COUPLING WATER, FIRE AND CLIMATE RESILIENCE WITH BIOMASS PRODUCTION IN FORESTRY TO ADAPT WATERSHEDS TO CLIMATE CHANGE

LIFE RESILIENT FORESTS

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INTRODUCTION

Effects of **global change in forests ecosystems** variate with forest type and climatic region. However, in most cases, global change is decreasing forest resilience against disturbances (fires, diseases, droughts…), at the same time that negatively affects both environmental and socioeconomic conditions of rural areas.

Forest management could be conceived as a **strategy to adapt forests ecosystem** to global change. When managing a forest, besides enhancing the productive functions, it may also contribute to reduce fire risk, increase ecosystem resilience, increase water yield, improve tree growth and vigor, landscape value, etc.

This approach could be easily applied into **productive areas**, where the marketable forest products might result profitable enough to cope with the management costs, and the rests of the benefits can just be considered as additional. On the contrary, low productive areas, such as semi-arid forests, face an extra difficulty as its marketable forests products are far from coping with the management costs, and the rest of the benefits are not usually considered nor quantified.

To face this problem, the LIFE RESILIENT FORESTS project has, as main objective, the development of a **Decision Support System** (DSS) tool that optimizes the forest management strategy according to the basin hydro-ecological, social and economical needs.

AIM OF THIS STUDY

The aim of the study is to develop a **demonstration of a forest management** approach at the watershed scale that improves the **resilience of forests** to climate change, enhancing the basin resilience to wildfire and other climate-induced disturbances, such as water scarcity and environmental degradation.

At the same time, it tries to take advantage of the answers needed for the **environmental and socioeconomic challenges** that will arise in rural areas, providing a wide range of environmental, social and economic **benefits**, such as the biomass management and exploitation.

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METHODS

As a first approach, the pilot case of the semi-arid Mediterranean catchment, Carraixet (E of Spain), is presented here. Carraixet basin is a water scarce environment of 84,492 ha, whose upper part (11,901 ha) corresponds to a mountainous area with 64 % of its territory within the Natural Park La Sierra Calderona. The catchment includes 15 populations, 6 (35 932 inhabitants) of which are located within the mountainous area, and whose main water source (drinking water and agricultural irrigation) is the groundwater. Sierra Calderona has historically suffered wild fires as lightning is highly frequent here (one of the most frequent zones in Spain), and agricultural field burning practices are very common in its rural areas.

Vegetation in a unmanaged forest inside the Parc Natural Serra-Calderona

The effects of forest management of typical Aleppo pine post-fire regeneration stands are analysed in terms of water yield (TETIS-VEG hydrological model), fire risk (KDBY index and FARSITE model) and biomass production, at catchment scale. TETIS-VEG model is calibrated and evaluated by using both, field measurements (soil moisture and transpiration) and satellite information (soil temperature from Landsat 8 OLI/TIRS Data). In order to analyse the profitability of the management strategy, a simple economic estimation is carried out by means of comparing the Benefit/Cost ratio (BC) of the managed and unmanaged scenarios as follows:

$$BC = \frac{MVW \cdot W \cdot (1 - P_f) + MVW \cdot W_f \cdot P_f + BV \cdot TB \cdot (1 - P_f) + BV \cdot TB \cdot P_f}{P_f \cdot FEC \cdot BrA + P_f \cdot RC \cdot BrA + MC}$$

Vegetation in a managed forest inside the Parc Natural Serra-Calderona

where MVW is the Marginal Value of Water (€/m³),Wf and W are the water contribution (m³) with and without wildfire, respectively, Pf is the probability of a wildfire occurrence, BV is the Biomass Value (€/Mg), TB is the Total extracted Biomass (Mg), BrA is the Burned Area (ha). FEC are the Fire Extinction Costs (€/ha), MC are the Management Costs (€/ha), and RC are the restoration costs after a wild fire (€/ha).

STUDY SITE

Black line indicates the lower limit of the mountainous area.

× indicates the location of the soil temperature points used in the model validation.

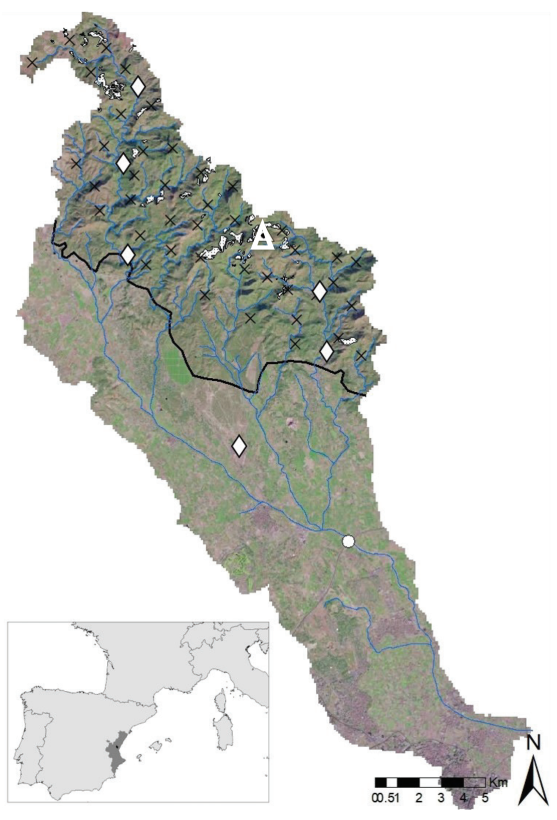
Blue line is the river network.

∆ represents the field experimental plots.

◊ indicates the populations that exclusively use groundwater.

• indicates the gauging station used during the calibration and validation of the model.

Dotted polygons represent the Aleppo pine post-fire regeneration stands.



Vegetation in the control plot adjacent to the experimental plot

The field experimental plot in the Carraixet catchment

RESULTS&DISCUSSION

The results showed a slight effect of forest management on water budget increase (average increase of 0.27 ± 0.29 mm/yr), although it only increases under yearly precipitation values above 345 mm, while at lower precipitation values the applied forest management (Table 1).

The biomass production wass estimated in 4161.6 Mg of biomass, and a fire risk and fire propagation decreased 27 ± 17 % and 25.6 ± 14.1%, respectively. Regarding to the profitability of forest management, the BC ratio of both scenarios was always above the unity when just considering water as benefit, although the unmanaged scenario produced a higher ratio, as no management costs are expended.

Contrarily, when wildfire was also included into the evaluation, the situation is overturned for wildfires equal or higher than 1.5 day duration (> 500 ha), where the forest management is shown as the most convenient alternative (Table 2).

Water contribution as deep percolation of both scenarios, managed and unmanaged, during the 10 water years. Net increasing is the difference between unmanaged and managed deep percolation.

Water year	Gr(mm)	Demand (hm³)	Contribution/Demand		Net increasing	
			Unmanaged	Managed	(m³)	(mm)
2007-2008	345	2.3	1.3	1.4	8416.7	0.71
2008-2009	443	2.4	1.5	1.5	8863.0	0.74
2009-2010	352	2.4	1.1	1.1	0	0
2010-2011	314	2.5	0.7	0.7	0	0
2011-2012	228	2.5	0.4	0.4		0
2012-2013	460	2.5	1.8	1.8	4375.9	0.37
2013-2014	167	2.5	0.2	0.2	0	0
2014-2015	348	2.6	1.0	1.0	2767.9	0.23
2015-2016	232	2.6	0.5	0.5	4847.4	0.41
2016-2017	552	2.6	4.2	4.2	3390.1	0.28

Table 1 - Water contribution as deep percolation of both scenarios, managed and unmanaged, during the 10 water years. Net increasing is the difference between unmanaged and managed deep percolation.

Scenario	Gr (mm)	Water	Water + Biomass + Fire							
		Managed	Unmanaged				Managed			
			0.5 d.	1 d.	1.5 d.	2 d.	0.5 d.	1 d.	1.5 d.	2 d.
1	299 299 371	2.3	1.7	0.7	0.3	0.2	1.3*	1.2	0.4*	0.2*
2	246 213 312	1.5	1.1	0.4	0.2	0.1	0.9*	0.8	0.3*	0.2*
3	145 221 434	2.2	1.6	0.6	0.3	0.1	1.3*	0.7	0.4*	0.2*

*Table 2 - Benefit/Cost ratio of the three different climatic scenarios with and without forest management and under wildfire duration of 0.5, 1, 1.5 and 2 days. * indicates significant differences (p≤ 0.05) between Managed and Unmanaged.*

CONCLUSIONS

The economic quantification showed the managed scenario as profitable, just considering the water contribution.

However, this efficiency in monetary terms is still lower than the current situation, where no management costs are considered.

When fire propagation is included, the results are overturned, and forest management becomes more efficient by avoiding fire extinction and restoration costs. These results reveal the difficulties of semi-arid forests to be managed.

In other words, this optimal management should be approached from a multi-purpose perspective that maximizes all the potentials profitability of the forest ecosystem services, which individually cannot be enough efficient from an economical point of view.

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