Geoecology and biodiversity – Problems and perspectives for the management of the natural resources of Bolivia's forest and savanna ecosystems

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Abstract. A brief review of geoecology, biodiversity and biogeography is given, as well as a discussion of the problems and options for the natural resource management of Bolivia's forests and savannas.

The high level of biodiversity in Bolivia's forests and savannas is due to its geographical position that borders a tropical climate and is closely related to strong longitudinal and altitudinal gradients. Soil conditions and hydrology in combination with regional geology are strong determinants for biogeography and diversity. Bolivia is not located in the heart of any of the main neotropical biotas. The general high biodiversity of Amazonian ecosystems in juxtaposition with other very different floras and faunas is the reason for Bolivia's high diversity.

In many regions of Bolivia, low soil fertility, floods and geomorphology make it difficult to improve land utilization, but the chances are good for seeing management of forests and savannas implemented. In recent years, the Bolivian government has opened up to reform and is creating the foundation necessary for natural resource management. The low human population-forest and savanna ratio meets the prerequisites for the management of natural ecosystems. The past policy of "free" land has affected ecologically sensible planning up to the present. Timber logging, colonization and agro-business accelerated the exploitation of extant areas.

Nevertheless, there are options for the sustainable management of the country's forests, that also take various constraints and restrictions into consideration. In fact, Bolivia's savannas have the best prospects for implementing wildlife management programs based on a few economically promising species in the near future.

Geo-ecología y biodiversidad - Problemas y perspectivos para el manejo de los recursos naturales de los ecosistemas del bosque y la sabanas de Bolivia

Resumen. Se ofrece una breve visión de la geoecología, la biodiversidad y la biogeografía, así como una discusión sobre los problemas y alternativas para el manejo de los recursos naturales de los bosques y las sabanas de Bolivia.

El alto grado de biodiversidad en los bosques y sabanas bolivianos se debe a su posición geográfica fronteriza con un clima tropical y guarda una estrecha relación con fuertes gradientes longitudinales y altitudinales. Las condiciones del suelo y la hidrología, en combinación con la geología regional determinan decisivamente la biogeografía y la diversidad. Bolivia no se encuentra en el centro de ninguna de las principales biotas

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neotropicales. La alta diversidad de Bolivia es causada por la biodiversidad generalmente alta del ecosistema amazónico en yuxtaposición con otras floras y faunas muy diferentes.

En muchas regiones de Bolivia, el bajo grado de fertilidad del suelo, las inundaciones y la geomorfología dificultan una mejora del uso de la tierra, pero existen buenas perspectivas de cara a una implementación del manejo de bosques y sabanas. En los últimos años, el gobierno boliviano se ha mostrado abierto a reformas y está creando la base necesaria para el manejo de los recursos naturales. La baja proporción de población humana en bosques y sabanas responde a los prerrequisitos para el manejo de ecosistemas naturales. La política de tierra "libre" seguida en el pasado ha dificultado hasta ahora el ejercicio de una planificación preocupada por la ecología. La tala de madera, la colonización y la industria agraria aceleró la explotación de áreas aún existentes.

Sin embargo, existen posibilidades para el manejo sostenible de los bosques del país, posibilidades que contemplen también varias restricciones y limitaciones. De hecho, las sabanas de Bolivia cuentan con las mejores perpectivas para la implementación en un futuro próximo de programas de manejo de la vida salvaje basados en unas pocas especies económicamente prometedoras.

1 Introduction

About ten years ago, Bolivia was one of the biologically and ecologically least known countries in South America. Even in the early nineties, many parts of Bolivia's eastern Andean slope and its lowlands were largely unknown to science. Although this situation has since changed, it would be an exaggeration to say that today we have sufficient knowledge about the country's biodiversity. Numerous expeditions lead to the first-time registration of new plant and animal species in Bolivia and reports on species that are new to science.

There are few relatively complete long-term local inventories of biodiversity. Our knowledge regarding the distribution of endemism is meagre. The same is true of geoecological data. Too little is known of the soil properties of larger regions – information that is needed for evaluating land-use potential and for land-use planning.

This paper briefly reviews the relationship between the geoecology, biodiversity and biogeographical complexity of Bolivia's forests and savannas, and discusses some problems and options for natural resource conservation and utilization.

2 A brief review of the geography and geoecology of the Bolivian lowlands and the eastern Andean slope

The Bolivian territory encompasses three hydrological systems. Most parts of the lowlands and the eastern Andean slope belong to the Amazon drainage system. Only the southern-most areas drain into the La Plata basin. The smaller Andean highland (Altiplano) system is strictly endorrheic, without any drainage into the sea.

2.1 Area covered by forests and savannas

Forests cover still about 535,000 km² (CDC 1995) of Bolivia's territory. They are distributed throughout the eastern part of the country, with the exception of *Polylepis* open forests that occur in some parts of the Altiplano which can be found altitudes up to 5,000 m above sea level (Kessler 1993). Inner-Andean forests were destroyed in the years following the colonial period as the *ordonanzas* of the Spanish viceroy Francisco de Toledo (1563-1583) indicate (Heinrich & Equivar 1991). In recent decades, some 3% of the natural forest cover has been lost.

Natural savannas occupy 170,000 km² or more of the lowlands, primarily in the Beni savannas (Beck 1983, Hanagarth 1993), the Cerrado woodlands in the Chiquitania highlands (Killeen 1990) and the western-most parts of the Pantanal. The isolated mountain savannas in the Yungas mountain forests are probably the result of human influence. They displaced dry, semihumid and subhumid forests (Beck 1993).

2.2 Geology, soil and hydrology – Decisive factors for biota and diversity distribution

There is a marked relationship between the distribution of certain biota and regional geology, soil, hydrology and geomorphology. Bolivia's geographical location between the Andes in the west and the Brazilian shield in the east largely determines its geology.

The upper and mideastern Andean slope (1,000 - >6,000 metres above sea level) consists mainly of Paleozoic rocks. The terrain is extremely rugged and has deep valleys that are encompassed by high mountain chains. Although it is shallow and generally acidic, the soil is quite fertile. Cretacic, Tertiary and Pleistocene sediments as well as deeper, more nutrient-rich soils are much more widely distributed in the wider valleys found at lower altitudes.

The Precambrian Chiquitania highlands constitute the western-most part of the Brazilian shield. This ancient peneplain is located at altitudes of 200 to 300 metres above sea level. Much of it is covered by weathered lateritic and leached soils that are probably Tertiary in origin. A few scattered inselbergs and mountain chains reach altitudes ranging from 800 to 1,200 m above sea level (Killeen *et al.* 1990, Ibisch *et al.* 1995).

Located between both massifs, the Beni Chaco plain is part of the Pericratonic basin which extends from Venezuela to Argentina along the Andes. Most parts of this plain do not exceed an altitude of 200 metres above sea level. Exceptions are the subandean piemont and the Santa Cruz region which can reach more than 400 m a.s.l. This flat plain extends southward from northern Bolivia to the Chaco and Pantanal. Geologically speaking, it is divided into an older northern and a younger southern region by the Bala Rogagua line which runs through the middle of the Beni savannas. Large areas of the northern waterlogged Beni savannas are covered by highly weathered, extremely leached soils. Lateritic duricrusts,

pisolithic and plinthic soils extend north to the Pando province in Bolivia and the Brazilian Acre province in Brazil which are covered by Amazonian forests.

Sediments from the southern Beni flooded savannas to the Chaco plain are from late Pleistocene and Holocene age, and are covered by slowly weathered soils. Alkaline soils are found even in the southern Beni savannas, where periodic floods cover areas of 80,000 km² or more, and occur more frequently with increasing proximity to the dry Chaco (Hanagarth 1993).

2.3 Latitudinal and altitudinal climate gradients

In addition to Bolivia's geological history, the country's diverse climates are vital to an understanding of the high degree of variability and heterogeneity found in Bolivia's forest and savanna ecosystems. The country's geographical location near the border to the tropics, and the structure of the Andes influence the movement of the intertropical convergence zone (ITCZ) which drifts south to southern Bolivia during the southern hemisphere's summer season and determines climatic conditions in the Bolivian lowlands, along the eastern Andean slope and in the Andean highlands. The ITCZ and low pressure centres in the Paraguayan Chaco cause extremely high precipitation levels, mainly in the southern part of the Beni Chaco plain and along the Andean slope.

In climatic terms, the eastern Andean slope is much more diverse than the lowlands. The most humid and perhumid area is located in the Chapare region, with annual precipitation exceeding 5,000 mm. The northwestern part of the Bolivian lowlands and the Andean slope is influenced by the southwestern Peruvian precipitation centre near Quince Mil and receives 7,000 mm or more of precipitation. Along the Andean slope, high altitudinal differences, "Massenerhebungseffekt", latitudinal gradients, mountain-valley wind systems and a complex orography that is related to the geology of this landscape are responsible for the region's high geoecological diversity which is a juxtaposition of arid and humid valleys, arid valley bottoms and perhumid mountain crests.

A general northwest-southeast precipitation gradient prevails in the lowlands. The eastern parts are generally drier than the western parts near the Andes, where humid and perhumid conditions dominate; a hot subhumid climate predominates in the centre of the country and in the northern lowlands. In the Santa Cruz region, a narrow west to east oriented semihumid-semiarid transition zone with strong rainfall gradients separates the arid Chaco from the tropical humid areas in the north.

Cold waves of polar origin, known as "surazos," cause the temperature to drop sharply to a absolute minimum of 6° to 7°C in the Beni province, and 0°C in the southernmost regions, and are occasionally accompanied by strong rainfalls (Hanagarth 1993). These cold waves affect most parts of the Bolivian territory, and possibly serve a selective function in regard to the distribution of tropical plant and animal species. Most parts of the country are influenced by strong El Niño phenomenon (Ronchail 1995, Hanagarth 1993).

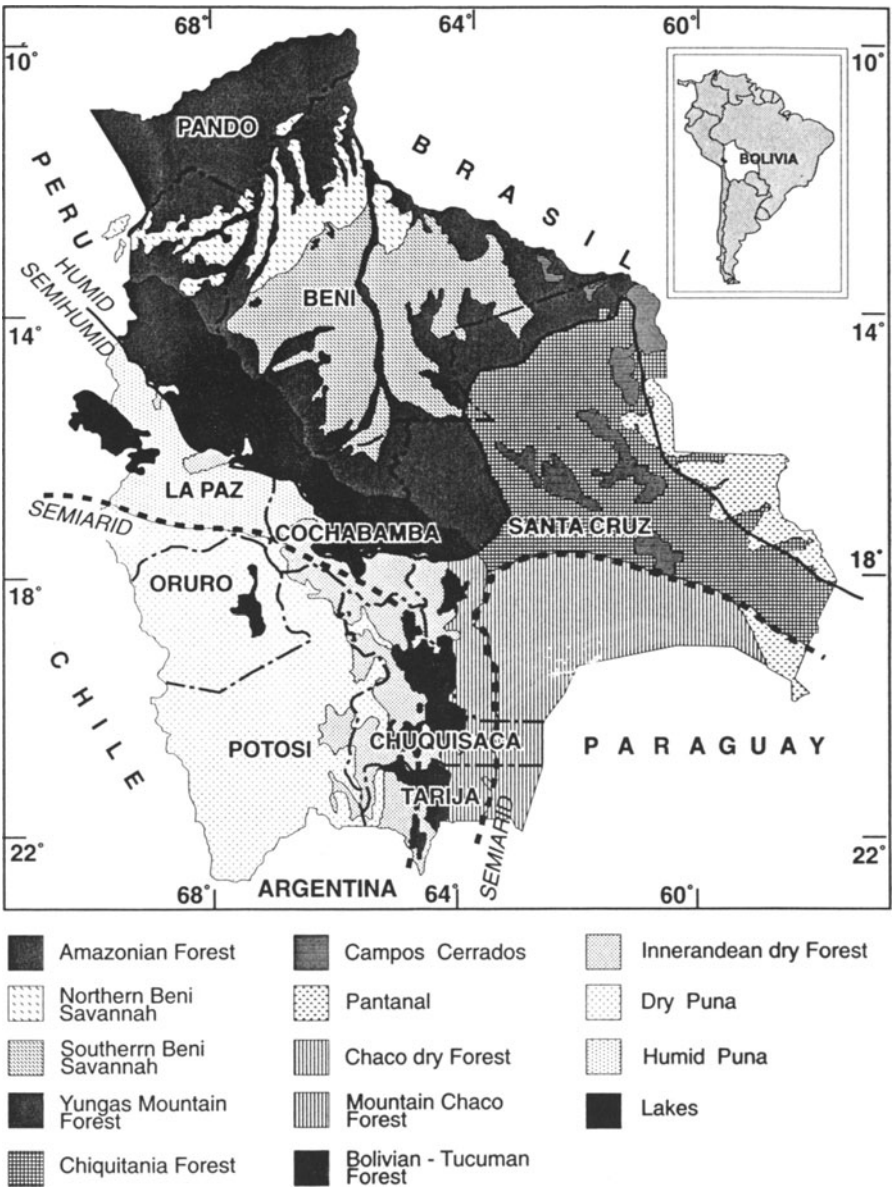

Fig. 1. Main Bolivian vegetation formations and biotas
Ilustración 1. Principales formaciones y biotas de vegetación en Bolivia

2.4 Biodiversity and biogeography

Bolivia's overall species richness is related to the country's biogeographical complexity. Bolivia is not located in the heart of any of the large biota. It can however claim to be the most important transitional country between the major

biotic regions in southern South America (Conservation International 1991). This is due to its strong climatic gradients, markedly regional geological differences, and its edaphic and hydrological variability.

Aout twelve primary biogeographically different biotas exist in Bolivia (Fig. 1). They range from hot and perhumid rain forests, dry Chacoan woodlands, edaphic Cerrado and Pantanal-like savannas to cold, dry puna deserts and tropical glaciers. Ribera (1992) names 40 different vegetation formations.

Climate is a major factor in the distribution of forests and woodlands, as is the case along the eastern Andean slope. Humid and perhumid mountain forests, which are biogeographically related to similar mountain forests in Peru and Ecuador, dominate the northern and central parts of the eastern Andean slope. But geomorphology, and the effects of the Andes' geological and tectonic evolution interact with certain valley-mountain wind systems, thus permitting the existence of arid and semiarid inner-Andean valleys that are surrounded by humid forest ecosystems in the upper and middle Yungas. Subtropical semiarid and arid climatic conditions become increasingly important along the southeastern Andean slope. The mountain vegetation in this region is closely related to the Chaco biota and Bolivian Tucuman forest. It covers large parts of these areas, depending on th respective hygric and thermic conditions.

In the lowlands, factors other than climate are decisive as well. Table 1 shows how differences in geological evolution result in two very different edaphic and hydrological subregions in the apparently homogeneous Beni plain (Fig. 1). In contrast to the geologically younger southern Beni savannas which are more closely related to the geologically and ecologically similar Pantanal, the northern Beni savannas are dominated by Cerrado-like vegetation which is similar to the vegetation of the Cerrados of the Chiquitania highland and that of Brazil. Although the species diversity in both Beni subregions seems to be similar, many plant species are of different biogeographical origin and the distribution boundaries of both floras are strongly related to the previously mentioned geological and edaphic borders. These differences could be found up to family level (Hanagarth & Beck 1996).

Distribution of seasonal evergreen rain forests in the lowlands, woodlands and grasslands seems to be related with sedimentation caused by fluvial processes which alter the soil and the hydrology of surface and ground waters. Savannas predominate waterlogged areas, in areas with lateritic duricrusts and in young alluvial overflow plains with compact soils.

Climatic factors play a larger role in the semihumid-semiarid transition zone and particularly in the south. However, the distribution of Cerrado and Chaco dry forests still reflects the general influence of the region's geology and soils. Cerrado vegetation is generally found only in the old Precambrian shield. Chacoan forests are found only in areas having young Pleistocene and Holocene sediments that were deposited by rivers originating in the Andes. Although the sharply defined biogeographical boundaries of the northern Chaco and of the Chiquitanian semidecidous forest seem to be determined mainly by climate, but their occurrence within this climatic zone is generally related to geomorphology, certain drainage patterns and soils.

Table 1. Geoecological differences between the northern and southern Beni savannas

	Northern Beni	Southern Beni
Savanna type	Termite-earthworm-mound-savanna; proposed denomination: "Campos del Beni"	Levee-Isla-Park Savanna; proposed denomination: "Llanos de Mojos"
Main biogeographical relationship	Brazilian and Chiquitanian Cerrado	Brazilian Pantanal
Relief	Flat to moderately rolling high plains; glen-like, and river plain valleys	Generally flat to slightly rolling plains with deep riverbeds; comparable valleys do not exist
Geology, geomorphology	Old alluvial plain, partially dissected, large, poorly drained plains with zoogenic *sartenejales*, subrecent sedimentation present only near the Andes, erosional processes dominate in the centre	Young alluvial overflow plain, subrecent, and recent river levées, terraces, and platforms; erosional processes low, recent sedimentation near the Andes
Soils	Highly weathered, leached, very acidic to acidic (pH 3.5->5), presence of lateritic duricrusts, pisoliths, nodules, plinthites; acrisols, ferralsols, distric luvisols, and cambisols; contains no carbonates	Slightly weathered, moderately nutrient-rich, very acidic to alkaline (pH 3.4->9) laterites are absent, plinthite is scarce; hydromorphic soils, eutric luvisols, and cambisols, alkaline soils; rich in carbonates
Type of inundation	Large periodically waterlogged *sartenejales*, floods restricted to river flood plains, large swamps only west of the Beni river	Periodically deep (till up to over 2-5 m), large-scale floods (>80,000 km²), large swamps, duration of floods 3-4 months, in marshes 6-10 months
Surface waters of regional origin	Electric conductivity very low to low (4.2- 20(51)µS/cm); clear (white) waters dominate, "black" waters are rare	Electric conductivity low to high (very high) (13-130(600)µS/cm); in rivers white waters in dry season, "black" waters in rainy season, seasonal "black" and "brown-clear" water dynamic in swamps and creeks
Ground waters	Electric conductivity extremely low to low (5.5-40(50)µS/cm; fluctuation of water level high (up to 8 m)	Electric conductivity moderate to very high (135-1743µS/cm), fluctuation of water level low to moderate (1-5 m)

Sources: Hanagarth (1993), Hanagarth & Beck (1996), Hanagarth (unpubl.).

A biogeographical patchwork exists in the area surrounding the city of Santa Cruz where strong climatic gradients predominate. It is here that most Amazonian and Yungas elements reach their southernmost, Chaco and Bolivian-Tucuman forest

species their northernmost, Cerrado species their westernmost, and Andean species their eastern-most distribution boundary (Hanagarth & Beck 1996).

2.5 Megadiversity is mainly the result of biogeographical juxtaposition

Species numbers are strikingly high, giving Bolivia a level of diversity that is comparable to that of the most diverse countries in South America as well as throughout the world. Moraes and Beck (1992) calculate that there are 18,000 to 20,000 plant species (Bryophyta: 1,200 species, Pteridophyta: 1,300 species, Gymnospermae: ca. 16 species, Dicotyledoneae and Monocotyledoneae: 17,000 species). Ibisch (1996) offers a checklist containing 1,054 Bolivian epiphyte species. About 14,000 plant species are actually known (Beck, pers. com.).

Birds are the best-studied groups of all animals. Arribas *et al.* (1995) registered 1,358 species (43% of all South American fauna). Compared with the data of Remsen and Traylor (1989), who mention 1,274 species, this represents an increase of 6.2% in six years. As more inventories are conducted in several lesser known areas near the Brazilian, Peruvian and Paraguayan borders, the number of bird species may rise to nearly 1,500. Although fish are little-known vertebrates, approximately 500 species are registered today and 200 more species may be expected when the Yungas rivers, the northern most Amazonian waters and the Bolivian Pantanal are studied more intensively. Almost 400 fish species were found in the Río Mamoré basin. New mammals were caught during several expeditions conducted in the past few years, raising the number of known native species to a total of 319. Reptiles and amphibians are the least known vertebrates. Ergueta & Sarmiento (1992) listed 220 reptile species, and De la Riva (1990) 112 amphibians. The number of species is increasing continually in both groups. Eleven new amphibian species have been described for Bolivia since 1990 (Erqueta & Morales 1996).

The level of our knowledge of endemism is still inadequate. Taxonomic revisions and more collections are needed. Previously published data regarding species numbers is not representative and requires correction. Ibisch (1996) mentions 298 (28%) confirmed or probable epiphyte endemics, distributed primarily in the eastern Andean slope. This is a contrast to the Beni savannas where actually 14 revised plant species seem to be true endemics (Hanagarth & Beck 1996). The level of our knowledge of fish, amphibians and reptiles does not permit any definitive conclusions. Today, 26 reptiles and 23 amphibians may be considered as endemic to Bolivia (Ergueta & Morales 1996). A recent review by Anderson & Tarifa (1996) yielded 15 endemic mammal species. Several potentially "new" species are still to be described.

Endemism seems to be very high in the Yungas mountain forests and in some transition zones with extremely pronounced rainfall and temperature gradients, such as those in the Cochabamba area, east of the Cordillera Real in the Department of La Paz, and along the extreme southern Andean slope, where climatic conditions were more stabile in the past. They seem not to have been as

strongly affected by climate changes as most other areas were. The level of endemic diversity is considerably lower in the lowlands. However, this is not the last word on the subject. It seems that both species endemism and the number of species with a narrow distributional range areas are low. On the other hand, the number of subspecies endemics may be somewhat higher than is currently known.

Bolivian forests and savannas are considerably different in terms of their diversity. The greatest diversity has been found along the eastern Andean slope. Although alpha diversity is lower in the upper and middle Yungas than in the lower Yungas, beta diversity is high due to the orographical and local variations in the region's ecosystems. The northern part of the lower Yungas displays unusually high regional and local diversity due to the strong influence of the high general species richness of the upper Amazonian forests near the base of the Andes (Conservation International 1991) and as the result of the close juxtaposition of different floras and faunas. For example, it was possible to collect 988 plant species in a little more than one week and to register 403 bird species within two weeks in the Alto Madidi area. This, together with the region's suspected 140 mammal species, evidences a very high level of diversity. Remsen & Parker (1995) stress that the whole Madidi area may contain somewhat more than 1,000 bird species, and even several more when the adjacent fauna of the Tambopata-Candamo reserve is taken into account as well. They believe this area to have the greatest bird richness in the world.

Similar patterns of diversity may exist in many other areas along the Andean slope southward to Santa Cruz, where Clarke & Sagot (1996) were able to register more than 830 bird species in and around the Amboró National Park where biogeographical diversity of species and ecosystems may be higher than in the north due to high beta diversity. Although diversity decreases further south, endemism seems to remain high in the Bolivian-Tucuman and inner-Andean dry valleys (Ibisch 1996).

A strong north to east species-richness gradient as well as a slighter west to east gradient exists in the Bolivian lowlands.

It is estimated that diversity in the Amazonian rain forests near the base of the Andes is extremely high, with more than 2,000 plant species and over 800 tree species per 10,000 km^2 (Ibisch 1996). Conservation International (1994) and Duellman & Koechlin (1991) cite more than 550 bird species over the space of a few thousand hectares. 92 mammals more than 20 lizards, 47 snakes, five turtles, four crocodilians and almost 80 amphibians are expected in one locality in the neighbouring Peruvian Tambopata-Candamo reserve. Species numbers of mammals may increase to about 130 (including >50 bat species). There may be 500 ant species, some 1100 diurnal butterfly species (Lepidoptera) and 300 carabid species (Carabidae, Coleoptera), evidencing the high local diversity of many insect groups. The areas inhabited by several endemic bird species of the southwestern Amazonian Inambari endemism centre extend south to Santa Cruz. The eastern parts of the Bolivian Amazon region seem to have a biogeographical influence of the Rondônia centre and a lower species richness. A high level of diversity may exist along the base of the Andes and south to Santa Cruz, even though cold waves may keep some tropical plant and animal species from existing

in the area's southern humid and perhumid forests. In contrast, southern elements may have increasingly greater influence.

The transition zones of forests and savannas draw sharp biogeographical borders for many species, and diversity is lower in savannas, compared to the rain forests.

Because they are more arid, Chiquitanian semideciduous forests may have only 200 to 400 tree species. Bolivian inselbergs which mostly occur as granitic outcrops are the most southeastern outcrops on the continent and are probably quite isolated from other neotropical inselbergs. Their species composition differs from the surrounding vegetation. Compared to Venezuela and Brazil, these inselbergs have lower levels of general and gamma diversity which can perhaps be attributed to their marginal and isolated location within a climatic transition. It appears that endemism is lower in Bolivian inselbergs than in other neotropical inselbergs (Ibisch *et al.* 1995).

There is somewhat more information regarding local and regional diversity in the Beni savannas and the Chiquitanian cerrado. Long-term botanical studies of two localities of the Beni savannas yielded 523 and 799 plant species respectively (Hanagarth & Beck 1996). Killeen (1990) collected 609 species in the Chiquitanian cerrados of Concepción. A total of 284 birds, 68 mammals and about 25 amphibians has been registered in the inundated savanna of Espiritu (Hanagarth & Specht in prep., Aguirre *et al.* 1996) as well as 257 bird species in Concepción (Davis 1993). This data tallies with comparable studies in other neotropical savannas. The same is true of many other faunal groups. That is to say, the number of ant species, including those species living in gallery and island forests, does not exceed 200 (Verhaagh, pers. com.), compared to more than 500 species in the rain forest.

The Chacoan dry forest has the lowest diversity. Based on their numbers, flora and fauna species are less diverse. Nevertheless Chacoan endemism is high. Abundances, among several mammal species for instance, may occur in resource-rich areas.

3 Outlooks for natural resource management

There is tremendous potential for the Bolivian economy in the high biodiversity of the country's forests and savannas and their biogeographical differentiation. At the same time however, this potential poses a tremendous challenge to efforts to implement the biodiversity convention and to realize sustainable development because it is not possible to apply general resource-use strategies. Considering how much must be done in the political, social and economic fields, Bolivia is confronted with problems that are directly or indirectly related to the destruction of natural resources. Poverty is no longer the only factor that accelerates the exploitation of valuable resources. It has been joined by the interests of powerful groups such as agro-business and the logging industry.

The Bolivian government expressed its interest in sustainable development in the "Cumbre de las Americas", the second western hemisphere meeting of politicians

on energy, water, and biodiversity that was realized in December 1996 in Santa Cruz de la Sierra. Time will tell whether it is possible to create the foundation necessary to sustainable development at national and international level.

3.1 Status of Bolivian conservation

In counterpoint to the past (Hanagarth 1990), the Bolivian government has reformed several laws and passed a number of new ones such as the environmental law in the last eight years. The new law on the conservation of biodiversity has not yet gone into force. Several laws are essential to the implementation of sustainable development and natural resource management (see Sánchez de Lozada, this volume). Hopefully, the decentralization process supports these activities, but there is the possibility that local and regional bodies will favour the exploitation of resources for short-term economic gains. Efficient long-term monitoring systems are needed.

3.2 Protected areas

In recent years, Bolivia has made substantial progress in the conservation sector, with the help of international cooperation. The National System of Protected Areas (SNAP, Sistema Nacional de Areas Protegidas) consists of 26 conservation units (Sánchez de Lozada, same volume) Other areas have been proposed and their inclusion in the system is still pending. Several areas require a redefinition and/or need manageable boundaries (or limits). A few protected areas have management committees. The SNAP protects approximately 10% of Bolivia's entire territory.

The conservation and rigorous protection of several protected areas' natural key ecosystems may be very important for the long-term maintenance of many species. Nevertheless, conservation should not be restricted solely to these areas. Protected areas must be the heart of "source areas."

Representative examples of Amazon forests, Chiquitania semidecidous forests, Pantanal, the dry forests of the inner-Andean valleys, and the Beni savannas still need to be protected. The dry forests in the southeastern Bolivian Andes and in the western parts of the Chaco also need protection due to their high endemism and to the fact that several endemics exist in areas outside existing protected areas, where humans have lived for hundreds of years or where recent colonization could threaten some endemics. Our lack of knowledge about endemics makes it necessary for land-use planning activities to draw upon scientific studies for developing conservation and utilization action plans in such areas.

3.3 Land-use potential and constraints

The regional options for land use in Bolivia are as varied as the country's flora and fauna are diverse. The orographically, climatically and pedologically highly diverse landscape of the eastern Andean slope limits intensive land utilization in that region. Poor soils and periodic inundations hamper intensive land use in large parts of the lowlands. Several studies conducted in the Santa Cruz department, in the Pando and in the Beni prove that using large areas of land that are not appropriate for intensive production due to low soil fertility and other constraints is problematic. Although Furley (1990) holds that some earlier fears concerning the impact of possible agricultural developments on the soil resources of the Brazilian Amazon may have been premature, he establishes that maintaining tropical soil fertility requires sophisticated management methods. The number of strategies for improving or initiating cultivation, ranching and other forms of land use depend on how well they can be adapted to local conditions.

Bolivia's social, economic and infrastructure problems leave little room for establishing a basis for implementing intensive agricultural systems. Highland peasants have neither the know-how or experience necessary to manage the soil or natural lowland ecosystems. Agro-businessmen generally do not show any interest in appropriate land-use management. Similar patterns can be found among long-established inhabitants and, to some degree, among indigenous people who also contribute to the overexploitation of natural resources nowadays. Different strategies for the implementation of sustainable development and natural resource management have to be developed for all four groups. It is urgently necessary that we learn from the negative effects of the earlier, destructive policy of "free" land which created numerous problems for regional planning and complicated the implementation of reforms needed for successful resource management.

The regulation of population movements is one of the most important prerequisites for planning and implementing colonization programs in areas with high land-use potential. New plans are needed that go beyond establishing an infrastructure and assigning plots of land, that extend to assessing peasants in agroforestry and other land use systems, and integrate adjacent areas for natural resource management. If government development organizations and NGOs fail to take research findings from colonization areas elsewhere in the humid tropics into account, they will continue to implement plans that are at odds with field results. Each colonization area has its own special properties and has to be understood as an experimental area where ecologically and economically feasible farming strategies emerge only slowly (approximately 10 years) (Moran 1990). Future colonization projects have to be geared toward minimizing loss of nature and toward balanced growth that causes a minimum of ecological damage.

3.4 Forest management: Problems and options

Despite several land-use constraints, Bolivia still has good chances (at least in theory) for implementing resource management systems in extant natural forests

and savannas. Any future success depends on appropriate policies, education, regional planning, control of land occupation and the monitoring of migration, assessment and other factors. Bolivia must develop clear-cut strategies that reconcile the need to utilize the land and the need to conserve nature on the basis of ecological, conservational and bioeconomical know-how.

Since the logging industry presently holds logging concessions for approximately 37% of Bolivia's forest land, it is a highly crucial factor and must be taken into account in any discussion of the management of natural forests. There are approximately 190 logging companies in Bolivia. Forty of them held logging concessions for 2.2 million hectares in the Beni department alone. In 1995, logging concessions had been granted for some 200,000 km^2 (about 18% of the national territory). Most logging areas are located in the Santa Cruz province (64%), in the Beni (20%) and in the Amazonian La Paz province (11%)(CIMAR, unpubl.). Approximately 443,000 m^3 and 477,600 m^3 were harvested in 1993 and 1994 respectively, primarily in Santa Cruz, Cochabamba and Beni (INE-SNIC 1996). About 160 timber species are exploited throughout the entire country. Fifty to 80% of all cut timber is mahogany (mara, *Swietenia macrophylla*). Illegal "motosierristas" (chain-saw loggers) exploit many other areas. It is worth noting that only a few larger areas are not yet affected by timber exploitation. Both logging companies and "motosierristas" use only 10 to 50% of a tree's usable timber. Today's primary forest exploitation is destructive (Fig. 2) and corresponds to a "cut, cash and run strategy. Such strategies are closely related to bioeconomical and market problems (see also the analysis by Rice *et al.* 1996).

Following extensive debate, Bolivia's new forest law was passed in 1996. Under this new law, 40-year forest concessions are transferred to companies that have to meet stringent requirements and obligations. The law allows indigenous peoples and other traditional groups, to use the forest in their native areas. Areas rich in rubber (gen. *Hevea*), Brazil nuts (*Bertholletia excelsa*) and palms (mainly *Bactris gasipaes, Attalea phalerata, Euterpe precatoria*) are transferred preferably to the peasant communities that have traditionally used them. The Ministry of Sustainable Development and Environment is politically responsible for this. The logging industry is not in a position to implement sustainable forest management. Experience is meagre and logging companies do not possess the necessary technical and economic know-how. Further, there are no incentives for implementing sustainable management. Technical assistance may be needed. The governments of Bolivia and the United States recently applied for the inclusion of mahogany in the CITES Appendix II because its status has become critical.

Existing logging concessions are not incorporated into general regional planning. Corresponding reforms are urgently necessary in light of the experience of other tropical countries which shows that conditions are most favourable for the sustainable management of natural forests when (1) there is little competition



Fig. 2. Legal logging of mahogany *(Swietenia macrophylla*) in a lowland forest
Ilustración 2. Tala legal de mara *(*caoba; *Swietenia macrophylla)* en un bosque de las tierras bajas

over use of the forest, (2) large tracts of forest still exist and (3) the quality of the forest products is so high that they can be sold for high prices (Prabhu *et al.* 1993).

3.5 Use of biodiversity by local people

Since it is highly unlikely that local inhabitants and people living in adjacent areas will accept the situation, when logging companies have exclusive rights for utilization of large forests concessions, forest protection policy must include, as one of its most important components, the promotion of social forest management programs. In addition to some form of certification or a "green" label for the sustainable production of timber, natural-forest management needs a "red" label as well, to signal that it is "socially sustainable." Tests for applying such methods, integrating the needs of local people, are being conducted in many parts of the tropics (Poffenberger 1990, Plotkin & Famolare 1992, Kiernan *et al.* 1992). Socially sustainable forest management needs to include other ways of utilizing forests than just logging, because of economic necessity. Many Bolivian forests are used in diverse ways. For instance, the Chácobo Indians who live in the northern Beni use 82% of the tree species. In the vicinity of the Ríos Blanco y Negro Wildlife Reserve, three indigenous tribes reported using a total of 305 medicinal plant species (Halloy 1996). The value of sustainable "unimproved"

forests is several times greater than the value of the same land after it has been converted to cattle ranching or plantations (Plotkin & Famolare 1992). But given our abysmal lack of knowledge of natural products and their potential uses, it is still hard to answer the essential question of how far high biodiversity is reflected in a high diversity of useful plants. Many non-timber products have only a "local price" for subsistence but no market price because their potential use is unknown.

The cultivation of pharmaceutical useful plants for industrial use may be just one option. Their utilization for health-care purposes at local and regional level is another alternative. It is however doubtful that such products could be subject to long-term demand as several conservationists and politicians hope. The forests' potential is diversified by the harvest of fruits, racines and nuts. Good marketing strategies are important instruments for introducing new products to national and international markets. Forests rich in Brazil nuts and palms (see also Moraes, same volume) must be placed under management before their last natural resources suffer any more negative impacts. We run the risk of losing natural capital that is needed to initiate successful projects. Bioeconomical assessments of rubber and other promising products that permit the implementation of low-cost initial projects are needed.

Although there is potential for improved market-oriented production that uses various enrichment/refining-systems, natural forest management, conserving biodiversity of an acceptable level, support a relative low human carrying capacity. This includes that each managed area needs to be clearly zoned in a way that indicates areas with different levels of utilization and conservation, as well as the type and degree of intervention required, applying the source-sink model, considering the creation of a corridor network, permitting the exchange of populations, among the partial areas. An array of alternatives such as agroforestry, cattle ranching and ecotourism has to be evaluated before their introduction, in order to buffer the human impact they involve.

Traditional communities and indigenous peoples have fundamental know-how, but their current forest utilization systems suffer destructive changes when they are adapted to market demands and Western culture. They are not capable of dealing with the complex socio-economic, cultural and ecological changes of a rapidly-changing environment on their own. It is therefore necessary to develop strategies for implementing management systems that integrate the specialized knowledge of traditional resource users into scientific knowledge and vice versa.

3.6 Wildlife utilization in forests

The future of the forests and the people who inhabit them will also depend in part on how successfully we incorporate wildlife management into the broad array of land-use options. If large tracts of wilderness do not begin to produce significant returns in the form of forest and wildlife products for local peoples within the next few years, the pressure that leads to spontaneous colonization and larger

development projects will quickly gain the upper hand (Freese & Saavedra 1991). Even though most game species seem to be reaching their natural population limits in some remote areas of Bolivia, there is a strong tendency to overhunt, even in regions with low human density. Even in the Pando province which is almost completely forested (0.6 inhabitants/km², INE-SNIC 1996), large mammals were decimated in the region, probably by Brazil-nut gatherers. Several regions are still suffering from the effects by the trade in animals and hides that occurred between the 1950s and 1980s. The fauna in areas covered by logging concessions has been depleted to feed the loggers, and in several other areas that villages and towns can access, monkeys and other game mammals are the target of intense commercial hunting. So-called "vaciamientos," which means "abnormal absence of populations of game species in one or more areas" caused by excessive hunting are also found in sparsely populated protected areas such as the Biological Station Beni and the indigenous territory Isiboro Sécure.

As in other countries, large mammals are more endangered than smaller ones. Since monkeys have low reproduction rates, they disappear more quickly than larger animals with higher reproduction rates and smaller mammals and birds (Robinson & Redford 1991, Ojasti 1991). For many species, productivity depends on their density and on the carrying capacity of the ecosystems in which they live. In Bolivia, only a few studies have been conducted on the qualitative and semiquantitative status of game species, but it has been proven that the most commonly hunted game species are usually the largest members of their taxonomic group as well as the largest species in the forest. Hunting has a strong effect on such species. The effects of moderate and 'heavy' hunting were reviewed by Redford (1993), who stresses that moderate hunting reduces non-primate mammalian game populations to 19.3% of the levels reported at similar, unhunted sites, and 'heavy' hunting can even reduce them to 6.3%. A similar comparison made for game birds shows that their original density falls to 26.5% under the effects of moderate hunting and to 5.4% in the case of 'heavy' hunting.

Comparisons of data indicate that non-commercial subsistence hunting may affect the populations of some game species when human density is about or more than 1.3 inhabitant/km², causing some local thinning and/or a general population decrease. Townsend (1996) confirms that several species are overexploited in the Sirionó territory of Ibiato (1.35 inhabitants/km²) in the eastern Beni province. Cuellar (1997) documents that the Guaraní Indians living in the territory of Akae (which measures 33 km² and has about six inhabitants/km²) in the northwestern Chaco have reported a severe depletion of game species. Stearman (1990) and Robinson & Redford (1991) doubt that the Yuquí Indians' hunting of certain game species is sustainable.

Although Bolivia's indigenous territories suffer the negative effects of overhunting today, they may have the best options for implementing long-term management of game species, as well as the larger protected areas. Native people utilize game in more diversified ways than peasants and colonists do (Redford 1993). But there are serious long-term constraints such as very rapid human population growth and the growing amount of settled territory, the erosion of cultural integrity, the restricted diversity and heterogeneity of ecosystems and

their carrying capacity for game species. Townsend (1996) concludes that the Sirionó population may double through natural growth in about 10 years' time, and Cuellar (1997) reports annual growth of about 4 % in the Akae community which means a doubling in about 18 year's time. Game management has to include source areas where ecological conditions permit high reproduction rates and sink areas – where reproduction rates are lower as a result of unfavourable conditions – which may be the most important hunting areas. Establishing resource management in such territories involves widely diverse political and economic interests which makes conflict inevitable. When indigenous territories must have a role in biodiversity utilization and conservation, then they have to be designated for long-term sustainability, must be large enough. Moreover, planners together with native communities have to look for economical alternatives to reduce or to moderate the pressure on game species. Townsend (1996) ascertained that the territory of Ibiato, which covers an area of 340 km^2 (459 Sirionó inhabitants in 1993) with 161 km^2 of forest and 179 km^2 of savanna woodlands, grassland and swamps, comprises only one third to one half of the minimum area needed for sustainable game management. Management must integrate the surrounding areas. The Isiboro Sécure, in Pilón Lajas and in the Chacoan Kaa-Iya territories may have the best chances for the implementation of game management with high subsistence and economical benefits.

3.7 Restrictions on and options for integrating wildlife management in the Beni savannas

Natural resource management in Bolivian savannas is different from forest management in several ways. Since the Beni savannas are the largest and most promising savannas for specific wildlife management, the following comments will focus mainly on their potential for natural resource management. Land in the Beni savannas is generally used for private low-level cattle ranching. In contrast to agriculture which must deal with economical and ecological constraints, cattle ranching could be improved by about 30% to 50% in the southern Beni savannas with ecologically sound management methods.

Few other regions can match the benefits that the Beni savannas offer for the implementation of wildlife management systems. Human population density is low (1.3 inhabitants/km^2, INE-SNIC 1996). Most parts are periodically flooded wetlands that have many small and large swamps (some covering more than 300 to 400 km^2) and comprise one of the most important ecosystems for waterfowl, wading birds and migrant birds of South America. Although crocodiles and some other species have been decimated as the result of commercial hunting since the 1950s and 1960s, it would be possible to implement game management systems in a relatively short time, in addition the black caiman (*Melanosuchus niger*) and the londra *(Pteronura brasiliensis)* have not yet been able to recover their populations and swamp deer populations *Odocoileus dichotomus*, Fig. 3) are currently being reduced by hunting and possibly by the transmission of cattle diseases. In the years since the Bolivian government's "veda total" (total



Fig. 3. The Beni savannas are important habitats for the swamp deer (*Odocoileus dichotomus*)
Ilustración 3. Las sabanas de Beni constituyen hábitats importantes para el ciervo de los pantanos *(Odocoileus dichotomus)*

prohibition of hunting) in 1986, the caiman or "lagarto" populations (*Caiman yacare*) have increased well in several extant swamps and rivers. Capibaras or "tapiguaras" (*Hydrochaeris hydrochaeris*) are very numerous because they are only occasionally hunted for hides and their meat is not consumed. Ornamental and commercial fish are abundant, sometimes with more than 200,000 individuals/hectare in swamps (Sarmiento & Hanagarth unpubl.). Since most terrestrial savanna mammals depend in part on forests (Redford & Da Fonseca 1986, Aguirre *et al.* 1996) they are less abundant in open grassland savannas. As a result, peccaries, tapirs and other mammals do not offer interesting opportunities for economically-oriented management. Conservation plans are nevertheless needed. Mammals are more abundant in forest-savanna transition zones (Townsend 1996).

Inundation savannas are fragile ecosystems. For this reason, it is important that decision-makers determine how they are to be changed and utilized on a long-term basis. Although inundation savannas are highly productive ecosystems, there are some constraints that restrict their management. The following options are available for the development of wetland savannas: (1) Conversion of the wetland into a radically different ecosystem in order to create new conditions; (2) Strict conservation of the wetland as a whole to profit from it (3) Maintenance of the wetland ecosystem, its functions and the benefits it provides while allowing a

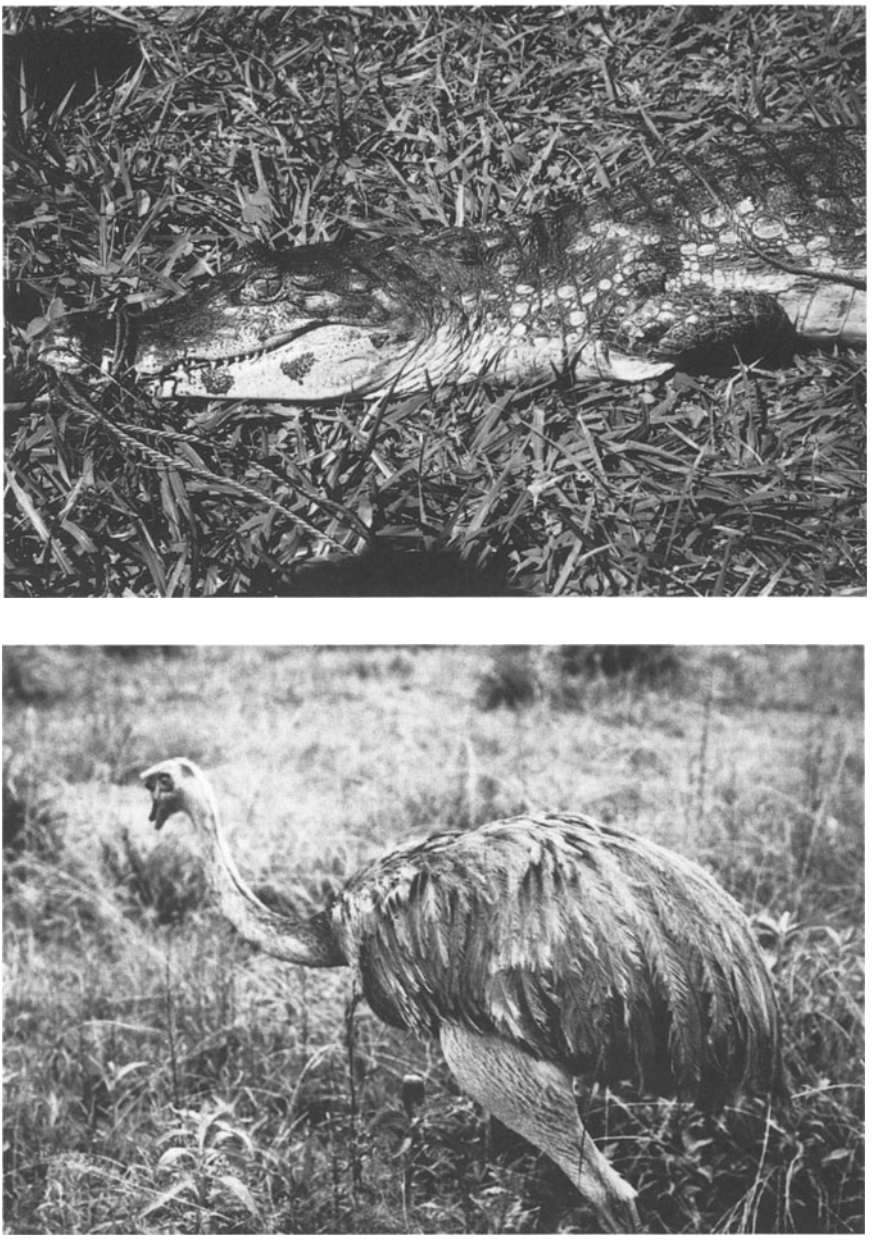

Fig. 4. *Caiman yacare* (a, above) and *Rhea americana* (b, below) are promising species for cattle and wildlife ranching in the southern Beni
Ilustración 4. *Caiman yacare* (a, arriba) y *Rhea americana* (b, abajo) son especies prometedoras para ganadería y manejo de vida silvestre en el sur de Beni

certain level of resource use; and (4) Maintenance of the greater part of the wetland and conversion of the rest (Roggeri 1995).

In light of the fact that the geomorphology and ecology of these savannas is very complex, options 3 and 4 are to be recommended. A basin-wide management plan that integrates the bordering regions of the Santa Cruz and Cochabamba departments into cross-sectoral and cross-departmental planning and coordination activities is needed. Poorly planned drainage projects in the Santa Cruz region and adjacent regions could cause flood peaks in the central-southern Beni savanna that greatly exceed those experienced during the enormous floods of 1982 and 1992, and thus put towns, villages, cattle breeding operations and natural resources at threat.

Drainage measures and natural erosion processes prove that although local alteration of water regimes changes the composition of pastures in a favourable way in one area, it may have a catastrophic effect in others. Ecologically important areas such as the Biological Station Beni Biosphere reserve could be adversely affected when large swamps, that play a key role in the region's ecology are drained, a measure that would drastically alter plant and animal communities. Road construction projects can cause severe changes. Drained areas may suffer edaphic aridity that causes water and feed shortages during the dry season affecting the regional ecology and economy. Because these savannas are extremely flat, drainage measures can result easily in uncontrollable, chaotic and unfavourable erosion processes along artificial channels.

These savannas offer excellent options for the integration of wildlife management into cattle ranching operations, which would enhance the economic value of large parts of this region particularly if this is accomplished in conjunction with the controlled harvesting of three pre-selected wildlife species which could represent the most efficient economic value. For this purpose, the abundant caiman (*Caiman yacare*, Fig. 4a), ñandu (*Rhea americana*, Fig. 4b) and capibara (*Hydrochaeris hydrochaeris*) currently offer the best basis for implementing management systems. The farming of neotropical species has not proven to be more economical than ranching to date because the higher overhead costs reduce any profit (Terborgh *et al.* 1986). In the case of caiman, ranching may be the only economical method for managing a species whose hides are not as valuable as those of crocodiles and alligators, which can also be found in other tropical regions and compete with the neotropical caiman (Magnusson 1984, Thorbjarnarson 1991). The population of the more valuable benian black caiman remains very small, and they may need rigorous protection for many years to come.

Since passage of the "veda total" in 1986, the caiman population in some areas has recovered considerably better than in the years before. The ñandu population is especially large in the wetlands of the central-southern Beni savanna, but excessive egg gathering takes a heavy toil on their numbers. Meat and valuable hides could be produced in the management of the ñandu. Capibaras remain abundant because their meat is still rarely consumed. Examples from Venezuela and Argentina prove that it is both possible and profitable to integrate the capibara into open-habitat management systems. All three species have high reproduction

rates. For instance, the reproductive efficiency of capibara is six times that of cattle and it produces 2.6 times more meat in Venezuela (Ojasti 1991). Whether management is successful depends on the development of markets for meat and the integrated utilization of the hides and derivative products. These three species offer an opportunity for implementing of wildlife management systems within a short time, and could serve to change the minds of politicians who advocate cattle and wildlife ranching.

The swamps, ponds, river and marshes in the cattle ranches around the Biological Station Beni, in the Isiboro Sécure and Ibiato territories as well as in some large swamps may contain areas with potential for management projects. Concepts and plans are needed – that benefit not only ranchers, but small farmers and landless peasants who may resort to poaching in order to access these resources, should game management be placed exclusively in the hands of the ranchers (see also Ojasti 1991).

3.8 The "common property" problem

The 'tragedy of the commons' where communally-held resources tend to be overexploited is likely to prevail. This "common property" problem is of great importance for the management of natural resources (Endres & Querner 1993). At the root of this problem is non-existent or insufficient regulation of property, harvesting and hunting. Control mechanisms must prevent the overexploitation not only of game species, but of timber and non-timber products as well. Optimal long-term utilization of natural resources has to be oriented to the maximum annual yield which is used together with other components to determine a resource's bioeconomically optimal use. Without such regulations, overexploitation and even local or regional extinction may happen. Voluntary restraint on the part of individuals does not have much success. Plotting "common property" may be a remedy, but does not take into account that resource stock moves freely between plots. In this case the user's right in one plot does not give him the right to use a certain resource unit; he is given only the possibility of accessing defined quantities within defined spatial limits. It is absolutely necessary to determine the intensity of use and form of utilization which in turn have to be adjusted to the carrying capacity of the ecosystems and to the dynamics and regenerative capacity (and migration) of each resource. A wealth of experience proves that the "common property" problem exists and that efficient solutions are decisive for the successful management of natural resources. Cost-benefit analyses that also take the biological-economic, social and cultural potential of an area into consideration are indispensable for the development of a conservation-oriented economy.

4 Final comments

The high geoecological and biological diversity of Bolivia is a true challenge that does not permit us to recommend general "prescriptions" for the sustainable management of natural resources. Various examples have been given which could be implemented within a relatively short time, demonstrating to politicians and people that there are opportunities for sustainable resource management. It must however be recognized that the conservation and use of biological resources is much more complicated than the management (or manipulation) of abiotic resources or biological elements in an altered or man-made environment. Managing biological diversity successfully with long-term aims depends on whether politicians complete the task of creating the various necessary foundations soon. This means working to develop a socio-economic and ecological conscience at national and international level. Globalization in its present form does not seem to be compatible with numerous prerequisites for the management of diversity and sustainable development. If the necessary political measures are not implemented, this dream may burst like a soap bubble. The question is: Is there a serious desire for integrating the conservation and utilization of biodiversity into sustainable development? Scientists can offer usable and practical know-how, and managers have to integrate the knowledge and experience that exists at international and local level into projects. Politicians have to create the national and international basis for success.

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