LAND USE ZONING BASED ON A WORLD SOILS AND TERRAIN DIGITAL DATABASE STUDY TO CONSERVE THE BRAZIL-NUT FORESTS IN BOLIVIA'S AMAZONIA

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SUMMARY

Botanists have long recognized the western Amazon forests as the area of origin of Brazil-nut (Bertholletia excelsa) and many other tree-crop species. As increasingly large areas of these forests in Bolivia's Amazonian Pando Department were being destroyed in the early 1990s for cattle ranching, a land resource study following the World Soils and Terrain Digital Database approach was commissioned to provide a basis for zoning the region to conserve the Brazil-nut forests. It was found that the soils of the Pando have low fertility levels and would be incapable of supporting forests were it not for the nutrient-cycling phenomenon. This finding was supported by the study of many representative soil profiles. Local experience confirmed that the forests of the region regenerate very slowly following clearing. The soils are patently unsuitable for agricultural "colonization". Complementary forest inventory studies confirmed that the forests often have very high concentrations of Brazil-nut trees and could support a more intensive extractive activity. In order to arrest the destruction of the native forests, a Regional Land Use Zoning map was drawn up in consultation with other specialists and local people. Unfortunately, little attention has been paid to the latter to date, and irresponsible forest clearing continues at an ever-accelerating pace. In view of this situation, the authors would suggest that serious thought should be given to the creation a World Heritage Area with international finance sought for the conservation of representative areas of these unique Brazil-nut forests.

Forests rich in Brazil-nut (*Bertholletia excelsa*) and rubber (*Hevea brasiliensis*) cover a large part of Bolivia's Amazonian Pando Department (Figure 1). This region, which extends over about 6,319,000ha of Northeastern Bolivia, is a key part of the "center of origin" of Brazil-nut, rubber, cacao (*Theobroma cacao*) and other tree species of incalculable genetic value (Purseglove, 1968, Dias *et al*., 2003). Until relatively recent times, the forests of this region were virtually untouched, in contrast with the neighboring Amazon territories of Brazil, where forest removal for pasture production has proceeded apace over the past forty-odd years. However, with the collapse of the Bolivian rubber tapping industry in the mid-1980s and the rapid build-up of migratory pressures following the construction of roads to connect the region with the Bolivian highlands, felling for timber and forest clearing for cattle ranching has taken a serious toll of what was one of the most spectacular forest regions of south-western Amazonia (Cochrane, 1973).

The FAO-UNESCO Soil Map of the World (FAO-UNESCO 1971, 1976, 1990a) indicates that the soils of the region are low fertility Ferralsols (Oxisols) and Acrisols (Ultisols), which support a fragile tropical forest ecosystem. More detailed surveys of the region were carried out by Cochrane (1973) and Cochrane *et al*. (1985, 1992). Those studies invariably painted a picture of inherently poor soils supporting fragile forest ecosystems dependent on the nutrient cycling phenomenon of the forests.

In view of the increasing rate of the destruction of the forests in the Pando, a Dutch Government financed land resource survey of the region was carried out to detail how the region might best be "zoned" to ensure its future prosperity (Cochrane *et al*., 1994a). The land resource survey followed on from, and complemented an earlier World Bank sponsored project to study the Brazil-nut and rubber region of north-eastern Bolivia (Co-

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Figure 1. Location of the Amazonian Pando Department, Bolivia.

chrane *et al*., 1992). It was considered that the sustained development of the Pando Department would be enhanced and its forest resources preserved through the preparation of a Regional Land Use Zoning (LUZ), Map and Plan, and its implementation.

The objective of this report is to summarize and draw attention to the findings of the land resource study of the Pando Department of Bolivia by Cochrane *et al*. (1994a), and specially the Regional Land Use Zoning (LUZ), Map and Plan drawn up to reduce the destruction of Pando's Brazil-nut forests. Unfortunately to date, very little if any attention has been paid to the recommendations of the latter plan; the destruction of Pando's Brazil-nut forests continues at an ever-accelerating pace.

Methods

The Pando Department land resource study (Cochrane *et al*., 1994a) followed the World Soils and Terrain Digital Database SOTER, methodology (ISRIC, 1993); it was complemented with additional forestry and socio-economic studies (ZONISIG 1996, 1997). The SOTER methodology identifies and maps areas of land or SOTER Units with "distinctive, often repetitive patterns of land form, lithology, surface form, slope, parent materials and soil". Effectively, SOTER Units delineate areas of similar landscape where the same type of farming or forestry management might succeed; their careful description is fundamental to land use planning and agrotechnology transfer. SOTER Units may be sub-divided into "terrain components" to provide more detailed information of their land patterns. The mapping of the SOTER Units was designed to cover the region with an average precision approximating a scale of 1:500,000.

The work was carried out as an integral part of the world-wide SOTER initiative, and followed the SOTER land resource database file set detailed in the SOTER procedures manual (ISRIC, 1993). The database developed for the work was in fact the first computerized SOTER database to be setup up in the entire world in accordance with the 1993 standards. The methodology has been summarized by Cochrane and Cochrane (2002, 2006), who explain how the methodology was complemented with climate and other information databases. Some details of the methodology adopted for the land resource study may be noted.

Climate studies

The SOTER database was complemented with a climate database. From the outset of the study an examination and analysis of the available meteorological data was made. Meteorological data sets from 5 meteorological stations, Cobija, Guayaramerim, Puerto Maldonaldo (in neighboring Peru), Riberalta and Rurrenabaque were digitized and integrated with the SOTER database. The climate data was analyzed following the approach of Hargreaves (1972, 1977, 1989).

Satellite imagery preparation and field work

Collateral with the climate studies, composite, geographically corrected satellite imagery, using bands 3, 4 and 5 of the Thematic Mapper (TM) 1:250,000 imagery was compiled and examined for the region to delineate very provisional SOTER Units to help plan the field-work. Field-work followed to describe the region's terrain and soil characteristics, record representative soil profile descriptions and collect their horizon samples for laboratory analysis. The field study expeditions transected the region from west to east and north to south. The soil profile samples taken during the course of the field work were analyzed according to the methodology detailed by Cochrane and Barber (1993). The soil profile descriptions were standardized according to the FAO guidelines (FAO-UNESCO, 1990b) and digitized using the FAO-ISRIC Soil (profile) Database program SDB2 Version (FAO-ISRIC, 1991). This facilitated the storage, retrieval and examination of that data.

Vegetation database

The land resource study was complemented with a vegetation database. The native vegetation of the region was described in terms of the physiognomic classes used by UNESCO (1973), with some minor modifications partly based on Eyre (1968) descriptions for tropical forests. An evaluation of the economic value of the forests was prepared as a complementary activity to the land resource studies (ZONISIG, 1996, 1997). During the course of the study, a quantitative assessment of the extent of forest clearing was recorded in the database, based on an examination of the satellite imagery and in-field observations.

Report compilation and development of a PC users' packet

Following the successive completion of the climate studies, field work, the laboratory analysis of soil sample data, the vegetation surveys and the subsequent compilation of the SOTER database of the region, definitive SOTER Units were delineated directly onto the 1:250,000 satellite imagery and subsequently digitized using a Geographic Information System (GIS). The database files that summarized the soils and terrain information gathered during the course of the survey work, together with the SOTER Unit map and a series of thematic map files, were recorded as an integral Personal Computer (PC) Users Packet which complemented the printed report on the region (Cochrane *et al*., 1994a).

The PC Users' packet was organized into three sections: Section 1, SOTER database files; Section 2, IDRISI map files,

and Section 3, FAO-ISRIC SDB2 (soil profile) database. The SOTER Unit map was recorded in Section 2 along with a series of thematic maps. The vegetation and other data were compiled as separate but interconnectable relational database files. Details of the PC User's packet have been summarized by Cochrane *et al*. (1994b), and the packet is available with that report. It enabled the speedy compilation of accurate statistical information about the land resources of the region, apart from providing detailed land related information. It provides detailed information on each of the SOTER Units mapped for the Pando.

Results and Discussion

Land resources

a- The agricultural climate of the Pando

Analysis of the meteorological data supported the findings of Cochrane *et al*. (1985) that the major determinant of the climate of this area of the Amazon is the seasonal migratory movements of the low pressure Equatorial Trough. During the southern hemisphere summer a continental heat low pressure zone develops and results in high instability and heavy rains throughout the region in the December to March period. In contrast to the warm northerly air masses, invasions of cold polar air masses are common during the drier "winter" months of April to August, and produce marked and rapid drops in temperature as the cold front passes northward.

The moisture availability indices calculated for the region following Hargreaves (1972) method for determining agricultural seasons indicate that the region has a distinct dry season, ranging from 3 to 5 months between April and August. The dry season is more pronounced in the eastern part of the region; annual rainfall is higher in the western sector of the region, ~1800mm, and grades to ~1600mm in the east.

b- SOTER Units

Over the Pando Department 54 SOTER Units were delineated and mapped, most of which were further subdivided into "terrain components" to provide details of the landscape and soil variations within any one Unit. The SOTER Units were delineated following fieldwork to describe the terrain and examine typical soil profiles of the region, and the results of the laboratory analysis of profile soil samples. The samples of the 360-odd soil profiles were analyzed following the method of Cochrane and Barber (1993), and the results digitized as an integral part of the SOTER database. From the mapping and digitalization of the SOTER Units, some generalized features of the lands found in the Pando may be summarized.

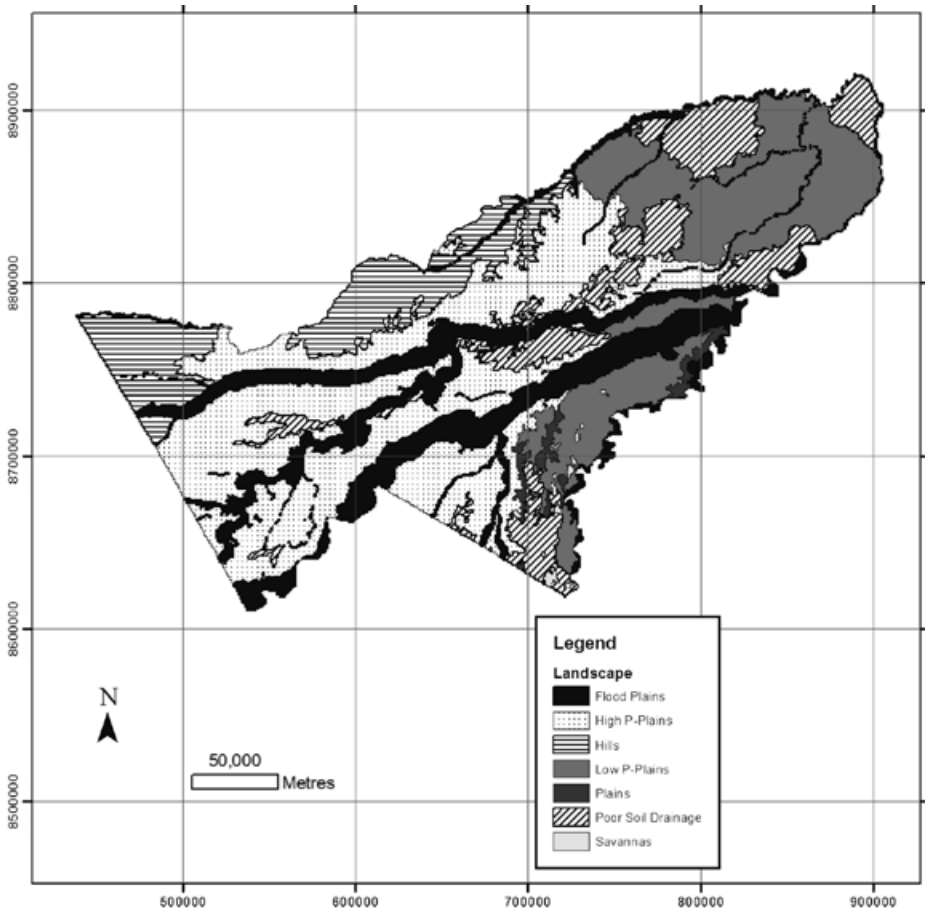

Figure 2. Landscape map of the Pando showing significant areas with poor soil drainage and flooding problems. Note: UTM zone 19S, coordinates in meters.

c- Landscape

A landscape map of the Pando was computer generated on the basis of the SOTER Units, according to overall soil drainage conditions and native forest versus savanna vegetative cover (Figure 2). The region is essentially a dissected plains area. To the west it is slightly higher, with a median altitude a little in excess of 150m. A significant proportion of the region has soil drainage problems in addition to flooding problems; a third of the land surface is affected by these two problems.

d- Soils

The soils were mapped and classified according to both the FAO-UNESCO revised legend (1990a), and the United States Department of Agriculture's Soil Taxonomy classification (USDA, 1987). It was found that 82% of the soils classify as Ferrasols or Lixisols according to the FAO system, and 58% classify as Oxisols and 24% as Ultisols, according to Soil Taxonomy. This confirmed that the majority of the soils of the region are highly weathered and poorly supplied with plant nutrients.

Soil physical characteristics. During the course of the in-field studies, the soils of the region were examined according to their physical properties to facilitate the evaluation of their susceptibility to erosion and their suitability for agricultural and tree crop production from a physical standpoint. It was estimated that >30% of the region is covered by steeply sloping lands that are very susceptible to erosion; only their existing forest cover protects these lands from severe soil loss.

It was further estimated that ~32%, or 2,024,000ha of the region is covered by soils that are either poorly drained and/or are subject to annual flooding. In fact, it was found that 825 700ha of the non-flooded soils have drainage problems, as seen on the landscape map of the region (Figure 2). The magnitude of the flooding, and especially the soil drainage problems impose a severe limitation on

TABLE I
CHEMICAL PROPERTIES OF THE 3,308,782 HA OF THE FLAT, WELL-DRAINED, NON-FLOODED SOILS FOUND IN THE PANDO DEPARTMENT OF BOLIVIA

Property	Percentages of the defined area		
pH	Low <5.4	Med 5.4 - 6.5	High >6.5
topsoil	79	21	0
subsoil	70	30	0
Carbon	Low <0.6%	Med 0.6 - 3%	High >3%
topsoil	4	96	0
subsoil	79	21	0
Phosphorus (Olsen)	Low (3ppm)	Med (3-6ppm)	High (>6ppm)
topsoil	48	52	0
subsoil	94	6	0
Exchangeable cations, $cmol_c \cdot kg^{-1}$			
Calcium:	Low <0.4	Med 0.4 - 4	High >4
topsoil	26	74	0
subsoil	67	33	0
Magnesium:	Low <0.2	Med 0.2 - 0.8	High >0.8
topsoil	18	68	14
subsoil	28	76	6
Potasium:	Low <0.15	Med 0.15 - 0.3	High >0.15
topsoil	32	57	11
subsoil	79	10	11
Sodium:	Low <0.1	>0.1	
topsoil	72	28	
subsoil	78	22	
Aluminium:	Low <1	Med 1 - 1.5	High >1.5
topsoil	22	27	51
subsoil	21	20	59
ECEC:	Low <4	Med 4 - 10	High >10
topsoil	70	30	0
subsoil	77	23	0

Al Sat. >55% of ECEC: Topsoil 51%, Subsoil 70% of total area

land usage throughout the region.

*Soil chemical characteristics***.** The soil analyses provided a wealth of information relevant to potential plant toxicity conditions and nutrient deficiency problems. This information was collated on a SOTER Unit by Unit basis.

Table I provides a brief summary of the soil fertility conditions of the flattish (<8% slopes), well-drained lands of the region that are not affected by flooding, which cover ~52% of the Pando. From Table I it can be seen that these soils have low pH levels, base exchange properties, P and C levels. Soil organic matter as gauged by their C levels, is intimately linked to the nutrient-cycling phenomenon of these forested lands. It was evident that the soils would be incapable of supporting forests were it not for the nutrient-cycling phenomenon. Further, the low pH values and high Al saturation levels would indicate that many of the soils have potentially toxic conditions for crops; they would require high levels of lime for adequate crop production (Cochrane *et al*., 1980). This problem, coupled with the need to fertilize to correct other low plant nutrient levels, would cast serious doubts as to the economic cost of these lands for crop production such as oil palm (*Elaesis guineensis*) or improved pastures. Those lands that have been deforested in recent years for cattle raising are already showing the effects of nutrient degradation. Near the town of Cobija in western Pando (Figure 1) deforested lands under pastures are barely capable of sustaining one head of cattle per 6-8ha (Cochrane *et al*., 1994b). Local experience indicates that forest regeneration on abandoned cultivated land regenerates very slowly, and even more so if it had previously been under pasture.

e- Native vegetation

The SOTER Unit delineation facilitated the compilation of a map of the several major native vegetation formations (Figure 3). Tropical semi-evergreen seasonal forests predominate through the region, with hydroseres found as inclusions on poorly drained or flooded lands. The forests on the well drained lands have emergents forming an open upper story canopy that ranges 35-50m in height, depending on the specific land areas. In addition to their considerable amount of valuable timber species, it was seen that they are a rich source of both Brazil-nuts and rubber. Native cacao is common in the more western parts of the region; in areas with deficit drainage conditions heart of palm is harvested from some of the palm species (*Palmaceae* spp.; ZONISIG, 1996). An interesting finding from the complementary ZONISIG forestry inventory studies was that there was a much higher proportion of Brazil-nut tress in these forests than previously thought. In fact, it was found that the Brazil-nut tree populations in some areas of the forests were the highest recorded for the Amazon as a whole (ZONISIG 1996, 1997).

Apart from the forest formation, some minor areas of mainly poorly drained savanna lands, ~18,600ha in all, are found in the south-eastern areas of the region.

f- Deforestation

The land resource study showed that deforestation, especially in the vicinity of Cobija, the capital city of the Pando, has increased dramatically in recent years. Between 1986 and 1990, satellite imagery showed that the area cleared, in the vicinity of Cobija alone, increased by 56%; 27,680-43,080ha (Cochrane *et al*., 1994a). Figure 4 shows a lonely Brazil-nut tree standing in a degraded pasture on land cleared of its original luxuriant forest near Cobija. Clearing these forest lands for ranching has invariably led to degraded and unproductive pasture lands.

Throughout the Pando Department as a whole, Cochrane *et al*. (1994a) estimated that over 50,000ha of the forests had been cleared for cattle ranching by 1990, and over 80,000ha seriously degraded by timber extraction and other activities. Follow-up work by Steininger *et al*. (2000), and the satellite imagery work of Killeen *et al*. (2007), indicate that deforestation in the Pando has been proceeding apace since 1990; at least 200,000ha of the forests have now been cleared for cattle raising and twice as much again seriously degraded by careless timber felling. This is a continuing ecological tragedy that the objective of the land resource studies to help local land use was intended to ameliorate.

A LUZ map (Figure 5), was prepared as the major objective of the land resource study (Cochrane *et al*. 1994a), to guide the rational use of the natural resources of the Pando Department and the conservation of its forest resources. The "zones" were defined and delineated as a result of interdisciplinary findings and discussions (ZONIZIG 1996, 1997). The objective was to provide a framework for the development of the region without destroying its unique Brazil-nut forests. Eight land use zones were delineated:

Settlement areas. The choice of settlement areas for agricultural activities were qualified from the outset by emphasizing that these were delineated for non-intensive agricultural systems, and only as a response to the sociological realities within the region. The areas zoned for settlement were not designated for colonization by people from other regions of Bolivia; agricultural colonies invariably expand and the resultant land clearing would only speed the destruction of the natural forestry resources of the Pando. Approximately 306,000ha

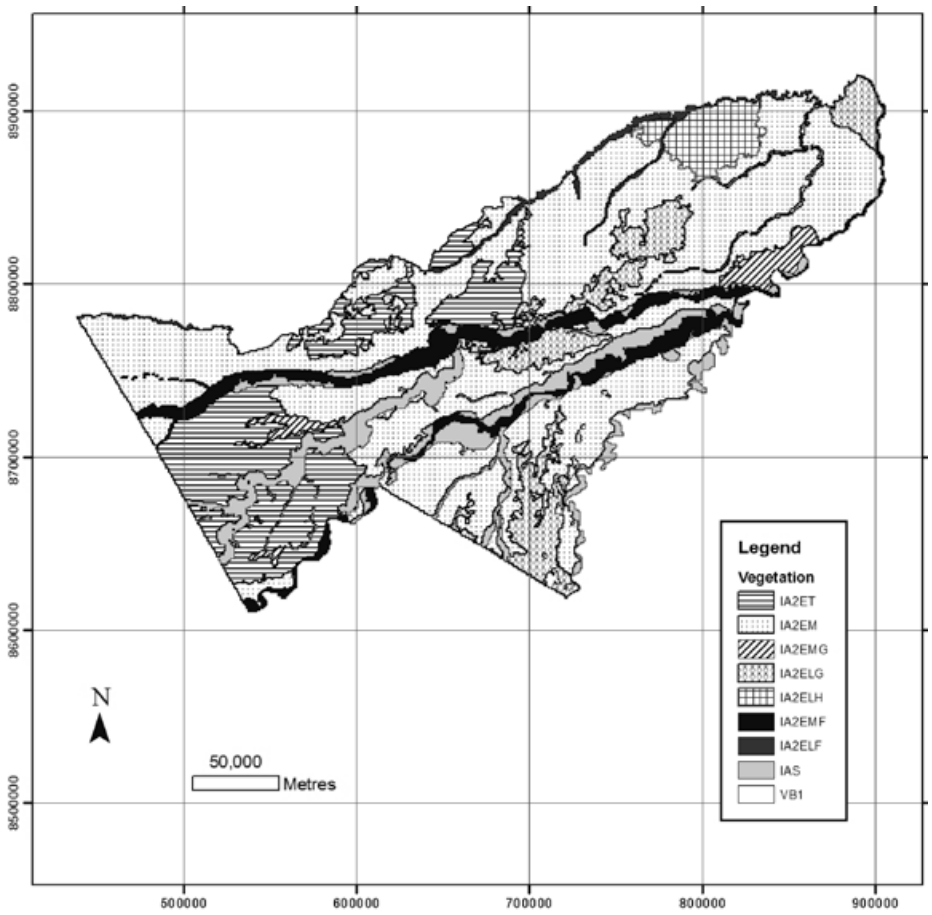

Figure 3. Native vegetation of the Pando as described in terms of the physiognomic classes used by UNESCO (1973). The IA2E code refers to tropical semi-evergreen seasonal forest (50-100% of emergents are dry season deciduous). IA2ET, IA2EM, and IA2EL refer to forests on well drained non-flooded forested soil with emergents >40m, 30-40m, and <30m, respectively. IA2EMG, IA2ELG, IA2ELH, IA2EMF, and IA2ELF refer to forests on imperfectly drained or flooded soils with suffix of G, H, F representing imperfect drainage, poor drainage, and annually flooded forests respectively. IAS refer to swamp forests and VB1 to poorly drained savannas.

(4.9%) of the Pando Department were delineated as settlement areas.

Extensive ranching on native savannas. Minor areas of natural wetland savannas, 18,600ha (0.3%), of the Pando Department, mosaic with the forested lands in the south-eastern quadrant of the region and were zoned for extensive ranching.

Native forest reserves for flora. The area zoned as a native forest reserve for the conservation of native flora includes the major physiognomic forest types of the region, that range from low to tall semi-evergreen seasonal to almost evergreen forests, along with their hydroseres. These forests may well prove to be invaluable in the years to come in terms of their genetic diversity. They cover 1,028,000ha (16.3%) of the Pando Department.

Native forest reserves for fauna. Two areas were chosen as forest reserves for fauna, where hunting for animals should be prohibited. a) An area of 281,000ha in the north-eastern Pando Department, which is virtually unpopulated by human beings, mainly because of its poorly drained soils. b) An area of 115,000ha in the north-western corner of the Pando, which is hilly and would otherwise be categorized as a critical watershed region. These areas cover 6.3% of the Department.

Figure 4. A solitary Brazilnut tree (2m diameter) in land cleared for cattle ranching near the city of Cobija.

Extractive reserves. Over 43.4% of the Pando, some 2 745 000ha, were zoned for extractive activities that would cause a minimum of damage to the forest ecosystem. The forests covering the zone are seres (intergrades) of tropical semi-evergreen seasonal forests naturally endowed with Brazil-nut, rubber and many tropical hardwood trees. Selective extractive activities, but under more closely managed or supervised conditions, were also envisaged for Zones 3, 4, 6, 7 and 8, giving a total of ~5,994 000ha (94.9% of the Department). Efforts in sustainable timber and non-timber forest extraction and management in some of these regions are ongoing with different levels of success (Guariguata *et al*., 2008; Dauber *et al*., 2005).

Areas with significant, but still relatively sparse rural populations were zoned in this land use category. They are found on different landscapes throughout the region. Nevertheless, their soils are uniformly poor; Ferralsols (Oxisols and Ultisols) predominate. Deforestation for cattle raising should be prohibited on these lands, and attempts made to re-establish forests in areas already affected. Indiscriminate forest removal on these lands, and in fact over most of the Pando, can only lead to massive soil water erosion problems and exacerbate soil nutrient degradation.

Managed forest reserves. An area of ~486,000ha (7.7%) of the Department, running along Bolivia's northern border with Brazil, was zoned as a reserve for managed forests. This zone has a complex of landscapes including hills, high and low peneplains with varying soil-forest combinations. It is currently used for Brazil-nut collection and some rubber tapping.

Critical watersheds, hilly areas. The hilly area along the eastern portion of the northern border of Pando, which covers ~512,000ha (8.1%) of the Department, has been zoned as a critical watershed area.

Critical watershed, flooded areas. Most of the alluvial lands along the extensive river sys-

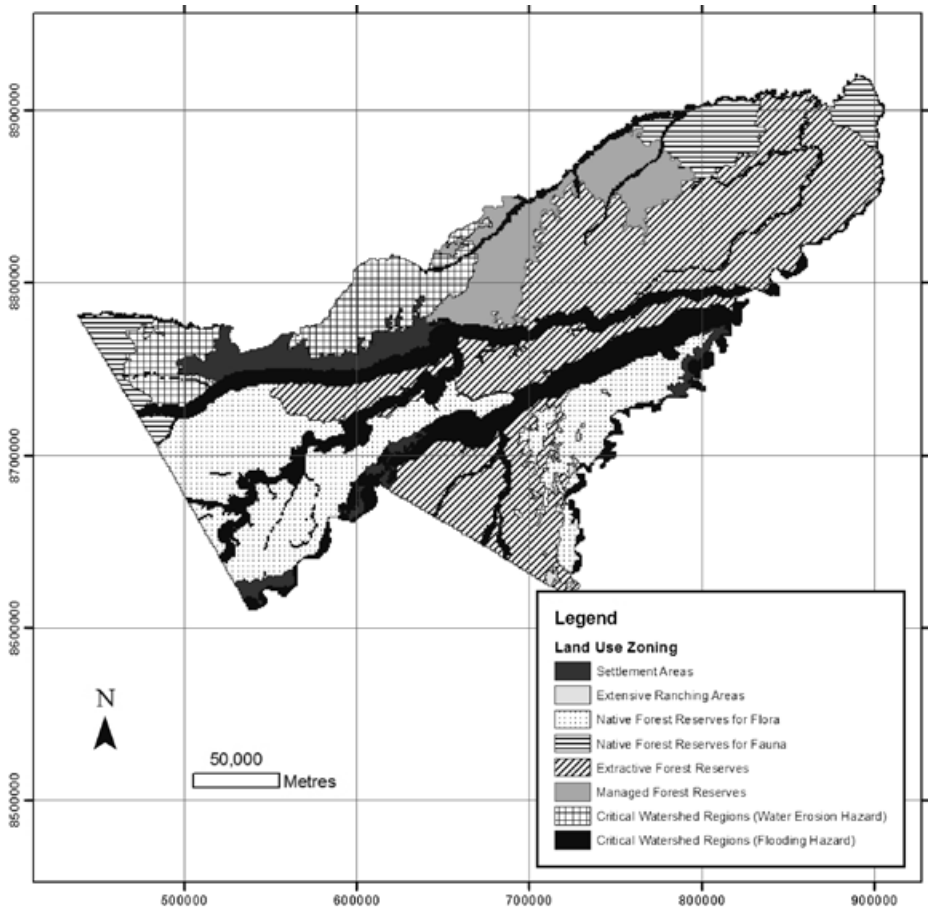

Figure 5. The Land Use Zoning map for the Pando Department, Bolivia.

tems of the Pando Department, ~827,000ha (13%), are subject to severe annual floods, and are quite unsuitable for close settlement. The existing flood plains provide expansion zones to ameliorate peak flow rates of rivers. Without such settlements sited in riberine areas, would simply be washed away.

Conclusion and a Recommendation

The land resource study did not identify any substantial areas of land that could be considered as being inherently fertile and suitable for agricultural and/or agro-pastoral purposes. Although it was estimated that 52% of the region has soils with slopes <8% that are neither flooded nor poorly drained, this statistic does not take to account other physical let alone nutrient limitations. The soil analyses show that almost all of the latter land have poor and fragile fertility states. Apart from low nutrient and pH levels, many have potentially severe Al toxicity problems. The little fertility they have is intimately linked to the carbon cycle of the forest cover, which has been built up over the centuries. In short, the findings indicate that forest removal for agricultural and agro-pastoral activities, can only lead to an ever-accelerating pattern of land degradation.

Up until the early 1990s ~80,000ha of the Pando Department had already been affected by land clearing. More recent studies have shown that deforestation has increased substantially during the last 20 years, in order to use more and more of these lands for cattle ranching. The typical forest sound in many parts of the region is no longer the whistle of the *seringeiro* (rubber tapper) birds or the early morning chattering of monkeys, but the high-pitched whine of chain-saws. Most deforested lands are degrading rapidly, and high levels of expensive amendments and fertilizers will be needed if production is to be maintained.

The land use zoning (LUZ) map (Figure 5) was drawn up on the basis of the research on the soil and forest resources of the Pando Department, taking socio-economic factors to account. Unfortunately, to date little has been achieved by the local authorities to implement the recommendations of the study. However, although deforestation is proceeding at an ever-accelerating pace throughout the region, the authors note that there are still a reasonable proportion of the native forests physiognomically intact. Parts of the areas zoned as natural reserves can still be saved as areas for the preservation of the region's typical flora and fauna. As these are some of the last remaining relatively intact remnants of the centre of origin of many of Amazonia's natural forest trees, especially the Brazil-nut trees, their unique biodiversity and genetic resources should be preserved as a biological treasure trove for humanity, and further forest clearing prohibited. In view of the ongoing and irresponsible destruction of the forests of the region, the authors would suggest that serious thought be given to the creation of a World Heritage Area with international finance, sought for the conservation of representative areas of these unique Brazil-nut forests.

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ZONIFICACIÓN DEL USO DE TIERRA PARA LA CONSERVACIÓN DE BOSQUES DE CASTAÑA EN LA AMAZONIA BOLIVIANA

Thomas T. Cochrane, Thomas A. Cochrane y Oscar E. Llanque Espinoza

RESUMEN

Es reconocido por botánicos que los bosques occidentales de la Amazonia son el centro de origen de la castaña Bertholletia excelsa y de muchas otras especies de árboles productivos. En los años 90 fue comisionado un estudio de recursos de suelos y tierras utilizando la metodología del World Soils and Terrain Database (SOTER) para establecer una base para la zonificación de la región con el objetivo de preservar la castaña del departamento de Pando, Bolivia. Se encontró que las tierras del Pando tienen niveles bajos de fertilidad y serían incapaces de sustentar bosques si no fuera por el fenómeno de reciclaje de nutrientes que ocurre en esa región, hallazgo apoyado por el estudio de suelos de la región. La experiencia local confirmó que los bosques de la región regeneran muy lentamente. Los estudios también demuestran que las tierras son evidentemente inapropiadas para la "colonización" agrícola. Estudios complementarios de inventarios forestales confirmaron que hay concentraciones muy altas de árboles de castaña que podrían apoyar una actividad extractiva más intensa. Para detener la destrucción de los bosques nativos, un mapa regional de zonificación del uso de la tierra fue preparado en consulta con especialistas y gente del lugar. Desafortunadamente, poca atención fue dada a los mapas y la deforestación continúa a ritmo acelerado. En vista de esta situación, los autores sugieren que se piense seriamente en la posibilidad de crear un área de Patrimonio de la Humanidad con financiamiento internacional para la conservación de áreas representativas de los bosques de castaña.

ZONIFICAÇÃO DO USO DE TERRA PARA A CONSERVAÇÃO DE BOSQUES DE CASTANHA NA AMAZONIA BOLIVIANA

Thomas T. Cochrane, Thomas A. Cochrane e Oscar E. Llanque Espinoza

RESUMO

É reconhecido por botânicos que os bosques ocidentais da Amazônia são o centro de origem da castanha Bertholletia excelsa e de muitas outras espécies de árvores produtivas. Nos anos 90 foi comisionado um estudo de recursos de solos e terras utilizando a metodologia do World Soils and Terrain Database (SOTER) para estabelecer uma base para a zonificação da região com o objetivo de preservar a castanha do departamento de Pando, Bolivia. Encontrou-se que as terras de Pando têm níveis baixos de fertilidade e seríam incapazes de sustentar bosques se não fosse pelo fenômeno de reciclagem de nutrientes que ocorre nessa região, descoberta apoiada pelo estudo de solos da região. A experiência local confirmou que os bosques da região regeneram muito lentamente. Os estudos também demonstram que as terras são evidentemente inapropriadas para a "colonização" agrícola. Estudos complementários de inventários florestais confirmaram que existem concentrações muito altas de árvores de castanha que poderiam apoiar uma atividade extrativa mais intensa. Para deter a destruição dos bosques nativos, um mapa regional de zonificação do uso da terra foi preparado em consulta com especialistas e gente do lugar. Desafortunadamente, pouca atenção foi dada aos mapas e a deflorestação continua a ritmo acelerado. Em vista desta situação, os autores sugerem que se pense seriamente na possibilidade de criar uma área de Patrimônio da Humanidade com financiamento internacional para a conservação de áreas representativas dos bosques de castanha.