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The role of quantitative accessibility information in understanding resource extraction patterns: Examples from the Peruvian Amazonia

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Preface

"No hay entrada, ni salida. – There is neither an entrance, nor an exit." This is how one of the rural dwellers describes the prevailing transportation realities in his community along the Amazon River in the Peruvian Amazonia. Long travel times in river boats make him wish a paved road connection to his community. "Sería más facil la vida – The life would be easier". Many rural dwellers in Amazonia share his hope. This makes me worried, considering the environmental devastation often related to road building in Amazonia.

But indeed, there is a lot of uncertainty, risk and informality related to the fluvial transportation in here. People may wait hours, even days, to catch a river boat to the nearest market centre, which may be several days away. Mrs. Angelica, owner of a boat company in Iquitos told me how she keeps track on where her boats are: boat captains call her every time that the cell phone signal appears along the route. Relying on cell phones in any small business has become common in Iquitos and its surrounding, where it seems that almost everyone has a cell. Along the boat´s five-day route, however, the cell coverage varies and phones catch a signal only occasionally. You never know if the boat is stuck on a sandbar and you can´t tell the customers when the boat will arrive in the next community.

- August 2011, Field notes by Maria Salonen

Introduction

Marginality, the theme of Tropentag 2011, can be defined as lack of access: *Marginal people* suffer from poor access to facilities and resources, and *marginal areas* lack proper infrastructure that would connect them with other areas. Indeed, a well-functioning transportation system and physical accessibility are crucial for human livelihoods, social interaction, and access to health care and education opportunities, particularly in the developing world.

Amazonian lowlands are one of the marginal areas of the world, both globally (Nelson 2008) and nationally in all Amazonian countries (Mäki 2003). In Amazonia many rural dwellers face chronicle difficulties in earning their living and gaining education due to lacking transport facilities and poor accessibility to the regional centers (Padoch *et al.* 1985; Shanley *et al.* 2002). On the other hand, Amazonian lowland rainforests and their biodiversity face a continuous increase in land use pressure caused by population migration and the intensification of logging and oil extraction in the region (Barreto *et al.* 2006; Killeen 2007). One important regulating factor for human actions in the region is the physical accessibility of different places: Land use intensity and pressure on existing resources is likely to be highest in easily accessible areas (Peres & Lake 2003; Salo and Toivonen 2009) and high rates of accessibility have been shown to be connected with increased deforestation (Imbernon 1999; Laurance *et al.* 2002). In all, questions

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of accessibility are highly topical, but in many ways controversial. A key question is whether increased accessibility can be sustainable from both human and environmental perspectives.

In the Peruvian Amazonia, roads are scarce and rivers provide the main platform for regional mobility. This “natural transportation network” can be thought of as an ecosystem service provided by the rivers, but it is a challenging platform for transportation. Rivers are dynamic both seasonally and inter-annually, causing unpredictability in the form of water depths, sand bars and torrents. The lateral movement of the river meandering channels may be dramatic (Kalliola *et al.* 1992) and weather anomalies caused by climate change further increase these natural risks (Marengo *et al.* 2008). Moreover, informality is a typical characteristic of the whole transportation business (Neira 2003) and travel times between cities and communities are generally long (Salonen *et al.* 2011). Road transportation is often considered more lucrative and consequently road building is in many cases anticipated among the rural population. Experiences of road building in Amazonia are, however, very controversial: it has facilitated improved mobility and access to new areas, but the consequences of new road openings have often proven to be environmentally devastating and socially unsustainable (Fearnside 2005; Pertz *et al.* 2007). Actions that could support the reliability of riverine transportation would promote sustainability of land use, and support the local population in the Peruvian Amazonia.

Our previous work has focused on quantifying spatial patterns of accessibility in the north-eastern Peruvian Amazonia. We have developed an accessibility model for the Loreto region that quantifies accessibility as distances between the rural hinterland and the regional centre of Iquitos (Salonen *et al.* 2011). In this paper we look at how quantitative accessibility models can be used to understand spatial patterns of resource extraction in our study area and introduce ideas for future work with accessibility questions in Amazonia. More precisely, we apply the previously developed accessibility model (Salonen *et al.* 2011) to 1) model timber extraction (deforestation) patterns and their dependency on distances from the main market centre, and 2) analyze potential accessibility-driven extraction regions of different agricultural and non-timber forest products.

Material and Methods

First we analyzed the influence of accessibility on deforestation patterns. Peruvian authorities maintain yearly deforestation maps based on satellite image interpretation. We utilized these maps as reference data and simulated deforestation patterns using a land use / land cover change (LUCC) model (Soares-Filho 2002). The model received the following input variables: elevation, soils, protected areas, indigenous areas and accessibility, measured as time distance between the rural areas and Iquitos. The Weights of Evidence (WoE) method (Bonham-Carter 1994) was used to analyze the effect of each variable on transition (from forested area to deforested area) and to produce a transition probability map that describes the probability of deforestation on a pixel-by-pixel basis.

In order to analyze extraction patterns of regional agricultural and non-timber forest products, we conducted a survey of marketplace vendors (n=112), asking for typical shelf lives of commercially important products. Based on shelf lives of a few indicator products and modelled time distances, we delineated potential extraction regions for typical regional market place products around the city of Iquitos.

Results and Discussion

The transition probability map (Figure 1) shows that the risk of deforestation is clearly higher on areas that are within shorter time-distances from the main markets in Iquitos. The probability of transition from forested to deforested area is highest along the main rivers where transportation towards the centre is faster; the probability gets lower further from the main rivers where travel times to the city are longer (Salonen *et al.* manuscript in preparation). As an example, the probability of transition is on average nearly four times greater in areas that are within a 24 hours time distance from Iquitos as compared to areas that are within 25-48 hours time distance from the city. The weight of evidence values of accessibility range from 4.0 to -6.6, whereas the range of elevation was from 2.8 to -4.3, the range of soils from 1.2 to -2.1, the range of protected areas from 0.3 to 0.0, and the range of indigenous land from 0.1 to -0.9. Thus, accessibility gets the strongest positive and the strongest negative values. Although the WoE-values for accessibility get rather noisy as the distance increases, the smaller distances are assigned with a strong positive weight for deforestation. The overall trend (the red trend line) is also clear (Figure 1).

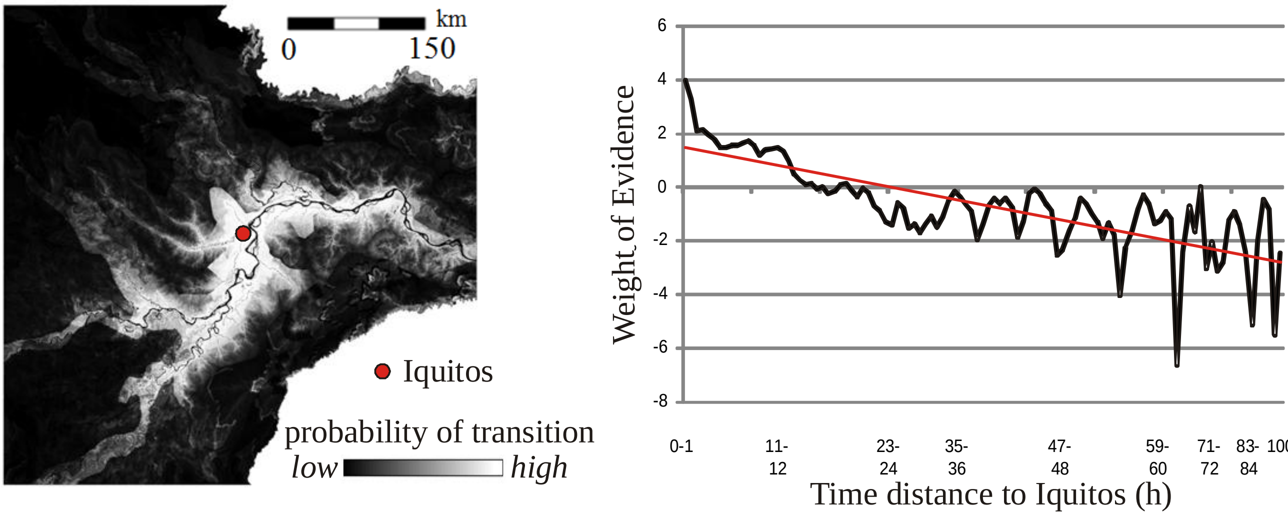

Figure 1. Transition probability map showing the probability of deforestation in our study area and a Weights of Evidence graph for the accessibility variable.

Figure 2 shows how travel times to the city of Iquitos limit the geographical extent of commercial agricultural production and the extraction of non-timber forest products for market purposes in Loreto. The figure includes two examples of potential extraction regions for different product categories: For products perishable within approximately one day, such as fresh fish and game, the potential extraction region covers 13,600 km^2. Orchard and native fruit (such as pineapple and *cocona*) last for approximately two days and their potential extraction region covers 85,800 km^2. Shapes of the regions are determined by the spatial configuration of the river network and are rather irregular (see also Salonen et al. 2011).

These results provide an example on how human pressure on the environment and peoples´ economic opportunities and livelihood choices are shaped by patterns of accessibility. In case of deforestation, easily accessible areas face the greatest pressure and distance to market centres is a powerful predictor of deforestation (Maeda *et al*. 2011). In case of perishable products this pattern is supposedly even stronger: The economic return to common market place products is limited by accessibility, since perishability of fruits and vegetables determines the acceptable duration of transportation (Porter 2002). Although the potential extraction region model is a simplification ignoring several factors that in reality are involved in shaping these resource use patterns, it nevertheless demonstrates that people living in areas with better market access clearly have more production choices available in comparison to those living in more marginal areas (Nepal and Thapa 2009). Overall, consideration of transportation realities and the role of physical accessibility to markets are vital when evaluating the economic potential of different livelihoods and sustainability of land use practices (Grimes *et al.* 1994).

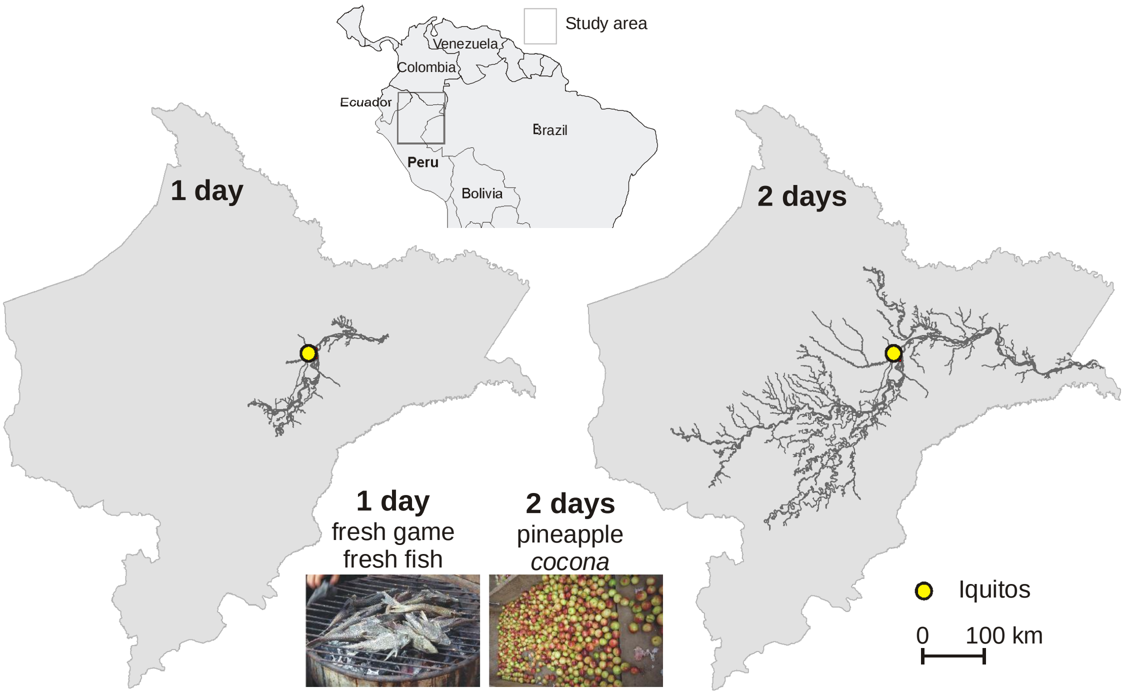

Figure 2. Potential extraction regions for different types of agricultural and non-timber forest products (adapted from Salonen *et al*. 2011).

Conclusions and Outlook

Our results demonstrate the value of quantitative accessibility information when we wish to understand the spatial organization of resource use activities and human pressure on the environment. While their importance is evident as such, quantitative accessibility measures have seldom been used in Amazonia. In the Amazonian context, accessibility measures must also take into account the spatial structure and the dynamic nature of the fluvial transportation network. Time distance provides the most relevant measure of accessibility, as many human actions and livelihoods are controlled by travel times between the regional core and the riverine settlements.

A future challenge in accessibility modeling in Amazonia lies in the dynamic nature of fluvial transportation. In order to be able to better take into account the dynamics and irregularities of river transportation, we have started to gather long-term monitoring data on river navigation routes and speeds. We have established a pilot system of GPS tracking devises that follow movements of a few river boats in real time. Once the system has been running for longer time, these data can be used to analyze the frequency of transportation and the seasonal and inter-annual changes in the accessibility pattern. This would allow us, among other things, to analyze the impacts of climate change related weather anomalies on transportation.

The tracking system will also be harnessed for serving the local population. Data on river boat movements will be made available through online maps and an SMS service. These services, we believe, provide examples of grass root level actions that might enhance the reliability of riverine transportation in peoples' perceptions, promoting sustainability of land use.

Postscript

¡The first GPS tracking devices are installed in boats and they send their signal every 10 minutes! One is on Angelica's boat. She finds astonishing that she can now follow the movement of her boat reliably in real time. At her office, she has a web browser open all the time, the boat locations on an on-line map in one tab and e-mails in another. Mr. Victor, another collaborator, is also excited about the idea of being able to follow the movements of his boats in real time. For him the online map is too challenging. He is not used to reading a map, nor using a web browser. While we´re looking at the map and talking about it, his cell phone keeps ringing. ¡If only I could receive

the location information as SMS to my cell phone! "¿Cómo?- Excuse me?" he asks me to repeat, when I say that I guess we could try that too.

- *September 2011, Field notes by Maria Salonen*

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