



Livestock-driven land use change to model species distributions: Egyptian vulture as a case study



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ABSTRACT

Species distribution models (SDMs) are increasingly used to predict species ranges and their shifts under future scenarios of global environmental change (GEC). SDMs are thus incorporating key drivers of GEC (e.g. climate, land use) to improve predictions of species' habitat suitability (i.e. as an indicator of species occurrence). Yet, most SDMs incorporating land use only consider dominant land cover types, largely ignoring other key aspects of land use such as land management intensity and livestock. We developed SDMs including main land use components (i.e. land cover, livestock and its management intensity) to assess their relative importance in shaping habitat suitability for the Egyptian vulture, an endangered raptor linked to livestock presence. We modelled current and future (2020 and 2050) habitat suitability for this vulture using an organism-centred approach. This allowed us to account for basic species' habitat needs (i.e. nesting cliff) while gaining insight into our variables of interest (i.e. livestock and land cover). Once nest-site requirements were fulfilled, land use variables (i.e. openland and sheep and goat density) were the main factors determining species' habitat suitability. Current suitable area could decrease by up to 6.81% by 2050 under scenarios with rapid economic growth but no focus on environmental conservation and rural development. Local solutions to environmental sustainability and rural development could double current habitat suitability by 2050. Land use is expected to play a key role in determining Egyptian vulture's distribution through land cover change but also through changes in livestock management (i.e. species and stocking density). Change in stocking densities (sheep and goats/km²) becomes thus an indicator of habitat suitability for this vulture in our study area. Abandonment of agro-pastoral practises (i.e. below ~15–20 sheep and goats/km²) will negatively influence the species distribution. Nonetheless, livestock densities above these values will not further increase habitat suitability. Given the widespread impacts of livestock on ecosystems, the role of livestock and its management intensity in SDMs for other (non-livestock-related) species should be further explored.

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1. Introduction

Human-driven global environmental change (GEC) causes colonisation and extirpation of local populations altering species' distributions (Yackulic et al., 2011; Guisan et al., 2013). Species distribution models (SDMs) are increasingly used to predict species ranges and their shifts under future scenarios (Ladle and Whittaker, 2011), being frequently proposed to support conservation actions under GEC (Guisan et al., 2013). In this context, SDMs increasingly incorporate key drivers of GEC (i.e. climate, land use, invasive

species) – which are also key indicators of the state and pressure on biodiversity (Butchart et al., 2010) – to improve predictions of habitat suitability for species (i.e. as an indicator of species occurrence; Barbet-Massin et al., 2012; Guisan et al., 2013). While most work has focused on the effects of climate change on future species' distributions, including other GEC drivers such as land use has been shown to improve SDMs, even becoming the most important variables to consider when modelling at some extents (Barbet-Massin et al., 2012). However, most SDMs that include land use variables only consider dominant land cover types (i.e. low thematic resolution; see Martin et al., 2013). These models largely ignore other key aspects of land use such as land management intensity and livestock (Van Asselen and Verburg, 2012) despite their huge impact on natural ecosystems.

Livestock represents the largest of all anthropogenic land uses on Earth (FAO, 2006). It accounts for 30% of the land surface

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of the planet causing deforestation, soil compaction and erosion and threatening biodiversity mainly through habitat loss (Steinfeld et al., 2006). Livestock is also responsible for 18% of greenhouse gas emissions and for over 8% of global human water use (Steinfeld et al., 2006). However, as with other anthropogenic impacts (Ladle and Whittaker, 2011), the effect of livestock varies across the planet. In many developing countries, rapid livestock-induced land use change is destroying natural ecosystems (Steinfeld et al., 2006, 2010). Yet in other regions natural ecosystems have co-evolved with livestock-based human activities throughout centuries, resulting in areas characterised by a high biodiversity and ecosystems deserving protection (Pykälä, 2000; Steinfeld et al., 2010). Agro-pastoral practises (i.e. those mainly relying on natural resources and with low dependence on external inputs; Steinfeld et al., 2010) have been often highlighted as a sustainable approach to resource exploitation by humans (Pykälä, 2000; Olea and Mateo-Tomás, 2009; Steinfeld et al., 2010). Most of these practises are currently threatened by either abandonment or intensification (i.e. changes in management intensity and/or livestock species; Pykälä, 2000; Steinfeld et al., 2006; Olea and Mateo-Tomás, 2009). The way in which land-use change in agro-pastoral practises could affect ecosystem conservation is thus expected to be complex (Steinfeld et al., 2010), but remains largely unknown.

Land use usually changes in time in response to socioeconomic factors (Van Asselen and Verburg, 2012, 2013). For example, global food consumption of livestock products is expected to double by the year 2050 (FAO, 2006), driving major changes in land use worldwide (Van Asselen and Verburg, 2013). Land use by grazing will increase pastureland by 2 million km² by 2020 and by 5.4 million km² by 2050 (Steinfeld et al., 2006). This increase will not be equally distributed across the globe, depending on different economic, ecological, technical and policy contexts (Steinfeld et al., 2010; Van Asselen and Verburg, 2013). Livestock-driven land-use changes do not act alone, but they are associated with changes in human population density within a more complex socioeconomic context (Pelletier and Tyedmers, 2010; Steinfeld et al., 2010). Therefore, predicting future land use is challenging and thus integrating all its drivers will provide a more accurate picture of future impacts on ecosystems (Steinfeld et al., 2010; Van Asselen and Verburg, 2013). Threats acting at smaller (local) scales (e.g. illegal poisoning, collision with wind turbines) also influence species' distributions (Yackulic et al., 2011; Olea and Mateo-Tomás, 2014). Their inclusion in SDMs, coupled with global drivers, may improve model predictions.

In this work, we aim to advance the knowledge on how a main driver of GEC (i.e. land use change) can affect species' distributions. We pay special attention to the role of livestock as a major component of land use change (see above; FAO, 2006; Steinfeld et al., 2006, 2010). Livestock impacts several taxa (e.g. plants, arthropods, vertebrates; Lavergne et al., 2005; Lütolf et al., 2009; Olea and Mateo-Tomás, 2009; Amar et al., 2011) in many different ways (e.g. occurrence, breeding performance, population dynamics; Tichit et al., 2007; Mateo-Tomás and Olea, 2010a,b; Villar et al., 2014). However, SDMs rarely include livestock (e.g. Lavergne et al., 2005; Lütolf et al., 2009). Vultures are one of the guilds most closely related to livestock worldwide (Mundy, 1982; Tella, 2001; Oaks et al., 2004; Mateo-Tomás and Olea, 2009, 2010a; Olea and Mateo-Tomás, 2009). These species are therefore proper organisms to study how changes in livestock-driven land use affect their habitat suitability and thus foresee shifts in their distribution. The rapid response of vultures to livestock changes (Tella, 2001; Oaks et al., 2004; Olea and Mateo-Tomás, 2009) also highlights their potential as early indicators of livestock impacts on other taxa and/or ecosystem functions (e.g. ecosystem services such as limiting disease spreading; Şekercioğlu et al., 2004). Accordingly, we perform SDMs

including the main land use components (i.e. land cover, livestock and its management intensity; Van Asselen and Verburg, 2012) to account for their relative importance in determining habitat suitability for the Egyptian vulture *Neophron percnopterus* Linnaeus. This endangered vulture is closely related to livestock. Although Egyptian vulture also feeds on wild preys (Donazar, 1993; Cabrera-García, 2012), livestock is identified as a key food resource for the species worldwide (see Section 2; Donazar, 1993; Cabrera-García, 2012). Moreover, livestock is also frequently highlighted as a cornerstone in Egyptian vulture conservation, with the decline in extensively bred livestock considered a critical threat (BirdLife International, 2008; Mateo-Tomás and Olea, 2009, 2010a). The species is also affected by other threats (e.g. illegal poisoning, collision with wind turbines; BirdLife International, 2008; Olea and Mateo-Tomás, 2014). Thus, beside land use, we include other factors (e.g. food resources other than livestock, illegal poisoning), as potential predictors of the species distribution.

To increase the ecological realism of our SDMs we model habitat suitability from an organism-centred perspective, accounting for basic species' habitat needs (e.g. nesting cliff) and landscape characteristics (e.g. livestock and land cover). This type of modelling accounting for the different scales at which species' needs could operate is rarely used in SDMs (Scott et al., 2002; Elith and Leathwick, 2009). We also use dynamic land use variables (e.g. openland, livestock; see Martin et al., 2013) to project future species' habitat suitability under four different scenarios. These scenarios represent different assumptions about human population, economy, technology and rural development (Rounsevell et al., 2006).

2. Material and methods

2.1. Study area

The study area covers around 24,639 km² in NW Spain (Fig. 1). The region holds a high biodiversity, including several protected areas (i.e. >55% of the total area) such as 10 biosphere reserves and 20 sites within the network of protected areas of the European Union (i.e. Natura 2000). The study area is mainly within the temperate climatic region, with a transition area to the Mediterranean region in the south. The landscape consists of a high variety of habitats, from oak and beech woodlands and pastures devoted to extensively bred livestock to rocky outcrops. Rocky cliffs, principally of limestone, are common throughout the area (Olea and Mateo-Tomás, 2013). Livestock consists mainly of cows, which are increasingly occupying the pastures of most of the study area. Sheep and goats were previously abundant as the study area provided high quality summer pastures for transhumance (i.e. a traditional livestock practise based on moving livestock between winter and summer pastures; Olea and Mateo-Tomás, 2009). Today the presence of sheep and goats is sharply decreasing in most of the study area (see Mateo-Tomás and Olea, 2010a,b; Mateo-Tomás et al., 2010).

2.2. Study species

The Egyptian vulture is a territorial, cliff-nesting raptor distributed from the Mediterranean to India and in Africa. The species has recently been upgraded to endangered worldwide (BirdLife International, 2014). It is also categorised as endangered in Spain, which now holds the largest population (c. 1500 breeding pairs) in the western Palearctic (Del Moral, 2009).

The Egyptian vulture is a long-lived species (up to 37 years in captivity) with delayed maturity (i.e. first breeding at 4–5 years old; Donazar, 1993). Breeding pairs rear one or two chicks and the

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