Geophysical Research Abstracts
Vol. 17, EGU2015-15368, 2015
EGU General Assembly 2015
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A spatial dynamic model to assess piospheric land degradation processes of SW Iberian rangelands

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Iberian open wooded rangelands (known as dehesas or montados) constitute valuable agro-silvo-pastoral systems traditionally considered as highly sustainable. Nevertheless, in the recent decades, those systems are undergoing changes of land use and management practices that compromise its sustainability. Some of those changes, as the rising construction of watering points and the high spatial fragmentation and livestock movement restriction associated to fencing, show an aggregated effect with livestock, producing an impact gradient over soil and vegetation. Soil compaction related to livestock pressure is higher around watering points, with bare soil halos and patches of scarce vegetation or nude soil developing with higher frequency in areas close to them.

Using the freeware Dinamica EGO as environmental modeling platform, we have developed a theoretic spatial dynamic model that represents some of the processes of land degradation associated to livestock grazing in dehesa fenced enclosures. Spatial resolution is high since every cell in the model is a square unit area of 1 m2. We paid particular attention to the relationships between soil degradation by compaction (porosity), livestock pressure, rainfall, pasture growth and shrub cover and bare soil generation.

The model considers pasture growth as related to soil compaction, measured by the pore space in the top 10 cm soil layer. Annual precipitation is randomly generated following a normal distribution. When annual precipitation and pore space increase, also does pasture growth. Besides, there is a feedback between pasture growth and pore space, given that pasture roots increases soil porosity. The cell utility for livestock function has been defined as an exponential function of the distance of a cell to watering points and the amount of pasture present in it. The closer the cell to a pond and the higher the amount of pasture, the higher is cell utility. The latter is modulated by a normal random variable to capture accidental effects. This variable has zero mean and a standard deviation linearly related to the distance to the pond. Livestock utilization of a cell is a function of its relative utility, the stocking rate and the time that animals spend at the enclosure. Since livestock trampling promotes soil compaction, livestock utilization has a negative effect on pore space.

The probability of transition from herbaceous to shrubs is also modulated by pore space, and thus livestock utilization, as shrub development needs a minimum porosity value for seeds to successfully germinate. In addition, it is influenced by the proportion of cells occupied by shrubs in a radius where seed dispersal or exclusion by competition may occur. The model contemplates the probability of transition from shrubs to herbaceous through shrub mortality, and the age of the shrubs, which influences seed production and shrub cover. Pasture consumption by livestock and pasture remaining at the end of summer were also modeled, so that it is possible to obtain maps of bare soil at that time. Likewise, the model generates maps of vegetation state (shrubs or herbaceous) and pasture growth.

The values of the set of 31 parameters were obtained from field measurements and from publications. Those parameters lacking quantitative information were calibrated by comparing model performance with the dynamics of true enclosures analyzed between 1984 and 2009 in ortophotographs. Stocking rates were inferred from farmers' interviews performed in 2009 about present and past land use and management practices.

The model developed is intended to analyze strategies of livestock management in dehesas. Particularly, soil conservation practices as related to livestock pressure can be simulated looking for optimized schemes. Moreover, the model provides the possibility of generating simulations for future climate scenarios, studying the effects of climate change on livestock carrying capacity on these systems.

Thanks to the Spanish Ministerio de Economía y Competitividad for financially supporting this study through AMID (CGL2011-23361) project.