maldonado, the communities selected for the research were located in the surroundings of these two regional urban centres. From the communities visited, the communities Callería, Nuevo San Alejandro, El Porvenir and Alto Loero were selected for an intensive analysis.

2.2 Methods

Considering that biophysical and socio-economic aspects were part of the analytical framework, specific methods were applied depending on the research components:

- Market and value-added chains analysis, were carried out to collect and process information regarding to market characteristics in terms of enterprises, products and prices paid to smallholders. In addition, and based on the value-added chains analysis, I identified different processing stages of timber products, the actors involved and their roles in each stage of the chains.
- A Rapid Rural Appraisal was applied to collect socio-economic information regarding smallholders´ logging practices and marketing of their timber products. Semi-structured interviews, transect walks, participatory observation and revision of secondary information were applied.
- Forest inventories were carried out to analyse the commercial potential of forests and the effects of smallholders´ logging practices in farm forests. Tree species were classified according to their market values to quantify their monetary potential. Graphs showing basal area, total and commercial volumes and DBH distribution curves allowed the

comparison between primary and logged areas to analyse the effects of smallholders´ logging on structure and composition.

- Univariate and multivariate statistical methods were applied to classify smallholders according to their management practices and to identify statistical differences between primary and logged-over forest areas.
- Simple projection models for timber harvesting were performed for primary and logged-over forest areas to identify timber productivity and to analyse the effects of smallholders ‘logging practices in the long term.
- Profitability scenarios for different forest areas, accessibility conditions and availability of means of production were performed to analyse the financial profitability for smallholders.

In the following the different methods are described in more detail.

2.2.1 Participatory methods

Participatory methods were applied to collect information at the household level. This included semi-structured interviews, mapping of farms and transect walks (McKracken et *al.* 1989). Table 2.3 lists the communities and the number of cases selected according to the total population of the community, completing a sample of at least 25% of the households or smallholders. In Riberalta a total of 30 cases were analysed, in Macas 30, in Pucallpa 26 and in Puerto Maldonado 8 cases.

Table 2.3. Communities visited and number of cases selected for collection of socio-economic information in Bolivia, Ecuador, and Peru.

Bolivia	N	Ecuador	N	Peru			
				Pucallpa	**N**	**Puerto Maldonado**	**N**
12 de Octubre	4	Wachmas	8	Callería	6	Alto Loero	4
Palmira	6	Quinta	4	Patria Nueva	4	San Agustín	4
Campo Central	4	Cooperativa		Nuevo San	4		
Santa María	4	Octava	6	Alejandro			
26 de Octubre	4	Cooperativa	6	7 de Junio	4		
El Hondo	4	Pajanak	6	El Porvenir	4		
Santa Rosa	4	Edén		San Alejandro	4		

The monetary income obtained during the last year from farm forests was calculated based on the information gathered during the interviews. They included forest products collected, amounts sold and prices, and production costs.

2.2.2 Stakeholder interviews

Interviews with experts from governmental and non-governmental organizations were carried out in the four regions to obtain the point of view of different actors according to the potentials and limitations that smallholders face to generate monetary income from forests. In addition, interviews with timber traders and sawmill owners were carried out to obtain information about market characteristics, species and prices paid to smallholders. A total of 27 interviews were carried out (see Table 2.4).

Table 2.4. Number of stakeholders interviewed in Bolivia, Ecuador and Peru.

Country	NGOs	Government	Traders or sawmills
Bolivia	2	2	4
Ecuador	2	2	4
Peru	3	2	6

2.2.3 Secondary information

Secondary information related to market characteristics of each region, species marketed and legal frameworks for the forest management of each country was obtained from the literature. In addition, inventory databases were obtained from different development organizations for each region to generate a list of species with common and scientific names, and market characteristics.

This information was useful to identify value added chains in each region, to process information related to the commercial potential of forests and potential financial values; and to project timber logging scenarios for management.

2.2.4 Forest inventories in farm areas

At least six farm forests were inventoried in each country; three farms were inventoried in the same community to assess the local variation in the composition of commercial species between neighbouring forests, and the other three farm forests in different communities (see Table 2.5). In Riberalta a total of 4.05 ha plots were established to inventory six farm forests subjected to different logging intensities. In Peru, a total area of 4.05 ha plots were established to inventory six farms subjected to different logging intensities, four located on Pucallpa, and two in Puerto Maldonado. In the surroundings of Pucallpa, one of the cases selected in the inventory was affected by fire. In Macas nine farm forests were inventoried, of which 6 were previously logged and three represented primary forest.

Table 2.5. Number of farms and communities where forest inventories were carried out in the four study regions of Bolivia, Ecuador and Peru.

Bolivia		**Ecuador**		**Peru**	
Community	**Farms (N)**	**Community**	**Farms (N)**	**Community**	**Farms (N)**
Palmira	3	Wachmas	3	Nuevo San Alejandro	3
26 de Octubre	1	Pajanak	2	El Porvenir	1
Santa María	1	Quinta Cooperativa	2	Alto Loero	2
Santa Rosa	1	Octava Cooperativa	2		

With the map of the farm and a GPS, a systematic distribution of the plots across the farm forest was established, and circular 0.05 ha inventory plots were established. In secondary forests, which were characterized by a high density of small trees, the area of inventory plots was 0.01 ha. The number of plots varied according to the local conditions, but was sufficient to ensure on a sampling error of less than 20% as determined by the Ecuadorian and Peruvian legislation for forest inventories, and according to the Formula (1) described by Shiver and Boarders (1996):

$$ni = (t^2 \times CV^2\%) / E^2\ \% \qquad (1)$$

Where: ni = number of plots of size Pi necessary to obtain an inventory with a given sampling error

t = statistical value of t distribution for 95% likelihood (two tailed)

CV % = coefficient of variation of basal area expressed in percentage

E % = desired level of error of the inventory expressed in percentage

Species greater than 10 cm DBH (Diameter at Breast Height) were measured and the following variables were registered: common name, commercial height measured up to the first major branch or trunk deformation, and presence or absence of vines. Plots that exhibited obvious signs of logging, like stumps or gaps resulting from tree felling, were categorized as logged according to the recommendation of Kammesheidt (1998).

The participation of farm owners in the inventory process was essential for the guidance through the forest and to identify the tree species by their common names. Furthermore, the help of a local botanical expert, the so called "*matero*", was sought to help with the identification of species by their common names. When the list of species was completed with their common names, they were identified by their scientific names through databases of local organizations and then lists were submitted to expert botanists to review possible incongruences.

2.2.5 Commercial potential of forests

Tree species were classified according to their present marketability. When enterprises processed timber species for regional or international markets, they were catalogued as "regional or international". When tree species were traded in local markets they were catalogued as "local" and when no uses were reported, they were catalogued as "no" potential for markets. The list was then reviewed by experts in the local organizations to confirm possible incongruences.

The uses of timber in the Macas region presented a different context because most of the timber was fed into in regional markets. The local market of Macas demands the same tree species as do regional markets, but in lower volumes. So, species were differentiated only according to the categories "regional or international" potential and "no" potential. In addition, since different timber prices according to its use were provided, species were classified in low, medium and high values.

In this sense, the term "commercial potential" can be understood as the potential that forests have for logging and timber sales. This commercial potential is expressed in terms of cubic meters per hectare.

2.2.6 Structural parameters of forests

Structural parameters including basal area, commercial volumes and DBH distribution curves were processed in primary and secondary forests. Basal Area (BA in m^2) and Volume (m^3) were calculated through the application of the formulas (2) and (3). Number of trees and basal area per ha were calculated for different groups of species.

$$BA = ((DBH/2)/100)^2 \times 3.1416 \quad (2)$$

$$Volume = BA \times CH \times 0.7^1 \quad (3)$$

Where: DBH: Diameter at breast height (cm)

CH: Commercial Height (m)

[1] Form factor correction for the volume estimation (Shiver and Borders 1996)

Secondary forests were classified according to the successional stage of the stand, in young (< 6 years), intermediate (6-10 years) late (12-15) and old (>15 years). According to these stages, structural characteristics were analysed. In addition, comparisons between old secondary and primary forests were performed. The composition and relevance of species was evaluated by computing dominance (basal area), abundance (number of trees) and frequency (frequency of each species in the different sample plots). Importance Value Index (IVIs) proposed by Curtis and McIntosh (1951) was calculated by adding together the relative abundance, relative frequency and relative dominance of each species

2.2.7 Economic potential of forests

Based on commercial timber stocks and market prices, monetary values of forests per hectare were calculated. In the four study areas, prices were calculated for commercial timber volumes available in forest areas and prices per cubic meter of round wood. Considering that in Ecuador a common practice of smallholders was the selling of sawn wood, monetary potential values were also calculated considering different dimensions:

- Planks for production of furniture and doors. Dimensions: 3m x 0.25m x 0.05m
- Planks used for moulds in the construction of houses. Dimensions: 3m x 0.25m x 0.025m.
- Beams used for houses construction. Dimensions: 0.1m x 0.1m x 5m.

The economic potential was calculated considering the products and common strategies that smallholders apply for income generation. In this sense, calculations were based on the following assumptions: (1) The owner has a chainsaw for the transformation of logs into planks, (2) He has own horses for the transportation of the planks to roads, (3) the forest is located within 3 hours walking distance from the road, (4) the owner uses his own manpower for the activity, (5) he does not bear the costs of compliance through approved management plans, and (6) sell the wood to traders at the border of the road. Costs included: Chainsaw depreciation, manpower help of two assistants, valuation of the farmers´ manpower, costs of fuel, oil and chain; horse-related investments and maintenance.

In addition, and considering that species fetch different prices in markets, calculations also considered that within a given tree species, smallholders could harvest different qualities in the proportion of one tree of low value, two trees of medium and one tree of high value.

2.2.8 Statistical analysis

The information was processed an analysed using SPSS 13.0 for Windows (SPSS Inc. 2005). All variables were first tested for normality (Kolmogorov-Smirnov) to meet prerequisites of parametric tests that included t-tests and linear simple regressions. If these assumptions were not met, the data were transformed using either common logarithm or square roots forms. Simple regressions were chosen as the optimum method to determine the factors that influence in the abundance of stems per ha in farm forest areas. For the variables that even after the transformation were not normally distributed, an analogous non-parametric test (Kruskal-Wallis test) was applied followed by a Mann-Whitney U-test.

To determine groups of smallholders according to the different forest management strategies, a Hierarchical Cluster analysis was performed using Ward`s method and the Square Euclidean Distance. The entered variables in the cluster analysis were standardized before the analysis and their structure described as follows:

- Access to means of production by owning or renting, including chainsaws, horses, carts, boats or trucks for transportation and other additional tools, if it was the case. It was a categorical variable according to the number of means to which the smallholders had access.
- Time invested in the activity: 1) at least three days per week, 2) only occasionally (at least one day per week on average), and 3) rarely (only when it is necessary to sell trees)
- A valuation of the financial investments in means of production in US Dollars

2.2.9 Logging effects in forest areas

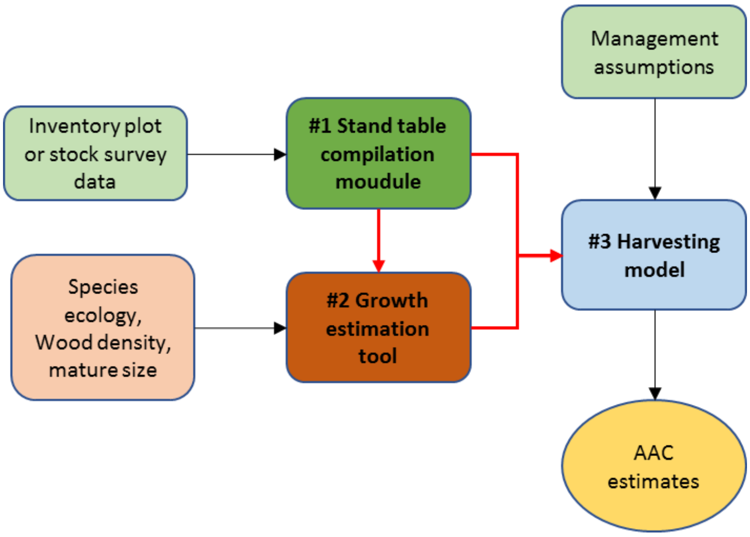
Forests areas inventoried were classified in primary, lightly logged, or heavily logged according to smallholders logging reports and their intensities. In this sense, primary forests were recorded when smallholders did not report logging activity and there were no signs of it in the forest. Lightly logged forests were classified when up to 6 trees or approximately 30 m^3 ha^{-1} where reported as logged by smallholders. Intensive logging was recorded when more than 30 m^3 ha^{-1} were being harvested.

To identify differences between primary and logged areas, structural parameters were compared, including basal area, commercial volumes and DBH distributions. In addition, statistical methods (non-parametric tests) were applied to identify differences between primary forests and those logged at different intensities.

2.2.10 Timber harvest projections

Timber harvest projections at farm levels (stands) were performed to analyse potential volumes to be logged using the software Methods of Yield Regulation with Limited Information (Khan and Singh 2001). This software is composed of three modules where information about inventories, species ecology and management assumptions is entered (Figure 2.3).

Figure 2.3. Structure of the MYRLIN software to perform projections about timber management.



Source: http://www.bio-met.co.uk/myrlin/

Inventories at farm level were entered into the system and species were classified according to their ecological characteristics. Management scenarios were performed for the first 30 years, defined as the time for the first cutting cycle, obtaining values of standing commercial volume, annual allowable cut, and harvested volumes. Each farm forest area was considered as a stand. In this sense, projections varied according to previous logging activity at the farm.

2.2.11 Financial scenarios of timber management

In the case of Macas, Ecuador, scenarios of timber management for different farms were performed considering availability and costs of means of production and different distances to the road border, to analyse their influence in the potential financial benefits. The following scenario was considered: smallholders own a chainsaw for the transformation of the timber in planks, own horses for timber transportation, the forest is located no more than three hours walking from the road, the owners use their manpower for the activity, and sell the timber to traders without the compliance of the legal framework. This assumption is based on the most common practices that smallholders apply in the region. Costs details are presented in Table 2.6. This scenario was developed only for Ecuador since in the other regions the common practice is only the selling of standing trees to traders.

Table 2.6. Costs to analyze the potential financial incomes of timber products (per m³).

Item	Moulds for houses construction	Furniture and doors	Beams
Manpower cost of the farm owner	11.1	11.1	20.8
Labour per day for two assistants	14.3	14.2	26.8
Chain saw (fuel, oil and chain)	8.9	6.7	16.7
Chain saw depreciation	6.7	3.3	12.5
Chainsaw renting	26.7	26.7	50
Payment of transportation by horses	26.7	26.7	20
Horses (investment and maintenance	9.1	9.1	9.1
Legal framework compliance	9.6	9.6	9.6

Potential monetary values per ha were calculated with information of market timber prices, commercial volumes per ha and costs of production.

3 RESULTS

According to the research questions raised, this chapter is organized into five sections:

a) Market characteristics and value-added chains for timber products are presented in section 3.1. Timber industry characteristics for each study region are presented in terms of type of industry (primary or secondary) and type of products processed. Value-added chains of tree species commonly traded in the four study regions are presented for round wood and sawn wood, considering the role of smallholders. Market characteristics are also described in terms of species traded in local, regional, or international markets, as well as prices paid to smallholders.

b) The commercial potential of forests is presented in section 3.2. Results for primary and secondary forests are presented through a classification of timber species according to their commercial values. Stand characteristics of smallholders´ forests in the four regions are analysed, as well as for the three countries. In secondary forests, results are presented depending on successional stage and importance value indexes (IVI) identifying the commercial species.

c) Smallholders´ management of forest areas, including a characterization of technology used and practices applied for timber logging, is presented in section 3.3. An analysis of the key factors for production was performed to identify typologies of smallholders in relation to their specialization in timber management.

d) The effects of local management on smallholders´ forest areas are presented in section 3.4. To determine these effects, the structural parameters of basal area, commercial volumes, and DBH distribution between primary and logged areas were obtained. This analysis aids in understanding how current activities are affecting the structure and composition of forests, principally of the commercial species.

e) The final section integrates the results obtained to generate possible long-term scenarios for timber management. Harvest volumes and financial incomes are projected for different scenarios, including availability of means of production, distance to markets, and compliance with legal requirements for timber logging. The results of these analyses help to explain the possibilities that smallholders have for timber management in the long term in terms of intensity and financial incomes, given the current scenarios of market potential.

3.1 Market characteristics and value-added chains

The contexts of the regions analysed were very different with respect to geographical and enterprise-related characteristics. Riberalta is located in the extreme depths of the Bolivian amazon region, more than 1,000 kilometres distance from La Paz. That isolation probably influenced the fact that only few enterprises of primary transformation were registered without the capacity to generate final products. Pucallpa is located in the centre of the Peruvian Amazon region and has the highest level of timber volume production in the country. Thus, a large quantity of primary and secondary timber enterprises that produce different timber products are located there. Puerto Maldonado is located in the extreme south of the country, which probably influenced the fact that very few enterprises of primary transformation exist there, at least those that are principally connected with regional markets. Finally, Macas is located in the centre of Ecuadorian Amazon region, relatively close to regional markets that demand a variety of timber products in plank form. These markets are principally composed of primary and secondary small and medium sawyers and furniture enterprises.

These differences resulted in large variations in timber potential for smallholders and different market dynamics, influencing the incomes obtained. This led to the conclusion that when markets are favourable to smallholders, they take advantage of these opportunities and develop strategies to generate income from timber products.

3.1.1 Market characteristics

In Riberalta, only 14 small and medium sawmills for primary transformation were found, and five of the sawyers were exporters. In the region of Pucallpa, 52 primary and secondary enterprises were reported, five of which were exporters of timber products. In comparison with the other regions, Macas was quite different in terms of context. This is because Macas' enterprises were in a regional market 120 km away from the city of Macas in the province of Azuay, where around 120 small and medium timber enterprises were reported (Table 3.1).

Table 3.1 Market characteristics of the study regions.

Region	Number of enterprises	Volume extracted (m^3)	Details
Riberalta	14 enterprises of primary transformation (sawmills)	2006: 18,473 round wood	Timber transformed to planks and sold to regional markets in La Paz
Pucallpa	20 enterprises of primary transformation (sawmills) 32 enterprises of secondary transformation (parquetry, moulds)	2005: 373,103 round wood 298,674 sawn wood	Timber transported as round wood to regional markets in Lima or processed and transformed to parquetry, plywood or other final products in the region
Macas	More than 120 enterprises of primary (sawmills) and secondary transformation (parquetry, doors, furniture)	2007: 14,860 sawn wood 2008: 20,200 sawn wood 2009: 36,000 sawn wood	Located in Cuenca, 120 km away, demanding only sawn wood for furnishing and house moulds

The enterprises in Riberalta bought timber rights to communities or standing trees to smallholders and transformed the round wood into planks to be traded, principally with La Paz markets, which in turn use the timber for furnishing floors, doors, window frames, and structures for houses. In the region of Pucallpa, most of the round wood production entered value-added chains in the plywood industry. In this region, a total of 20 enterprises of primary transformation were registered, but only three owned complete machineries for the whole transformation process (dryer ovens, multiple saws, and moulders). In addition, a total of 32 enterprises of secondary transformation were identified that produced planks, furniture, structural inputs, parquetry, and general carpentry. In the province of Morona Santiago (Macas region), extractions were increasing annually between 2007 and 2009 according to official reports, but this value represented only 0.9 percent of Ecuador`s national timber production (MAE 2010a). This region only produced sawn wood as tables and planks, which was transported directly from local gathering places in rural areas to Cuenca, where a dynamic industry exists. It was divided into two market segments: 1) secondary small and medium furnishing enterprises and 2) primary enterprises (sawmills) that provide prepared timber for structures and moulds for house construction. In fact, the region of Azuay was recognized as the principal furniture producer of Ecuador. In terms of market characteristics, Macas showed a more dynamic context, when compared with the other regions, with many small timber enterprises with capacity to process few quantities of sawn wood. The Pucallpa market presented an important number of medium and big timber enterprises that demanded large amounts of few timber species to produce diverse final products. Finally, Riberalta presented a limited market demanding low volumes of timber from smallholders´ forest areas.

These market characteristics influenced the number of species and products marketed from smallholders' forest areas, which were as low as 15 species in Riberalta, 22 in Pucallpa and Puerto Maldonado, and up to 80 in Macas (Table 3.2). In Riberalta, the most common practice was to sell timber to traders connected with enterprises that paid prices of about USD$ 32 per standing tree in areas with sustainable management plans. For individual forest areas, smallholders sold up to ten species, principally to traders that had connections with sawmills. Prices were around USD$ 20-25.6 per standing tree of around 6 m^3, according to species. The timber market in Pucallpa began more than thirty years ago when timber traders arrived and started to buy the following species: *Chorisia integrifolia, Cedrela odorata, Dipteryx alata, Hura crepitans, Amburana cearensis,* and *Manilkara bidentata*. In recent years in Pucallpa and Puerto Maldonado smallholders sold timber as standing trees from one species only (for instance, *Cedrelinga cateniformis, Manilkara bidentata*, *Callycophyllum spruceanum*, *Cedrela odorata*) or up to eight species, depending on their prevalence in forest areas and the requirements of traders or middlemen. Prices paid were around USD$ 5.3 m^3. In both regions, smallholders sold timber from up to 22 species in the form of planks to local markets, but only according to the capacity of those markets to consume the products. For instance, in the case of Pucallpa, the market demanded sawn timber for house construction due to population dynamics. In general, there was an agreement that in every community there were at least one or two timber traders who were part of the same community and negotiated the prices of commercial trees for the rest of the smallholders.

Table 3.2. Characteristics of timber species marketed by smallholders in Riberalta, Bolivia; Macas, Ecuador; and Pucallpa and Puerto Maldonado, Peru.

Country - Region	**Species presently marketed**	**Destination**	**Price[2]**
Bolivia Riberalta	Usually marketable as standing trees: *Dipteryx odorata, Vochysia vismiifolia, Astronium lecointei, Tabebuia serratifolia, Bertholletia excelsa, Cedrelinga cateniformis, Pithecellobium corymbosum, Mezilaurus itauba, Amburana cearensis, Cedrela odorata.*	Local, regional, or international	USD$ 13 – 26 per standing tree
	Extracted by enterprises in communal areas: *Vochysia vismiifolia, Astronium lecointei, Dipteryx odorata, Tabebuia serratifolia, Cariniana micrantha, Peltogyne heterophylla, Clarisia racemosa, Hymenaea courbaril, Amburana cearensis, Pithecellobium corymbosum, Parkia pendula, Qualea paraensis, Mezilaurus itauba, Cedrelinga cateniformis, Cedrela odorata.*	Regional or international	USD$ 13 - 32 per standing tree
Ecuador Macas	High commercial value: *Cedrela* sp.*, Manclura tinctoria, Tabebuia chrysantha, Clarisia racemosa, Micropholis chrysophyllum,* Terminalia amazonia, and *Symphonia globulifera.*	Regional	USD$ 100 - 150 m^3 beams[3].
	Medium commercial value: at least 27 species[1]	Regional	USD$ 60 - 80 m^3 planks.
	Low commercial value: at least 45 species[1]	Regional	USD$ 40 m^3 planks.
Perú Pucallpa and Puerto Maldonado	Presently marketable by smallholders to traders: *Cedrelinga cateniformis, Manilkara bidentata, Callycophyllum spruceanum, Dipteryx alata, Guazuma crinita, Schizolobium amazonicum, Virola* sp.*, Cedrela* sp.	Local and regional	USD$ 16 per standing tree around 50 cm of DBH and USD$ 32 around 80 cm DBH.
	Usually traded by smallholders as sawn timber, at least 22 species[1].	Local	USD$ 40 - 200 m^3 depending on species

[1] See Annex 1 for the complete list of species.
[2] For Bolivia, the rate of change was 7.68 bolivianos per USD$ as of September 2007 and Peru had a change rate of 3.1 soles per USD$ at June 2007.
[3] Each standing tree contained on average 2 m^{-3} of transformed wood. Costs of processing were not included.

In the Macas region of Ecuador market dynamics were very different when compared to Riberalta, Pucallpa, and Puerto Maldonado in terms of the number of species logged. The most important aspect was that almost the total proportion of species with height and diameter suitable to be harvested by chainsaw were being logged directly by smallholders or local traders from the communities. Then sawn timber was gathered at the road edge, collected by trucks, and sold principally in regional markets in Cuenca. Prices of timber also varied depending on species and use, which were classified into three categories. The first group, with high commercial value, consisted principally of high wood density species that included C*edrela* sp.*, Manclura tinctoria, Tabebuia chrysantha, Clarisia racemosa, Micropholis chrysophyllum,* *Terminalia amazonia,* and *Symphonia globulifera.* These species were all used as beams in the construction of houses, except for *Cedrela* sp*.* which was used for furniture. Their prices ranged from USD$ 100 to 150 m^{-3} sawn. However, these species did not have open markets, so smallholders normally sawed this timber according to traders' demand. A second group of species consisted of *Aniba* sp*., Ocotea* sp*., Nectandra* sp*., Cabralea canjerana, Cedrelinga cateniformis, Dacryodes peruviana*, and others. These species, in contrast, were used principally for the construction of furniture and doors, and presented a medium wood density. Their prices varied from 60 to 80 USD$ m^{-3} sawn. The last group consisted of timber species with low wood density, large diameters, and good stem quality. These species were being used as moulds in the construction of houses, with prices of around USD$ 40 m^{-3} sawn. Because of these factors, many smallholders have specialized in timber harvesting and processing depending on their opportunities, capacities, and capital access to invest in means of production such as chainsaws and horses.

According to the market characteristics of the regions analysed, prices and timber species marketed were very different (Table 3.3). Only two species were common across the three countries: *Cedrela* sp*.* and *Cedrelinga cateniformis.* Large differences were observed in the prices per cubic meter of wood for these species. In the region of Macas, were around 2.5 times higher than in Pucallpa and Puerto Maldonado, and around 4 times higher than in Riberalta. Considering these market prices, a standing tree with a stem volume of around 5 m^3 may fetch around USD$ 80 in the Macas region, whereas it may only be worth around USD$ 20 to 34 in the regions of Riberalta, Pucallpa, and Puerto Maldonado respectively. Another example was the species *Callycophyllum spruceanum,* which presented a high demand in the markets of Pucallpa to elaborate parquetry, meanwhile in Riberalta the species did not present any market demand. These aspects influenced the potential financial value of forests and returns of the timber activity carried out by smallholders in the different regions, and therefore their specialization to supply timber products according to market demands.

Table 3.3. Market characteristics of the commonly harvested tree species in Riberalta, Bolivia Macas, Ecuador and Pucallpa and Puerto Maldonado, Peru.

Species	**Riberalta**			**Macas**			**Pucallpa and Puerto Maldonado**		
	Common name	**Market**	**Price[1] USD$ m³**	**Common name**	**Market**	**Price[1] USD$ m³**	**Common name**	**Market**	**Price USD$ m³**
Amburana cearensis	Tumi	RI	3.4 – 4.2	--			Ishpingo	RI	NR
Aniba sp. and *Ocotea* sp.	Chileno, Canelón	Lo	NR	Canelón, Alcanfor	Re	16.2	Moena	Lo	5.3
Astronium lecointei	Cuta	RI	1.7 – 4.2	--			--		
Callycophyllum spruceanum	Guayabochi	Lo	NR	--			Capirona	Re	5.3
***Cedrela* sp.**	**Cedro**	**RI**	**4.6**	**Cedro**	**Re**	**25.0**	**Cedro**	**RI**	**10**
Cedrelinga cateniformis	**Mara macho**	**RI**	**3.9**	**Seike, Chuncho**	**RI**	**16.1**	**Tornillo**	**RI**	**6.7**
Clarisia racemose	Mururé	RI	2.2	Pitiuca	Re	25.4	--		
Dipteryx odorata	Almendrillo	RI	1.7 – 3.4	--			--		
Dipteryx alata	--			--			Shihuahuaco	Lo	5.3
Dacryodes peruviana	--			Copal	Re	8.3	--		
Hura crepitans	--			--			Catahua	Lo	NR
Manilkara bidentata	--			--			Quinilla	RI	5.3
Mezilaurus itauba	Itauba	RI	3.4 – 4.2	--			--		
Ormosia schunkei	--			--			Huayruro	Lo	NR
Otoba parvifolia	--			Llora sangre	Re	6.0	--		
Pithecellobium carymbosum	Maní	RI	1.7 – 3.4	--			--		
Ruagea insignis	--			Cedro macho	Re	16.2	--		
Simarouba amara	--			Capulí	Re	25.3	Marupa	Lo	NR
Tabebuia sp.	Tajibo	RI	3.4 – 4.2	Pechiche	Re	16.1	--		
Terminalia amazonica	Verdolago	Lo	NR	Yumbingue	Re	16.4	--		
Vochysia vismiifolia	Aliso	RI	1.7 – 3.4	--			--		
Vochysia sp.	--			Bella María	Re	6.0	--		

Remarks: RI: Regional – International, Re: Regional, Lo: Local, NR: No reported

[1] For round wood.

The market destination of timber was also an important characteristic that influenced demand and prices. In the Macas region, all tree species were commonly traded in regional markets, whereas in the regions of Pucallpa, Puerto Maldonado, and Riberalta some species were traded only in local markets. This aspect influenced the demand, since local markets had a limited capacity to consume timber products and timber was normally only used by local carpentries to supply local demands. Therefore, only species traded in regional or international markets had unrestricted demand. For instance, the commonly abundant species of the genera *Aniba* and *Ocotea* were traded in Ecuador with attractive prices (16 USD$ m^{-3}) to elaborate furniture, whereas in the regions of Pucallpa and Puerto Maldonado they showed limited demand in local markets, with prices of 5.3 USD$ $m^{-3.}$ There was no reported market value in the region of Riberalta.

A general agreement of the smallholders and traders of the regions analysed was that markets started to demand new timber species or identify new uses when the most valuable species began to become rare in the forests and thus extraction costs for trees from remote forest areas became too high. For instance, in the Macas region the species *Dacryodes peruviana* was initially used for moulds for house construction, whereas nowadays, due to the rarity of other species, it began to be used for furniture and to gain a higher price in markets, from 6 to 8 USD$ m^{-3}.

As presented above, the Macas region showed higher market values for timber when compared the other regions analysed. Four principal aspects have been identified:

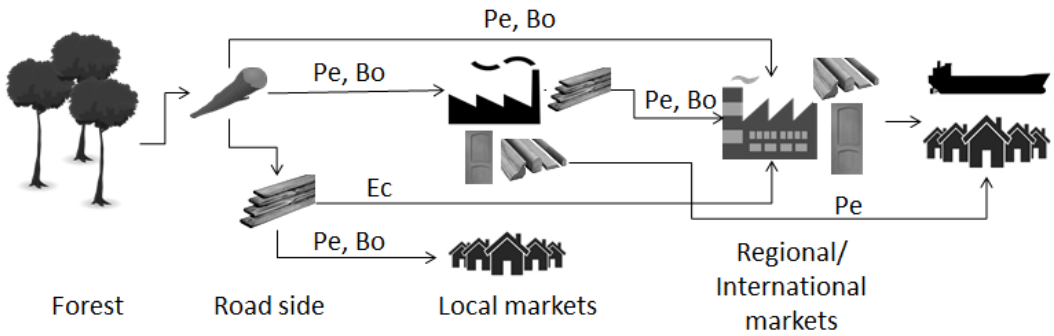
- The closeness to regional markets, located in average twelve hours by trucks, which reduces transport costs, allowing small traders access to these markets.
- Most of forest areas in Ecuador are in the hands of native communities or colonist smallholders. In the absence of forest concessions to private companies, the market is very dynamic, with many traders and sellers, and characterized by a high competition.
- The Ecuadorian forest law allows the harvest of timber through simplified management plans when using non-mechanized equipment. This allows smallholders to use chainsaws and to log in small forest areas, according to the density of commercial trees.
- The weak enforcement of the law to control illegal logging and trade by the environmental authority, and the allowed use of chainsaw in the forest law, enable smallholders to enter the timber market with relatively low financial investments.

3.1.2 Value-added chains from *Cedrelinga cateniformis*

This section presents a description of the most common value-added chains of the timber species *Cedrelinga cateniformis,* considering its abundance in many regions of the Amazon and its similar use throughout the regions studied. This analysis was important in order to understand stakeholders' participation in the value-added chains, particularly between regions, and the income obtained.

The products constructed from this species were planks, doors, and moulds for windows, but smallholders' participation in the value-added chains across the three countries was limited to selling standing trees or transforming them into planks (Figure 3.1). In the region of Riberalta, value-added chains were based on round wood and sawn wood, materials traded principally in the regional markets of La Paz, where timber was processed into doors or moulds and marketed locally or exported to international markets. In these cases, smallholders´ participation was limited to selling standing trees to traders who were connected directly to local saw mills. Smallholders obtained about USD$ 3.9 m^{-3}. Logs from felled trees were transported by rivers or trucks to saw mills or timber yards located in Riberalta. If it went to saw mills, timber was transformed into planks and subsequently transported to markets in La Paz, but in some cases logs were transported directly to La Paz for further transformation. Another value-added chain in the region was the sale of planks in local markets to be processed by local carpenters or sawyers. In this case, smallholders transformed logs into planks in the forest with chain saws, and then the planks were transported to local markets by carts and trucks. However, this type of value-added chain served only the local demand of small saw mills and small enterprises for furniture or house construction. When planks were sold in local markets, the price increased substantially—up to USD$ 25 m^{-3}.

Figure 3.1. Participation of smallholders in the value-added chain based on Cedrelinga cateniformis in Macas, Ecuador, Riberalta, Bolivia, and Pucallpa and Puerto Maldonado in Peru.



Bolivia	3.9[a] (88) [b]		25 (12)	
Ecuador	16 (16)	60 (76)		108 (8)
Peru	6.7 (75)		36 (25)	

[a] Net value (USD$ m^{-3}) of wood stand or transformed into planks.
[b] Percentage of smallholders participating in the segment of the value-added chain.
Products obtained are planks, doors, and moulds for windows. Sample size (n): Bolivia (Bo) 25, Ecuador (Ec) 25, Peru (Pe) 20.

In the region of Macas, the principal value-added chain was the production of planks that were sold principally into the regional markets of the Azuay province, where wood was processed into doors and moulds. Depending on the participation of smallholders, this value-added chain took on different forms: i) the selling of standing trees to local traders, who were normally also smallholders of the community that owned production means (chainsaws, horses, and even cars or trucks), and ii) the sawing of logs into planks and their transport to the roadside, where they were sold to traders who transported the planks to local storage areas and then to regional markets. There was one additional value-added chain that was less common and which was related to the trade of timber in the regional markets by the smallholders themselves. When planks were sold at roadsides, prices increased substantially as compared to the sale of standing trees—from 16 up to 60 USD$ m^{-3}. In this case, smallholders had to invest in chainsaws and horses for the transportation of planks from the forest to the roadside. The highest profit margin occurred when planks were sold at regional markets, which increased their value to 108 USD$

m^{-3}. However, the risk was also high if the sale of timber was not properly documented regarding its origin. If documentation were lacking, the wood load and trucks might be confiscated by the Ministry of Environment, which controls the sources of timber.

In Pucallpa and Puerto Maldonado, there were two common value-added chains: i) the selling of standing trees by smallholders or communities to traders, who sawed the logs into planks, and ii) the selling of standing trees to traders, who cut the trees into logs and transported them by rivers or trucks to local saw millers in Pucallpa and Puerto Maldonado. In the case of Pucallpa, timber might be processed into planks, doors, or moulds, and marketed locally, nationally, or sold to international markets. In the case of Puerto Maldonado, timber was normally transported as round wood to the regional markets in Lima, where it was processed into doors and moulds. Another less common value-added chain in which the smallholders participated was the transformation of planks in the forest with chainsaws and their transportation and sale in the local saw mills of Pucallpa and Puerto Maldonado. When standing trees were sold, the common market price was 6.7 USD$ m^{-3}, depending on the accessibility of the forest areas, but when smallholders sold planks in local markets, timber prices rose to 36 USD$ m^{-3}. In some cases, local traders used portable saw mills to cut planks directly in the forest to facilitate transportation. In contrast, when smallholders cut the planks, they used chainsaws and carts to transport them to local markets. Depending on the technology used, the amount of timber wasted varied; it was around 50% when chainsaws were used, but around 30% with the use of portable saw mills.

In all value-added chains, smallholders had the maximum capacity to arrive to local or regional markets with planks processed with chain saws. The processing of final products including brushed and dimensioned dried wood requires large financial investments to set up sawmills.

Summarizing, the principal factors that explain market dynamics in the regions analysed are the following: i) the size of local markets and their capacity to consume timber products, ii) the structure and capacity of the local or regional industry to process products for national consumption or export, and iii) the abundance of forest resources in the region. In the Macas region, markets were highly dynamic in terms of an abundant number of sawmills to produce dried and dimensioned products, and furniture industries. They demanded planks and tables, principally of medium and low-density species. In addition, the difficult accessibility conditions to forest areas to extract timber have influenced in the scarcity of valuable species, which in turn promoted the use of a broad number of forest species. In the Pucallpa region, principally medium and big timber industries of primary and secondary transformation that demanded big amounts of a limited number of timber species were observed, chosen according to their production chains. This aspect was influenced by the large abundance of forest resources in the region. In the Riberalta region there was an incipient industry of sawmills, and a limited local market that demanded only the most valuable species to be traded in regional markets of La Paz. These aspects influenced directly in the prices obtained by smallholders for their timber resources, with the result that the Macas region showed the highest profitability margins for smallholders. This aspect also influenced in the different strategies applied by smallholders to maximize their incomes, for instance investing in chainsaws and horses.

3.2 Smallholders´ strategies to engage in timber markets

This section presents the results of the strategies that smallholders have developed to engage in timber markets, according to the opportunities they had to enter the value-added chains. The results describe the means of production that smallholders used to become an actor in the value-added chains. The results of the strategies that smallholders have developed for timber logging are also presented. Finally, a typology of smallholders in relation to their level of specialized production means is suggested.

3.2.1 Means of production used for timber harvesting and marketing

The means of production used in the different regions depended on the opportunities and possibilities that smallholders had to sell timber products in markets in each region analysed. The pattern in the regions of Pucallpa, Puerto Maldonado, and Riberalta was that only a small number of smallholders owned some production means, such as chainsaws, which added value to their timber through the cutting of planks and transportation to markets (Table 3.4). In the region of Riberalta, only two smallholders (representing 8% of the sample) owned chainsaws in the four communities explored, whereas in the regions of Pucallpa and Puerto Maldonado, there was only one case. In contrast, in the Macas region 11 smallholders (44% of the sample) owned one chainsaw, and in some cases, they owned more than one. In this region, the common method of transporting the planks to the roadside was by horse, and almost one quarter of all smallholders owned at least one horse for timber transport.

Table 3.4 Activities and technologies applied by smallholders in the timber value-added chains in the regions of Riberalta, Bolivia, Macas, Ecuador, and Pucallpa and Puerto Maldonado, Peru.

Activity	Technology used	Region	Country	Percentage (%)
Tree felling	Chainsaw	Macas	Ecuador	44
		Riberalta,	Bolivia	8
		Pucallpa and Puerto Maldonado.	Peru	5
Cutting logs into planks	Chainsaw	Macas	Ecuador	44
		Riberalta	Bolivia	4
		Pucallpa and Puerto Maldonado.	Peru	5
Transport to roadside	Air cables	Macas	Ecuador	4
	Carts	Riberalta	Bolivia	4
		Pucallpa and Puerto Maldonado	Peru	5
	Horses	Macas	Ecuador	24
Transport to local markets	Trucks	Macas	Ecuador	8
Transport to regional markets	Trucks	Macas	Ecuador	4

Sample size (n): Bolivia: 25, Ecuador 25, Peru: 20.

In the Macas region, the favourable market for planks and attractive timber prices had stimulated smallholders to make significant investments in chainsaws and horses, considering that a chainsaw cost around USD$ 1,000 and a horse around USD$ 300. In fact, when smallholders had had access to finance, they had made substantial investments in trucks and other specialized tools, such as cable systems for extracting planks in steep zones.

In addition, smallholders who invested in equipment also contracted between five and eight workers to help with different activities along the value-added chain. These investments obviously required the maintenance of high production volumes supplied through other forest areas once they had impoverished their own timber stocks.

3.2.2 Timber management practices

Smallholders implemented different timber management practices to generate income from their forests that included the following: i) sale of timber rights to enterprises or traders, ii) sale of standing trees to traders, iii) sawing and sale of planks to local markets or traders, and iv) sawing and sale of planks to regional markets (Table 3.5). In the first and second practices, smallholders only negotiated prices of trees from their forest areas and did not participate further in the value chain. In the third and fourth practices, smallholders transformed logs into planks in the forest and transported to roads borders to be traded. In a few cases, smallholders transported the planks to regional markets.

The sale of timber rights from communal areas to enterprises was a common practice in Riberalta, Pucallpa, and Puerto Maldonado, where timber enterprises dominated markets and bought timber in areas covered by management plans. This aspect restricts smallholders from increasing the benefits of their forests due to their inability to comply with requirements of sustainable forest management plans of the Bolivian and Peruvian laws. In some cases, local development organizations have provided intensive support by financing costs of management plans, investing in sawmills, organizing people for harvesting activities, and organizing the activities of marketing and trading. The cost of a forest management plan alone may amount to USD$ 30,000 (José Martínez, ex-forest manager in Bolivia, personal communication). In ten visited cases in Riberalta, Pucallpa, and Puerto Maldonado, only two communities had developed timber management plans with strong support of local Non-Governmental Organizations (NGOs). When there was no the support of a local development organization, the forest industry in Riberalta and Pucallpa controlled the markets of timber and the most important NTFPs, defining the number of species logged, volumes demanded, and prices paid.

The sale of standing trees to traders or middlemen was a common practice in all three countries. Presently in Riberalta, depending on the local abundance of tree species, only up to ten species were commonly sold by smallholders as standing trees. In Pucallpa and Puerto Maldonado the number of species varied from one species only (for example, *Manilkara bidentata*, *Callycophyllum spruceanum,* or *Cedrelinga cateniformis*) to twelve species, depending on traders' demand. In Ecuador, the sale of standing trees is a practice frequently carried out by smallholders without the capacity to cut the logs into planks or transport the logs by horses. These smallholders sold the trees to other smallholders that owned chainsaws.

Table 3.5. Characteristics of timber trade carried out by smallholders in Riberalta, Bolivia; Macas, Ecuador; Pucallpa and Puerto Maldonado, Peru.

Timber management strategies	**Level of organization**	**Country**	**Frequency**	**Number of species logged**	**Volume/trees removed**	**Description**
Sale of timber rights to enterprises or traders	Communal	Bolivia, Peru	Common	Up to 10 species depending on the enterprise characteristics	10 - 30 m^3 ha^{-1}, depending on the number of species logged	Subjected to national normative of forest management plans
Sale of standing trees of the most valuable species to traders	Individually / Communal	Bolivia Ecuador Peru	Common Common Common	1 – 80 species depending on demand	1 - 3 trees ha^{-1} from the entire forest area	Sale of individual standing trees to traders or other smallholders that own chain saws, focusing on the most valuable species depending on demand characteristics
Sale of planks to local markets or traders	Individually	Bolivia and Peru Ecuador	Rare (according to local demand characteristics) Common	Up to 14 species in Riberalta, and 80 in Macas depending on market characteristics	2 - 25 trees ha^{-1} from the entire forest area, depending on context factors and individual smallholder's characteristics.	Sawing of trees inside forest areas, transformation to planks with chainsaws and transportation through carts, boats (Bolivia and Peru), or horses (Ecuador) to borders.
Sale of planks to regional markets	Individually	Ecuador	Rare	Normally specialized on a few species depending on their connections with regional markets	15 and 23 trees per month in two cases analysed.	As the last practice, but in connection with regional markets. Normally they buy standing trees from other smallholders

The sawing of planks or beams in the forest was another common practice commonly found among smallholders in Macas, and among small percentages of smallholders in Riberalta, Pucallpa, and Puerto Maldonado. Transportation was by horse in Macas and cart or boat in Riberalta, Pucallpa, and Puerto Maldonado. In the latter three regions, this practice was carried out by only a small proportion of smallholders according to the capacity of local markets to consume this type of timber production.

In general, smallholders adapted their timber production according to context factors and individual possibilities or preferences. So, in the Macas region, there was a more favourable environment for smallholders, because of better market conditions when compared to the other regions in Bolivia and Peru. This has led to the development of a diversity of timber management practices and to the substantial increase of those benefits.

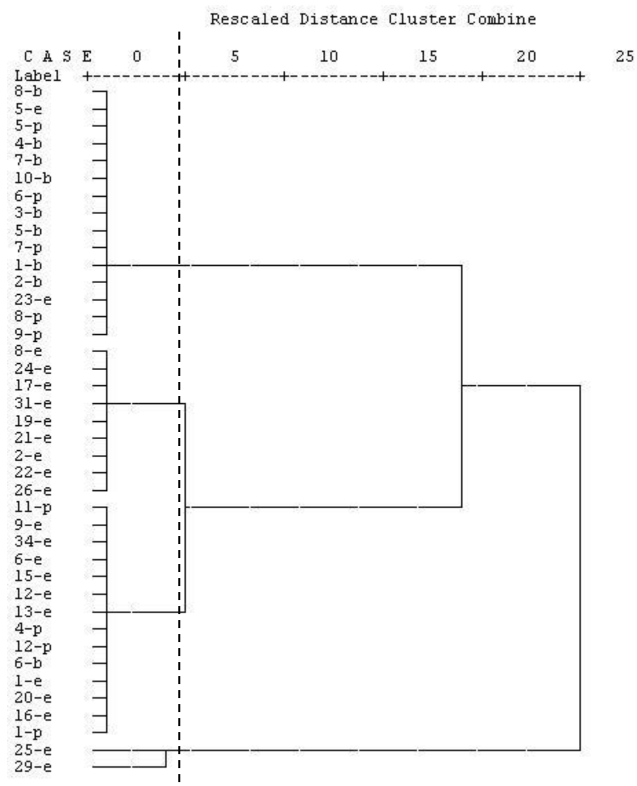
3.2.3 Categories of smallholders regarding to timber management strategies

According to their respective timber management strategies, smallholders were classified to reflect the importance of timber management activity on their livelihoods. The cluster analysis (Figure 3.2) indicated four groups of timber producers (at the level of the vertical dotted line in the dendrogram) that depended on timber to different extents. An additional category, not included in the cluster analysis, represented smallholders who did not depend on timber to generate income. The resulting five categories can be described as follows:

- Not dependent on income from timber: represented by smallholders who had no capacity to extract timber, had no access to it, had no commercial timber in their forest areas, or simply preferred other production systems. This category is not represented in the cluster analysis.
- Smallholders requiring occasional income from timber: represented by smallholders who normally sold timber as standing trees in times of financial hardship or when traders appeared to buy the most valuable species. The volume removed could vary from three to five trees per year, according to the forest area and commercial species available.
- Smallholders requiring complementary income: these groups of smallholders focused on timber activity as a complementary source to other productive activities, making limited investments in production means such as chainsaws or horses, depending on the features of the local context.
- Smallholders obtaining their principal income from timber: represented by smallholders who focused on timber as the most financially attractive activity in comparison with other alternatives and invested most of their time for work on this activity. They had normally made substantial investments in production means and in many cases bought timber from other smallholders after having exploited their own forest areas.
- Smallholders specializing in timber harvesting and trade: represented by producers acting as entrepreneurs that specialized in the timber activity and made important investments in chainsaws, horses, and cars or trucks. They normally contracted workers for different activities, including sawing, transportation, and marketing. The volume of timber logged per

year was much higher than the other groups, and they moved between different areas to buy standing trees from smallholders working under less favourable conditions.

Figure 3.2. Cluster analysis of smallholders in relation to the importance of timber management for their income.



The dendrogram forms different groups of smallholders (Label) that share similar characteristics in terms of the strategies for timber management.

The categories were obtained analysing the time invested in the timber activity, access to means of production and financial investments for timber production. In this sense, the most common strategies in the regions of Bolivia and Peru were related to smallholders that did not depend on incomes from timber during the last year, followed by those that generate occasional incomes from timber. In the region of Macas in Ecuador, the most common strategies were related to smallholders requiring complementary income and also obtaining their principal income from timber. Regarding the category of smallholders specializing in timber harvesting and trade, two cases were reported (8% of the sample) in the region of Macas that corresponded to colonists that arrived at the Amazon region during the agrarian reform in the seventies.

3.2.4 Incomes generated from forest products

In accordance to the different timber management strategies, the incomes obtained from forest products varied highly between regions, between smallholders, and also depending on the product (Table 3.6). In this context, the availability and value of non-timber forest products can play an important role. For example, in the Riberalta region, the Brazil nut was the most important source of income generation. In the communities analysed there, only four smallholders (20% of the sample) generated income from selling timber during the last year; of these, three sold standing trees and only one processed planks and sold them in Riberalta.

Table 3.6. Timber monetary incomes obtained by smallholders during the last year in Bolivia, Ecuador and Peru.

Region	Number of cases	Min	Max	Mean (Std)	Median
		USD$			
Riberalta	4 of 20	98	521	216 (204)	
Macas	22 of 20	80	19,250	2,589 (4,654)	1,374.8
Pucallpa and Puerto Maldonado	4 of 20	129	387	194 (131)	

Sample size (n): Bolivia: 20, Ecuador: 25, Peru: 20.

In the communities of the Macas region, most smallholders generated incomes during the last year (88% of the sample), and timber was the sole product that they harvested from their forest areas. There was only a single case of a smallholder who sold palm leaves. However, there were substantial differences between smallholders who sold only a few standing trees and generated relatively low income, and others that had access to capital to make important investments in chainsaws, horses, and cars or trucks. They also acted as traders and bought timber from other smallholders and sold it in regional markets, generating incomes of up to USD$ 19,000 yr^{-1}. The median was around USD$ 1,400 annually, indicating that smallholders could generate around USD$ 120 per month. This value was relatively high as an income source in the rural sector, especially for indigenous peoples where subsistence is still important for households.

In Pucallpa and Puerto Maldonado there were four smallholders (20% of the sample), that generated income during the last year, and two of them (one in Pucallpa and one in Puerto Maldonado) sold sawn timber to local markets.

The smallholders that obtained the major incomes are those specialized on timber harvesting and trade who were found in the Macas region of Ecuador. By contrast, the lower incomes were obtained by those smallholders requiring occasional income, distributed as follow: 8% in Macas, 10% in Riberalta and 10% in Pucallpa and Puerto Maldonado.

3.3 Commercial potential of smallholders´ forests

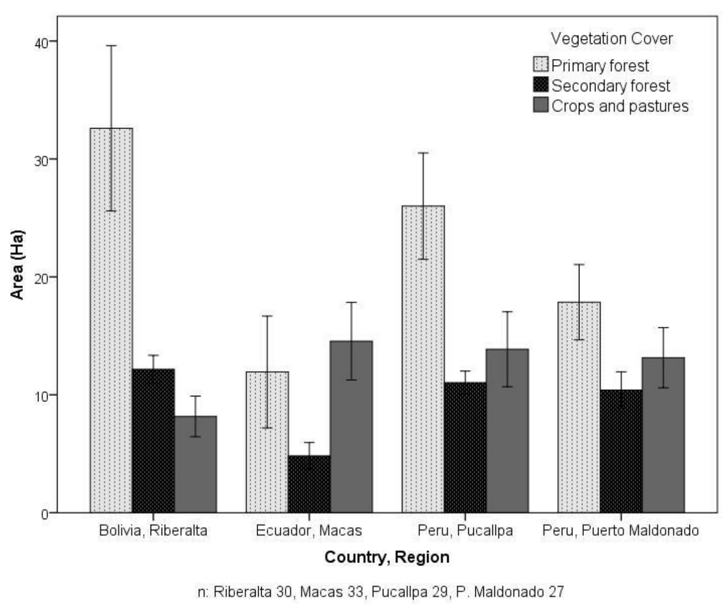
This section presents an analysis of the commercial potential of primary, logged, and secondary forests in the case study regions. First a description of the vegetation cover at farm level is presented to identify potential forest areas to be managed in households. A classification of species according to their potential commercial values was performed to obtain sellable basal area and volumes per hectare in different stands at the farm level. A large variation in terms of structure and composition was identified between farm forests of the same region, and even within the same community.

3.3.1 Vegetation cover of smallholders´ farms

Plot sizes and proportions of forest were highly variable between regions and farms analysed. In Riberalta, the average farm size was 53 hectares, in Macas 31 ha, in Pucallpa 51 ha, and in Puerto Maldonado 40 ha (Figure 3.3). In the regions of Peru and Bolivia, plots were bigger than those in Ecuador due to agrarian reforms in each country that recognized lands rights to indigenous communities or smallholders that colonized these forest areas. In addition, other influential factors were lower population densities and longer distances to the principal development hubs of each country, such as La Paz, Santa Cruz, and Lima. In the Macas region, farm size varied greatly with the community's location and socio-economic dynamics. For instance, in one of the indigenous communities, farm plots had been fragmented to distribute the lands between the inheritors and had shrunk to around to 12 ha per family. Meanwhile, in another community, migration to urban centres had allowed farm plots to maintain the same size (around 50 hectares per family) that had been common at the time of land adjudication during the agrarian reform of the 1970s.

The area of primary forests was larger than the area occupied by crops and pastures in all regions except Macas (Figure 3.3). In the region of Riberalta, where the plot size was higher than in other regions, primary forest occupied an average of 32.6 hectares, which was more than in the other regions. In the Macas region, the area of primary forests was on average smaller than the area of crops and pasture.

Figure 3.3 Vegetation cover of smallholders´ plots in Bolivia, Ecuador and Peru (Mean ± Standard Error).



In the Riberalta region, there was more area occupied by secondary forests than by crops and pastures, but in the other regions they represented the shortest proportion of vegetation cover. In the regions of Peru and Bolivia slash and burn were common practices to open new productive areas when productivity in crops had declined. In this sense, secondary forests are commonly part of the smallholders´ production systems, because these lands are recovering fertility for future crops. In the region of Macas there were commonly extensive areas of pastures to maintain cattle and horses, even in indigenous communities.

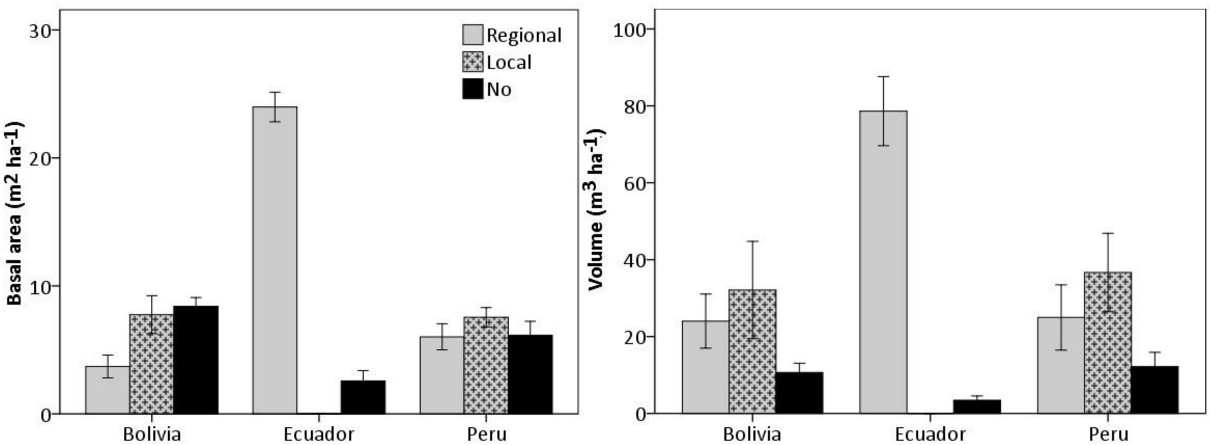
The maintenance of forests in farms depended on the function of these areas as part of the production systems at household level. At the Riberalta and Puerto Maldonado regions they were maintained principally to conserve Brazil nut trees, considering its importance to sustain household economies. In the Macas region some forest areas were found where smallholders depleted the entire stock of commercial timber species, and others completely conserved them depending on the livelihood strategies.

There was a general agreement between smallholders that the value of their forests was related to the quality of commercial timber available and the number of commercial Brazil nut trees in the regions of Riberalta and Puerto Maldonado. Distance to roads was also a common factor that smallholders considered as essential to assess the potential of forests. Secondary forests were highly appreciated when smallholders reported the regeneration of commercial species including Brazil nut trees.

3.3.2 Commercial timber in primary forests

There were large differences in terms of the number of tree species with market potential in the regions analysed (Macas 80, Riberalta 15, Pucallpa and Puerto Maldonado 22). In terms of commercial volume, around 80 m^3ha^{-1} were available on average in primary forests of the Macas region, whereas in the other regions the commercial volume amounted to only 25m^3 ha^{-1} (Figure 3.4). The small proportion of species without market in Macas will probably be further reduced in the interim due to the opening of markets for the pioneer *Cecropia* sp. This species represented an important proportion of the trees without markets, and in some cases smallholders were beginning to sell this wood to use as moulds for the construction of houses. Additionally, one palm species (*Iriartea deltoidea*), which was very abundant in forest areas, was being harvested for parquetry fabrication.

Figure 3.4. Basal area and commercial volume of tree species with current market potential (Regional, Local, or No market) in Riberalta, Bolivia; Macas, Ecuador, and Pucallpa and Puerto Maldonado in Peru.



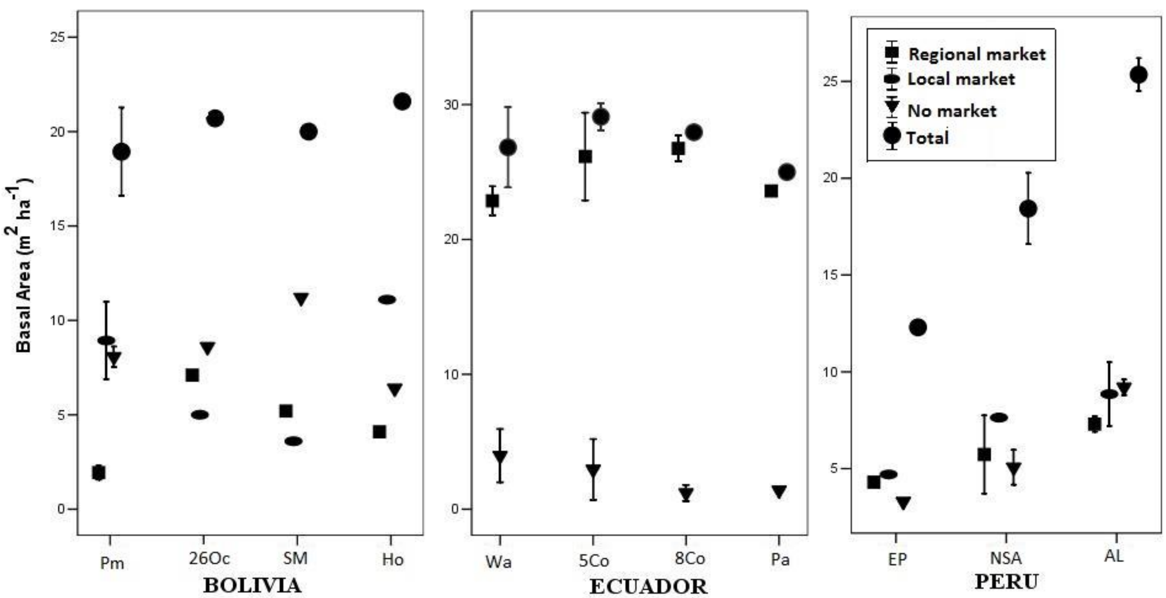
The basal area per hectare was based on trees with DBH greater than 10 cm and the commercial volume on trees with DBH greater than 50 cm. In Riberalta, the sample size was based on 6 forest farms, where a total of 81-0,05 ha plots were inventoried. In Macas, a total of 153-0,05 ha plots were inventoried on 9 forest farms. In Pucallpa and Puerto Maldonado a total of 81-0,05 ha plots in 6 forest farms were inventoried. Vertical lines indicate the standard error.

In the Peruvian regions, the existence of more species with market potential produced slightly higher commercial volumes for local and regional markets when compared to Riberalta. For instance, species such as *Aniba* sp. and *Virola* sp. were only being harvested in Peru, despite their high abundances in Riberalta. Another species that was being logged extensively in Peru for parquetry production was *Calycophyllum spruceanum*, but in Riberalta it was either not logged or processed by the local industry only.

In terms of basal area of commercial species, large differences between different regions were observed at the country level, within each region of each country, and within each community (see Figure 3.5). Whereas in Ecuador the average total basal area was around 28 m^2 ha^{-1}, in Bolivia and Peru the average value was around 20 m^2 ha^{-1}. The high variation in basal area in different regions is partially explained by the high number of palms found in certain areas where they dominated the forest composition and previous disturbance intensities, including fire. However, palms were not included in the analysis, since they were not considered to be trees nor timber.

In Riberalta, there were no major differences between the four communities analysed in terms of total basal area. But in terms of basal area of commercial species for regional markets, large differences were observed, because Palmira community presented very low values when compared to the other communities. This is explained by the fact that this community was the closest to the city of Riberalta, and because higher logging intensities of the valuable trees were reported in farms forests.

Figure 3.5 Basal Area in terms of market characteristics in communities in Riberalta, Bolivia; Macas, Ecuador; and Pucallpa and Puerto Maldonado in Peru.



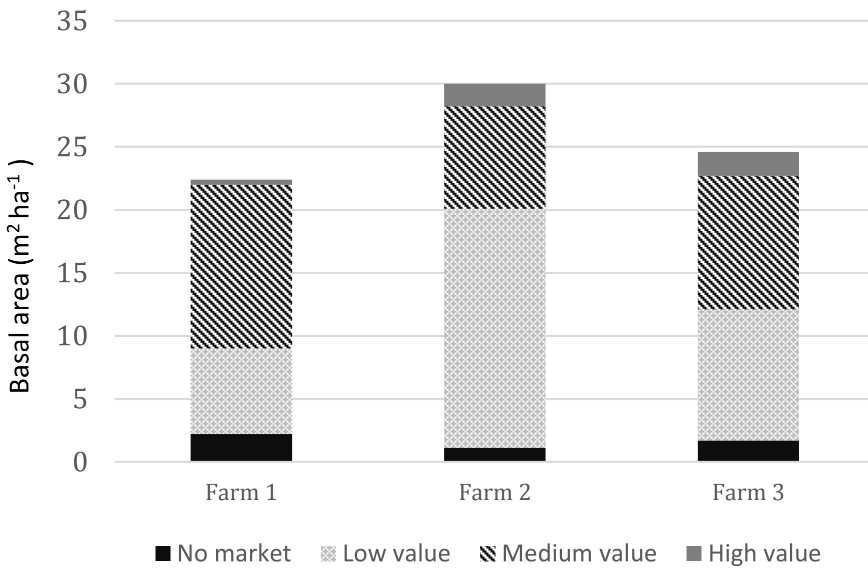
Pm: Palmira; 26Oc: 26 de Octubre; SM: Santa María; Ho: El Hondo; Wa: Wachmas; 5Co Quinta Cooperativa; 8Co: Octava Cooperativa; Pa: Pajanak; EP: El Porvenir; NSA: Nuevo San Alejandro; AL: Alto Loero. When more than one farm forest was inventoried, vertical lines are drawn.

In Macas, there were no large differences among communities, but the first community presented lower values in terms of species for regional markets. Similar to Riberalta, the differences could be explained by the high logging intensities in certain forest areas which reduced the availability of some commercial species. In the regions of Peru large variations were observed in terms of the total basal area and market characteristics of different species. The forest analysed in the community of El Porvenir showed the lowest basal area due to a fire that impacted on part of the forest area. The forest areas in Nuevo San Alejandro were affected by previous logging and partially by slash and burn practices.

The differences in terms of basal area and potential commercial volumes in the regions and communities indicate that commercial potential is broadly variable, depending on local biophysical characteristics and smallholders' management practices of their forest areas. In addition to the market characteristics of the regions, these aspects will influence the potential of forests for smallholders.

To analyse the influence of local biophysical factors in forest structure and potential commercial value, comparisons at farm level were performed in forest areas not affected by human activities. Figure 3.6 presents basal area values for timber species according to commercial values on three primary forests in Macas, Ecuador, because that was the only region where forests without logging were inventoried. In the cases of Riberalta, Pucallpa, and Puerto Maldonado, inventoried forests had been subjected to selective logging of the most important commercial species, according to the interviews.

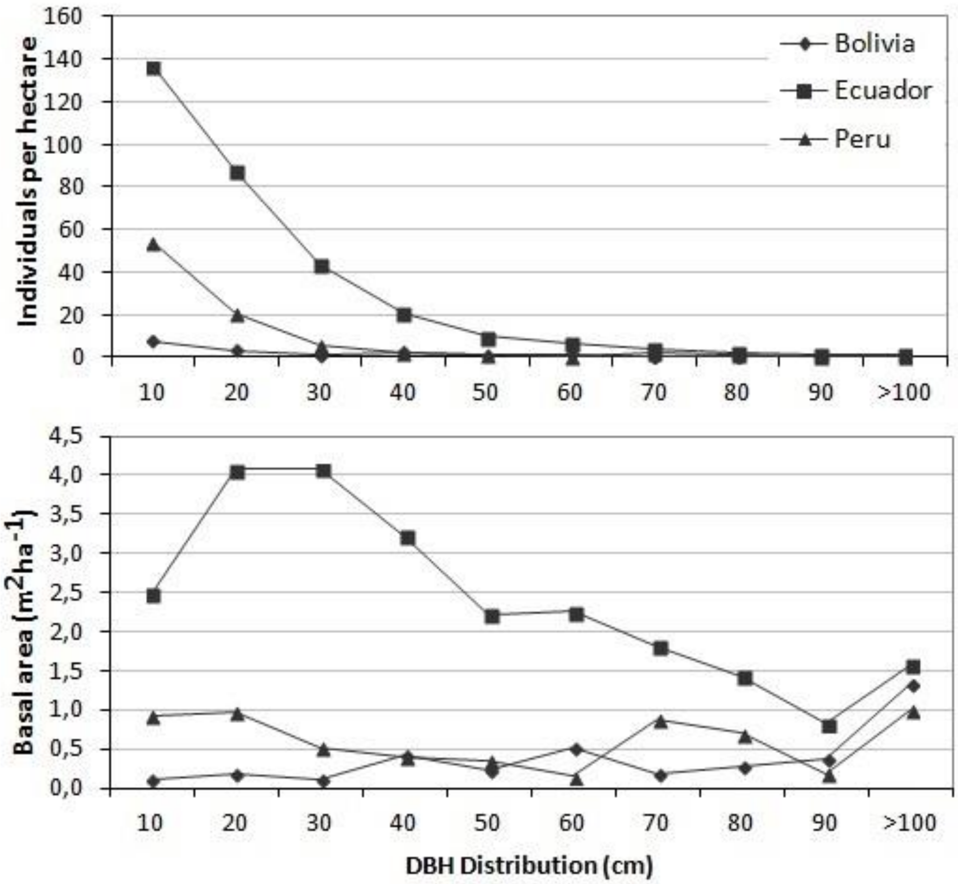
Figure 3.6. Differences in forest composition according to timber commercial value in primary forests on farms in the Macas region in Ecuador.



Large differences were observed in terms of total basal area and timber commercial values. As seen in Figure 3.6, although the first farm did not contain species with high commercial value, more than sixty percent of the basal area consisted of species with medium commercial value. For the second farm forest, most species were those with low commercial value; and the third farm forest contained the highest proportion of species with high commercial value. A rich forest composition in terms of medium or high commercial species was highly valuated by smallholders, influencing also in the strategies of timber management applied to generate incomes. When smallholders owned highly valued forest areas, they normally invested in means of production to sell processed timber as planks or beams. The presence of species with high commercial values (such as *Cedrela* sp. or *Cedrelinga cateniformis)* in large volumes, influenced the interest of smallholders to log their forest areas, even when they were located far from roads, which has an influence incrementing transportation costs, but maintained the profitability of logging.

The DBH structure of the regionally traded species indicated large differences in terms of DBH distribution between the three countries (Figure 3.7). In Bolivia, a total of 20 trees per hectare were counted, in Ecuador a total of 314 trees and in Peru a total of 89. Harvestable species (above 50 cm DBH) in Peru and Bolivia indicated only six and five trees respectively, whereas there were 26 trees in Ecuador. The total basal area varied highly from 3.7 and 24 to 6 m^2 ha^{-1} in Bolivia, Ecuador and Peru respectively.

Figure 3.7. DBH structure of commercial tree species on farms in Bolivia, Ecuador and Peru.



For Bolivia the figure was based on a total sample size of 4,05 ha distributed over 6 forest farms, for Ecuador the sample size is 7.65 ha distributed over 9 forest farms; and for Peru the sample size is 4.05 ha distributed over 6 forest farms.

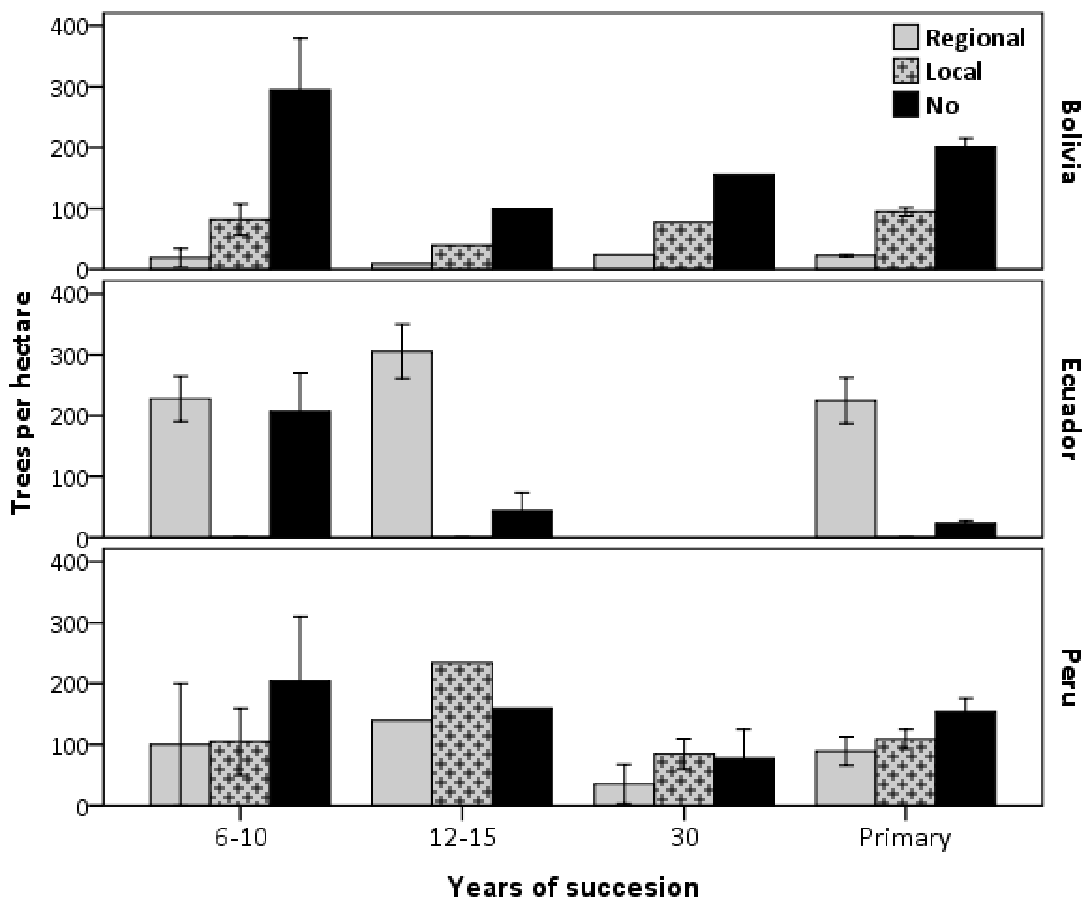
In Ecuador, a DBH distribution like that of uneven-aged populations, also known as an "inverted J", was observed. There, abundant trees with low diameters and the low abundance of trees in the high diameter classes indicated an adequate regeneration of these species. The DBH distribution in Peru shows an intermediate range between Ecuador and Bolivia. For Bolivia, the situation was more critical due to the low number of species in low diameters, which indicated a lack of regeneration of these commercial species. The increment of basal area in the largest diameter classes in the Bolivian forests could be explained by the existence of a relatively high number of *Bertholletia excelsa*, canopy trees with a high basal area. These trees were not harvested for smallholders due to their production of Brazil nuts, which was very important for their household economy.

The information about forest inventories at the farm level indicated that commercial potential was broadly variable, depending on region, local characteristics, and timber. This aspect influences the potential financial value of forests and smallholders´ logging practices.

3.3.3 Commercial timber in secondary forests

Secondary forests were classified according to their successional stage in intermediate, late, and old secondary forests (6-10, 12-15, and >30 years) and by market characteristics. Primary forests were also presented for comparisons. There was a reduction of the number of trees and the increase of basal area when the age of secondary forests increased. Primary forests presented a higher basal area than secondary forests, but they had fewer trees than did intermediate and late successional. This trend was similar for commercial trees in Ecuador and Peru (Figure 3.8).

Figure 3.8. Trees per hectare with current market potential (Regional, Local, No) in different secondary aged successional and primary forests in Riberalta, Bolivia; Macas, Ecuador, and Pucallpa and Puerto Maldonado in Peru. Data show the mean ± SE.



In Peru, the dominance of certain pioneer species with regional potential, including *Guazuma crinita, Calycophyllum spruceanum* and *Schizolobium amazonicum*, was observed. In Ecuador, the pioneer species *Pollalesta discolor* and *Vochysia* sp. were the dominant species in secondary areas. In Bolivia, the number of commercial trees per hectare in secondary forests was comparable to primary, and no dominance of any species with potential for local or regional markets was reported. However, the Brazil nut trees presented higher abundances in secondary than in primary forests, with 10.9 (±16.7) and 3 (±2) trees per hectare respectively. According to smallholders´ interviews, this was the result of tree planting and promotion of regeneration of this species in the aforementioned areas.

Some species abundant in secondary forests (such as *Guazuma crinita* in Pucallpa and *Pollalesta discolour* in the Ecuadorian Amazon) were already being used in small dimensions (around 10 cm DBH) to produce boards for house construction or fruit boxes. In the north of the Macas region, there was observed that smallholders introduced portable saw mills and implemented provisional camps for processing the *Guazuma crinita* to produce boards used for fruit boxes.

The species *Callycophyllum spruceanum*, which regenerates in abundance in secondary flood plain forests in the Pucallpa region, was used extensively as small round wood for house construction or for parquetry when harvested in big diameters. Hence, there was a large demand for these species in local and regional markets, and they increased the potential monetary value of secondary forests.

One important change in old secondary forests was the reduction of the number of trees per hectare when compared to late secondary forests, but there was an increase in the diameter classes and therefore an increment in size of the basal area. This could be interpreted as the transitional stage of the structural characteristics to primary forests. The structure and composition of old secondary forests in the three countries became more like that of primary forests. This was related to the turnover of the pioneer species that dominated the first stage of succession, and the subsequent development of a more diversified composition, which indicated the massive regeneration capacity of these forests (Table 3.7). Old secondary forests had a lower number of trees, a smaller basal area, and a smaller volume in total and market potential than primary forest, even though the differences were very small.

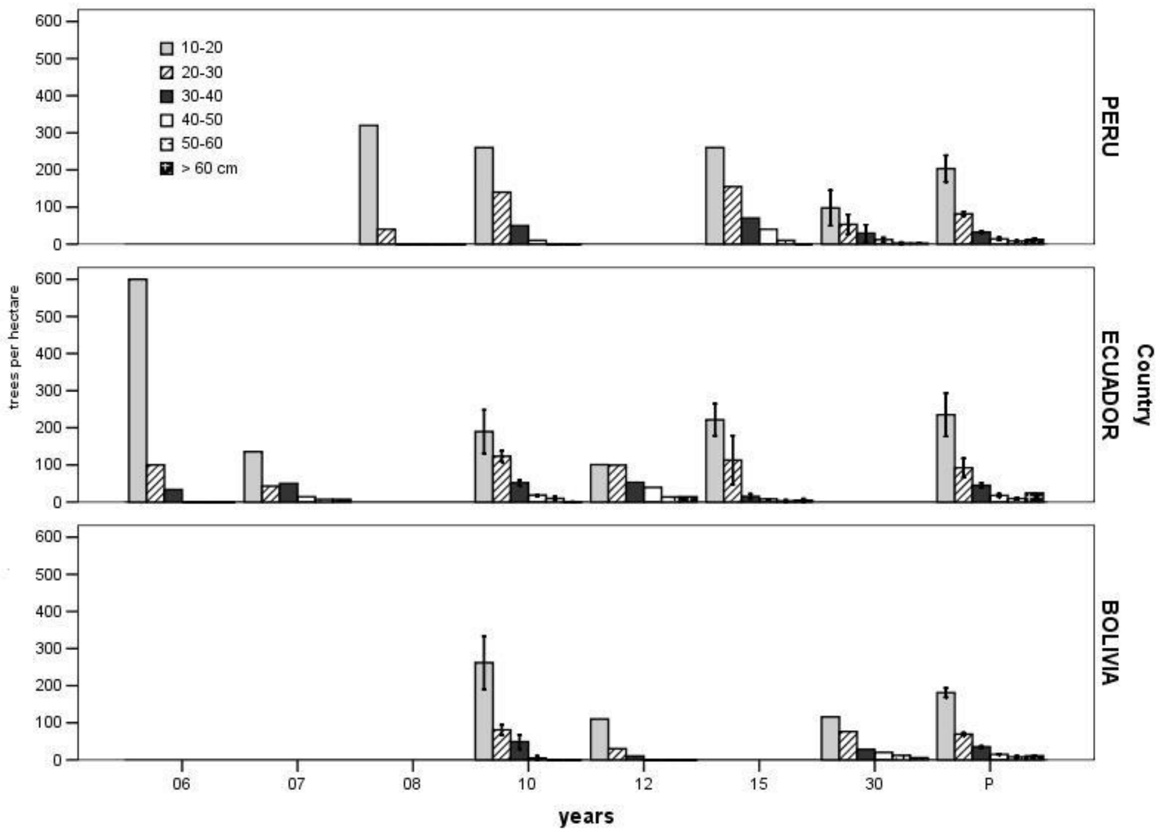
Table 3.7. Number of trees, basal area and commercial volume in primary and old secondary forests in Bolivia, Ecuador, and Peru.

	Bolivia		**Ecuador**	**Peru**	
	Primary	**Old secondary**	**Primary**	**Primary**	**Old secondary**
Trees (N ha^{-1})	319 (33)	258	237(60)	341(67)	303
Trees with commercial potential	117 (15)	102	224(65)	196(71)	178
Basal area (m^2 ha^{-1})	19.8(2.8)	16.4	26.0(3.7)	19.7(5.4)	15.6
Basal area with commercial potential	11.4(3.4)	9.0	24.7(4.3)	13.6(3.6)	11.4
Total volume (m^3 ha^{-1})	132.9(23.6)	105.2	181.6(22.9)	136.5(36.7)	82
Commercial volume	82.7(31.6)	68	172.5(25.4)	98.2(34.0)	62.1

Standard deviation is given in parenthesis. For Bolivia n=6, Ecuador n=3 and Peru n=6.

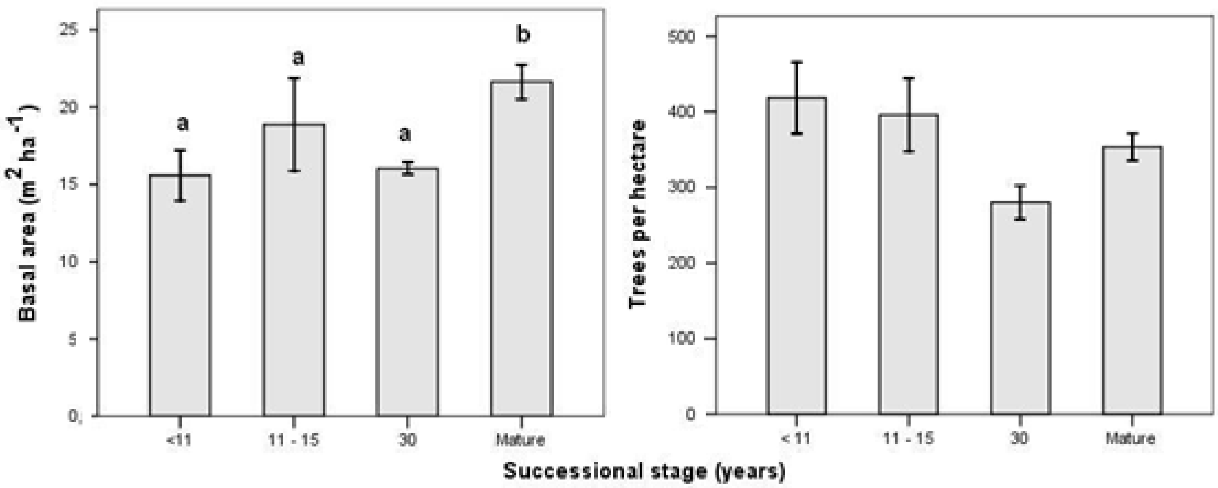
Structural characteristics between different-aged successional forests differed substantially between regions. In terms of DBH distribution, secondary forests in Macas region in Ecuador showed more trees in the higher diameter classes when compared to secondary forests in Bolivia and Peru (Figure 3.9). These differences may be explained by the fact that smallholders in Ecuador did not practice slash and burn, and so remnant trees from primary forests were retained. In addition, a large variation in terms of diameter distribution was observed between different stands in different regions.

Figure 3.9. DBH distribution of trees in different secondary forests and Primary (P) forests on farms in the regions of Riberalta in Bolivia; Macas in Ecuador, and Pucallpa and Puerto Maldonado in Peru.



In the intermediate successional stage the presence was registered of trees in the diametric class of 30-40 cm DBH and even some trees in the higher diametric class, indicating the high capacity of regeneration of biomass and carbon sequestration of abandoned areas by smallholders. These trees were principally pioneer species including *Cecropia* sp. and *Ochroma* sp*.* However, in the following successional stages the number of trees was lower. In old secondary forests, the basal area also was reduced when compared to the previous successional stages. This aspect was explained by a change in the composition from light-demanding to shade-tolerant species. When aged successional stands were grouped, only differences between primary forests and secondary were detected in terms of basal area (Figure 3.10, ANOVA $F_{3,26} = 3.5$, $P = 0.029$).

Figure 3.10. Basal area and stems per ha in different-aged successional farm forests in Riberalta, Bolivia; Macas, Ecuador, and Pucallpa and Puerto Maldonado in Peru. Different letters in the basal area graph indicate statistical differences. Data show the mean ± SE.



The successional stages also differed in species composition. The common pioneer species (*Cecropia* sp. and *Ochroma* sp.) were the most important ones in the intermediate successional stage (Table 3.8). According to the ecological characteristics, these two species were catalogued as short lived – light demanding. In addition, the commercial timber species *Pollalesta discolor* in Macas and *Guazuma crinita* in Pucallpa were abundant in intermediate and late secondary forests. In Riberalta the brazil nut (*Bertholletia excelsa*), the most important forest product for smallholders, also contributed substantially to the composition.

For the late secondary forests, *Pouteria macrophylla,* a tree with timber potential for local markets and catalogued as shade tolerant, was of major importance in the Riberalta region. In Macas, the commercial species *Pollalesta discolor*, followed by *Vochysia* sp*.,* were the most important species. In Pucallpa and Puerto Maldonado, the most important species was *Cecropia* sp*.*, followed by the commercial species *Ficus antihelmintica* and *Callycophyllum spruceanum*.

In old secondary forests in Riberalta, the species *Jacaranda copaia,* which showed potential for local markets, was the most important. In Puerto Maldonado, *Cecropia* sp*.* was the most important, followed by the commercial species *Schizolobium amazonicum.* In terms of the ecological characteristics, no significant change was seen in terms of abundance of shade-tolerant species.

A common pattern observed at farm level was a high dominance of single species, including *Cecropia* sp*., Ochroma* sp*., Pouteria macrophylla, Jacaranda copaia, Pollalesta discolour, Ficus antihelmintica, Callycophyllum spruceanum,* and *Schizolobium amazonicum.* In some secondary forests in the north of Macas and the surroundings of Puerto Maldonado, stands were observed of the single species *Pollalesta discolor* and *Guazuma crinita* being managed by smallholders, considering their economic potential. When the species had potential for local or regional markets, smallholders valuated these areas, and, in some cases, the enrichment with other commercial species was observed, including

Cedrela odorata, Amburana cearensis, Bertholletia excelsa, Mezilaurus itauba, Clarisia racemosa, and *Cedrelinga cateniformis.*

Table 3.8. Importance Value Index (IVIs) of the 10 most important tree species for each successional stage in Riberalta, Macas and Pucallpa and Puerto Maldonado.

	Species	Common name	Successional stage (years) 6-10	11-15	30	Ecological characteristic	Market potential
Riberalta	*Bertholletia excelsa*	Almendro	12.3	16.5	7.4	S.t.	R
	Cecropia sp.	Ambaibo	43.1	0.0	2.5	S.l - L.d	No
	Inga sp.	Pacay	15.4	36.9	9.4	L.l - L.d	L
	Jacaranda copaia	Chepereque	13.1	0.0	62.2	L.l - L.d	L
	N.d.	Malva	14.0	0.0	3.5	N.d.	No
	Poeppigia procera	Ramillo	17.9	0.0	0.0	N.d.	L
	Pouteria macrophylla	Coquino	4.4	82.0	20.4	S.t.	L
	Sclerolobium guianense	Palo santo	2.0	33.6	2.0	N.d.	L
	Xylopia ligustrifolia	Piraquina	1.6	0.0	37.7	S.t.	L
	Zanthoxylum sprucei	Sauco	10.8	54.4	9.4	N.d.	L
Macas	*Bixa platycarpa*	Achotillo	7.1	23.6		L.l - L.d	R
	Cecropia sp.	Guarumo	52.1	11.5		S.l - L.d	No
	Croton mutisianus	Sangre de	2.7	27.7		L.l - L.d	R
	Dacryodes peruviana	Copal	3.2	14.2		S.t.	R
	Miconia spp.	Miconia	10.0	5.4		N.d.	R
	N.d.	Balsa jíbara	8.0	16.1		S.t.	R
	N.d.	Guabo	30.4	8.1		*N.d.*	R
	Ochroma pyramidale	Balsa	47.7	2.5		S.l - L.d	R
	Ocotea sp.	Canelón	9.1	15.6		L.l - L.d	R
	Pollalesta discolor	Pigüe	27.0	67.2		S.l - L.d	R
	Vochysia sp.	Bella maría	4.0	43.5		L.l - L.d	R
Pucallpa and Puerto Maldonado	*Cecropia* sp.	Cetico	33.7	70.5	52.1	S.l. - L.d	No
	Ochroma sp.	Topa	93.5	0.0	35.1	S.l. - L.d	No
	Ficus antihelmintica	Ojé	0.0	70.2	16.5	L.l - L.d	L
	Guazuma crinita	Boliana	39.8	0.0	19.4	S.l. - L.d	L
	Inga sp.	Shimbillo	3.1	37.2	9.8	L.l - L.d	No
	Callycophyllum spruceanum	Capirona	0.0	45.6	0.0	S.t.	R
	Schizolobium amazonicum	Paschaco	18.5	0.0	40.0	L.l - L.d	R
	Couma macrocarpa	Lechecaspi	0.0	29.9	0.0	N.d.	L
	Apeiba membranacea	Peine de mono	12.7	0.0	11.9	S.t.	L
	Pouteria torta	Quinaquina	12.3	0.0	0.0	S.t.	L

S.l.-l.d.: Short lived – Light demanding. L.l.-l.d.: Long lived – Light demanding. S.t.: Shade tolerant. Not defined: N.d
R Regional market potential, L: Local market potential No: No market potential
IVIs was calculated by adding together the relative abundance, relative frequency and relative dominance of each species.

The minor development of markets in Riberalta determined that the unique species with potential to regional markets was the brazil nut, which meant in practice that smallholders were not harvesting timber species from secondary forests. However, in other regions, other species were reported as regenerating in abundance in secondary forests and were being marketed by smallholders, as in the case of *Schizolobium amazonicum* in the region of Santa Cruz (Zulma Villegas, personal communication). However, in the region of Riberalta, the most important characteristic of secondary forests, as far as providing incomes to smallholders was concerned, lay in the high regeneration and enrichment of *Bertholletia excelsa.*

3.3.4 Financial potential of forests

The potential financial value of forests depended on the abundance of commercial trees in farm areas, market prices of standing trees or processed products, and costs of production. In Macas, smallholders normally logged trees when they had reached diameters around 50 centimetres. In Pucallpa and Puerto Maldonado smallholders sold the trees to traders or middlemen from 50 centimetres up, with different prices for lower and higher diameters. In Riberalta traders bought only logs with high diameters, normally from 80 cm up. Differences in the number of trees and volume per hectare are presented in Table 3.9.

Table 3.9. Number of trees and potential commercial volume for regional markets in farm forests in the regions Riberalta, Bolivia; Macas, Ecuador and Pucallpa and Puerto Maldonado in Peru.

	Trees (N ha^{-1})			Volume (m^3 ha^{-1})	
	< 50 cm DBH	**50-80 cm DBH**	**>80 cm DBH**	**< 50 cm DBH**	**> 50 cm DBH**
Bolivia	14.8(3.1)	2.9(1.4)	1.9(1.9)	4.9(1)	24.0(17.3)
Ecuador	288.5(98.9)	20.8(5.7)	4.9(4.0)	83.5(18.2)	78.6(26.9)
Peru	83.2(48.5)	4(2.4)	2.2(2.2)	16.4(5.8)	25.0(20.8)

Standard deviation given in parenthesis

While in Ecuador on average 26 trees per hectare were available for logging, in Peru there were only 6 and in Bolivia 2 trees per ha. The potential commercial volume, was also higher in Ecuador, with around 80m^3 ha^{-1} and 25m^3 ha^{-1} and 24m^3 ha^{-1} in Bolivia and Peru respectively, with considerable differences between farm forests.

Of the stock of potential commercial species inventoried in farm forests and market prices, a valuation of the potential monetary value per hectare for timber is presented in the Table 3.10. The potential financial values were calculated under the assumption that all trees were harvested in one felling, sold as standing trees to traders and middlemen, and without management plans. In the case of Ecuador, two additional valuations were presented under the assumption that smallholders sell planks and legalizing timber harvesting.

Table 3.10. Potential monetary value of timber in forests of the Riberalta, Macas, Pucallpa and Puerto Maldonado regions.

Country	Trees (N ha^{-1})	Value (USD$ per tree)	Value (USD$ m^3)	Value as standing trees (USD$ ha^{-1})	Value if cut into planks (USD$ ha^{-1})	Value legally harvested (USD$ ha^{-1})
Bolivia	1.9 (1.9)[1]	26.0	4.3	50.6(49.5)		
Ecuador	25.7 (7)[2]	20.0-80.0	10 – 16	531.8(216.7)	727.2(375.9)[4]	302.0[5]
Peru	2.2(2.2)[1] 4.0(2.4)[3]	32.2 16.1	5.3	136(103)		

[1]Per stand tree with DBH greater than 80 cm.
[2]Per stand tree with DBH greater than 50 cm
[3]Per stand tree with DBH between 50-80 cm
[4]Under the following assumptions: (1) The owner had a chainsaw for the transformation to planks (2) the owner owned horses for the transportation of the planks to roads (3) the forest is located 3 hours walking from the road, (4) the owner uses his manpower for the activity (5) he does not legalize the extraction, and (6) they sell the wood to traders at the border of the road. Costs included: chainsaw depreciation, manpower help of two assistants, valuation of the farmers´ manpower, costs of fuel, oil and chain; costs of investments for horses and maintenance.
[5]Based on the assumption that the smallholder harvests one tree of low value, two trees of medium value and one tree of high value.
Standard deviation given in parentheses.

When timber was sold as standing trees, smallholders did not have any production cost, considering that middlemen assumed the costs of sawing and transporting the logs. The common practice in most of the cases in Bolivia and Peru, and some cases in Ecuador, was to sell the standing trees when smallholders faced financial hard times and to buy school supplies. This practice influenced in the fact that in Bolivia, 50% of the sample (three farms inventoried) and in Peru 16% (1 farm) did not show commercial volume, and therefore the financial potential value was zero. The maximum potential value of a hectare (USD$ 771.4), was observed in a primary forest in the Macas region in Ecuador, but the average was around USD$ 531.8.

In many cases, the financial values were limited in their potential to be converted to cash income due to limited physical conditions, especially in the regions of Riberalta and Pucallpa. For instance, some communities living in floodplain forests were limited to the dry season for timber harvesting. Yet, the dry season causes the decrease of river flows, which limits the transportation of timber by floating. In the region of Pucallpa, smallholders have only five months each year to log the timber before the water floods the forest lands under management.

When logs are cut into planks, as is common in Ecuador, the average value would be USD$ 727.2, with notable differences between farm forests with a range value from USD$ 31.8 to 1,324.4 depending on the availability of commercial trees and previous logging activities. The lowest value corresponded to a forest subjected to logging during the past 15 years. An aspect considered in the costs of processing planks was the inclusion of the owner's manpower, with a value that was normally paid to a sawyer. However, in many cases the opportunity cost of the time invested in the timber activity would be much less when other production activities were the option, or even zero when they did not have other options. In this sense, the net benefits would be much higher.

If smallholders comply with the legal requirements through simplified management plans that normally allow the logging of four trees per hectare in average, the potential benefits to be obtained are reduced to USD$ 302 per hectare.

3.4 Effects of logging on the structure and composition of farm forests

This section presents an analysis of the effects of logging carried out by smallholders in their forest areas in terms of their structure and composition. Some analysis was carried out only in the Macas region of Ecuador, because only there were primary forests inventoried as reference areas. Also, different logging intensities were identified. Characteristics of smallholders' forest areas are presented in terms of structure and composition of commercial species and differences in terms of potential commercial volumes according to logging intensity. Characteristics in terms of DBH distribution of the commercial species and the most commonly logged species were compared between primary and logged forests to identify possible structural changes that occurred because of timber logging.

3.4.1 Logging intensities in farm forests

Table 3.11 shows information about logging intensity in terms of the number of trees logged per ha, and the effects in forest areas in terms of structure and composition of stands. Characteristics analysed included number of trees, basal area, DBH average, volume of commercial tree species, and basal area. In the region of Riberalta, logging intensities varied from 0.2 to 2 trees per ha, whereas in the regions of Pucallpa and Puerto Maldonado intensities ranged from 0.2 to 3 trees per ha. In contrast, logging intensities in the region of Macas ranged from 2.1 up to 25 trees per hectare during a period of around fifteen years. It was an effect of the demand; timber markets started to demand species used for doors, floors, furniture, and structures for houses. Normally, logging started from the areas nearest to the roads, and then expanded to more distant areas. The most intensive logged farm forest was already abandoned for its owner because commercial species became scarce, reducing the potential profitability of timber-related activities.

The logging intensity caused an increment of the number of trees per hectare, changing the structure of the forest areas (R^2=0.64, $p<0.01$). Comparing primary and logged areas in the Macas region, significant differences were seen in the total number of trees and also in the number of the commercial trees (t-test [$p < 0.05$]). In terms of basal area, there was no observed pattern as an effect of logging intensity, probably since extraction of commercial volume is balanced by the emerging new stems. In the Macas region, there were large differences in terms of the basal area in primary and logged areas.

Table 3.11. Structural and commercial characteristics of primary and logged farm forests in Bolivia, Ecuador, and Peru.

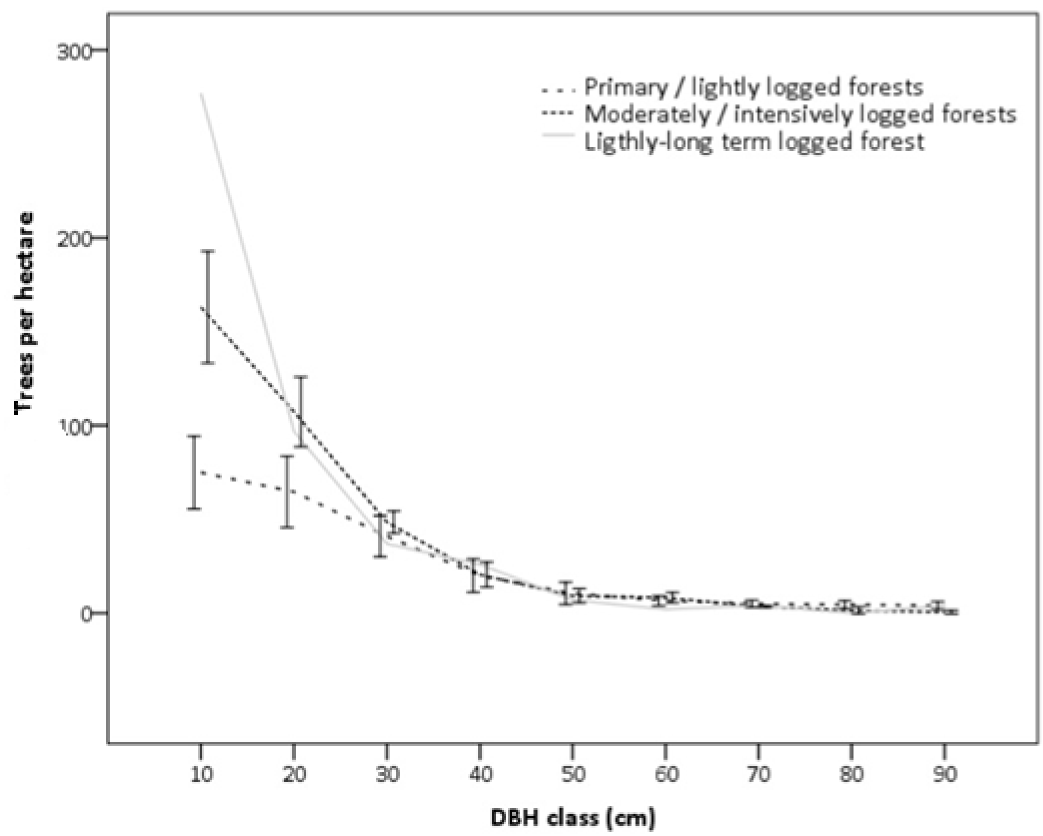
Country	Trees logged (N ha^{-1})	Years since logging started	Trees (N ha^{-1})	Stems of commercial species (N ha^{-1})	Basal area (m^{2}ha^{-1})	DBH average (cm)	DBH average of commercial species (cm) (Std)	Commercial volume (m^{3}ha^{-1})
Bolivia	2.0	6	380	5	19.9	21.6^a	26.4(13.2)	0.0
	1.0	8	317	3	15.8	21.9^a	12.3(3.0)	0.0
	1.0	6	318	6	17.4	22.4^a	34.7(21.2)	5.3
	0.7	10	322	8	20.8	23.7^a	41.3(32.0)	12.4
	0.3	11	289	7	23.4	25.1^a	21.7(16.1)	0.0
	0.2	8	288	10	21.7	25.1^a	35.7(28.9)	11.2
Average			**319**	**6.5**	**19.8**	**23.3**	**28.7**	**4.8**
Ecuador	Primary		230	200	22.9	30.1^a	31.0(19.6)	89.8
	Primary		315	298	30.1	29.7^a	30.3(18.5)	116.2
	Primary		196	176	25	32.5^a	33.2(24.8)	116.2
	25.0	15	333	288	19.4	24.1^b	24.9(12.9)	42.8
	21.8	15	396	355	24.8	24.6^b	24.8(14.1)	45.0
	6.9	10	526	414	32.7	25.2^b	24.5(12.8)	64.3
	5.5	15	481	453	27.6	22.4^c	22.2(15.3)	71.6
	5.0	5	358	254	28.1	28.3^a	30.2(15.4)	71.7
	2.1	12	400	392	28.3	26.3^b	26.2(14.6)	90.0
Average primary			**247**	**224**	**26.0**	**30.8**	**31.5**	**107.4**
Average logged			**416**	**359**	**26.8**	**25.2**	**25.5**	**64.2**
Peru	3.0	21.0	283	11	12.3	21.1^b	30.1(22.5)	6.8
	3.0	6.0	439	49	16.2	18.9^a	21.2(16.3)	17.9
	3.0	7.0	378	32	16.8	20.3^a	22.4(10.8)	0.0
	1.0	8.0	360	27	24.5	24.3^b	39.4(30.8)	38.0
	1.0	6.0	255	10	26.2	30.7^c	41.9(19.2)	10.0
	0.2	0.0	334	32	22.1	23.3^b	19.6(11.1)	4.8
Average			**341.5**	**26.8**	**19.7**	**23.1**	**29.1**	**12.9**

Letters a, b, c correspond to differences of DBH structure between farms through Mann-Whitney non-parametric test. Letter a corresponds to the farm forests that were not or only to a small extent disturbed; b and c correspond to disturbed farm forests.

Regarding DBH average between stands as a result of logging intensity, in Riberalta no differences were discovered between farm forests (Kruskall-Wallis test, $Xi^2 = 10.7$; p=0.057), even though there were slight variations in terms of the number of trees logged. In Pucallpa and Puerto Maldonado three groups of farm forests appeared in terms of DBH average, probably related to site-specific factors and the fact that one forest was affected by fire. In Macas, also three groups of farm forests were identified by performing a Kruskall-Wallis test (Xi^2 = 2019, p<0.01). The first group, composed by three primary farm forests and a farm forest that was partially logged, had the highest DBH mean; the second group showed intermediate DBH values; and the third was composed of a single forest that presented the lowest DBH average, but at the same time presented the highest number of commercial trees per hectare. The average DBH of commercial species was significantly higher in primary than in logged forests in the Macas region, as seen through a t-test (P<0.01). In addition, primary forests were more heterogeneous than their logged counterparts in terms of DBH distribution due to the existence of more trees with larger diameters.

Figure 3.11 presents the DBH distribution of commercial stems for the three categories statistically identified in the Macas region in Ecuador (Primary/lightly logged, Moderately/intensively logged and Lightly-long term logged), with large differences between logged and primary forests in the first and second diameter class, where logged forests had almost twice as many trees as primary forests.

Figure 3.11. DBH distribution of commercial trees in three groups of farm forests in the Macas region, Ecuador.



Vertical bars indicate standard deviation. Primary/lightly logged forests n=4. Long term-lightly logged forest n=1. Moderate logged forest n=4.

The abundance of trees in the lower DBH class was related to disturbances that generated gaps and provided opportunities for regeneration. In contrast, more trees were observed with larger diameters in primary forest areas, resulting in different structural characteristics between logged and primary forests.

The commercial volume of commonly logged species was very low in Bolivia, with an average of 4.8 m^3 ha^{-1}, but three of the six farm forests did not contain any commercial volume. In Peru, the volume was higher, with an average of 12.9 m^3 ha^{-1}, but around 50% percent of these values corresponded to the abundant *Aniba* sp*. and Ocotea* sp*.* In the region of Macas, the volumes of commercial species were much higher in primary forests than in logged areas and differences were significantly different (t-test [$p<0.01$]). A direct relation is observed when comparing the number of trees logged per hectare and the commercial volume.

The characteristics analysed indicate a clear relationship between logging intensity and number of trees. Disturbance is causing an increment in the number of trees and changing the structure of forests. However, and according to the number of commercial species of each region, it is important to analyse the types of species that regenerate in the gaps opened so as to identify the potential to manage forest areas in the future. This aspect is analysed in the next section.

3.4.2 Composition and population structure of the logged species

Logging dynamics have changed according to market demands. Around thirty years ago markets were limited to the single species *Swietenia macrophylla, Cedrela odorata, Amburana cearensis,* and *Chorisia integrifolia*. These species appear in low density, normally less than one tree per hectare. When these species became scarce in many areas of the Amazon, markets started to demand new species for different purposes including furniture, plywood and parquetry. Even though nowadays new species have been included in timber markets, in the regions of Riberalta, Pucallpa and Puerto Maldonado the species demanded were characterized by a relative low density when compared to the region of Macas, excepting the species of the genera *Aniba* and *Ocotea*, which showed demand in the markets of Pucallpa and Puerto Maldonado (Table 3.12).

In Riberalta, the abundance of the species logged was generally low, but highly variable between farm forests, with densities varying from 0.5 trees per hectare for *Tabebuia serratifolia* to 2.2 for *Mezilaurus itauba*. The most valuable species, *Swietenia macrophylla, Cedrela odorata* and *Cedrelinga cateniformis*, were not reported in the inventories, probably due to their low density and the logging that took place around twenty years ago by timber companies.

In Pucallpa and Puerto Maldonado, the species *Amburana cearensis*, *Cedrelinga cateniformis*, and *Swietenia macrophylla* were not reported. In most of the cases, colonist smallholders had arrived in the forest areas after that timber companies had already logged the most valuable species, including *Cedrela odorata* and *Chorisia integrifolia.*

Table 3.12. Number of trees per ha of commonly logged species on forest farms in Riberalta, Macas, Pucallpa and Puerto Maldonado (for trees with DBH > 10cm).

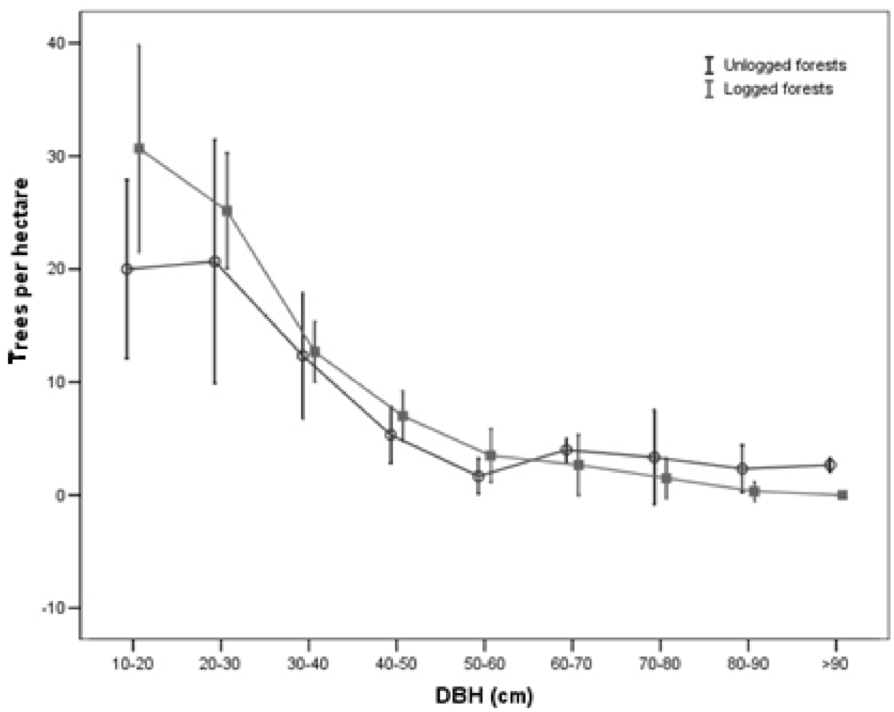
Specie	Riberalta	Macas Primary forest	Macas Logged forest	Pucallpa Puerto Maldonado
Amburana cearensis	0.6(1.0)			Not found
Aniba sp. and *Ocotea* sp.		**24.7(11.8)**	**27.9(14.5)**	**12.8(15.2)**
Aspidosperma macrocarpon				0.2(0.5)
Astronium lecointei	0.8(1.2)			
Cabralea canjerana		10.6(12.9)	14.4 (11.4)	
Callycophyllum spruceanum				2.8(2.2)
Calophyllum brasiliense		3.8(6.6)	0	
Cedrela odorata	**Not found**	**1.6(0.8)**	**1.1 (1.2)**	**0.5(0.7)**
Cedrelinga cateniformis	Not found	0.6(1.1)	0	Not found
Chimarrhis glabiflora		1.2(1.3)	4.0(5.8)	
Chorisia integrifolia				0.2(0.6)
Clarisia racemosa		1.0(1.6)	6.1(6.8)	
Dipteryx odorata	0.9(1.4)			
Dipteryx alata				1.9(4.0)
Dacryodes peruviana		16.8(2.2)	19.4(8.8)	
Hura crepitans				0.6(0.9)
Hyeronima alchorneoides		0	3.6(7.2)	
Manclura tinctoria		0	0.3(0.7)	
Manilkara bidentata				1.7(3.0)
Mezilaurus itauba	2.2(0.9)			
Nectandra sp.		6.3(11.0)	0	
Ormosia schunkei				1.4(2.2)
Otoba parvifolia		22.2(6.0)	24.5(14.3)	
Pithecellobium carymbosum	0.9(1.0			
Podocarpus sp.		0	0.5(1.2)	
Pourouma guianensis		6.9(3.8)	28.5(20.1)	
Ruagea insignis		1.4(2.5)	1.3 (1.5)	
Simarouba amara		**2.8(1.9)**	**3.7 (5.8)**	**1.4(2.2)**
Symphonia globulifera		0	0.7(1.6)	
Swietenia macrophylla	Not found	Not found	Not found	Not found
Tabebuia chrysantha		0.8(1.4)	0.3(0.7)	
Tabebuia serratifolia	0.5(0.8)			
Terminalia amazonia		0.8(1.4)	3.4(4.1)	
Tapirira guianensis		Not found	1.9(3.4)	
Vochysia vismiifolia	0.7(0.8)			
Vochysia sp.		7.7(7.5)	11.3(15.5)	
Rest of commercial species		115(39.5)	206(48.9)	
Sum		224.2	358.9	

Standard deviation is given in parenthesis.

In Macas, a higher number of commercial trees were present in logged forests when compared to primary, although with a high variation between farms. In addition, not all species were present in both forest types. For example, the species *Cedrelinga cateniformis* was present only in one of the four studied communities. The abundance of species per hectare varied from non-existent in some logged or primary forests to 28.5 individuals for *Pourouma guianensis,* which was more abundant in logged than primary forests. This was probably due to its ecological characteristics—it is a semi-pioneer or gap opportunistic species that regenerates in gaps created by logging. Although the species *Swietenia macrophylla* and *Cordia alliodora* were reported as previously logged by farm owners during the interviews, they were not reported during the inventory process.

To analyse the structure of the population of the most common commercial species, and the impacts of logging, DBH distribution in primary and logged areas was performed for the following species: *Aniba* sp. and *Ocotea* sp., *Dacryodes peruviana, Otoba parvifolia*, and *Vochysia* sp. (Figure 3.12). The five species analysed were more abundant in logged than primary forests, presenting a total number of 83 and 71 trees per hectare respectively, even though the species *Dacryodes peruviana* was shade tolerant and therefore it could be expected that gaps were the cause the population reduction.

Figure 3.12. Diameter distribution of four most commonly logged species between logged and primary farm forests in Macas, Ecuador.

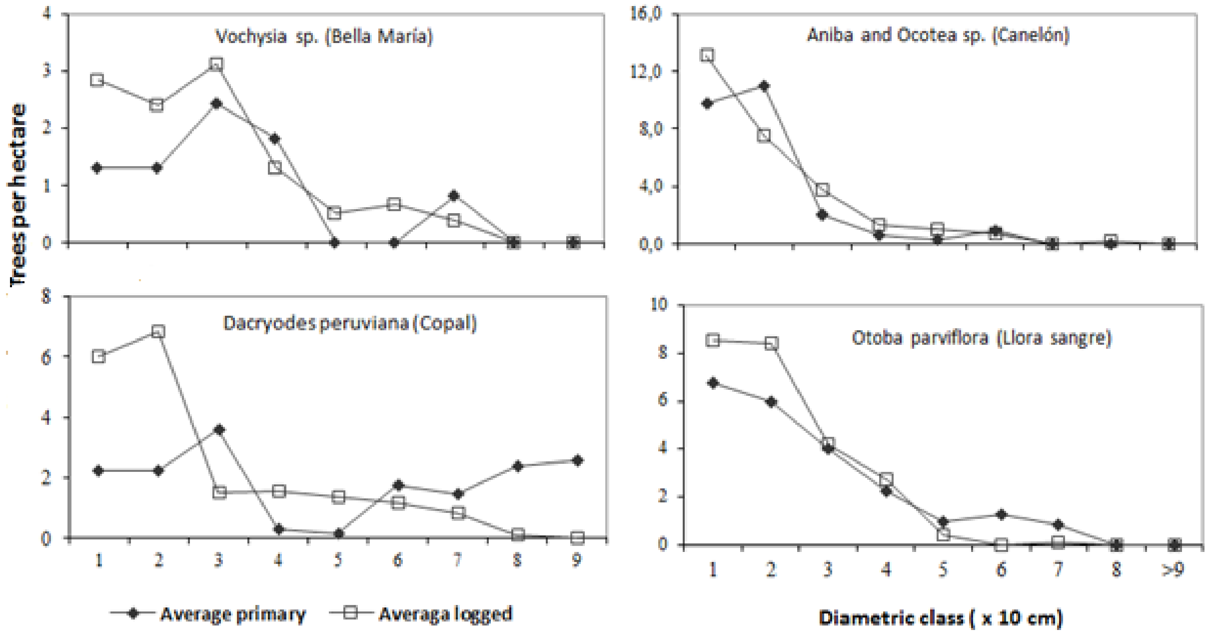


For primary forests n=3 and logged forests n=6. Vertical lines indicate the standard deviation.

Primary forests were more heterogeneous in terms of the structure of the species analysed when compared to logged areas and also the average diameter was significantly higher in primary areas (P<0.01). The logging effects have generated a major abundance of species in the lower DBH as result of the gaps opened by logging, changing the structure of forests. The composition also was affected, considering that primary forests presented at least 82 species versus 65 species identified in logged areas.

Figure 3.13 presents a detailed DBH distribution in primary and logged areas of the most common commercial species, to observe particular responses in their population structure to logging effects.

Figure 3.13. Diameter distributions for the four most commonly logged species, in primary and logged forest in Macas, Ecuador. a) Vochysia sp., b) Aniba and Ocotea sp., c) Dacryodes peruviana; d) Otoba parvifolia.



Vochysia sp. was a species used principally for moulds in the construction industry. It was the less abundant of the most common commercial species analysed presenting an average of 8 and 11 trees per hectare in primary and logged areas respectively. The number of commercial trees per hectare was higher in logged forests for the fifth diametric class with 1.6 and 1 individuals respectively, indicating that logged forests have higher possibilities for timber management.

Aniba sp. and *Ocotea* sp. are medium density species, largely appreciated in timber markets in Ecuador, and are used principally in the furniture industry. They were the most abundant species in the Macas region, with an average of 25 and 28 trees per hectare in primary and logged areas respectively. In addition, DBH average was slightly higher for the third diametric class in logged areas, while primary forests did not show trees for the sixth diametric class. These aspects indicate that the logging effects are modifying the structure of the population, increasing the potential of timber management when compared to primary forests. However, the commercial potential was limited in the short term because of the low abundance of individuals with harvest conditions.

The species *Dacryodes peruviana* is one of the most intensively logged species in the region of Macas because its physical conditions of a big tree, which determine large commercial volumes. In addition, during the last years the timber started to be used as furniture by markets, increasing its commercial value. In the Macas region it was abundant, with 17 and 19 individuals per hectare in primary and logged areas respectively. As expected, in primary forests this species showed more trees in the higher diameter classes when compared to logged forests, but few trees were observed in the lower diametric classes when compared to logged areas. A relatively high abundance of individuals of 8 and 3 trees per hectare in primary and logged areas respectively indicated a high potential of management for this species.

Otoba parvifolia was a commercial species used principally as moulds in the construction industry, and also presented a high abundance, with 22 and 25 trees per hectare in primary and logged forests respectively. According to Figure 3.13, logged forests did not present conditions for management of this species, because there were not reported individuals with harvestable volumes.

This section analysed the effects of smallholders' logging on forests in terms of structure and composition. In the regions of Riberalta, Pucallpa, and Puerto Maldonado, several commercial species were present in low quantities (commonly less than one tree per hectare). Some valuable species, including C*edrela odorata, Swietenia macrophylla, Cedrelinga cateniformis*, and *Amburana cearensis*, were not found in the studied forest areas. In the region of Macas, where logging processes have been more intensive, logging effects had affected the forest structure and composition by increasing the number of trees per hectare in the lower diameter classes and changing the species abundance of certain species when compared to primary forests. In addition, it was observed that the commercial potential in logged forests remained high (Table 3.11), considering that some areas had been subjected to permanent logging during the last fifteen years.

3.5 Possibilities for long term management of smallholders´ forest areas

This section presents an analysis of the possibilities for long term management of smallholders´ forest areas considering three aspects: i) the practices that smallholders apply to manage their timber resources, ii) modelling scenarios of their forest areas for timber management in the long term, and iii) projecting financial scenarios of timber management.

The first subsection summarizes the elements that characterize timber management by smallholders and compare them with timber management frameworks, to identify possible elements of convergence related to the sustainability of smallholders´ practices. The next subsection presents projections for timber logging in smallholders' forest areas under 30-year rotation scenarios, to identify possibilities for management in the long term. Finally, potential financial incomes were performed, depending on logging characteristics, accessibility to forest areas, and availability of means of production for logging activities. These analyses contributed information for the analysis of the viability of timber management in social, ecological, and financial terms.

3.5.1 Smallholder's forest management practices

Although it could be argued that smallholders´ timber management practices lack sustainability, some important elements have been identified through this research. These elements are presented in the Table 3.13, and summarize most of the aspects analysed in the previous sections and compare them with the elements defined within the Sustainable Timber Management schemes.

Table 3.13. Comparison of Sustainable Timber Management and Smallholders Timber Management on smallholders´ lands.

Element of analysis	Smallholders Timber Management in the Amazon region	Sustainable Timber Management in tropical areas
Harvesting criterion	Ecuador: Logging of commercial trees permanently from the entire forest area. Bolivia, Peru: Selling of standing tree of few species according to markets or traders demand.	Turning cycles of minimum 30 years through the definition of annual cutting blocks of around 20-30 ha, where around 80% of commercial trees are proposed for harvesting.
Number of species logged	Ecuador: Between 1 to 80 species depending on smallholders´ logging strategies. Bolivia and Peru: up to 22 species according to market demands.	Depending on market characteristics and value-added chains of timber industries.
Logging intensity	Ecuador: From 20 to 75 $m^3\ ha^{-1}$ depending on the smallholder´s timber logging strategy. Bolivia, Peru: Up to 12 $m^3\ ha^{-1}$ depending on abundance of commercial species., but in most cases between 30 and 45$m^3\ year^{-1}$ of the entire forest area.	From 11.8 to 40 $m^3\ ha^{-1}$, depending on value-added chains of timber industries, market demand and production costs.
Logging practices	- No criteria for felling activities. - Transformation into planks or beams in the forest with the use of chainsaw, and extraction with horses or trucks, depending on accessibility conditions.	- Reduced Impact Logging practices to minimize impact of logging activities. - Use of heavy machinery for logging and log extraction.
DBH of trees logged	Minimum 50 cm to obtain some planks with the use of chainsaw.	Normally more than 40 cm, depending on each forest national regulation.
Silvicultural treatments	Liberation of vines and competence of valuable trees and tree enrichment of commercial species.	Liberation of vines and thinning, according to each forest national legislation.
Criteria to conserve vulnerable species	No	According to abundances or pressures identified with individual populations.
Conservation criteria	- Sometimes protection of big and healthy trees as seedlings, but according to the criteria of the smallholder. - Logging does not take place on steeply zones due to difficulties of sawing.	- Around 20% of the commercial trees for protection or seedlings. - Protection of vulnerable species - A buffer zone around rivers or slopes depending on each national forest law.
Smallholders or communities' participation in the logging activity	Ecuador: logging, transformation to planks or beams, transporting to roads by horses, and sometimes marketing, depending on the smallholder timber strategy. Bolivia and Peru: Normally negotiation of prices of trees	-Negotiation of timber rights in forest areas with traders or enterprises. -Smallholders contracted as workers for the enterprise for logging activities.

[1]For instance, in Ecuador only around four trees per ha can be removed through simplified management plans.

[2] For instance, in Brazil it is prohibited to harvest "rare" species, whose density of trees in harvestable dimensions falls below three trees per 100 ha (Brazil 2006 in Schulze et *al.* 2008).

One of the most important aspects of smallholders´ timber management is that the logging of trees is carried out permanently and located in any part of the farm forest, depending on species occurrence, conditions of accessibility, and market demands. Logging impact is distributed during the first years in the most accessible areas, and then distributed along the entire forest area. This aspect influences the impact over the biomass and the ecological processes of regeneration after logging. Depending on the logging intensity, the impact over the biomass would be reduced, because of the logging is carried out permanently and not only in a specific moment as occurs with STM.

Smallholders respond to local and regional market demands to define the number of species logged. Depending on the logging strategies, smallholders have the capacity to respond to different market demands, and therefore a more diverse selection of species is logged from forest areas. When STM is applied by an industry, the number of logged species is limited according to their value-added chains. The same aspects influence the logging intensity. Smallholders specialized in timber logging apply higher logging intensities when compared to timber enterprises.

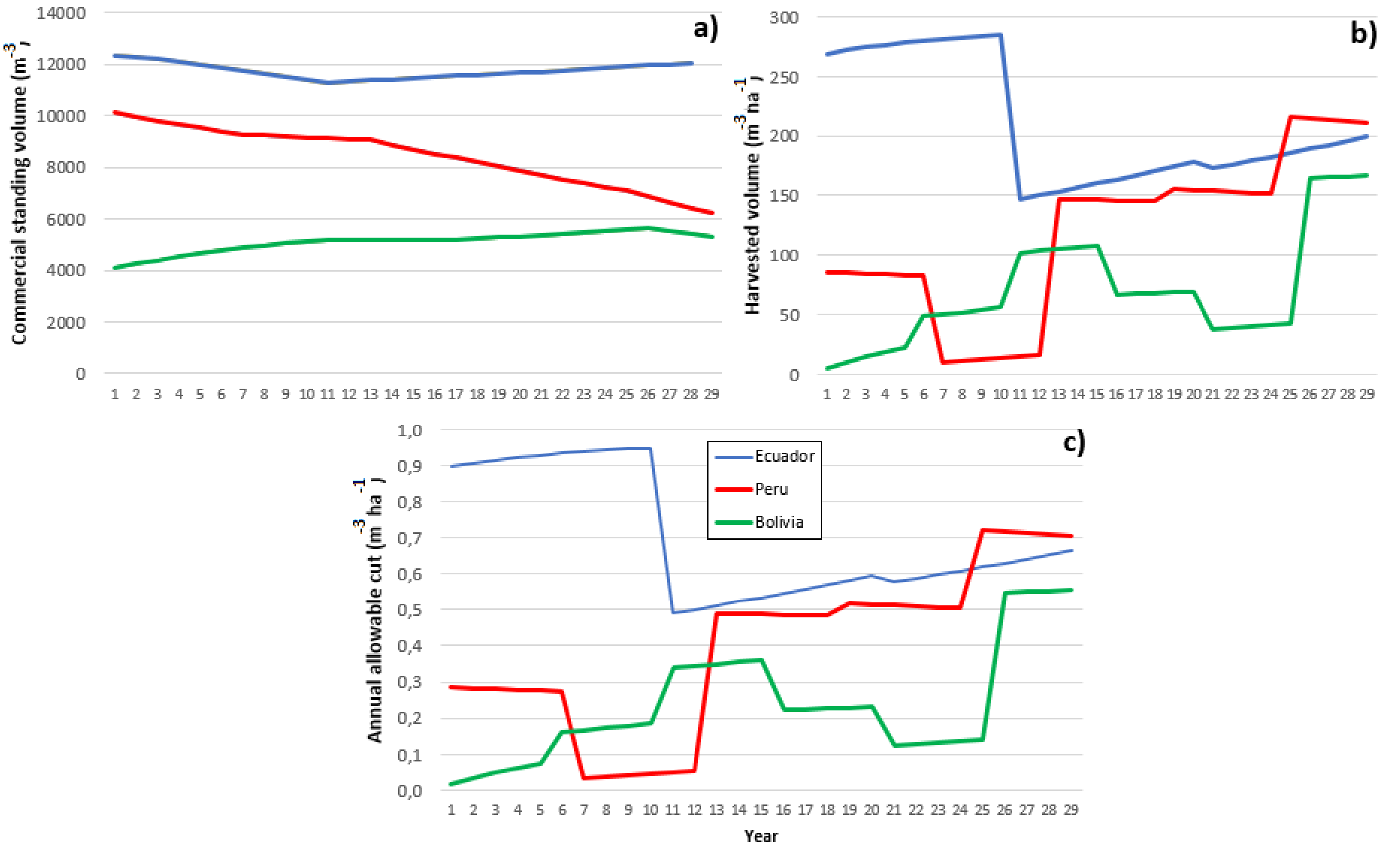
Regarding logging practices, the technologies applied for smallholders were based on the chainsaws, which limits cutting diameters to a minimum of 50 cm DBH, and extraction is based on the use of horses or carts, with minimum effect on soils. Timber enterprises use heavy machinery to extract logs, causing major impacts on soils and biomass, and normally log trees of 40 DBH depending on forest legislation.

In terms of silvicultural actions and ecological criteria for management, some smallholders implemented some practices of liberation of vines, planting of valuable trees and conserved seedlings to ensure regeneration processes. The practices applied depended on the level of importance of the forest in the smallholders´ livelihoods. STM define criteria to conserve vulnerable species, protect water sources and soils, depending on each forest legislation.

3.5.2 Harvest projections in forest areas

With the purpose to identify the possibilities of timber management in the long term, projections of timber production were performed for each country. They were based on the forest areas inventoried, and to facilitate data analysis, each one was considered as a stand. The total forest management area contained 300 ha that will be subjected to timber management for the next 30 years (10 ha $year^{-1}$). In Ecuador three stands were grouped (without logging or primary, lightly logged, and intensively logged), according to a previous analysis presented in the Table 3.11. The Figure 3.14 presents the modelling scenarios that include the Annual Allowable Cut (AAC), Standing Commercial Volume and the Harvested Volume.

Figure 3.14. Projections for timber management of commercial species for the thirty first years in farm forests of Riberalta, Bolivia, Macas, Ecuador and Pucallpa and Puerto Maldonado in Peru.



a) Standing commercial volume; b) Harvested volume and c) Anuall allowable cut

For each of the three countries, those species that showed potential for markets were considered. Average volumes of 7.4, 20.9, and 12.2 m^3 ha^{-1} were obtained in Bolivia, Ecuador, and Peru respectively. The harvested volumes varied strongly between different stands because of previous logging practices carried out by smallholders and local forest characteristics. In Bolivia, the harvested volume varied from 0.54 m^3 ha^{-1} to 16.7 m^3 ha^{-1}. In Ecuador, the lowest value was 14.7 m^3 ha^{-1} and the maximum was 28.5 m^3 ha^{-1}. The first stand in the Figure 3.14 corresponds to primary forest. Primary forest influenced the harvested volume projections since logged areas clearly show lower values than primary ones. In Peru, the lowest value was 8.3 m^3 ha^{-1} and the maximum was 21.6 m^3 ha^{-1}.

The standing projected volumes (the green line in Figure 3.14) remained stable in the regions of Bolivia and Ecuador, with around 5,000 m^3 and 12,000 m^3 respectively, thus ensuring a sufficient timber stock in the long term. Meanwhile in Peru, the volume declined about 40% over time, from 10,000 m^3 to 6,000 m^3. When projections were performed for a span of two hundred years, a standing volume of 4,800 m^3 was obtained in Bolivia and up to 16,000 m^3 in Ecuador. In Peru, the volume remained about 6,000 m^3.

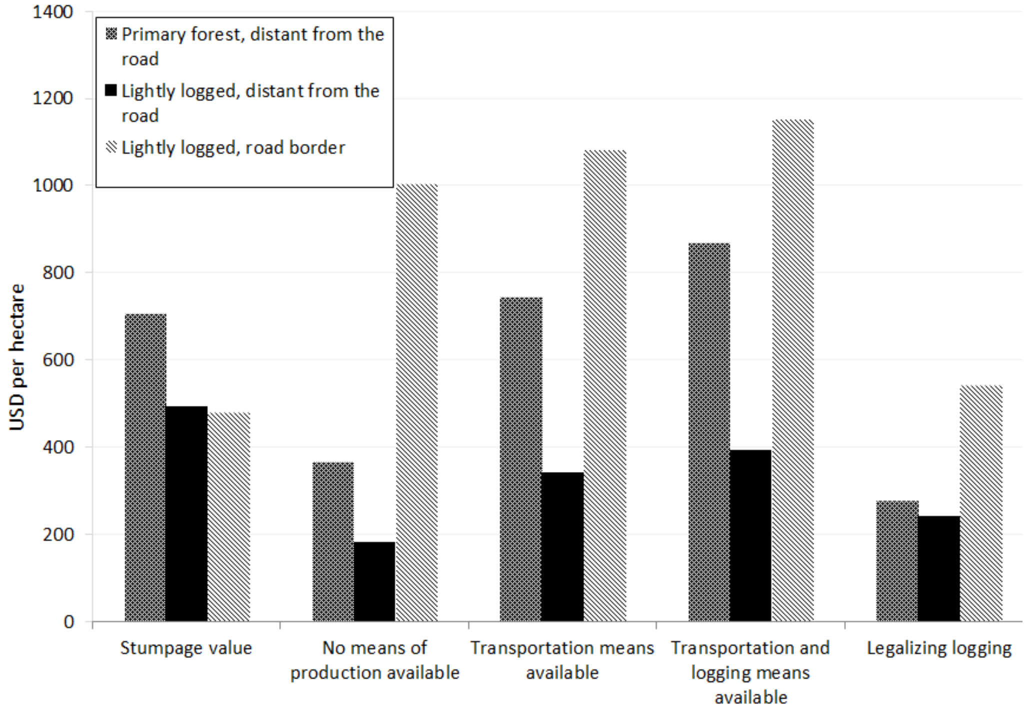
The Annual Allowable Cut varied from 0.05 m^3 ha^{-1} $year^{-1}$ in a stand located in Puerto Maldonado, Peru, to 1 m^3 ha^{-1} $year^{-1}$ in a primary stand in Ecuador. The lowest values made any type of timber management practically impossible, especially considering that smallholders did not own more than 100 ha of forest. In the case of Ecuador, an average of 0.6 m^3 ha^{-1} $year^{-1}$ was projected for forest areas previously logged. Considering that the average forest area was 33 ha in Bolivia, 12 ha in Ecuador, and 25 ha in Peru (reviewed in Table 3.4), the potentially harvestable volume in smallholders´ forests would be around 11.5 m^3 $year^{-1}$, 7.2 m^3 $year^{-1}$, and 12.5 m^3 $year^{-1}$ in Bolivia, Ecuador, and Peru respectively.

3.5.3 Management scenarios of timber logging

Potential incomes from forest areas were calculated according to the different scenarios analysed and observed in the field in the Macas region in Ecuador: i) stumpage value, ii) sawing planks and marketing in the road border, but renting horses and sawchains for processing and logging; iii) l sawing planks and marketing on the road border, assuming that the smallholders own horses for timber transportation; iv) the smallholder owns horses and a chainsaws as part of the value-added chain for logging and sawing; v) the smallholders legalize the timber extraction. Three different farm forests were analysed to capture the local conditions in terms of distance to roads and previous logging activities. In this sense, two farms were located at a walking distance of three hours from the road and one was located at the roadside. The estimations were based on the net present values of the commercial timber available in the farm forests only, as the basis to analyse the influence of distance to roads, means of production, present commercial values as result of previous logging activities, and legalizing the logging (Figure 3.15).

The areas had to contain 29, 28, and 16 trees per hectare, which equated volumes of 89.8, 71.6 and 63.4 m^3 ha^{-1} respectively. The stumpage value was estimated by factoring the commercial value of the standing tree with the number of trees per hectare, without the influence of accessibility conditions. As expected the potential value of the primary forest was higher when compared to the logged forests. In addition, there were not observed differences between the second and the third farm although the logging intensity of the third farm was higher when compared to the second, as result of continuos lighthy logging during the past fifteen years.

Figure 3.15. Potential incomes in three farms forests in Ecuador under different scenarios of timber logging.



Potential incomes reduced significatively in farms located distant to the roads when smallholders did not own means for production, but in the third farm located adjacent to the road, up to USD$ 1,002 per hectare could be potentially generated, as effect of reduced costs for transportation the planks to the road border. When smallholders had access to horses for transportation, the potential incomes increased almost double for the farms distant from the roads. The sawchain had only a marginal effect on the increment of the potential benefits. In this sense, the major influence in the potential incomes for farms with limited accessibility conditions is related to the availability of horses for transportation of planks. For this reason, a common pattern observed in the Macas region was that smallholders started to log forests areas nearer to roads and deforest them to produce crops and pastures once their forest areas were depleted. There was observed that those farms located more than eight hours at walking distance from roads were not attractive for timber logging.

Potential incomes were largely reduced when smallholders carried out logging based on a forest management plan, because the allowed number of trees to be logged was reduced to an average of four trees per hectare with a volume of around 14 m^3, and legalization costs were an average of USD$ 8 per m^3, resulting in potential financial values of USD$ 260, 240 and 520 per hectare respectively for the three cases reported in Figure 3.15.

These analyses were not performed in the cases of Bolivia and Peru due to the common pattern there: middlemen connected with enterprises only buy timber as standing trees.

4 DISCUSSION

4.1 Summary of results

The aim of this research was to clarify some aspects that continue being debated among scholars and development organizations regarding the possibilities that smallholders have to manage their forest areas. Four research questions were raised: 1) What are the possibilities that smallholders have to engage in timber markets? 2) What is the commercial potential of primary and secondary forests? 3) What are the effects of smallholders´ logging in forest areas? 4) What are the possibilities for the long-term management of timber resources? The following paragraphs resume the most relevant findings of this research, as basis for discussion:

Smallholders had the possibilities to engage in timber markets under favourable conditions that included a high number of buyers requiring different timber products from a wide range of species. In the region of Macas in Ecuador, markets were dynamic and characterized by small- and medium-sized primary and secondary timber industries located relatively close to the communities. Smallholders produced planks and beams from low-, medium- and high-density timber used as moulds in the construction sector, furniture and house structures. In the other regions analysed, few companies demanded only timber species according to their value-added chains. These aspects have limited the demand to only 15 species in Riberalta and 22 in Pucallpa and Puerto Maldonado, with an effect in the prices obtained for their timber resources. These market conditions influenced the commercial potential of primary and secondary forests.

Large variations were found between the inventoried farm forests. Under the less favourable conditions found in Riberalta and Pucallpa, there were farm forests that did not show any commercial potential at all, because of previous logging activities and an unsuitable forest composition. In the Macas region in Ecuador, the commercial potential was high (up to 90 m^3 ha^{-1}). Even some forests subjected to continuous intensive logging during the last fifteen years showed a high commercial potential (around 40 m^3 ha^{-1}). Considering these conditions, timber management in many forest areas is not able to generate attractive incomes. New perspectives will depend on the demand of new abundant species already demanded in other timber markets (for instance *Aniba* sp. and *Ocotea* sp.).

In the regions analysed, two principal logging schemes applied by smallholders with different consequences in the forest areas were identified: 1) The first logging scheme was low-intensive and limited to the main commercial trees per hectare (up to 18 m^3 ha^{-1}). This scheme has no major impacts on forest structure including basal area and DBH distribution, but may lead to the disappearance of the high-value, low-density species such as *Swietenia macrophylla*, *Cedrela odorata,* and *Amburana cearensis.* 2) The second logging scheme –widely spread in Ecuador– was more intensive, with removed volumes of up to 75 m^3 ha^{-1} (or around 25 trees ha^{-1}) when smallholders focused on timber harvesting as their principal activity. This practice generated a reduction in forest diversity and a major abundance of some commercial species, as well as changes in the DBH distribution when compared to primary forests, including commercial trees.

Projections for timber management for a thirty-year period showed very different rates, depending on the present conditions of the forested areas. Projected volumes varied between 7.4, 12.2 and 20.9, m^3 ha^{-1} for Bolivia, Peru, and Ecuador respectively. The Annual Allowable Cut (AAC) was as low as 0.05 m^3 ha^{-1} $year^{-1}$ in a stand located in Puerto Maldonado, Peru, up to 1 m^3 ha^{-1} $year^{-1}$ in a primary stand in Ecuador. Considering the forest area in smallholders´ hands, the potential harvestable volume was in average 7.2, 11.5, and 12.5 m^3 $year^{-1}$ in Ecuador, Bolivia, Ecuador, and Peru respectively.

4.2 Quality of the results

This research addressed three levels of analysis: 1. Regional, in terms of the characterization of timber value-added chains and markets for timber. 2. At a community level, in terms of the characterization of local dynamics of the marketing of timber products and the participation of smallholders in timber markets. 3. At the smallholders´ level, in terms of the analysis of the use and management of forest areas and the assessment of the long-term potential of this activity.

One of the limitations of this study is related to the impossibility to find replicated samples of farms with similar characteristics. There were too many variables related to characteristics of smallholder logging practices and forest composition so that that each case analysed and inventoried was somehow different.

In addition, it is also important to point at the limitations of this study in relation to the analysis of the impacts of smallholders´ logging on forests structure and composition. Stem density alone gives little information about sustainability in the absence of basic understanding of species, endemism, population structure, growth, and mortality rates, among other life history traits (Lobo et *al.* 2007, Schlutze et *al.* 2008). Although these aspects are more related to forest ecology, they are important to assess the long-term viability of species in managed forests and are relevance for the conservation of biodiversity.

It has been highlighted that smallholders depend on timber and Non Timber Forest Products for income generation and subsistence. This study analysed the importance of timber products for smallholders only, but in some regions analysed in Bolivia and Peru, timber was not an income source, and NTFPs were the most important. In this sense, it is important to consider that the analysis and recommendations about the potential of forest management by smallholders in the long term should include an integral management of timber and NTFPs in smallholders´ farms.

4.3 Opportunities for smallholders in the Amazon to engage in timber markets

The difficulties that smallholders in the Amazon face to generate incomes from timber production of their forest areas have been stated, principally related to the financial capital needed to engage in the activity, i.e. costs of compliance with management plans, logging, and transportation machinery. These aspects allow the entering of external and capitalized actors in their forest areas that capture most of the benefits generated (Pacheco 2012, Agrawal 2013). In the study regions of Pucallpa, Puerto Maldonado and Riberalta, smallholders generated only marginal incomes by selling standing trees to middlemen connected with sawmills and timber industries. Only a small proportion of smallholders transformed timber into planks and commercialized them in local markets. The timber industry defined the number of species commercialized according to their value-added chains and also influenced the timber prices. In the Macas region of Ecuador, the most common timber management strategy applied by smallholders was the selling of planks or beams of a large number of species (around 82) in the border of roads. This strategy was also observed in other regions of the Ecuadorian Amazon region (Palacios and Malessa 2010, MAE 2010a, Mejia et *al.* 2015). In some cases, smallholders obtained financial capacity to invest in trucks to transport and sell planks to regional markets. The factors that influenced on these dynamics are related to a limited industrial-scale timber extraction and dynamic markets (Messina et *al.* 2006, Mejia et *al.* 2015).

It has been suggested that smallholders have no capacity to capture the benefits of timber logging; those actors located downstream in the value chain capture most of the benefits (Pokorny and Johnson 2008). Regarding this aspect, this study identified that smallholders have the capacity to advance in the value-added chain to produce planks with saw chains and sell in local or even regional markets. When the planks were traded in regional markets, prices became very attractive for smallholders, considering –for instance- that a cubic meter of the species *Cedrelinga cateniformis* reached up to USD$ 106 m^{-3}, while when sold as standing tree the price was only USD$ 16 m^{-3} in the Macas region. There were no observed options that smallholders could benefit from in the value added-chain to obtain basic final products, including dried brushed and dimensioned timber, considering the high investments needed. This favourable context has been described in the sense that location greatly influences community interactions with markets in terms not only of geographical distance but also of market networks, influencing also in the pressure from buyers, and leading in turn to more transparent markets (Pacheco 2012). On the other extreme, unfavourable contexts have been described where timber markets tend to be dominated by a few companies and buyers that wield considerable influence over the final prices (Pacheco 2012). This situation was observed in the Riberalta region, where only a few sawmills connected with regional timber industries were located, that paid only USD$ 3.9 m^{-3} of the species *Cedrelinga cateniformis.*

According to the contexts in the regions analysed, the strategies of timber logging were grouped into the following: i) smallholders requiring occasional income from timber, ii) smallholders requiring complementary income, iii) smallholders obtaining their principal income from timber; and iv) smallholders specializing in timber harvesting and trade. There were also smallholders that did not generated incomes from timber, because they were dependent of other production systems including Non-Timber Forest Products, agriculture, or livestock. The first two strategies were common in the regions of Riberalta, Pucallpa, and Puerto Maldonado, while the last two were common in the region of Macas. But even in this region there were smallholders that depended on timber only occasionally or to round out their incomes, according to their livelihood strategies preferences. In this sense, it is important to understand that smallholders implement different livelihood strategies according to different factors related to the availability of means of production, natural forest area and richness, manpower capacity, and available time for market-based activities (Schmink 2004, Zenteno et *al.* 2012).

When favourable contexts were present, smallholders showed endogenous capacity to analyse the options and opportunities for timber production, and adapt them to their own circumstances and livelihood strategies. In the Macas region, it was observed that smallholders adapted technology in two cases: i) to extract planks from steep slopes using air cables and pulleys, and ii) through the introduction of portable saw mills in secondary forests, for processing low-density timber from pioneer species to produce boards used for fruit boxes. These experiences were carried out without the support of external actors. Sears et *al*. (2007) also reported a study case in the Trans-Amazonian highway that demonstrated the capacity of smallholders to adopt and adapt technologies under their own contexts to process timber products to be commercialized in local markets. The cases of endogenous innovation and adaption capacity are relevant when development projects or policies are being designed.

4.4 Economic importance of forests to improve people livelihoods

a) *Commercial potential of forests*

In the Amazon a potential timber volume of 1.2 billion m^3 currently profitable to harvest has been reported, with a potential stumpage value of US 15.4 billion (Merry et *al*. 2009). However, large forest areas are not exploitable because of different limitations related to physical, ecological, or market aspects. An ecological limitation is related to the low or extremely low abundance of valuable commercial species, normally less than one tree per hectare (Schulze et *al*. 2008), including the big-leaf mahogany (*Swietenia macrophylla*). The commercial potential of the forests in the regions analysed was highly variable depending on the market context, previous logging practices, and forest composition. The commercial timber volume for regional markets was around 25 m^3 ha^{-1} in Riberalta, Pucallpa, and Puerto Maldonado, and 80 m^3 ha^{-1} in Macas. However, there was no observed commercial potential in three of the six farm forests inventoried in Riberalta and one in Pucallpa. This was the result of previous selective logging of the most valuable commercial species during the last fifteen years and the limited number of commercial species in these regions, with an abundance of less than one tree per hectare of the most valuable species. On the other hand, the commercial potential in the Macas region remained high, despite the previous logging activities carried out in farm forests. The commercial potential available in farm forests resulted in a financial potential per hectare of USD$ 50.6, 136, and 727.2, in the regions of Riberalta, Pucallpa, and Puerto Maldonado and Macas, respectively.

Despite the regions analysed in Bolivia and Peru showing a very low commercial potential for timber, in the near future it will probably increase as a result of the incorporation of new species in the value-added chains of the timber industries and an expansion in the demand in local markets. In Riberalta, Pucallpa, and Puerto Maldonado, markets started demanding only *Swietenia macrophylla, Cedrela* sp. and *Amburana cearensis*; when these species were depleted, prices increased substantially and new species were incorporated into the markets. Similarly, Silva et *al.*

(1995) reported that from 1981 to 1993 in Santarem, Brazil there was an increment of 29 species for timber markets that represented a growth of 18 to 54 m^3 ha^{-1} of commercial volume in forest areas. This aspect has been also highlighted by Mostacedo and Fredericksen (1999): when the most valuable species become scarce, new species are incorporated into the markets. When the abundant commercial species that include *Aniba* sp. and *Ocotea* sp*.* start to be demanded in regional markets, the commercial potential will increase markedly.

Some secondary-forest pioneer species showed important commercial potential in the three countries. Several species including *Callycopyllum spruceanum, Guazuma crinita* and *Schizolobium amazonicum* in Peru, *Pollalesta discolor* and *Ocotea* sp*.* in Ecuador, and *Schizolobium amazonicum* and *Cordia alliodora* in Bolivia are normally commercialized in local or regional markets as clapboards for houses construction or boxes for fruits. Smallholders were involved more actively in these processes due to the low investments needed. When secondary forests were dominated by these species, around 100m^3 could be obtained of one hectare in only around ten years, and potential values may be higher than US$ 1,000 per hectare. This potential has been highlighted in Peru and Brazil, where the species *Callycopyllum spruceanum* has regenerated in high densities and fast growth rates, attaining up to 20 cm DBH in eight years in secondary flood plain forests (Vásquez et *al.* 2000, Sears and Pinedo-Vásquez 2004). *Guazuma crinita* has been also highlighted as a dominant pioneer species in some places around Pucallpa, its importance lying in the provision of monetary incomes for smallholders (Galván et *al.* 2000). In addition, it was observed in the Riberalta region that smallholders managed some secondary forests by planting and managing natural regeneration of useful commercial species like the Brazil nut tree. Despite the recognized importance of recovering soil fertility in Amazonian soils, they were valued by smallholders as an important element of their productive systems in terms of providing other important products like timber and NTFPs.

In large areas of the Amazon region, Non-Timber Forest Products (NTFPs) are more important than timber production (Zenteno et *al.* 2012). In fact, in the region of Riberalta, Puerto Maldonado, and some places of Pucallpa, NTFPs were more important than timber. In Riberalta and Puerto Maldonado the most important product was the Brazil nut. PROMAB-IPHAE (2007) also reported in four communities around Riberalta that Brazil nut represented 70% of the annual incomes, which were in average USD$ 1,608, while timber only represented 2% of the income. In some communities around Pucallpa it was also observed that smallholders were generating incomes from different products, but the most important was the "*aguaje*" fruit, derived from the *Mauritia flexuosa* palm*.* On the other hand, in most of the Ecuadorian Amazon timber was the most financially profitable product from forest areas (Romero and Gatter 2010, Pacheco et *al.* 2016). These aspects highlight the need for an integrated assessment of timber and NTFPs to evaluate the potential of forests for smallholders.

b) Possibilities to maintain forestry activities versus alternative land uses

A common concern about the maintenance of forest areas in smallholders' farms is related to the low opportunity costs of forestry, when compared to agriculture and livestock. As it was observed in the regions of Riberalta, Pucallpa and Puerto Maldonado, timber management presented very low opportunity costs, meanwhile, in some cases in the region of Macas in Ecuador timber production had high opportunity costs. However, agricultural activities carried out by smallholders in the Amazon tended also to show low levels of profitability. As stated in the previous section, NTFPs are more important than timber production as an income source in many areas of the Amazon. In fact, in the region of Riberalta, smallholders generated higher incomes from brazil nut combined with timber production when compared to agricultural activities (Zenteno et *al*. 2012). These aspects ensure the maintenance of forest areas as part of a diversified portfolio of production systems characteristic of smallholder's livelihoods.

In the regions of Riberalta, Pucallpa, and Puerto Maldonado farming activities occupied a lower area than natural forests, and they were characterized by low levels of productivity and profitability, and were mostly dedicated to subsistence, hence they do not pose greater risks in terms of land conversion. In general, it can be asserted that smallholders do not deforest large areas due to their limited capacities to produce intensively and their diversified sources of income (Zenteno et *al.* 2012). Rather, the greatest risks for maintaining forest areas are determined by extensive farming, such as soybeans in Brazil and livestock in Brazil and Bolivia.

4.5 Smallholders´ timber management

a) Effects of smallholders' timber management in forest structure and composition of forest resources and timber harvest projections

The viability of Sustainable Timber Management (STM) continues to be debated, especially in relation to forest areas in hands of smallholders and the limited and questionable impact of the programs implemented (Silva et *al.* 1995, Pearce et *al.* 1999). Recent evaluations of the first timber management cycles suggest that harvest intensities need to be reduced considering the incapacity to return to initial conditions in terms of commercial potential (Mostacedo and Fredericksen 1999, Putz 2012, De Avila et *al.* 2017). This research showed that the most intensive practices of logging are changing the forest structure and also affecting forest composition through the increment of the number of trees per hectare and the basal area. Another effect of intensive management practices registered in Ecuador was the disappearance of some important commercial species. Similar effects have been detailed in timber managed areas by various regional studies in the Amazon and other rain forests (Silva et *al.* 1995, Keller et *al.* 2007, De Avila et *al.* 2017). These effects have been recognized in temperate forests, where intensive managed operations have focused on increased timber production and favouring the productions of even-aged single species (Puettmann et *al.* 2015).

Through this study some low-density valuable species that include *Swietenia macrophylla, Cedrelinga cateniformis, Amburana cearensis and Cedrela odorata* were reported. However, these species present extremely low abundances, as in the case of *Swietenia macrophylla* and *Amburana cearensis*, which present a density of 0.014 and 0.06 trees per hectare respectively in a communal area near Riberalta and the study area (PROMAB-IPHAE 2006). Therefore, the inventory intensity carried out in this study might have been insufficient to find a single stem. In addition, in Bolivia and Peru these species were previously logged by timber enterprises that had concessions on these areas.

Regarding projections for timber management in smallholders´ forest areas in Ecuador, where major logging intensities were registered, the Annual Allowable Cut (AAC) was between 0.5 to 1 m^3 ha^{-1} $year^{-1}$. These values are comparable to the reported by de Avila et *al* (2017) where average volume increments were around 0.6 m^3 ha^{-1} $year^{-1}$ in logged areas without silvicutlure treatments in Brazil. Reference values of logging intensity are established in the norms of Small-Scale Sustainable Forest Management Plans in Brazil that permit a maximum logging rate of 0.86 $m^3ha^{-1}year$ (Menezes and Fearnside 2014). In addition, In terms of volume regeneration capacity and smallholders´ logging intensity, it is important to highlight that in Macas most smallholders present low logging intensities, around 10 - 15 trees $year^{-1}$ or around 30 - 45 m^3 $year^{-1}$ from the entire farm forest area. In this sense, the effects of timber logging and the possibilities for long term management are also related to the forest area at farm level.

b) The need to review policies to promote the participation of smallholders in the timber management and value-added chains

Most timber management practices applied by smallholders had the potential to maintain the forest productivity in the long term, although the practices did not consider the technical schemes defined in STM and were applied informally. Policy makers should consider the basis of these practices and the relaxation of the requirements to obtain licences for timber management.

Ecuador and Bolivia have been recognized in the promotion of changes in their policies to favour the participation of smallholders in the timber management process through flexible instruments (such as *Planes de Manejo Forestal Simplificado* in Ecuador and *Autorización de Volúmenes Menores* in Bolivia), including processes to support the elaboration of these plans through advisory in the field. However, these efforts have not addressed some critical constraints that smallholders face in managing their forests either individually or collectively, and therefore smallholders continue implementing informal practices (Pacheco et *al.* 2016). Two important actions can be proposed to promote the participation of smallholders in the timber management of their forest resources:

1) Reinforcing mechanisms broadly proposed by scholars and development organizations, including: improved access to credit and know-how, as well as more transparent markets able to distribute more efficiently the benefits from timber extraction (Pokorny and de Jong 2015).
2) Pokorny and de Jong (2015) proposed that national policies should enable smallholders to control timber exploitation and trading. In practice, this policy would consist in the relaxation of the legal framework after smallholders are registered as forest users, including a cadastre of their farms. Only some criteria and indicators that are presently applied by

them in their timber logging activities would be included as part of the procedure to obtain the harvesting licences. These are: the logging of a limited number of species per hectare per year depending on the extension of the forest area, respecting minimum cut diameters, the conservation of tree seedlings, the use of chainsaws to transform standard blocks and avoid excessive waste, and trees plantation in logged areas to maintain forest productivity in the long term. These areas could be monitored by third-party control institutions to avoid over-exploitation of forest areas. This concept could be implemented as part of an integral management plan at farm level, as proposed in the next section.

4.6 Integrated management of farms as the strategy to contribute to maintain livelihoods systems and forests conservation

Livelihood strategies applied by smallholders resulted in different landscape units dominated by primary, logged, secondary forests and agroforestry systems. Although this research did not assess cash incomes from other productive systems, it is important to highlight that timber a) also comes from secondary forests and agroforestry systems, and b) that timber is not the only income source. In a recent analysis, Muzo *et al.* (2013) reported that timber incomes in two provinces of northern Ecuador represented around 16% of the total income of at least six income farm sources. In Riberalta, forest products from Brazil nut and timber production were the main income sources contributing around 60% of all household incomes (Zenteno et *al.* 2012). Given the importance of the forest products in household economies, smallholders are managing their forest areas to increment the potential commercial values. For instance, in secondary forests in the Riberalta region, there were more trees of the Brazil nut in relation to mature forests, with values of 10.9±16.7 and 3±2 trees per hectare respectively, as result of the management of regeneration or tree planting that smallholders apply. When these trees become productive, incomes from NTFPs will increase, including the importance of this landscape unit. In Peru and Ecuador, the potential financial of secondary forests when commercial species dominate forest composition was also observed. In addition, the importance of agroforestry systems in terms of timber potential could be assessed in Ecuador, where timber volumes legally extracted from agroforestry systems in smallholder's farms were higher than timber from primary forests (MAE 2010). The timber logged from agroforestry systems in the Amazon region of Ecuador normally results from the regeneration management of commercial trees (e.g. *Cordia* sp.) or remnant commercial trees from natural forests. These aspects have been highlighted as part of an integrated management of the landscape units at farm level, considering that different land use units are part of an integrated production system (Galloway et *al.* 2014).

Sustainable forest management may adopt a wider perspective of sustainable land management that goes beyond a focused-on forest management (Sist et *al.* 2014). Two elemental values have been identified: i) The recognition of the importance of sustaining the provision of forest goods and ecosystem services under the notion of multifunctional landscapes, and ii) the need to optimize land uses to ensure adequate food and energy supplies for a growing population, without increasing the pressures on forests from the expansion of croplands. These elements are part of a multifunctional landscape management. This, in turn, makes the practical implementation of sustainable forestry both more challenging and complex (Sist et *al.* 2014). Similar objectives have been recognized in the management of temperate forests to answer concerns about the ecological consequences of intensive forestry practices, promoting alternative schemes based primarily on the provision of a broad range of goods and services, including the extraction of products (e.g. close to nature forestry, ecological forestry, multipurpose forestry) (Puettmann et *al.* 2015).

5 FINAL CONSIDERATIONS

Based on this research, some aspects are clearer regarding the possibilities for long-term management of forest areas on smallholders' farms. The intention is both to promote the conservation of forest areas and to improve the well-being of smallholders.

- To increase the potential benefits from smallholders´ timber management activities, policy makers should implement development policies and eliminate barriers that limit the partaking of smallholders in the value-added chains, encouraging their participation in markets. Despite certain efforts that have been implemented over the last years to adjust legal frameworks to accommodate smallholders' contexts (for instance, permitting the use of chainsaws in Ecuador), the participation of smallholders continues to be limited due to limited financial profitability and cumbersome bureaucratic procedures that hinder a legal entry into the markets. Therefore, even though they continue to participate in the value-added chains as informal actors, their incomes are limited because they do not want to run the risk of selling their processed products for fear of being sanctioned.

- Smallholders´ timber practices respond to local or regional market demands, and favourable market conditions promote the use of a diversified number of species and therefore a more extensive use of forests. However, even under favourable market conditions smallholders decide to exploit their forest areas depending on their livelihood strategies. When smallholders maintain a diversified portfolio of income sources the logging intensity will be low, thus influencing the maintenance of the timber stock in the long term. In this sense, public policies should promote the maintenance and reinforce traditional livelihoods systems based on a diversified portfolio of incomes and an integral management of farms, including primary forests, secondary forests, and agroforestry systems, with effects in the maintenance of a stable ecological landscape.

- Smallholders' timber management practices were comparable to sustainable timber management schemes. Logging intensities may be like those defined in timber management plans and have similar effects on forest structure and composition, but the use of chainsaws in the forest to transform logs into planks avoids the use of heavy machinery and impacts on vegetation cover, soils, and water sources. Projections of long-term management in smallholders´ logged areas indicated that they have the capacity to continue to be managed in the long term, even in the more intensively logged areas (such as in Ecuador). In this sense, smallholders could consider applying a flexible management system to their forest areas to avoid bureaucratic procedures such as inventories and administrative taxes. To do this, smallholders would have to take certain values into account, such as logging a limited number of species per hectare depending on the extension of the forest area, respecting minimum cut diameters, conserving tree seedlings, using chainsaws to transform standard blocks to avoid excessive waste and planting trees in logged areas to maintain forest productivity in the long term. These areas could be monitored by third-party control institutions to avoid the over-exploitation of forest areas.

- One important aspect to consider in relation to the potential of timber management in smallholders´ forest areas is that, in most cases, this activity alone probably will not be financially attractive while market conditions do not evolve to favour smallholders. It is also evident that other forest activities, including NTFPs, are frequently more important than timber production, and secondary forests show in many cases a high financial potential. In this sense, policy makers and development organizations should consider timber management in smallholders' forest areas as a complement to an integral management of the landscapes wherein secondary forests, agroforestry systems, and non-timber forest products are all part of the management of forest resources.

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6 ANNEXES

Annex 1. List of species with medium commercial value in the region of Riberalta, Bolivia

Scientific name	Family	Common name	Market
Abuta grandifolia(Mart.) Sandwith	Menispermaceae	Pitón	Local
Acacia pholyphylla	Leguminosae	Cari cari	Local
Amburana cearensis (Allemão) A.C. Sm.	Leguminosae	Tumi	Regional
Ampelocera cf. Edentula Kuhlm.	Ulmaceae	Canilla de vieja	No
Anacardium occidentale L.	Anacardiaceae	Cayú	No
Aniba aff. Canelilla (Kunth) Mez	Lauraceae	Chileno	Local
Aniba aff. Guianensis Aubl.	Lauraceae	Canelón	Local
Annona cherimolia Mill.	Annonaceae	Chirimoya	No
Apeiba membranacea Spruce ex Benth	Malvaceae	Cabeza de mono	Local
Aspidosperma aff rigidum Rusby	Apocynaceae	Gavetillo	Local
Aspidosperma tambopatense A.H. Gentry	Apocynaceae	Palo amarillo	Regional
Aspidosperma vargasii A. DC.	Apocynaceae	Amarillo	Regional
Astrocaryum aculeatum G. Mey.	Arecaceae (Palmae)	Chonta	No
Astrocaryum murumuru Mart.	Arecaceae (Palmae)	Chontalora	No
Astronium lecointei Ducke	Anacardiaceae	Cuta	Regional
Attalea maripa (Aubl.) Mart.	Arecaceae (Palmae)	Motacusillo	No
Attalea phalerata Mart. ex Spreng.	Arecaceae (Palmae)	Motacú	No
Attalea speciosa Mart.	Arecaceae (Palmae)	Cusi	No
Bactris gasipaes Kunth	Arecaceae (Palmae)	Chima	No
Bellucia grossularioides (L.) Triana	Melastomataceae	Guayabilla	No
Bertholletia excelsa Bonpl.	Lecythidaceae	Almendro	Regional
Bixa arborea Huber	Bixaceae	Urucú	No
Brosimum guianense (Aubl.) Huber	Moraceae	Quecho	No
Byrsonima chrysophylla Kunth	Malphygiaceae	Muela	Local
Calycophyllum spruceanum (Benth.) Hook. f. ex K. Schum.	Rubiaceae	Guayabochi	Local
Cariniana estrellensis (Raddi) Kuntze	Lecythidaceae	Yesquero	Regional
Cariniana micrantha Ducke	Lecythidaceae	Enchoque	Regional
Cecropia sciadophylla Mart.	Cecropiaceae (Moraceae)	Ambaibo	Local
Cedrela odorata L.	Meliaceae	Cedro	Regional
Cedrelinga cateniformis (Ducke) Ducke	Leguminosae	Mara macho	Regional
Ceiba pentandra (L.) Gaertn.	Malvaceae	Mapajo	Local
Ceiba speciosa (A. St.-Hil.) Ravenna	Malvaceae	Toboroche	Local
Celtis schippii Standl.	Ulmaceae	Fariña seca	Local
Chelyocarpus chuco (Mart.) H.E. Moore Search in The Plant List	Arecaceae (Palmae)	Hoja redonda	No
Clarisia racemosa Ruiz & Pav.	Moraceae	Mururé	Regional
Cochlosperpum orinocence	Cochlospermaceae	Algodoncillo	No

Scientific name	Family	Common name	Market
Cordia alliodora (Ruiz & Pav.) Cham.	Boraginaceae	Picana	Regional
Cordia sp.	Boraginaceae	Pitichoco	Local
Cordia sp.	Boraginaceae	Lagaña de perro	Local
Couma sp	Apocynaceae	Sulva	Local
Couratari macrosperma A.C. Sm.	Lecythidaceae	Pancho amargo	Local
Couratari macrospermas	Lecythidaceae	Bitumbo	Local
Coussarea macrophylla Müll. Arg.	Rubiaceae	Palo agua	No
Dialium guianense (Aubl.) Sandwith	Leguminosae	Tamarindo	No
Didymopanax morototoni (Aubl.) Decne. & Planch.	Araliaceae	Guitarrero	Local
Diplotropis purpures	Leguminosae	Manicillo	Local
Dipteryx odorata (Aubl.) Willd.	Leguminosae	Almendrillo	Regional
Endopleura uchi (Huber) Cuatrec.	Humiraceae	Aceitillo	Local
Erythrina poeppiggiana	Leguminosae	Cosido	No
Eschweilera coriacea (DC.) S.A. Mori	Lecythidaceae	Pancho	Local
Eugenia florida DC.	Myrtaceae	Saguinto	Local
Euterpe precatoria Mart.	Arecaceae (Palmae)	Asaí	Regional
Ficus insipida Willd.	Moraceae	Bibosi	Local
Galipea simplicifolia (Nees & Mart.) Schult.	Rutaceae	Cafecillo	Local
Guarea guidonia (L.) Sleumer	Meliaceae	Trompillo	No
Helicostylis tomentosa (Poepp. & Endl.) Rusby	Moraceae	Pata de michi	No
Hevea brasiliensis (Willd. ex A. Juss.) Müll. Arg.	Euphorbiaceae	Siringa	Local
Himatanthus sucuuba (Spruce ex Müll. Arg.) Woodson	Apocynaceae	Sucuba	No
Hirtella triandra Sw.	Chrysobalanaceae	Coloradillo	Local
Hymenaea courbaril L.	Leguminosae	Paquió	Regional
Hymenaea parvifolia Huber	Leguminosae	Paquiosillo	Local
Inga sp.	Leguminosae	Pacay	Local
Iriartea deltoidea Ruiz & Pav.	Arecaceae (Palmae)	Pachubilla	No
Jacaranda copaia (Aubl.) D. Don	Bignoniaceae	Chepereque	Local
Jacaratia spinosa (Aubl.) A. DC.	Caricaceae	Gargatea	Local
Lacistema aggregatum (P.J. Bergius) Rusby	Flacourtiaceae	Cacharí	Local
Lacistema sp.	Flacourtiaceae	Llave	No
Mabea fistulifera Mart.	Clusiaceae	Siringuilla	No
Maclura tinctoria (L.) D. Don ex Steud.	Moraceae	Mora	No
Macrolobium acaciifolium (Benth.) Benth.	Leguminosae	Pipa	No
Metrodorea sp.	Rutaceae	Pata de anta	Local
Mezilaurus itauba (Meisn.) Taub. ex Mez	Lauraceae	Itauba	Regional
N/I (Voucher 1731 JB/JCM)	Leguminosae	Carachupa	Local
Nectandra amazonum Nees	Lauraceae	Negrillo	Local

Scientific name	Family	Common name	Market
Ochroma pyramidale (Cav. ex Lam.) Urb.	Malvaceae	Balsa	Local
Oenocarpus bataua Mart.	Arecaceae (Palmae)	Majo	Local
Oenocarpus mapora H. Karst.	Arecaceae (Palmae)	Bacaba	No
Ormosia sp	Leguminosae	Sirari negro	No
Parkia pendula (Willd.) Benth. ex Walp.	Leguminosae	Toco colorado	Regional
Parkia sp	Leguminosae	Toco blanco	Local
Peltogyne heterophylla M.F. Silva	Leguminosae	Morado	Regional
Phenakospermum guianensis Aubl.	Strelitziaceae	Patuju	No
Physocalymna scaberimum	Lythraceae	Chaquillo	Local
Pithecellobium corymbosum (Rich.) Benth.	Leguminosae	Maní	Regional
Poeppigia procera C. Presl	Leguminosae	Ramillo	Local
Pouruma cf minor	Cecropiaceae	Ambaibillo	Local
Pouteria macrophylla (Lam.) Eyma	Sapotaceae	Coquino	Local
Pouteria macrophylla (Lam.) Eyma	Sapotaceae	Lucuma	Local
Pouteria trilocularis Cronquist	Sapotaceae	Sapito	Local
Protium carnosum A.C. Sm.	Burseraceae	Isigo blanco	Local
Protium sagotianum Marchand	Burseraceae	Isiguillo	Local
Pseudolmedia aff. Macrophylla Trécul	Moraceae	Macanui	No
Pseudolmedia laevis (Ruiz & Pav.) J.F. Macbr.	Moraceae	Nui	Local
Psychotria cf. Grandis Sw.	Rubiaceae	Ojo de mutún	No
Qualea grandiflora Mart.	Vochysiaceae	Tinto	Local
Qualea paraensis Ducke	Vochysiaceae	Trompa de anta	Regional
Rinoreocarpus ulei Ducke	Violaceae	Blanquillo	Local
Salasia gigantea	Hipocrataceae	Guapomo	Local
Sapium marmieri Huber	Euphorbiaceae	Leche leche	No
Schizolobium amazonicum Huber ex Ducke	Leguminoseae	Cerebó	Local
Sclerolobium guianense Benth.	Leguminosae	Palo santo	Local
Simarouba sp	Simaroubaceae	Durmi durmi	No
Sloanea guianensis(Aubl.) Benth.	Elaeocarpaceae	Urucusillo	Local
Sterculia sp	Malvaceae	Palo maní	No
Sterculia striataA. St.-Hil. & Naudin	Malvaceae	Sujo	No
Tabebuia serratifolia (Vahl) G. Nicholson	Bignoniaceae	Tajibo	Regional
Terminalia amazonia (J.F. Gmel.) Exell	Combretaceae	Verdolago	Regional
Tetragastris altissima (Aubl.) Swart	Burseraceae	Isigo	Local
Theobroma cacao (Mill.) Bernoulli	Malvaceae	Chocolate	No
Theobroma subincanum Mart.	Malvaceae	Chocolatillo	No
Virola sp.	Myristicaceae	Sangre de toro	Local
Vismia sp	Clusiaceae	Riberalteño	Local
Vitex cymosa Bertero ex Spreng.	Verbenaceae	Tarumacillo	No
Vochysia sp	Vochysiaceae	Aliso barbechero	Local

Scientific name	Family	Common name	Market
Vochysia vismiifolia Spruce ex Warm.	Vochysiaceae	Aliso	Regional
Xylopia ligustrifolia Humb. & Bonpl. ex Dunal	Annonaceae	Piraquina	Local
Xylosma sp.	Flacourtiaceae	Limoncillo	Local
Zanthoxylum sprucei Engl.	Rutaceae	Sauco	Local

Source: IBID – PROMAB - IPHAE

Annex 2. List of species with low commercial value in the region of Macas, Ecuador

Scientific name	Family	Common name	market
Aspidosperma verruculosum Müll. Arg.	APOCYNACEAE	Remo	No
Ficus spp.	MORACEAE	Matapalo	Regional
Acacia glomerosa Benth.	FABACEAE - MIMOSOIDAE	Casepo	Regional
Alchmea triplinervia	EUPHORBIACEAE	Balsa colorada	Regional
Apeiba aspera Aubl.	TILIACEAE	Peine de mono	Regional
Bactris spp	ARECACEAE	Chonta	Local
Blixa platycarpa	BIXACEAE	Achiotillo	Regional
Brosimun lactescencs	MORACEAE	Sande	Regional
Cabralea canjerana (Vell.) Mart.	MELIACEAE	Cedrillo	Regional
Calophyllum brasiliense Cambess.	CLUSIACEAE	Cascarilla	Regional
Caryodendron orinocense H. Karst.	EUPHORBIACEAE	Mani de árbol	Regional
Cecropia telenitida Cuatrec.	CECROPIACEAE	Guarumo	No
Cedrela odorata L.	MELIACEAE	Cedro	Regional
Cedrelinga cateniformis (Ducke) Ducke	FABACEAE	Seique	Regional
Chimarrhis glabriflora Ducke	RUBIACEAE	Jicopo	Regional
Clarisia racemosa Ruiz & Pav.	MORACEAE	Pitiuca	Regional
Cordia alliodora (Ruiz & Pav.) Cham.	BORAGINACEAE	Laurel	Regional
Croton mutisianos	EUPHORBIACEAE	Sangre de drago	Regional
Dacryodes peruviana (Loes.) H.J. Lam	BURSERACEAE	Copal	
Faramea spp	RUBIACEAE	Cafetillo	No
Ficus spp.	MORACEAE	Higuerón	Regional
Grias pruviana	LECYTHIDACEAE	Aguacatillo	Regional
Guarea grandifolia DC.	MELIACEAE	Manzano colorado	Regional
Guarea guidonia (L.) Sleumer	MELIACEAE	Tucuta	Regional
Heliocarpus americanus L.	THYMEACEAE	Balsa blanca	No
Hyeronima alchorneoides Allemão	EUPHORBIACEAE	Mascarey	Regional
Inga spp	FABACEAE	Guabilla	Regional
Iriartea deltoidea Ruiz & Pav.	ARECACEAE	Pambil	No
Maclura tinctoria (L.) D. Don ex Steud.		Leylapo	Regional
Miconia spp	MELASTOMACAE	Miconia	Regional
Micropholis chrysophylloides Pierre	SAPOTACEAE	Sacha caimito	Regional
Naucleopsis concinna (Standl.) C.C. Berg	MORACEAE	Pitiu	No
Nectandra sp.	LAURACEAE	Jigua	Regional
not identified		Ajulemo	Regional
not identified		Balsa jíbara	Regional
not identified		Caimitillo	No

not identified		Capulisi	Regional
not identified		Cerembo	Regional
not identified		Chirimoya	Regional
not identified		Chontilla	No
not identified		Comida de pavas	No
not identified		Corcho	No
not identified		Desconocido	No
not identified		Fotomo	Regional
not identified		Guabo	Regional
not identified		Huevo de perro	Regional
not identified		Jeliquinda	Regional
not identified		Kalum	Regional
not identified		Leche amarillo	Regional
not identified		Leche blanco	Regional
not identified		Leche café	Regional
not identified		Lengua de vaca	Regional
not identified		Lenteja	Regional
not identified		Lorocaspi	Regional
not identified		Luma	Regional
not identified		Mamando	Regional
not identified		Maquero blanco	Regional
not identified		Milisho	Regional
not identified		Nakascol	Regional
not identified		Naranjilla silvestre	No
not identified		Palmito	No
not identified		Sacha café	No
not identified		Sacha caoba	Regional
not identified		Sacha capulí	Regional
not identified		Sacha copal	Regional
not identified		Sacha Pechiche	Regional
not identified		Sacha pera	Regional
not identified		Sachi	Regional
not identified		Sande blanco	Regional
not identified		Sapan aromático	Regional
not identified		Sapan bobo	No
not identified		Sapan soga	No
not identified		Tiria	No
not identified		Yumbingue blanco	Regional
not identified		Abejón	Regional
Ochroma pyramidale (Cav. ex Lam.) Urb.	BOMBACACEAE	Balsa	Yes
Ocotea costulata (Nees) Mez		Alcanfor	Regional
Ocotea spp.	LAURACEAE	Canelón amarillo	Regional

Otoba parvifolia (Markgr.) A.H. Gentry	MYRRISTICACEAE	Llora sangre	Regional
Podocarpus sp	PODOCARPACEAE	Romerillo	Regional
Pollalesta discolor (Kunth) Aristeg.	ASTERACEAE	Pigue	Regional
Pouroma guianensis	CECROPIACEAE	Uvilla	Regional
Pseudolmedia laevigata Trécul	MORACEAE	Cauchillo	Regional
Rodostemonodaphne kunthiana	LAURACEAE	Canelón blanco	Regional
Ruagea insignis (C. DC.) T.D. Penn.	MELIACEAE	Cedro macho	Regional
Saurabia sp	LECYTHIDACEAE	Limoncillo	Regional
Schefflera morototoni (Aubl.) Maguire, Steyerm. & Frodin	ARALIACEAE	Palo fósforo	Regional
Simarouba amara Aubl.	SIMAROUBACEAE	Capulí	Regional
Sterculia apetala (Jacq.) H. Karst.	STERCULIACEAE	Sapotillo	Regional
Swietenia macrophylla King		Caoba	Regional
Tabebuia chrysantha (Jacq.) G. Nicholson	BIGNONIACEAE	Pechiche	Regional
Tapirira Guianensis Aubl.	ANACARDIACEAE	Maquero	Regional
Terminalia amazonia (J.F. Gmel.) Exell	COMBRETACEAE	Yumbingue	Regional
Theobroma spp	STERCULIACEAE	Cacao del monte	No
Trema sp.	ULMACEAE	Sapan	Regional
Triplaris spp.	POLYGONACEAE	Fernan Sanchez	Regional
Vitex orinocensis Kunth	VERBENACEAE		Regional
Vochysia spp	VOCHYSIACEAE	Bella María	Regional

Source: Palacios 2012

Annex 3. List of species traded in local markets in the region of Pucallpa, Peru

Scientific name	Family	Common name	market
Aniba sp	Lauracea	Moena	regional
Apeiba membranaceae Spruce ex benth	Not identified	Peine de mono	Local
Apuleia molaris Spruce ex Benth.	Fabaceae	Anacaspi	Local
Aspidosperma macrocarpon Mart.	Apocynaceae	Pumaquiro	regional
Aspidosperma vargasii A. DC.	Apocinaceae	Quillobordon	Local
Bertholletia excelsa Bonpl.	Lecythidaceae	Castaña	regional
Bixa sp	Bixaceae	Achiotillo	Local
Brosimum guianense (Aubl.) Huber	Moraceae	Huayra caspi	regional
Brosimum lactescens (S. Moore) C.C. Berg	Moraceae	Tamamuri	Local
Brosimum spp	Moraceae	Manchinga	regional
Calophyllum brasiliense Cambess.	Guttíferae	Lagarto caspi	regional
Calycophyllum spruceanum (Benth.) Hook. f. ex K. Schum.	Rubiaceae	Capirona	regional
Cecropia sp	Moraceae	Cetico	Local
Cedrela odorata L.	Meliaceae	Cedro	regional
Ceiba pentandra (L.) Gaertn.	Bombacaceae	Huimba	regional
Chorisia integrifolia Ulbr.	Bombacaceae	Lupuna	regional
Clarisia racemosa Ruiz & Pav.	Moraceae	Mashonaste	Local
Cordia alliodora (Ruiz & Pav.) Cham.	Boraginaceae	Chullachaqui caspi	regional
Couma sp.	Sapotaceae	Leche leche	Local
Dialium guianense (Aubl.) Sandwith	*Caesalpiniaceae*	Palo sangre	Local
Dipteryx alata Vogel	Fabaceae	Shihuahuaco	regional
Erythroxylum spp	Not identified	Yutubanco	Local
Eschweilera sp	Lecythidaceae	Machimango	Local
Ficus americana Aubl.	Moraceae	Renaco	Local
Ficus anthelminthica Hassl.	Moraceae	Ojé	Local
Ficus sp	Moraceae	Matapalo	Local
Ficus sp	Moraceae	Loro micuna	Local
Guarea trichilioides L.	Meliaceae	Requia	regional
Guatteria elata R.E. Fr.	Anonacea	Carahuasca	Local
Hevea brasiliensis (Willd. ex A. Juss.) Müll. Arg.	Euphorbiacea	Siringa	Local
Huberodendron swietenioides (Gleason) Ducke	Bombacaceae	Achigua	Local
Hura crepitans L.	Euphorbiaceae	Catahua blanca	regional
Hymenaea oblongifolia Huber	Cesalpinaceae	Azucar huayo	Local
Jacaranda copaia (Aubl.) D. Don	Bignoniaceae	Huamansamana	Local
Licaria sp	Lauracea	Palta moena	Local
Manilkara bidentata(A. DC.) A. Chev.	Sapotaceae	Quinilla	regional
Matisia spp	Sapotaceae	Sapote	Local
Miconia sp	Melastomataecea	Rifari	Local
Myroxylon balsamum (L.) Harms	Fabaceae	Estoraque	regional

Not identified	Not identified	Frente de toro	Local
Not identified	Not identified	Guabilla	Local
Not identified	Not identified	Isigo	Local
Not identified	Not identified	Paufilruma	Local
Not identified	Leguminoseae	Ucshaquiro	Local
Not identified	Not identified	Atadijo	
Not identified	Not identified	Cromillon	
Ocotea marmellensis Mez	Lauracea	Moena negra	regional
Olmedia aspera Ruiz & Pav.	Morácea	Yanchama	Local
Ormosia schunkei Rudd	Fabaceae	Huayruro	regional
Pouteria caimito(Ruiz & Pav.) Radlk.	Sapotaceae	Caimitillo	Local
Pouteria neglecta Cronquist	Sapotaceae	Caimito	Local
Pouteria torta (Mart.) Radlk.	Sapotaceae	Quinaquina	Local
Protium sp	Burseraceae	Copal	Local
Pseudolmedia laevis(Ruiz & Pav.) J.F. Macbr.	Moraceae	Chimicua	Local
Schizolobium amazonicum Huber ex Ducke	Cesalpinaceae	Pashaco	regional
Schizolobium sp	Cesalpinaceae	Pashaco colorado	regional
Septotheca tessmannii Ulbr.	Bombacaceae	Utucuro	regional
Simarouba amara Aubl.	Simaroubaceae	Marupa	Local
Spondias mombin L.	Anacardiaceae	Ubos	Local
Symphonia globulifera L. f.	Clusiaceae	Azufre huasca	Local
Tabebuia serratifolia (Vahl) G. Nicholson	Bignoniaceae	Tahuarí	Local
Terminalia oblonga (Ruiz & Pav.) Steud.	Combretaceae	Yacushapana	regional
Trattinnickia peruviana Loes.	Burseraceae	Caraña	Local
Virola spp	Myristiceceae	Cumala	regional
Zanthoxylum rigidum Humb. & Bonpl. ex Willd.	Rutaceae	Hualaja	Local

Source: AIDER 2005.