Effects of fuel treatments on reducing carbon emissions in fire-prone Mediterranean landscapes

Action C5. Strategic fuels management aimed at reducing wildfire risk

Beneficiary responsible: University of Lleida

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CLIMARK
Forest management promotion for climate change mitigation through the design of a local market of climatic credits

DELIVERABLE

11. Technical report on risk-smart management

SUMMARY

After analysing carbon-credit oriented fuel treatment opportunities in CLIMARK, we found these opportunities varied widely across the LUs in the project. Stand conditions and fire regime both determined the feasibility of fuel reduction programs aimed at increasing the carbon-sink capacity in multifunctional Mediterranean forests.

Assuming a carbon emission of 3 T × CO_2 ha^{-1} during prescribed fire treatment implementation, a 8 year duration period, and a 13 € T CO_2 carbon credit market price, the economic benefit from carbon credits covered up to 15% of the fuel treatment implementation cost in high-priority strategic management points. We note that the fuel treatment cost is > 100 € ha^{-1} per year, and carbon credits would therefore compensate just partially the total cost.

The 40 m resolution results were presented in an APP to inform ongoing fuel reduction programs and assist future fuel reduction projects. Our work is the first study of this type conducted in southern European regions and may serve as a baseline for the development of a carbon credit market intended to economically compensate small forest landowners for preserving fire resilient cultural landscapes.

Keywords: carbon credits, gross benefit, sustainable forest management, fuel treatments

1. – Using quantitative data to inform a carbon-credit oriented forest management

Assessing existing carbon stocks in forests and expected biomass consumption from wildfire, the largest contributor to carbon dioxide emission, is essential to develop a carbon credit market in fire-prone landscapes (Hurteau *et al.* 2013). Previous studies conducted on Mediterranean areas showed that active forest management could increase the carbon sequestration in forests (Prada *et al.* 2016; Ruiz-Peinado *et al.* 2017), and multiple species-specific and stand-level adaptive management rules have been developed for different wildfire hazard scenarios based on forest stand structure (Beltrán *et al.* 2011; Piqué *et al.* 2011; González-Olabarria *et al.* 2017). However, expected carbon dioxide emissions from the long distance spreading high-severity rare events that burn large portions of the landscape have been largely ignored.

In this study, we implemented a quantitative assessment framework to estimate expected annual carbon dioxide emissions across various landscape units in Catalonia (northeastern Spain) where historic large fire events caused very substantial losses (Retana *et al.* 2002; Salis *et al.* 2019). In contrast to most previous carbon studies conducted in Mediterranean areas, we used spatially explicit wildfire likelihood estimates and dead biomass data for the dominant forest types on the study areas to estimate fuel consumption under severe-weather (97^{th} percentile) conditions. Specifically, we estimated the carbon benefits from ongoing prescribed fire programs aimed at reducing fuels on strategic management points (SMPs), and we identified the "high emission hot-spots" where treatments (i.e., prescribed fire, thinning and mastication) are most likely to generate long-term carbon benefits. Specifically, we estimated the reduction in expected carbon emissions across the different landscape units (LUs) by implementing fuel treatments on SMPs identified by the local wildfire managers (see further details in the Deliverable 12).

In these "hot-spots", forest landowners and wildfire managers of Catalonia can prioritize the fuel reduction aimed at increasing the carbon pools on the forest. The design of optimized fuel treatment allocation, though, was not the purpose of this study, and we emphasize that results should be carefully interpreted considering that the treatment intensity (i.e., % biomass removed on treatments), fuel treatment type (prescribed fire versus mechanical mastication), as well as different treatment shape/size and aggregation patterns across the landscape may have an effect on the final outcome.

2. – Landscape scale potential benefits from reducing fuels on SMPs

We estimated landscape scale potential benefits by reducing fuels on strategic management points. The fuel treatment types on SMPs combined a thinning plus a prescribed fire. We used emission, cost and duration reference data from bibliography (Table 1). Previous studies assessing emissions from prescribed fire combustion provided a wide range of reference values which varied in most cases between 2 and 10 T $CO_2 \times ha^{-1}$ depending on the forest systems and treatment intensities (North *et al.* 2009; Sorensen *et al.* 2011; Stephens *et al.* 2012;

Restaino and Peterson 2013). Indeed, the right timing of the year for implementing prescribed fire programs may result essential to prevent duff and > 100 h log fuel consumption, and therefore conducting prescribed fires on early spring would likely present best weather conditions (i.e., high fuel moisture content values for the duff and dead logs). We assumed a treatment cost for the worst-case scenario i.e., unmanaged stands requiring a thinning from below.

Table 1. Summary table with fuel treatment assumptions considered to assess the benefit of a carbon credit-oriented fuel reduction program. Previous studies implemented in the study area showed that the duration of the treatments was about 8 years (Casals et al. 2016). The treatment cost was provided by local landscape managers. On average, we can consider a reference annual cost of 188 € ha^{-1} per year. Note that the maintenance cost could be 2 to 3 times lower in previously treated areas, but this is not currently the case. We assumed an 8-year treatment duration to annualize the emission and cost.

Type of treatment	**Cost** (€ ha^{-1})	**Emission** (CO_2 T ha^{-1})	**Duration** (yr)	**Annualized cost** (€ ha^{-1} per yr)	**Annualized emission** (CO_2 T ha^{-1} per yr)
Prescribed fire	800	3	6 to 8	100	0.38
Thinning	700	0	8 to 12	87.5	0.00

We accounted not only the local effects on treated stands but also the benefits at landscape scale (reduction of expected carbon dioxide gas emission) to estimate the net and the gross benefit from potential carbon credits (Table 2). In the calculations we considered a reference market price of 13 € per T CO_2 gas. The SMP also reduced expected carbon emissions outside the LUs, this analysis was conducted considering the positive effects inside the LU.

Table 2. Gross benefit from a carbon credit market in the different landscape units. The benefits of the SMPs was estimated collectively for the LUs as a treatment cluster. Nonetheless, we computed here only the area of the SMPs with stand level reductions > 0.01 CO_2 T ha^{-1} per yr in order to exclude treatments that did not substantially contribute to mitigate expected carbon emissions.

Landscape unit	**SMP*** (ha)	**Treatment cost** (€ yr^{-1})	**Reduction in emissions** (T CO_2 yr^{-1})	**Gross benefit**	**% from cost**
El Montmell	294	55,272	49	637	1.15
Serres d'Ancosa	3,784	742,788	213	2,769	0.37
Vall de Rialb	845	114,680	59	767	0.67
Capçaleres del Llobregat	-	-	55	715	-
Els Aspres	802	150,776	246	3,198	2.12
Replans del Berguedá	3,939	740,532	444	5,772	0,78

(*) SMP suitable for increasing carbon pools at landscape scale.

Given the assumptions considered on this study, the highest contribution was obtained in Els Aspres LU, where the gross benefit from carbon credits was about the 2.12 % of the treatment cost. Please, note that this is an overall value derived from all SMP working as a "cluster of treatments" where the efficiently of the individual SMP varies very substantially (i.e., SMP located in "hot-spots" achieved values close to the 8%). Moreover, the contribution will increase substantially (up to 3 times) after the first rotation since the maintenance or the reburn cost is much lower. On the other hand, as expected, the fuel treatments on the Capçaleres del Llobregat

LU did not have any interest if the objective is to mitigating carbon dioxide emissions because the long distance spreading extreme events here are very rare.

3. – Providing a tool to prioritize fuel treatment implementation

Not all forest landowners could require compensation and the potential economic benefits from carbon credits should be determined in each case at stand level. For instance, forest treatments on LUs such as Capçaleres del Llobregat and remote northern portions of Vall de Rialb would hardly encounter a fire in the lifespan of the treatment, and the short-term carbon loss from prescribed fires here would be much higher than the potential benefits. On the other hand, some old-growth forest stands on the Replans del Berguedá and especially the carbon emission "hot-spots" in Els Aspres present interesting opportunities. In order to provide a management-oriented result, we combined our high-resolution annual expected carbon emission maps to estimate the gross benefit from treatments (Fig. 1). We note that we show the annual gross benefit per treated area, and not the net benefit. Since the fuel treatments cost > 100 € ha^{-1} per year, carbon credits would cover up to 15% of the total cost in the best-case scenario. Pere Gelabert (University of Lleida) generated a risk-smart tool to assist in prioritizing the fuel treatments (Fig. 2). This tool is an APP developed using Google Earth Engine where we posted our results. The user can click in a given location of interest to know the stand-level gross economic benefit.

4. – Concluding remarks and future analyses

Landscape managers could fine-tune the gross benefit estimates using local data. For instance, forest managers could consider the implementation of mechanical mastication instead of fuel treatments with prescribed fire and this would substantially change the results (e.g., the carbon emission during treatment implementation is lower). Likewise, the landscape managers could explore and compare results for different future scenarios (e.g., a changing carbon-credit price over time).

Increasing carbon stocks on forest systems may represent a major management objective in future projects, but optimal solutions may compete with other existing objectives such as wildfire risk mitigation in the wildland-urban interface (Alcasena *et al.* 2019). In order to explore multifunctional solutions among competing objectives, analyzing trade-offs allows assessing co-location opportunities (i.e., forest stands where treatments can meet multiple objectives) on vast landscapes (Alcasena *et al.* 2018). For instance, the SMPs are specifically designed to reduce large-fire potential and increase firefighting contention capacity and do not explicitly attempt to reduce carbon emissions (Gonzalez-Olabarria *et al.* 2019). Future efforts should be oriented at determining the tipping points between carbon benefits and losses from a wider range of forest management actions (i.e., changing % treated areas on the landscape) in response to expected fire likelihood and severity, which should provide better and more accurate information to compute realistic compensations (Campbell and Ager 2013).

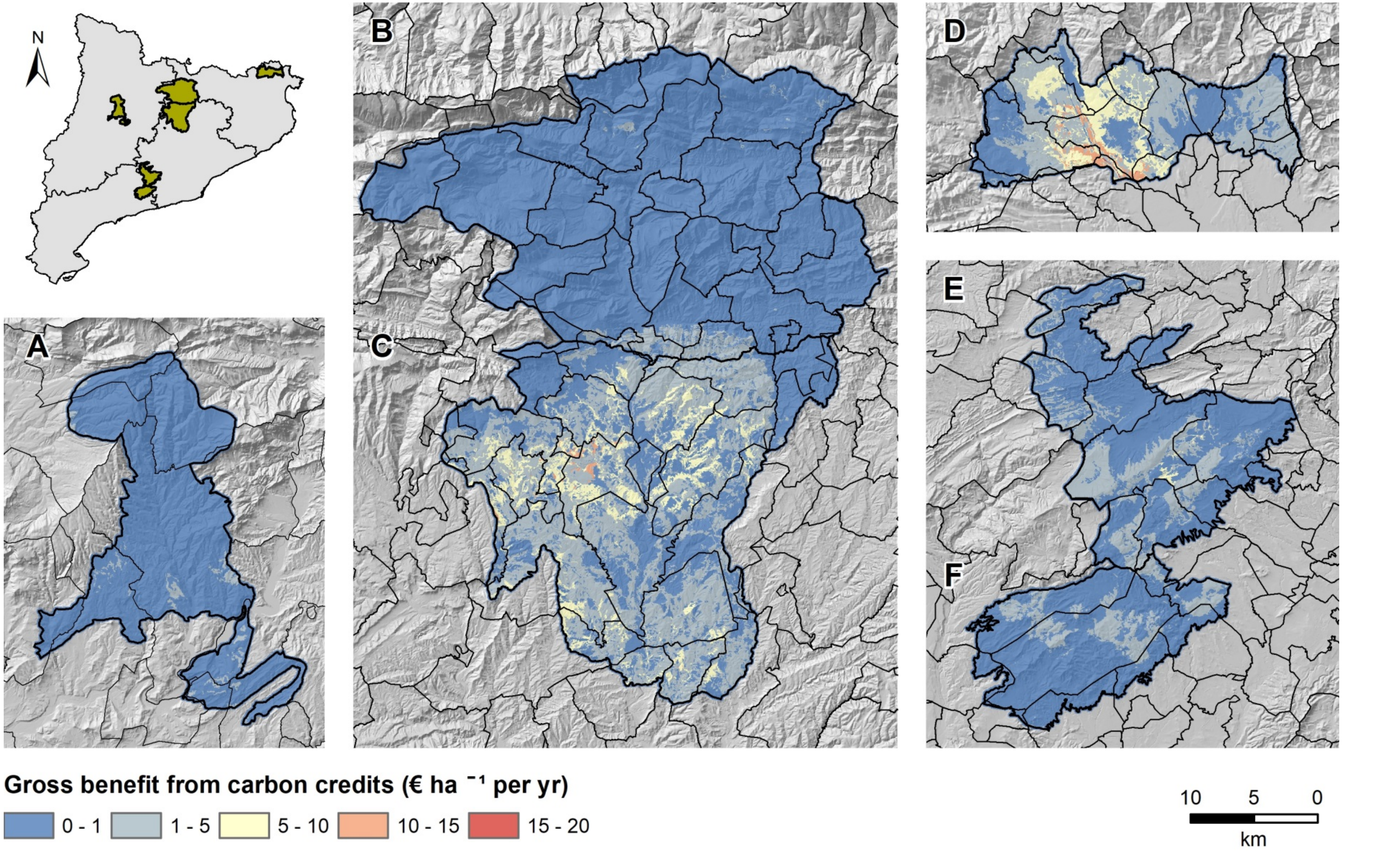

Fig. 1. High-resolution (40 m) gross economic benefit (€ × ha^{-1} per year) from treatments oriented at increasing the carbon sink capacity in the different LUs. The blocks represent the municipality boundaries. We show the results for the landscape units (LU) of Vall de Rialb (A), Capçaleres del Llobregat (B), Replans del Berguedá (C), Els Aspres (D), Serres d'Ancosa (E), and El Montmell (F).

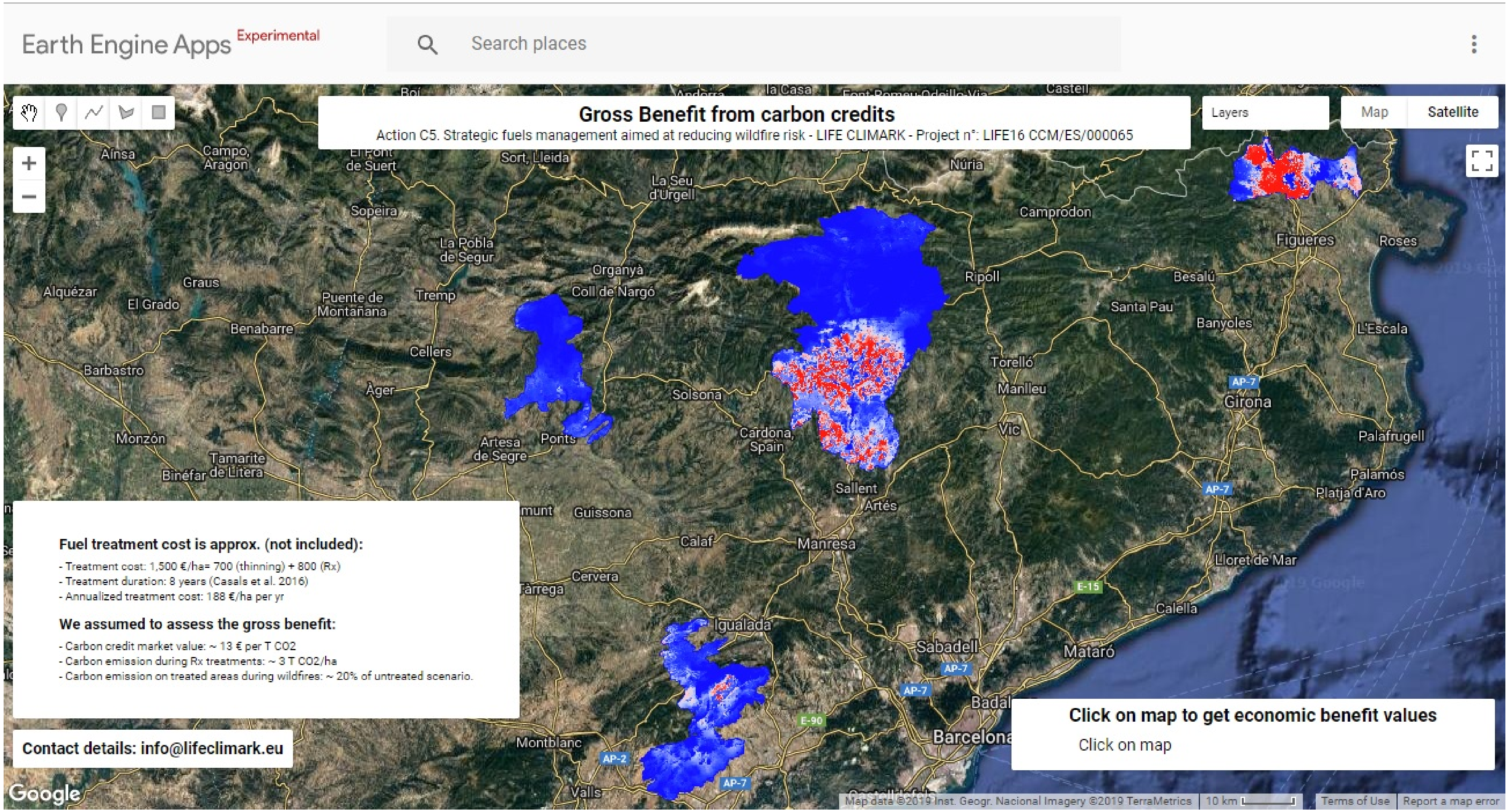

Fig. 2. Application developed by P. Gelabert on Google Earth Engine to show the gross benefit from treatments (Link to the app: https://pjgelabert.users.earthengine.app/view/climark). Using this tool, landscape managers and small landowners will be able to estimate stand-level economic compensation for the fuel reduction treatment implementation.

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