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Ground and satellite based assessment of rangeland management in sub-tropical Argentina[☆]

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ABSTRACT

Sustainable rangeland management is an important issue not only in semi-arid areas but also in sub-tropical regions. For optimal utilization and protection of natural resources, spatial information on the current state and grazing intensity are required. In this paper the integration possibilities of remote sensing derived information for an optimized rangeland management in the sub-tropical province of Corrientes, Argentina, are investigated. Multi-temporal Landsat imagery is utilized in order to classify land cover types and grazing intensity. The map legend was produced according to the United Nations/Food and Agriculture Organization Land Cover Classification System with special emphasis on separating different rangeland types and management practices. Grazing intensity categories were defined based on percentage of bare soil, sward height and standing dead material. Following a correlation analysis between spectral information and historical ground truth data, above ground biomass was estimated for rangelands. The relationship between total above ground biomass and NDVI ($r^2 = 0.5$, $P = 0.05$) was significant but weak. However, rangeland biomass estimation excluding the complex influence of non-edible vegetation remained a challenge. Accurate stocking rates calculated for the Empedrado Department indicated that current rates were 16% higher than those calculated only on an area basis.

Introduction

On an area basis, rangelands contribute significantly to the worlds land surface and an important share is devoted to grazing. Management of these areas alters drastically their natural characteristics. In northern Argentina, raising cattle is a very important economic activity and continuous grazing all year round is possible at almost all sites. Nowadays, due to favorable external conditions beef exports from Argentina have increased, although most beef is consumed domestically (INDEC, 2007). With increasing livestock, pressure on natural and semi-natural rangelands also increases (FUCOSA, 2006; INDEC, 2007). But not all rangeland types have the same production potential and therefore a specific land cover classification is essential in order to support appropriate management. Particularly in the Corrientes province (Northeast of Argentina – Fig. 1), high primary production based on C_4 grasses is achieved, but often only low levels of animal production are achieved (Royo Pallarés, Berretta, & Maraschin, 2005).

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Conventional land cover estimates indicate that rangeland in Empedrado covers a total of about 97,000 ha (INDEC, 2007 – Fig. 1). However, this is only a rough estimate which lacks details of specific rangeland types and respective production potential. Hence, precise land cover information and a quantification of rangeland area are required. In principle, mapping land cover types provides key information needed for the analysis of agricultural activity, carbon accounting, landscape functioning and diversity (Hill et al., 2005). Several studies reported successful mapping of rangelands in arid and semi-arid environments (*e.g.* Evans & Geerken, 2006; Laliberte et al., 2004) as well as in temperate areas (*e.g.* Price, Guo, & Stiles, 2002) based on remotely sensed data. In tropical and sub-tropical regions, attempts to classify land cover have been performed (*e.g.* Sedano, Gong, & Ferrão, 2005; Seyler et al., 2002), but classifications normally considered only very general land cover classes. Previous studies have shown that the utilization of multi-temporal optical satellite imagery (Friedl & Brodley, 1997) and combination of optical and Synthetic Aperture Radar (SAR) data (Franklin, 1989) can significantly improve discrimination among rangeland classes. The use of multi-temporal analysis and ancillary information can produce accurate land cover classifications.

Besides classification of rangeland types, above ground plant biomass is one of the key parameters related to efficient rangeland management. Many advanced remote sensing methods have been used to estimate bio-physical parameters of vegetation, like pasture growth rate (Hill, Donald, Hyder, & Smith, 2004), pasture quality (Dymond, Shepherd, Clark, & Litherland, 2006) and primary production (Paruelo et al., 2000). Furthermore, attempts have been carried out to estimate biomass from remotely sensed data (*e.g.* Anderson, Hanson, & Haas, 1993; Boschetti, Bocchi, & Brivio, 2007; Edirisinghe et al., 2004; Everitt, Escobar, & Richardson, 1989; Kelly, Edirisinghe, Donald, Oldham, & Henry, 2003). Tucker (1980) indicated that remotely sensed biomass estimation worked well for large area surveys, but only when limited to specific cover types. Coarse resolution NOAA-AHVRR images (National Oceanic and Atmospheric Administration-Advanced Very High Resolution Radiometer) have been widely used to derive rangeland yield and vegetation status across large areas (*e.g.* Hill et al., 2004; Jianlong, Tiangang, & Quangong, 1998). But, rangeland management often requires imagery with finer spatial resolution than NOAA-AVHRR can provide (1.1 km pixel size) due to the spatial heterogeneity in rangelands at a finer scale (Di Bella et al., 2004; Ikeda, Okamoto, & Fukuhara, 1999). The potential of biomass estimation on rangelands with Landsat imagery (30 m pixel size) has been demonstrated previously (Anderson et al., 1993; Edirisinghe et al., 2004; Everitt et al., 1989; Kelly et al., 2003).

When analyzing Landsat imagery, Guo, Price, and Stiles (2000) found that species composition affected spectral reflectance of the vegetation. They suggested that biomass estimation would be significantly influenced by the presence and arrangement of grasses and forbs. Further, on a landscape scale, rangeland productivity is influenced primarily by livestock

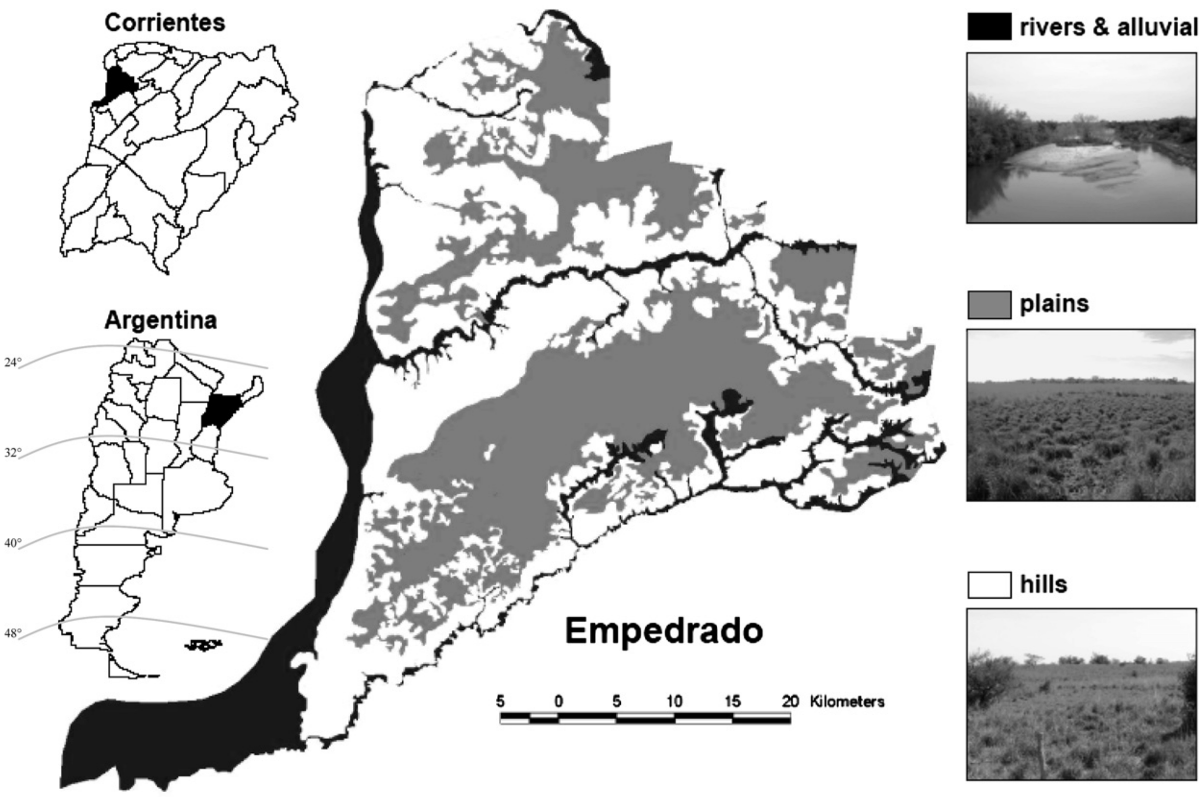

Fig. 1. Map of the investigated area of Empedrado and aspects of rangeland vegetation near rivers, on plains and on hills.