# Peruvian peatlands (bofedales):

## *from Andean traditional management to modern environmental impacts*

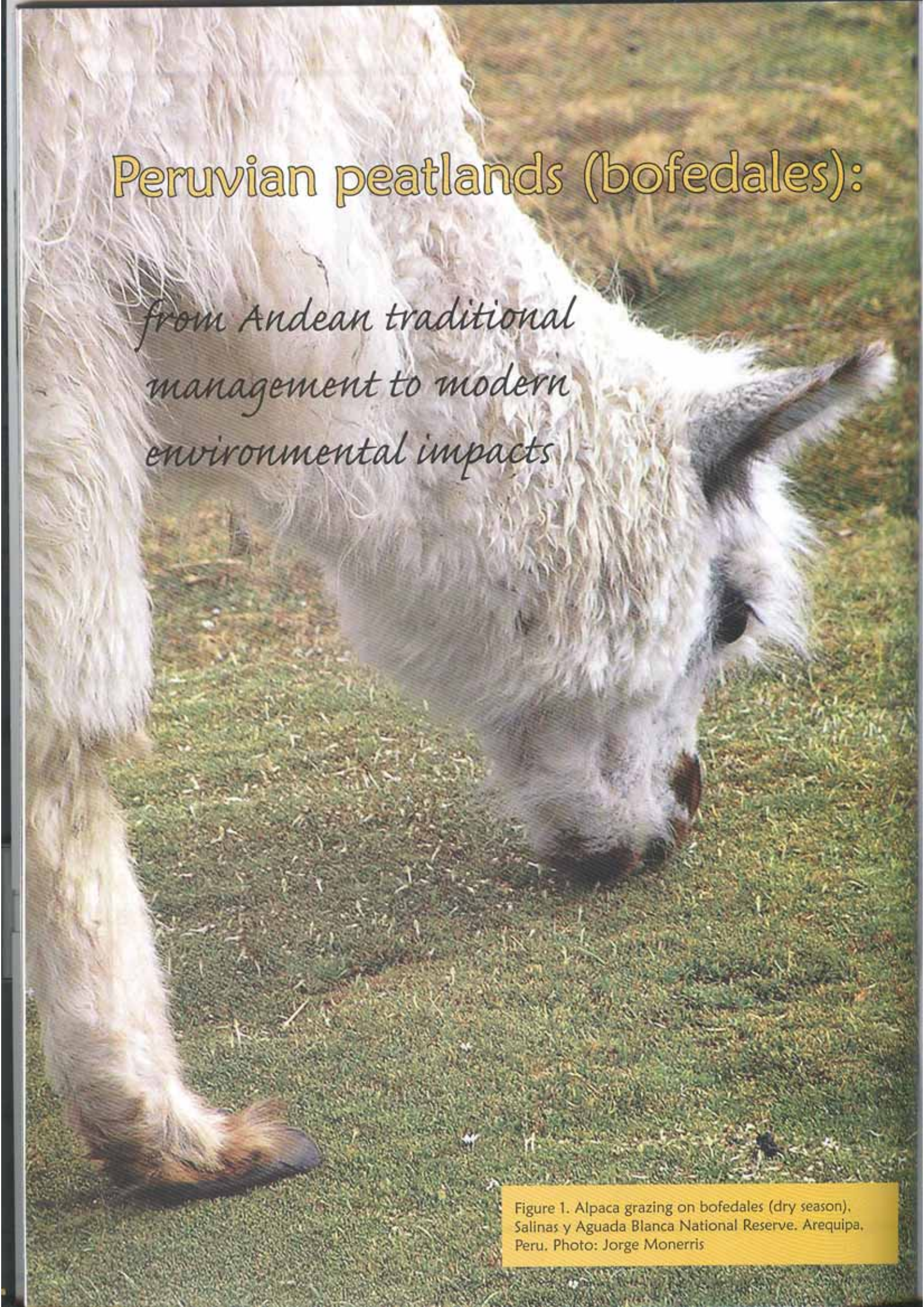

Figure 1. Alpaca grazing on bofedales (dry season). Salinas y Aguada Blanca National Reserve. Arequipa, Peru. Photo: Jorge Monerris

Text: Flor Salvador, Jorge Monerris and Line Rochefort

**Tropical alpine-like vegetation is found in the Andes above the altitudinal limit (3,300 and 4,000 m above sea level) and below the permanent snow-line (5,500 m). In Peru and southward this relatively dry altitudinal region is known as "puna" (Young et al., 1997). The predominant vegetation types of puna are grasslands. In contrast, peatlands are much less abundant but they have considerable importance as a water source and pasture.**

In Peru, puna peatlands are locally known as oconales or bofedales (Palacios Rios, 1977; Salvador and Cano, 2002). Description of this form of peatland has been made by Warner et al. (2008) mainly in Chile. Bofedales are present from 7º to 18° in Peru, South along the eastern and western cordillera (Young et al., 1997).

Since ancient times Quechua and Aymara families have used bofedales in a sustainable way. Nevertheless, today increasing economic activities and a demand for greater productivity in agriculture, bofedales face great threats. Among impacts we could mention their over utilization due to a long history of introduction of new livestock and more modern uses such as a source of water to attend necessities of the private and public sector. Here, we raise a question: in what measure the capacity of bofedales to provide these services (e.g. water and pastures) has declined? The functioning of bofedales as well as the impact of human activities on these ecosystems are poorly known (Salvador, 2008; Squeo et al., 2006a). The main problem is the lack of information and consciousness about their services and benefits. This article aims to focus on these issues in order to encourage better conservation practices and responsible management.

## Camelid pastoralism and bofedales

The llama (*Lama glama*), alpaca (*L. pacos*), guanaco (*L. guanicoe*), and vicuña (*L. vicugna*) form a group known as South American camelids. The llama and alpaca are domesticated camelids. Camelids grazed in all type of vegetation of the Puna but most of them do show a preference for the peatlands of the high Andes. The earliest evidence

Figure 2. Exotic livestock grazing. On the left, sheep grazing on bofedales (wet season), Junin National Reserve, Junin. On the right, equines grazing on bofedales (dry season), Lauricocha, Huanuco. Photos: Line Rochefort and Flor Salvador

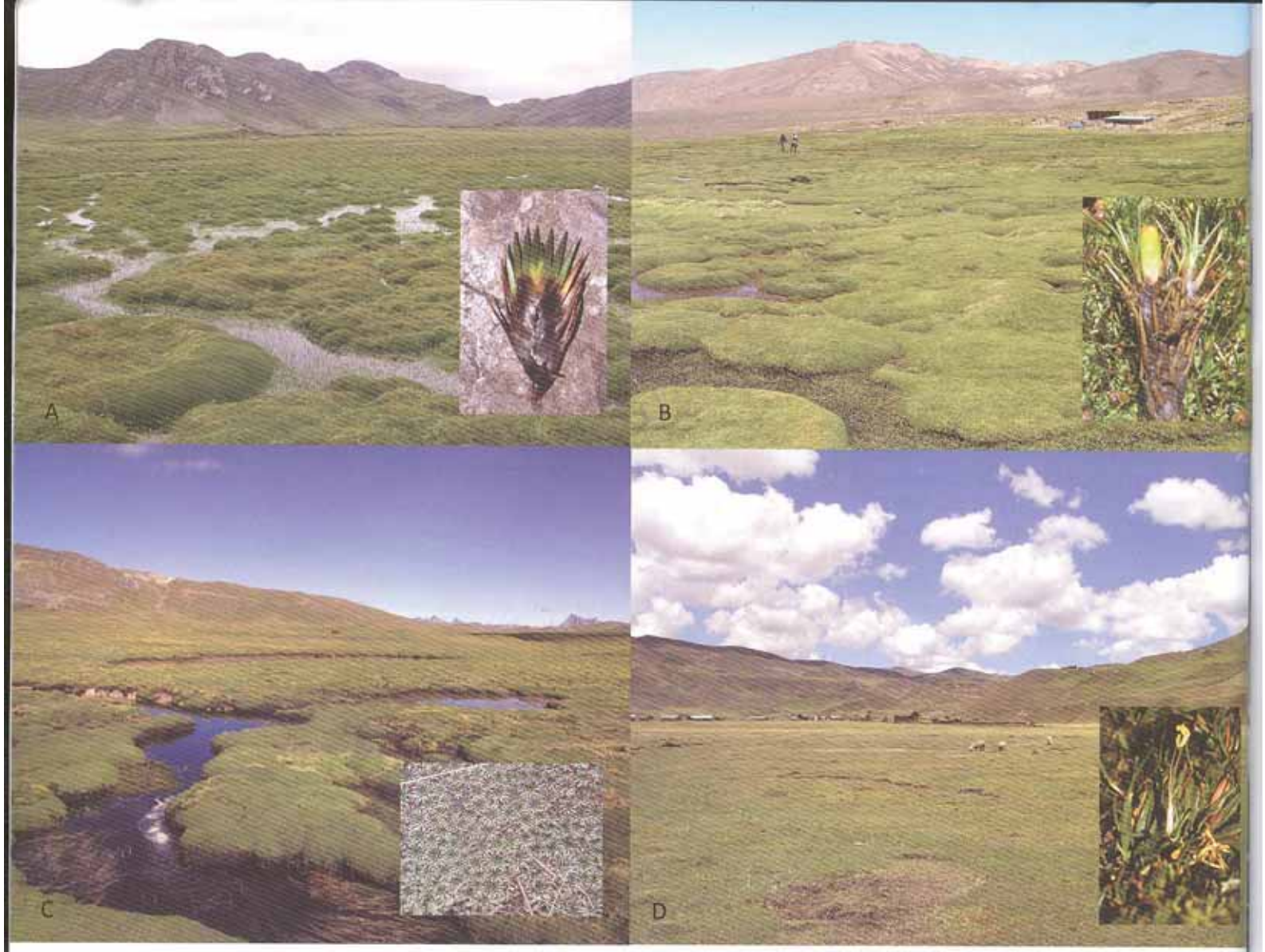


Figure 3. Peruvian bofedales of the central and southern Andes. Cushion vegetation of *Distichia muscoides* (A), *Oxychloe andina* (B) and *Plantago rigida* (C) and carpet vegetation of *Plantago tubulosa* (D). Photos: Jorge Monerris and Flor Salvador

of camelid domestication comes from archaeological sites located in the puna of Junin (Peruvian central Andes). The guanaco and the vicuña have inhabited this area for approximately 12,000 years (Wheeler, 1995). There is evidence of llama and alpaca production 1400 years ago; but it was under the Inca Empire (A.D. 1430 and 1532), that llama and alpaca distribution reached its maximum Andean extension: from southern Colombia to central Chile (Baied and Wheeler, 1993; Wheeler, 1995).

Bofedales exist naturally, but interestingly some were managed by the Incas and/or cultures established before them (Kent, 1988; Morlon, 1992). This management had one objective: increase their extent in order to ensure their sustainable use as a resource of water and pastures for camelid's herding (Figure 1). Official records to describe the anthropogenic methods of irrigation to increase bofedales areas, especially for alpacas, have only been described in a remote zone in the south of Peru (Palacios Rios, 1977). Still nowadays, bofedales are considered as high quality pasture by local people. Pastoralists use canals to regulate the flow of water into the bofedales (Figure 2) that are cleaned and repaired after the rainy season. However the practice to manage peatlands with the goal to ameliorate the pasture and even increase its extent has been scarcely studied.

It is during the dry season of the central Andes that the green vegetation of bofedales is highly valued to sustain the populations of vicuña, guanaco, llamas but also exotic livestock like ovines (*Ovis aries*), bovines (*Bos taurus*) and even equines (*Equus ferus*), (Figure 3) (Tapia & Flores-Ochoa, 1984; Flores & Malpartida, 1987; Salvador, 2008). Exotic livestock (ovines and bovines) were introduced into South America during the Spanish invasion. Nowadays, numerically sheep are the most important livestock species in the Peruvian Andes (Pfister et al., 1989). In most pastoral Andean communities, the livelihood of the "campesinos" (peasants) depends on the camelid and ovine herding. Now, alpacas are raised primarily for fiber production for export or local use, whilst the sheep or goat to produce wool, meat, and in good

years, milk (Yacobaccio, 2007). Rotation of livestock among different grazing sites throughout the year has been a traditional management strategy (Blench, 2001). During the wet season, alpaca and sheep, in particular, alternated grazing between upland and bofedal sites on a daily basis to reduce pressure on bofedales. In the dry season, however, alpaca, llama and sheep spent most of their time grazing bofedales (Buttolph et al., 2004). At present, bofedales show patterns of overgrazing by the excessive stocking density of alpacas and sheep (Lara, 2003).

The vegetation of the bofedales is characterized by a rich flora of good feed quality vital for the alpaca herding (Palacios Rios, 1977; Wheeler, 1982). However, some studies have also demonstrated that bofedales are preferential grazing areas for the vicuñas (Lucherini et al., 2000; Renaudeau d'Arc, 2000).

Contrary to the main characteristic vegetation found in northern hemisphere peatlands, vegetation in the bofedales is dominated by vascular plants (Figure 4). Plants of *Distichia muscoides*, *Oxychloe andina* and *Plantago rigida* are often conspicuous, forming large cushions. Other type of vegetation includes carpets of *Plantago tubulosa* and *Werneria pygmaea*. Some species of *Gentiana*, *Hypsela*, *Isoetes*, *Lilaeopsis*, *Ourisia*, *Phylloscirpus*, *Zameioscirpus* and *Carex* are also present. The most common aquatic plants in ponds and streams include *Myriophyllum quitense*, *Elodea potamogeton*, *Potamogeton* spp. (León, 1993; Salvador et al., 2006; Salvador et al., 2009).

Camelids, ovines and bovines have different grazing habits. Camelids have a longer history of co-evolution with Andean rangelands than do European livestock (Wheeler, 1988). For example, Camelids are adapted to digest bofedales pasture (San Martin and Bryant, 1989). They have incisors and canines in both jaws adapted to graze the prickly and tightly growing bofedales cushions. In contrast the other ruminants (sheep and cattle) have neither upper incisors nor canines (Fernández Baca, 1975).

Camelids cause less damage because they bite off their forage to perform the grasping of grasses and do not tug or pull as sheep and cattle but carry out a cut that best preserves the bofedales plants. Furthermore, their soft, padded feet do not create holes or the serious trampling done by the bovines while grazing bofedales vegetation (Figure 5) (Flores Ochoa, 1977; Wheeler, 1982). Digestibility of forages is higher in camelids than in ovines (Reiner et al., 1987; San Martin, 1991; Dulphy et al., 1994). Greater camelids efficiency may be related to longer retention time of digestion than in ovines (Florez, 1973; San Martin, 1989). Although we know that camelids may be more efficient grazers, sheep present some advantage such as a higher reproductive rate and a more ready market for their meat (Tichit, 1995).

Bofedales are considered a year-round pasture however, Squeo et al. (2006b) working in Chile showed that climate phenomena also could contribute to alter the biomass production in bofedales from year to year in response to water availability and length of the growing season that are directly controlled by El Niño Southern Oscillation (ENSO). Nevertheless, in Peru so

Figure 4. Photo showing a constructed canal to irrigate the bofedal. Salinas y Aguada Blanca National Reserva, Arequipa, Peru. Photo: Line Rochefort

Figure 5. Some morphological adaptation of alpacas to graze on bofedales. On the left alpaca pad, softer than a hoof; on the right alpaca's upper incisive dents.

far, there is just no information about the productivity of these peatland ecosystems, let along their productivity in relation to climate changes.

If global climate change in the high Andes induces a drier climate (ENSO phenomena) (Squeo, 2006b), impacts could be decisive for camelid and ovine herding. Studies aimed at evaluating the interactions between climate and effects of camelid and ovine mix grazing on the structure and functionality of the bofedales are needed. All this information is crucial for the long term management of these fragile ecosystems, and increasing water demand by the mining sector and the Peruvian state (Salvador and Cano, 2002).

In relation to this issue, there is some good news, research groups like the Wetland Ecology and Restoration Lab (Michigan Technological University, USA) and the Andes Biodiversity and Ecosystem Research Group (University of St Andrews, UK) are conducting research on the Peruvian Andes particularly in the response ecosystems included peatlands have to climate change.

## Modern environmental impacts

Peru has a long tradition in mining, an activity with a significant share in the national economy. During the period of 1990-2000 the privatization of mining in Peru attracted hundreds of foreign companies motivated by an opening up of policy for international investments (Pasco-Font, 2000). This policy was favoured by the high prices of metals at international level and the fact that mineral resources in Peru (e.g. gold, silver, cupper, iron, zinc and lead) have only been 12% extracted (Damonte et al., 2002). Mineral deposits tend to be located at high altitudes like the puna region, where water courses are nascent and grazing pastures and bofedales are dependent primarily on groundwater flows. The ground water is originated from glaciers, snowmelt and rain (Squeo et al., 2006a). With regard to water use, the volumes of water required for mineral extraction and processing are not well known. This is crucial because the dynamics of water flow are not well understood on bofedales.

In the Central Andes of Peru, lakes of glacial origin and bofedales are typical characteristics of the landscape. Mining activities, when occurring close to lakes and bofedales, transform the wetland landscape (Salvador, 2008). The consequences can include reduction and modification of wetland areas, alteration of quality of superficial and ground waters, peat erosion, decreasing of species diversity and cover vegetation on wetlands (Figure 6) (Salvador, 2008).

Figure 6. Some consequences of mining activities on the Peruvian central Andes. Loss of vegetation, erosion of peat and reduction of bofedal areas. Photo: Flor Salvador

There is visual evidence of changes in water flows; nevertheless up to now there is no data about water flow monitoring on the high basins. Hydrological studies are definitively required to determine the impacts of using underground water for exploitation and when the aquifers are confined or not. Plant diversity on the bofedales is still overestimated on reports of EIAs made for mining companies. New registers of plants for Peru as well as endemic species has been reported on bofedales (Salvador et al., 2009). Thus, bofedales also have to be seen as exceptional places that hosts a potential source of richness and rarity of flora.

On the other hand, an other impact that has not been studied is the effect of using High Andean streams as source of water for a coast water transfer project initiated in the 1980s in the dry territories of southern Peru. One of the overall objectives of this project is to maintain current production and increasing the agricultural land in the valleys of the region through the implementation of investment projects for the development and optimization of water resources.

In the zones of puna of this region, bofedales are artificially maintained because of the long dry periods. Consequences of the implementation of water projects for better agricultural production near the coast would surely compromise water availability to bofedales, plant productivity and its future existence.

## Future of bofedales

Local communities living in the puna have mainly formed around existing water sources and use them traditionally, as in the case of bofedales. Although the government continues to stimulate mining activity and water transfer projects, it is necessary to work together in order to insure the health of bofedales as natural resources for present and future generations and pastoralism of camelids.

Since the information about main components and functioning of the bofedales is scarce, basic studies should be oriented to assess its components and its interactions in a quantitative and qualitative way. Thus the application of technologies according to restoration ecology studies, based on the understanding of the system dynamics could help in maintaining or enhancing ecosystem functions. By investigating these issues as a whole, critical and specific questions have to emerge about the influence of grazing and mining activity in the bofedales in a context of global change.

Starting with a little drop of water in the ocean, the Peatland Ecology Research Group of Université Laval, Québec, Canada (PERG) initiated an expedition under the leadership of Flor Salvador (1) to assess the status of bofedales in two regions of Peru, (2) to explore the interest of the Peruvian environmental authorities, and other academic institutes related to the conservation and management of bofedales and (3) to establish a link with the mining industry for potential partnership developing an ecological restoration research programme for the damaged bofedales.

The general idea is to start to build up a collaborative framework towards a more responsible management of bofedales in the Peruvian puna.

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