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ACCESSIBILITY AS A DETERMINANT OF OPPORTUNITIES
-
A CASE STUDY FROM PERUVIAN AMAZONIA

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Tiivistelmä – Referat – Abstract

Accessibility is a crucial factor for interaction between areas in economic, cultural, political and environmental terms. Therefore, information concerning accessibility is relevant for informed decision making, planning and research. The Loreto region in the Peruvian Amazonia provides an interesting scene for an accessibility study. Loreto is sparsely populated and because there are few roads in the region, in practice all movement and transportation happens along the river network. Due to the proximity of the Andes, river dynamics are strong and annual changes in water level combined with these dynamic processes constantly reshape accessibility patterns of the region. Selling non-timber forest products (NTFP) and agricultural products (AP) in regional centres is an important income source for local rain forest dwellers. Thus, accessibility to the centres is crucial for the livelihood of local population.

In this thesis I studied how accessible the regional centre Iquitos is from other parts of Loreto. In addition, I studied the regional NTFP/AP trade patterns and compared them with patterns of accessibility. Based on GPS-measurements, using GIS, I created a time-distance surface covering Loreto. This surface describes the time-distance to Iquitos, along the river network. Based on interview material, I assessed annual changes to accessibility patterns in the region. The most common regional NTFP/AP were classified according to the amount of time they can be preserved, and based on the accessibility surface, I modelled a catchment area for each of these product classes.

According to my results, navigation speeds vary considerably in different parts of the river network, depending on river types, vessels, flow direction and season. Navigating downstream is, generally, faster than upstream navigation. Thus, Iquitos is better accessible from areas situated south and south west of the city, like along the rivers Ucayali and Marañon. Differences in accessibility between different seasons are also substantial: during the dry season navigation is slower due to lower water levels and emerging sand bars. Regularly operating boats follow routes only along certain rivers and close to Iquitos transport facilities are more abundant than in more distant areas. Most of the products present in Iquitos market places are agricultural products, and the share of NTFP is significantly smaller. Most of the products were classified in product class 2, and the catchment area for these products is rather small. Many products also belonged to class 5, and the catchment area for these products reaches up to the edges of my study area, following the patterns of the river network.

The accessibility model created in this study predicts travel times relatively well, although in some cases the modelled time-distances are substantially shorter than observed time-distances. This is partly caused by the fact that real-life navigation routes are more complicated than the modelled routes. Rain forest dwellers having easier access to Iquitos have more opportunities in terms of the products they decide to market. Thus, they can better take advantage of other factors affecting the market potential of different products.

In all, understanding spatial variation in accessibility is important. In the Amazonian context it is difficult to combine the accessibility-related needs of the local dwellers with conservation purposes and the future challenge lies in finding solution that satisfy both of these needs.

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Tiivistelmä – Referat) Abstract

Saavutettavuus on keskeinen tekijä eri alueiden välisessä vuorovaikutuksessa, olipa kyse taloudellisista, kulttuurisista, poliittisista tai ympäristöseikoista. Sen huomioiminen päätöksenteossa, suunnittelussa ja tutkimuksessa on tärkeää. Loreton maakunta Perun Amazonialla on mielenkiintoinen tutkimuskohde saavutettavuutta ajatellen. Alue on harvaanasuttua ja vaikeakulkuista; teitä on vähän, joten käytännössä kaikki liikkuminen ja kuljetukset perustuvat alueen jokiverkkoon. Andien läheisyydestä johtuen jokidynamiikka on alueella voimakasta, ja vuosittaiset tulvat sekä virtaaman vaihtelu yhdistettynä näihin dynaamisiin prosesseihin muokkaavat jatkuvasti alueen eri osien saavutettavuutta. Viljely- ja keräilytuotteiden myyminen isompien keskusten markkinoilla on yksi keskeisimmistä tulonhankkimismuodoista sademetsän asukkaille, joten keskusten saavutettavuudella on heidän elinkeinojensa kannalta tärkeä merkitys.

Tässä tutkimuksessa selvitettiin, kuinka Iquitosin kaupunki on saavutettavissa muualta Loreton maakunnasta ja kuinka tämä saavutettavuus vaikuttaa viljely- ja keräiltytuotteiden kauppaan. Kenttätyöjakson aikana tehtyihin GPS-mittauksiin perustuen Loreton maakunnasta luotiin paikkatietomenetelmin aikaetäisyyspinta, joka kuvaa Iquitosin kaupungin saavutettavuutta jokiverkkoa pitkin. Saavutettavuuden vuotuista vaihtelua arvioitiin haastatteluaineiston pohjalta. Alueen tavallisimmat viljely- ja keräilytuotteet luokiteltiin niiden säilyvyyden perusteella ja kullekin tuoteluokalle mallinnettiin saavutettavuuteen pohjautuva keräilyalue.

Tutkimus osoitti, että navigointinopeudet vaihtelevat huomattavasti jokiverkon eri osissa, riippuen jokityypistä, kulkuvälineestä, kulkusuunnasta ja vuodenajasta. Myötävirtaan navigointi on pääsääntöisesti nopeampaa kuin vastavirtaan navigointi, mistä johtuen Iquitos on paremmin saavutettavissa alueilta, joilta kuljetaan kaupunkiin myötävirtaan. Vuodenaikojen väliset erot saavutettavuudessa ovat myös suuret, sillä kuivana kautena navigointi on hitaampaa alhaisen vedenpinnan tason ja jokiin muodostuvien särkkien takia. Säännöllisesti liikennöivät laivat ja veneet kulkevat vain tiettyjä jokia pitkin, ja lähellä Iquitosia kuljetusmahdollisuudet ovat huomattavasti paremmat kuin kauempana keskuksesta. Suurin osa toreilla esiintyvistä tuotteista on viljelytuotteita, ja puhtaasti keräilytuotteiden osuus kaikista tuotteista on melko pieni. Suurin osa tuotteista luokiteltiin noin kolme päivää säilyviin tuotteisiin, joiden keräilyalue on hyvin suppea. Paljon tuotteita kuului myös yli viisi päivää säilyvien tuotteiden luokkaan, ja niiden keräilyalue ulottuu jokiverkkoa mukaillen monin paikoin maakunnan rajoille saakka.

Saavutettavuusmalli arvioi aikaetäisyyttä suhteellisen hyvin, joskin paikoittain mallin mukaiset arvot ovat huomattavasti todellisia aikaetäisyyksiä lyhempiä. Todelliset navigointireitit ovat siis mallia monimutkaisempia. Paremman saavutettavuuden piirissä olevilla asukkailla on enemmän valinnanvaraa tuotteissa, joita he markkinoivat. Näin ollen he voivat kiinnittää enemmän huomiota muihin tekijöihin, joilla on vaikutusta tuotteiden markkinapotentiaaliin.

Saavutettavuuden alueellisen vaihtelun ymmärtäminen on tärkeää. Amazonialla haasteellista on yhdistää suojelunäkökulma ja paikallisten ihmisten tarpeet saavutettavuuden suhteen, ja tulevaisuuden haasteena on löytää ratkaisuja, jotka tyydyttävät molempia tarpeita.

Avainsanat – Nyckelord) Keywords

Saavutettavuus, NTFP, maataloustuotteet, Iquitos, Loreto, Perun Amazonia, GIS, kustannusetäisyys

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Abbreviations

Abbr.	*Concept*	*Translation (if needed)*
AP	Agricultural products	
BF	Bote fluvial	Small motorized boats tranporting both people and goods
CORPAC	Corporación peruana de aeropuertos y aviación comercial s.a.	Peruvian corporation of airports and commercial aviation
ESRI	Environmental Sciences Research Institute	
GIS	Geographic Information System	
GOREL	Govierno Regional de Loreto	Regional government of Loreto
GPS	Global Positioning System	
IIAP	Instituto de Investigaciones de la Amazonía Peruana	Peruvian Amazon Research Institute
IIRSA	Iniciativa para la integración de la infraestructura regional suramericana	Initiative for the Integration of Regional Infrastructure in South America
INEI	Instituto nacional de estadística e informática	National Institute of Statistics (Peru)
MF	Motonave fluvial	Large motorized ship tranporting both people and goods
NTFP	Non-timber forest product(s)	
PCAr	Product catchment area	
RIVM	Rijksinstituut voor volksgezondheid en milieu	National Institute of Public Health and the Environment (The Netherlands)

1 INTRODUCTION

No man is an island. This quote by John Donne (1572-1631), despite its old age and different context, would fit well into World Bank´s (2009) latest World Development Report. The report states that accessibility and connectivity are key factors in economic well-being of different areas; isolated regions tend to be the ones that lag behind economically.

Physical accessibility, whether it is to the closest bus stop, capital of our country or a holiday destination on the other side of the globe, affects our everyday life and choices we make. However, it is not solely the individual that is affected by accessibility – in fact accessibility forms the basis of interaction for whole societies and affects relations between environmental, economic, political and cultural processes.

Accessibility is not a new research theme. It was of interest to pioneers of economic geography who created the first location theories (see Dicken & Lloyd 1990). Since those times, concepts of accessibility have been incorporated in urban studies, development research and conservation themes. Methodologies for analyzing accessibility vary a lot, depending on how accessibility is defined and the purposes of the research. Researchers generally acknowledge the challenges in capturing all aspects of accessibility in one measure (e.g. Hodge 1997; Martín & Reggiani 2007). Often accessibility is considered as a synonym for distance in geographic units. In reality, however, Euclidian distance may not accurately reflect patterns of accessibility (Dicken & Lloyd 1990; Kwan & Weber 2003; Verburg et al. 2004): For example, two suburbs may lie an equal distance in kilometres from downtown but the time-distance (distance measured in time), may be drastically different, depending on availability of transportation means and networks. Thus, so called cost-distance provides often a more realistic measure of accessibility.

Geographic Information Systems (GIS) provide useful tools for modelling accessibility (e.g. Nelson 2000; Toivonen & Mäki 2003). One example of GIS-based cost-distance accessibility model is “A global map of accessibility” which reflects travel-times to major cities worldwide (European Commision 2008). This map is related to the World

Development Report 2009 and is based on a travel time study performed by European Commission together with World Bank. Often the purpose of accessibility studies is to identify "hot-spots" and "cold-spots" in accessibility patterns, and based on this information, priority can be given to lagging areas in planning. One clear "cold-spot" in the global accessibility map is Amazonia, and indeed, a need for accessibility information regarding this region has been acknowledged in research literature (Toivonen & Mäki 2003; Schulman et al. 2007; Toivonen et al. 2007). Each individual living in this region probably recognizes accessibility possibilities and constraints affecting his or her personal life, but what is lacking, is an overall understanding of accessibility patterns for the region, measured in a reliable way.

Peruvian Amazonia provides an interesting and challenging scene for an accessibility study. The majority of studies examine accessibility from the point of view of terrestrial transport networks, but in Peruvian Amazonia there are only a few roads and no railways exist. Instead, the fluvial network is the most dominating element in the landscape. Rivers form the basis for all mobility and transport of both people and goods (Abizaid 2005). Analyzing accessibility based on elements of a constantly changing natural environment provides different challenges compared to accessibility research within built environment. Several studies show that the structure and dynamics of the river network strongly affects accessibility patterns of the region (Kvist and Nebel 2001; Toivonen & Mäki 2003; Abizaid 2005; Toivonen et al. 2007) and determines the time-distance to regional centres from the surrounding areas. Yet the transportation patterns of rivers are rather poorly examined.

In general, there is a lack of consistent, reliable and well documented spatial data conserning Peruvian Amazonia (e.g. Salo & Toivonen 2009). Accessibility information could act as one component in a toolbox for decision makers, scientists and planners in the area. Such information combined with other data would be benefitial in many senses: Resource use planning is crucial for local livelihoods, and the potential of different resources is often dependent on accessibility. Conservation of the Amazonian rain forest is essential not only locally but also in a global context, and defining conservation needs should be based on the best possible understanding of these complex ecosystems. Accessibility patterns cause spatial bias in research (see Reddy & Dávalos 2003; Schulman et al. 2007), and in order to make informed decisions about conservation needs, it is important to consider this research bias. Additionally, land use pressure and human impact on the environment could be assessed with help of accessibility information.

In the Loreto region, accessibility to markets of the regional centre, Iquitos, is essential to the livelihoods of local residents. Many floodplain dwellers earn their living by practising agriculture, extracting regional non-timber forest products (NTFP) and selling their products in Iquitos (Padoch et al. 1985; Padoch 1988b; Kvist & Nebel 2001; Kvist et al. 2001). NTFP have been of interest to tropical forest researcher in several parts of the world because these products could potentially provide a means for sustainable use of rainforests and economic advantages to rainforest dwellers (Nepstadt & Schwartzman 1992; Shanley et al. 2001). When talking about Amazonian livelihoods and regional markets, it is essential to include agricultural products (AP) in the discussion, because NTFP alone hardly provide sufficient income for Amazonian families (Padoch et al. 1985; Pyhälä et al. 2006).

Regional products (both NTFP and AP) and accessibility are both important research themes as such, but examining the combination of these two provides interesting insights (Toivonen & Mäki 2003; Perez & Lake 2003; Abizaid 2005). Trade potential of NTFP and AP relies on the accessibility of the resources and river transport forms a significant part of their commercialization (Padoch 1988a; Pulido & Cavelier 2001). Fruits and vegetables are perishable and must arrive at a market place within a limited timeframe. The river network, being limited both in space and time, regulates the activities of floodplain dwellers collecting and cultivating regional products for commerce. Thus, the relationship between these themes is twofold: on one hand, accessibility regulates the potential for NTFP extraction and AP cultivation for commercial use, and on the other hand, observed extraction and cultivation patterns may reflect accessibility of different areas. The relation between accessibility and NTFP/AP-trade is recognized in several studies (e.g. Padoch et al. 1985; Padoch 1988a; Kvist et al. 2001; Takasaki et al. 2001; Perez & Lake 2003; Pyhälä et al. 2006), but no deeper analysis of this theme has been done.

This thesis corresponds to current research needs by modelling accessibility pattern around the city of Iquitos, using cost-distance methods and empirical data on navigation speeds. In addition, the regional NTFP/AP trade patterns are studied and compared with patterns of accessibility. The specific study questions are:

1. *What is the spatial pattern of accessibility in Loreto?*

2. *What are the effects of these accessibility patterns, specifically on NTFP/AP trade?*

The importance of accessibility as a determinant of land use patterns has been confirmed in previous studies (e.g. Verburg et al. 2004). My hypothesis is that the accessibility of Iquitos (meaning the time-distance to the city from the surrounding areas) determines the product catchment areas for different NTFP/AP, along with general environmental and socio-economic circumstances.

2 BACKGROUND OF THE STUDY

2.1 Accessibility

2.1.1 Definition

In literature, accessibility has been defined in various ways and there does not seem to be a commonly accepted definition for the concept (Miller 1999; Martín & Reggiani 2007; Chang & Lee 2008). Thus, accessibility needs to be defined according to the specific objectives of each study. Some common definitions are "the ease with which one reaches a desired location" (Bryceson et al. 2003: 179) and "the amount of effort for a person to reach a destination" (RIVM 2001: 19). Chang & Lee (2008: 90) define accessibility as "potential of opportunities for spatial interaction" whereas according to Miller (1999: 1) accessibility is the "true objective of transportation". Nelson (2000: 1) suggests that accessibility could be a central, integrating concept that grasps the complex interaction between subsistence, economic and social needs of any population.

One way of approaching accessibility is to separate the concepts of *place accessibility* and *individual accessibility*. This is a frequently used division especially in urban studies (e.g. RIVM 2001; Kwan & Weber 2003, Weber 2006). Place accessibility refers to accessibility of a location whereas individual accessibility is concerned with individuals and their characteristics in terms of accessibility. Place accessibility can be thought of as physical accessibility (RIVM 2001), which is in the focus of this study.

In some cases, accessibility is divided into separate components. In a report published by National Institute of Public Health and the Environment in the Netherlands (RIVM 2001), accessibility is divided into four independent components:

1) *transport component*, that describes the effort to travel between an origin and a destination and can be measured in terms of travel time or cost,
2) *land-use component*, that reflects the spatial distribution of activities at destinations and the demand for these activities,

3) *temporal component*, which refers to time restrictions of both activities and individuals, and
4) *individual component*, reflecting the need and opportunities that individuals have

Many researchers claim that it is hard to handle all these components when assessing accessibility, and often only one or two of these components are taken into account. For instance, Verburg et al. (2004) concentrated solely on the transport component. In their study, determinants of accessibility were threefold: *origins and destinations*, *transport network* and *means of transport*.

2.1.1.1 Accessibility-related concepts

Accessibility and mobility are closely linked terms that often get mixed but in reality they mean different concepts. Accessibility is the *potential* for interaction whereas mobility is a measure of behaviour, *realization* of interaction (Hodge 1997). Higher rates of accessibility normally lead to higher mobility, which may be harmful for the environment and sustainability (Hodge 1997; Fenley et al. 2007). Accessibility and mobility can also be seen as human rights (Vasconcellos 1997). For example poor women´s restricted mobility in India violates against the ideal of gender equality (Anand and Tiwari 2006).

Connectivity is also an accessibility-related concept, when talking about transportation networks or landscape patterns (DeMers 2000; Adrianensen et al. 2002; Wiens 2002; Kwan et al. 2003; Toivonen & Mäki 2003). The better the different parts of transportation network are connected, the higher is the rate of accessibility. In a landscape context, connectivity and accessibility between separated habitats reduces fragmentation of natural systems and facilitates movement of organisms (Adrianensen et al. 2002; Wiens 2002).

Accessibility, policies and planning are interrelated: on one hand, accessibility measures provide a means for planning and policy-forming (Chang & Lee 2008) and conversely, planning and policies may determine accessibility. Development is closely linked to accessibility, and here, physical transport infrastructure plays a major role (Kessides 1993; Dixon-Fyle 1998).

2.1.2 Applications

Accessibility is an interesting research theme in several fields. It has been studied in many parts of the world, both in rural and urban contexts. As Weber (2006) and Nelson (2000) suggest, accessibility can be seen either as desirable or as non-desirable, depending on the application.

Perhaps the earliest and most traditional frameworks for accessibility are found in economic geography and transport literature. Von Thünen considered accessibility in his spatial analysis of land-use patterns by creating a model of a hypothetical isolated state ("*Isolierte Staat*") where agricultural land-use pattern consisted of concentric rings of different agricultural land-use types around an urban-industrial centre. The only significant land-use determinant was distance (see Haggett et al. 1977; Dicken & Lloyd 1990). Despite their highly simplifying assumptions, classical location and central place theories by von Thünen, Christaller and Lösch and their later modifications (see Dicken & Lloyd 1990) still provide an important framework for analyzing the role of transportation networks and accessibility to the relationship between economic functions and land-use patterns (Mäki 2003; Verburg 2004).

Nowadays, the interaction between land use and accessibility has been studied in detail within urban research. An accessibility point of view can provide useful insights in following themes within urban-planning: public transport (Juliao 1999; Miller & Wu 2000; Liu & Zhu 2004; Matrín & Reggiani 2004; Rodríguez & Targa 2004; Chang & Lee 2008), provision of social services (Wilkinson et al. 1998; Black et al. 2004), commuting patterns and accessibility of jobs (RIVM 2001; Kwan et al. 2003; Ristimäki et al. 2008).

Development studies indicate that accessibility is a key factor in rural development. On an individual level, rate of accessibility can be interpreted as an indicator of social inequality (Anand & Tiwari 2006), and many studies indicate that poor accessibility and poverty tend to appear side by side in both urban and rural contexts (Dixon-Fyle 1998; Bryceson et al. 2003; Anand & Tiwari 2006). Accessibility to education in rural Brazil was studied by Vasconcellos (1997), who states that rural people in developing countries face several accessibility restrictions when trying to fulfill important needs. Accessibility and poor transport planning also have impacts on the productivity and structure of agriculture – high transport costs provide an example of this (Dixon-Fyle 1998; Leinbach 2000). Accessibility provides a useful framework even for rural land-use change studies: a case study of the North Eastern Philippines confirms that accessibility is a key determinant of land-use patterns and agricultural production (Verburg et al. 2004).

In a conservation context accessibility is often interpreted as a negative factor. Economic interests and conservation needs tend to collide - higher rates of accessibility supporting the former and poorer accessibility the latter. Indeed, several studies prove that road-based accessibility is one of the most significant factors causing deforestation (Laurance et al. 2002; Pan et al. 2004; Mena et al. 2006; Fenley et al. 2007; Soler et al. 2009). Interestingly, access via navigable rivers was not found to be as significant a cause of deforestation as road access (Laurance et al. 2002; Fenley et al. 2007). Pressure on ecosystems and existing natural resources, including oil, gas and wild-life, is growing in many parts of the world (Perez & Lake 2003; Laurance et al. 2006; Finer et al. 2008). In addition, the rights of indigenous peoples that live in voluntary isolation, are threatened by this growing pressure on natural resources and an increased rate of accessibility (Finer et al. 2008).

2.1.3 Methodology: measuring accessibility

It is widely understood that there is a need to measure accessibility in a reliable way (e.g. Hodge 1997; Chang & Lee 2008). Such measures are useful in identifying and ranking areas with varying degrees of accessibility, and this information can be further used in policy-framing and decision making (Martín & Reggiani 2007; Chang & Lee 2008). It is also widely recognized that it is not an easy task to develop a measure that captures all aspects of accessibility (Hodge 1997; Martín & Reggiani 2007). Given that accessibility can be defined in a variety of ways suggests that there are numerous ways of measuring it. It is difficult to define one best approach to measure accessibility since different purposes require different approaches – basically, it is up to each individual researcher to decide which type of measure is best suited to her or his purposes (Verburg et al. 2004; Chang & Lee 2008; Matrín & Reggiani 2007).

Methods for measuring accessibility have been classified in literature in different ways (e.g. Miller 1999; Miller & Wu 2000; RIVM 2001). However, for the purposes of this study it is relevant to review just some of the basic methods of measurements.

2.1.3.1 Numerical accessibility measures

Numerical indicators of accessibility usually have two components: destination attractiveness and travel impedance (Chang & Lee 2008). One commonly used index-based approach is the so called Hansen accessibility index (Hansen 1959; Fotheringham et al. 2000) (Formula 1):

$$A_i = \sum_j S^{\alpha}_j d^{\beta}_{ij} \qquad (1)$$

where A_i is the accessibility of place i (origin) for some activity such as market place activities, S_j is a measure of the number of opportunities at j (destination), and d_{ij} is the distance between i and j (origin and destination). The parameters α and β determine the importance of size and attractiveness (*S*) and distance (*d*), in terms of accessibility. Usually α get a positive value, where as distance is inversely weighted – the bigger the distance the more negative β. Hansen´s (1959) index was designed to be used as a basis for residential land use models. It was later modified and criticized by several researchers (e.g. Kwan & Weber 2003; Chang & Lee 2008).

2.1.3.2 GIS-based accessibility measures

Many researchers agree on that Geographic Information Systems (GIS) provide a useful and cost-effective tool for accessibility analysis at different scales and in different contexts (Juliao 1999; Miller 1999; Miller & Wu 2000; Nelson 2000; Chang & Lee 2008; Kwan et al. 2003; Kwan & Weber 2003; Toivonen & Mäki 2003; Black et al. 2004; Liu & Zhu 2004; Rodríguez & Targa 2004; Verburg et al. 2004). Possibilities for database management and visualization of accessibility are particularly appreciated.

In GIS there are two essentially different approaches to accessibility analysis: the vector and the raster approach. The vector model is feature oriented and presents the environment as discrete objects, points, lines and areas. Accessibility analysis in vector format is performed in a network of nodes and lines. Raster-model is location oriented and describes the environment as a continuous surface. Here, cost-distance analysis is used for evaluating accessibility. The fundamental difference between these approaches lies in the fact that movement in vector-model can occur only within limits of the restricted network, whereas the raster model allows for connections anywhere in space (Steinberg & Steinberg 2006).

In a vector-based approach, accessibility is analyzed as a network of interconnected elements, such as lines connecting points – or in reality, transport network connecting interesting locations. The vector model includes impedances, restrictions and hierarchies attributed to different segments of the network, and the algorithms used in network calculations are often based on Dijkstra´s (1959) shortest path algorithm (see Fotehringham et al. 2000). Assessing accessibility within a network means finding an optimal path from one location to another – "optimal" being shortest, fastest, cheapest or something else, defined by the analyst. Some systems permit other network functions, like allocation (DeMers 2000; Fotheringham et al. 2000).

In the raster approach, cost-distance analysis provides a useful way of analyzing accessibility (Nelson 2000; Toivonen & Mäki 2002; Adriaenssen et al. 2003; Toivonen & Mäki 2003; Black et al.2004; Verburg et al. 2004; Soler et al. 2009). Cost-distance analysis is based on the idea that distance can be measured in terms of something other than geographic units: cost-distance (also called functional distance) can be measured for example in monetary terms or as travel time (DeMers 2002). For cost-distance analysis, a friction grid and a source grid are needed as inputs. The friction grid is usually a combination of multiple grids and each grid cell represents either a transport route (roads, railways, navigable rivers and so forth), or relatively inaccessible land (Nelson 2000). Each cell on the surface has a cost associated with it, representing the effort needed to pass that location, for example time. The source grid consists of point(s) of interest, such as regional centres or hospitals within a city.

The purpose of cost-distance operation is to find the least accumulative cost from each friction grid cell to the source cell(s) (DeMers 2002). In the calculation, the algorithm utilizes a node/link –logic, where centres of cells are represented as nodes, and all adjacent nodes are connected to each other with links. Every link has an impedance value, determined by the cost values of the friction grid cells that the link connects. The model is based on eight-neighbour-cell logic which means that movement is allowed horizontally, vertically and diagonally. In vertical and horizontal movement, each cell value is multiplied by the cell resolution and in case of diagonal movement the cost is adjusted to compensate for the longer distance (DeMers 2002). The output of cost-distance analysis is a cost distance grid that represents the accumulative cost of travelling from each cell to the source(s).

A common problem with accessibility measures is their subjective nature: for example in Hansen´s accessibility index, it is up to each individual researcher how to determine parameters α and β, and their definition significantly effects the results of the analysis (Fotheringham et al. 2000). This also applies to GIS-based measures, where impedance values may be arbitrary (DeMers 2002; Toivonen & Mäki 2003).

2.2 The fluvial system of Amazonia

"Los ríos son la vida de la Selva." Rivers are the life of the rainforest. This is how Garcia Sanchez and Bernex de Falen (1994) sum up the role of the river network for the Amazonian rainforest and its dwellers. Water is the most characteristic feature in Amazonian landscape and processes of the fluvial system strongly affect both plant, animal and human life of the area. The Amazon and its tributaries present the mightiest river system on earth: more than 7 million km^2 of land drain to the Amazon (Sioli 1984). The drainage system is extremely complex, consisting of small streams, huge rivers, lagoons, oxbow lakes, fluvial bars, islands and floodable terrain. This chapter presents some typical ways of classifying rivers and basic processes of river dynamics that affect Amazonia.

2.2.1 Water types and channel morphology

The rivers of Amazonia are traditionally classified according to their channel width, colour and channel morphology (Schumm 1972; Sioli 1984). In terms of colour, Amazonian rivers are usually divided into *white-water* (turbid), *black-water* (transparent but of brown colour) and *clear-water* (transparent) categories (Sioli 1984). Waters of different colour differ in their physical and chemical properties and reflect the physical, edaphic and biotic conditions of the landscape. White-water rivers are rich in nutrients and fertile sediments, black-water rivers are generally acidic and poor in nutrients whereas clear-water rivers have an intermediate nutrient load (Junk & Furch 1985, 1993). It is not always an easy task to classify a river into a specific category. Changes in the load of suspended sediments occur not only in space but also in time: during the dry season the water may appear clear, but when flood season arrives, the colour of the water changes into white (Sioli 1984; Junk & Furch 1985; Puhakka et al. 1992). In addition, different water types are connected to each other and get mixed, forming intermediate types (Sioli 1984). Some authors (e.g. Puhakka et al. 1992; Kvist & Nebel 2001) refer to these intermediate waters as “mixed-waters”.

Similarly, three categories based on river channel morphology can be distinguished: *meandering*, *anastomosing* and *braided* channels (Fig. 1) (Schumm 1972). The determining factors are channel multiplicity and sinuosity, a measure of “wiggliness” of a watercourse (Gordon et al. 2004). A meandering channel is winding and shifts constantly due to erosion by undercutting on outside of bends. A braided stream consists of multiple channels with bars and islands that are in constant movement. Anastomosing streams are an intermediate category between meandering and braided. They have multiple channels, but the nature of islands is different from braided streams: islands of anastomosing channels are relatively permanent and stable vegetated (Puhakka et al. 1992). Channel patterns may vary within one stream: streams that are braided at one flow level may be meandering at another level. In general, high slopes and high stream power are indicated by braided channels, whereas meandering channels occur with lower slopes and lower stream power (Gordon et al. 2004).

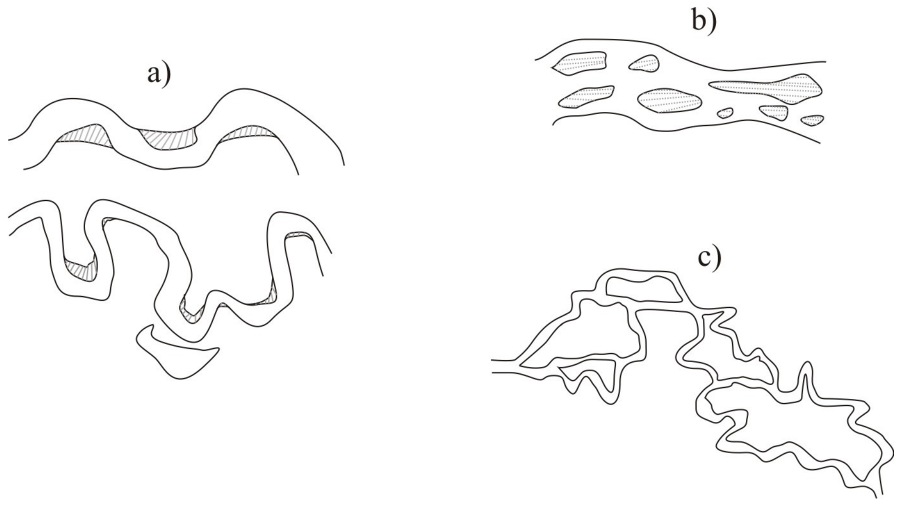


Figure 1. Different channel types. a) meandering; b) braided; c) anastomosing. Based on Gordon et al. (2004).

2.2.2 Flooding patterns

High rainfall and its seasonal distribution is characteristic of all tropical South America (Junk & Furch 1993). In rain forest areas, up to 75 % of total precipitation may be due to evapotranspiration, while the remaining rainfall is carried by winds from the Atlantic Ocean (Junk & Furch 1985). Typically, one rainy season and one dry season can be distinguished but the timing of these seasons varies spatially (Sioli 1984). Due to changes in precipitation, large fluctuations in water level are normal and cause periodic floods. The flood amplitude varies from year to year, leading to variation in flooded areas (Junk & Furch 1993; Kalliola & Puhakka 1993). The flooding pattern of larger rivers is usually more predictable than that of smaller tributaries (Kvist & Nebel 2001), which depends on the fact that smaller channels react more strongly to local rainfalls whereas the discharge of larger rivers represent the average precipitation of a larger area (Junk & Furch 1985). Differences between highest and lowest water levels vary spatially and can reach up to 20 metres (Sioli 1984).

Flooding patterns have profound effects on the environment. One indicator of this is that the basic classification of Amazonian forests is based on inundation patterns. Forests in annually inundated areas, floodplains, are called *várzea*-forests and these are distinguished from *tierra firme* -forests that remain out of reach of periodic floods (Sioli 1984). The biota of floodplains is well adapted to these periodic inundations and differs substantially from the vegetation present in *tierra firme* –forests (Junk & Furch 1993). This also applies to animals living in *várzea*, although flood stress does restrict species diversity, compared with upland areas (Puhakka et al. 1992; Junk & Furch 1993; Adis & Junk 2002). As Sioli (1984) states, floodplains have very peculiar conditions for plant, animal and human life.

2.2.3 Erosion and deposition

Erosion and deposition are basic processes of river dynamics which take varied forms in different channels. Erosion is most pronounced in meandering rivers, where it occurs at the concave (outer) bank of the meander. Thus, the channel is constantly shifting and migrating laterally, from time to time making “cut-offs” across the base of meander loop, leaving one part of the channel abandoned, called an oxbow lake (Fig. 2). The speed of this process varies spatially: some river segments show faster channel migration rates whereas erosion is more constrained in other segments. Channel migration in meandering streams is usually unidirectional, in contrast to anastomosing channels, where the changes in river course take on a more “patch-like” structure (Puhakka et al. 1992; Kalliola et al. 1992).

Sudden and dramatic changes in river course are also possible. This process is referred to as river *avulsion* (Kvist & Nebel 2001). An Amazonian example of river avulsion is given by Salo & Pyhälä (1991): some 200 years ago, owing to a strong earthquake, a long river segment along Ucayali-river suddenly relocated more than 50 kilometres to West, leaving a missionary station land-locked and abandoned.

Sedimentation may take place either within a river channel or beyond it. Forms of deposition can be divided into three categories: channel deposits, overbank deposits and floodplain deposits (Kalliola & Puhakka 1993). In meandering rivers, the most common form is channel deposition which takes the form of fluvial bars, locally known as *playas* (Fig. 3). Fluvial bars are formed in the convex (inner) bank of a meander (*point bars*) or in the middle of a channel (*channel bars*). Overbank deposition places sediment either as levees or crevasse splays on the river banks (Fig. 2). Levees are typically large, plain surfaces and form the highest points of the flood plain. Crevasse splays are formed when a stream cuts through a levee and sediments start to deposit along this channel, taking on a delta-like form. Floodplain deposition occurs further away from the channel when sediments start to accumulate in the flood basin area (Kalliola & Puhakka 1993; Kvist & Nebel 2001).

Successional vegetation patterns are closely related to lateral channel migration and different forms of deposition. *Playas* are under water during floods, but once exposed during the dry season, the bare land is available for plant colonization (Puhakka et al. 1992). During each flood, the bar grows larger, eventually forming into a ridge. Ridges are separated by narrow depression swales which ultimately become colonized by plants (Kalliola & Puhakka 1993; Kvist & Nebel 2001). In a meandering landscape, this so called scroll relief consisting of ridges and swales (Fig. 2) supports a clearly age-zonated vegetation pattern where no old forests exist due to constant erosion (Puhakka et al. 1992). In contrast, the rather stable islands of anastomosing landscapes have old vegetation where age-zonation is less clear. Floodplains of unstable braided channels typically have abundant young successional vegetation (Puhakka et al. 1992).

In the Western part of the Amazon basin, the fluvial processes are especially active, due to the vicinity and tectonic activity of the Andes (Räsänen et al. 1990). River dynamics constantly disturb the forests, causing site turnover and a mosaic-like forest structure that consists of forest patches in different successional phases. These processes have been suggested as the main cause for the abundant richness of both plant and animal species of Amazonia (Salo et al. 1986; Puhakka et al. 1992; Junk & Furch 1993).

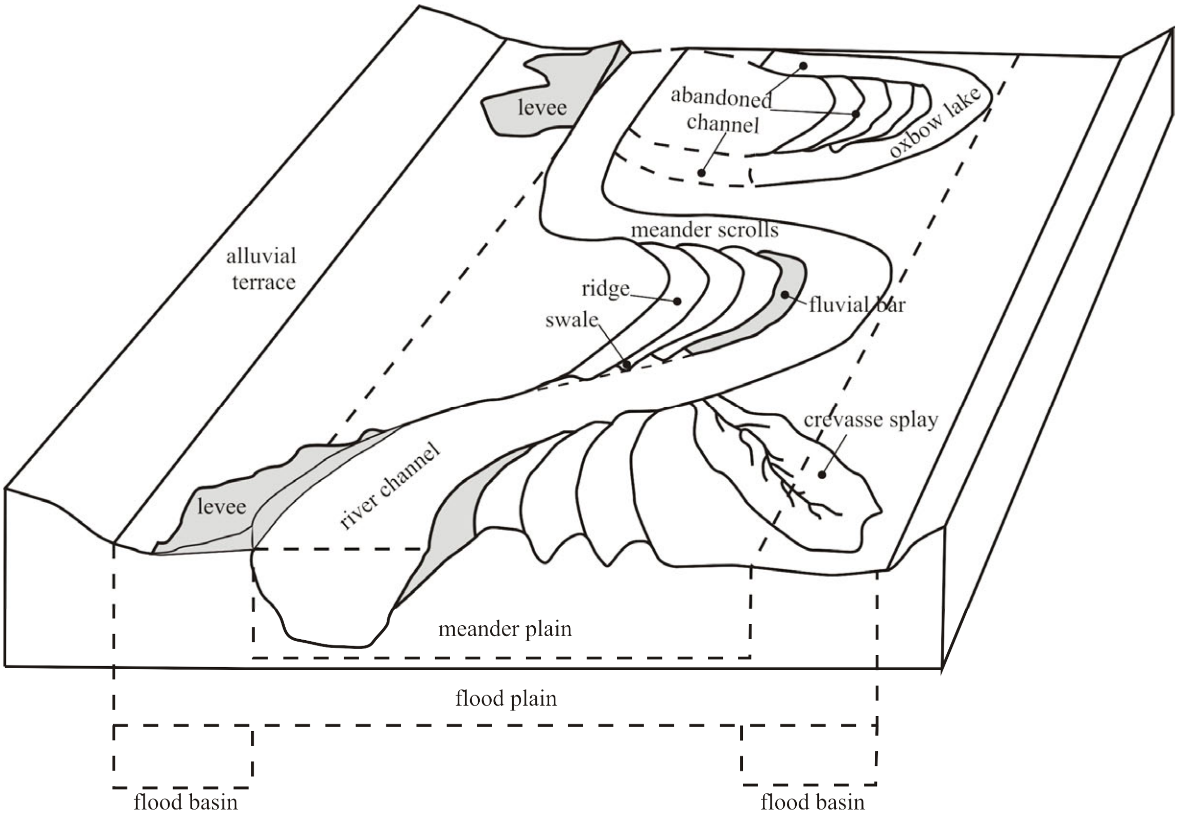


Figure 2. Some fluvial terminology as a picture. Modified after Kalliola & Puhakka (1993: 15).

2.3 Typical livelihoods in the Amazon region

Typically Amazonian livelihoods cover a large range of activities, including agriculture, fishing, hunting, logging and extraction of both aquatic and forest products (Padoch et al. 1985; Coomes & Barham 1997; Takasaki et al. 2001; Coomes 2004; Pyhälä et al. 2006). Products are cultivated and extracted mainly for subsistence use but a fair amount of products are also sold in regional centres (Padoch et al. 1985; Padoch 1988b; Padoch & de Jong 1990; Brack Egg 2001; Duivenvoorden et al. 2001; Kvist et al. 2001; Kvist & Nebel 2001; Pyhälä et al.2006). Agricultural products (AP) and non-timber forest products

(NTFP) present in local marketplaces are the focus of this study, so some discussion of these products and their trade is presented in this chapter.

2.3.1 Terminology

A non-timber forest product refers to any wild-harvested forest products, excluding timber. Depending on the source, products included under NTFP concept include: forest fruits, fish, bushmeat, latex, fibres, palm thatch, palm heart, nuts, seeds, roots, resin, vines, barks, honey, medicinal plants, rubber, etc. (Nepstadt & Schwartzman 1992; Voeks 1996; Pulido & Cavelier 2001; Takasaki et al. 2001; Shanley et al. 2002; Perez & Lake 2003; Pyhälä et al. 2006).

Normally wild-extracted products and cultivated agricultural products are treated as separate categories in the literature (e.g. Kvist & Nebel 2001; Takasaki et al. 2001; Pyhälä et al. 2006). In some cases an unambiguous definition of these concepts is problematic. A common misunderstanding is that NTFP extraction does not involve any manipulation of the natural forest; in reality, however, NTFP extraction practices range from minimum forest disturbance to enrichment planting of species in secondary forests (Muñiz-Miret et al. 1996; Shanley et al. 2002). If a previously wild-harvested species is cultivated in monospecific plantations, it is no longer considered as a NTFP (Muñiz-Miret et al. 1996). Between wild NTFP and monocultivations there seems to be an intermediate category that in some cases belongs to NTFP category and in some cases is classified as agricultural product.

Padoch et al. (1985) discuss Amazonian agroforestry and include both cultivated fruits, intensively managed crops and forest fruits in their study. Vazquez & Gentry (1989) examine fruits in Peruvian Amazonia and make a division between wild-harvested and cultivated fruits. Pulido & Cavelier (2001) follow partly Padoch et al.´s (1985) classification, and suggest the use of a broader concept NTVP (non-timber vegetable products) that extends the definition of NTFP to cover also cultivated products. In this study, I combine these approaches as follows: With NTFP I refer to wild-harvested, non-cultivated fruits (leaving out all other products). Cultivated fruits and intensively managed crops - no matter if they are a result of an agroforestry system or slash-and-burn practice - are combined under concept agricultural products (AP).

2.3.2 Potential and risks

NTFP extraction has been proposed as a strategy for rainforest conservation and simultaneously, as a means for sustainable economic development of rural rainforest dwellers, not only in Amazonia but also in other tropical regions (see Nepstad & Schwartzman 1992; Voeks 1996; Shanley et al. 2001, Hiremath 2004). The rationale behind NTFP enthusiasm that begun in the late 1980´s is that rainforests contain a multitude of valuable resources and native rainforest dwellers preserve an intimate knowledge of the various ways in which these resources may be utilized (Shanley et al. 2002). Prevalent rainforest-uses, like timber logging, large agricultural fields or cattle pasture often lead to greater rates of deforestation whereas NTFP extraction is based on the idea that products are extracted leaving the forest structurally and functionally intact, thus promoting biodiversity in forests (Nepstad & Schwartzman 1992; Shanley et al. 2002). NTFP have for long provided an important complement to daily subsistence of rainforest dwellers but, more than that, NTFP could provide a meaningful employment combined with higher incomes for rainforest dwellers when extracted for commercial purposes (Padoch 1988a; Voeks 1996).

Despite all the positive notions related to NTFP, risks caused by this type of action are also recognized. For subsistence, NTFP are traditionally extracted in a sustainable way, but once outside market-forces enter the picture, many products are over-harvested or depredatory extraction methods are used in search of short-term profit (Padoch 1988a; Vasquez & Gentry 1989; Coomes & Barham 1997; Kvist & Nebel 2001; Kvist et al. 2001; Perez & Lake 2003; Coomes 2004; IIAP 2006; Pyhälä et al. 2006). Several studies indicate that NTFP trade is not as profitable as it was expected to be: the market value of NTFP has proven to be only marginal in comparison with their subsistence value (Nepstad & Schwartzman 1992; Pulido & Cavelier 2001; Pyhälä et al. 2006).

Discussion on potential and risks of NTFP extraction and commerce from the late 1980´s until today is summarised in figure 3.

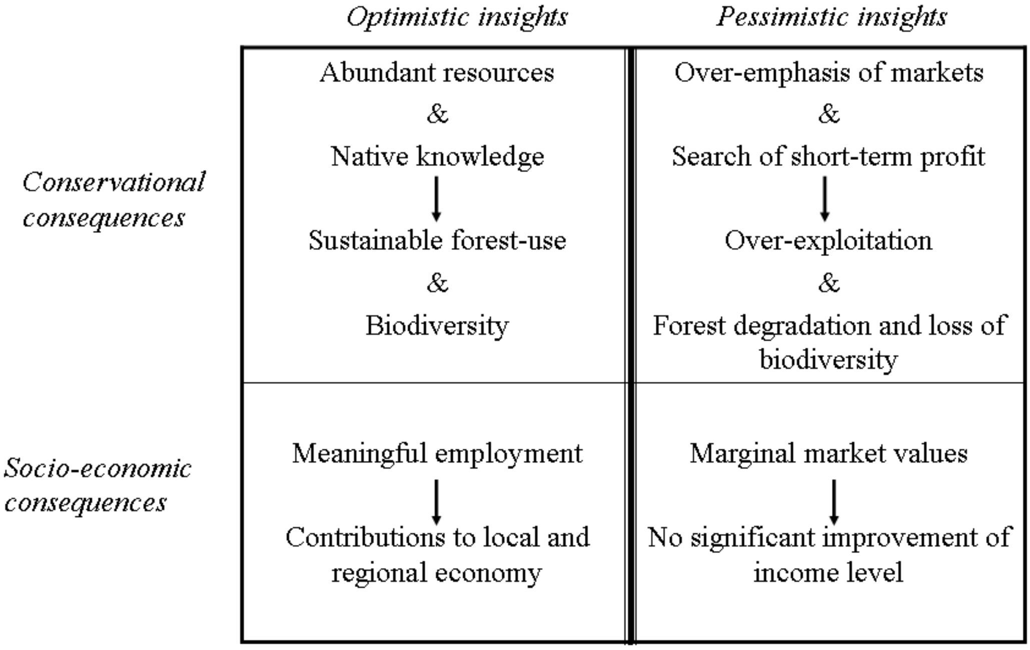


Figure 3. Different aspects of NTFP extraction and trade presented in relevant literature.

In addition to NTFP extraction, participation in agriculture is commonplace among floodplain households (Takasaki et al. 2001; Pyhälä et al. 2006). Agriculture is practiced in the form of agroforestry on uplands, high and low levees and annual cropping on mudflats and sandbars - each of these agricultural land types having different conditions and challenges for cultivation. Uplands are never flooded, high levees are occasionally flooded, and low levees get inundated every year. Fertile mudflats and sandbars appear only during dry season, and their extent varies significantly from year to year (De Jong et al. 2001; Kvist & Nebel 2001; Takasaki et al. 2001). Although flooding makes the soils fertile, it may also destroy cultivated crops by occurring too early in the season, being too high or by eroding the land (De Jong et al. 2001; Kvist & Nebel 2001; Takasaki et al. 2001). Consequences of such unexpected flooding patterns may be dramatic, including local food scarcity and loss of income (Takasaki et al. 2001).

Much of the NTFP/AP-research includes estimates of the socio-economic value of different livelihood-strategies (Padoch et al. 1985; Muñiz-Miret et al. 1996; Kvist et al. 2001; Takasaki et al. 2001; Coomes 2004; Pyhälä et al. 2006) Comparisons of profitability between NTFP and AP in different Amazonian communities reveal that AP, in general, are more significant income sources than NTFP. Padoch et al. (1985) found in Tamshiaycu village in Peruvian Amazonia that on average AP accounted for 84% of household incomes whereas NTFP (if only forest fruits were included) only accounted for 1%. Pyhälä et al. (2006) studied NTFP-dependence in different wealth classes and found that NTFP dependence is highest in very poor households whose income share of AP was smaller than that of NTFP. In wealthier households the share of NTFP-related income was significantly smaller than the AP-related income. In addition, wealthier households tended to be more engaged in commercialization than poorer households. Similar findings were published also by Takasaki et al. (2001). Pulido and Cavelier (2001) calculated that income share of forest fruits was only marginal both in Colombia and Peru compared with income generated by AP.

As Coomes and Barham (1997) point out, the choice between NTFP extraction and AP cultivation is dependent on larger economical and political trends. In the late 1980´s many floodplain households in Peruvian Amazonia shifted labour towards agriculture from extraction, due to improved access to agricultural credits and secured land tenure provided by the APRA government. Later, changes in the political climate and problems in public economy resulted in “drying up” of agricultural credits, and extraction became more attractive again (Coomes & Barham 1997; Mäki et al. 2001).

These results highlight both the diversity of livelihood strategies and the importance of environmental and socio-economical factors in NTFP/AP utilization. Some sites provide better circumstances for NTFP extraction whereas conditions on other sites are more favourable for cultivation (Kvist et al. 2001; Takasaki et al. 2001; Pyhälä et al. 2006). Families with little access to agricultural land (land-poor households) need to compensate their lack of agricultural opportunities with extractive activities (Takasaki et al. 2001; Pyhälä et al. 2006). In all, the degree and manner to which natural resources are incorporated in livelihoods of floodplain dwellers, varies considerably (Coomes et al. 2004).

2.3.3 NTFP/AP trade as a production system

Forest product trade in Amazonia has long traditions, though larger-scale commerce started only after arrival of the Europians (Kvist & Nebel 2001). The great rubber boom in the late 19^{th} and early 20^{th} century was the most dramatic example of commercial NTFP use, having really troublesome social consequences (Padoch 1988b).

As indicated by Padoch (1988a) and Coomes & Barham (1997), the commerce of regional products is a rather complicated process with many stakeholders. The process can be described with the help of a production system chart presented by Dicken & Lloyd (1990) (Fig. 4).

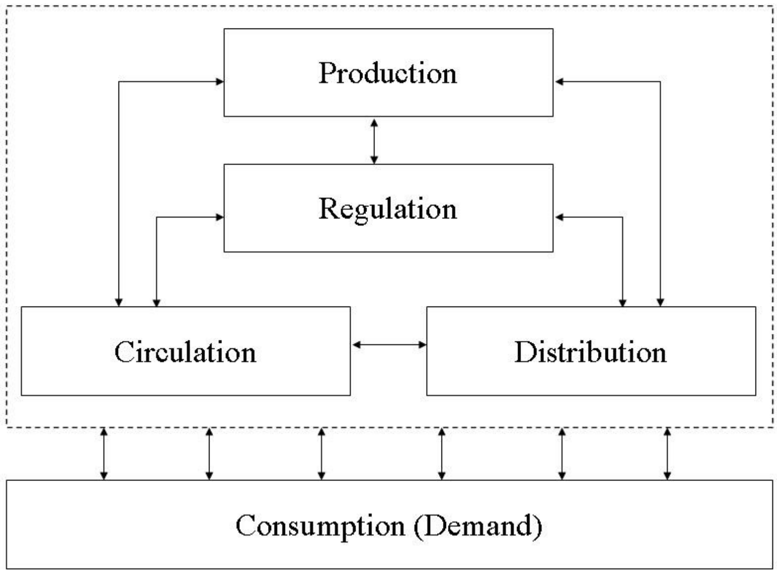


Figure 4. Major components of a production system according to Dicken & Lloyd (1990), fig. 1.3.

The production system consists of five major components or processes described below:

1. *Production process*: within NTFP/AP context this means extraction or cultivation of products, which are often sold as such without transforming them into semifinished or finished products. Some NTFP/AP, however, may be further processed, like handicrafts made of *chambira* palm (Vormisto 2002; Coomes 2004) or pulp, popsicles and drinks made of *aguaje* palm fruit (Padoch 1988a; IIAP 2006). The production phase is carried out by the rain forest dwellers in their immediate environment, in forest, agricultural fields or rivers. Further processing of products may be conducted either in villages or in the city, as indicated by Padoch (1988a) and Vormisto (2002).

2. *Circulation process*: intermediary activities that connect various parts of the system. These activities include transportation and the work of middlemen (dealers, contractors, harvesters, wholesalers, retailers, shippers, carriers, processors, etc.) (Padoch 1988a; Coomes & Barham 1997).

3. *Distribution process*: activities that make products available for final consumers. This process takes place in market places of bigger cities. Most of the market place vendors are resellers that bought their goods from intermediaries, but some producers who are capable of conducting all phases of the process themselves, do sell their products directly to the final consumer (Padoch 1988a).

4. *Regulation process*: mechanisms that control the process, for example laws and regulations. In NTFP/AP trade, land use/tenure rights and extraction licences are such factors (Padoch 1988a; Ruiz Perez & Byron 1999; Pyhälä et al. 2006).

5. *Consumption or demand*. In the Peruvian Amazonia, food security of bigger cities is highly dependent on the products that come from the surrounding villages. An interesting detail is that in Iquitos the daily demand of one single product, *aguaje* (a typical NTFP of the Amazonia) is 20 tons (IIAP 2006).

3 STUDY AREA

3.1 Location, physical and environmental conditions of Loreto

The study area of this thesis (Table 1; Fig. 5) comprises the region of Loreto in North Eastern Peru. Loreto shares its Eastern border with Brazil and the North and North Western parts of the region are limited by Colombia and Ecuador. In East and South, Loreto meets the regions on Amazonas, San Martin and Ucayali.

Table 1. Some statistics of Peru, Loreto and Iquitos (Sources: INEI 2007; GOREL 2006c; Municipalidad provincial de Maynas 2009).

	Peru	***Loreto***	***Iquitos***
Status	Country	Region	Capital of region
Area (km^2)	1 285 000	369 000	369
Population	28 221 000	891 700	371 000
Capital	Lima	Iquitos	-
Administrative subdivisions	25 regions	8 provinces	4 districts
Population density (inhabitants per km^2)	22	2.4	1006
Distribution of rural / urban population (%)	24.1 / 75.9	34.6 / 65.4	-
Rate of poverty (%)	39.3	54.6	-

Loreto is part of Peruvian lowland rainforest, frequently referred to as *selva baja* (e.g. Kalliola et al. 1993). Differences in elevation are minimal: for instance the approximate gradient of Ucayali river is only five centimetres per kilometre (Abizaid 2005). This can be observed in figure 5 where elevation data of Peru is presented.

Figure 5. Study area. Peru in South America (a); Elevation pattern in Peru and location of Loreto region (b); River and road network and some important cities in Loreto (c).

In all, Loreto region is highly fluvial with rivers dominating the landscape. Channel widths vary from very narrow to almost three kilometres (Puhakka et al. 1992; Toivonen & Mäki 2003; Toivonen et al. 2007). Meandering channels are both in length and area the far most common type in Loreto (e.g. Ucayali), but anastomosing (e.g. Amazon proper) and braided channels (e.g. Pastaza) are also present (Puhakka et al. 1992; Kalliola & Puhakka 1993; Kvist & Nebel 2001; Toivonen & Mäki 2003; Toivonen et al. 2007) (For the names of the rivers, see fig. 13). It should be kept in mind that one river may belong to several channel categories along its course. For instance, Ucayali is mainly meandering but it presents other channel patterns (Puhakka et al. 1992; Kalliola & Puhakka 1993) and Marañon is mainly anastomosing but includes parts that can be classified as braided (Kalliola & Puhakka 1993; Kvist & Nebel 2001).

According to Salo et al. (1986), white-water rivers are the most typical ones in Peru, and this holds true for Loreto as well. Clear-water rivers are rare in Peruvian Amazonia but black waters are rather common in smaller channels. The mixed-water type is also important (Kalliola & Puhakka 1993; Puhakka et al. 1992; Kvist & Nebel 2001). Figure 6 presents a confluence of white-water Marañon river with a black-water tributary.

Figure 6. Confluence of two rivers with different colour waters. Black water from a smaller tributary gets gradually mixed with white water of Marañon river (Vuori 2009).

The climate in Loreto is tropical and humid: The average annual temperature in Iquitos is 26.1 celcius and average annual rainfall 2879 mm (Worldclimate 2009). As well as in other parts of South America, the precipitation pattern shows great temporal fluctuation in

Loreto (Fig. 7), which is further reflected in water levels of the rivers. Differences in dry and flood seasons vary between years: Year 2000 the water level was highest in May (117.4 m.a.s.l.) and lowest in November (109.6 m.a.s.l.), the difference between these values being 7.8 metres. In 2008 the high water peak occurred a bit earlier, in April (116.6 m.a.s.l.) and the lowest level was measured in September (109.3 m.a.s.l.), the difference being 7.3 metres (Fig 8).

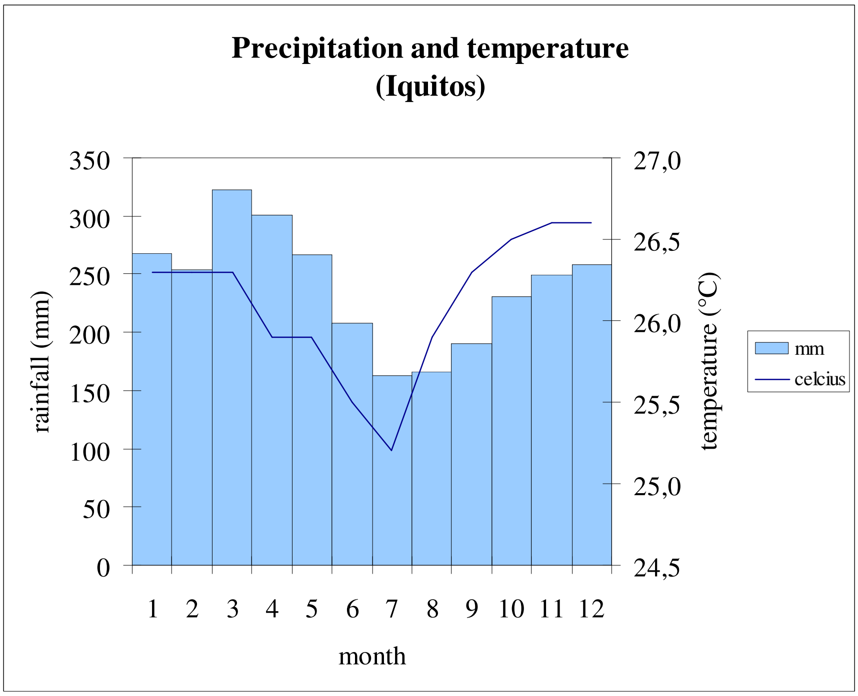


Figure 7. Monthly rainfall and temperature in Iquitos (Worldclimate 2009).

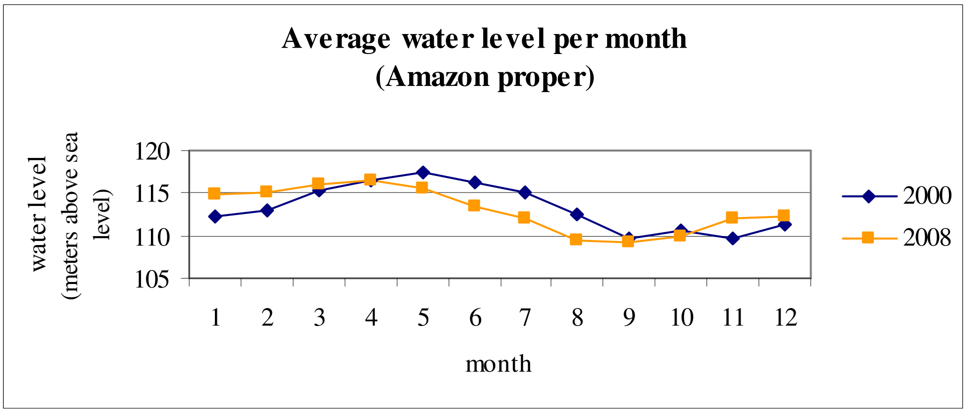
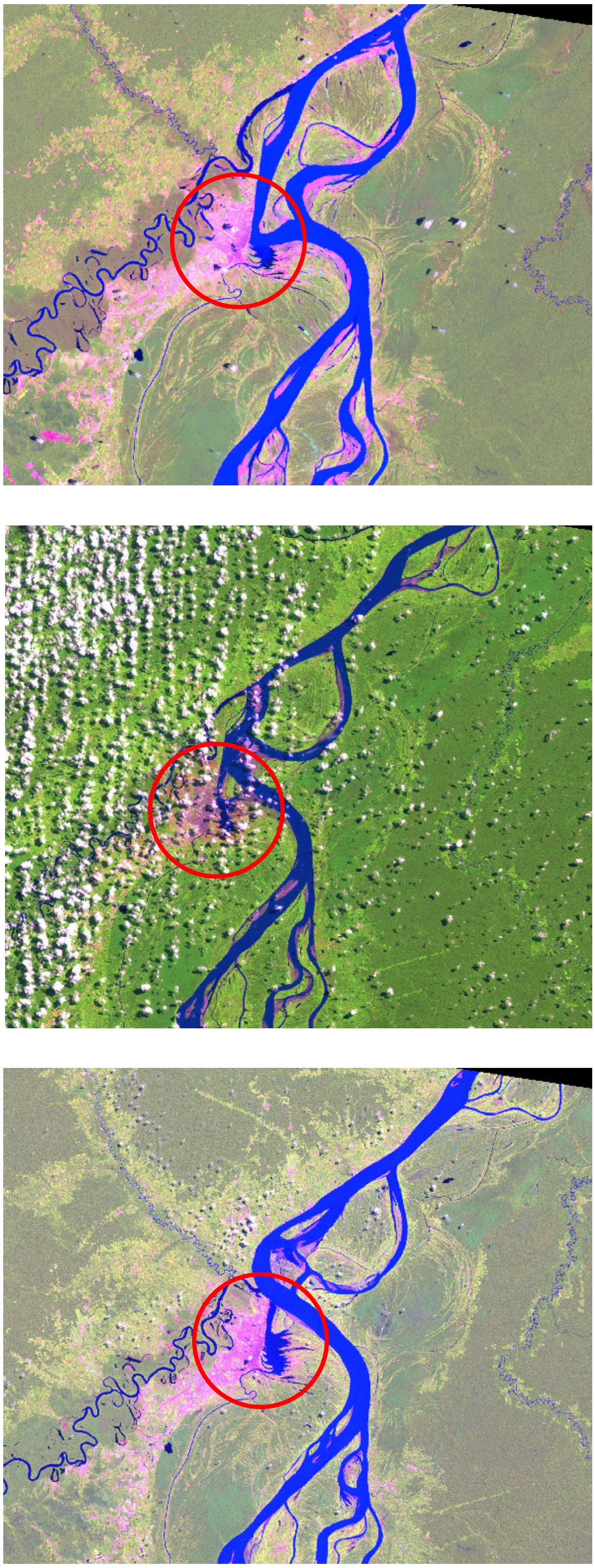


Figure 8. Fluctuation in water levels along Amazon proper during years 2000 and 2008 (Agroloreto 2009).

Examples of channel migration rates in Loreto can be found in Kalliola et al. (1992). Along Ucayali, annual lateral migration may reach up to 160 metres, and the rate is even higher along Amazon proper. A good example of changes in river courses is found near

Iquitos: To begin with, the place where Iquitos is now situated used to be along Itaya. It was not until 1755-57 that the Amazon had eroded its course close to the place that is now the leading centre of Peruvian Amazonia (Villarejo 1979: 302). Evidence of these prior circumstances and subsequent changes can be found in historic documents and diaries that date back to 18th century and were written by explorers and missionaries (see Villajero 1979; García Sanchez & Bernex de Falen 1994). More recent changes can be studied with help of remote sensing data. Indeed, subsets of Landsat images from 1987 to 2005 reveal a significant change in the form that Amazon takes near Iquitos (Fig. 9).



a) b) c)

Figure 9. Subsets of Landsat images representing changes in the course of Amazon proper from a) November 1987, b) July 1996, and c) June 2005. Each image has a width of 55 kilometres, and a red circle is drawn around Iquitos.

3.2 Iquitos and riparian villages

The capital of Loreto region is Iquitos with its approximately 370 000 inhabitants (Table 1). Apart from its position as the administrative centre of Loreto, Iquitos plays an important role as a commercial centre of a large area. Commercial competition to Iquitos is provided only by border cities on Colombian and Brazilian side, by Pucallpa in Ucayali region and by Yurimaguas in the South Western side of Loreto. All these other centres are located several days travel away from Iquitos (Padoch 1988a).

Iquitos is situated at the confluence of three rivers: Amazon proper, Nanay and Itaya, and these rivers play a rignificant role in the life and economy of the city (Rodriguez Achung 1994). Iquitos was founded in 1757 (Villarejo 1979: 243) and it gradually became the administrative and commercial centre of the region (Rodriguez Achung 1994). The history of Iquitos is closely linked to the exploitation of natural resources: the rubber boom was a significant factor in the economic history of the city (Padoch 1988a; Padoch & De Jong 1990; Rodriguez Achung 1994; Barham & Coomes 1994; Kvist & Nebel 2001; Mäki 2003), and it grew quickly during the 1970´s due to activities related to petroleum (Rodriguez Achung 1994; Gomez Romero & Tamariz Ortiz 1998). Apart from these well-known export products, many minor forest resources have played and continue to play a significant role for the economy of Iquitos and the whole region (Padoch 1998a; Padoch & De Jong 1990).

Iquitos has several market places and ports which characterize life in the city. The biggest and most famous market place in the whole Peruvian Amazonia is *Belen* with its approximately 4000 vendors (Bionegocios 2009). *Mercado de Productores* was originally constructed for producers who would sell their own products in a covered hall providing more income than when relying on resellers (Bionegocios 2009). Other significant market places are *Mercado Modelo* where retailers sell products that they buy in nearby harbours and *Bellavista de Nanay*, which is popular among local and international tourists. Not surprisingly, many of the market places are situated close to harbours.

Apart from Iquitos, Peruvian Amazonia in general, and Loreto in particular, is sparsely populated (see table 1) with settlements concentrated on river shores due to both their easy access and relatively fertile conditions (Kvist & Nebel 2001; Toivonen & Mäki 2003; INEI 2007). The present population of the rainforest consists of *ribereño*s (“riverbank people”, who descend mainly from Amerindian people and are ethnically mixed), indigenous people and newer immigrants (Padoch 1988b; Hiraoka 1995; Kvist & Nebel 2001; Pinedo-Vasquez & Padoch 2001; Abizaid 2005). The population of Loreto is highly dependent on the biodiversity of the region. Flood plain dwellers preserve intimate knowledge about their living environment, its habitats and uses (Padoch 1988a). As Abizaid (2005) points out, they are very familiar with the dynamic nature of the river network and have adapted their life style according to that. Indeed, understanding and predicting the processes of river dynamics is a matter of survival for these people.

The dependence between riparian villages and Iquitos is mutual: riverbank dwellers need the markets of Iquitos in order to maintain a living, and the food security of Iquitos relies almost entirely on rain forest products.

3.3 Transportation networks

In general, the Amazon region of Peru is geographically remote and poorly accessible from the capital region of the country. It has traditionally been seen as peripheral from political and economical perspective as well: Public policy and decision making concerning the region is largely conducted by outsiders who do not sufficiently understand the reality of the area (Mäki 2003).

The Loreto region is characterised by the fact that there is only one major paved road: the 105 km long *carretera* leading from Iquitos to Nauta (GOREL 2006b) (Fig. 5). In addition, there are some smaller roads that connect villages and are used for short-distance transport, such as the approximately 5 km long paved path connecting villages of Mazan and Indiana. In practice, however, almost all movement, be it of people or goods, happens along the river network (Kvist & Nebel 2001; Abizaid 2005). In this sense, Loreto and Peruvian Amazonia differ from Brazilian Amazonia, where the road network has been rather ambitiously developed (Mäki 2003; Soler et al. 2009).

In contrast to the practically non-existent road network, the river network in Peruvian Amazonia and Loreto is extensive and compared to other Amazonian countries, well connected (Toivonen & Mäki 2003; Toivonen et al. 2007). Since rivers provide much of the transport infrastructure, they are used a lot and there are a large variety of different transportation vessels operating on them (Fig. 10). These can be divided into two major categories: *motonaves fluviales* and *botes fluviales* (Capitanía de Puertos 2009). The first category refers to big boats that have an average capacity of more than 100 tons of cargo and around 100 passengers. *Motonaves* are also known by the name *lancha*, and they are used along bigger channels (like Amazon, Ucayali, Marañon, Huallaga). The latter category refers to smaller vessels that can carry less than 100 tons of cargo and less than 50 passengers. These are used in shorter distance travel around Iquitos and along smaller channels that have less traffic and can not be navigated by larger ships. In addition, smaller canoes are used for transport of both people and goods, floating rafts mainly for timber transport, and fast motor boats, *delizadores*, for more rapid and expensive transport of people.

In general, travelling along rivers via boat is time consuming and thus unsuitable for urgent needs or busy people. Air traffic remains the only alternative for fast transport. However, the airport network is sparse: in Loreto there are only two airports with regular traffic and six small local landing strips with irregular traffic and poor maintenance (CORPAC 2003; Ministerio de Salud 2009). From the point of view of regional NTFP/AP transport air traffic is of minor importance since in practice all transport occurs within the limits of rivers (Padoch 1988a; Abidzaid 2005).

Figure 10. Different means of transport. In upper left corner, *motonaves* or *lanchas* that travel along bigger channels. In upper right corner, an example of a *bote fluvial*, motorized by a so called *peque peque* motor. In lower left corner, a floating raft, *balsa*, and in lower right corner, two fast *delizadores*, only for passengers (Vuori 2009).

4 MATERIALS AND METHODS

The workflow of this study can be divided into five separate, yet interconnected components (Fig. 11). Each component consists either of accessibility (time-distance) – related tasks, NTFP/AP-related tasks, or both. First, I conducted fieldwork in the Loreto region, collecting material in the form of interviews, GPS measurements and general observations. Then, I analyzed the interview material with simple statistical methods. The third task was to create the accessibility model (time-distance surface), based on existing secondary data combined with my own data. Next, I estimated product catchment areas for different product classes, and finally validated the modelled results with field observations. Each of these steps and the materials and methods used are explained in detail in following chapters.

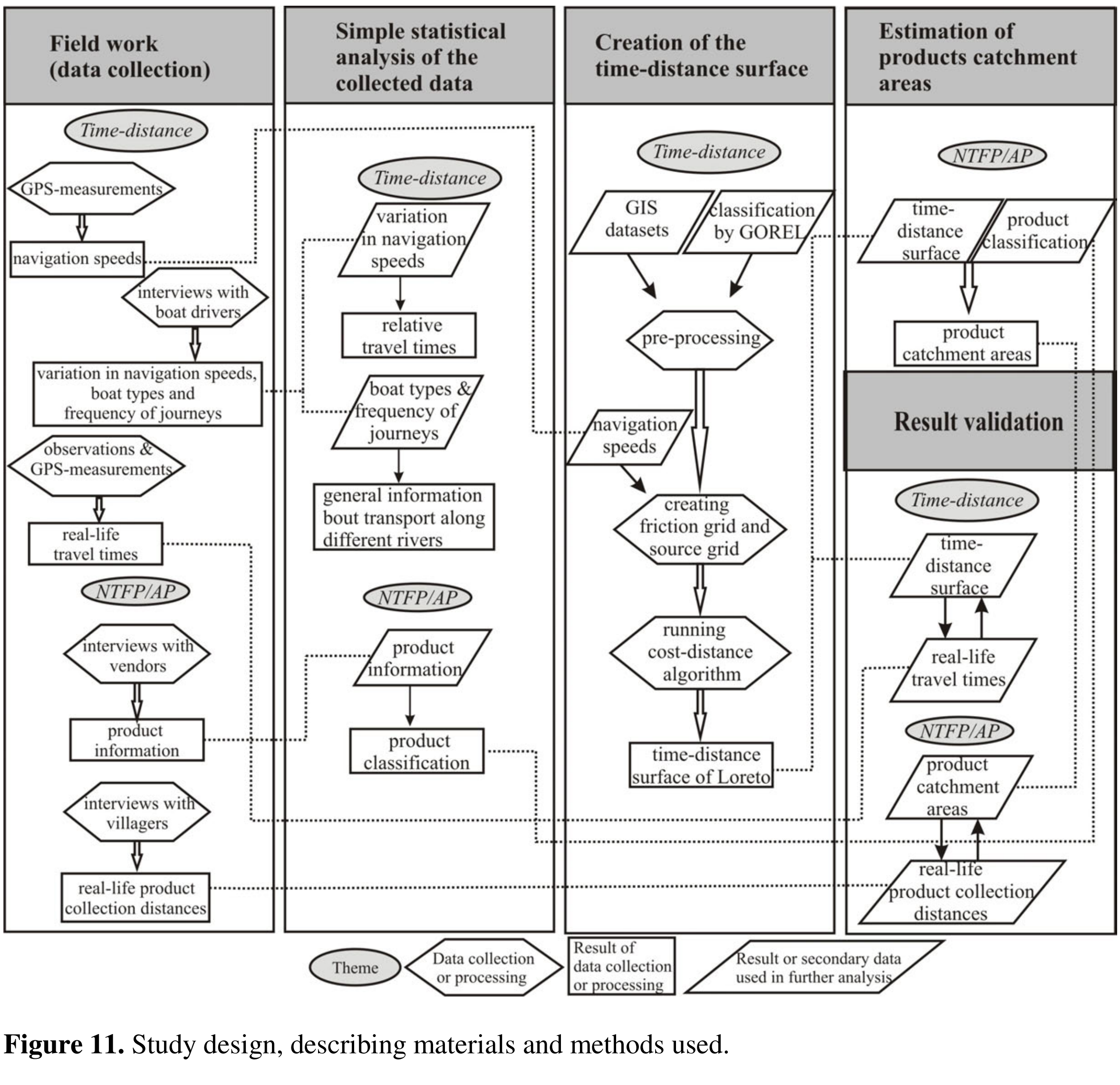


Figure 11. Study design, describing materials and methods used.

4.1 Materials

In my study I used both primary and secondary material (table 2). Primary material was collected during a field work period which is described in more detail within methods-section. These data included interview material, GPS-measurements and field observations. Interview material included both qualitative and quantitative data, and GPS-measurements included information about speed and travel times during boat trips along six different rivers. Secondary sources of material included literature, statistics, maps and digital datasets. The literature consisted of scientific publications and books, reports by different organizations and digital publications. Statistics and maps were collected from available Internet services provided by national statistical institution of Peru (INEI), regional government of Loreto (GOREL) and other organizations. Digital datasets included Landsat TM and ETM+ satellite images and GIS-datasets obtained from Peruvian Amazon Research Institute (IIAP).

As a basis for accessibility analysis I used a river classification developed by GOREL (2006a) (table 3). In this classification, the rivers of Loreto are divided into four categories, based on their navigability. It is worth noting that not all the rivers of Loreto are taken into account in this classification: smaller tributaries are ignored. Different river categories are presented also in figure 12.

Table 2. List of materials used in this study.

Theme	*Data*	*Source (primary/secondary)*	*Additional information*
Accessibility	Navigation speeds	GPS-measurements (P)	
	Variation in navigation speeds	Interviews with boat drivers (P)	n = 66
	Real-life travel times	GPS-measurements (P)	
	River classification	GOREL (S)	See table 3 and fig. 13
	GIS-datasets of Loreto region	IIAP (S) GOREL (S) Ministerio de transportes y comunicaciones (S)	Administrative borders (polygon); smaller rivers (polyline); larger rivers (polygon); populated places (point); roads (polyline).
NTFP / FAP	Product information	Interviews with market place vendors (P)	n = 112
	Real-life collection distances	Interviews with riparian dwellers (P)	n = 35
Background	Literature	Scientific publications, books, reports (S)	
	Statistics & maps	Internet services (S)	
	Satellite images	Landsat (S)	Landsat TM and ETM+ scenes covering part of Loreto (Path 006, Row 063) from 11/1987, 7/1996 and 6/2005.

Table 3. Navigability of rivers in Loreto region (GOREL 2006a).

Class	*Rivers*	*Explanation*
1	Amazonas, Ucayali, Marañon, Huallaga	Navigation on these rivers does not have any restrictions, it can be done with big vessels (MF*) and year-round. Small and medium size boats (BF**) do not have problems navigating these rivers.
2	Napo, Putumayo, Morona, Pastaza	During the flood season big vessels (MF) have no difficulties navigating these rivers. However, during the dry season, navigation with big vessels may be problematic especially in upper parts of Pastaza river. This river has sand banks that make navigation difficult during the dry season. Small and medium size boats (BF) do not have problems navigating these rivers.
3	Nanay, Tapiche, Apaga, Potro, Cahuapanas, Aypena, Huasaga, Manchari, Huitoyacu, Chuinda, Rimachi, Chapuli, Parinari, Corrientes, Tigre, Yavari	These river are navigable by small and medium size boats (BF) during the flooding season. However, navigating gets difficult during the dry season, when only small vehicles can operate (boats, *deslizadores* or *peque peques*).
4	Itaya, Curaray, Yanayacu, Shishinahua, Ungumayo, Sasipahua, Nucuray, Blanco, Galvez, Pucacuro, Copalayacu, Urituyacu, Capirona, Tigrillo, Samiria, Pintuyacu, Campuya, Atacuari, Pacaya, Maquía, Cushabatay, Pisqui	These rivers are navigable during the flood season, and small vehicles such as boats, *peque peques* and canoes, are used.

(*) MF = *motonave fluvial*, see chapter 3.3 for further information
(**) BF = *bote fluvial*, see chapter 3.3 for further information

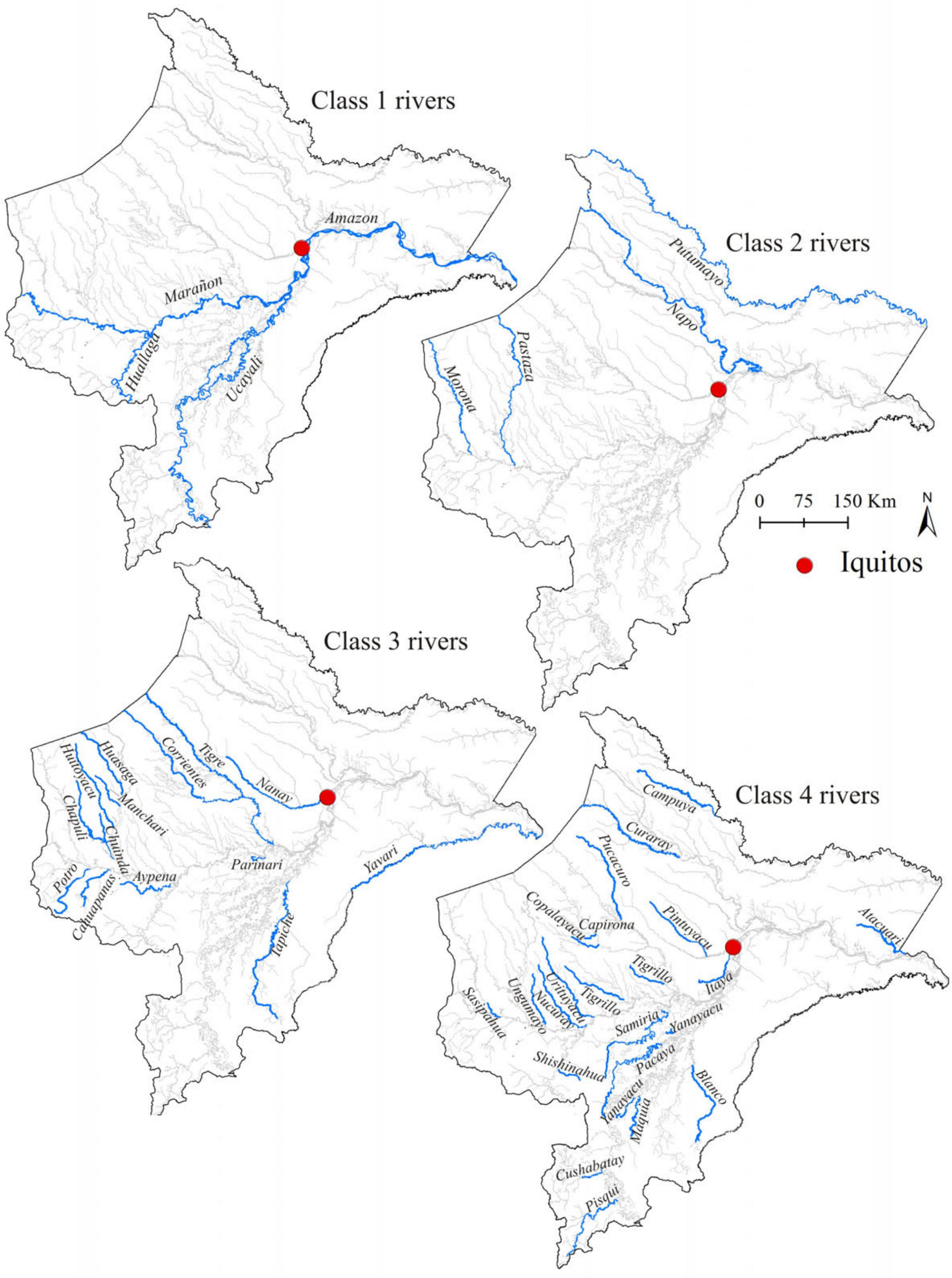


Figure 12. Main rivers of Loreto region, divided into four categories according to a classification made by the regional government of Loreto. Based of GOREL (2006a).

4.2 Methods

4.2.1 Field work methods

Field work in Iquitos and in other parts of Loreto region took place during January and February 2009. Data collection involved structured interviews with stakeholders, GPS-measurements and field observations. To avoid language barriers and culture-related misunderstandings I had a local research assistant with me and we conducted the interviews together.

In order to collect data for the time-distance surface, I visited ten different harbours in Iquitos and interviewed people in charge of boats operating regularly along different rivers. Approximately half of the harbours were large ones with significant amount of traffic, and half of them were smaller ones. The questionnaire (Appendix A) included questions about routes of the boats and duration of transport upstream versus downstream and during different seasons. In addition, some general information about the boat and products transported was acquired. During these visits to harbours, a total of 66 people were interviewed. Data on navigation speeds along different rivers using different vessels I collected with a GPS device (Garmin eTrex Venture Cx, coordinate system set to WGS84). I travelled along five different rivers, including Amazon proper, Ucayali, Marañon, Napo, Nanay and Itaya (Table 4; Fig. 13). These rivers were chosen partly because they were frequently mentioned in the market place interviews as a source of market products and party because of the classification made by GOREL (see table 3). The chosen rivers represent all the categories mentioned in the classification.

Table 4. Rivers visited during field work period.

River	*Times mentioned in the interviews*	*Classification according to GOREL*	*Type of transportation vessel I used (*)*
Amazon	28	1st order	MF / BF
Ucayali	9	1st order	MF
Marañon	3	1st order	MF
Napo	6	2nd order	MF
Nanay	3	3rd order	BM
Itaya	4	4th order	BF

(*) MF = *motonave fluvial*, see chapter 3.3
BF = *bote fluvial*, see chapter 3.3
BM = *bote motor*, a small boat with rather powerful motor only for passengers.

To gain information about regional NTFP/AP and their trade, I interviewed local market place vendors in five different market places in Iquitos. I chose my interviewees according to the products they were selling, the regional fruits and vegetables (NTFP/AP) being my focus. I asked about the products, for how long they could be preserved, where they originated from and how they were transported. The questionnaire included only few questions, thus being easy and fast to conduct (Appendix B). All together, 112 interviews with market place vendors were done. Then, I travelled to some of the villages where the products in Iquitos originated from. The objective was to visit several villages close to Iquitos (Mazan, Indiana, Mishana, San Carlos) and others that were at the edge of Iquitos catchment area (Maypuco, Victoria), meaning that part of the products produced in the village would be transported to Iquitos and other part to other centres. In the villages, I interviewed first the head of the village, asking for general information about the community and for permit to conduct interviews with villagers. Then, I conducted structured interviews with available farmers (heads of households) who were willing to participate in my study. The questionnaire included questions about products which the family was cultivating or collecting and about marketing and transport of the products (Appendix C). In some villages, due to lack of time, I only talked to the head of the village. In all, I visited six riparian villages and interviewed 35 people during these visits.

I visited also the *carretera* Iquitos-Nauta, and some smaller centres (Nauta and Requena). Figure 13 presents visited places and routes on a map.

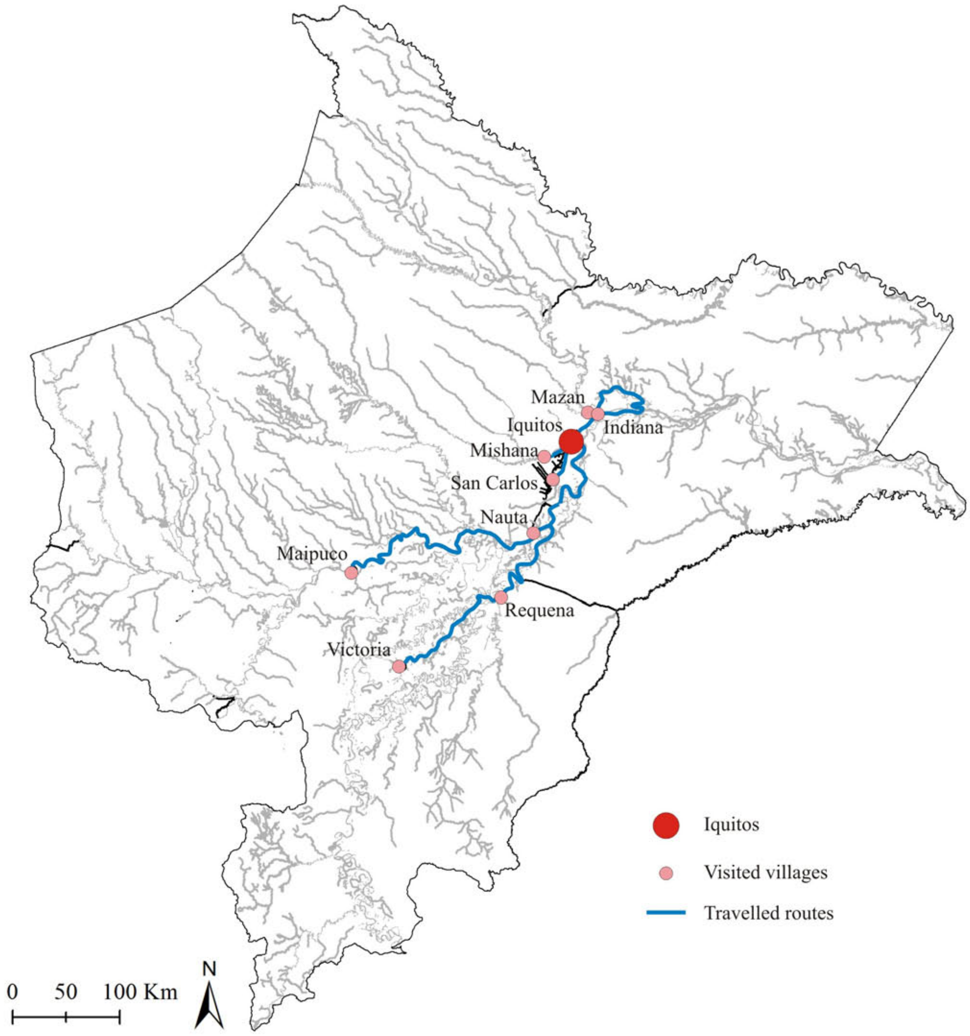


Figure 13. Routes travelled and villages visited during the field work period.

4.2.2 Simple statistical analysis of the collected data

Data that I collected in form of interviews was fed into a Microsoft Excel spreadsheet and analyzed with simple statistical methods using both Excel and SAS JMP. Based on interviews with boat drivers, I calculated relative travel times upstream and downstream, during both the flood and dry seasons. The interviewees told me how long their journey took towards Iquitos, how much time they spent going back the same route, and the respective travel times during dry season. I calculated the following ratios:

- downstream (flood) / upstream (flood)
- downstream (dry) / upstream (dry)
- upstream (dry) / upstream (flood)
- downstream (dry) / downstream (flood)

In addition, I compared different rivers mentioned in the interviews in terms of vessel types and frequency of traffic along each river.

In case of interviews with market place vendors, I counted the frequency of each product in order to find out, which products were the most common. Then, I calculated the average amount of time each product could be preserved, and based on these values, classified the products into different categories according to their shelf-life. The idea behind the classification was that the easily perishable products would need to be on sale at least one or two days before they go bad. For example a product that can be preserved for 2 days, would need to be collected within 12 hours time-distance from Iquitos in order to get to market place on time. The classification is based on logic presented in table 5:

Table 5. Product classification.

Shelf-life (days)	***Maximun time-distance from Iquitos (days)***	***Class***
1-2	0.5	1
2-3	1	2
3-4	2	3
4-5	3	4
5<	4	5

4.2.3 Accessibility analysis

I used the cost-distance functions in ArcGIS 9.3 (ESRI 2009) as a method for the accessibility analysis. The general idea of raster-based accessibility analysis is explained in chapter 2.1.3.2 (GIS-based accessibility measures), and below I clarify the spesific application in this study.

Before starting the accessibility analysis, the GIS-datasets (table 2) required some pre-processing. Pre-processing was done mainly in MapINFO, whereas ArcGIS 9.3 provided the accessibility analysis functions. To begin with, the coordinate system for all datasets was defined as Universal Transverse Mercator, datum WGS84, zone 18S (Southern hemisphere). River datasets did not have any classification as attribute information, so I edited the databases in order to add names and classes to different river segments. The classification was mainly based on GOREL´s classification (see table 3), but for my purposes, I added three extra classes: two classes to represent the main river, Amazon proper upstream and downstream, and one class to represent all the rivers that were not included in the classification. The final classification of rivers is presented in table 6.

All the datasets were initially in vector format, and as I chose raster to be the data type for my analysis, all datasets had to be converted from vector to raster. As cell size for my analysis I chose 30 meters, since that is the cell size of Landsat images that were the source data for the river datasets I used.

In order to create a friction grid, all datasets needed to be reclassified into a common scale representing the impedance of crossing through each cell. In this case, the impedance values were travel times (seconds) through one cell. Values were calculated using the following formula (2) introduced by Farrow & Nelson (2001):

$$Time \quad = \quad Cell\ size\ x \left(\frac{1}{\left(Speed(km/hr)\ x \left(\frac{1000}{3600} \right) \right)} \right) \qquad (2)$$

Final impedance values used in analysis are presented in table 6. All the other rivers except for a part of the Amazon, run downstream towards Iquitos. That is why only Amazon is divided into two classes (upstream and downstream), and all the other values represent down-stream speeds. Speeds along larger rivers (subclasses 1-4) were measured in a *motonave*, whereas Itaya river's measurement was done in a *bote fluvial*. These represent the typical vessel types in these rivers when a large scale transport pattern is concerned.

Most of the values are based on actual in situ–measurements, and missing values were estimated based on different criteria. In case of subclass 4 (class 2 rivers), the speed was measured only upstream, and thus the respective downstream value was estimated with general differences in upstream / downstream–travel times (see chapter 5.1.1). In subclass 5, measurements were done using a motorized small and fast boat, and thus these results could not be used here. Instead, the value was calculated as a mean of values in subclass 4 and 6, since it is assumed that speed reduces as the river gets narrower.

Roads were divided into two categories. The first one includes *carretera* Iquitos-Nauta which is the only fully paved and maintained road within the study area. The second category includes smaller dirt roads that are not maintained on a regular basis. Speeds assigned to roads are estimated based on my own experience when travelling along different roads, and additional references are found for example in Soler et al. (2009).

When reclassified, the geographic extents of all the layers were defined as the whole study area. No data –values in all layers were assigned a remarkably high impedance value of 10800, which means that the speed would be 10 metres per hour when crossing other land than roads or rivers. This was done because in practice no movement related to NTFP/AP transport happens in the deep forest.

Table 6. Impedance values for different variables and reasons for selecting a certain value.

Surface type	***Subclass***	***Explanation***	***Speed (km/h)***	***Ground (vessel used)***	***Impedance value (Time (s) / cell)***
River	1	Amazonas (upstream)	11.9	Two measurements (MF)	9
	2	Amazonas (downstream)	21.3	Two measurements (MF)	5
	3	Other class 1 rivers	16.15	A mean value of two measurements along Ucayali and Marañon (MF)	7
	4	Class 2 rivers	9.3	Estimated based on measurements of Napo river (MF) upstream. Napo speed / 0,73 (*)	12
	5	Class 3 rivers	9.1	A mean value of speeds in class 2 and class 3 rivers	12
	6	Class 4 rivers	8.9	Based on one measurement along Itaya (BF)	12
	7	Other rivers	7	An estimated value for small rivers	15
	NoData	Cells with no rivers	0.01	Land areas where in practice no moving related to NTFP/AP trade occurs	10800
Road	1	Carretera I-N	60	An estimate based on own experience and literature	2
	2	Other roads	15	An estimate based on own experience and literature	7
	NoData	Cells with no roads	0.01	Land areas where in practice no moving related to NTFP/AP trade occurs	10800

(*) See chapter 5.1.1

The final friction grid was created by combining all the previously reclassified layers. This was done in Raster Calculator using the minimum function (Formula 3) (ESRI 2009). Thus, each cell in the friction grid received the smallest value present in original layers.

$$Friction\_grid = min(reclassified\_roads, reclassified\_rivers\_lines, reclassified\_rivers\_polgons) \quad (3)$$

For the source grid, the city of Iquitos was selected from *populated places* database and converted to raster. The model was based on one centre, and thus no additional smaller centres were included as sources.

4.2.4 Creation of PCArs and result validation

Product catchment areas were estimated based on the product classification and time-distance surface created in the previous phases. For class 1, I delineated an area within 0.5 day´s distance from Iquitos, for class 2, an area within one day´s distance, and so forth. Altogether, five PCArs were created. In order to estimate differences in catchment areas between flood and dry season, I created another time-distance surface describing dry season time distances. These values were estimated based on boat driver interviews and flood season travel times. Product catchment areas for flood and dry seasons were then visualized together.

Finally, I validated the results of these previous phases against real-life observations. I compared the modelled time-distances with travel times that I measured and observed during the boat trips. Modelled PCArs were compared with information that I gained through village interviews.

5 RESULTS

5.1 Accessibility

5.1.1 Relative travel times and real navigation speeds

According to boat drivers, differences in travel times upstream and downstream and during different seasons are rather big (Fig. 14). If travel time upstream during flood season is set as 1, the same journey downstream during the same season gets a value of 0.73 which means that it takes 27 % less time (standard deviation in answers was 0.16). The same journey upstream during dry season takes 16 % more time (st. dev. 0.27), whereas the ratio between downstream and upstream travel during dry season is 0.74 (st. dev. 0.18).

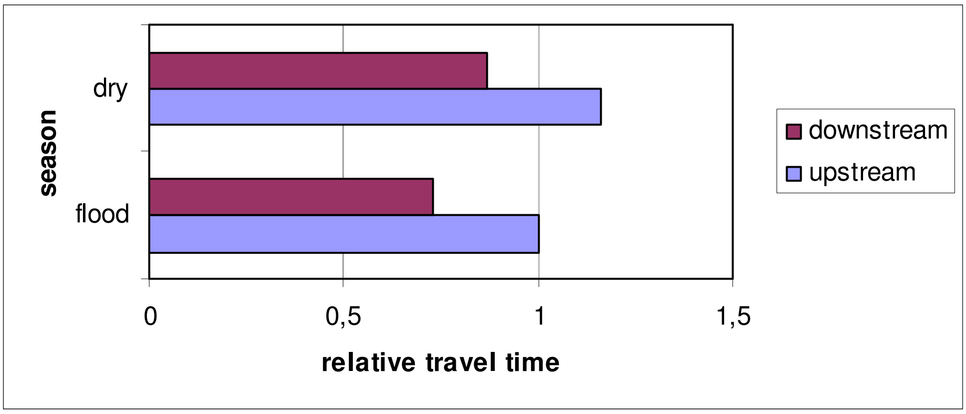


Figure 14. Relative travel time during dry and flood season.

The above analysis was based on interview material collected from boat drivers and it included several types of rivers. According to the interviewees, navigation during dry season demands more attention due to emerging *playas* and is thus more time consuming. Some of my interviewees mentioned that it might be more time consuming to travel during the floods if the water runs *too* quickly. According to them, navigation along fast running rivers requires more attention both downstream and upstream. Many of the interviewees said that differences between flood and dry season do not really affect travel times on large rivers, like Amazon proper, because the current is almost equally strong throughout the year. Yet, this sort of conclusions could not be made from the statistical analysis. There was no clear evidence of the statement that travel time on smaller rivers would be more dependent on seasons than travel time on large rivers. This can partly be due to the fact that smaller rivers were rather poorly represented in my interviews, which in turn may act as an estimate on the amount of traffic along different types of rivers: bigger rivers have more traffic and get thus easily more represented in the randomly chosen interviews.

It should be taken into account, however, that not only stream direction and season affect the travel time. Number of stops during travel plays a significant role when measuring total travel time. Stops tend to be more frequent and longer when travelling towards Iquitos, because market goods are loaded into boats, whereas on the way back from the city, passengers are just quickly dropped off the boat.

This interview-based velocity information gives a good general view of how navigation speeds vary. Travel times given by interviewees are, though, in some cases rough estimates. It may be hard to estimate travel time in hours when the whole journey takes several days. In these cases the accuracy of the answers may not be as precise as in case of shorter journeys.

In addition to interview-based information, I collected examples on real navigation speeds along different rivers (table 7). Values in table are *total average speeds*, meaning that all stops are included in calculations. *Average speeds in motion* are given as a reference, but total average values give a more realistic view on how long the journey actually takes. According to these measurements, differences between downstream and upstream travel during flood season are even greater than reported by boat drivers – my measurements show that the ratio is on average 0.68, whereas according to the interviews it was 0.73.

Table 7. Navigation speeds along different rivers, measured with a GPS device. Empty cells represent cases where no measurements were done.

River	*Category(*)*	*Average speed (km/h) upstream (vessel type used**)*	*Average speed (km/h) in motion*	*Average speed (km/h) downstream (vessel type used)*	*Average speed (km/h) in motion*
Napo	2	6.8 (M/F)	6.9	-	-
Amazon (downstream from Iquitos)	1	7.4 (B/F)	9.4	11.5 (M/F)	11.5
Itaya	4	-	-	8.9 (B/F)	11.4
Amazon upstream from Iquitos (***)	1	11.9 (M/F)	12.5	21.3 (M/F)	21.3
Marañon	1	10.6 (M/F)	11.5	16.2 (M/F)	17.6
Ucayali	1	11.3 (M/F)	12.8	16.1 (M/F)	16.6
Nanay	3	30.4 (BM)	30.4	34.8 (BM)	34.8

(*) GOREL (2006a)
(**) M/F = *motonave fluvial*; B/F = *bote fluvial*; BM = *bote motor*. a fast passenger-only boat with strong motor
(***) Mean value of two measurements

In general, navigating along bigger rivers is faster than navigating on narrower rivers. However, in my observations there are some exceptions to this rule which require a closer look. The first and the second row, Napo upstream and Amazon proper downstream, have remarkably low speeds compared to other values. This is partly due to a special situation: the *motonave fluvial* used during this journey was fully loaded with cargo and passengers and needed to navigate with extra caution and slower speed.

5.1.2 Transportation along different rivers

Information obtained from interviews with boat drivers relating to transportation along different rivers is summarized in table 8. Most of the 66 boat drivers interviewed had their route solely along the Amazon proper (42%). Ucayali was the second most frequently mentioned river in the interviews (14%), and Napo was the third one (9%). The remaining rivers were mentioned less than five times. Although different rivers are unequally represented in my material, some conclusions can be made based on these data. As discussed previously, the fact that Amazon proper is so strongly represented in my interviews reflects the amount of traffic along it. In addition, almost all boats coming from other rivers (except for Itaya and Nanay that run directly to Iquitos), make some part of their journey along Amazon proper, which further increases the traffic along it. Vessels operating close to Iquitos (along Amazon proper, Itaya, Tahuayo and Momon) make several journeys per week, whereas boats coming from more distant rivers (Corrientes, Tigre) make fewer journeys, because each journey takes a longer time. This finding suggests that transportation facilities are more abundant closer to Iquitos. Some rivers, however, despite their location close to Iquitos do not have very frequent traffic when measured as frequncy of traffic per vessel, so the relationship between river´s Euclidian distance to Iquitos and frequncy of traffic is not linear.

Figure 15 represents the frequencies of traffic per vessel along each of the rivers studied. The darker shades represent more frequent journeys and the lighter shades less frequent journeys. The boat symbols indicate the times each river was mentioned in the interviews. Rivers marked with a small boat were mentioned only one or few times and rivers with a bigger symbol were frequently mentioned. The size of the boat symbol and the shade of the frequency color do not present similar trends along all rivers: For example Napo has many boats operating along it but the frequency of journeys per vessel is low. Manati (South of Napo) belongs to the same frequency category with Napo but the amount of vessels operating on it is significantly smaller.

In general, larger boats traffic along larger rivers (Amazon proper, Ucayali, Napo, Marañon) and smaller boats are common in smaller channels. However, the Amazon proper has a wide range of different size boats operating along its course and it should be kept in mind that ranges in boat types along other rivers might be bigger, if more interviews had been done concerning those rivers.

Table 8. Transportation along different rivers.

River	*No of interviews*	*Frequency of journeys per vessel (times / week)*	*St.dev.*	*Type of boat (passangers / cargo (tons))*	*Range (passangers / cargo)*
Amazon	28	4	1.79	60 / 12	20-200 / 2-150
Ucayali	9	1.5	0.9	150 / 240	120-300 / 100-700
Napo	6	2	0.92	60 / 75	30-220 / 25-180
Itaya	4	5	1	35 / 3	30-50 / 0.5-8
Tigre	4	0.88	0.35	50 / 70	5-60 / 7-85
Marañon	3	1	0.58	150 / 110	90-200 / 100-180
Tahuayo	3	3	0	60 / 15	20-60 / 8-25
Nanay	3	2	2.89	40 / 25	22-50 / 2.5-40
Manati	2	2	0	50/15	50-50 / 15-15
Momon	2	4.5	2.12	45 / 4	30-60 / 3-5
Chambira	1	0.25	-	15 / 25	-
Corrientes	1	0.5	-	100 / 120	-

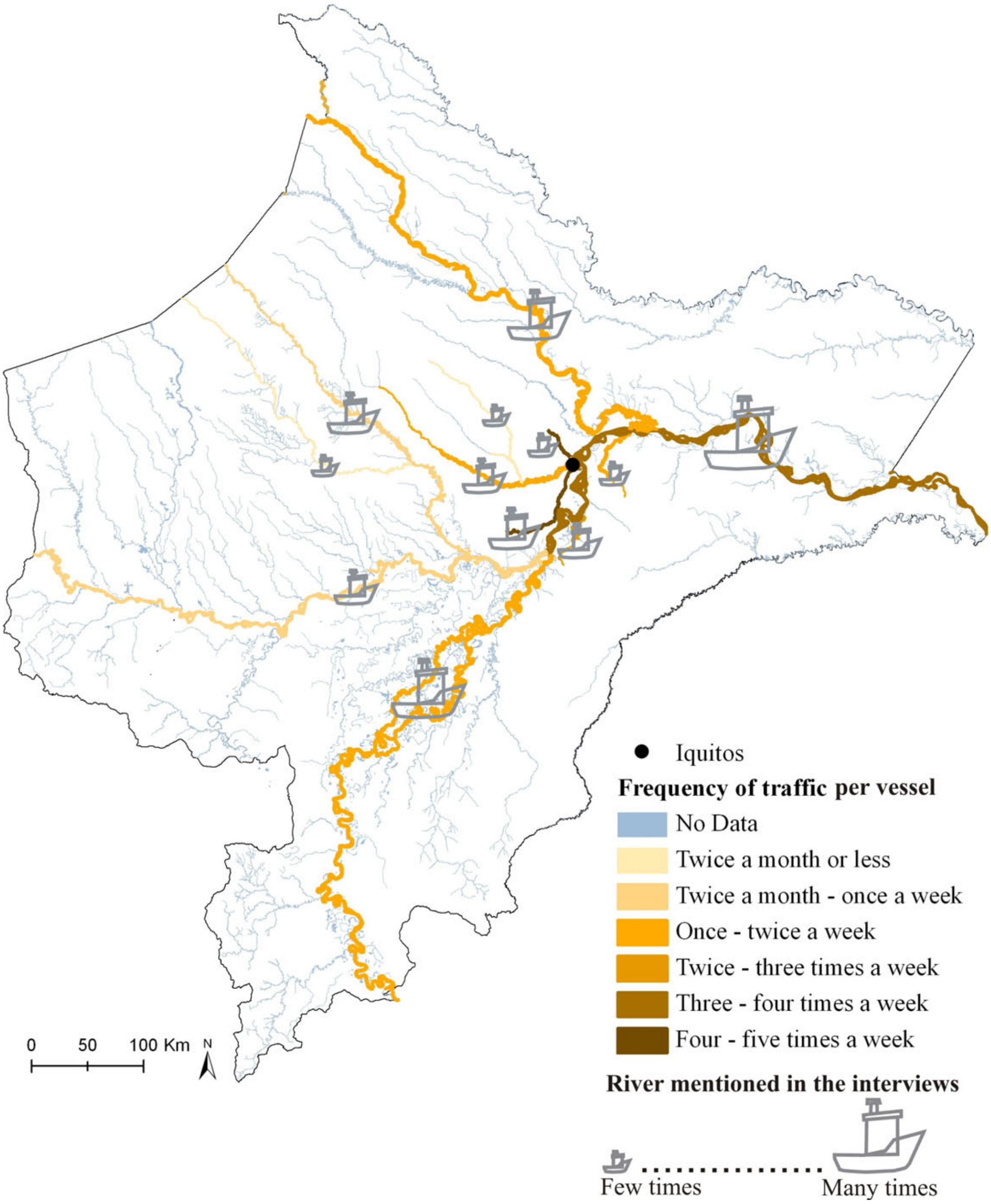


Figure 15. Frequency of traffic per vessel along the studied rivers and the relative amount of times each river was mentioned in the interviews.

5.1.3 Accessibility pattern around Iquitos

The result of the cost-distance analysis is presented in figure 16. Iquitos is marked as a red spot in the map, and areas with varying degree of accessibility with different colours. Darker shades of brown represent rather easily accessible areas, and lighter shades of brown poorer rates of accessibility. Areas of extremely poor accessibility are represented with different shades of blue, the darkest areas having poorest level of accessibility.

Accessibility patterns follow the form of transportation networks. Differences in upstream versus downstream travel are rather clear in the pattern: areas that are situated upstream from Iquitos – or in other words, from where travelling to Iquitos occurs downstream - have higher rates of accessibility towards Iquitos than areas from where travelling happens upstream. Darker shades of brown reach longer distances along bigger rivers where travel speeds are faster.

Edges of the study area, especially in North and West, appear to have extremely poor rates of accessibility. This may be partly true, but it is also dependent on "edge effects" of the analysis: the river network was artificially broken when delineation of study area was done. Thus, river segments in these areas are not connected to any other segments in the model, although in reality they do belong to the network.

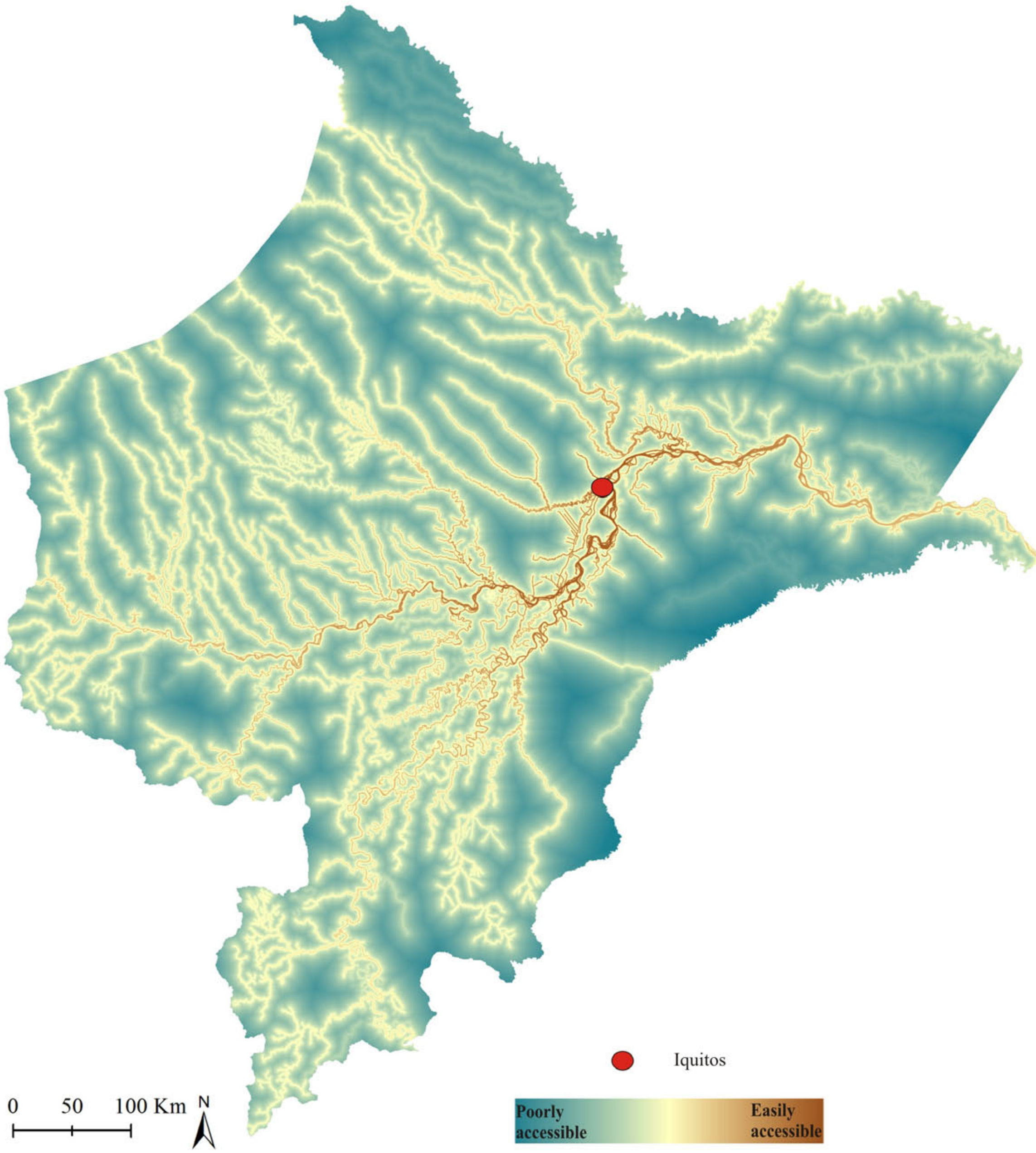


Figure 16. Accessibility pattern around the city of Iquitos

5.2 NTFP/AP

5.2.1 Market place products and classification

According to the interviews, the most common regional fruits and vegetables in Iquitos market places were plantain (green), grapefruit, manioc, papaya, ripe plantain, *cocona*, cucumber and cilantro. The majority of the products mentioned in the interviews, their classification, frequency in interviews, average preserving time (median), standard deviation in preservation time and product category (NTFP/AP) are presented in table 9. Scientific names and available English translations are also presented. Products that have no standard deviation in the table were mentioned only once. The most common products are highlighted with grey. The product category (NTFP/AP) is determined by previous literature (Padoch et al. 1985; Vasquez & Gentry 1989; Pulido & Cavelier 2001) and my observations.

Class 1 products that can be preserved only for two days were relatively few. The largest number of products belong to class 2 and can thus be preserved for approximately three days. Class 5 products that may be preserved for more than 5 days were also common.

Since the majority of market place vendors were resellers and had bought products from middlemen, they could not specify the exact origin of their products. Most of the vendors knew, however, along which river the products originated from. Due to the vague nature of this information, these results are not presented here.

Table 9. Market place products and classification.

Cl.	*Product*	*Scientific name*	*English name*	*Freq.*	*Av. Pres.time (median)*	*St. Dev.*	*NTFP/AP*
1	Culantro	*Eryngium foetidum*	Cilantro	14	2	0.6	AP
1	Tomate	*Lycopersicum esculentum*	Tomato	4	2	1.9	AP
1	Granadilla	*Passiflora nitida*		2	2	0.7	NTFP
1	Ubos	*Spondias mombin*	Grape	1	2	-	NTFP/AP
2	Yuca	*Manihot esculenta*	Manioc	26	3	2.2	AP
2	Papaya	*Carica papaya*	Papaya	18	3	1.3	NTFP/AP
2	Caihua	*Cyclanthera pedata*		9	3	3.0	AP
2	Pijuayo	*Bactris gasipaes*	Peach palm	7	3	4.5	AP
2	Lechuga	*Lactuca sativa*	Sallad	6	3	2.1	AP
2	Ubilla	*Pourouma cacropiifolia*		4	3	0.5	NTFP/AP
2	Caimito	*Chrysophyllum cainito*	Star apple	4	3	0.6	NTFP/AP
2	Cebolla chino	*Allium fistolosum*		3	3	1.0	AP
2	Anona	*Annoma exellens*		2	3	-	NTFP/AP
2	Guayaba	*Psidium guajaba*		1	3	-	AP
2	Taberiba	*Spondias dulcis ciatera*		1	3	-	AP
2	Cocona grande	*Solanum sessiliflorum*		1	3	-	AP
2	Capirona	*Calycophyllum spruceanum*		1	3	-	
3	Pepino	*Cucumis anguria*	Cucumber	14	4	2.7	AP
3	Aji dulce	*Eugenia uniflora*	Pimiento	9	4	4.5	AP
3	Aji picante	*Capsicumm annuum*	Hot pepper	5	4	1.1	AP
3	Carambola	*Averrhoa carambola*		2	4	0.7	AP
3	Mullaca	*Clidemia hirta*		1	4	-	
4	Cocona	*Solanum sessiliflorum*		16	5	2.2	AP
4	Aguaje	*Mauritia flexuosa*		4	5	6.4	NTFP
4	Camu camu	*Myrciaria dubia*		4	5	1.3	NTFP
4	Zapote	*Matisia cordata*		2	5	4.2	NTFP/AP
4	Lima	*Citrus limetta*	Sweet lime	1	5	-	AP
5	Plátano	*Musa paradisiaca*	Plantain (green)	44	7	4.3	AP
5	Toronja	*Citrus paradisi*	Grapefruit	38	7	5.6	AP
5	Manzana	*Musa sp.*	Plantain	17	7	2.2	AP
5	Naranja	*Citrus aurantium*	Orange	5	7	1.8	AP
5	Limón	*Citrus aurantifolia*	Lime	5	9	4.1	AP
5	Piña	*Ananas comosus*	Pineapple	2	7	4.9	AP
5	Chambira	*Astrocaryum chambira*		2	13	11.3	NTFP

5	Palta	*Persea americana*	Avocado	1	7	-	AP
5	Mango	*Mangifera indica*	Mango	1	7	-	AP
5	Coco	*Cocus nucifera*	Coco	1	15	-	AP
5	Sandía	*Citrillus vulgaris*	Water melon	1	20	-	AP
5	Zapallo	*Cucurbita moschata*	Squash	1	21	-	AP

5.2.2 Estimated PCArs around Iquitos

Estimated product catchment areas around Iquitos are presented in figure 17. Iquitos is marked with a green spot, and areas accessible within a certain time during dry season are represented with blue colour. Differences in travel times between dry and flood season suggest that product catchment areas reach further during flood season, because travelling is, in general, faster when the level of water is higher. Thus, the flood-extended catchment areas are marked with orange. The larger the catchment area is (or in other words, the longer the allowed time-distance to Iquitos is) the bigger are the differences between dry and flood season catchment areas. Examples of products belonging to each class are given under class numbers.

Class 1 products that were relatively few in my data have a small catchment area. Class 2 products were plentyful but even their catchment area is relatively restricted. The catchment area for product class 5 is the largest and following the river network, it extends to the edges of the study area.

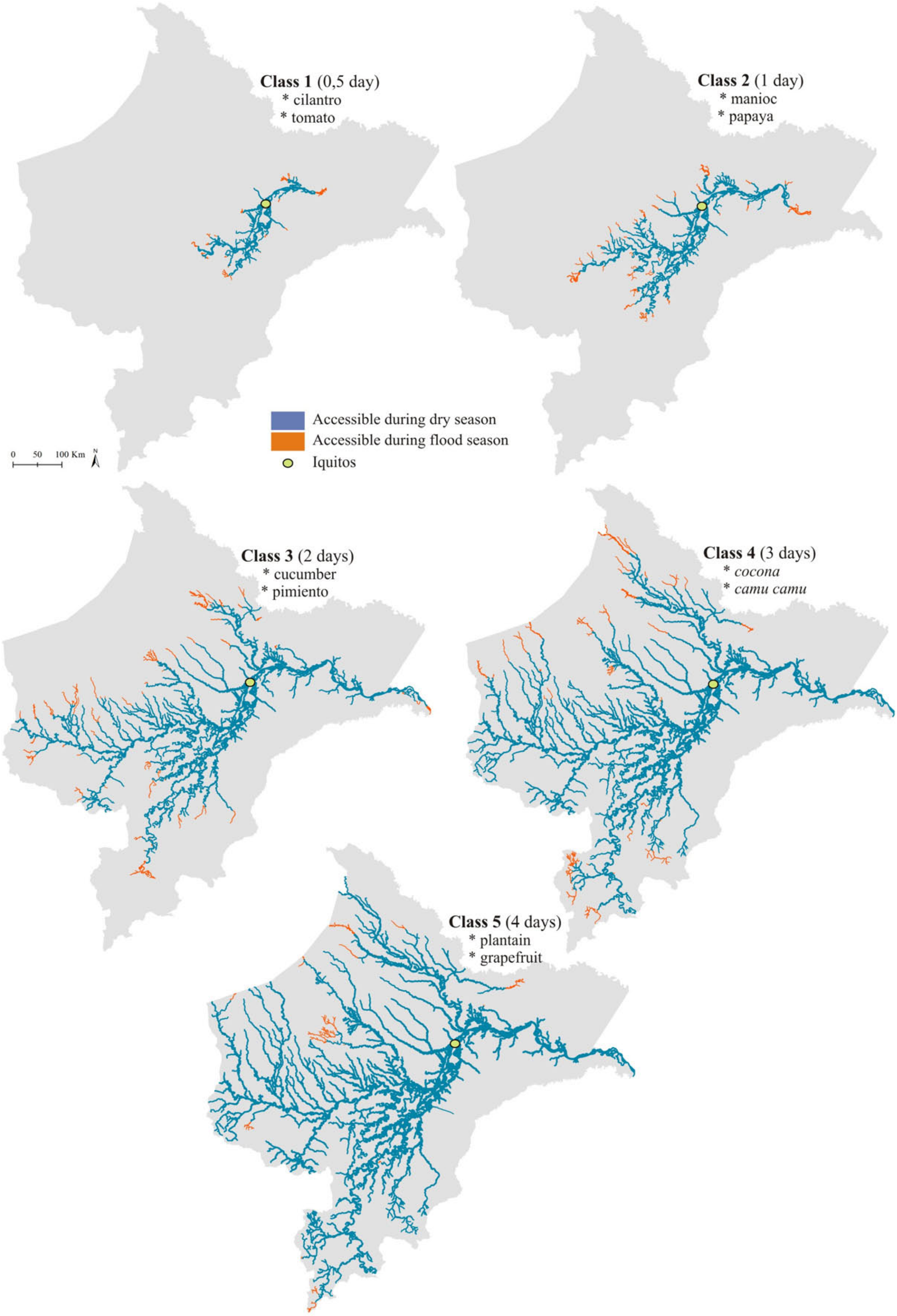


Figure 17. Product catchment areas of different NTFP/AP groups.

5.3 Result validation

5.3.1 A summary of visited villages: observed travel times and collection distances of different NTFP/AP

The community of Mazan is situated along Napo river and it has approximately 6000 inhabitants (all the villages presented this chapter can be found in figure 13). Most commonly extracted products in Mazan are manioc, plantain, *chonta* and *camu camu*, and the products are usually sold in Iquitos although there is a small market place even in Mazan. A *motonave* trip from Iquitos to Mazan (Amazon down-stream, Napo up-stream) takes approximately 16.5 hours. Although Mazan is along Napo, the distance to Amazon side is less than five kilometres. There is a paved path connecting Mazan to the *varadero de Mazan* which is a loading place along Amazon from where the trip to Iquitos only takes approximately five hours. Thus, travel time from Napo side to Iquitos is significantly shorter if the shortcut is used. Many villagers from Napo´s side transport their products with their own canoes or boats to Mazan, sell them there to river traders who then transport the products first to the *varadero* by a motorcycle taxi and then to Iquitos with a public boat.

Indiana, along Amazon proper, is quite similar to Mazan, and even the number of inhabitants is similar. The most commonly commercialized products include plantain, corn, manioc, *fariña* and *tapioca*, and even though Indiana has a small market place of its own, the majority of products are transported to Iquitos. Travel time from Indiana to Iquitos in a *bote fluvial* is roughly five hours. Villagers who live close to Indiana bring their products there with their own vessels, and from Indiana the products are transported to Iquitos by a public boat. Most of the villagers take the products to Iquitos themselves but river traders are ready to buy the products in Indiana harbour.

The Mishana community is situated along Nanay and it has less than 100 inhabitants. From there people bring the following products to Iquitos: plantain, manioc, *ubilla*, pineapple, *guaba*, *cocona*, peach palm, *aguaje* and *chonta*. Travel time to Iquitos is about three hours. The first part is travelled with a *bote fluvial* of the village and the second part with a public *combi* (a small van). Most of the villagers bring their products to Belen market themselves and resell them there.

Along Itaya I visited the community of San Carlos, where approximately 200 people live. Here a variety of different products were mentioned, but the most common ones were manioc, plantain, corn, pimiento, cucumber, *zapote*, *caihua*, peach palm and grapefruit. All of the products are commercialized in Iquitos. Since 2001 there has been a road connection from the village to Iquitos, but it can be used only during the dry season (from June to October), because during the rainy season the road gets extremely muddy and *combis* cannot reach the village. Along Itaya the trip to Iquitos takes roughly 3.5 hours (down-stream), whereas the road connection is much faster. For this reason, many of the villagers use *combis* when it is possible and public boats when the road cannot be used. Most of the interviewees (67%) told that they transport the products themselves but sell them to resellers in Belen harbour. One person told me that he stays in Belen market and sells his products himself. The rest of the respondents (25%) used both strategies.

The village of Maypuco along Marañon has an interesting history. The present village is the third one with the same name; two previous Maypucos were destroyed by the high erosion rates of Marañon and the village had to be relocated. Nowadays Maypuco has more than 2000 inhabitants and it is constantly growing. The most commonly commercialized products in the village are plantain, corn and manioc, but also *caihua*, pimiento, *sachapapa* and rice were mentioned. Travel time from Maypuco to Iquitos during flood season is 23 hours and all products are transported in a *motonave fluvial*. According to the head of the village, most of the villagers previously relied on floating raft -transportation but due to increasing violence and assaults against rafts, people started to use safer modes of transport, meaning public *motonaves*. Half of the interviewees sell their products to river traders in Maypuco, whereas four out of ten respondents reported using both river traders and travel themselves to Iquitos. If producers have a lot to sell, it is more profitable to travel to Iquitos, but if the quantity of products is small, it is best to rely on a river trader. One interviewee always transports his products to Iquitos himself. River traders take the products both to Iquitos and to Yurimaguas, depending on demand and prices.

Along Ucayali I visited the community of Victoria, which is situated inside the natural reserve of Pacaya-Saimiria and has approximately 2800 inhabitants. The most commonly commercialized products are fish, corn, plantain, *camu camu*, manioc, bean and rice. A variety of other products were mentioned as well. Travel time from the village to Iquitos is about 28 hours during the flood season. Travel time to another commercial centre in Ucayali region, the city of Pucallpa, is more or less equal, so the products of the village are taken to both cities. The destination of the products depends on demand and prices in different market places. Some of the villagers (33% of the interviewees) rely solely on river traders and sell their products to them in the village. None of the interviewees reported to travel to the city every time he/she was selling products, but most of the people used both strategies: if the producer had a lot to sell, he/she would travel to the city him/herself, but if there was a smaller amount to sell, the producer would rely on a river trader. All products were transported in a *motonave fluvial*, regardless of the destination – no private or small boats were used.

Table 10 below summarizes the observed collection distances (measured in travel time to Iquitos) for different products. Product classes present in each village as well as destinations of product transport and the most typical means of transport are provided.

Table 10. Visited villages, products, related product classes, product destinations, travel times to Iquitos and different means of transport at a glance.

Village	*Products*	*Product classes*	*Travel time to Iquitos (h)*	*Destinations of the products*	*Most typical means of transportation*
Mazan	manioc, plantain, *chonta*, *camu camu*	2, 4, 5	5	Iquitos	motorcycle taxi + BF
Indiana	fish, plantain, corn, manioc, *fariña*, *tapioca*	2, 5	5	Iquitos	BF
Maipuco	plantain, corn, manioc, pimiento, cucumber, *zapote*, *caihua*, peach palm, grapefruit	2, 3, 5	23	Iquitos, Yurimaguas	MF
San Carlos	manioc, plantain, corn, pimiento, cucumber, *zapote, caihua*, peach palm, grapefruit	3, 4, 5	3.5	Iquitos	BF *combi* (during dry season)
Victoria	fish, plantain, corn, manioc, *camu camu*, bean, rice	2, 4, 5	29	Iquitos, Pucallpa	MF
Mishana	plantain, manioc, *cocona*, *ubilla*, pineapple, *guaba*, *chonta*, peach palm, *aguaje*, *ungurahui*	2, 3, 4, 5	3	Iquitos	BF + *combi*

5.3.2 Model versus reality

Time distance surface and estimated product catchment areas were validated with information on real-life travel times and observed collection distances for different products. Table 11 demonstrates the differences between observed travel times and time-distance that is based on the model. The ratio between these two values varies between 1-1.4 which means that the model underestimates the time-distance with 23% on average. In case of San Carlos village the observed travel time and the modelled time were exactly the same. The biggest difference between values is found in the case of Requena, where the observed travel time is 1.4 times longer than the modelled time.

Table 11. Observed travel times versus time-distance according to the model.

Village	*Observed travel time*	*Time distance according to the model*	*Ratio*
Requena	14 h 35 min	10 h 10 min	1.4
Maypuco	23 h	17 h 40 min	1.3
Victoria	29 h	24 h 10 min	1.2
San Carlos	3 h 30 min	3 h 30 min	1

Observations of real-life collection distances of NTFP/AP were all done rather close to Iquitos, the most remote village being Victoria 29 hours from Iquitos (or, according to the model, 24 hours 10 minutes). Thus, evaluating product classes 3-5 was not possible with these observations. However, some idea of the real-life collection distances was provided by boat driver interviews (table 12). Despite the fact that the level of precision in this information is not very detailed - products may be collected at any point of the river course – some valuable conclusion can be made.

According to my classification, class 1 products would need to be extracted or cultivated within 12 hours distance to Iquitos. In this case, the model seems to work: none of class 1 products was mentioned in Victoria or in Maypuco that are, according to my assumptions, too far away. Class 1 products were not mentioned in any of the other villages where, according to the model, they could be present. However, according to boat driver interviews, class 1 products were transported along Amazon proper and Itaya, which are close to Iquitos, but not along other rivers, which further supports my hypothesis.

Class two products would need to be collected within 24 hours distance to Iquitos, but manioc seems to violate this rule. It was mentioned in Victoria from where time-distance to Iquitos exceeds the limit. It was also mentioned frequently by boat drivers, even by those having their routes along more remote rivers, but due to the imprecise nature of this data, it may actually be collected near Iquitos. However, the case of manioc reflects the arbitrary nature of the product classification.

In boat driver interviews, only product classes 4 and 5 were present along Corrientes river, the most remote one of the mentioned rivers. This, again, supports the idea that highly perishable products are not collected for commerce in remote sites.

Table 12. Products mentioned in boat driver interviews.

River	***No of interviews***	***NTFP/AP transported***	***Product classes***
Amazon	28	manioc, plantain, máiz, papaya, *fariña*, *aguaje*, rice, *humari*, ripe plantain, pineapple, grapefruit, pimiento, *cocona*, cilantro, *guaba*, cucumber, hot pepper, *camu camu*, *mangua*, peach palm, tomato, *zapote*, *caimito*, *chiclayo*, bean, mango, *sacha, ubilla, zapallo*	1,2,3,4,5
Ucayali	9	plantain, corn, manioc, papaya, *aguaje*, rice, orange, *zapote*	2,4,5
Napo	6	plantain, manioc, corn, rice, *aguaje*, *mani*, grapefruit	2,4,5
Itaya	4	manioc, *zapote, aguaje*, grapefruit, plantain, *cocona*, grapes	1,2,4,5
Tigre	4	plantain, *aguaje*, manioc, *cocona*, rice, corn, *chonta*, peach palm	2,4,5
Marañon	3	plantain, *aguaje*, manioc, *chonta*, papaya, ripe plantain	2,4,5
Tahuayo	3	manioc, plantain, aguaje, *camu camu*, papaya, cucumber, pimiento, *ubilla*	2,3,4,5
Nanay	3	manioc, peach palm, *zapote, aguaje*, plantain, *cocona*	2,4,5
Manati	2	plantain, manioc, *aguaje*, peach palm	2,4,5
Momon	2	manioc, plantain, *aguaje*, cucmber, *ubilla*, peach palm, *guaba, caimito*	2,3,4,5
Corrientes	1	plantain, *aguaje*	4,5

6 DISCUSSION

6.1 Accessibility

The results of this thesis clearly demonstrate the importance of accessibility for local livelihoods and the necessity of robust methods for accessibility measures in different environments. In Loreto, the patterns of accessibility follow the river network and Euclidian distance as an accessibility measure would be useless. Two villages within a same radius from Iquitos may have drastically different rates of accessibility, depending on how they are situated as for the river network. The varying degrees of accessibility are reflected in the opportunities that rainforest dwellers have in terms of gaining living. Land-use potential for NTFP/AP trade is dependent on accessibility of markets, making it justified to state that accessibility is one major determinant of opportunities for these people.

6.1.1 River dynamics and accessibility

The results of this thesis demonstrate how the dynamic nature of the river network reshapes accessibility in various ways, having both short-term and long-term implications. Changes in water-level provide an example of short-term implications. As was demonstrated by the boat driver interviews, differences in travel times between dry and flood season were substantial. In most cases, travelling is faster during floods, because it is easier to navigate in deeper water and the stronger current facilitates navigation downstream. In addition, along certain routes the floods make short-cuts possible, thus diminishing the length of the journey both in kilometres and in time. As Abizaid (2005) points out, local people have a good spatial sense that is reflected in their ability to find the shortest routes during floods. In some cases, however, boat drivers reported that the current may get too strong during floods, making both up- and downstream travel more time consuming since navigation is dangerous and needs to be done more slowly. An additional challenge introduced by strong current is the amount of tree trunks and other material floating on river surface, making the navigation difficult.

During the dry season, forming *playas* make travel more challenging. Navigation requires more caution because the boat can get stuck if the water level is too low. If that happens, alternatives are twofold: either the boat driver needs to wait for rain to occur or get help from a tugboat. In either case, delay is often inevitable and travel time significantly longer. In addition, during the dry season the water level in some tributaries becomes too low for bigger boats to enter at all (see also Kvist et al. 2001). This, of course, drastically reduces the level of accessibility of villages situated along such channels.

Wiens (2002) notes that the occurrence and magnitude of flooding affects the connectivity pattern of different riverine elements, making connectivity a seasonal phenomenon: During flood season, when water in more abundant, some parts of the river network are better connected to each other. As was discussed previously, accessibility is closely connected to connectivity – thus, Wiens´ (2002) findings further emphasize the seasonal nature of accessibility.

Erosion provides an example of longer-term changes in accessibility. Although erosion rates may be surprisingly high (e.g. Kalliola et al. 1992; Abizaid 2005), changes in channel pattern happen gradually, as was demonstrated by the satellite images in figure 9. The gradual changes can, nevertheless, be dramatic, as was the case in Maypuco village that has so far been relocated three times because of erosion. Meander cut-offs naturally occur from time to time as a result of erosion, but they may also be facilitated by human beings (Abizaid 2005). The main reasons for facilitating a meander cut-off are related to improving river transportation and to make it safer for the transport of both people and goods. A complete alteration of a river course caused by a meander cut-off may be beneficial for some villages, but is often a catastrophe for others, as was indicated by Abizaid (2005). A man-made cut-off along the Ucayali river cut off eight villages and one town from access to active river channel, and at least one village disappeared as a result of the cut-off.

When discussing the effects of river dynamics on accessibility, it must be kept in mind that the strength and implications of river dynamics have a considerable spatial and temporal variation (Kalliola et al. 1992; Puhakka et al. 1992; Kvist & Nebel 2001; Toivonen et al. 2007). Yearly variation in flood amplitude is normal (Puhakka et al. 1992; Junk & Furch 1993) but talks with local people revealed that nowadays predicting the behaviour of riverine environment and floods is more challenging than what it used to be. Fenley et al. (2007) mention that 2005 was atypically dry in all parts of Amazonia, leaving many communities isolated from river based transportation networks. An interesting research theme related to these findings is the role of climate change in accessibility. How will the changes in climate conditions affect river dynamics, and how will these effects be reflected in accessibility? How will the poorer predictability of the living environment´s behaviour affect local and regional planning and decision making?

6.1.2 Evaluation of the selected methods and reliability of the accessibility model

As was indicated by Hodge (1997), RIVM (2001) and Martín & Reggiani (2007), capturing all aspects of accessibility in one single model is extremely challenging. This can be observed in the present study: the accessibility model created here does manage to describe several essential aspects of accessibility and is relatively easy to interpret, but as always, the reality is significantly more complex than the model. Below I will clarify what the model actually tells, reasons for the differences between model and observed travel times, and what could be done differently in order to enhance the model.

My study aimed at modelling accessibility within the river network and thus, movement occurring across land was minimized by setting the impedance value for off-river and off-road travel extremely high. Other studies (Nelson 2000; Farrow & Nelson 2001; Verburg et al. 2004; Soler et al. 2009) do take into account movement across different land surface types, often using a land cover classification and slope information as a basis for accessibility analysis. Perez & Lake (2003) suggest that NTFP extraction occurs within approximately 5 km radius around villages, and according to my observations, agricultural fields and agroforestry sites are situated rather close to producers´ homes, normally less that half an hour´s walk away. Therefore, considering the scale and purpose of my study, movement across land areas is of minor significance, and leaving different land surface types out of the analysis was a reasonable decision.

Differences in variables that are included in a cost-distance accessibility model reflect the subjective nature of accessibility measures which was criticised by Fotheringham et al. (2000). However, these differences reflect the fact, that each case is different and therefore requires a different measure (Husdal 1999; Verburg et al. 2004; Matrín & Reggiani 2007;

Chang & Lee 2008). Impedance values in my model were based on empirical data on navigation speeds which reduces the arbitrary and subjective nature of these values (see Toivonen & Mäki 2002; Toivonen & Mäki 2003).

The comparison of the accessibility model with real-life travel times showed that the model predicts travel times almost perfectly in some parts of the model whereas the error in some cases reaches up to 40%. These differences may depend on various factors. One possible explanation is the difference between real-life river network and the GIS-layers. The digitized rivers are simpler than actual navigation routes: For example, *playas* that significantly slow down the navigation speeds are not represented in the digitized rivers. This explains to some extent the underestimation of travel times. Another thing affecting the exceptionally big difference in case of Requena is the special nature of the journey that was used for validation. The *motonave* used during that journey belonged to the regional government and was performing a free of charge transport service for NTFP/AP producers. Due to the free transportation, the amount of stops, cargo and passengers was greater than normal, leading to a slower journey.

The validation material was quite small, and in order to evaluate the model more profoundly, a significantly larger evaluation dataset would be needed. In addition, speed data were collected from places that were easily accessible from Iquitos and can thus be regarded as somewhat biased. Data about smaller channels further away from Iquitos and on the edged of my study area would have been interesting and perhaps made my model better. This further stresses the importance of knowing and paying attention the accessibility pattern. Sampling bias related to accessibility pattern has been recognized also in other studies (Reddy & Dávalos 2003; Schulman et al. 2007).

The accessibility model of this study was built based on a river classification where each river was assigned one single impedance value along its whole length. One river may, however, have different channel characteristics along its course (Sioli 1984; Puhakka et al. 1992; Gordon et al. 2004; Toivonen et al. 2007) and thus, navigation speeds may vary in different parts of one river. One possible enhancement of the model could lie in this: river classification could be done based on channel types and travel speeds measured according to that, instead of entire rivers. However, defining exact boundaries for different channel types in a river network is challenging, thus making this sort of measurements difficult.

The present model describes the accessibility pattern around Iquitos *during flood season*. In order to get a deep understanding about accessibility in the region, another model describing *the dry season* is necessary. The need to distinguish flood season accessibility from dry season accessibility has been recognized also in other accessibility studies conducted in tropical regions (Verburg et al. 2004; Soler et al. 2009). In order to estimate differences of dry and flood season PCArs, I did create a dry season accessibility model, but values used in that model were only estimates calculated based on boat driver interviews and the reliability of the model is thus questionable. In order to create a reliable dry season model, measurements during that season would be needed.

The model does not take into account the amount of traffic along different rivers – it describes the *potential* time-distance to Iquitos assuming that transport facilities exist. However, as my results demontrated, the amount of traffic and frequency of journeys per vessel vary significantly along different rivers and due to this, it is not realistic to assume that transport facilities would exist everywhere at anytime. Thus, the accessibility model cannot be interpreted as a mobility model that would describe the *realized* interaction between places (see Hodge 1997). Creating a model to realistically represent the amount of traffic along each river in Loreto would be challenging: information needed for such a model is not readily available, since the level of organization in river transport is relatively poor. According to the harbour authorities´ register (Capitanía de puertos 2009) the majority of registered vessels operating in Loreto have irregular routes. In addition, it is estimated that a large proportion of vessels are not registered at all (Informalidad persiste… 2007).

Difficulties in combining multiple scales in one accessibility measure have been recognized by Kwan & Weber (2003) and according to Kwan et al. (2003), scale-issue remains a challenge for accessibility research. The accessibility model of this study describes a large-scale transportation pattern, because time-distance was calculated based on speeds of the most typical vessels on each river. However, if a smaller-scale pattern was examined, another model would be needed, since especially around Iquitos, there is a large variety of vessels operating, as was indicated by the boat driver interviews. Thus, the model created in this study may not reflect the reality of producers living close to Iquitos, if they are not using same vessels that were the basis of the calculation.

If a larger scale accessibility pattern covering all of Western Amazonia (see Mäki 2003) is considered, interesting reference can be found in Toivonen & Mäki (2003) and Toivonen et al. (2007). According to these studies, Peruvian Amazonia is rich in water surfaces and riverine corridors, and the connectivity of these patterns is much higher in Peru than in other Western Amazonian countries. Based on these finding it can be assumed that opportunities for higher accessibility are better in Peru than in other parts of Western Amazonia. Again, the realized mobility is a different matter and more research would be needed to assess this. In all, since Western Amazonia is considered a reasonable research and planning unit (e.g. Mäki 2003), studies assessing differences in accessibility pattern of the whole area would be useful.

6.2 NTFP/AP

Although I did not quantify market place products by counting the amounts, the frequencies in market place interviews can be interpreted as an estimate of each product´s significance. The fact that same products were also mentioned by boat drivers and flood plain dwellers further confirms these findings. So do visits to local restaurants: a slice of plantain or a portion of fried manioc accompanies many meals. Most of my results are in accordance with a fruit study that was conducted in Iquitos´ Belén market place for 20 years ago (Vasquez & Gentry 1989). At that time, plantain, cucumber and papaya were "very important fruit in Mercado Belén", as Vasquez and Gentry (1989) express it. In contrast, *cocona* and grapefruit that were among the most frequent ones in my material, were not classified as "very important" but only as "observed sold in Mercado Belén". Some products that were weakly represented in my material were "very important" in Vasquez and Gentry´s (1989) study. These differences may result from several things. My material was collected within a limited period of time, and as many of the regional products are highly seasonal in their availability (Muñiz et al. 1996; Pyhälä et al. 2006) It may be that some products were extra well represented where as others were absent from my data due to seasonal avalability. Also, changes in supply and demand - perhaps even in taste – have possibly occurred during these 20 years that separate our studies.

Distinguishing NTFP from AP was challenging, since various authors classify products in different manners. The most frequent, and thus most important products in my material could, however, rather unquestionably be classified as agricultural products. This result is consistent with previous studies (Padoch 1985; Takasaki et al. 2001; Pyhälä et al. 2006) where the commercial value of AP was proved to be higher that that of NTFP.

Interviews with flood plain dwellers revealed that government actions continue to affect the choices of livelihood strategies, as was stated by Coomes & Barham (1997). The head of Maypuco village confirmed that the growth of the village in recent years is mostly a result of credits that the regional government gives for cultivation of *camu camu* and *sacha inchi*. These governmental programs came up even in Victoria and Mazan.

6.2.1 Drawbacks in NTFP/AP trade

The process of NTFP/AP trade is complicated and consists of several actors (Padoch 1988a; Coomes & Barham 1997; Shanley et al. 2002). One indicator of the complicated marketing chain in my study was the fact that market place vendors could not tell where their products originated from. Also trade strategies in villages were varied; sometimes, although rarely, producers sell their products directly to the final consumer, but more often, a varying number of intermediaries act between producer and consumer.

Previously I suggested that viewing NTFP/AP trade as a product system would provide interesting insights to the theme. The *circulation* part of the process seems to be the most troublesome in Loreto´s case. Unfair structures and practices are common within the complicated chain of middlemen (Padoch 1988a; Coomes & Barham 1997) and intermediaries are known for taking advantage of the vulnerable position of producers (Pyhälä et al. 2006). This was apparent even during my visits to the villages when river traders coming from cities offered lousy prices for prime products. Coomes and Barham (1997) remind, however, that eliminating middlemen and traders would not be the solution: they act as important sources of information and provide access to markets and credits. So, attempts to make the process fairer for producers should rely on profound understanding of the roles of different actors.

One example of the unfair structures in the trade process, in the *distribution* phase, is given by *Mercado de productores*. As was described previously, a covered hall was built with the idea that producers could sell their products there without relying on middlemen and make a bit more money. In reality, however, all vendors that I encountered inside the covered hall were resellers, whereas the original producers were standing outside in the rain, having their products on the wet ground where they easily go bad.

One attempt to enhance the position of the producers is the *feria* service provided by the regional government of Loreto. This activity has encountered criticism, but the idea behind it is good: the regional government arranges free transportation for producers and the products are sold in a market place which is reserved solely for this purpose. Thus the role of middlemen is diminished and payoffs for producers are higher. Prices of the products are determined beforehand and are thus attractive for consumers. The free transportation is available only along certain routes with a certain frequency, but there are plans to expand the area of influence in the near future (Araujo 2009).

Transportation-related problems have been recognised as a bottleneck of the commercialization process, not only in Peru (Padoch 1985) but also in Brazil (Muñiz et al. 1996; Shanley et al. 2002). From the accessibility point of view transportation is, of course, critical. It is not uncommon to get disappointed by the fact that time-tables are almost an unknown concept within river transport. If *motonaves* for some reason do not traffic – sometimes the reasons may be technical, sometimes political – the remote villages have no access at all to markets. As was indicated by my results, reliance on public transport is very high. Private transport may be an alternative if the distance is short and the producer or his/her community happens to own a boat. However, since many of the distances are measured in days, canoes or small *peque-peque* –driven boats are not a realistic alternative for transportation.

Transport is vital not only from NTFP/AP aspect but also because people living in small villages need goods from cities. Vessels operating on rivers are never empty: on the way towards the city they are filled with products coming from villages and on the way back, they carry important goods that are not available in the villages, like rice, sugar, pasta, vegetable oil, milk, lemonade, beer, soap, fuel and construction materials.

Another pitfall in transportation is the security aspect which is often forgotten: it was not only once or twice that the boat drivers reported the capacity of their vessel way bigger than what was stated in the formal registers of the harbour. These problems have been acknowledged, but because different authorities have different opinions about the situation, security problems persist (Informalidad persiste… 2007).

Rules and sanctions governing resource use are inefficient and there is a lack of clearly defined property rights (Pyhälä et al. 2006). All this promotes unsustainable resource use.

As the arrows in the production system chart (Fig. 4) suggest, all the five components of the system are interconnected; changes in one component affect the others as well. If the circulation process does not work, as discussed above, the products produced by the production process do not get to the markets of Iquitos, the distribution process gets interrupted and the demand of consumers is not fulfilled.

6.2.2 Evaluation of the classification and PCAr model

An undisputable classification of products according the amount of time they can be preserved was difficult and it is necessary to discuss the reliability of the classification. Some products in table 9 had rather big standard deviations in their average shelf-life which reflects the wide range of answers. Different answers may depend on the way interviewees understood the question but also different means of transport affect the amount of time products last (Padoch 1988a). For example manioc, one of the most important products in my material, can last for several days if kept in a dry place but once it gets wet, it goes bad easily. The organization of the distribution process plays a significant role and as was discusses previously, does not work perfectly.

The PCAr model is based on simplifying assumptions, similarly as was the location model of von Thünen (see Dicken & Lloyd 1990). It does not take into account any biophysical factors like suitability of soils for agriculture and NTFP extraction, nor does it account for availability of resources. These factors are, or course, crucial for understanding NTFP/AP potential and use (e.g. Vormisto 2000), but they were not in the focus of this study. By stripping away all these other factors, the model focuses explicitly on the role of accessibility, which is another crucial component in determining land-use (see Verburg et al. 2004; Soler et al. 2009).

The estimated PCArs suggest that catchment areas would be bigger during flood than during dry season. In smaller areas (like in case of product class 1), the differences are not very significant, because in reality the perishability of products is rarely a matter of one or two hours. However, with greater distances from Iquitos the difference between dry and flood season ranges gets bigger and may become more significant. In this study the dry season areas are estimated only using the average ratio between the flood season and dry season travel time. However, during dry season, navigating along some channels is not only slower but may in fact become impossible due to the low level of water. Therefore, differences between flood and dry season catchment areas are probably even bigger in reality. More measurements with a wider spatial and temporal coverage would be needed to model this change in a reliable way and to evaluate the PCAr model.

Dicken & Lloyd (1990: 149) suggest that "the general effect of improved transportation [which can be interpreted as better accessibility] on the location of agricultural production has been to increase the relative importance of natural environmental factors". Based on my results, I agree. As the village interviews reveal, not only perishable but also long lasting products are cultivated and extracted near Iquitos. Due to this I suggest that floodplain dwellers having easier access to markets have more opportunities and a wider range of choice in terms of products they decide to market. Thus, they can better take advantage of the environmental and socio-economical factors determining the land-use potential of different areas and maybe make their decision according to the market demand, not solely based on accessibility. Thus, the poorer the rate of accessibility, the more it affects livelihood decisions and opportunities of floodplain dwellers.

In this study, PCArs are estimated only around Iquitos and smaller centres are left out of the analysis. There are, of course, market places in other centres as well – for instance Requena and Nauta - but in comparison with Iquitos, catchment areas of these smaller centres are marginal and their demand is fulfilled with products coming from nearby villages. As Padoch (1988a) suggests, serious commercial competition to Iquitos in Loreto area is provided only by Yurimaguas. Therefore, this monocentric model was, in my opinion, well justified. However, a larger scale study including other regions in Peru and whole Western Amazonia could provide interesting insights to PCAr delineation. NFFP/AP commerce does not necessarily obey administrative borders, as was indicated by my village interviews in Victoria. River traders came to the village both from Iquitos and from Pucallpa. Additionally, Pulido and Cavelier (2001) report that a significant proportion of NTFP/AP present in Leticia markets (close to the Peruvian border, on Colombian side) come from Peru and Brazil.

One interesting theme for further studies would be to explore the relationship between profitability of NTFP/AP trade and accessibility. Padoch (1988a) describes a situation in Iquitos harbours during flood season when water reaches higher up the slopes but is not deep enough for big vessels to pass. An additional phase is required in transportation process, and small canoes are used to get products from bigger vessels to the market place. This phase has, of course, its cost. This is a small scale example of the relationship between accessibility and prices, but the concept could be extended to larger scale as well. Do sites with poor rates of accessibility suffer not only from the restrictions they face in terms of product alternatives, but also from higher transportation costs and thus lower profitability of commercialization? Do poverty and poor rates of accessibility appear side to side in Loreto, like in other parts of the world (see Dixon-Fyle 1998; Bryceson et al. 2003; Anand & Tiwari 2006)?

6.3 Accessibility planning in Peruvian Amazonia and future of accessibility research

Abizaid (2005) suggest that human intervention on riverine environments of Amazonia has occurred for centuries. Local people have accelerated changes in the course of large rivers that without intervention would have taken decades or even centuries to occur. The goal of such intervention is to improve transportation and facilitate access to regional markets. I suggest that such action can be seen as "informal accessibility planning" that is done locally, without official supervision.

An example of formal accessibility planning on a larger scale is provided by the IIRSA initiative (Initiative for the Integration of Regional Infrastructure in South America). IIRSA aims at promoting the development of transport, energy and communication infrastructure in twelve South American countries (IIRSA 2009). One of IIRSA´s projects is active in Amazonia and concrete actions in Peru include, among others, enhancement of navigability of the main rivers, improvement of harbour facilities, and construction and pavement of roads. IIRSA has been strongly criticised and accused for having inadequate means to address the environmental, social and cultural impacts of such large-volume actions and it is feared that IIRSA projects lead to displacement of rural and indigenous peoples, massive migration, deforestation and loss of biodiversity (Giménez & Spang 2005). Similar accusations have been posed against large-scale oil and gas projects in Western Amazonia (e.g. Finer et al. 2008) that have recently led to confrontations and violence in Peruvian Amazonia (Human Rights Watch 2009).

So, the juxtaposition of accessibility as a desirable thing and accessibility as a non-desirable thing remains. The future challenge of accessibility planning is to combine these two ways of thinking and find sustainable accessibility solutions that satisfy both economic, social, political, and environmental needs. Another challenge is to combine the regional and local scales, and formal and informal stages of planning: local needs need to be addressed in a wider scale planning and "the informal planners", meaning local people must have a right to take part in the planning process. Since accessibility affects such a large scale of matters, Weber (2006) suggests that interdisciplinary approach is a key factor in future accessibility research.

Some researchers (Hodge 1997; Kwan & Weber 2003) claim that the concept of accessibility is constantly changing and becoming unclear due to rapid changes in society: especially as new communication technologies reshape possibilities of interaction between people and places. The potential role of these technologies in Loreto remains to be seen. Logically, possibilities for utilizing such technology are limited in an area where electricity and water facilities are only a dream in several villages. At least for the time being, accessibility in Amazonian context is still largely a matter of physical transport infrastructure.

6.4 Synthesis

Accessibility is an extremely important matter for local economies and can thus be seen as a human right. In the Peruvian Amazonian context, accessibility is a significant determinant of commercial potential provided by regional NTFP/AP, both by enabling the commercialization and by restricting it. Thus, if NTFP/AP are to be used for more than just subsistence ends, spatial patterns of accessibility should be taken into account when planning governmental subsidence programs and directing aid. The need for accessibility information conserning the region is obvious but Amazonia as a planning area is challenging. Accessibility is dependent upon a dynamic and constantly changing river network which cannot be controlled by human beings similarly as built environment. An additional challenge is posed by the seasonal nature of accessibility. There are examples of local, informal accessibility planning where local people take action by facilitating meander cut-offs and thus enhance accessibility. This sort of action may, however, have unintended consequences and the harms caused by such actions may be bigger than the benefits. Thus, accessibility planning must be coordinated but participatory, it has to recognise local needs, yet by integrating them with larger-scale needs. Also unfair structures and institutional and organizational problems in NTFP/AP trade must be adressed. In addition, accessibility planning within Amazonian context must take into account the fact that the ecosystems of the area are sensitive and deforestation and loss of biodiversity, which often are a result of road building and developed infrastructure, must be avoided, both for the sake of local and global environment.

In all, accessibility information is an important factor in informed decision making, not only in Amazonia but in other parts of the world as well. The most appropriate ways of measuring accessibility must be considered according to each specific situation, but since accessibility affects a large scale of matters in society, an interdisciplinary approach is highly recommended in future accessibility research.

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APPENDICES

Appendix A

Questionnaire for boat drivers transporting regional NTFP/AP in Loreto

Date:

Place:

Interviewee:

Name of the *bote fluvial* / *motonave fluvial*:

General observations:

1. What is the route of this boat (from - to)?
2. What are the biggest harbours along the route?
3. Does the boat stop in every village along its route?
4. How long does the journey take (upstream / downstream)?
5. What are the respective travel times during the dry season?
6. Do you reach your destination even during the dry season?
7. How many times a week do you travel the route?
8. What products are being transported to Iquitos in this boat?
9. What products are being transported from Iquitos in this boat?
10. What is the capacity of the boat (cargo / passengers)?
11. How much is the cargo rate / price for a passenger ticket?

Appendix B

Questionnaire for market place vendors selling regional NTFP/AP in Iquitos

Date:
Place:
Interviewee:
General observations:

1. What regional NTFP/AP are you selling?
2. For how long can these products be preserved (counting from the moment of collection / harvesting)?
3. Where do the products originate from (name of the village)?
4. How were the products transported?
5. Where did you buy the products (if they were not collected / cultivated by you)?

Appendix C

Questionnaire for villagers cultivating or collecting NTFP/AP for commercial purposes in Loreto

Date:

Place:

Interviewee:

General observations:

1. What products do you cultivate / collect in order to commercialize them?
2. What products do you cultivate / collect for subsistence?
3. Where do you sell your products? Why?
4. Do you rely on river traders or do you sell your products self?
5. How are your products transported?
6. What is the size of your field?