Range management and land-use practices in Chiquitanía, Santa Cruz, Bolivia

Timothy J. Killeen

Introduction

Chiquitanía is situated on the western edge of the Brazilian (Precambrian) Shield in northeastern Santa Cruz, Bolivia (Fig. 1). Colonized over 250 years ago by Jesuit missionaries, the local inhabitants have used the native savanna vegetation for cattle production, while exploiting the forest for timber and wildlife. Slash and burn agriculture is common, but does not pose a significant threat to forest vegetation due to low population density and the emigration of inhabitants to the departmental capital, Santa Cruz de la Sierra. The recent introduction of exotic forage grasses adapted to forest soils threatens to disrupt this traditional land-use pattern. The increased productivity and high nutritional quality of these grasses, principally *Brachiaria decumbens* and *B. brizantha,* allow for higher stocking rates and easier management of cattle (Paterson 1984). Consequently, forest destruction for pasture establishment is occurring at accelerated levels. Following are some observations of the area which are intended to promote investigations leading to improved range management in this important cattle producing area of tropical lowland Bolivia.

Description of the Region

Chiquitanía has a typical savanna climate with a pronounced dry season of 5 months coinciding with the austral winter. Mean annual precipitation is about 1,200 mm but can vary from 700–1,500 mm (for 35 years of data at Concepción). Mean daily temperature varies only slightly throughout the year, reaching a maximum of 26° C in June. Cold fronts sweep through the region during the dry season, causing the temperature to drop to 10° C for short periods; maximum temperatures of about 33° C are common in November at the beginning of the rainy season.

Concepción and San Ignacio lie on dissected Tertiary planation surfaces which overlie large portions of the Precambrian Shield. Highly weathered ferralitic soils have developed on the ancient sediments and well drained savanna predominates on red, distrophic ultisols and oxisols, while forest islands occur over mesotrophic, reddish brown alfisols. Entisols, inceptisols, or histosols predominate in valley bottoms and on erosional services associated with savanna wetlands. North and east of the Tertiary peneplain is an undulating plain where the soils have developed in situ from undifferentiated, granitic gneiss of the Precambrian Shield. Forest predominates on this landscape and the soils are more fertile than those of the Tertiary plain. South and west of Concepción is a hill region known as Lomerío with a topography that varies between 300 and 1,000 m above sea level. This area has a complex geology with formations of granite, quartzite, schists, and phyllites; the vegetation of Lomerío is composed of a rich mosaic of forest, savanna, wetland, and granitic outcrops (Killeen et al. 1990).

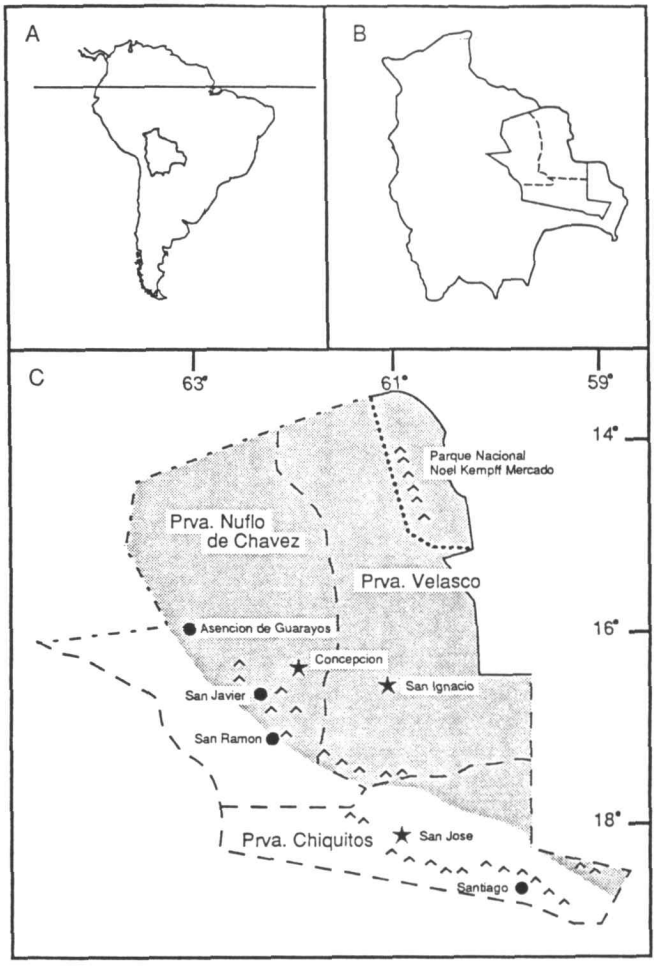

Fig. 1. *A)Map of South America showing Bolivia. B) Geographic position of Chiquitanía within Bolivia. C) Chiquitanía in detail: stippled area corresponds to the Brazilian (Precambrian) Shield; stars represent provincial capitals; dots are other large villages; and carats mark serranías or hill country (after Killeen 1990).*

Floristically, the vegetation is most closely related to the *cerrado* of the central Brazilian plateau (Killeen and

The author is with the Missouri Botanical Garden, his current address is Casilla 8854, Correo Central (Nuevo), La Paz, Bolivia.

Nee 1990). The term *cerrado* refers to a complex of intergrading communities which range from low forest to open grassland (Fig. 2) and is derived from the term *campo cerrado,* which translates as "closed grassland." *Cerrado* is floristically rich and is characterized by woody species which display a tortuous aspect; most species are deciduous with simple, coriaceous leaves. The grass sward is dominated by caespitose perennial grasses which form characteristic "bunches" 10–30 cm wide at ground level and which form a closed herbaceous stratum approximately 1 km in height. The *cerrado* vegetation has been extensively studied and its ecology has been described by Eiten (1978). In Santa Cruz, Bolivia, the *cerrado* vegetation of well drained soils is generally classified into three categories which are referred to as *pampa* (grassland), *pampa arbolada* (wooded grassland), and *arboleda* (woodland).

Physically associated with *cerrado* communities is a treeless savanna wetland that forms a clinal sequence along a gradient of increasing water surplus. Known locally as *puquios,* these "valley-side *campos*" (as they are known in the Brazilian literature) occur wherever there is a fluctuating, perched water table which seeps out on gently sloping valley sides (Fig. 2). Except for an abrupt narrow ecotone at the top of the soil moisture gradient, there is virtually no floristic similarity between valley-side *campo* and *cerrado* (Goldsmith 1974). In larger valleys with a flat bottom, impeded drainage or the overflow of an adjacent stream leads to the formation of a seasonally inundated savanna complex. Known variously as *curiches* or *campos* in Bolivia, these savanna wetlands are referred to as *pantanal* or *murundu campos* in Brazil. Scattered across these open grasslands are raised earth platforms associated with termite mounds. Situated a few cm above the level of maximum inundation these platforms support woody plants typical of *cerrado* communities (Fig. 2). Phytosociological studies of similar savanna wetlands have been conducted in the Llanos de Mojos of northern Bolivia (Haase and Beck 1989), the Gran Pantanal (Prance and Schaller 1982), and in central Brazil (Diniz de Araujo Neto et al. 1986).

Forest vegetation in the area remains poorly studied but a preliminary inventory conducted by Ruiz (1982) classified the forest into several categories based on the height of the canopy and the abundance of economically valuable tree species. All forest types are semideciduous with a predominance of trees with compound leaves. Stands with canopy trees 20 to 25 m tall were classified as "high forest" (Fig. 2) and an almost continuous vegetation gradient exists that eventually intergrades with *cerrado.*

Range Management

Savannas are fenced into enclosures of 100–3,000 hectares and no attempt is made to subdivide the *estancias* (ranches) to allow for a systematic rotation of grazing. Cattle graze throughout the enclosures but are lured with salt back to the paddocks in the evening. In the morning, *vaqueros* (cowboys) accompany the cattle and "guide" them to parts of the *estancia* with "more grass." However, this informal grazing rotation is not uniformly practiced, especially on poorly managed *estancias* with nontenant owners.

Fire is the range management procedure most frequently used in this region. *Ganaderos* (cattlemen) systematically burn savannas towards the end of the dry season and burns are staggered over a 3-month period between July and October. Fire stimulates the immediate regrowth of many savanna grasses and provides green forage during a critical time of the year. This growth occurs independently of precipitation, indicating that soil moisture at the end of the dry season (in average years) is sufficient to support growth.

Stocking rates vary widely, but in *cerrado* vegetation, Paterson (1984) recommended 0.2–0.3 animal units per hectare (one animal unit = 400 kg live weight). *Estancias* commonly are stocked at approximately double the recommended rate.

The dominant plant species in *cerrado* (i.e., >50% total cover) is the unpalatable grass, *Elionurus muticus,* an extremely coarse plant with a lemon-like odor. The regional names, *paja carona* and *pasto amargo* (sour grass), refer to the traditional use of the fibrous leaves for weaving saddle pads *(caronas)* and the presumed bitterness of its foliage. *E. muticus* is readily eaten by cattle for a short period after the annual burn, but the rest of the year this grass is not grazed at all.

Frequent anthropogenic fire may be partially responsible for the dominance of *E. muticus.* Not only is the vegetative growth of this grass stimulated by fire, but plants will bloom approximately 3 weeks after being burned; if populations are not burned, plants will not flower. This fire-dependent phenological strategy ensures that diaspores escape fire and are deposited on the soil surface shortly after the input of mineral-rich ash. A few weeks later the rainy season will begin and provide seeds with a favorable environment for germination. This strategy is not restricted to the *cerrado* dominant: *Imperata brasiliensis, Eragrostis polytricha, Paspalum erianthum,* and *Digitaria neesiana* have a similar phenological strategy (Killeen 1990).

Although a greater proportion of the biomass of the grass sward is provided by fire-dependent species, there are a greater number of species whose reproductive cycle is dependent upon photoperiod. These species bloom within a well-defined time period during the rainy season. The most palatable *cerrado* grasses, *Thrasya petrosa, Schizachyrium micrstachyum, S. sanguineum,* and *Paspalum plicatulum,* are in this category and flower between March and May towards the end of the rainy season.

Ganaderos have developed an ingenious method for renovating degraded *cerrado* by broadcast sowing of *Hyparrhenia rufa (yaragua)* into the existing grass sward. This procedure is practical because the diaspores of *H. rufa* have sharp calluses and long, geniculate awns, morphological characters which promote the germination of grass diaspores (Peart 1979). If left ungrazed for 3–5

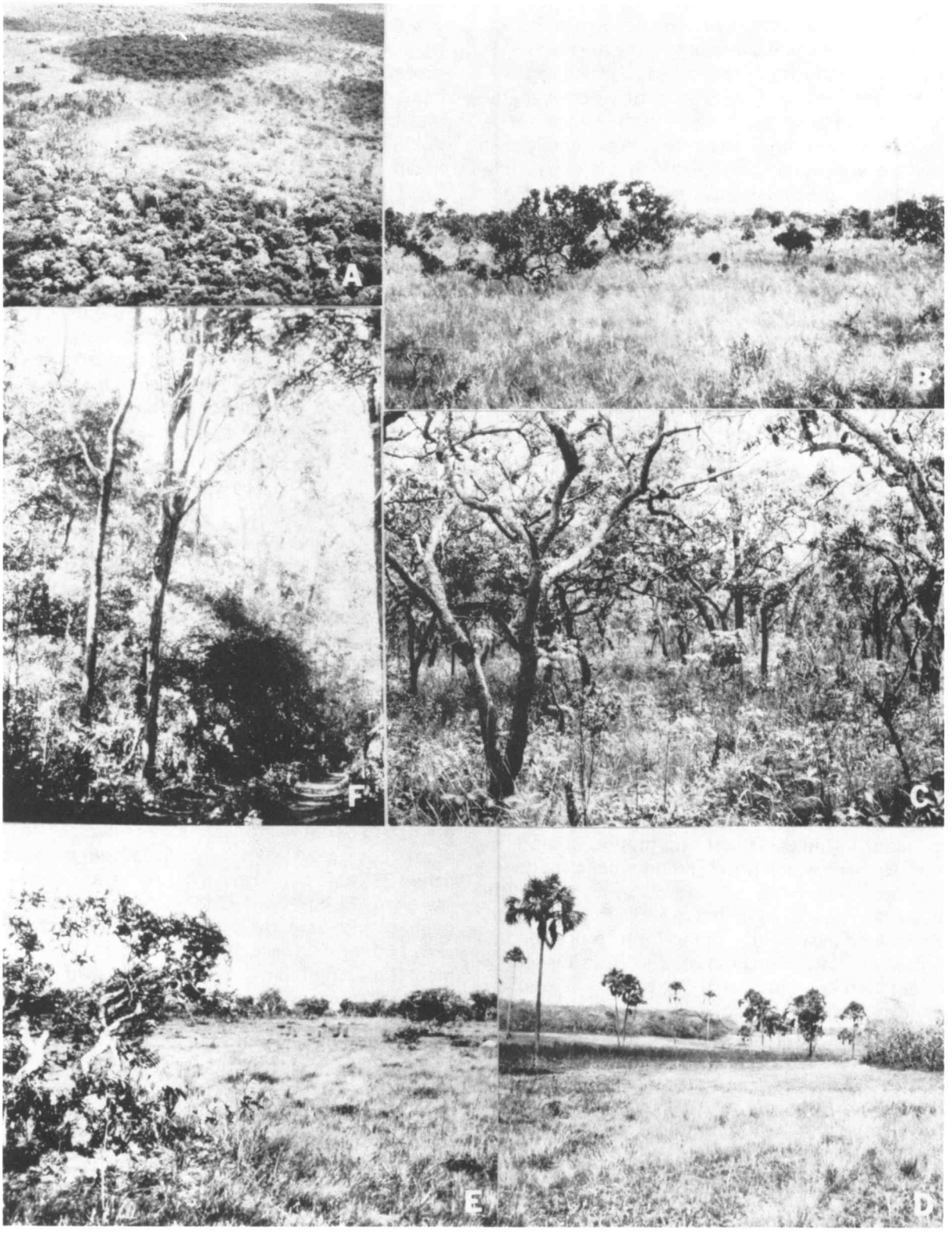

Fig. 2. *Vegetation types: A) Aerial photograph showing vegetation mosaic of* cerrado, *valley-side* campo *and semideciduous forest, B)* campo cerrado, *C)* cerrado, *D) valley-side* campo *E) seasonally inundated savanna complex with termite mound, and F) semideciduous forest.*

years, this aggressive African grass will eventually replace *E. muticus* as the dominant species in the herbaceous stratum. The resulting pasture (it can no longer be considered native savanna) will generally have more than twice the carrying capacity when compared to unaltered *cerrado*. Seed is available locally, the existing woody vegetation does not have to be cleared, and the soil need not be cultivated prior to sowing. This strategy is extremely cost effective if the landowner can allow the land to remain idle for several years. It has been used successfully in Concepción for decades and the estancias *El Recreo, Sebastián,* and *La Pachanga* have excellent examples of *yaragua* pastures established in this manner. Another methodology for "improving" the carrying capacity of *cerrado* has been recommended by Paterson (1984) but requires clearing all woody species and cultivating the soil prior to sowing *B. decumbens*. Although the pasture can be grazed within 1 year, the land-clearing requires a large capital investment, a requirement which excludes many landowners.

Pantanal complexes are considered to be the most productive rangeland in Chiquitanía. The spatially heterogenous and floristically diverse grass sward has many palatable species, of which the most important are *Coelorachis aurita, Paspalum lenticulare (camalote), Panicum laxum (cañuela)* and *Leersia hexandra (arrocilla)*.

In shallowly inundated portions of *pantanal* complexes, one finds differences in microtopography due to the interaction of worms and livestock. Worms form small, tubular earthen structures built up to just below the level of maximum inundation; worm-tubes form aggregates which result in the development of a system of channels and hummocks (Haase 1990). Cattle intensify the development of this microtopographic phenomenon by compacting the soil in the channels. Where a system of channels and hummocks is well developed, different grass species occur in the 2 distinct microtopographic environments. Grasses which grow on hummocks are generally caespitose perennials, which occupy a space in the perennial grass sward, while the grasses found in channels are a mixed assemblage of life-forms more adapted to disturbed habitats. Creeping grasses grow by vegetative propagation and colonize the exposed soil of channels, while annuals grow each year from seed. It is fortuitous that most of the species associated with channel microtopography are also palatable, particularly *P. laxum* and *L. hexandra*.

In the vast seasonally inundated savannas of the *Llanos de Moxos, ganaderos* believe that intensive grazing will improve the stocking rate of the land (Bauer and Galdo 1987). This folk-belief, expressed by the saying *"la uña del ganada mejora el campo"* (the hoof of the cattle improves the savanna) is apparently founded on the development of hummocks and channels, which is the result of the interaction of plants, animals, and hydrological regime.

In contrast to *pantanal* complexes, valley-side *campos* are uniformly considered to be worthless as a forage resource by *ganaderos,* but are useful as reliable water sources during the dry season. These bog-like meadows are dominated by the coarse grass *Paspalum malmeanum* and the equally coarse and unpalatable sedges *Rhynchospora globosa* and *Rhynchospora emaciata*.

Forest vegetation has an important role in cattle management. During the early dry season, when savanna grasses become increasingly senescent, livestock move into the forest in search of understory plants which remain green throughout the year. This is particularly true of the C_3, panicoid grasses *Lasiacis sorghoidea, Ichnanthus pallens, Oplismenus hirtellus,* and *Panicum millegrana,* which are collectively referred to as *taquarilla,* a misnomer meaning "little bamboo." The change in foraging habits also coincides with the onset of the austral winter, when cattle seek shelter in the forest from cold fronts *(surazos)*. Palm fruits particularly from *motocu (Scheelea princeps)* are an important source of oil and protein throughout the year. *Ganaderos* recognize the value of forest vegetation and avoid clearing the low forest islands scattered across the savanna landscape.

Conservation and Land-use

Recent interest in protecting tropical forests has focused attention on cattle management techniques in the Amazon Basin. Misguided development policies and economic incentives have actually promoted the destruction of valuable timber resources by converting forest to marginally productive pastureland. Most tropical soils will not sustain intensive agriculture and the productivity of perennial forage grasses in tropical regions with high rainfall (>1,500 mm annually) is limited to a few years (Buschbacher et al. 1988). However, in Chiquitanía the climate is more benign and the landscapes where forest predominates are inherently more fertile than Amazonia proper (Cochrane et al. 1985). Although continual cropping of annuals is not feasible, land will remain productive when planted to perennial grasses for a considerable length of time. I have seen pastures of *Paspalum notatum* established 25 years ago in good condition at *Estancia Piedra Marcada* (65 km S of Concepción). Although fertility declines with time, the associated problem of weed invasion is the primary factor leading to pasture abandonment (Paterson 1984). Intensive management incorporating mechanical or manual weed control and the planting of mixed swards of legumes and grasses may prove capable of prolonging the life of cultivated pastures in tropical dry forest regions indefinitely.

The primary reason for pasture establishment in forest soils on the Brazilian Shield region in eastern Santa Cruz is due to the increased productivity per hectare when compared to native savannas and to provide green forage in the dry season. Animal husbandry improves as livestock spend more time in proximity to the *estancia* headquarters and there is a reduction in the loss of cattle to jaguar predation. Although they are endangered in other parts of Bolivia, jaguars are viewed as a serious pest in Chiquitanía. During my 3-year residence in Concepción, at least 6 jaguars were killed each year by cattlemen whose primary motivation was pest eradication.

One important factor in determining the ultimate suc-

cess of pasture establishment is the method used for removing the forest cover. Deforestation using manual labor is more economical than mechanized clearing (Cordero 1986), and leaves a healthier soil microenvironment (Seubert et al. 1977). This is generally recognized by experienced *ganaderos;* but large, capitalized landowners prefer the use of heavy machinery for forest clearing. The practice persists for a variety of reasons, one of which is the perceived unreliability of indigenous workers. Another rational offered by landowners is the desire to clear large tracts of land quickly, so as to establish a working *estancia* capable of supporting a large herd in 1 or 2 years. Many large landowners are urban investors who are impressed with a "clean" pasture and may not be aware of subtle differences in productivity.

If forest destruction and land degradation are to be dealt with in an effective manner, development strategies must be devised which take into account the market forces which drive the process. Agronomists and range managers often justify their research and development projects under the rubric of improving productivity on existing lands, thus lessening the demand for new forest clearing. In fact, the effect is usually the reverse; successful land-use strategies increase the rate of forest clearing as investors are encouraged to develop more land for livestock production. Although government protected forest reserves must be the principal solution for forest conservation, millions of hectares of forested land are already in private holdings. Many individuals are motivated to buy and "develop" forest due to the lack of other investment opportunities. It is unlikely that any policy devised to protect forest vegetation on private lands will succeed until there are reasonably secure investment opportunities in business or finance.

Acknowledgements

My research in Bolivia was funded by a fellowship from the Organization of American States (OAS) and grants from the World Food Institute of Iowa State University. I thank the staff of the Instituto de Ecología (La Paz, Bolivia) for logistic support. I am indebted to the citizens of Concepción for their hospitality and assistance during my residence in their beautiful and historic community.

Literature Cited

Bauer, B., and E. Galdo. 1987. Manejo de sabanas inundables en el Beni. *In:* Humberto Alzérreca A. (ed.) Primer Reunión Nacional en Praderas Nativas de Bolivia. Instituto Boliviano de Tecnología Agropecuaria, La Paz, Bolivia. p. 26-29.

Buschbacher, B., C. Uhl, and E.A.S. Serrão. 1988. Abandoned pastures in eastern Amazonia. II. Nutrient stocks in the soil and vegetation. J. Ecol. 76:682-699.

Cochrane, T.T., L.G. Sanchez, L.G. Azevedo, J.A. Porras, and C.L. Garver. 1985. Land in Tropical America. vol. I, II, and III. Centro Internacional de Agricultura Tropical (CIAT) and Empresa Brasileira de Pesquisa Agropecuária dos Cerrados (EMBRAPA-CPAC), Cali, Columbia. 144 p.

Cordero, A. 1986. Efecto de la habilitación de tierras sobre la fertilidad del suelo de la región de Santa Cruz. *In:* Mem. del Simp. Impacto del Desarrollo en la Ecología del Tropico Boliviana. Santa Cruz, Boliva. p. 145-157.

Diniz de Araujo Neto, M., M.P.A. Haridasan, and C.E. Johnson. 1986. The *murundus* of the *cerrado* region of Central Brazil. J. Trop. Ecol. 2:17-35.

Eiten, G. 1978. Delimitation of the *cerrado* concept. Vegetatio 36:169-1787.

Goldsmith, F.B. 1974. Multivariate analysis of tropical grassland communities in Mato Grosso, Brazil. J. Biogeog. 1:111-122.

Haase, R. 1990. Plant communities of a savanna in northern Bolivia. II. Palm swamps, dry grassland, and shrubland. Phytocoenologia 18:343-370.

Haase, R., and S.G. Beck. 1989. Structure and composition of savanna vegetation in northern Bolivia: a preliminary report. Brittonia 41:80-100.

Killeen, T.J. 1990. The grasses of Chiquitanía, Santa Cruz, Bolivia. Ann. Missouri Bot. Gard. 77:125-201.

Killeen, T.J., B.T. Louman, and T. Grimwood. 1990. La ecología paisajística de Concepción y Lomerío, Santa Cruz, Bolivia. Ecología en Bolivia. 16:1-45.

Killeen, T.J., and M. Nee. 1990. Una catálogo de las plantas sabaneras de Concepción, Santa Cruz, Bolivia. Ecología en Bolivia. 16:(in press).

Paterson, R.T. 1984. Investigación y desarrollo de pastos tropicales, Santa Cruz, Bolivia. Centro de Investigación Agricola Tropical. Misión Británica en Agricultura Tropical. Santa Cruz, Bolivia. 204 p.

Peart, M.H. 1979. Experiments on the biological significance of morphology of seed dispersal in grasses. J. Ecol. 67:843-863.

Prance, G.T., and G.B. Schaller. 1982. Preliminary study on some vegetation types of the Pantanal, Mato Grosso, Brazil. Brittonia 34:228-251.

Ruiz, R., C. 1982. Levantamiento Integrado de los Recursos Naturales de la Provincia Ñuflo de Chavez (Sector Concepción) Estudio Forestal. CORDECRUZ, Santa Cruz, Bolivia. 103 p.

Seubert, C.E., P.A. Sánchez, and C. Valverde. 1977. Effects of land clearing methods on soil properties of an ultisol and crop performance in the Amazon jungle of Peru. Tropical Agricultural (Trinidad) 54:307-321.

EVP Report *(cont'd from p. 52)*

Final thoughts: I would be remiss if I didn't add my compliments to all the others given our Past President, Rex Cleary. He was an outstanding President. Rex quickly analyzed the situation when he took office last year and said, "You take care of the details, I've got a big job ahead of me giving leadership to the Science and Art of Range Management." Rex went right to the heart of the responsibility and his record of accomplishments speaks well for him. He did an outstanding job.

But now Stan Tixier is President and things have not changed. He is already well down the road in his job also. I'm looking forward to great progress this year. The membership always seem to plant great crops of leadership every year. That is what makes this such a great job that you have given me and I hope I always will keep it in mind.—**Peter V. Jackson,** Executive Vice-President.