



Effects of livestock management on the supply of ecosystem services in pastures in a tropical dry region of western Mexico



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ABSTRACT

Human beings manage ecosystems to obtain ecosystem services. Through selected interventions they modify ecosystem condition to increase the provisioning services of interest to people. We analyzed the effect of livestock management regime components (duration, grazing period, number of burns and slashes and stocking density) on ecosystem services (provisioning, regulating and supporting) in seeded pastures in a tropical dry region. Our main questions were: (1) How is livestock management duration related to the magnitude of service supply?; (2) How are the different components of the livestock management regime and site conditions related to the magnitude of ecosystem service supply?; and (3) How do the components of management regime, the site conditions and the magnitude of ecosystem service supply interact? We quantified 15 service indicators within 24 plots (20 × 50 m) chosen along a 40-year gradient of livestock management duration. Livestock management regime was documented with semi-structured interviews to landowners. Simple linear regressions showed that increasing livestock management duration was related to increasing forage amount ($p = 0.03$) and to decreasing forage quality ($p = 0.05$), soil structure ($p = 0.002$), and several biodiversity indicators ($p = 0.002$ – 0.03). Stepwise multiple regression analyses showed that the increase in the total number of burns was related to decreases in foliar and soil nitrogen ($p < 0.05$), carbon stock ($p < 0.001$), as well as woody, herbaceous, and seedling richness or evenness ($p < 0.001$). Increased frequency of slashes and of the grazing period also decreased soil fertility regulation and biodiversity. The canonical correspondence analysis showed a prominent role of the number of burns (which is correlated with duration, slashing frequency and grazing period) in promoting forage production, but in reducing most indicators of regulating and supporting services. Increased shallow soil moisture was related to increasing regulating and supporting services. Canopy covers inside the plot and in the surrounding forest were positively related to woody and seedling richness or evenness, but were independent of the effects of other management regime components. Our study suggests a conflict between the short-term management decisions such as burning to foster forage production and the long term sustainability of the management regime of these seeded pastures.

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1. Introduction

Human beings manage ecosystems to obtain ecosystem services that satisfy their basic needs. Through land management, people modify ecosystem condition to increase the supply of

services of interest to people (Van Oudenhoven et al., 2012). The expansion and intensification of production systems, however, may have unintended negative consequences for regulating and supporting services, so that the long-term supply of provisioning services may be at stake (Bennett and Balvanera, 2007). Thus, it is necessary to understand the consequences of different human activities involved in land management on the supply of ecosystem services.

The impact of land management on the biophysical properties of ecosystems and the supply of ecosystem services depends on the way ecosystems are managed (Bennett et al., 2009; Van Oudenhoven, 2015). The management regimes are determined by the bundles of human activities, also called management regime components, that define the way people use the land and modify

Abbreviations: GrBM, grass biomass; ++1/mAgg, 1/micro-aggregates; MAgg, macro-aggregates; 1/BD, 1/bulk density; tN, total nitrogen; NH₄, ammonium; NO₃, nitrates; avP, available phosphorus; tC, total carbon; Wr, woody richness; Ws, woody evenness; Hr, herbaceous richness; Hs, herbaceous evenness; Sr, seedling richness; Ss, seedling evenness; BSr, seed bank richness; BSs, seed bank evenness.

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land cover (Van Oudenhoven, 2015). From an ecological perspective (sensu Pickett and White, 1985), the anthropogenic disturbance regime of the ecosystem depends on the duration of each of the management practices (e.g., number of years), their frequency (e.g., twice a year), their intensity (e.g., number of cows per hectare) and their magnitude (e.g., number of hectares under management). From a social–ecological perspective (Reyers et al., 2013), management regimes are also dependent on the biophysical and social conditions within which the different management practices are undertaken (Van Oudenhoven, 2015). While a range of management regime indicators (Alkemade et al., 2013; Zermeño-Hernández et al., 2015) have been derived from the intersection of these approaches, and the range of ecosystem service indicators is growing (Layke et al., 2012; Van Oudenhoven et al., 2012), the impact of alternative management regimes and their components on ecosystem services needs to be further assessed.

Livestock management has changed ecosystem service supply in different ways (Van Oudenhoven et al., 2012). Livestock management has expanded and intensified to meet the growing meat and milk consumption needs (Steinfeld et al., 2006), at the cost of transforming ecosystems, largely dry ones, into livestock production systems (Miles et al., 2006). A variety of effects of forest-to-pasture conversion on soil (Elmore and Asner, 2006) and vegetation (Franklin and Molina-Freaner, 2010) have been documented. However, a better understanding of how the supply of ecosystem services changes under alternative livestock management regimes still needs systematic documentation (Barnosky et al., 2012).

In Mexico, livestock in pastures with introduced grasses has been the principal cause of tropical dry forest conversion (Stern et al., 2002). Slashing and burning of the woody biomass is the starting point of forest conversion to pasture for livestock, a land-use change with long-term consequences for ecosystem properties (Jaramillo et al., 2010) and, thus, most likely on ecosystem services. In this study, we explore the consequences of several components of the livestock management regimes on four ecosystem services in a tropical dry forest region of Mexico.

We ask the following questions: (1) How is livestock management duration related to the magnitude of ecosystem services supply? (2) How are the different components of the management regimes and the site conditions related to the magnitude of ecosystem services supply? and (3) How do the indicators of the components of the management regimes, of the site conditions and of the magnitude of ecosystem services supply interact in this tropical dry region?

2. Methods

2.1. Study area

The study was conducted in the Chamela region, on the Pacific Coast of Jalisco, Mexico. The mean annual temperature is 24.6 °C, and the mean annual rainfall is 759 mm, with significant interannual variation (data from the meteorological station at Chamela, IBUNAM). The Chamela-Cuixmala Biosphere Reserve (CCBR) (19°23'–19°30'N, 104°56'–105°04'W) is surrounded by land transformed for agricultural and livestock management (Fig. 1). The landscape is dominated by low hills (<300 m elevation) with steep slopes (>20°) (Noguera et al., 2002). The predominant vegetation type is a highly diverse tropical dry forest (1149 vascular plants), with trees 4–15 m tall and a well-developed understory (Lott and Atkinson, 2002). The forest is seasonal, and most plant species drop their leaves during the dry season each year. Along riparian zones of temporary streams and floodplains, a semi-deciduous tropical forest with distinctive vegetation structure also occurs (Noguera et al., 2002).

The region was very sparsely populated until the decades of 1950–1970, when government programs fostered the arrival of new residents and the establishment of “ejidos” a type of communal land tenure system (Castillo et al., 2005). Tropical dry forests are slashed and burned and predominantly converted into cattle pastures (Burgos and Maass, 2004). Evidence scattered throughout the region shows the differential outcomes of livestock management on soil and biodiversity (Maass et al., 2005).

This study was conducted in the five ejidos adjacent to the north-western and most heavily transformed border of the CCBR: San Mateo, Juan Gil Preciado, Santa Cruz de Oates, Los Ranchitos and Nacastillo (Fig. 1).

2.2. Characterization of the management regimes and its components

We characterized the livestock management regimes using a set of indicators using an ad hoc approach drawing from the growing literature on ecological, agronomic and socio-ecological assessments of ecosystem management (Alkemade et al., 2013; Van Oudenhoven, 2015; Zermeño-Hernández et al., 2015). The land use is pasture for livestock production and the land management involves planting alien grasses, slashing and burning for pasture maintenance, and managing livestock by modifying stocking density and grazing periods, which together comprise the components of these management regimes.

The duration of livestock management was used as a key descriptor of the management regimes, because it is well-known that the impacts of management on soil and vegetation accumulate through time (Martinez and Zinck, 2004). Furthermore, previous work in the region had shown that livestock management was a key driver of degradation (Trilleras, 2008), and implications for ecosystem services have been suggested (Balvanera et al., 2011).

2.3. Site selection and development of a gradient of livestock management duration

We aimed at identifying active seeded pastures evenly distributed along a gradient of livestock management duration to maximize coverage of potentially contrasting management regimes effects on ecosystem services. In the first stage, we visited 160 active pastures and assessed grass cover per unit area (percentage of the total plot area) and soil degradation condition (presence of gullies and bare ground). We qualitatively evaluated the relative condition of each plot (from 1 – excellent condition to 10 – very poor condition). We then selected 60 plots among the total which best represented the gradient of plant cover and soil degradation from the best to the worst conditions.

In the second stage, we conducted semi-structured interviews to inquire about the history of livestock management to landowners who agreed to participate in this study (40 ejidatarios, owners of 40 plots). We inquired briefly about the use of slash and burn for the initial clearing (including date and total area), grazing (duration, stocking density, total area used, most recent event), pasture maintenance (identity of species sown, initial date, most recent event), and slashing and burning for pasture maintenance (their use, most recent events). With such information, we selected plots that covered a range of duration of livestock management, from the most recently established plots to the oldest ones found in the region.

In the final stage, to determine the effects of the various components of the livestock management regimes, we selected 24 plots from the group of 40; we added three plots which corresponded to the category of “no use” (i.e., old-growth forest) included as a reference to consider the effect of conversion to pasture (Fig. 1). Thus, our gradient covered a range from 0 to 40 years of management. The youngest pastures were four years old.

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