SUMMARY OF RESULTS

The FORESTA project (PIEF-GA-2013-621940) aimed at developing a methodology of economic analysis applicable at a microeconomic scale to evaluate and predict the potential interactions between land-use, policy and market based incentives to encourage forest conservation, the ecosystem services (ES) that flow from it and changes in associated incomes and natural capital values. This project developed two complementary modelling approaches to examine forest management and land use decisions, and their impacts on the provision of a number of ecosystem services at the farm and forest unit levels. These modelling approaches have been applied to Andalusian forests including the seven most relevant tree species in this region.

The first approach is an *environmental-economic forest management* (EEFM hereinafter) model that integrates spatial-explicit economic and biophysical data and is used to simulate the long term evolution of forests in a sample of 567 silvopastoral farms distributed across Andalusia and the municipalities (193) at which those farms are located[1]. The forest units that make up the forested area of each farm are represented spatially considering main bio-geo-physical forest attributes at the municipality level (i.e. actual species and age class distribution, tree and shrubs density, slope of the land, and the quality of the site for growing different forest products). Those forest attributes, along with (i) the expected forest management regimes, (ii) forest fire and mortality ratios (based on historical observations and experimental data, respectively) and (iii) simulated economic scenarios, affect the expected net benefits from forest operations and investment decisions and their impacts on the provision of different ES at the site level. The ES that are simultaneously considered in this study comprise provisioning materials (timber, cork, firewood, nuts, grazing resources and natural regulated water flows) and carbon sequestration as a climate change regulating services. The study also considers 19 different forest management regimes that are site-and-species-specific and a set of economic scenarios based on expectations on output prices and intertemporal preferences. Finally, this model has been applied to examine the potential spatial and temporal trade-offs involved the provision of non-market ecosystem services (such as natural regulated water and carbon sequestration)[2] and between market-oriented provisioning services and non-market ecosystem services[1].

The results of the EEFM model applications reveal a noticeable spatial variability in the ES (asset) values and indicate the potential trade-offs associated with silvopastoral market-based provisioning services, carbon sequestration and water. The estimated ES are time varying figures that highly depend on future forest evolution and management. Therefore, an additional outcome of the model is that it identifies potential forestry abandonment at the forest unit level, as a result of an expected unprofitable forest regeneration investment for the landowner[1,2]. Likewise, the model allows for the exploration of the effect of payments for ecosystem services (PES) on forest investment decisions[2]. Changes in the assumptions made regarding the intertemporal preferences and expected prices lead to quite different states of potential forestry activity abandonment in Andalusian forests, which involves a high level of uncertainties concerning future provision of forest ES.

On the other hand, the results suggest that forestry activity abandonment is expected to reduce water inflow in regulated reservoirs (due to a rise in evapotranspiration due to tree and shrubs densification), while increasing carbon sequestration[2]. This trade-off is especially relevant for oak species[1]. PES for carbon sequestration could be key for encouraging the long-term conservation of multiple-use forestry. Those payments might, however, benefit areas with a higher carbon sequestration (growth) potential, thereby reducing water availability, which is a limiting factor in Mediterranean areas given the potential trade-off between those ecosystem services[1,2]. The latter result might have relevant policy implications for the design of PES schemes to promote forest ecosystems conservation in Mediterranean areas. The information produced by this study can support private and social planer decision making regarding forest

conservation and, in general, land planning policies. This work has also benefited from a previous ongoing research paper that has been completed during the FORESTA project implementation, which develops an ecosystem accounting system at the farm level aimed at the consistent integration of market and non-market output and costs to estimate farm incomes and capital values[3].

The second modelling approach developed by FORESTA project is a dynamic land use optimization model (DLUM hereinafter) that extends an existing optimal control model[4] that analyzed the optimal path of afforestation and natural regeneration investment decisions. The original model represented two native oak species, considering a rigid treatment of exogenous forest rotation ages and land available for afforestation. This latter model has been extended by including a third species (involving two additional state and control variables), being the three forest species at each farm any species out of the seven species included in the EEFM model. DLUM makes also the integration of rotation ages into the modelling framework and allocation of the land available for afforestation more flexible and general. The EEFM model has been adapted and coupled to the DLUM model, and applied to estimate each species rotation age considering the moment an homogeneous forest stand (of same species and age class) reach saw timber diameter (for timber species) or the diameter at which forest management models prescribe the regeneration treatments to be started (in case of native oak species).

The coupled EEFM-DLUM model has been applied to a group of eight representative silvopastoral farms in Andalusia (one representative farm with average bio-geo-physical forest attributes at the province level) to analyze the optimal afforestation and regeneration investment decisions over time[5]. The preliminary results of this model show that under current prices level, afforestation with oak species (specially cork oaks) are expected to expand in the future in those provinces with higher quality sites for growing cork, and those afforestations will involve a shift in forest species as abandoned forest of less profitable tree species (i.e. pine forest for timber production) become part of the land supply for new plantations. In Eastern Andalusian provinces no relevant afforestation and forest regeneration investments are expected in the short to long terms (from 2020 to 2050)[4].

The coupled EEFM-DLUM modelling framework is a benchmark for developing an spatial-explicit optimal land use decision model for Andalusia that extends the EEFM model results[1]. More research is however needed to analyze forestry abandonment and land use changes under changing climatic conditions, particularly regarding the likely intensification of wildfires under abandonment scenarios, which may increase carbon release and affect severely water availability. This idea is the main objective of a new research project presented to the Spanish Secretariat of State for Research, Development and Innovation (under evaluation).

References

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