MEDACC

Demonstration and validation of innovative methodology for regional climate change adaptation in the Mediterranean area

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Effects of the implementation actions in LIFE MEDACC case study basins

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Executive summary

This deliverable explains the results of the monitoring tasks accomplished in the project LIFE MEDACC to monitor the effects of the implementation actions in the three case-study basins: Muga, Ter and Segre.

The first section makes a general introduction to the deliverable objectives. The second section defines the monitoring tasks performed to assess the effects of action B1. The monitoring is accomplished in two ways: a) measuring the accuracy of calibrated models compared with the historical data, and b) inter-comparing project scenarios with other climate and socioeconomic projections performed by European institutions and research centres. The third section carries out the monitoring tasks performed to assess the effects of action B2. The monitoring is performed by measuring different variables on the field and comparing the changes of the variable’s values among treatments (control and management treatments) and along the time (annual campaign of 2015-2016-2017). The fourth section presents the monitoring tasks performed to assess the effects of action B3. The monitoring is done by the use of periodic opinion polls about the Platform and Website in order to know satisfaction degree and usability.

This deliverable delves into the results of monitoring the implementation actions of LIFE MEDACC project. The methodologies followed can be consulted at the *Deliverable 21.Methodology to monitor the effects of the implementation actions in the LIFE MEDACC case-study basins* (Pascual et. al 2018).

Contents

1. Introduction

As stated in the requirements of a new proposal in the LIFE programme "*all projects have to include monitoring actions of the implementation actions. The implementation actions (B actions) must lead to a measurable improvement of the state of the environment targeted by the project. Monitoring these effects have to take place throughout the project and its results should be evaluated on a regular basis. In this regard, every project proposal must contain an appropriate amount of monitoring activities in order to measure the project's impact on the environmental problem targeted. These activities are distinct of the monitoring of the project progress (E actions). For this purpose, the project management should identify specific indicators to be used to measure the impact of the project. These indicators should be coherent with the environmental problem addressed and the type of activities planned during the project. The initial situation from which the project starts should be assessed and progress should be regularly evaluated against it. The monitoring of the project impact on the environmental problem should allow the project management either to confirm the adequacy of the developed means to address the specific problems and threats, or to question these means and alternatively develop new ones. At the end of the project, the beneficiaries should be able to quantify the progress achieved, in terms of impact on the targeted environmental problem*".

LIFE MEDACC project has three implementation actions:

- Action B1: Definition of new climate change adaptation measures based on the assessment of climate change impacts and vulnerabilities and the diagnosis of existent adaptation measures
- Action B2: Implementation of demonstrative adaptation measures through pilot experiences
- Action B3 Creation and update of a platform to integrate the information of the project

The following chapters delves into the results of the monitoring tasks followed by the project to monitor the effects of the implementation actions. The methodologies followed can be consulted at the *Deliverable 21.Methodology to monitor the effects of the implementation actions in the LIFE MEDACC case-study basins* (Pascual et. al 2018).

2. Monitoring the effects of Action B1

2.1. Introduction

The Action B1 has the following objectives: 1) evaluate the main impacts of climate change in the case study basins and identify territorial vulnerabilities to climate change (sub-action B1.1); 2) perform a diagnosis of previous adaptation measures applied in the case study basins (sub-action B1.2); and 3) define new adaptation measures and an action plan to be applied into the basins (sub-action B1.3).

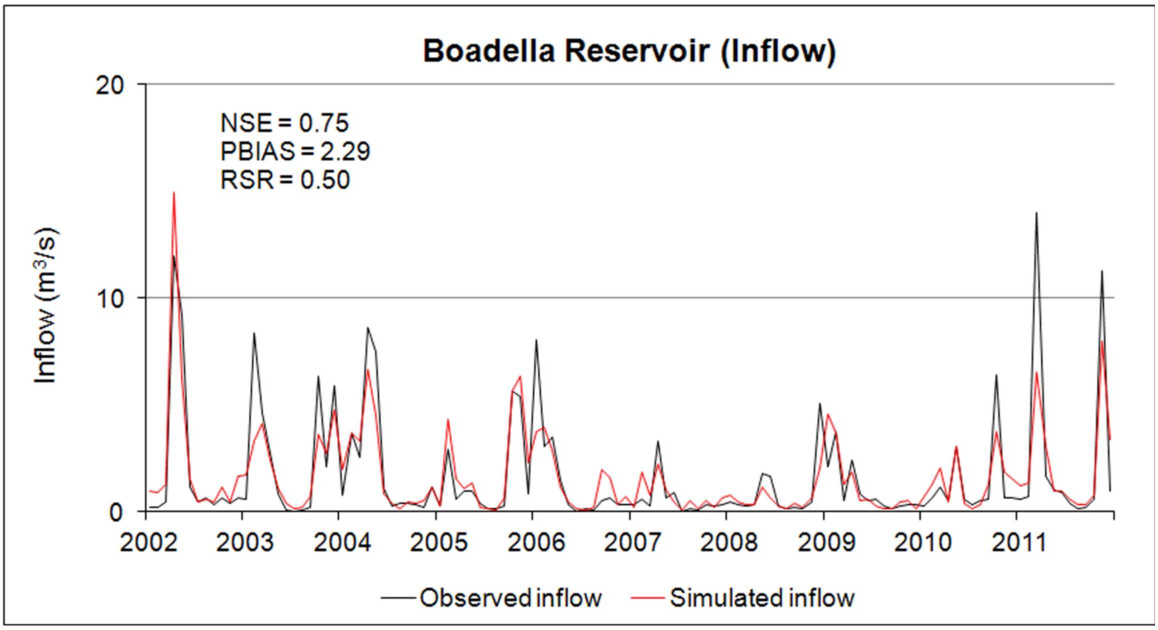
As stated in the Grant Agreement, Action B1 will be monitored in two ways: a) the accuracy of calibrated models compared with the historical data, and b) the inter-comparison between the project projections and other climate and socioeconomic projections performed by European institutions and research centres, such as CLIMB, ENSEMBLES, PRUDENCE or ALARM project.

2.2. Results

2.2.1. Accuracy of eco-hydrological calibrated models

Accuracy of RHESsys model in Muga basin

Figure 1 shows the graphical comparison between simulated and observed data for monthly stream flow and reservoir inflow (m^3/s) for two gauging stations: Boadella reservoir and Castelló d'Empúries. The graphical comparison showed a good fit, although in Castelló simulations overestimated low flood and underestimated flow peaks. The main reason to explain this is that RHESsys, in general, simulate in a not very good way the artificial streamflow. It is one of the main handicaps of this model, designed especially for mountainous areas. Assuming that the water demand data and the data about management of the Boadella-Darnius are good, the result of the



calibration is satisfactory.

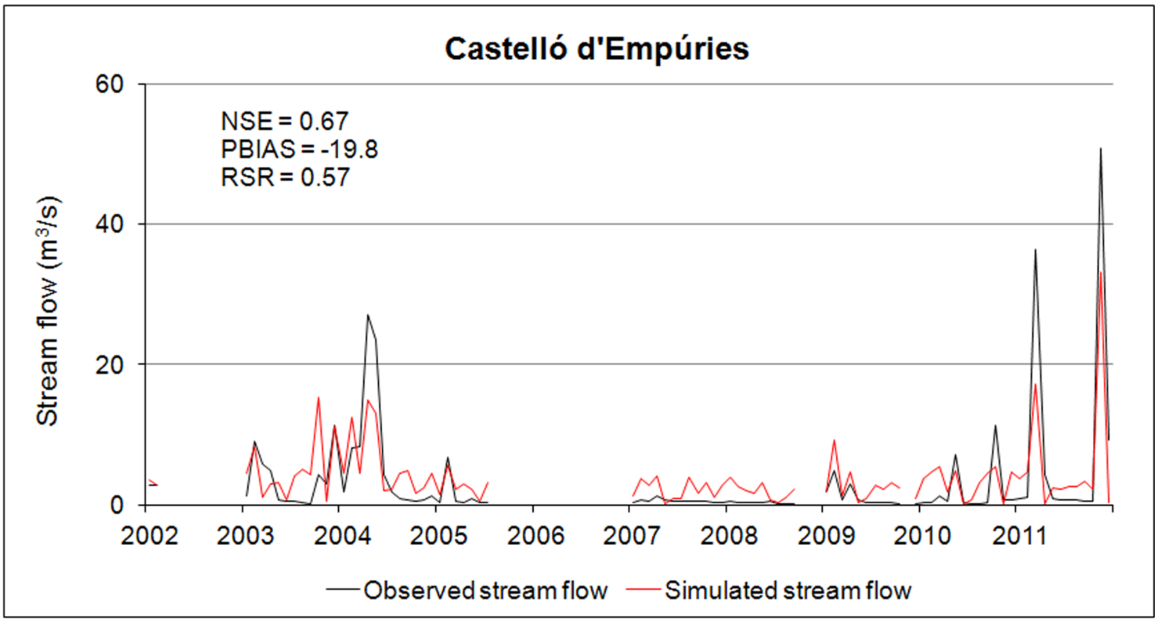


Figure 1.Observed (black line) and simulated (red line) dam inflow or stream flow at two points of the basin: Boadella reservoir (headwaters) and Castelló d'Empúries (river mouth).

Table 1compares simulated and measured dam inflow and stream flow data per gauging station. In Castelló, simulations overestimated mean stream flow values (by 19.8%). In Boadella, simulations overestimated observed data in a 2.3%. The NSE, PBIAS and RSR statistics show a very good fit for Boadella and a good/satisfactory in Castelló (Moriasi et al. 2007).

	Simulated Qm (m^3/s)	Observed Qm (m3/s)	Statistics		
			NSE	PBIAS	RSR
Boadella Dam	1.64	1.68	0.8	2.295	0.5
Castelló d'Empúries	3.89	3.25	0.7	-19.8	0.57

Table 1. Accuracy results at a monthly time step: dam inflow or stream flow values (Qm) from both simulated and observed data and statistics in each gauging station. Yellow colour identifies satisfactory performance ratio for the statistic, light green good and dark green very good, following Moriasi et al. (2007).

Accuracy of RHESsys model in Ter basin

Figure 2 shows the graphical comparison between simulated and observed data for monthly stream flow (m^3/s) in two gauging stations: Roda de Ter and Torroella de Montgrí. The graphical comparison showed a good fit, although, in the case of Torroella de Montgrí, at the end of the calibration period the simulations tend to underestimate peak flows, meanwhile the opposite trend is observed at the beginning of the period. The calibration in Roda de Ter shows that RHESsys can replicate the streamflow evolution very well both, the low flow and high flow.

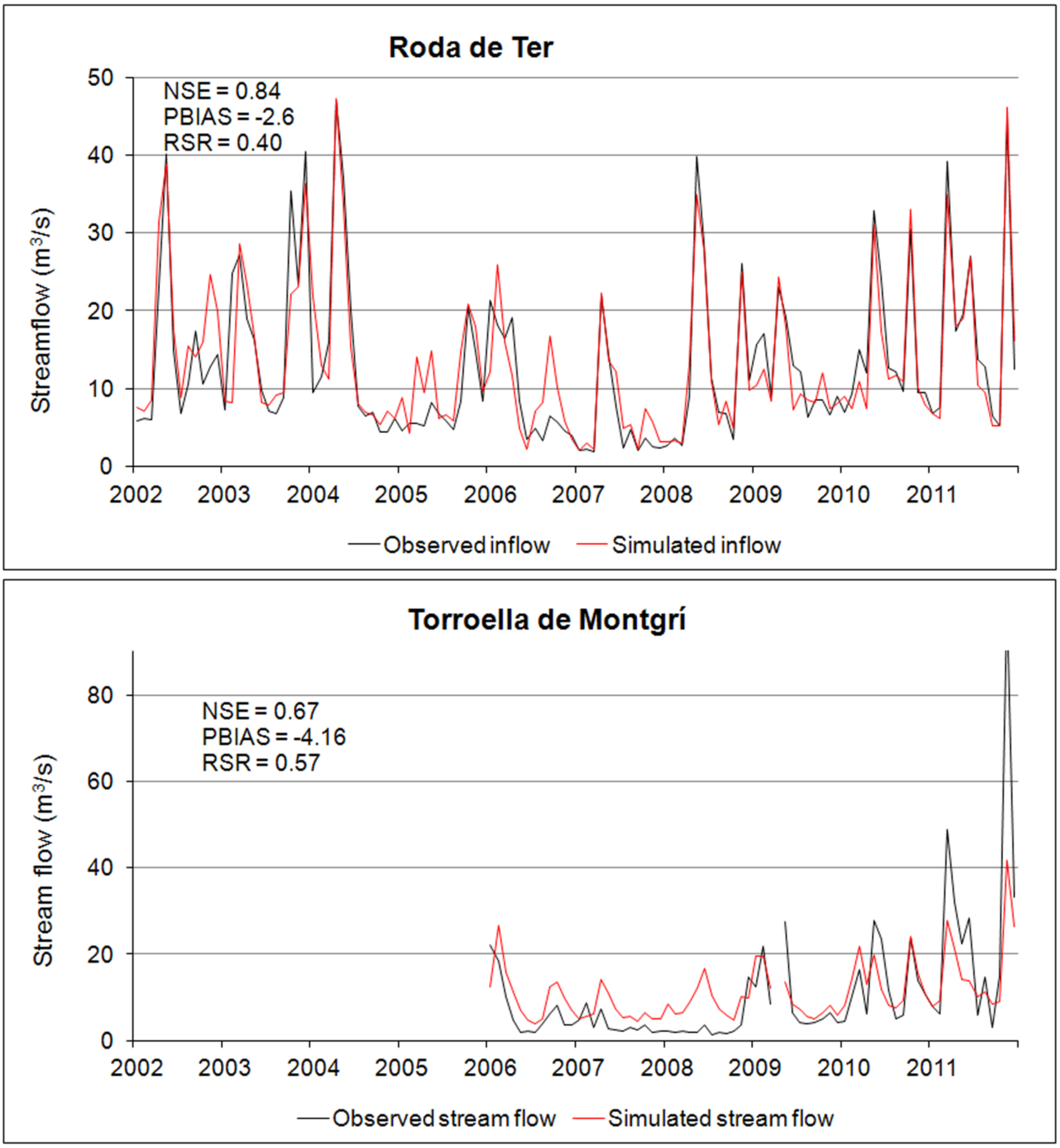


Figure 2. Observed (black line) and simulated (red line) dam inflow or stream flow at two points of the basin: Roda de Ter (headwaters) and Torroella de Montgrí (river mouth).

Table 2compares simulated and measured dam inflow and stream flow data per gauging station. In Roda and Torroella, the two stations have different results: slight underestimation in Roda de Ter (-2.29%) and high overestimation in Torroella de Montgrí (19.8). The NSE, PBIAS and RSR statistics show very good performance ratio for Roda de Ter gauging stations, while for the other stations only is able to get good/satisfactory ones (Moriasi et al. 2007).

	Simulated Qm (m^3/s)	Observed Qm (m3/s)	Statistics		
			NSE	PBIAS	RSR
Roda de Ter	13.26	12.92	0.84	-2.6	0.4
Torroella de Montgrí	11.20	10.62	0.67	-4.16	0.57

Table 2. Accuracy results at a monthly time step: dam inflow or stream flow values (Qm) from both simulated and observed data and statistics in each gauging station. Light green colour identifies good performance ratio for the statistic and dark green identifies very good, following Moriasi et al. (2007).

<u>Accuracy of RHESsys model in Segre basin</u>

Figure 3shows the graphical comparison for monthly stream flow and reservoir inflow (m^3/s and Hm^3, respectively) for five gauging stations: in the Valira river (La Seu d'Urgell), in the Segre river (Organyà and Seròs), Noguera Pallaresa (Escaló) and in Noguera Ribagorzana river (Escales Dam inflow). This figure shows that RHESsys is able to simulate the streamflow in a satisfactory way with a clear underestimation in some high flows, being the more representative one in 2008. Generally and knowing the complexity of this basin the calibrations can be regarded as satisfactory/good.

Table 3compares simulated and measured stream flow data per gauging station and dam inflow in the case of Escales Dam. Simulations underestimated mean stream flow values in all the cases (3.45% in Escalés, 13.9% in Escaló, 2.9% in Organyà and 12.71% in Valira) except in Seròs gauging station, where the simulation overestimated stream flows in a 25%. The statistics show satisfactory results what talks about the complexity of this basin. Indeed, the calibration in lowland (Seròs) is in the limit to be an unsatisfactory calibration, explained with the mismatch in the last two years of calibration. The statistics in this station are much better for the period 2002-2010 (NSE: 0.6, PBIAS: 18%, RSR: 0.64) and for the period 2002-2009 (NSE: 0.74, PBIAS: 10.4%, RSR: 0.5). The observed data in 2010 delays the peak streamflow of spring, while in 2009 is practically non-existent, what the model is not able to replicate. A part from this, the model show a clear adjust the first five years.

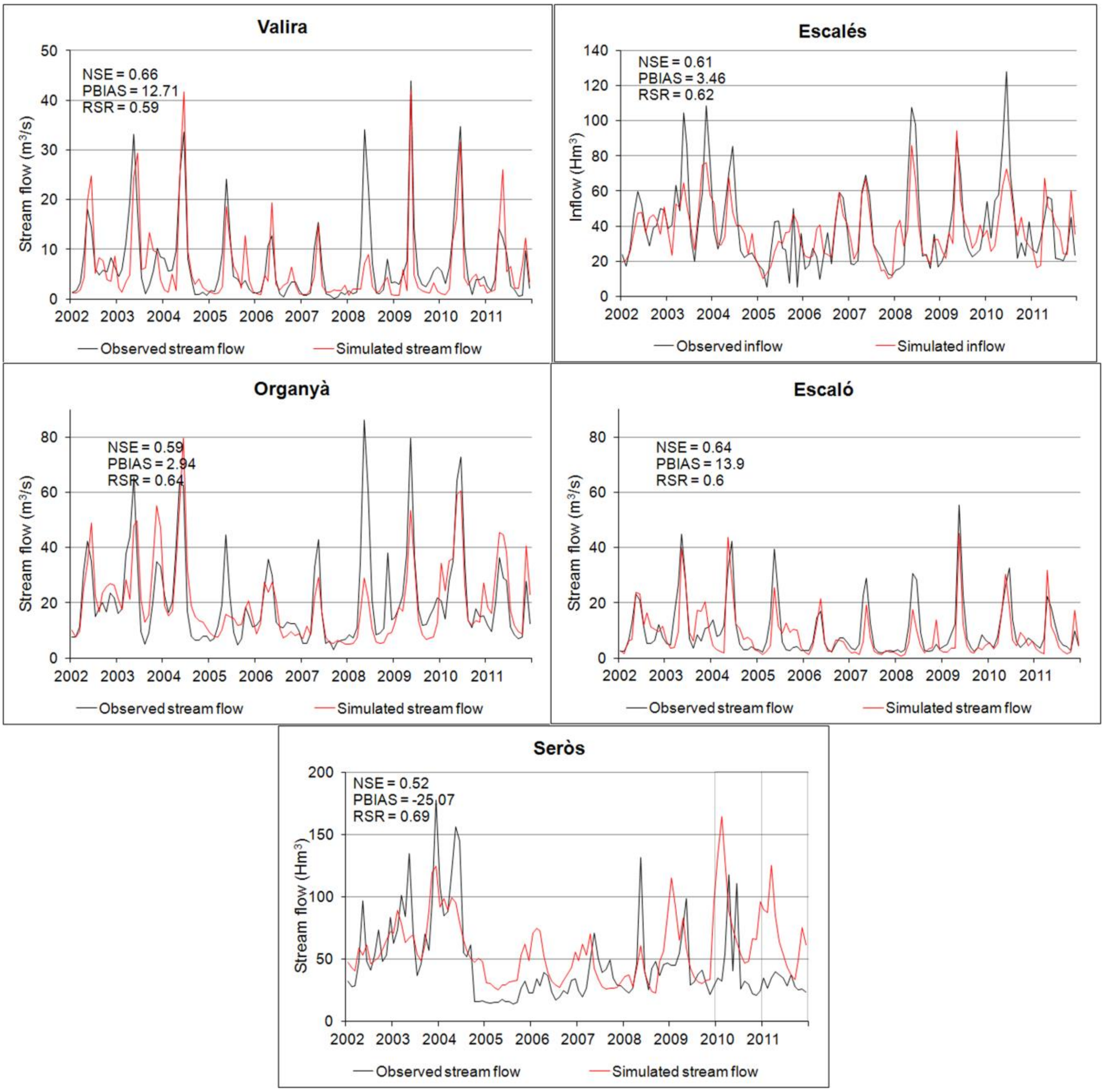


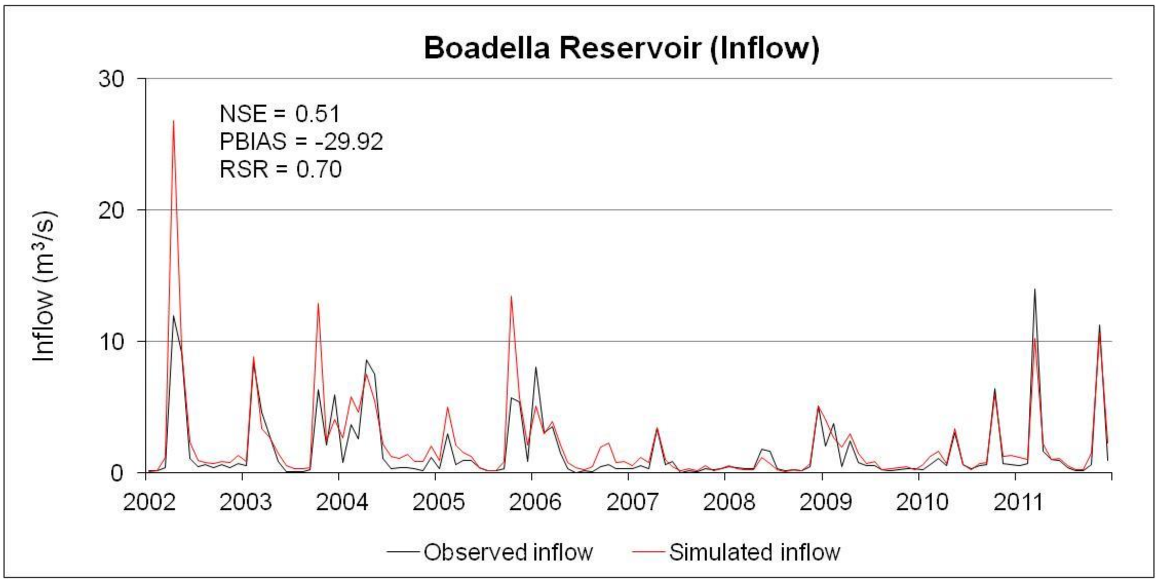
Figure 3.Observed (black line) and simulated (red line) dam inflow or stream flow at five points of the basin: Valira, Escalés, Escaló, Organyà and Seròs.

	Simulated Qm (m^3/s)	Observed Qm (m3/s)	Statistics		
			NSE	PBIAS	RSR
Escalés (Hm^3)	37.74	39.09	0.61	3.456	0.62
Escaló	8.58	9.96	0.64	13.9	0.6
Organyà	20.36	21.24	0.59	2.939	0.64
Valira	6.12	7.01	0.66	12.71	0.59
Seròs	57.44	48.39	0.52	-25.00	0.69

Table 3. Accuracy results at a monthly time step: dam inflow or stream flow values (Qm) from both simulated and observed data and statistics in each gauging station. Yellow colour identifies satisfactory performance ratio for the statistic, light green good and dark green very good, following Moriasi et al. (2007).

Accuracy of SWAT model in Muga basin

Figure 4 shows the graphical comparison between simulated and observed data for monthly stream flow and reservoir inflow (m^3/s) for three gauging stations: Boadella reservoir (in the headwaters, 190.7 km^2 upstream surface area and 25.0% of the total area), Peralada (in Llobregat d'Empordà Muga affluent, 304.3 km^2 and 39.9%) and Castelló d'Empúries (in the river mouth, 755.5 km^2 and 99.1%). The figure showed a good fit, although in Peralada and Castelló simulations underestimated high flood peaks and slightly overestimated base flows. One explanation could be the high spatial variability of the precipitation in the area, where the complex mountainous landscape causes orographic precipitation or convective phenomena that affect the climate (Barrera-Escoda and Cunillera 2011). This means that the precipitation measured in the meteorological station may be different than the total registered in the upstream area of the gauging station. Another reason can be the low capacity of the SWAT model structure to adequately account for hydrological extreme events (Ndombaet al. 2008).



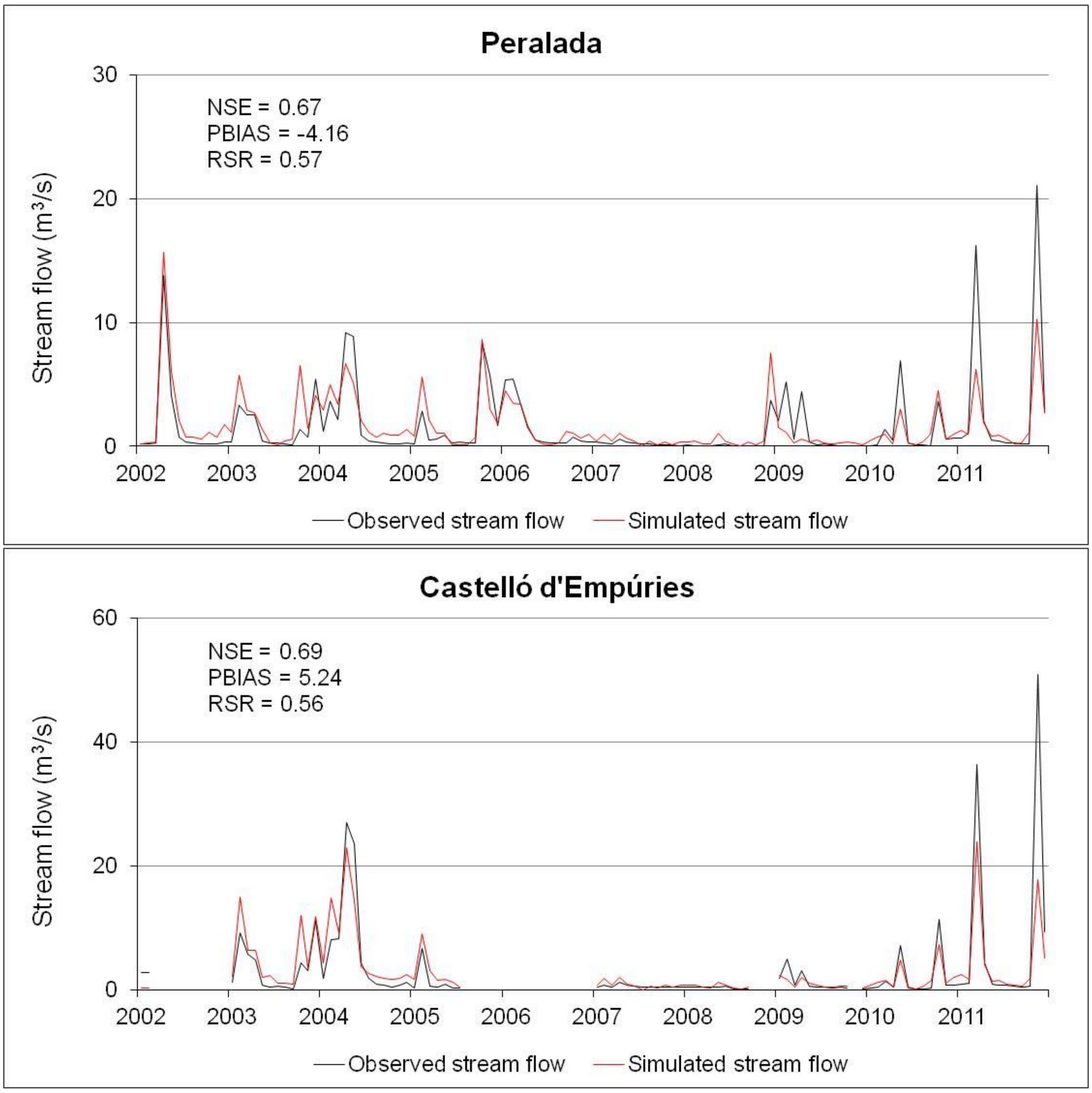


Figure 4.Observed (black line) and simulated (red line) dam inflow or stream flow at three points of the basin: Boadella reservoir (headwaters), Peralada (Llobregat d'Empordà) and Castelló d'Empúries (river mouth).

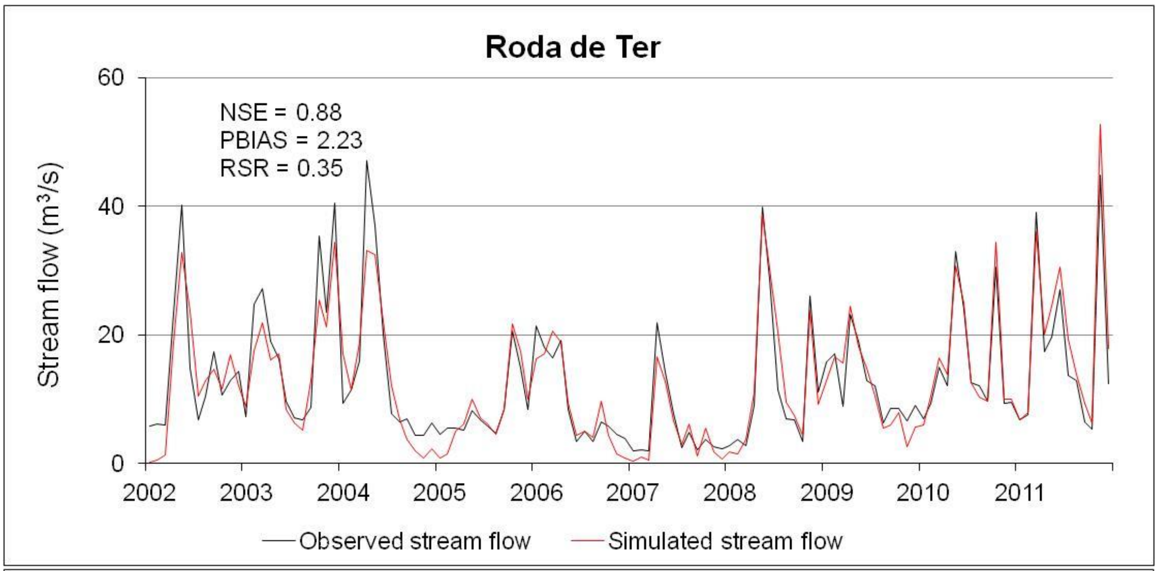
Table 4compares simulated and measured dam inflow and stream flow data per gauging station. In Boadella and Peralada, simulations overestimated mean stream flow values (by 29.9 and 4.2%, respectively). In Castelló, simulations underestimated observed data in a 5.2%. It is worthy to remember than Muga basin was fully calibrated with Castelló stations, so mean values and statistic were adjusted to the best fit in this station. The NSE, PBIAS and RSR statistics show a satisfactory fit for Boadella and a good or very good for Peralada and Castelló (Moriasi et al. 2007).

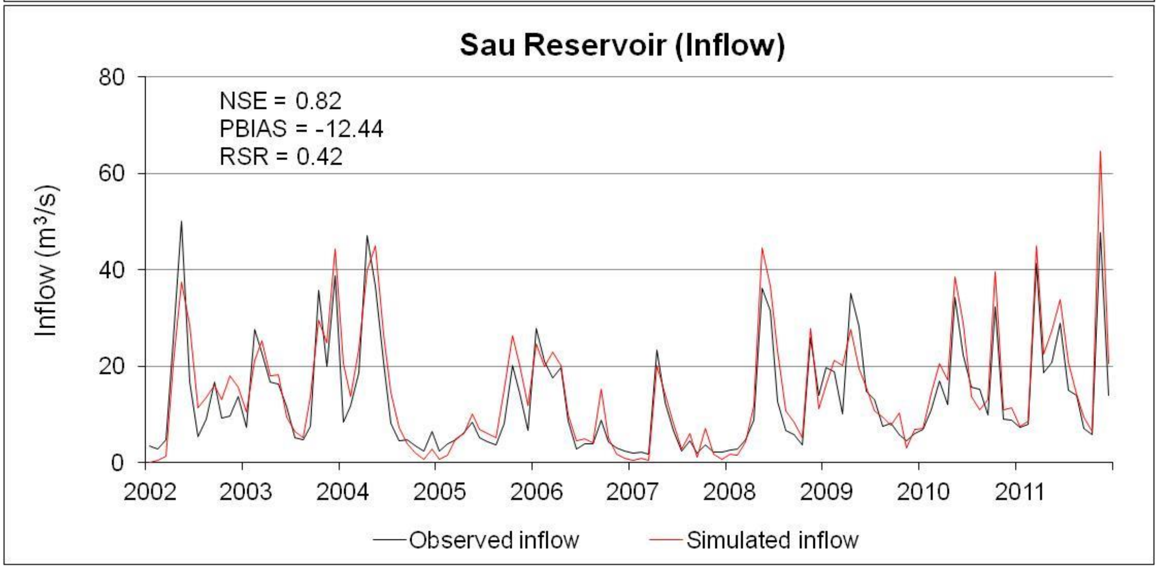
	Simulated Qm (m^3/s)	Observed Qm (m^3/s)	Statistics		
			NSE	PBIAS	RSR
Boadella Reservoir	2.18	1.68	0.51	-29.92	0.70
Peralada	1.62	1.56	0.67	-4.16	0.57
Castelló d'Empúries	3.08	3.25	0.69	5.24	0.56

Table 4. Accuracy results at a monthly time step: dam inflow or stream flow values (Qm) from both simulated and observed data and statistics in each gauging station. Orange color identifies unsatisfactory performance ratio for the statistic, yellow identifies satisfactory, light green good and dark green very good, following Moriasi et al. (2007).

<u>Accuracy of SWAT model in Ter basin</u>

Figure 5Figure 5shows the graphical comparison between simulated and observed data for monthly stream flow and dam inflow (m^3/s) for five gauging stations: Roda de Ter (in the headwaters, 1,388 km^2 upstream surface area and 47.0% of the total area), Sau reservoir (1,525 km^2 and 51.7%), Susqueda reservoir (1,770.5 km^2 and 60.0%), Girona (2,232 km^2 and 75.6%) and Torroella de Montgrí (in the river mouth, 2,952.25 km^2 and 100.0%). The figure showed a good fit, although at the end of the calibration period the simulations tend to overestimate peak flows, meanwhile the opposite trend is observed at the beginning of the period.





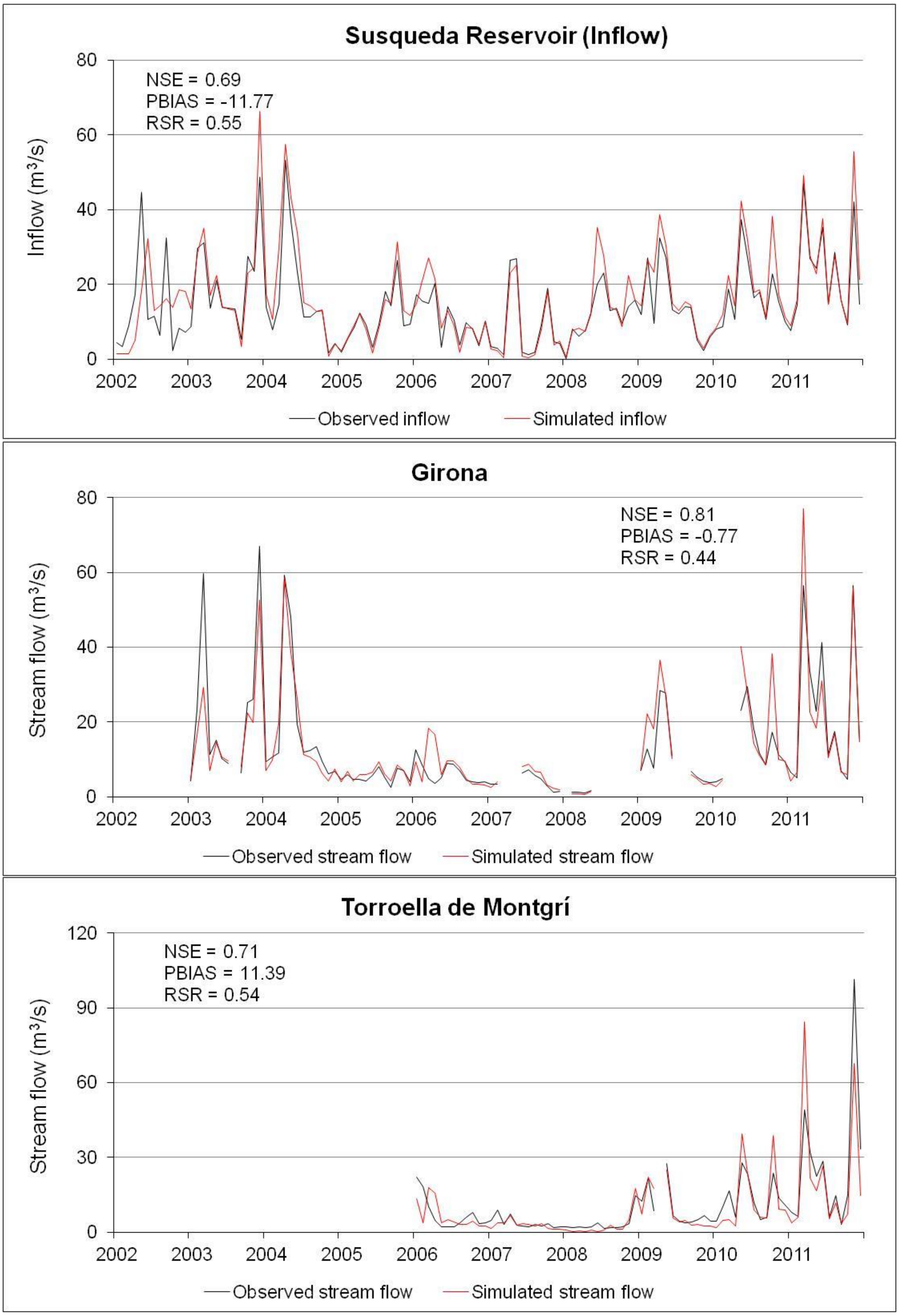


Figure 5. Observed (black line) and simulated (red line) dam inflow or stream flow at five points of the basin: Roda de Ter (headwaters), Sau and Susqueda dams, Girona and Torroella de Montgrí (river mouth).

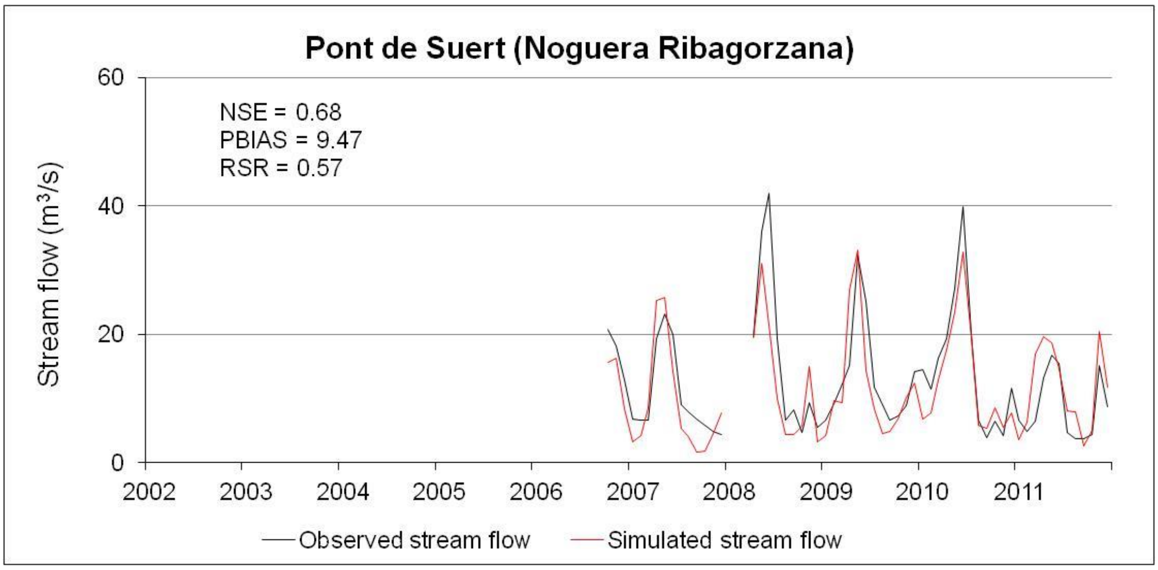
Table 5compares simulated and measured dam inflow and stream flow data per gauging station. In Roda and Torroella, the two stations used in this calibration, simulations underestimated mean stream flow values (by 2.2 and 11.4%, respectively). The NSE, PBIAS and RSR statistics show good or very good performance ratio for all the gauging stations (Moriasi et al. 2007).

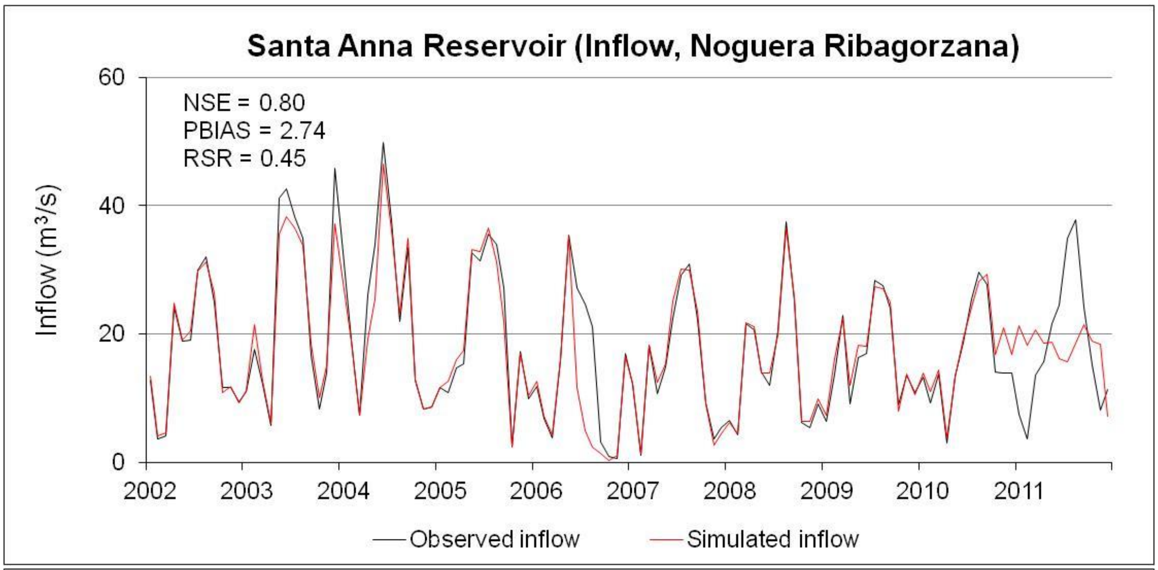
	Simulated Qm (m^3/s)	Observed Qm (m^3/s)	Statistics		
			NSE	PBIAS	RSR
Roda de Ter	12.63	12.92	0.88	2.23	0.35
Sau Reservoir	14.87	13.23	0.82	-12.44	0.42
Susqueda Reservoir	16.51	14.77	0.69	-11.77	0.55
Girona	12.90	12.80	0.81	-0.77	0.44
Torroella de Montgrí	9.41	10.62	0.71	11.39	0.54

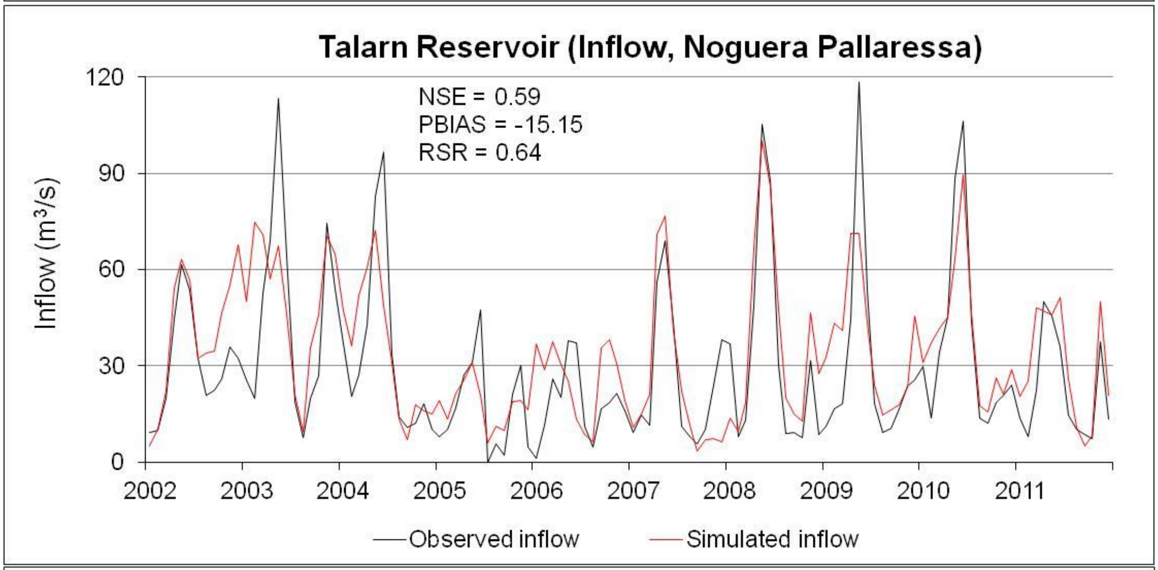
Table 5. Accuracy results at a monthly time step: dam inflow or stream flow values (Qm) from both simulated and observed data and statistics in each gauging station. Light green color identifies good performance ratio for the statistic and dark green identifies very good, following Moriasi et al. (2007).

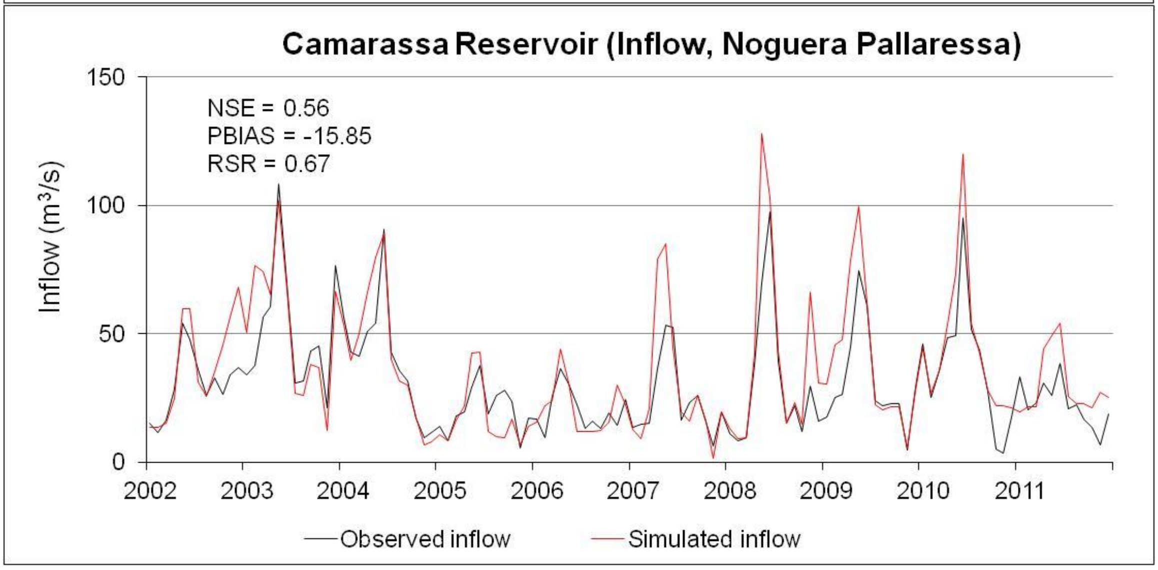
Accuracy of SWAT model in Segre basin

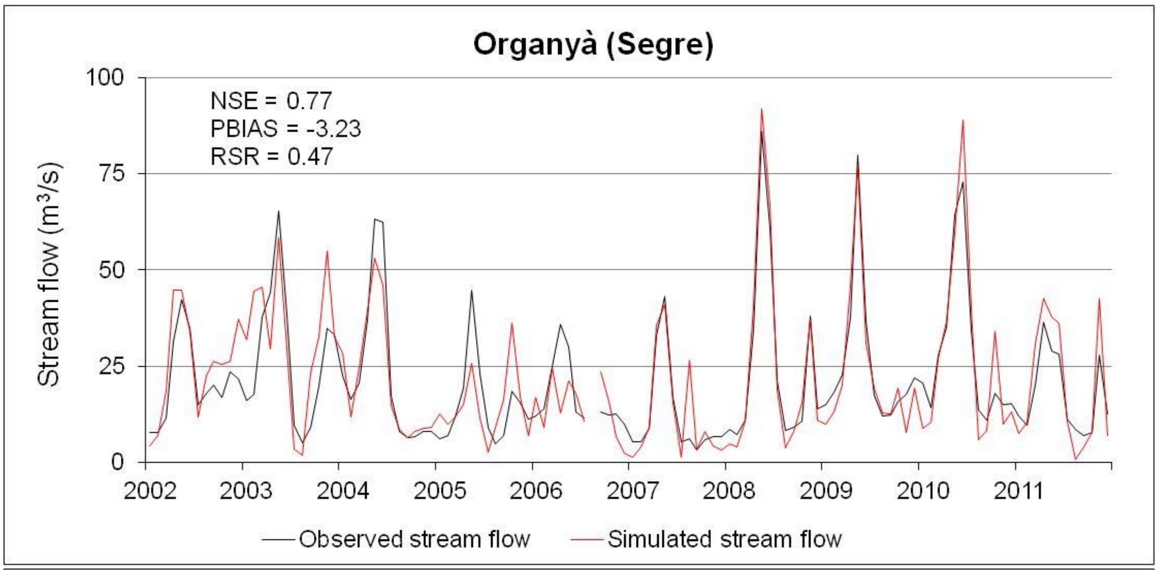
Figure 6 shows the graphical comparison between simulated and observed data for monthly stream flow and reservoir inflow (m^3/s) for eight gauging stations: in the Noguera Ribagorzana river, Pont de Suert (in the headwaters, 545.8 km^2 upstream surface area and 4.1% of the total area) and Santa Anna Reservoir(1,761.5 km^2 and 13.3%); in the Noguera Pallaresa river: Talarn Reservoir(1,913 km^2 and 14.5%) and Camarassa Reservoir (2,816.8 km^2 and 21.3%); and in the Segre river: Organyà (headwaters,2,381.3 km^2 and 18.0%), Oliana Reservoir(2,695.3 km^2 and 20.4%) and Rialb Reservoir(3,320 km^2 and 25.1%), and Seròs (river mouth, 12,941.8 km^2 and 98%).

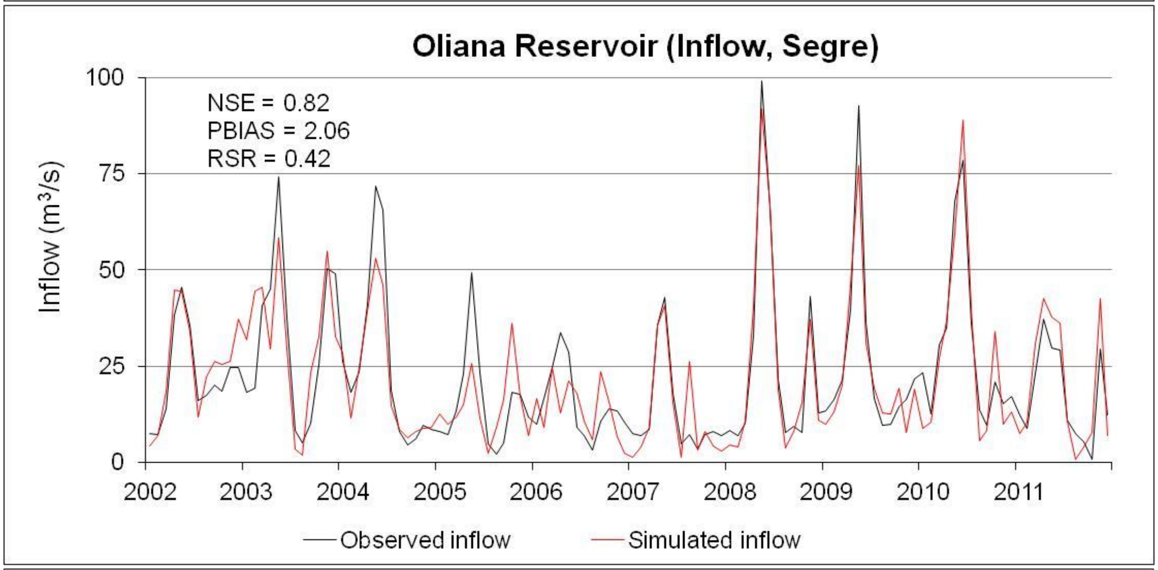


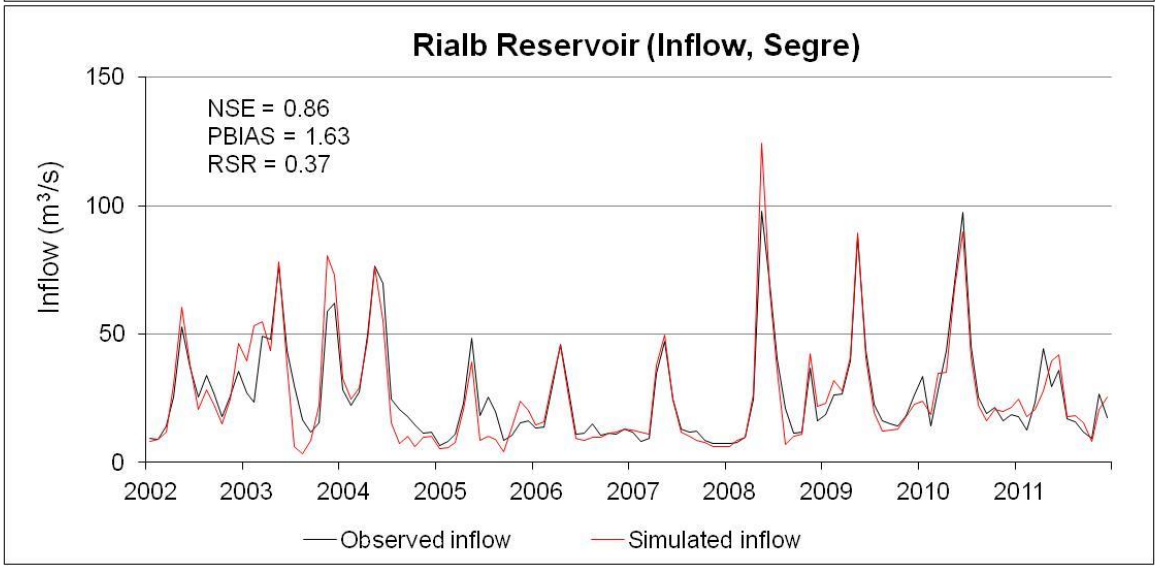

Santa Anna Reservoir (Inflow, Noguera Ribagorzana)
NSE = 0.80
PBIAS = 2.74
RSR = 0.45
Inflow (m3/s)
60
40
20
0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Observed inflow
Simulated inflow


Talarn Reservoir (Inflow, Noguera Pallaressa)
NSE = 0.59
PBIAS = -15.15
RSR = 0.64
Inflow (m3/s)
120
90
60
30
0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Observed inflow
Simulated inflow


Camarassa Reservoir (Inflow, Noguera Pallaressa)
NSE = 0.56
PBIAS = -15.85
RSR = 0.67
Inflow (m3/s)
150
100
50
0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Observed inflow
Simulated inflow


Organyà (Segre)
NSE = 0.77
PBIAS = -3.23
RSR = 0.47
Stream flow (m3/s)
100
75
50
25
0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Observed stream flow
Simulated stream flow


Oliana Reservoir (Inflow, Segre)
NSE = 0.82
PBIAS = 2.06
RSR = 0.42
Inflow (m3/s)
100
75
50
25
0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Observed inflow
Simulated inflow


Rialb Reservoir (Inflow, Segre)
NSE = 0.86
PBIAS = 1.63
RSR = 0.37
Inflow (m3/s)
150
100
50
0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Observed inflow
Simulated inflow

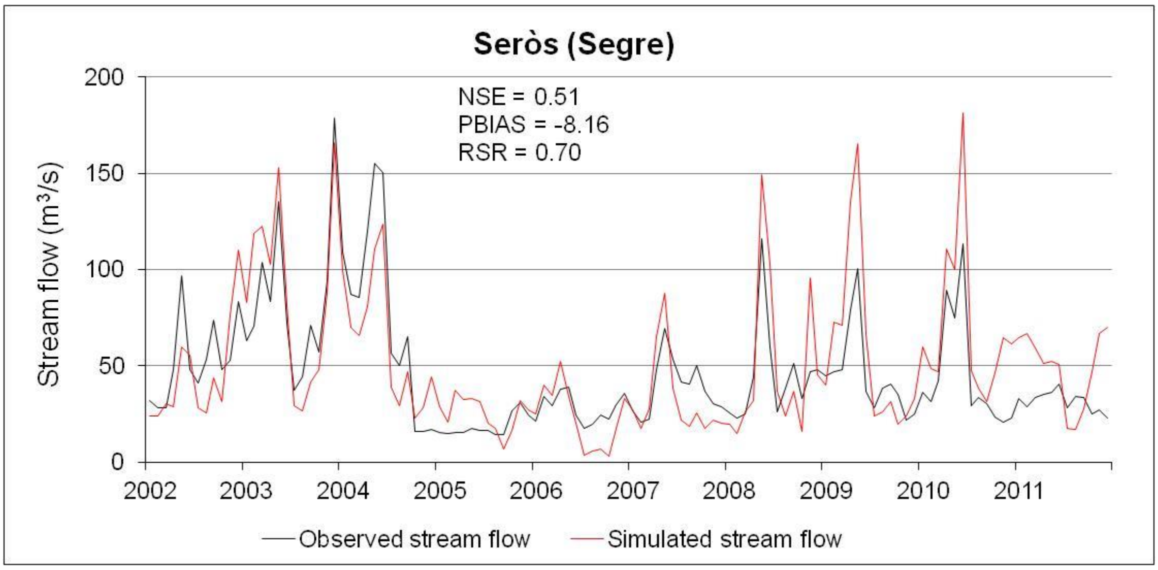


Figure 6.Observed (black line) and simulated (red line) dam inflow or stream flow at eight points of the basin, ordered by rivers: Noguera Ribagorzana river: Pont de Suert (headwaters) and Santa Anna Reservoir; Noguera Pallaresa river: Talarn and Camarassa Reservoirs; Segre river: Organyà (headwaters), Oliana and Rialb Reservoirs, and Seròs (river mouth).

Table 6compares simulated and measured dam inflow and stream flow data per gauging station. Simulations underestimated mean stream flow values in the Noguera Ribagorzana river (9.5% in Pont de Suert and 2.7 in Santa Anna Reservoir) and overestimated in the Noguera Pallaresa (15.1 and 15.9% in Talarn and Camarassa respectively). In Seròs, the river mouth of the Segre basin, the simulation overestimated stream flows in a 8.2% The NSE, PBIAS and RSR statistics show a majority of good or very good performance ratio for Noguera Ribagorzana and Segre gauging stations (except for Seròs). The Noguera Pallaresa was the most difficult to adjust.

	Simulated Qm (m^3/s)	Observed Qm (m^3/s)	Statistics		
			NSE	PBIAS	RSR
Pont de Suert (Noguera Ribagorzana)	11.60	12.81	0.68	9.47	0.57
Santa Anna Reservoir(Noguera Ribagorzana)	17.57	18.06	0.80	2.74	0.45
Talarn Reservoir(Noguera Pallaresa)	33.88	29.42	0.59	-15.15	0.64
Camarassa Reservoir(Noguera Pallaresa)	35.82	30.92	0.56	-15.85	0.67
Organyà (Segre)	22.02	21.33	0.77	-3.23	0.47
Oliana Reservoir(Segre)	21.88	22.34	0.82	2.06	0.42
Rialb Reservoir(Segre)	26.07	26.50	0.86	1.63	0.37
Seròs (Dam)	50.57	46.75	0.51	-8.16	0.70

Table 6. Accuracy results at a monthly time step: dam inflow or stream flow values (Qm) from both simulated and observed data and statistics in each gauging station. Yellow color identifies satisfactory performance ratio for the statistic, light green good and dark green very good, following Moriasi et al. (2007).

2.2.2. Inter-comparison of the climate and socioeconomic scenarios

Inter-comparison of climate scenario

As explained in Pascual et al. (2016) the generation of climatic series are based on 5th IPCC Inform, published in 2015, where the Representative Concentration Pathways (RCPs) are adopted. These describe four possible future climates, all of which are considered likely to happen depending on how much greenhouse gases are emitted in the years to come. In the case of

Catalonia the RCP4.5 was adopted, which is comparable to SRES B1 scenario (IPCC 2007), and assumes a radiative forcing of +4.5 W/m^{2}for 2100 relative to pre-industrial values.

The projections about changes in the climatic system are developed by means of a climatic models coupling in a hierarchy fashion: from the simplest models and other with intermediate complexity to more complete ones and earth system models. All of them, simulate changes under anthropogenic forcings and are based on a set of scenarios. The RCP's scenarios, unlike the previous SRES scenarios, include the effects and changes driven by adaptation and mitigation measures, which are one of the key aspect in the last report of IPCC.

The temporal series developed for MEDACC-Life Project are based on values of changes described in The Third Report on Climate Change in Catalonia (TICCC) (Table 7),

		TEMPERATURE			PRECIPITATION		
		Pyrenees	Inland	Coast	Pyrenees	Inland	Coast
2012-2020	winter	0.5	0.6	0.7	2.7	2.1	-5.7
	spring	-0.1	0.1	-0.2	-1.3	-6.3	-6.9
	summer	0.6	0.5	0.1	-2.6	-1.6	-1.8
	autumn	0.1	0.3	0.2	-3.1	-4.6	-8.2
2021-2030	winter	0.9	0.9	1	0.5	0.4	-6
	spring	0.2	0.3	0.1	-5.1	-9.1	-9.7
	summer	1.1	1	0.6	-5.8	-5.8	-6.7
	autumn	0.7	0.8	0.7	-6.4	-6.9	-8.8
2031-2050	winter	1.2	1.2	1.3	-1.8	-1.3	-6.3
	spring	0.5	0.5	0.3	-8.9	-11.9	-12.5
	summer	1.6	1.5	1	-9.1	-9.9	-11.6
	autumn	1.2	1.2	1.1	-9.7	-9.2	-9.4

Table 7. Temperature and Precipitation changes for the different areas in Catalonia, based on RCP4.5 scenario

The Table 7 shows a clear and spread temperature increase in all the areas and seasons. The median values for Catalonia are: an increase of temperature of 0.8 and 1.4 ºC for 2012-2021 and 2031-2050 periods, respectively, and a decrease of precipitation of -2.4% and -6.8% for the same periods respectively. The increase of temperature are more marked in the Pyrenees, while the decrease of precipitation is more important on the Coastal area.

All of these changes are always relative to the reference period, 1971-2000. In the Deliverable 14, where the results are explained, the changes have been analysed considering the calibration period of the models (2002-2011) as control period, because the analysis of changes in streamflow is referred to it.

The changes showed in Table 1 were applied to the observed temperature and precipitation series for the calibration period used in the project (2002-2011) year by year at daily scale. To avoid temporal patterns the results of this changes were randomly distributed along the different periods, 2012-2020, 2021-2030 and 2031-2050. In this manner, we ensure that the proposed changes are kept accurately.

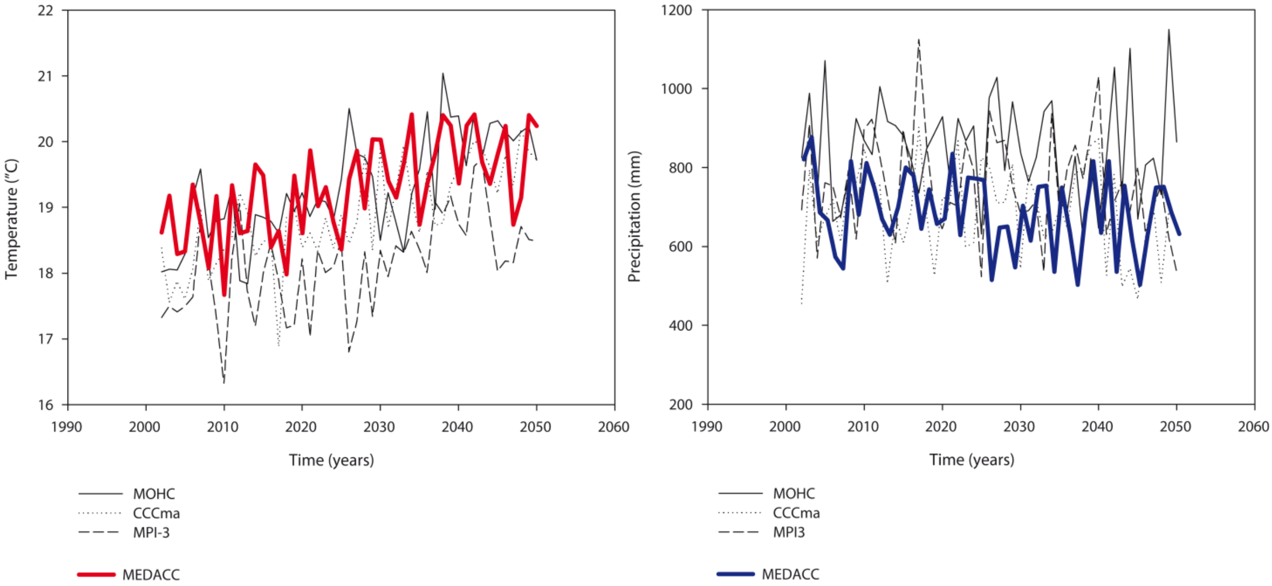


Table 7. Comparison between different models.

In the LIFE MEDACC project, the projections have been developed under the change values presented in the Third Report of Climate Change in Catalonia. In addition, they have been compared with the change values of other projections, such as the analysis of the quality of the projections and the verification of the robustness of the indicated changes.

Figure 7 shows a comparison between 3 different simulations and the series generated in the LIFE MEDACC: Maximum Temperature (red) and Precipitation (blue) Project. The series belonging to the LIFE MEDACC project are the result of a regional average of all available temperature and precipitation series. Although the series of the models are averages taken from a location window confining Catalonia, they can be considered comparable. It is clearly observed how the trend projected for temperature is similar between all simulations (albeit differences in variability), while the decreases in rainfall are more diffuse and do not show homogeneity between simulations. The data has been extracted from the website www.climexp.knmi.nl

Inter-comparison of socioeconomic scenarios

As explained in Pascual et al. (2018), the inter-comparison between the LIFE MEDACC socioeconomic scenarios and other socioeconomic projections performed by European institutions and research centres has been done through the IMAGE 3.0 scenarios.

IMAGE 3.0 is a comprehensive integrated modelling framework of interacting human and natural systems. The model framework is suited to large scale (mostly global) and long-term (up to the year 2100) assessments of interactions between human development and the natural environment, and integrates a range of sectors, ecosystems and indicators. The impacts of human activities on the natural systems and natural resources are assessed and how such impacts hamper the provision of ecosystem services to sustain human development. More details about the model scenarios can be reviewed at http://themasites.pbl.nl/models/image/index.php/IMAGE_framework. IMAGE model produces a long list of outputs representing the results of the various parts of the framework, either as end indicator or as intermediate inputs driving operations further downstream. Together the outputs span the range from drivers to pressures, states and impacts. Outputs include, among others, energy use, conversion and supply; agricultural production, land cover and land-use; nutrient cycles in natural and agricultural systems; emissions to air and surface water; carbon stocks in biomass pools, soils, atmosphere and oceans; atmospheric emissions of greenhouse gases and air pollutants; concentration of greenhouse gases in the atmosphere and radiative forcing; changes in temperature and precipitation; sea level rise; water

Land use and land cover outputs are treated at grid level to capture local dynamics, and the grid size has been reduced to 5 x 5 arcminutes in IMAGE 3.0 (corresponding to 5 x 5 km at Spain). Figure 7 shows the baseline land use / cover for 1970 for IMAGE 3.0 model, distinguishing 20 different land use / cover for the world.

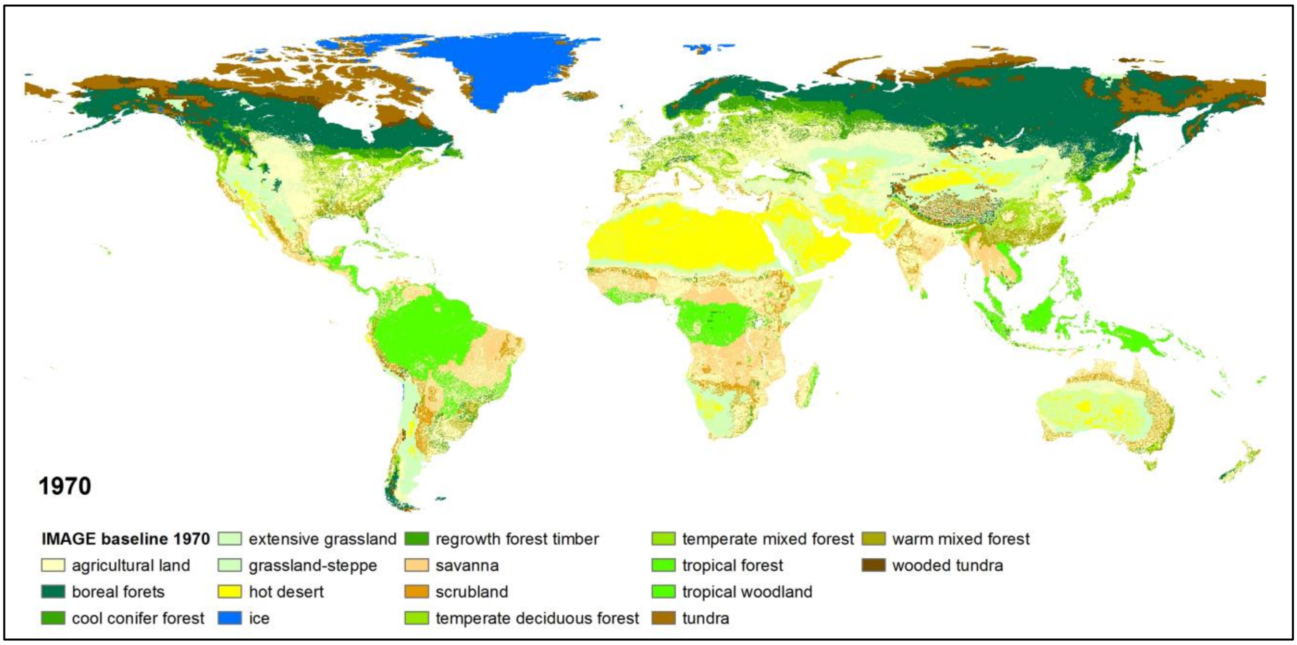


Figure 7. Baseline land use / cover (1970) for IMAGE 3.0 model

Figure 8 shows the land use / cover distribution in 2050 under the RCP4.5 scenario from IMAGE 3.0. In addition, Table 7 shows the changes in percentage of occupation of each land use / cover in 2050 respect the baseline. Agricultural land and regrowth forest timber are the two land uses / covers that experiment a most notable increases (3.6% and 4.6% respectively) along the middle 21st century. The reductions are more distributed along all land use / cover classes, although the reduction of savanna arrives until a 2.5%.

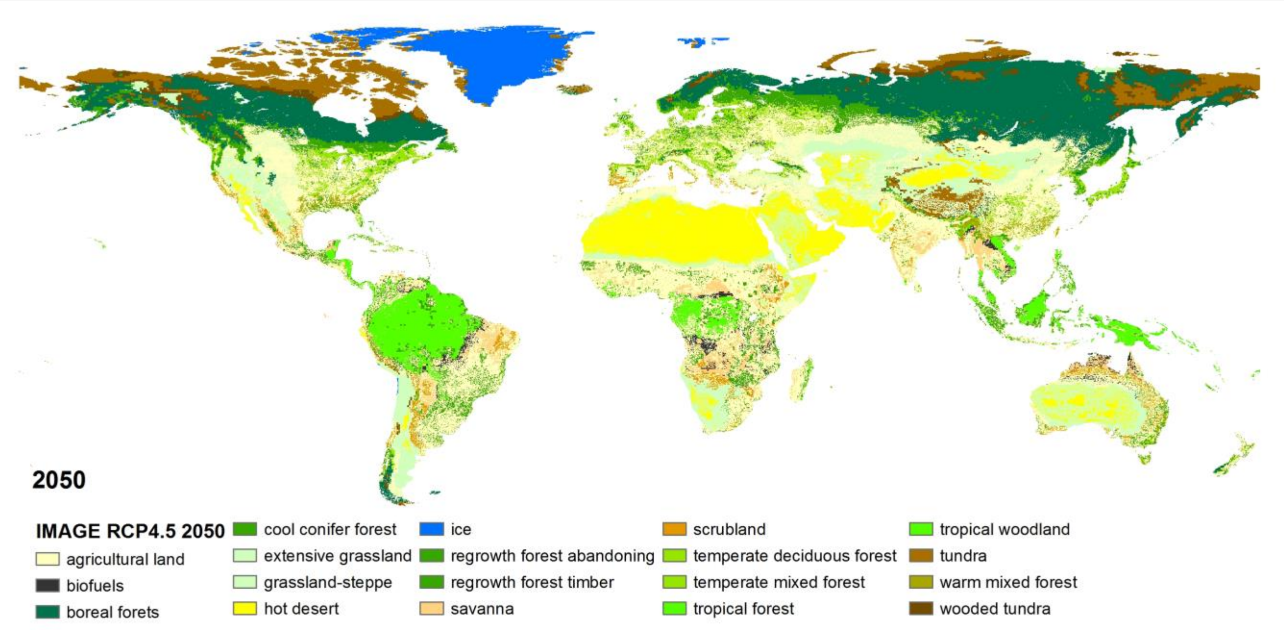


Figure 8. Land use / cover in 2050 for the RCP4.5 scenario (IMAGE 3.0 model).

Land use / cover	Percentage of cover in 1970	Percentage of cover in 2050	Change in the percentage of cover between 1970 and 2050
Agricultural land	23.1%	26.6%	3.6%
Extensive grassland	6.8%	6.2%	-0.6%
Regrowth forest abandoning		0.0%	0.0%
Regrowth forest timber	1.8%	6.4%	4.6%
Biofuels		0.9%	0.9%
Ice	4.6%	4.6%	0.0%
Tundra	7.1%	7.2%	0.1%
Wooded tundra	2.6%	2.6%	0.0%
Boreal forest	17.7%	16.7%	-0.9%
Cool conifer forest	2.4%	1.5%	-0.9%
Temperate mixed forest	2.1%	2.1%	0.0%
Temperate deciduous forest	1.3%	1.1%	-0.2%
Warm mixed forest	1.6%	0.8%	-0.9%
Grassland-steppe	4.9%	4.7%	-0.3%
Hot desert	9.2%	9.5%	0.3%
Scrubland	2.3%	1.5%	-0.8%
Savanna	5.0%	2.5%	-2.5%
Tropical woodland	3.2%	2.0%	-1.2%
Tropical forest	4.2%	3.0%	-1.2%

Table 7. Changes in percentage of occupation of each land use / cover in 2050 respect the baseline (1970). Green cells indicates increase in the surface occupied by the land use / cover in 2050 with respect to 1970.

In order to compare the IMAGE 3.0 scenario with LIFE MEDACC scenarios, a zoom to Catalonia has been done. Figure 9 and Table 8shows the results for Catalonia of the IMAGE 3.0 baseline (1970) and RCP4.5 scenarios (2050). The trends observed at Catalonia differ quite a lot from the world trends, with a notable reduction of agricultural land (9.7%) at the expense of the increase in forest area (regrowth forest timber 8.3%, biofuels 1.2%, warm mixed forest, 0.3% and scrubland 3.4%).

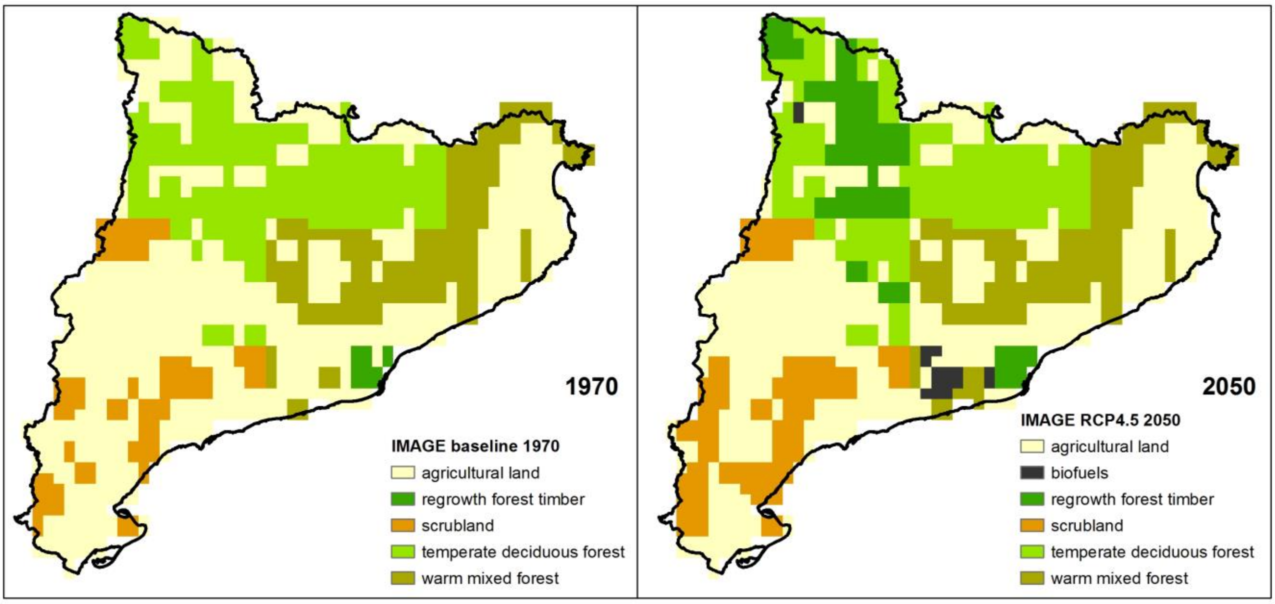


Figure 9. Land use / cover in 1970 (left) and 2050 (RCP4.5 scenario, right) obtained from the IMAGE 3.0 model for Catalonia.

Land use / cover	**1970**		**2050**		**Change in surface (km²)**	**Change in percentage (%)**
	Surface (km²)	**Percentage of cover (%)**	**Surface (km²)**	**Percentage of cover (%)**		
Agricultural land	17248.1	52.8%	14068.3	43.1%	-3179.8	-9.7%
Regrowth forest timber	289.1	0.9%	3011.2	9.2%	2722.1	8.3%
Biofuels			385.4	1.2%	385.4	1.2%
Temperate deciduous forest	7612.3	23.3%	6480.1	19.9%	-1132.2	-3.5%
Warm mixed forest	4842.0	14.8%	4938.4	15.1%	96.4	0.3%
Scrubland	2649.9	8.1%	3758.0	11.5%	1108.1	3.4%
	32641.4		32641.4			

Table 8. Surface and percentage of occupation of each land use / cover in 1970 and 2050, and changes in surface and percentage (IMAGE 3.0 model). Green cells indicates increase in the surface occupied by the land use / cover in 2050 with respect to 1970.

The afforestation scenario (AFOR) of LIFE MEDACC foresees more forested headwaters by 2050. The initial hypothesis of this scenario is that forests, mainly conifers, will colonize grass and shrub areas at high altitudes and shrub areas on slopes. The scenario has been generated using a random forest algorithm based on a set of drivers and predictor variables: topographic, climatic and landscape-based. Figure 10 shows the land cover maps used as reference (land cover map of Catalonia, LCMC 2009) and the output of the random forest algorithm for 2057. Foreseen changes on land uses / covers indicate an increase in the forest area in a 6.5% of the surface, slightly lower than the foreseen in the IMAGE scenario (8.6%) (Table 9). This increase in forest area is at the expense of scrublands (5.4%) and, in a lower extent, of agriculture (1.2%) and grassland (1.0%), differing from the IMAGE scenario.

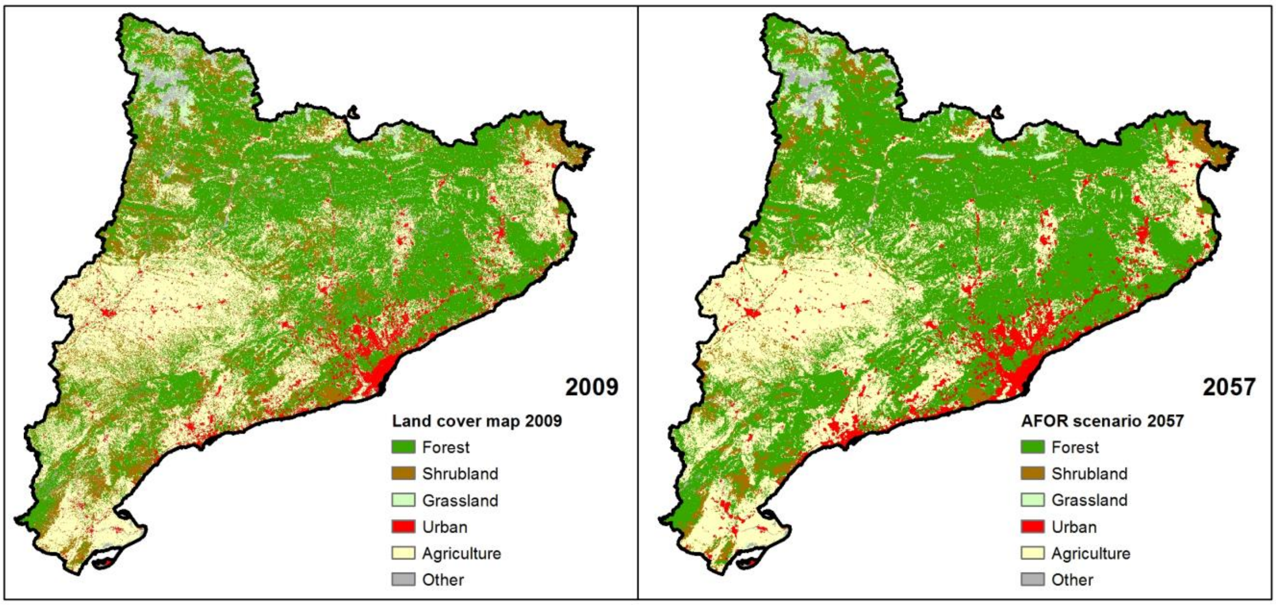


Figure 10. Land cover map (2009) (left) and AFOR scenario (2057) (right) for Catalonia.

Land use / cover	2009		2057		Change in surface (km^2)	Change in percentage (%)
	Surface (km^2)	Percentage of cover (%)	Surface (km^2)	Percentage of cover (%)		
Forest	14330.0	44.4%	16403.9	50.9%	2,074	6.5%
Scrubland	3685.4	11.4%	1933.8	6.0%	-1,752	-5.4%
Grassland	1202.2	3.7%	871.8	2.7%	-330	-1.0%
Urban	1782.2	5.5%	2211.5	6.9%	429	1.3%
Agriculture	10525.2	32.6%	10135.7	31.5%	-390	-1.2%
Other	727.6	2.3%	651.5	2.0%	-76	-0.2%

Table 9. *Surface and percentage of occupation of each land use / cover in 2009 and 2057, and changes in surface and percentage (AFOR scenario). Green cells indicates increase in the surface occupied by the land use / cover in 2057 with respect to 2009.*

The fire scenario (FIREFOR) of LIFE MEDACC foresees a less forested headwaters by 2050 as a result of an increased incidence of forest fires. The initial hypothesis is that the fires would affect mainly coniferous forests and shrublands that would be converted by the middle of the 21st century to shrublands and areas regenerated with evergreen forests. The scenario has been generated using the MEDFIRE model (Brotons et al. 2013). Figure 11 shows the land cover maps used as reference (land cover map of Catalonia, LCMC 2010) and the output of the MEDFIRE model for 2050. Foreseen changes on land uses / covers indicate a decrease in the area covered by conifer forest of a 3% of the surface, that leads to an increase of scrublands (1.9%), deciduous (0.9%) and evergreen forests (0.2%) (Table 10). This result is notable different to the IMAGE scenario, but we have to take into account that MEDFRE was forced to include fire as main driver of changes in land uses / covers, but afforestation was not simulated. Then, the scenarios are not comparable.

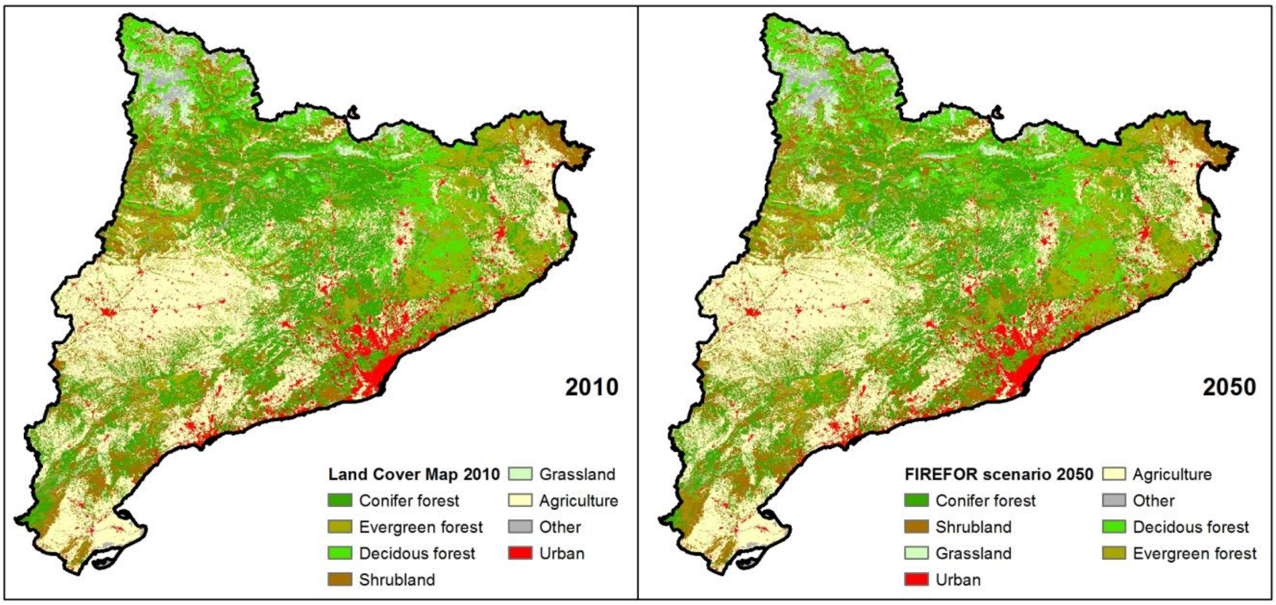


Figure 11. Land cover map (2010) (left) and FIREFOR scenario (2050) (down) for Catalonia.

Land use / cover	2010		2050		Change in surface (km²)	Change in percentage (%)
	Surface (km²)	Percentage of cover (%)	Surface (km²)	Percentage of cover (%)		
Conifer forest	7309	22.8%	6350	19.8%	-959	-3.0%
Evergreen forest	3064	9.5%	3114	9.7%	50	0.2%
Deciduous forest	3492	10.9%	3790	11.8%	298	0.9%
Shrublands	4718	14.7%	5328	16.6%	610	1.9%
Grassland	795	2.5%	795	2.5%	0	0.0%
Agriculture	10011	31.2%	10011	31.2%	0	0.0%
Other	935	2.9%	935	2.9%	0	0.0%
Urban	1786	5.6%	1786	5.6%	0	0.0%

Table 10. Surface and percentage of occupation of each land use / cover in 2010 and 2050, and changes in surface and percentage (FIREAFOR scenario). Green cells indicates increase in the surface occupied by the land use / cover in 2050 with respect to 2010.

The inter-comparison between socio-economic scenarios have been a difficult work. Only one scenario has been found in the literature to be compared, attending to the format (raster), spatial resolution (5km) and thematic (land use /cover). The IMAGE3.0 has been compared with the afforestation scenario (AFOR), and general trends are comparable among them.

3. Monitoring the effect of Action B2

3.1. Introduction

Action B2 objective is to perform all necessary tasks to implement pilot experiences in the selected basins and selected sectors/systems.

As stated in the Grant Agreement, the effects of the management activities in forests and agricultural crops developed in the pilot sites will be monitored and compared with the dynamic of the plots without intervention (control plots). This monitoring will include, among others, the changes in vegetation growth, health or structure. Besides, water management alternatives will be also monitored in terms of volume of water saved or reused.

3.2. Results

3.2.1. Monitoring agricultural demonstrative actions

The monitoring of the agricultural demonstrative activities consisted in measuring different variables on the field and comparing the changes of the variable's values among treatments (control and management treatment) and along time (annual campaign of 2015-2016-2017). The location and description of the actions and the plots can be found in Deliverable 5.

Demonstrative actions in La Muga and lower Ter

Between 2015 and 2017 some monitoring agricultural demonstrative actions were performed in this two areas with three main objectives: i) demonstrating the economic and technical viability of drip irrigation systems in maize to farmers in the lower Ter and the coastal plain of La Muga, ii) implementing two irrigation advice systems for farmers to facilitate irrigation water saving without reducing crop production in both basins: one for maize (*GIROREG Maize*) and one for apple crops (*GIROREG Apple*) and iii) validating through surveys if the irrigation recommendations from this advice system are followed by growers. We show here some results of the campaigns monitored during the project:

La Muga: Irrigation advice system (Maize)

An irrigation advice system was implemented to give recommendations to growers, aiming to facilitate water-saving irrigation without reducing crop yield by using GIROREG methodology and addressed to local growers in the coastal plain of La Muga.

During the study period, it was shown that GIROREG performance in maize implies a reduction of water consumption in crop irrigation maintaining yield rates. During the rainiest years, growers that cannot or do not assume GIROREG recommendations, used 50% more water, while in years with less precipitation differences between 20 to 30% differences on average were found.

Preparation and dissemination of the irrigation advice service (Figure 12) started in springtime, during the beginning of the irrigation campaign. 17 weekly brochure were produced on average each campaign during the years of the project (2015, 2016 and 2017).

Additionally, in this region of the Alt Empordà district, during the early years of the project, a plot called "Garriga" with drip irrigation was monitored. During 2014 part of the plot was drip irrigated, 8970 m^2 that were extended to 11494 m^2 in 2015. That is, during 2014 40 rows of maize were set with drip irrigation, while in 2015, 50 rows of maize were set. Water used for irrigation was 3.132 m^3/ha in 2015, and 2.532 m^3/ha for 2014 as 2015 was a hotter year with lower precipitation (Table 11), which resulted in lower production (Table 12) despite increased irrigation.

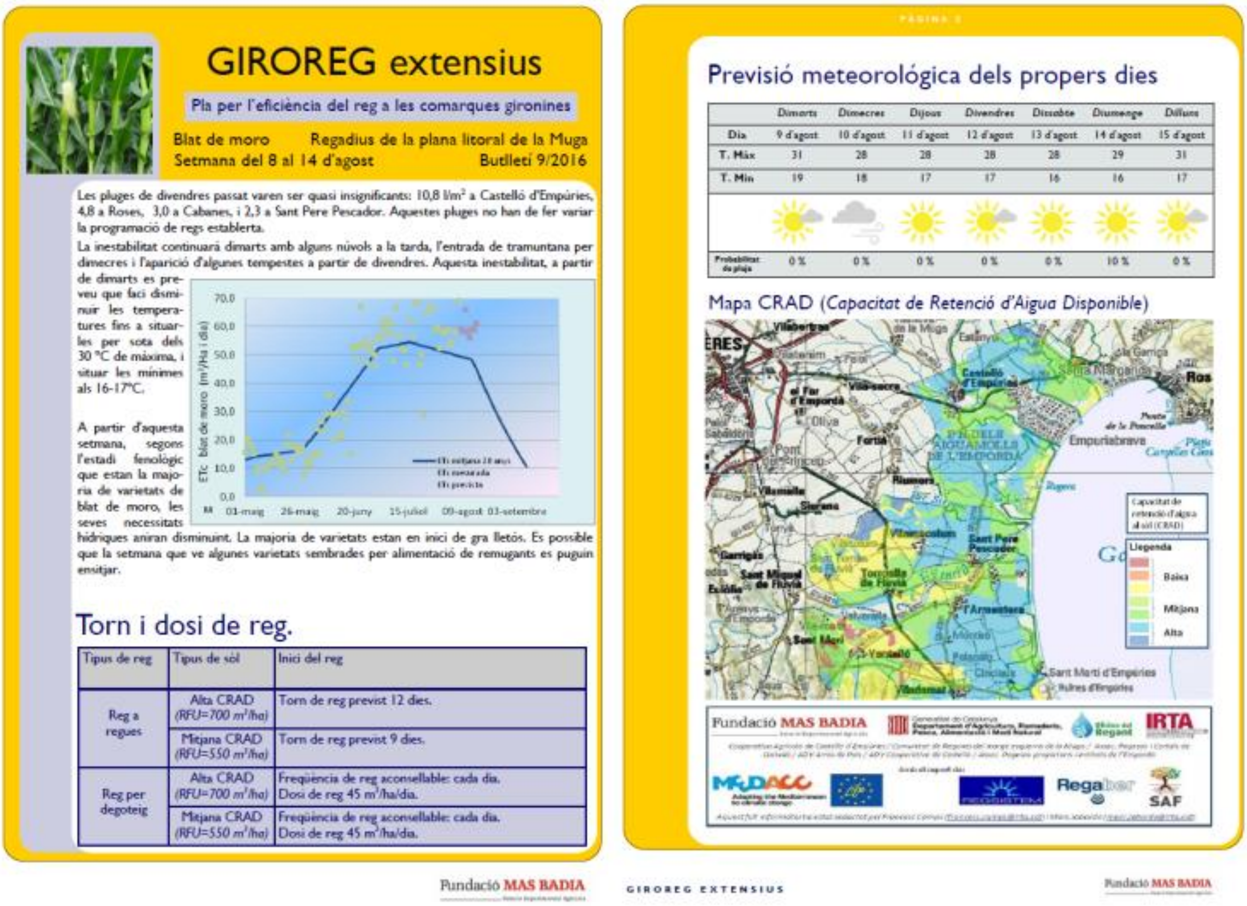


Figure 12. Detail of the weekly brochures that were sent during the irrigation campaign via email to interested growers in the coastal plain of La Muga.

Year	ETc	Total Pp	Efect. Pp	Irrigation water
2014	4692	2476	1751	2532
2015	4991	1940	1486	3132

Table 11. Crop (maize) Evapotranspiration (ETc), Total precipitation (Total Pp), effective precipitation (Efect. Pp)and irrigation water expressed in m3/ha corresponding to the monitored maize plot called "Garriga" during the years 2014 and 2015 from April 1st to September 15th.

Year	Yield (kg/ha)
2014	13100
2015	12500

Table 12. Yield (according to the farmer) expressed in kg/ha from the monitored drip irrigated maize plot "Garriga" in the coastal plain of La Muga.

La Muga: Irrigation advice system (Apple)

A comparative assay of water irrigation use for apple cultivation was performed in 2016 in order to detect differences in irrigation applied in two plots, one following GIROREG advices and other following a traditional irrigation criterion. This activity was located on the coastal aquifer of Fluvià-Muga, in the municipality of Sant Pere Pescador. Figure 13 shows detailed location of the plots we compared, which were almost contiguous.

Figure 13. Location map of both control plots in Sant Pere Pescador municipality. In red the plot following GIROREG advices and in blue the plot following traditional watering criterion.

The main results of this comparative assay about irrigation criterion in apple cultivation were:

- The plot following GIROREG advices was watered during the 2016 campaign with 3953 m^3/ha, 26% less of irrigation water than the plot following the traditional criterion (5350 m^3/ha).
- The plot following GIROREG advices yielded 95800 kg/ha, an increment of 1.4% with respect to the plot following the traditional criterion (94400 kg/ha). No differences in fruit quality were detected.
- The economic value of the yield produced in the plot following GIROREG criterion was 32580 €/ha, an increment of 4.2% in relation to the plot following traditional watering criterion (31210 €/ha).

Figure 14 and Figure 15 show the evolution of soil humidity (volumetric water content, %) at different soil depths during the irrigation campaign in both plots. The irrigation campaign following GIROREG criterion was characterized by frequent and low quantity irrigations, while irrigations following traditional criterion were of higher quantity and scattered in time.

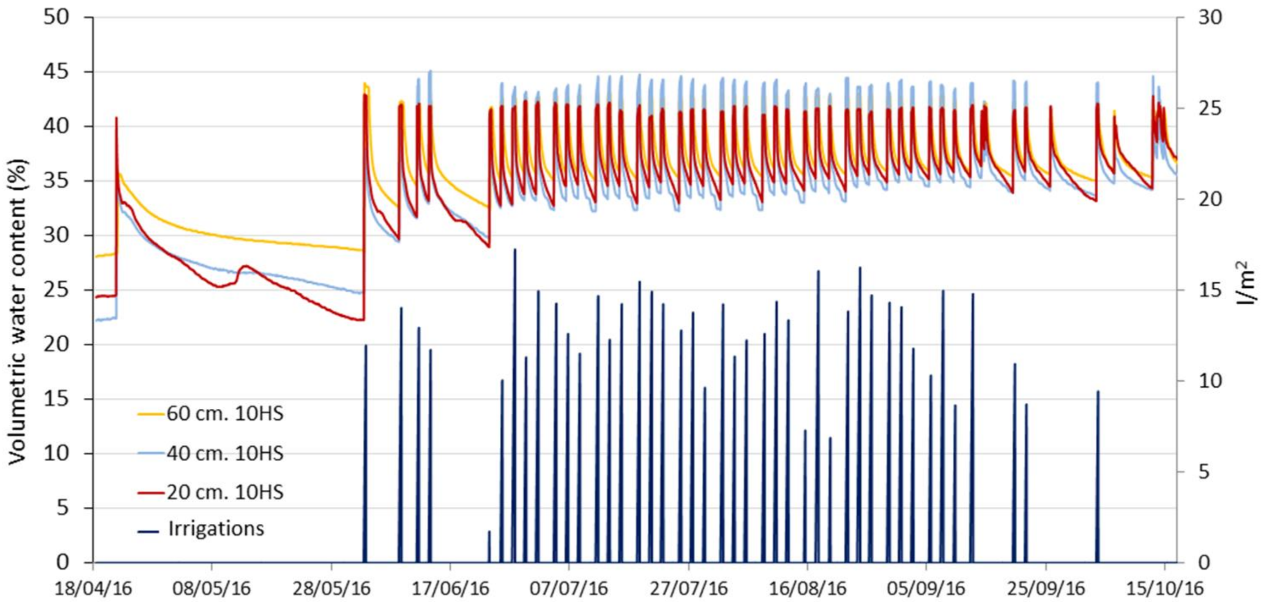


Figure 14. Soil humidity, as volumetric water content, during the irrigation campaign in the plot watered following the traditional grower criterion. Irrigations are represented in l/m^2 (dark blue, secondary vertical axis). Volumetric water content, in principal vertical axis, is presented in % at 3 soil depths.

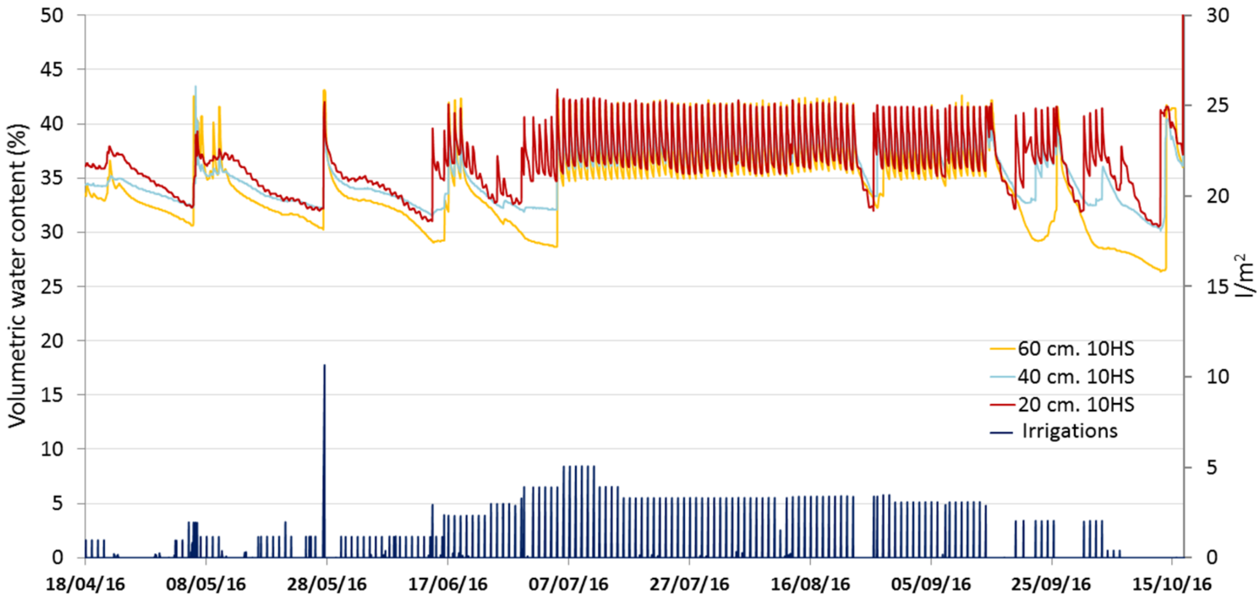


Figure 15. Soil humidity, as volumetric water content, during the irrigation campaign in the plot watered following GIROREG criterion. Irrigations are represented in l/m2 (dark blue, secondary vertical axis). Volumetric water content, in principal vertical axis, is presented in % at 3 soil depths.

The difference in the water irrigation use between previous figures is explained by better efficiency of irrigations. GIROREG recommendations using lower but more frequent water inputs, help to increase the efficiency as plants are able to take most water, hence reducing drainage.

Distribution of apple size (%)							
mm	80-85	75-80	72-75	72-70	68-70	65-70	<65
GIROREG	0	3.25	16.14	12.17	15.68	13.69	39.06
Traditional	0.22	1.95	15.42	12.17	15.46	11.69	42.55
Standard deviation of apple size							
mm	80-85	75-80	72-75	72-70	68-70	65-70	<65
GIROREG	0	0.87	2.81	2.93	2.87	1.17	9.12
Traditional	0.48	1.82	2.62	2.97	3.47	2.37	8.02

Table 13. Apple size distribution expressed in percentage and standard deviation for the irrigation assay in an apple orchard in Sant Pere Pescador municipality.

Table 13 shows that the plot watered following GIROREG criterion presented a slight trend to obtain higher percentages in the bigger apple size (> 75 mm) compared to apples obtained in the plot watered following the traditional criterion. Conversely, apples with smaller size (<65 mm) were more frequent in the plot following traditional criterion than in the plot following GIROREG criterion. Yield per m^2 of surface was very similar in both plots (Table 14). Nonetheless, the plot irrigated following traditional criterion showed higher variability (SD) than the plot irrigated following GIROREG criterion.

Yield per m^2		
	Mean (kg)	SD
GIROREG	9.58	1.25
Traditional	9.44	1.53

Table 14. Mean value of yield per square meter of surface, expressed in kg and standard deviation for both assays using different irrigation criteria in an apple orchard in Sant Pere Pescador municipality.

<u>Ter: Irrigation advice System (Maize)</u>

In the lower Ter, the same advice irrigation system for extensive crops such as maize was implemented (Figure 16).

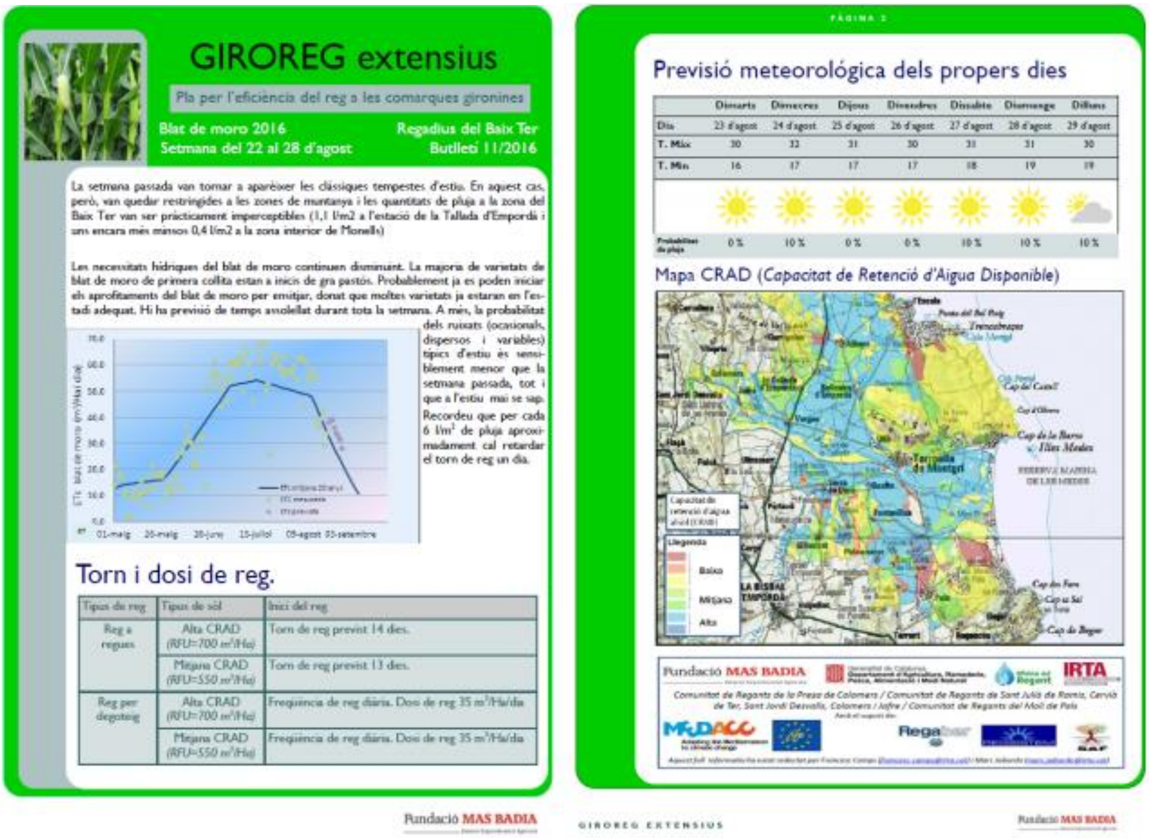


Figure 16. Detail of the weekly brochures that were sent during the irrigation campaign via email to interested growers in the lower Ter.

Additionally, in this region of the Baix Empordà district, a comparative assay of different irrigation criterion for maize was established: GIROREG methodology and traditional criterion applied by local growers (generally gravity irrigation). This assay was set in 2016.

Figure 17. Location of two plots comparing two different irrigation criteria for maize.

Figure 17 shows the location of both plots, established to the Northwest of Ullà municipality. Both plots were virtually contiguous in order to minimize the location effect and to assume the same climatic and topographic conditions. Yellow markers point the location of humidity sensors for monitoring irrigations. Where drip irrigation was used, (Figure 18)flowmeters to monitor water use were added to humidity sensors to monitor soil humidity.

Figure 18. Detail of setting-up of drip irrigation (right) and detail of setting-up of data logger EM50G de DECAGON (left).

Regarding irrigation and water consumption, the plot following irrigation traditional criterion suffered periodic flooding linked to watering shifts (Figure 19): when water is only available during a certain amount of time (a shift), it tends to be overused. Humidity sensors show, particularly during late June, an excess of water at deepest soil layers (60 cm), meaning drainage at lower soil layers.

Irrigations were performed eight times from late June to late August. Average water supply was about 680 m^3/ha per irrigation shift. Probably, distribution between irrigations is conditioned to the irrigation rules coming from the Community of irrigator of Presa de Colomer: depending on the color of the hydrant, irrigation shifts are each 7-8 days.

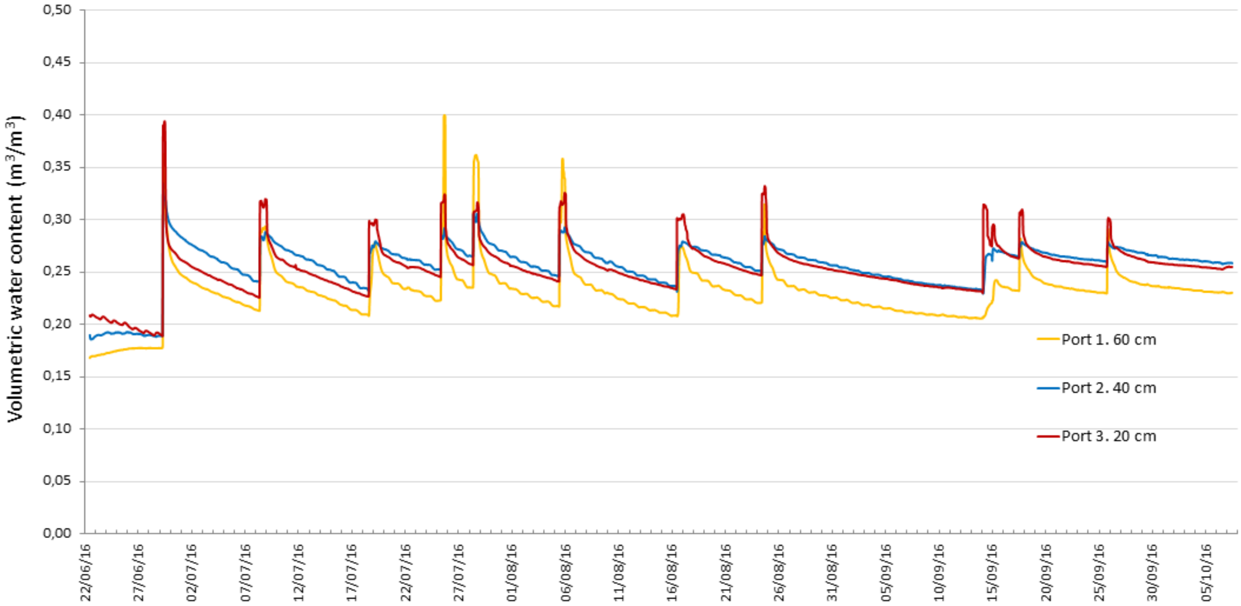


Figure 19. Soil volumetric water content (m3/m3) at different soil depths (yellow: 60 cm, blue: 40 cm and red: 20 cm) during the irrigation campaign at the plot not following GIROREG recommendations. Green arrows note soil humidity changes due to irrigation, and blue arrows note soil humidity changes due to precipitation events.

Figure 20 shows soil humidity evolution in time on the drip irrigation plot. Most of the irrigations were performed during the first part of the campaign. From mid-August growers could maintain the crop using the water from precipitation.

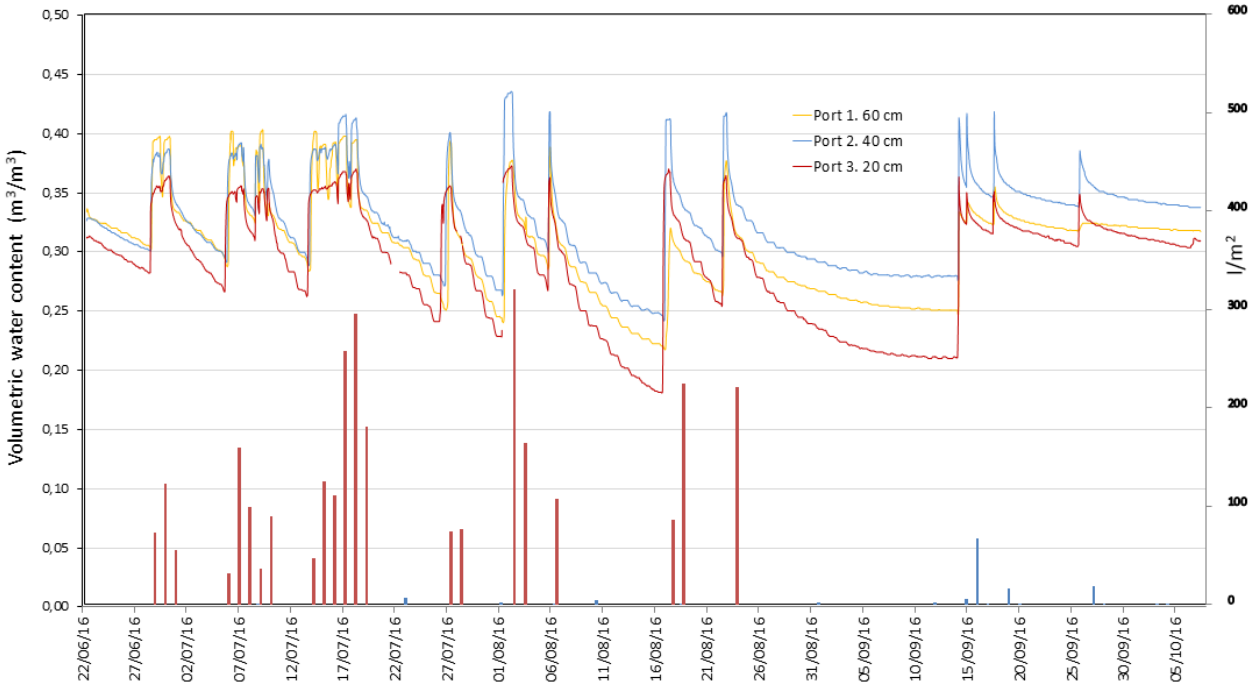


Figure 20. Soil volumetric water content (m3/m3) at different soil depths (yellow: 60 cm, blue: 40 cm and red: 20 cm). Secondary vertical axis expresses liters per square meter to illustrate irrigations conducted (red bars) and precipitation events (blue bars) during the campaign.

If previous figures are compared, we can observe that the precipitations during September were fundamental to maintain soil humidity until the end of the campaign, which allowed growers to save several of the last irrigations. However, in certain moments, water availability had decrease under comfort zone for the plant, at least in the drip-irrigated plot. Approximately, between August 14th and 15th and in early September, the levels recorded by the humidity sensors were lower than desired. In these cases, probably it had been better not to delay the irrigation. All these mismatches can be explained by pressure problems presented at the time of starting up irrigation in the plot with drip irrigation which prevented irrigation for several days.

In order to assess yield and other qualitative and yield-related parameters, a random sampling was conducted in five subplots. Sampling consisted in harvesting all the production in each subplot, and measuring other yield related parameters: number of ears per surface unit, mean ear weight, and grain humidity (Table 15).

	Number of ears per m²		**Mean weight of ears**		**Grain humidity**	
Irrigation System	n	SD	g	SD	%	SD
Gravity	15.0	1.9	285	30	20.6	0.3
Drip	17.0	1.7	235	38	19.8	0.9

Table 15. Yield related parameters for both monitored plots (gravity and drip irrigation): mean number of ears per square meter of surface, mean ear weight, mean grain humidity and their standard deviation.

The main conclusions suggested by results from the comparative assay of irrigation systems in maize carried out in this study are:

- The plot supplied with drip irrigation following GIROREG criterion for maize had been watered using 2961 m^3/ha supposing 45% less water consumption than in the plot irrigated by gravity that uses 5488 m^3/ha (Table 16).
- The plot supplied with drip irrigation following GIROREG criterion for maize had produced 13,29 grain tones/ha supposing 7% less yield than in the plot irrigated by gravity that obtained a yield about 14.27 grain tones/ha (Table 17).

	Irrigation water	**WUE**
Irrigation System	m^3/ha	kg/m^3
Gravity	5488	2.60
Drip	2961	4.49

Table 16.Water quantity supplied by irrigation and water use efficiency (WUE; kg of grain produced per m3 of water used) in each monitored plot.

	Yield (14% grain humidity)	
Irrigation System	Mean (t/ha)	SD (t/ha)
Gravity	14.27	2.24
Drip	13.29	1.49

Table 17. Mean grain production per hectare (14% of grain humidity) and standard deviation of both monitored plots.

The lack of irrigation during late August and early September, a vulnerable period marked by heat and water needs, conditioned the yield related results in the plot with drip irrigation. Yield was reduced by 7% mainly through a reduction of grain weight (weight of 1000 grains). Water use efficiency (WUE, Table 16), however, was clearly in favor of drip irrigation: with the same quantity of irrigation water, plot supplied with drip irrigation produced 72% more grain than the plot using gravity irrigation.

Ter and La Muga Irrigation advice systems: common results

For both basins (La Muga and Ter), GIROREG performance for maize and, according to the results obtained in the 4 campaigns (Table 18), resulted in a reduction of irrigation water consumption in maize, maintaining yields. During the rainiest years, growers that cannot or do not assume GIROREG recommendations, wasted about 50% of water, while for years with less precipitation differences between 20 to 30% on average for water use were found.

Basin	Campaign	Soil AWC*	Number of irrigations	Irrigation m^3/ha	Water use: Traditional vs GIROREG (%)
La Muga (Coastal Plain)	2014	Medium	7	3850	140%
	2014	High	6	4200	150%
	2015	Medium	8	4400	133%
	2015	High	7	4900	140%
	2016	Medium	8	4400	114%
	2016	High	7	4900	117%
	2017	Medium	9	4950	129%
	2017	High	7	4900	140%
	Average	Medium		4400	129%
	Average	High		4725	137%
Ter (Lower Basin)	2014	Medium	6	3300	150%
	2014	High	5	3500	167%
	2015	Medium	8	4400	114%
	2015	High	8	5600	133%
	2016	Medium	8	4400	114%
	2016	High	6	4200	120%
	2017	Medium	9	4950	113%
	2017	High	8	5600	133%
	Average	Medium		4263	123%
	Average	High		4725	138%

*Table 18. Number of irrigations and average irrigation water consumption for maize in Lower Ter and the coastal plain of La Muga followed by local growers that do not follow any method of irrigation scheduling (traditional criterion). Water use is also expressed as a percentage of water consumption in GIROREG-following plots. Results are shown for campaigns from 2014 to 2017.Two different Available Water Capacity of soil (medium: 550 m^3/ha and high: 700 m^3/ha) are presented. *AWC: available water capacity of soil at the first 100 cm.*

Ter: Irrigation advice System (Apple)

GIROREG apple is a collection, treatment and dissemination information System addressed to assess water needs of apple cultivation in the districts of Girona. The platform that manage this system is called Aquafruit, an expert system that put together all the information regarding soil water status, irrigation water quantity, weather information and local weather forecast of the next seven days. Aquafruit is able to generate in this way a providence of apple crop water needs that is sent daily to the technician staff of the fruit companies in the sector and weekly (or on demand) via email to growers.

Outputs from Aquafruit platform can be classified in 3 different typologies depending on the user addressed:

- **To fruit growers.** Information was weekly sent to growers, from apple flowering (April in our latitudes) to harvest of the latest cultivar (Pink Lady) in November, as this is the interval in which this crop is watered. Growers get information about irrigation forecast of their farms and generic information about the region where the farm is located. Growers placed humidity sensors in the soil and irrigation counters in their farms.
- **To technician staff from the fruit companies in the region**. Technicians are responsible of production in the farms they manage, and therefore, they got the same information than growers with which they work, and if they deemed it necessary, they could get this information more frequently (every 1-7 days).

- **To irrigation programmers that accept instructions**. More and more fruit orchards, particularly bigger orchards, present irrigation controllers (type AGRONIC 2500 or superior), that are able to accept irrigation instructions via GRPS. Aquafruit sent automatically the information, so the irrigation program could be executed in a totally automated way using water quantities estimated by GIROREG.

In order to assess incidence and applicability of information from GIROREG apple, interviews were made to farmers from the three main companies or fruit cooperatives in the area:Cooperativa Girona Fruits, Giropoma S.L. and Empordà Fruits S.L. All this information, together with data from a set of selected plots where irrigation had been monitored, made possible to assess and contrast how the system was followed by users, the level of satisfaction of users and finally, detect new needs and perspectives of the fruit sector. Table 19, Table 20 and Table 21 list plots monitored showing some irrigation related parameters from Cooperativa Girona Fruits, Giropoma S.L. and Empordà Fruits S.L, respectively.

Farm name	Apple cultivar	Fruit Tree Netting	District	Nº of irrigation weeks	Irrigation water (m^3/ha)	GIROREG Recommendation
Camp Palau	Golden Smoothee	NO	Baix Empordà	17	2194	**2156**
Cofrugi	Golden Crielaard	YES	Baix Empordà	24	1080	**1617**
Prima Ullà	Gala	-	Baix Empordà	17	2519	**2156**

Table 19. Detailed information from 3 plots from Girona Fruits and irrigation water applied depending on GIROREG criterion and recommendations.

Farm name	Apple cultivar	Fruit Tree Netting	District	Nº of irrigation weeks	Irrigation water (m^3/ha)	GIROREG Recommendation
La Llona	Gala	NO	Alt Empordà	23	2842	**3283**
Granny 1	Granny	YES	Alt Empordà	23	2354	**2457**
Gala	Gala	No	Alt Empordà	23	3400	**3283**
Camp d'en Creus	Gala	YES	Baix Empordà	23	3978	**2506**
Pont	Golden	Yes	Baix Empordà	23	2783	**2506**

Table 20. Detailed information from 5 plots from Giropoma S.L. and irrigation water applied depending on GIROREG criterion and recommendations.

Farm name	Apple cultivar	Fruit Tree Netting	District	Nº of irrigation weeks	Irrigation water (m^3/ha)	GIROREG Recommendation
Camp Gran	Golden Reinders	YES	Alt Empordà	16	1217	**2275**
Bussinyol	Golden Smoothee	NO	Alt Empordà	13	2200	**2583**
Les Gavarres	Golden Reinders	YES	Alt Empordà	17	1586	**2275**
Sarredà	BrookfieldGala	YES	Alt Empordà	13	2200	**1974**

Table 21. Detailed information from 4 plots from Empordà Fruits S.L. and irrigation water applied depending on GIROREG criterion and recommendations.

In general there was a certain variability in following the recommendations between different kinds of farms depending on the availability of humidity sensors. In contrast to fertilization or diseases treatment and other aspects related to the Field note, which are closely monitored and faithfully registered in order to pass inspections, irrigation records are usually abandoned because keeping record of the whole campaigns complex, it is not mandatory to keep record books and the low value that water represents (low price, availability, etc.).

However, growers of fruit sector have long assimilated the importance of introducing technology in farm management, thus following irrigation recommendations to accomplish an improvement in yield and water management is not strange to them. In contrast to arable crops, for fruit crops wasted water is an increase of production costs as it results in increased tree vigor, decreased yield for the following years, increased labor for winter pruning, occasionally less coloration in red cultivars.

For fruit orchards there is a perspective of improvement in water efficiency. Growers are overcoming obstacles more and more (economic investments, etc.) to continually improve water efficiency by implementing completely automated irrigation systems. Here the role of the grower is not to decide when or what quantity of water use to irrigate the crop, but notifying the technician staff, in the case some of the automatism would stop working.

Surveys to farmers

Several surveys were conducted at the end of the irrigation campaign 2017 to capture the introduction of GIROREG advices in the irrigated crops sector, to know how growers use this information, how growers appreciate this information and possible aspects to improve. Surveys were addressed to representative growers from the lower Ter and the coastal plain of La Muga
Growers were selected on the basis of the size of their farms and their implication in the continuous improvement of the sector.
From these surveys and all information monitored by GIROREG we conclude that recommendations in maize irrigation management resulted in a decrease in irrigation water of 20-30% on average, with no significant yield differences.

Demonstrative actions in Segre

In Segre watershed two demonstrative actions took place in vineyard plots: i) mulching and ii) altitude assays. The localisation of the plots is described in deliverable 15.

Mulching assay:

In this assay, two plots were set up in RAIMAT facilities in order to test mulching as a climate change adaptation measure. Different mulching treatments (biodegradable plastic and organic mulching) were established in both new and adult vineyard plantations chosen. The objective was to increase water available to the plant by two means: increasing water preservation in the soil below mulched area, and stimulating root growth in the beginning of the vegetative cycle, through increased temperature, especially in the plastic mulch.

a) Preliminary measurements at RAIMAT

Some variables were preliminarily measured in a long-time well established mulching in a vineyard plot located in the same RAIMAT facilities (Figure 21).

Figure 21. RAIMAT vineyard plot with long-time (pre-MEDACC) well established mulching. Picture in the left shows rows with and without mulching (straw from cover crop between rows) treatment. Picture in the right shows mulching treatment.

Results showed that plants of mulch treatment have morphological and physiological leaf characteristics (cuticular transpiration, relative water content at turgor lost point…) usually related to higher water availability when compared to control plants (and Figure 23).

Figure 23

Figure 22. Cuticular transpiration (TRc) related to relative water content (RWC) in control (black color) and mulch (green color) treatment.

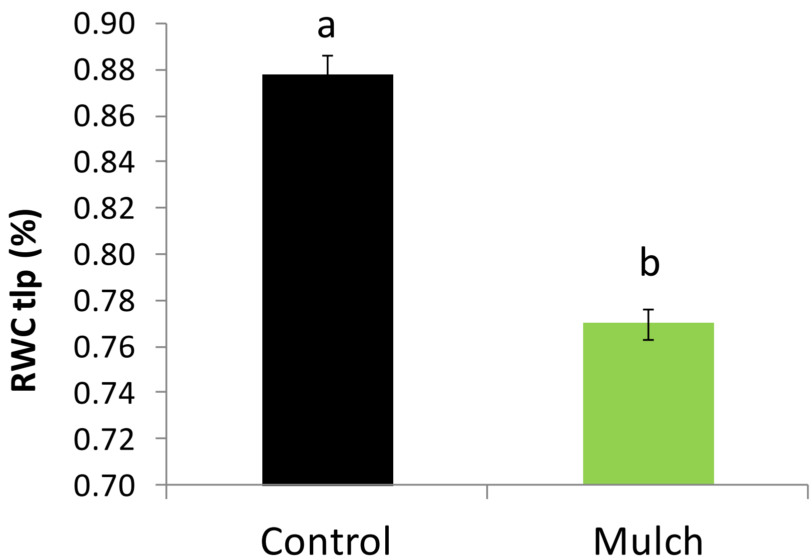


Figure 23. Relative water content control at turgor lost point (RWC tlp) in control and mulching treatment.

The treatments also affected some berry quality parameters represented in Figure 24for control and mulching treatment mulching treatment (M).

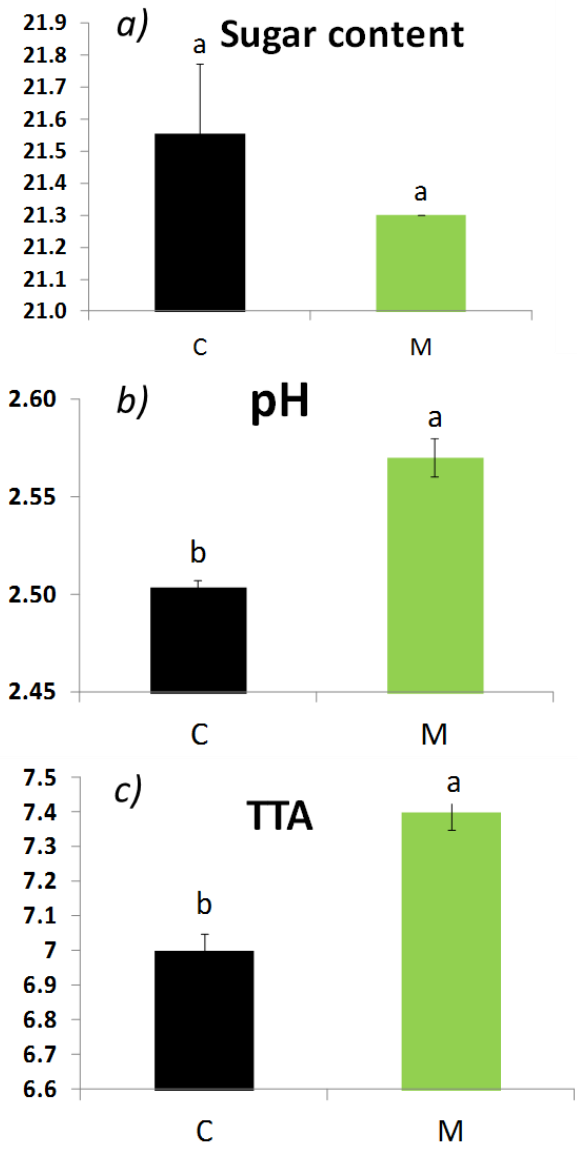


Figure 24. Berry quality parameters: sugar content (g/l) at 20º BRIX (a), pH (b) and total tartaric acidity (TTA, g/l) (c). Black color represents average values of control treatment (C) and green color average values of mulching treatment (M).

Given these preliminary results, demonstrative pilots were established in order to apply this adaptation action and relate expected effects on plant and berry characteristics with soil parameters affected by mulching.

b) <u>MEDACC pilot plots in RAIMAT: failure of mulching treatments</u>

Biodegradable plastic and organic mulching treatments were established in two plantations in RAIMAT: a new and adult vineyard plantation. Both mulching treatments in both plots failed. Organic mulching based in straw coming from spontaneous vegetation from the aisle between vine rows was scarce, added to the fact that, a dispersion of this mulch was probably caused by wild animals and/or wind (Figure 25). This is in contrast with the established mulching treatment used in RAIMAT, where organic mulch supplied by sown cover crops does affect leaf morphology and grape characteristics (*Figure 21*). Plastic mulching (from BASF) failed too: The criteria used to choose plastic thickness (basically price), the characteristics of the soil (with the presence of irregular cobbles and consistent clods) and an inadequate setting up (this plastic supposed to be better set up before planting) finally resulted in the tearing of the plastic film (Figure 26), suppressing the mulching effect.

Figure 25. Example of failed organic mulching treatment of spontaneous cover straw in adult vineyard. Bare soil can be easily seen in the mulching treatment.

Figure 26. Example of failed biodegradable plastic mulching treatment in vineyard plantation. Right, picture shows the inadequate setting up of plastic mulching in the new vineyard plantation in RAIMAT (the plastic got ripped because it was too thin, soil presented abundant sharp particles and the setting up was done after plantation). Left,

picture shows a couple of examples of plastic mulching failure in new (down) and adult (top) vineyard. Bare soil can be easily seen in the mulching treatment.

As a direct consequence of failure of both, mulching treatments in both plots of RAIMAT, data from measurements of monitored variables during the campaign of 2015 were not considered to be analyzed. Soil water content had been measured in both vineyard plantation (new and adult) using humidity sensors (Figure 27). More variables were measured before deciding to totally give up monitoring these plots due to failure of treatments. These variables were: plant survival and growth in the new plantation and productivity and basic grape quality parameters at harvest time in the adult plantation. All these measurements were dismissed in the same way as soil water content. As other pilots were giving good results, we finally decided to abandon these pilot plots and concentrate in them. However, before that, retesting plots were established in IRTA's facilities.

Figure 27. Humidity sensors implanted in RAIMAT new (right) and adult (left) vineyard plantations.

c) <u>Retesting biodegradable plastic mulching treatments in IRTA's facilities: Some relevant results.</u>

After the failure of biodegradable plastic mulching experience in RAIMAT as MEDACC demonstrative action plots, a new experiment was assayed at IRTA's facilities located outside basins studied in MEDACC (Torre Marimon, location in

Figure 28) from May 2016 to February 2017 using again BASF plastic as mulching. Factors presumably responsible of plastic mulching failure in RAIMAT were suppressed: This time a higher thickness plastic, more appropriate to endure adverse condition outdoor, was used and mulching was set up before planting; plastic mulching was applied before and not after planting, with controlled perforations made in the plastic to allow planting; and finally, soil in the plots did not present big clods or prominent cobbles. Two kind of plantations were implanted in Torre Marimon: a nursery plantation and a 1-year old plantation (Figure 29).

Figure 28. Location of IRTA-Torre Marimon facilities.

Figure 29. Appearance of the assays in IRTA's facilities at the begging of the campaign 2016-2017. In the left, nursery plantation is shown. In the right side, 1-year old vineyard plantation is presented.

Results of these plastic mulching experience in Torre Marimon showed in the **nursery plantation** that soil water content (SWC) showed fluctuations, along the studied period, in the same magnitude in both treatments, so no effect of plastic mulching on SWC was observed. Higher SWC values were observed at the beginning of the campaign, followed by a pronounced decline during July up to August when irrigation doses were corrected and increased (Figure 30).

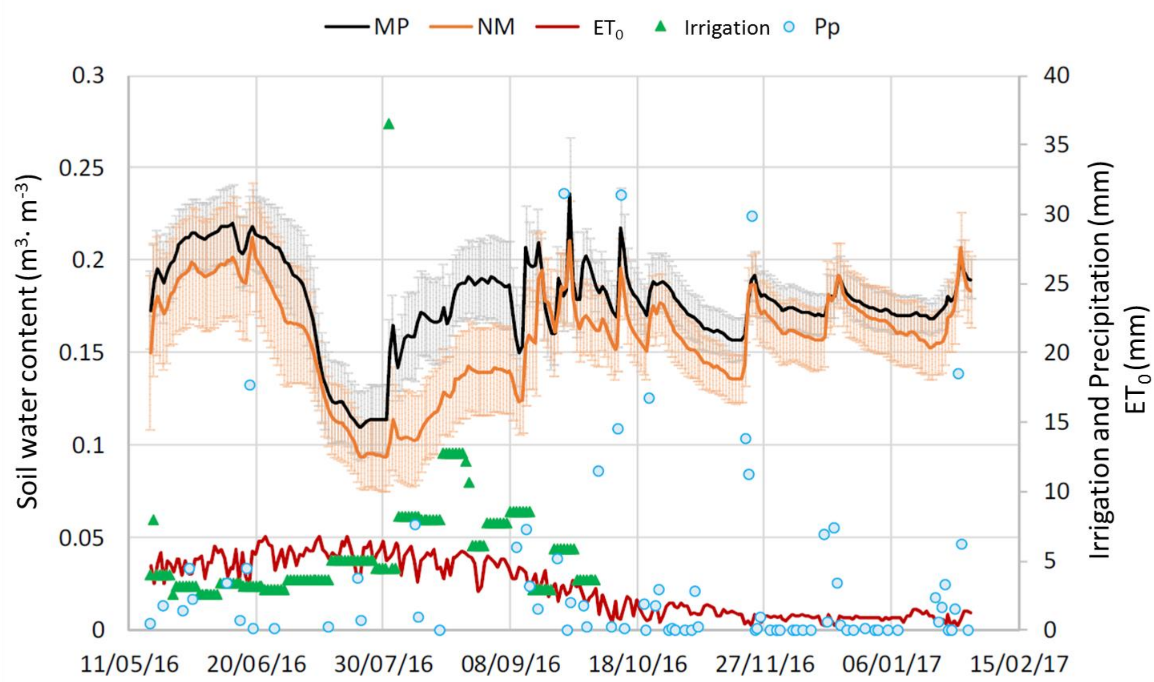


Figure 30. Evolution of soil water content (m3·m-3) in both treatments: control (NM) and plastic mulching (MP), applied irrigation doses (mm), precipitation (Pp, mm) and potential evapotranspiration (ET0, mm) at weekly time scale during the campaign period (May 2016- February 2017).

Differences were observed between treatments at the beginning of the campaign regarding soil temperature, with higher soil temperature in mulching treatment. As the season progressed, differences were lower and completely disappeared from August on (Figure 31).

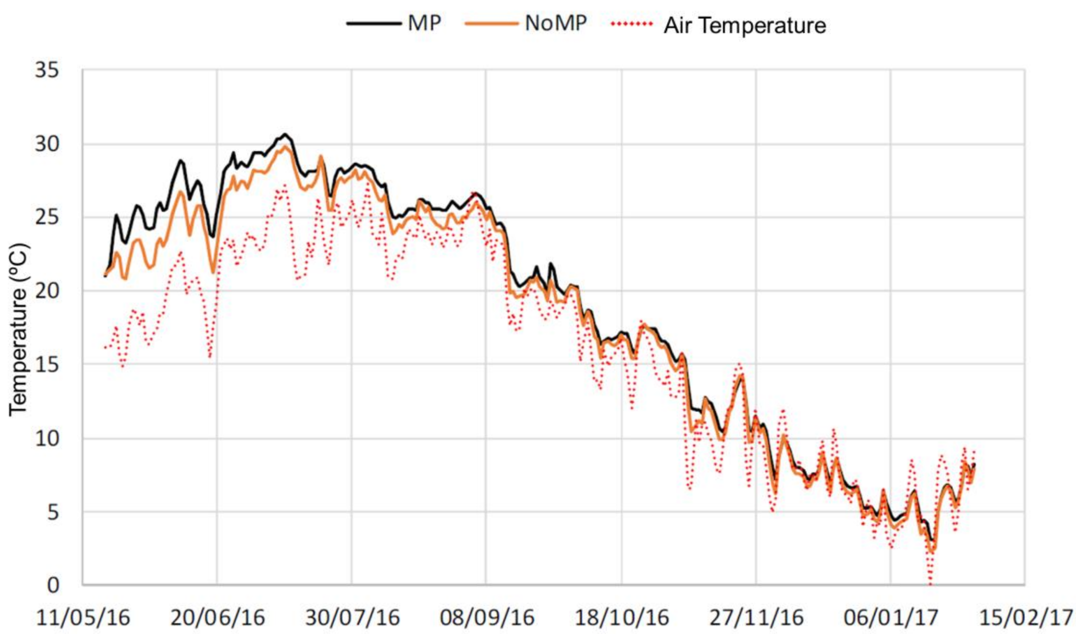


Figure 31. Evolution of mean soil temperature (ºC) in both treatments: control (NM) and plastic mulching (MP).

Trunk diameter growth showed different behaviour between treatments: both treatments started presenting similar diameters but no-mulch (NM) treatment ceased growing before mulching plastic (MP) treatment, showing a higher diameter at the end of the assay (Figure 32).

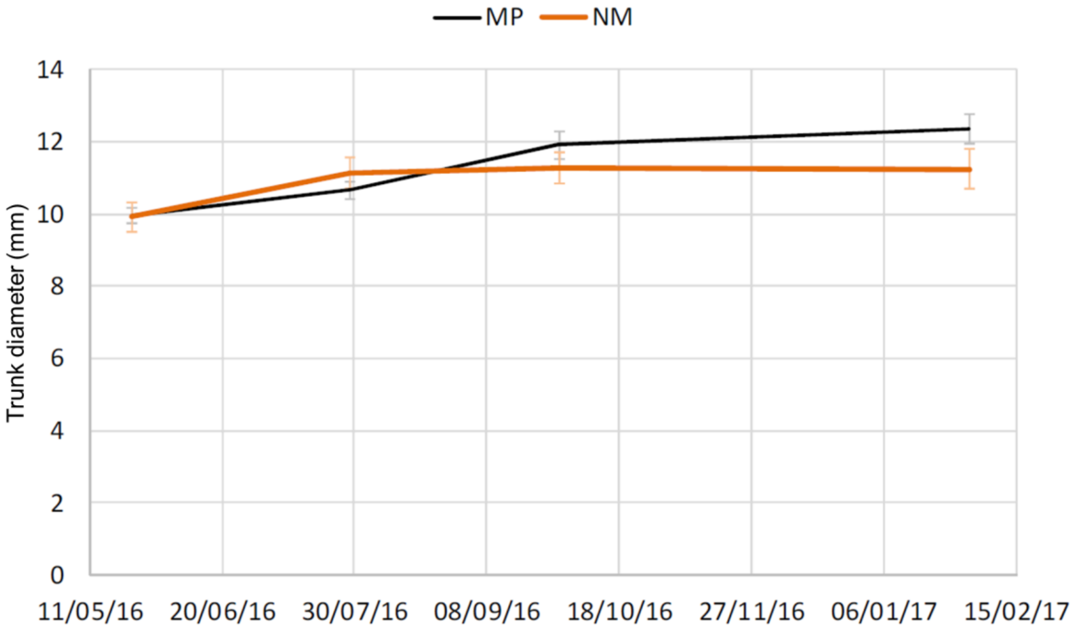


Figure 32. Evolution of mean trunk diameter (mm) ± Standard Error of the Mean along the campaign in both treatments: control (NM) and plastic mulching (MP). n=10

Total biomass and root to shoot ratio did not present significate differences for both treatments and mortality was not associated with treatments.

Plastic mulching experience in Torre Marimon in the **1-year old plantation** added treatments of irrigation and no irrigation. SWC evolution along the season differed among treatments: In general, irrigated treatments MP+ (irrigation + mulching) and NM+ (irrigation + no mulching) presented higher soil water content values than non-irrigated treatments MP- (no irrigation + mulching) and NM- (no irrigation+ no mulching) regardless mulching presence or absence. SWC values were decreasing as the season progressed (Figure 33).

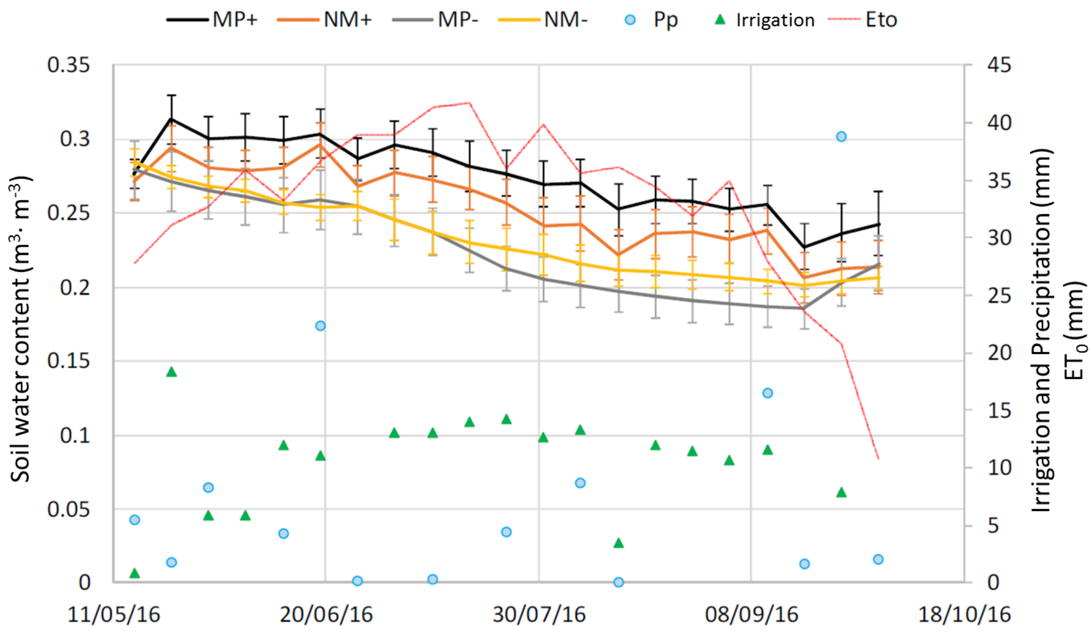


Figure 33. Evolution of SWC (m3·m-3) along the campaign in the four treatments, irrigation doses applied (mm), precipitation (Pp, mm) and potential evapotranspiration (ET0, mm) at weekly time scale.

Differences were observed between irrigated and non-irrigated treatments regarding relative growth of trunk diameter. Mulching presence or absence did not show significant differences in irrigated or rainfed treatments.

Notwithstanding the lack of effect of mulching on SWC, total biomass was affected both by irrigation and mulching (Figure 34). Irrigated treatments presented higher biomass respect non-irrigated in all biomass fractions (leaves, shoots, trunk and roots). Otherwise, mulching treatments showed higher total biomass than no mulching treatments mainly because of higher leaves and shoots growth. However, statistically significant differences were not observed regarding trunk and roots biomass. As a consequence, root to shoot ratio was higher in rainfed treatments than irrigated regardless the presence or absence of mulching.

The results in these retesting assays show that an effect of mulching in plant growth can be seen when properly applied, although it seems to be more related to higher soil temperature in the beginning of the growing season that to an increased water retention in the soil.

Altitude assay

Experimental plots Bodegas Miguel Torres has some vineyards in San Miquel land (Figure 35), Tremp (Lleida) with about 124 ha. Demonstrative/productive plots were designed to accommodate short cycle varieties to cool climates, where excessive temperature can reduce the quality of the grapes. The cultivated varieties are mainly Sauvignon Blanc, Riesling and Chardonnay (white) and Merlot and Pinot Noir (black), grafted on SO4 and R110 rootstocks, planted at 2.20 x 1 m. The conduction/ pruning system is mostly Royat 2 buds and 6 heads and buds, but there is Guyot in some specific plot. Fertilization and drip irrigation are applied under crop demand. Yield is between 4,000 – 5,000 kg/ha. It's a calcareous soil with deposits of gravel.

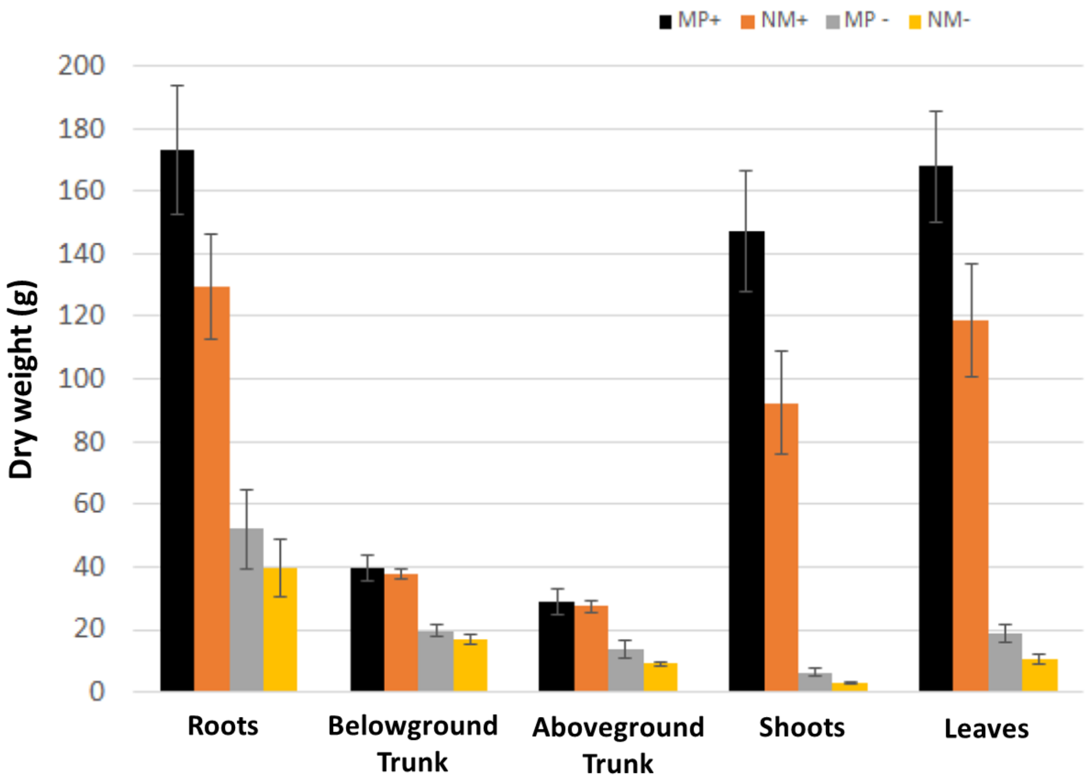


Figure 34. Partitioning biomass measured as dry weight (g) of uprooted plants in the assay (n=6 ± S.E.)

Figure 35. View of Sant Miquel vineyards in Tremp, property of Bodegas Miguel Torres. On the left, general view of terracing. On the right, anti-hail nets were implemented, because hail events are quite frequent at this altitude (850m over sea level).

The results obtained in Sant Miquel vineyards were compared with those obtained in Pacs, Alt Penedès (about 200m a.s.l), with the same cultivars. Results obtained during and before MEDACC project are shown in Figure 36 and Figure 37.

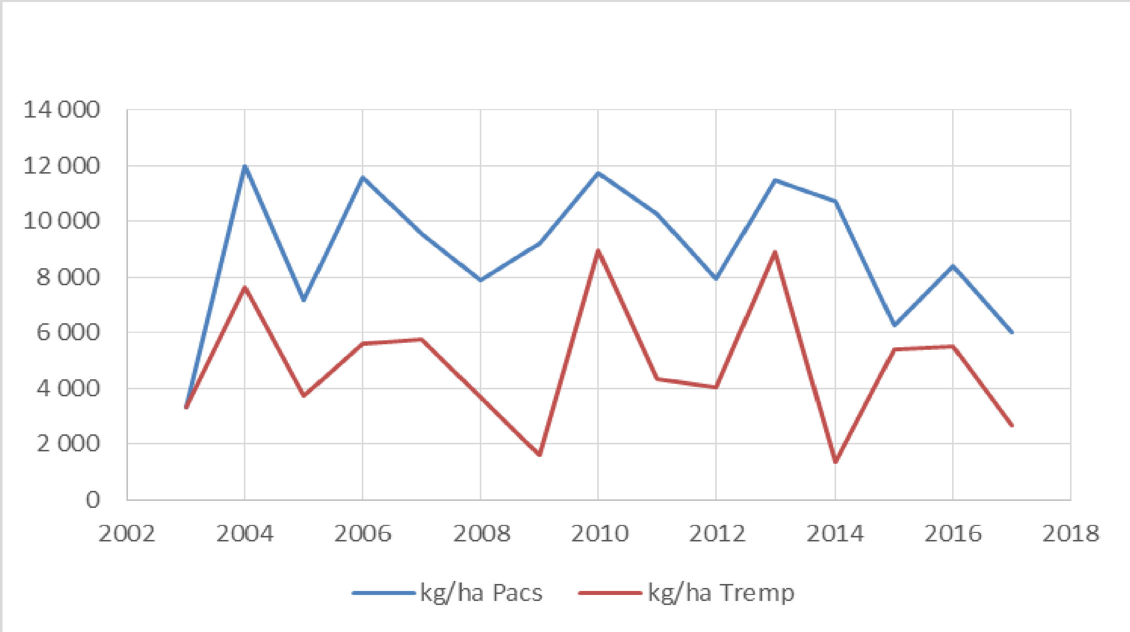


Figure 36. Grape production in Pacs, in blue (Penedès, Barcelona) and Sant Miquel, in red. (Tremp, Pallars Jussà, Lleida)

A consistent lower production has been observed for the last fifteen years in Tremp vineyards as they are, at present, facing colder temperatures and frequently frost episodes before or at the beginning of the growth cycle. However, as wine is a product of high added value, this may be compensated with grape and must quality. General must quality characteristics are shown in Figure 37, showing no differences between both vineyards.

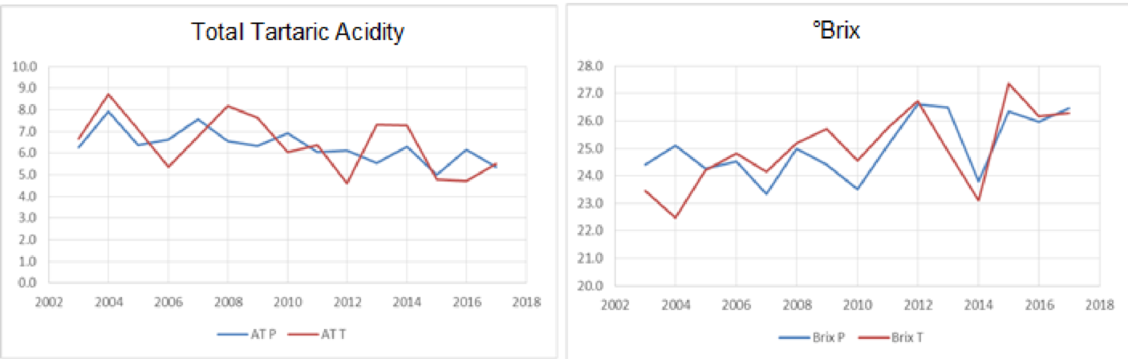


Figure 37. Total tartaric acidity and Brix values of grapes produced in Sant Miquel and Pacs vinyards. ATP and ATT Tartaric acidity in Pacs (blue) and Tremp (red), respectively. Brix P and Brix T, degrees Brix in Pacs (blue) and Tremp (red), respectively.

Productivity differences between Pacs and Tremp plots are quite obvious up to date and grape quality parameters do not differ. However, must phenolic characteristics might justify the move because of a higher wine added value. Such phenolic changes can be observed in areas of great diurnal temperature variation, such as Tremp. On the other hand, Pacs plot productivity has not yet been affected by climate change, most probably due to careful management, but this might not be enough in a near future, and grape productivity would then decline quite quickly, making the move to higher altitudes a wise decision.

3.2.2. Monitoring forest demonstrative activities

The monitoring of the forest demonstrative activities consisted in measuring different variables on the field and comparing the changes of the variable's values among treatments (control and different management treatments) and along time (from March 2015 to November 2017).

a. Evolution of monitoring variables

Demonstrative actions in Segre watershed

Monitoring of the forest demonstrative actions in the Segre watershed was conducted between 2015 and 2017 for one of the areas, and between 2016 and 2017 for the other one. The aim of the demonstrative actions was to evaluate the effectiveness of the treatments to reduce fire risk and to potentiate trees growth through the reduction of tree competitiveness. A control plot, a low intensity plot (selective understory clearing and low thinning) and a high intensity plot (selective understory clearing and intensive tree thinning) were set at each area.

No significant increment in tree growth was detected after the management actions, but two and three years may not be enough to detect this effect. However, in one of the two areas (Madrona), both treatments prevented pine decay, while in control plots pine decay increased (Figure 38).

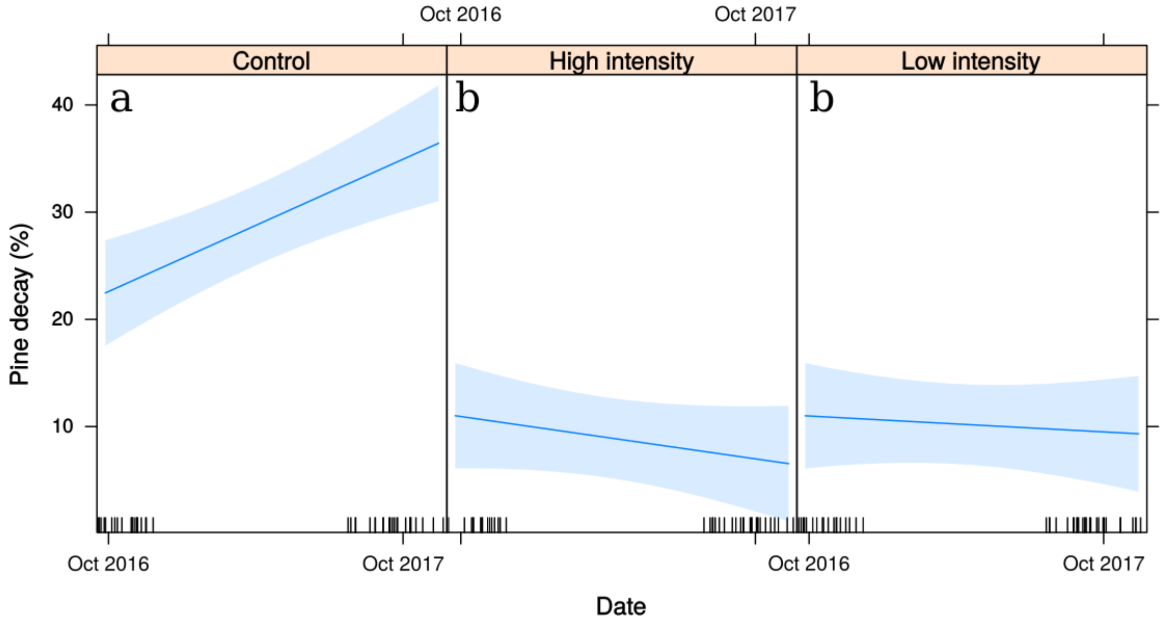
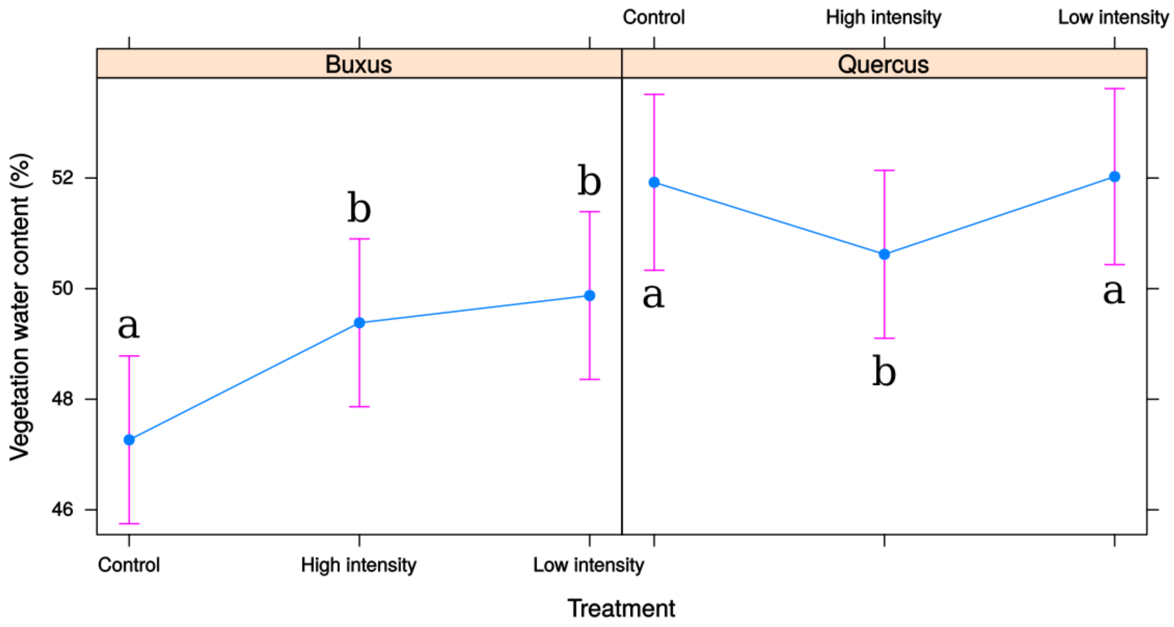


Figure 38. Treatment effect on pine decay along time in Madrona area; decay accentuated in control plots, while it did not change in any of the two treatments.

Regarding fire risk, both treatments reduced it, since they significantly increased understory vegetation (*Buxus sempervirens*) water content during the summer season compared to control plots (Figure 39). However, the benefit was not so clear for one of the dominant tree species, the pubescent oak (*Quercus pubescens*), since only the low intensity treatment increased water content compared to control in one area (Madrona), and canopy was even drier in the high intensity treatment than in the control in the other area (Llobera).



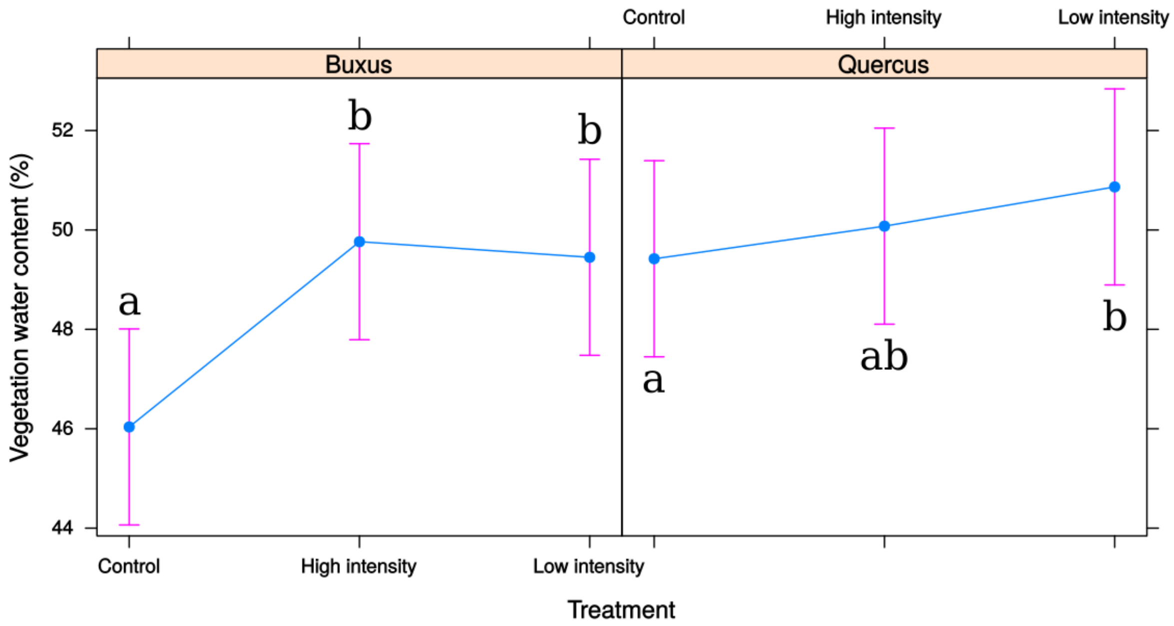


Figure 39. Treatment effect on vegetation water content in Llobera (top) and Madrona (bottom) areas; both treatments reduced fire risk for understory vegetation (Buxus sempervirens), while inconsistent outcome for canopy vegetation was found.

The potential increase in water availability after the treatments is probably behind the increase in understory water content and the halt in pine decay, and it presumably will also promote tree growth.

<u>Demonstrative actions in Ter watershed</u>

The forest demonstrative actions in the Ter watershed were monitored between 2015 and 2017, in order to evaluate the effectiveness of different treatments at improving tree health and preventing drought-induced mortality. Hence, a control plot and three plots with different treatments: low intensity (understory clearing), high intensity (low thinning and understory clearing), and replacement (elimination of Scots pine to accelerate replacement) were established.

Soil humidity increased in the low thinning and understory clearing treatment (high intensity) compared to control (marginally significant), and it also was higher in this treatment than in the replacement one (

Figure 40).

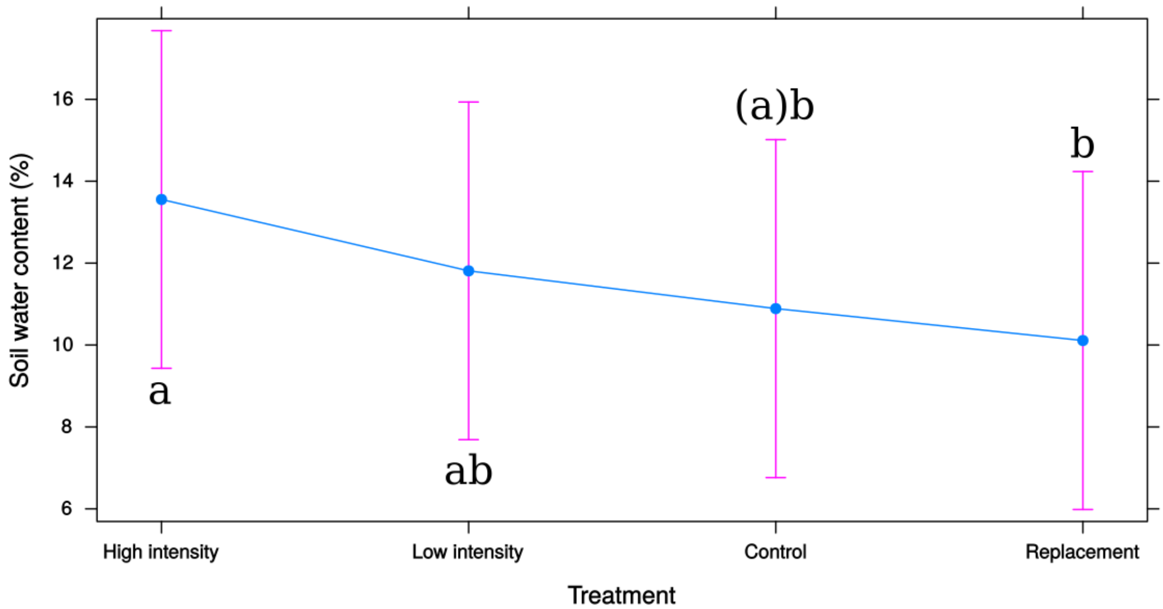


Figure 40. Treatment effect on soil water content; high intensity treatment increased soil humidity compared to replacement treatment and control (marginally significant in the latter).

Similarly to the Segre watershed, no significant differences in pine growth were detected after the treatments, but three years might be too short time for trees to significantly change their growth rates. Nevertheless, a significant increment in pine decay in control plots occurred compared to either low thinning and understory clearing or understory clearing treatments (Figure 41).

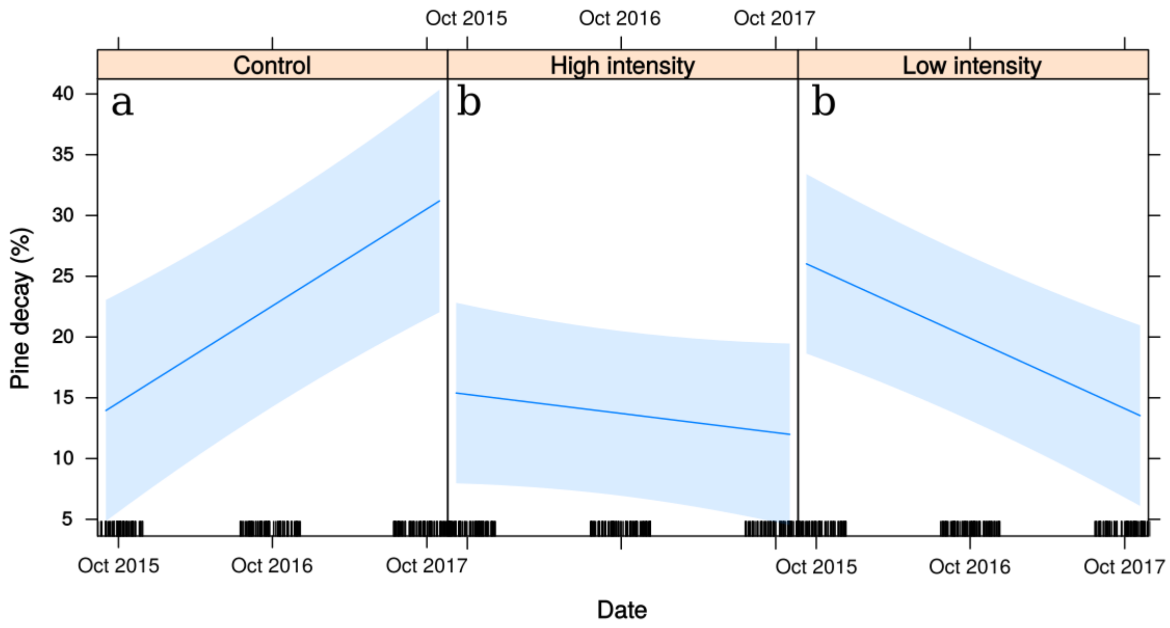


Figure 41. Treatment effect on pine decay; in the control plot pine decay significantly increased, compared with both treatments, where it remained constant or even decreased during the monitoring period.

Also, replacement of Scots pine (*Pinus sylvestris*) by pubescent oak (*Quercus pubescens*) is a slow process than cannot be detected during the monitoring time. In the mid-term, measuring oak growth rates would allow to evaluate whether Scots pine removal promotes replacement.

Demonstrative actions in Muga watershed

Monitoring of the forest demonstrative actions in the Muga watershed was conducted between 2015 and 2017. The objective of the demonstrative actions was to evaluate the effectiveness of the treatments to reduce fire risk through the reduction of tree density and the promotion of mature structures with bigger trees and fuel discontinuity. A control plot and two treatments (selection for an irregular structure and low thinning for a regular structure) were set.

Fire risk was reduced in the selection treatment, since a significant increase in summer vegetation water content both in the understory (*Erica arborea*) and canopy (*Quercus ilex*) main species compared to control and low thinning treatment occurred (Figure 42).

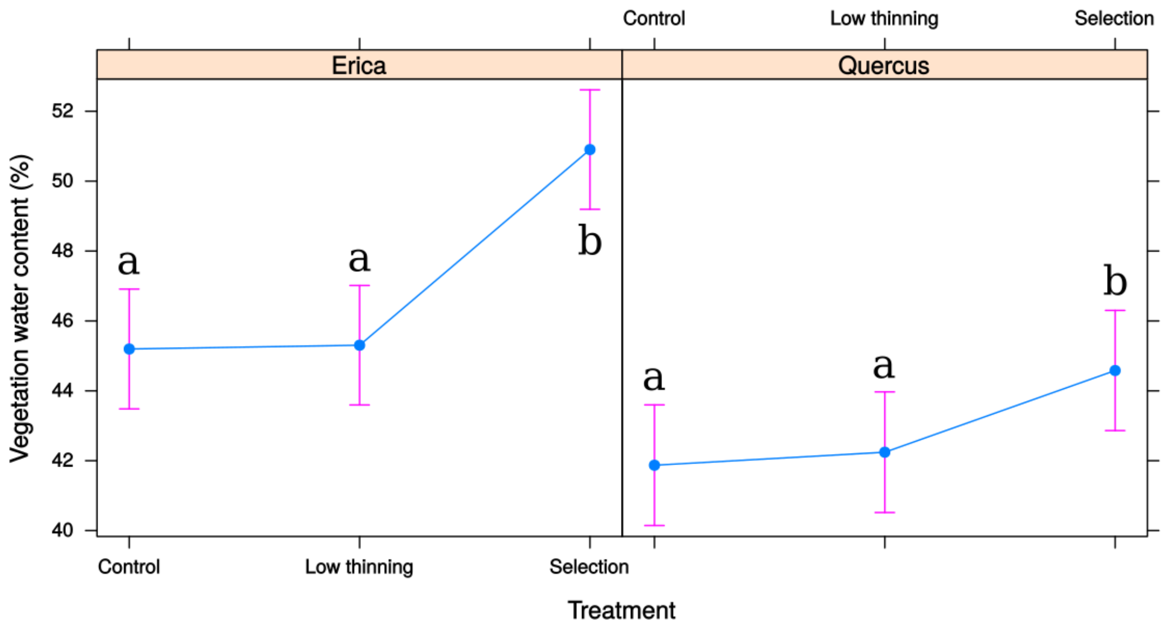


Figure 42. Treatment effect on vegetation water content; in the selection treatment, fire risk is reduced for both the understory (Erica arborea) and the canopy (Quercus ilex) main species, compared to control and low thinning treatment.

The potential increase in water availability after the treatments is likely the cause of the increase in vegetation water content and reduction of fire risk for the selection treatment. In addition, it may also promote holm oak growth. In the mid-term, monitoring will provide information on whether treatments changed forest structure, and which structure is more efficient in terms of water use.

b. Results of the soil analysis

Soil samples were taken at each subplot from each treatment in all watersheds, and organic matter and texture were analysed. Soil texture was loam or sandy loam in almost all subplots, and loam texture dominated in the Ter watershed site and Madrona (Segre watershed), while sandy loam was predominant in the Muga watershed site, and both textures were almost equally dominant in Llobera (Segre watershed). Organic matter was highly variable, especially in the Ter and Muga watersheds. It ranged between 6 and 10% in Llobera (Segre watershed), between 8 and 10% in Madrona (Segre watershed), between 8 and 27% in the Ter watershed site and between 4 and 39% in the Muga watershed site.

Differences in soil texture and organic matter between treatments were tested, since they would result in different water retention capacity, which could influence vegetation response between treatments.

Although there were significant differences in soil texture between sites, it was not significantly different between treatments within a site. Hence, all treatments are comparable regarding soil texture, and no vegetation response differences after the demonstrative actions can be attributed to previous differences in soil conditions.

Regarding soil organic matter, again some differences were found between sites, but no significant change in organic matter occurred between treatments within a site. Therefore, vegetation response to treatments was not influenced by it, and the disturbance produced by thinning and clearing actions did not result in a loss of soil organic matter.

c. Economic evaluation of implementation costs

Table 22 shows the total cost of implementing the forest management in the demonstrative sites in the three basins. The cost of implementation are aggregated for the whole site and values are given by hectare. Table 23breaks down the implementation costs of Requesens, Montesquiu and Llobera depending of the forest management treatment. This information is not available for Madrona demonstrative activity.

Basin	Demonstrative activity	Total cost of implementing forest management	Number of hectares implemented	Cost / ha
Muga	Requesens	3,600.0 €	2.0 ha	1,800.0 €/ha
Ter	Montesquiu	8,340.0 €	3.0 ha	2,780.0 €/ha
Segre	Llobera	9,531.0 €	3.3 ha	2,888.2 €/ha
	Madrona	5,148.8 €	4.6 ha	1,119.3 €/ha

Table 22. Total cost of implementing the forest management demonstrative activities in the three basins.

Basin	Demonstrative activity	Forest management treatment	Cost / ha
Muga	Requesens	Treatment 1 (T1): Application of a selection treatment in order to adapt forest to an irregular structure and to stimulate forest regeneration.	2,000 €/ha
		Treatment 2 (T2): Application of low thinning with the objective to adapt the forest to a regular structure.	1,600 €/ha
Ter	Montesquiu	Treatment 1 (T1): Application of understory clearing with the objective to reduce resources competition.	1,920 €/ha
		Treatment 2 (T2): Application of low thinning and understory clearing with the objective to reduce tree competition. Elimination of escort species and dominant Scots pines.	3,620 €/ha *
		Treatment 3 (T3): Elimination of Scots pine with the objective to accelerate the replacement by oak and evaluate oak's future development.	2,800 €/ha
Segre	Llobera	Treatment 1 (T1): Application of a selective understory clearing and low thinning.	2,850 €/ha
		Treatment 2 (T2): Application of a selective understory clearing and intensive low thinning.	2,940 €/ha

*Table 23. Disaggregated implementation costs of the forest management demonstrative activities per treatments. * The costs/ha in treatment 2 in Montesquiu is higher than expected due to was necessary to open two extraction lines to pull out the wood.*

Table 24 compiles the products (in tons) obtained in the demonstrative activities and the benefits obtained of the sold products.

Basin	Demons. activity	Firewood / Biomass		Wood		Paper wood		Pole timber		Total benefit (€)	Total benefit per ha (€/ha)
		ton	€/ton	ton	€/ton	ton	€/ton	ton	€/ton		
Muga	Requesens	12.0	60							720 €	360.0 €/ha
Ter	Montesquiu	11.2	28	43.2	38	21.4	20			2,383.2 €	794.4 €/ha
Segre	Llobera	25.0	27	25.0	46			20	66	3,145.0 €	953.0 €/ha
	Madrona	80.5	27	72.2	46					5,495.6 €	1,194.7 €/ha

Table 24. Total benefits obtained from the forest management demonstrative activities in the three basins. The products were sold for the subcontractor in charge of implementing the forest management.

Table 25 estimates the real costs of implementing the forest management treatments, as the difference between the implementation costs and the obtained benefits.

Basin	Demonstrative activity	Total cost of implementing forest treatments (€/ha)	Total benefit (€/ha)	Real cost of implementation (€/ha)
Muga	Requesens	1,800.0 €/ha	360.0 €/ha	1,440.0 €/ha
Ter	Montesquiu	2,780.0 €/ha	794.4 €/ha	1,985.6 €/ha
Segre	Llobera	2,888.2 €/ha	953.0 €/ha	1,935.2 €/ha
	Madrona	1,119.3 €/ha	1,194.7 €/ha	-75.4 €/ha

Table 25. Real costs of implementing the forest management demonstrative activities in the three basins.

d. Analysis of the aerial image of Requesens pilot experience

The 2016 summer was especially dry and vegetation of Requesens site suffered notable drought effects. These effects were observable when visiting the site but not recorded with the monitoring variables periodically measured. For this reason, an aerial image of the area created by a Remotely Piloted Aircraft System (RPAS) Phantom 3, from the DJI Company, was taken and digitalised to quantify the forest surface affected by droughts in each treatment. Annex 1 gives some details on the RPAS drone and the camera used to create the aerial image.

Figure 43 shows the limits of the pilot experiences implemented at Requesens over an orthophoto corresponding to summer 2012. The orthophoto shows a highly dense Holm oak forest (over 2,000 trees/ha) with a basal area of 30 m^2/ha and an irregular coppice forest structure. The forest has remained not managed for the last 80 years.

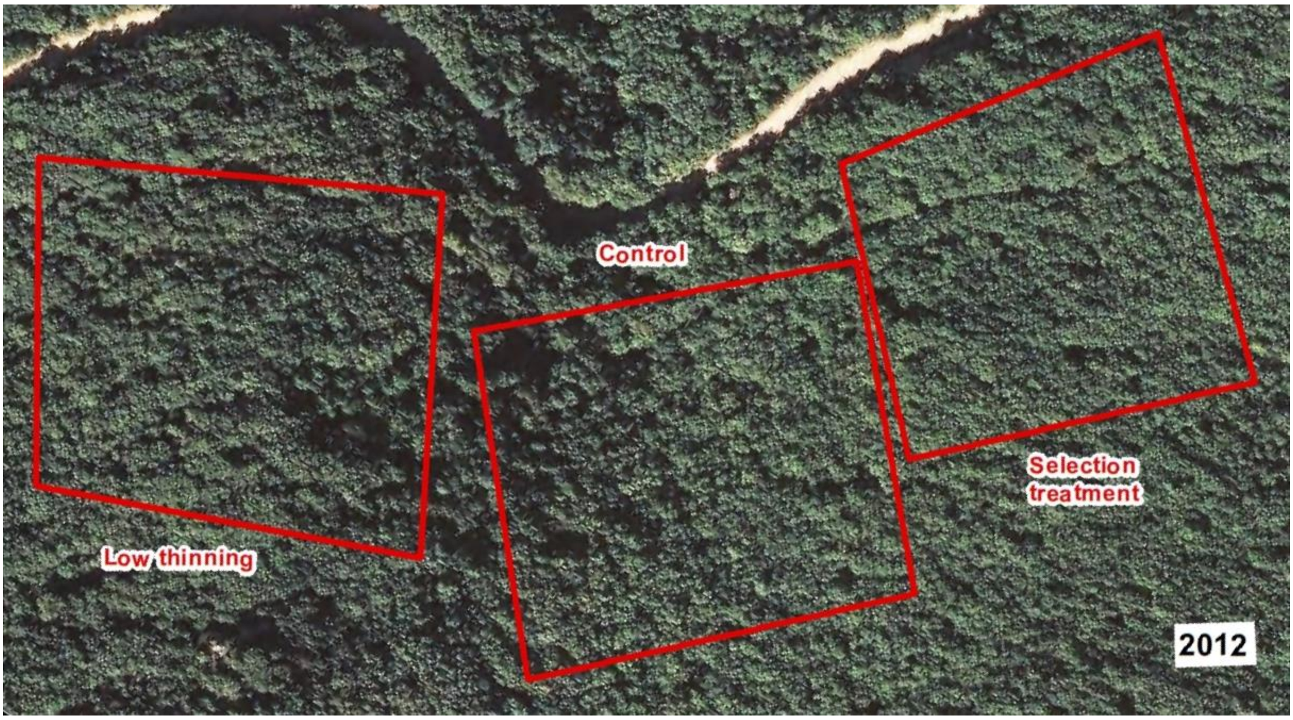


Figure 43.Limits of the Requesens pilot experience (red polygons) over an orthophoto showing the state of the vegetation in 2012 (Source of the orthophoto: Institut Cartogràfic i Geològic de Catalunya).

Figure 44 shows the same location that the previous image but over an orthophoto corresponding to summer 2015. In this case, the two management treatments implemented in the forest are visible:

- Control plot, with no intervention.
- Selection treatment: Application of a selection treatment[1] in order to adapt forest to an irregular structure[2] and to stimulate forest regeneration. The selection treatment implied a 40-50%-reduction of basal area, causing a higher opening of the forest canopy (leaving a final 60% cover) in order to stimulate resprouting.
- Low thinning: Application of low thinning[3]with the objective to adapt the forest to a regular structure[4].The low thinning has affected primarily the diametric classes 5 and 10, with a thinning intensity of the 15-25% of the basal area. The canopy cover has not been reduced in this treatment in order to prevent resprouting. The thinning has selected 2 or 3 stems per stump.

[1]Selection treatment: Removal of individual trees of all size classes more or less uniformly throughout the stand, to promote growth of remaining trees and to provide space for regeneration
[2] Irregular structure: Forest where trees have different diameters and ages.
[3]Low thinning: Removal of trees from the lower crown classes, poorly formed or undesirable codominants, to favor those in the upper crown classes.
[4] Regular structure: Forest where almost all trees have the same age and diameter.

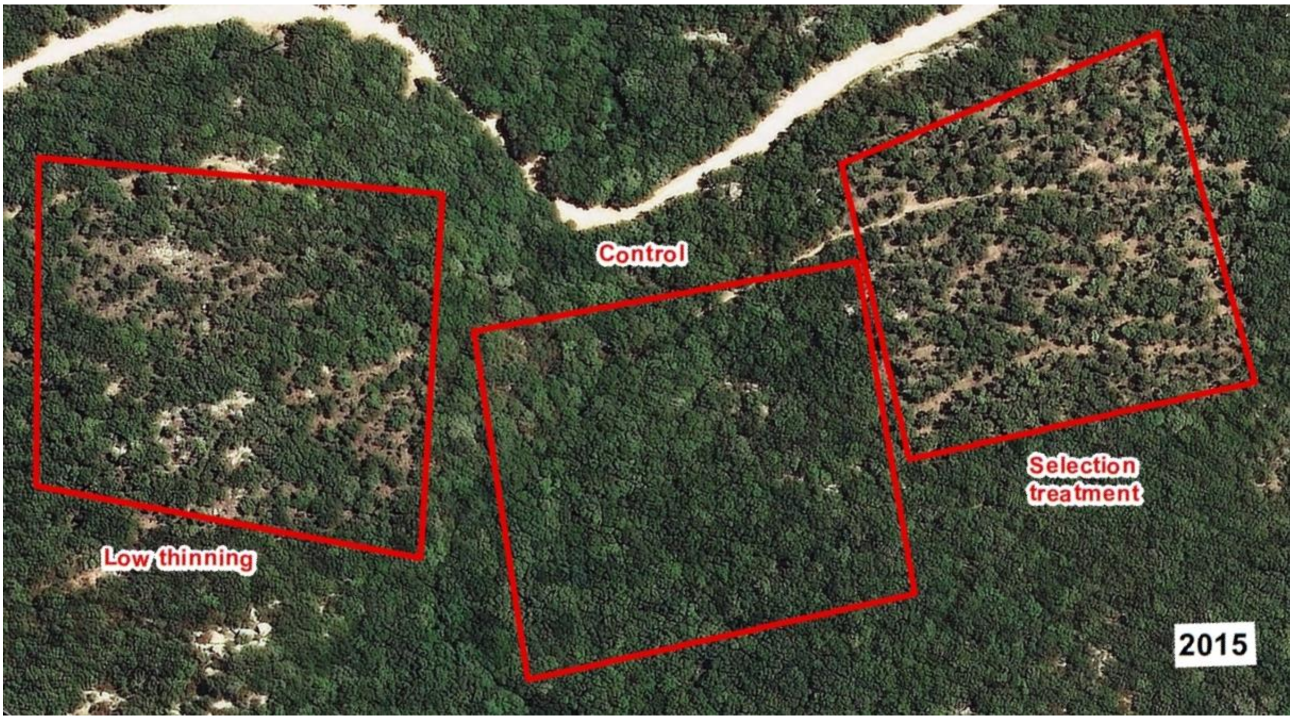


Figure 44.Limits of the Requesens pilot experience (red polygons) over an orthophoto showing the state of the vegetation in 2015, after the implementation of forest management treatments (Source of the orthophoto: Institut Cartogràfic i Geològic de Catalunya).

Figure 45 shows the aerial image of the area taken by a Remotely Piloted Aircraft System (RPAS) on September 30th, 2016. The aerial image shows clearly the effects of the drought on the vegetation on September 2016.The mean monthly temperature along September 2016 was 2ºC higher than the same temperature along September 2015 in the close meteorological station of Espolla (VZ, station from the Catalan Meteorological Service SMC) (Figure 46). The monthly precipitation was scarcely lower in 2016 than in 2015 in the same station, although summer precipitation (June, July and August) was higher in 2016 (81.3 mm) than in 2015 (40.5), mainly due to a more abundant precipitation in June (Figure 47).

Figure 45 shows a different impact between the non-managed plot (control) and the two managed plots (low thinning and selection treatment). In the control plot, signals of forest decline are clearly observable in the superior-left corner of the plot, where Holm oak trees present a decoloured crown due to the lack of water availability. More decoloured crowns are observed within the control plot and outside the plots, where no actuation has been neither implemented and can be also considered as control area. Visually, non-effects of the drought are observable in the treatment plots.

Figure 45.Limits of the Requesens pilot experience (red polygons) over an aerial image created by Remotely Piloted Aircraft System (RPAS), showing the state of the vegetation in 2016.

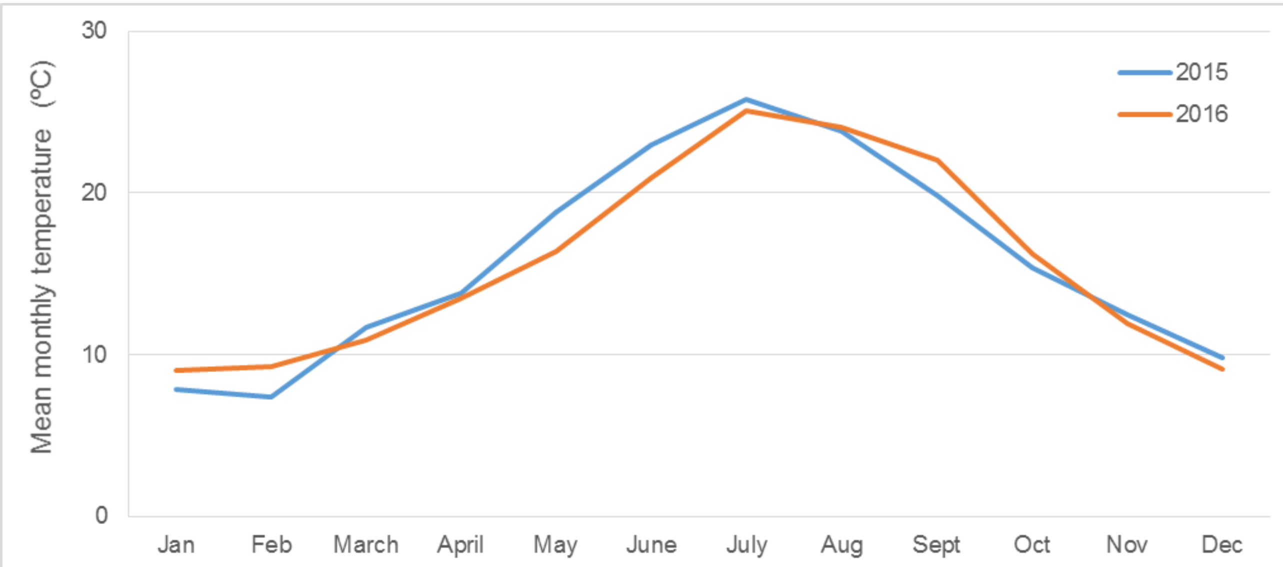


Figure 46.Mean monthly temperature in the meteorological station of Espollà (VZ, Catalan Meteorological Service SMC) in 2015 and 2016.

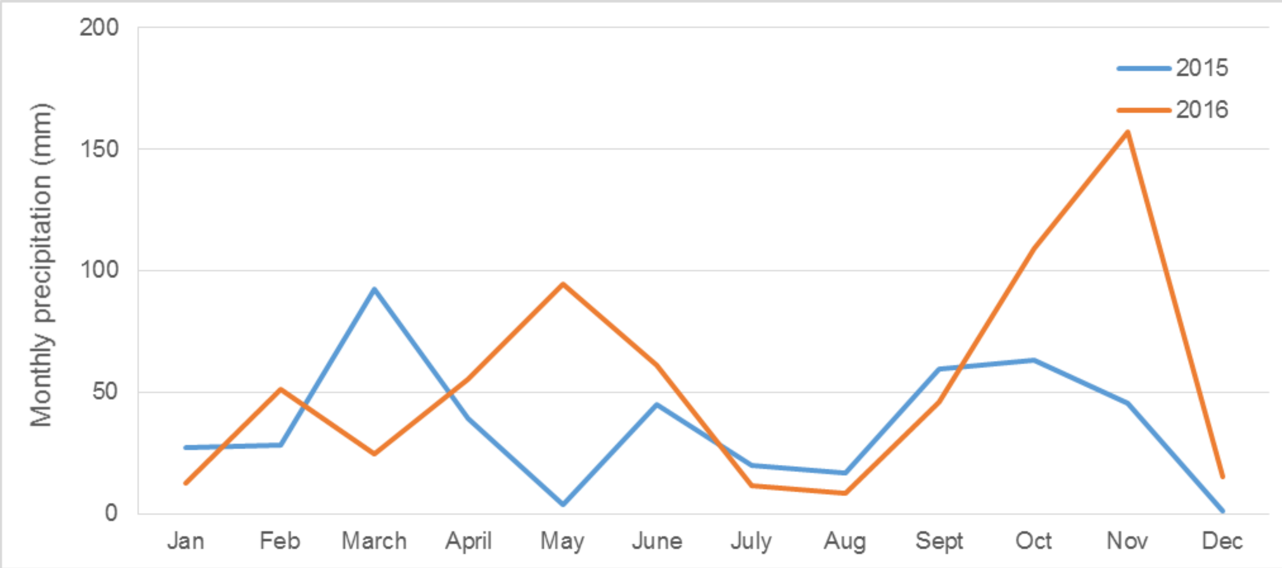


Figure 47.Monthly precipitation in the meteorological station of Espollà (VZ, Catalan Meteorological Service SMC) in 2015 and 2016.

In order to quantify the area affected by drought in each plot, a supervised classification of the aerial image was performed using ArcGIS. An image classification refers to the task of extracting information classes from a multiband raster image. The resulting raster from image classification can be used to create thematic maps. Depending on the interaction between the analyst and the computer during classification, there are two types of classification: supervised and unsupervised. The supervised classification uses the spectral signatures obtained from training samples to classify an image. The analyst uses an Image Classification toolbar to create training samples to represent the classes to extract. By giving example points of each class, the classification automatically create the polygons belonging to each class.

A supervised classification of the aerial image was performed distinguishing between vegetation affected by drought (decoloured crowns, in a wide range of brown, white, yellow and orange colours), vegetation without affection (wide range of green colours) and bare soil (rocks, roads, trails, paths … in a wide range of brown, white and grey colours). The initial classification was not able to distinguish correctly between vegetation affected by drought and bare soil. For this reason, only two classes (vegetation affected and non-affected) were created and bare soil remove manually by the analyst. Figure 48 shows the results of the classification, where vegetation affected by drought are covered by yellow polygons. Table 26shows the numerical analysis of the supervised classification, quantifying the surface affected by drought in each plot and its relation with the total surface (percentage of surface affected by forest decline). The numerical results shows that the 10% of the surface of the control plot presents forest decline, whereas in the two managed-plots, the effects of drought are almost inappreciable. This analysis reveals that forest management is key to reduce the vulnerability of Holm oak forests to face the effects of drought.

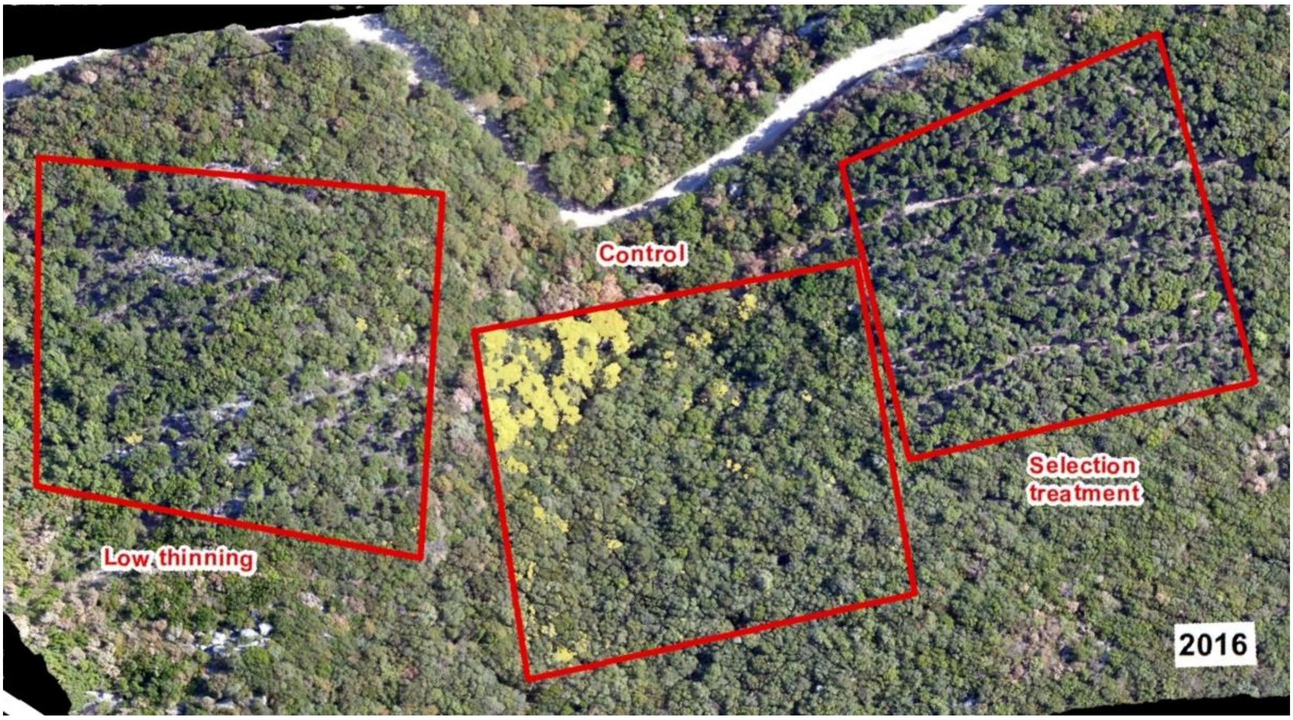


Figure 48.Limits of the Requesens pilot experience (red polygons) over the aerial image of 2016. Yellow polygons refer to decoloured crowns, identified with the supervised classification of ArcGIS.

Treatment	Total surface of the plot (m^2)	Surface affected by forest decline (m^2)	Percentage of surface affected by forest decline (%)
Control	8,232.6	752.1	9.1%
Low thinning	8,340.2	40.8	0.5%
Selection treatment	7,029.8	0.9	0.0%

Table 26. Numerical analysis of the supervised classification including: total surface of each treatment plot (m^2), surface affected by forest decline (m^2), and percentage of surface affected by forest decline (%).

e. Analysis of the aerial image of Montesquiu pilot experience

Following the successful results on Requesens pilot experience, a new aerial image of the Montesquiu site was created by the same Remotely Piloted Aircraft System (RPAS) Phantom 3 to capture the effects of the 2017drought. These effects were observable when monitoring the pilot experiences, but they were difficulty quantified because forest decline affected the superior part ov the crown and was complicate to estimate from the soil.

Figure 49shows the limits of the pilot experiences implemented at Montesquiu over an orthophoto corresponding to summer 2012. The orthophoto shows a Scots pine forest as the dominant species, but with a significant presence of oak (*Quercus pubescens*) in the understory and some escort species. The forest has not managed in the last 30 years (approximate). An initial inventory showed a medium-dense forest (over 1 000 trees/ha) and a basal area of 20 m^2/ha, with a regular structure.

Figure 49.Limits of the Montesquiu pilot experience (red polygons) over an orthophoto showing the state of the vegetation in 2012 (Source of the orthophoto: Institut Cartogràfic i Geològic de Catalunya).

Figure 50 shows the same location that the previous image but over an orthophoto corresponding to summer 2016. In this case, the three management treatments implemented in the forest are visible:

- Control plot, with no intervention.
- Understory clearing: Application of understory clearing with the objective to reduce resources competition. The clearing implied a 50%-reduction of basal area of oak and other escort species. Pine trees were not removed.
- Low thinning and understory clearing: Application of low thinning and understory clearing with the objective to reduce tree competition, eliminating the escort species and dominant Scots pines. This treatment has represented the total elimination of oak and other escort species and the reduction of the Scots pine basal area in a 30%.
- Elimination of Scots pine: Elimination of Scots pine with the objective to accelerate the replacement by oak and evaluate oak's future development. This treatment has represented the total elimination of Scots pine and has promoted the escort species maintenance.

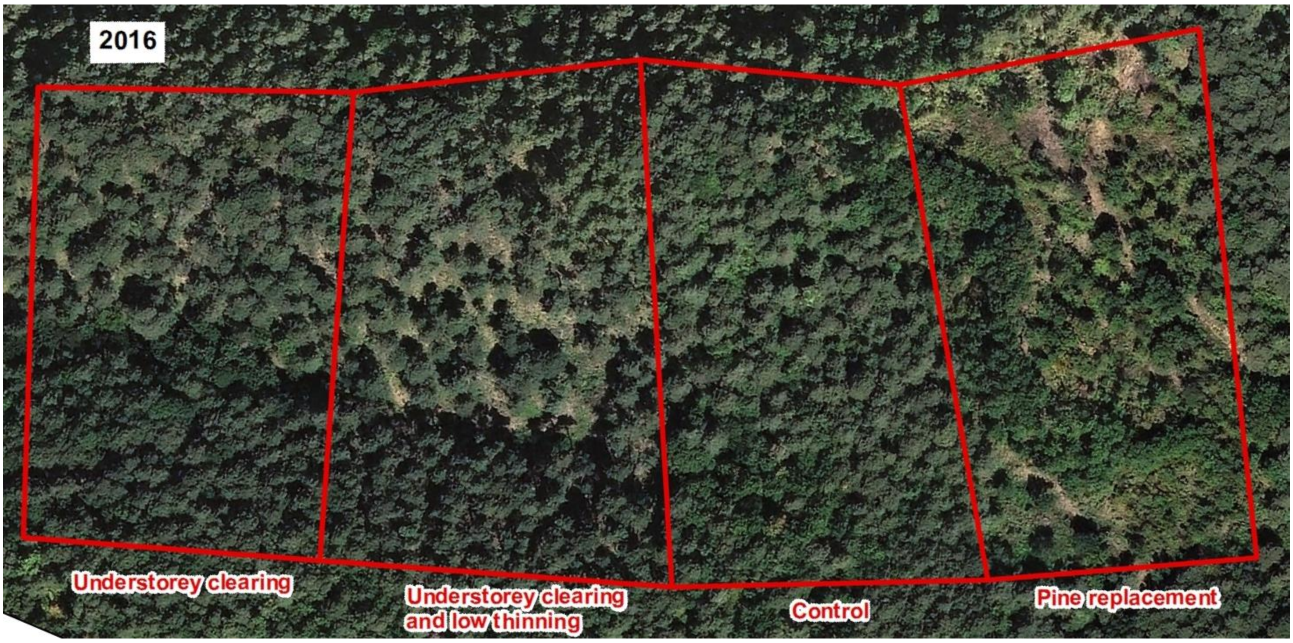


Figure 50.Limits of the Montesquiu pilot experience (red polygons) over an orthophoto showing the state of the vegetation in 2016, after the implementation of forest management treatments (Source of the orthophoto: Institut Cartogràfic i Geològic de Catalunya).

Figure 51 shows the aerial image of the area taken by a Remotely Piloted Aircraft System (RPAS) on November20th, 2017. A previous image was taken on October 30th but the low resolution of the image forced to repeated one month later. The aerial image shows hardly the effects of the drought on the Scots pine and is difficult to identify the dried pine crowns due to the decolouration of the deciduous species.

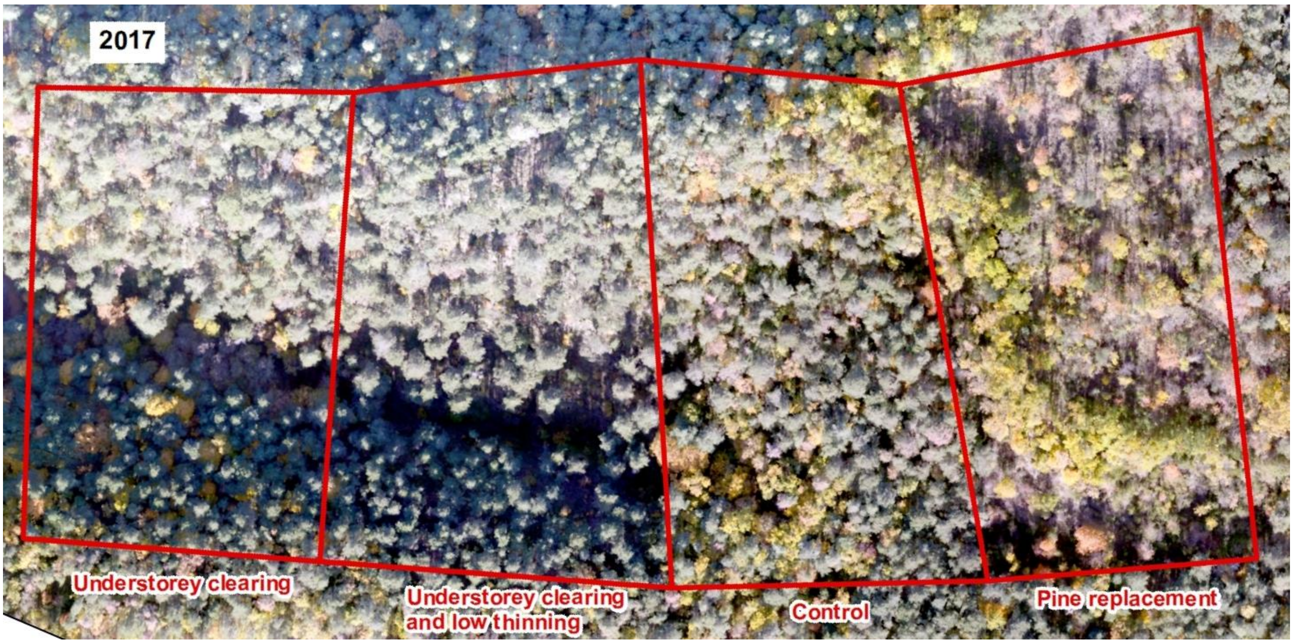


Figure 51.Limits of the Montesquiu pilot experience (red polygons) over an aerial image created by Remotely Piloted Aircraft System (RPAS), showing the state of the vegetation in 2017.

In order to quantify the area affected by drought in each plot, a supervised classification of the aerial image was performed using ArcGIS, similar to the process followed with the Requesens aerial image. It was highly difficult to distinguish the dried crowns of the pines (brown and grey colours mainly) from the effects of the autumn on the deciduous species (yellow, orange, brown and grey colours). Figure 52 shows the results of the classification, where vegetation affected by drought are covered by purple polygons. Table 26 shows the numerical analysis of the supervised classification, quantifying the surface affected by drought in each plot and its relation with the total surface (percentage of surface affected by forest decline). The numerical results shows a scarce 1% of the surface of the control plot presents forest decline, whereas in the two managed-plots, the effects of drought are almost inappreciable. In Montesquiu, this analysis was not enough to identify the effects of the drought due to the image was taken later than expected.

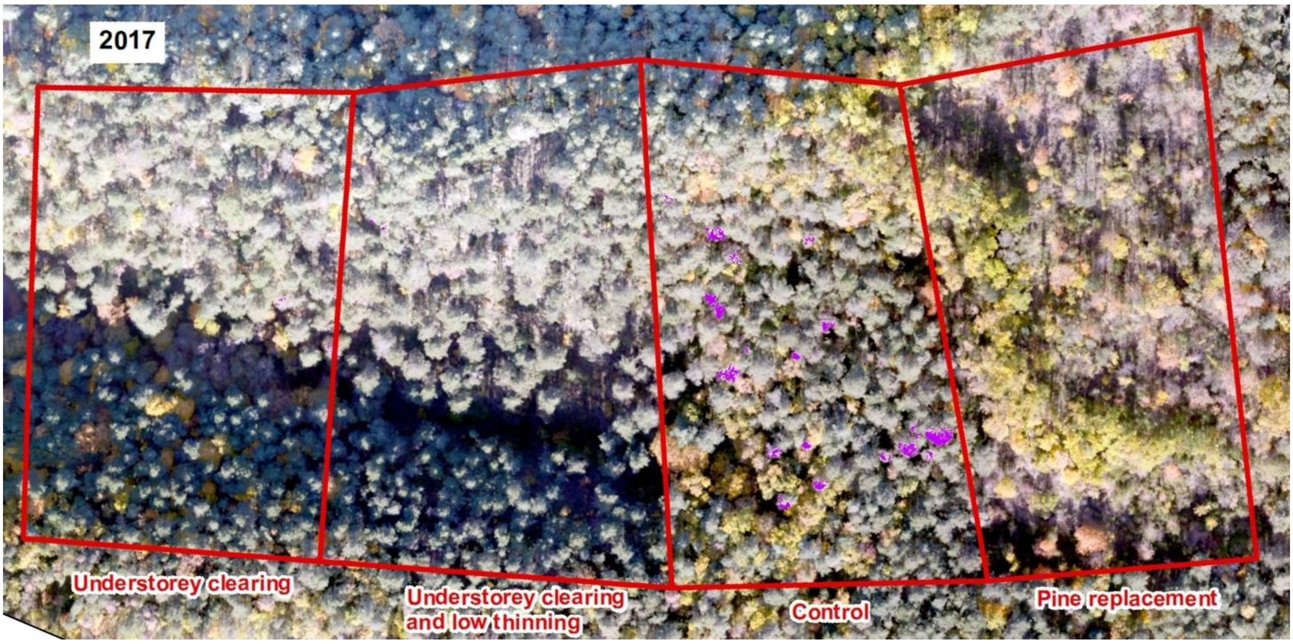


Figure 52.Limits of the Montesquiu pilot experience (red polygons) over the aerial image of 2016. Purplepolygons refer to

Treatment	Total surface of the plot (m^2)	Surface affected by forest decline (m^2)	Percentage of surface affected by forest decline (%)
Control	9,325.0	82.5	0.9%
Understorey clearing	8,846.3	2.1	0.0%
Low thinning and understorey clearing	9,978.2	1.7	0.0%
Pine replacement	9,204.2	0.6	0.0%

decoloured crowns, identified with the supervised classification of ArcGIS.

Table 27. Numerical analysis of the supervised classification including: total surface of each treatment plot (m^2), surface affected by forest decline (m^2), and percentage of surface affected by forest decline (%).

4. Monitoring the effects of Action B3

4.1. Introduction

The Action B3 has the objective to create a platform that integrates all the information and results generated in the project in a structured way that facilitates the use of the results for the different stakeholders. The platform will be frequently updated with the new information created including a database, a geographical information system and a web portal where the information can be consultable through Internet

As stated in the Grant Agreement, Action B3 will be monitored by the use of periodic opinion polls about the Platform and Website in order to know satisfaction degree and usability.

4.2. Results

Two opinion polls has been produced along the project:

- The first opinion poll launched on 17th January 2017
- The final opinion poll launched on March 2018

4.2.1. First opinion poll

The first opinion tool was launched on 17th January 2017, coinciding with the fourth meeting of the Monitoring and Management Committee. 28 participants attended the meeting, and 24 polls were answered (21 during the meeting and 3 sent by email, included in Annex 2).One of the polls has not been able to analyse quantitatively since the response was qualitative, through a very positive evaluation with written text instead of numeric.

The poll had 7 questions (grouped in 4 blocks) that had to be assessed from 0-10.

- The first block evaluated the information hosted in the platform: the quality of the information was scored with an average of 8.2, whereas the usefulness of the information with 7.8.
- The second block evaluated the medium used to access to the platform information, valued with an average of 8.2.
- The third block asked firstly whether the stakeholder has had a direct contact with any beneficiary of the project, where a 66.7% of the participants answered affirmatively. The attention received was valued with a 9.1 average.
- The last block evaluated the MEDACC website: the quality of the information was rated with an average of 8.0 and the usefulness of the information with a 7.8.

As conclusion of this first poll, the stakeholders showed a high level of satisfaction with the project, the data platform and the website.

4.2.2. Final opinion poll

The second opinion poll on the platform data was launched during the month of March 2018, on the occasion of the three focus groups. In this case, the feedback was not as successful as in the previous one, so it was launched again on April 24th on the occasion of the MEDACC Life Workshop and together with the result of the aforementioned workshop. We only have 9 opinion polls answered (22th May 2018).

The poll had 10 questions in two blocks apart from a third block about sociodemographic information. In general terms:

- The design of the Platform is very well considered in terms of structure, organization, sections, download method, information quality and quantity, formats, …,

- About the use of the platform, the users have used it terms of about the use of the platform, the users have used it terms of structure, organization, section, but they consider that the Platform is very useful to understand the Project.
- There are some suggestions about having more information on scientific publications, characteristics of the used models and other sources of information.

5. Conclusions

5.1. Monitoring the effects of Action B1

5.1.1. Accuracy of eco-hydrological calibrated models

- Both hydrological models, RHESsys and SWAT, have shown a satisfactory, good and very good performance ratio for the three statistics used (NSE, PBIAS and RSR) in Muga, Ter and Segre basins. Segre basin has resulted the most difficult to calibrate and adjust, due to the high complexity of the basin. The graphical comparisons have shown also a good fit, with slight over and underestimations.

5.1.2. Inter-comparison of the climate and socioeconomic scenarios

- Inter-comparison of climate scenarios has been developed in base of the Third Report of Climate Change in Catalonia, which is also based in the AR5 IPCC. These reports have already an inter-comparison of climate scenarios, as an ensemble of projections and simulations, extracting the most plausible scenarios for the study area. We have compared some of the main projections to check the plausibility of the climatic series used in the project.
- The inter-comparison between socio-economic scenarios have been a difficult task. Only one scenario has been found in the literature to be compared, attending to the format (raster), spatial resolution (5km) and thematic (land use /cover). The IMAGE3.0 has been compared with the afforestation scenario (AFOR), and general trends are comparable among them.

5.2. Monitoring the effects of Action B2

5.2.1. Monitoring agriculture demonstrative activities

<u>Muga and Ter demonstrative actions:</u>

In general, from surveys and all information monitored by GIROREG experiences, we conclude that there was an increment of water use efficiency in those plots where irrigation advices from GIROREG were followed at both crop types, maize and apple, supposing a reduction between 20% and 30% of irrigation water use. The implementation in the territory of GIROREG *maize* and GIROREG *apple* has been a case of success as regards the transfer of scientific and technical knowledge for these productive sectors mainly for the fruit sector.

Specific conclusions and considerations regarding arable crops and fruit orchard is exposed below:

- **Arable crops (Maize).** Growers to whom irrigation supposes a fixed cost, do not value weekly delivered GIROREG information. They only find useful the determination of the beginning and end of the irrigation campaign. However, for growers to whom irrigation supposes a variable cost depending on the amount of water they use, weekly delivered GIROREG information is quite valued because this information allows them to adjust irrigation doses to the crop water needs. It would be necessary to encourage the importance of field levelling that are to be gravity-irrigated. Field levelling could significantly increase the efficiency of gravity irrigation. Growers with fixed cost irrigation have no incentive to levelling as they can just use more water. In areas with higher water costs or water is scarcer than in Empordà district (in La Selva or Garrotxa districts, for example) drip irrigation systems for maize watering are quite attractive for farmers. The change of irrigation system means to growers the need of new knowledge to water their crop: GIROREG maize provides them a quite valued watering pattern. Unfortunately, the cost of soil humidity sensors cannot be recovered with the current maize prices, in contrast with in fruit orchards. Water management modernization in the framework of the traditional community of irrigators is one the most important deficiencies in water cycle management in Catalonia. For many growers, the irrigation decisions are strongly conditioned by irrigation shifts (approximately every 9 days) marked by the community of irrigators; hence, although GIROREG recommendations provide an useful and interesting information to the crop monitoring, these recommendations become impossible to implement. Consequently, following GIROREG recommendations becomes economically unfeasible for many growers if there is not global framework in the area that involves these actions and changes in water management. Providing forecast about water crop needs to growers and showing them the versatility that this information gives to manage crop irrigation should be the main contribution to growers in a water scarcity context.

- **Fruit crops**: Apple. Growers of the fruit sector have long assimilated the importance of introducing technology in farm management, so they easily recognize the importance of irrigation recommendations to achieve a better production and for general water management. In contrast with arable crops, excess water is detrimental for fruit crops, as it results in increase in costs of production (increase of tree vigour, yield losses, more winter pruning, losses of colour, etc.). Fruit production has a higher monetary value than arable crops, so, irrigation investment (drip irrigation, soil humidity sensors, irrigation programmers, etc.) turn out to be worthwhile and can be easily recovered. GIROREG fruits system implementation have been a case of success in Girona regarding transfer of scientific-technical knowledge to this productive sector. Finally, an inconsistency has arisen in the community of irrigators in Empordà districts: when a fruit orchard is located inside the territory regulated by a community of irrigators it is much easier to capture underground water than using surface water managed and supplied by the community of irrigators. This is because using underground water makes it easier the setting-up of drip irrigation and all the appropriate automatisms to water the fruit orchard. Drip irrigation is supposed to apply lower water quantities but more frequently in time, so irrigation shifts every 9 days and the impossibility to store water at the plot level seriously hinder this irrigation system. Again, as for arable crops, a global framework in water management in the area involving recommendations and changes is needed.

<u>Segre demonstrative actions:</u>

Segre demonstrative actions focused on vineyard cultivation and their possibilities to save water by reducing water losses through different types of mulching and to move in altitude in order to alleviate the climate change impacts

- **Mulching assay**. Due to the mulching assay failures caused by installation and design problems in RAIMAT facilities, other pilot tests were installed at the IRTA facilities in Torre Marimon to try again the effectiveness of the plastic mulching. In these trials it is shown how the plastic, that had been installed in a suitable way, had a positive effect on the growth of the vine, although it seems to be more related to an increase in temperature in the initial stages of growth that with an increase of the retention of water to the ground under these conditions. *Lessons learned: Be careful in the details when choosing a mulching option, take into consideration the particular place it has to be installed. This can be extended to any other adaptation measurement.*
- **Altitude assay.** Lower productivity were observed in altitude vineyards compared with vineyards located at a typically wine production area in Catalonia (Penedès). Notwithstanding, wine production in altitude could present better organoleptic characteristics that might give an added value to the final product and compensating lower production. Such organoleptic characteristics can be observed in areas of great diurnal temperature variation, such as Tremp. On the other hand, Pacs plot productivity has not yet been affected by climate change, most probably due to careful management, but this might not be enough in a near future, and grape productivity would then decline quite quickly, making the move to higher altitudes a great possibility. Notwithstanding, cropping in altitude should assume associated frost or hail storm-risk losses and carbon footprint of the final product associated to fruit transportation from grape production areas (higher altitude) to wine production areas (lower altitude).

5.2.2. Monitoring forest demonstrative activities

- There is evidence that forest management can help make forests more robust against future climatic conditions. However, the complexity and temporal scope of these studies makes it difficult to develop decision-making tools and adaptive management strategies based on the evaluation of the effectiveness of different forestry treatments from multiple viewpoints.
- It is for that reason that a series of forestry management actions have been designed and executed, reducing the vulnerability of the main forest typologies of the three basins; all this has been carried out using the principles of adaptive management. These actions have been carried out in potentially vulnerable forests, either because of previous episodes of decline or because they have an elevated risk of wildfire.
- In some pilot tests seasonal increments in soil humidity were observed where the management actions were carried out. During the spring and summer, high soil humidity is positively correlated with improved tree growth and health.
- Management also led to higher water contents of the vegetation in periods of elevated fire risk, which translates to lower flammability and combustibility of the vegetation. This was found both in parcels with black pine in the Solsonès region (Segre) and holm oak parcels of the Muga.
- In the case of the Scots pine at Montesquiu (Ter), forest management clearly reduced forest decline.
- Problems associated with drought in holm oak forests of Requesens (Muga) in the summer of 2016 barely manifested the managed areas (between 0 and 0.55% of the oaks showed symptoms of decline) while in the unmanaged parcel (control) 9.1% of the oaks showed signs of decline.
- Forest management proved key for reducing the vulnerability of the holm oak in the Muga basin, and for the Scots pine in the Ter basin, during the droughts of the summers of 2016 and 2017. In the case of the black pine in Solsonès (Segre basin) the effect was not as evident because the climatic anomaly was not as pronounced.
- In the Solsonès (Segre), the structural change of the black pine forests made through management clearly reduced vulnerability to fire by reducing the vertical continuity of combustible materials.
- The Muga holm oak forest's resistance to the drought of 2016 was very similar among the two management schemes tested. This leads to the conclusion that even the implementation of less intensive management treatments (elimination of the understory and low thinning) with costs 20% than more intensive treatments (selective felling) could have a notable effect of reducing vulnerability.
- The analysis of the cost of implementing the forest management in the demonstrative sites does not allow to extract general conclusions, since the costs depend on a high number of initial variables: forest structure, slope, access, distance to roads ... Understorey clearing treatment has an average cost around 1,600 and 1,900 €/ha. When understorey clearing is complemented with low thinning, costs increase between a 25 and 45%, reaching 2,000-2,800 €/ha. The benefit obtained for the actuation also depends of the site and the quantity of extracted products. In the pilot experience, the benefit of selling extracted products reduced notably the costs of implementation of Ter and Segre basin, but was reduced at Muga basin.
- Forest management in Requesens (Muga basin) has been key to reduce the vulnerability of the Holm oak to the effects of the drought occurred in summer of 2016. This effect has been quantified with an aerial image of the area created by a Remotely Piloted Aircraft System (RPAS) on September 30th, 2016. This summer was specially warm, with a monthly temperature along September 2ºC higher than the same temperature along September 2015. The monthly precipitation was scarcely lower in 2016 than in 2015, although summer precipitation (June, July and August) was higher in 2016 (81.3 mm) than in 2015 (40.5),

mainly due to a more abundant precipitation in June. A supervised classification of the aerial image performed using ArcGIS allowed to quantify the area affected by drought in each plot (control and treatments). The results showed that the 10% of the surface of the control plot presented forest decline (decoloured or defoliated crowns), whereas in the two managed-plots, the effects of drought were almost inappreciable (0.5% in the low thinning treatment and 0% in the selection treatment).

5.3. Monitoring the effects of Action B3

The Annex 3 titled “General Audience report” have a deep analysis about the audience, traffic, behavior, engaged and visited contents of the Platform data.

6. References

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7. Annexes

7.1. Annex 1. Characteristics of the Remotely Pilot Aircraft System used to create the aerial image of forest pilot experiences.

RPAS

Peso (Batería y Hélices Incluidas)	1280 g
Tamaño Diagonal (Hélices Excluidas)	350 mm
Velocidad Máx. en Ascenso	5 m/s
Velocidad Máx. en Descenso	3 m/s
Precisión en Vuelo Estacionario	Vertical: +/- 0.1 m (si el Posicionamiento Visual está activado) o +/- 0.5 m Horizontal: +/- 1.5 m
Velocidad Máx.	16 m/s (modo ATTI, sin viento)
Altura Max. de Servicio sobre el Nivel del Mar	6000 m (Límite de altura por defecto: 120 m sobre el punto de despegue)
Temperatura de Funcionamiento	de 0°C a 40°C
Modo GPS	GPS/GLONASS
Máx. Duración de Vuelo	Aproximadamente 23 minutos

CÁMARA

Sensor	1/2.3” CMOS
Píxeles efectivos	12.4 M (píxeles totales: 12.76 M)
Lente	FOV 94° 20 mm (35 mm formato equivalente) f/2.8, enfoque a ∞
Rango ISO	100-3200 (vídeo) 100-1600 (foto)
Velocidad Del Obturador	8s -1/8000s
Tamaño Máx. de Imagen	4000×3000
Modos de Fotografía	Disparo único Disparo en ráfaga: 3/5/7 disparos
Exposición Automática en Horquillado (AEB)	3/5
Horquilla de Exposición	0.7EV Bias
Modos de Vídeo	UHD: 4096x2160p 24/25, 3840x2160p 24/25/30 FHD: 1920x1080p 24/25/30/48/50/60 HD: 1280x720p 24/25/30/48/50/60 2.7K: 2704 x1520p 24/25/30 (29.97)
Tipos de Tarjetas SD Compatibles	Micro SD
Capacidad Máx.	64 GB
Tasa de Bits Máx. de Almacenamiento de Vídeo	60 Mbps
Formatos de Archivo Admitidos	FAT32 (≤ 32 GB); exFAT (> 32 GB)
Temperatura de Funcionamiento	de 0°C a 40°C

7.2. Annex 2. First opinion pool fulfilled by stakeholders

ENQUESTA SOBRE EL GRAU DE SATISFACCIÓ DE LA INFORMACIÓ REBUDA I SOBRE EL WEB LIFE MEDACC

INFORMACIÓ REBUDA (puntueu de 0 a 10)

Qualitat de la Informació	9
Utilitat de la Informació	8

MITJÀ D'ACCÉS (puntueu de 0 a 10)

Valoreu el mitjà utilitzat per accedir a la informació	8

ATENCIÓ REBUDA Sí / No

		(puntueu de 0 a 10)	
Heu tingut contacte directe amb algun soci del projecte MEDACC?	Sí	Valoreu l'atenció	10

WEB MEDACC (puntueu de 0 a 10)

Qualitat de la Informació	9
Utilitat de la Informació	9

OBSERVACIONS

- Pel temps per participar en el CTT i validar les accions proposades

ENQUESTA SOBRE EL GRAU DE SATISFACCIÓ DE LA INFORMACIÓ REBUDA I SOBRE EL WEB LIFE MEDACC

INFORMACIÓ REBUDA (puntueu de 0 a 10)

Qualitat de la Informació	10
Utilitat de la Informació	10

MITJÀ D'ACCÉS (puntueu de 0 a 10)

Valoreu el mitjà utilitzat per accedir a la informació	10

ATENCIÓ REBUDA Sí / No

		(puntueu de 0 a 10)	
Heu tingut contacte directe amb algun soci del projecte MEDACC?	SÍ	Valoreu l'atenció	10

WEB MEDACC (puntueu de 0 a 10)

Qualitat de la Informació	9
Utilitat de la Informació	9

OBSERVACIONS

Caldria plantejar-ne la continuïtat: Life Medacc II?

ENQUESTA SOBRE EL GRAU DE SATISFACCIÓ DE LA INFORMACIÓ REBUDA I SOBRE EL WEB LIFE MEDACC

INFORMACIÓ REBUDA (puntueu de 0 a 10)

Qualitat de la Informació	9
Utilitat de la Informació	9

MITJÀ D'ACCÉS (puntueu de 0 a 10)

Valoreu el mitjà utilitzat per accedir a la informació	8

ATENCIÓ REBUDA

Sí / No		(puntueu de 0 a 10)	
Heu tingut contacte directe amb algun soci del projecte MEDACC?	NO	Valoreu l'atenció	

WEB MEDACC (puntueu de 0 a 10)

Qualitat de la Informació	9
Utilitat de la Informació	9

OBSERVACIONS

ENQUESTA SOBRE EL GRAU DE SATISFACCIÓ DE LA INFORMACIÓ REBUDA I SOBRE EL WEB LIFE MEDACC

INFORMACIÓ REBUDA (puntueu de 0 a 10)

Qualitat de la Informació	7
Utilitat de la Informació	7

MITJÀ D'ACCÉS (puntueu de 0 a 10)

Valoreu el mitjà utilitzat per accedir a la informació	8

ATENCIÓ REBUDA Sí / No — (puntueu de 0 a 10)

Heu tingut contacte directe amb algun soci del projecte MEDACC?	8	Valoreu l'atenció	9

WEB MEDACC (puntueu de 0 a 10)

Qualitat de la Informació	8
Utilitat de la Informació	7

OBSERVACIONS

ENQUESTA SOBRE EL GRAU DE SATISFACCIÓ DE LA INFORMACIÓ REBUDA I SOBRE EL WEB LIFE MEDACC

INFORMACIÓ REBUDA (puntueu de 0 a 10)

Qualitat de la Informació	7
Utilitat de la Informació	6

MITJÀ D'ACCÉS (puntueu de 0 a 10)

Valoreu el mitjà utilitzat per accedir a la informació	8

ATENCIÓ REBUDA Sí / No

		(puntueu de 0 a 10)	
Heu tingut contacte directe amb algun soci del projecte MEDACC?	NO	Valoreu l'atenció	

WEB MEDACC (puntueu de 0 a 10)

Qualitat de la Informació	6
Utilitat de la Informació	6

OBSERVACIONS

ENQUESTA SOBRE EL GRAU DE SATISFACCIÓ DE LA INFORMACIÓ REBUDA I SOBRE EL WEB LIFE MEDACC

INFORMACIÓ REBUDA (puntueu de 0 a 10)

Qualitat de la Informació	6
Utilitat de la Informació	6

MITJÀ D'ACCÉS (puntueu de 0 a 10)

Valoreu el mitjà utilitzat per accedir a la informació	7

ATENCIÓ REBUDA Sí / No (puntueu de 0 a 10)

Heu tingut contacte directe amb algun soci del projecte MEDACC?	~~S~~ I	Valoreu l'atenció	8

WEB MEDACC (puntueu de 0 a 10)

Qualitat de la Informació	6
Utilitat de la Informació	6

OBSERVACIONS

ENQUESTA SOBRE EL GRAU DE SATISFACCIÓ DE LA INFORMACIÓ REBUDA I SOBRE EL WEB LIFE MEDACC

INFORMACIÓ REBUDA (puntueu de 0 a 10)

Qualitat de la Informació	7
Utilitat de la Informació	6

MITJÀ D'ACCÉS (puntueu de 0 a 10)

Valoreu el mitjà utilitzat per accedir a la informació	7

ATENCIÓ REBUDA

Sí / No		(puntueu de 0 a 10)	
Heu tingut contacte directe amb algun soci del projecte MEDACC?	NO	Valoreu l'atenció	—

WEB MEDACC (puntueu de 0 a 10)

Qualitat de la Informació	6
Utilitat de la Informació	5

OBSERVACIONS

ENQUESTA SOBRE EL GRAU DE SATISFACCIÓ DE LA INFORMACIÓ REBUDA I SOBRE EL WEB LIFE MEDACC

INFORMACIÓ REBUDA (puntueu de 0 a 10)

Qualitat de la Informació	9
Utilitat de la Informació	7

MITJÀ D'ACCÉS (puntueu de 0 a 10)

Valoreu el mitjà utilitzat per accedir a la informació	9

ATENCIÓ REBUDA Sí / No

		(puntueu de 0 a 10)	
Heu tingut contacte directe amb algun soci del projecte MEDACC?	SI	Valoreu l'atenció	9

WEB MEDACC (puntueu de 0 a 10)

Qualitat de la Informació	9
Utilitat de la Informació	7

OBSERVACIONS

ENQUESTA SOBRE EL GRAU DE SATISFACCIÓ DE LA INFORMACIÓ REBUDA I SOBRE EL WEB LIFE MEDACC

INFORMACIÓ REBUDA (puntueu de 0 a 10)

Qualitat de la Informació	8
Utilitat de la Informació	8

MITJÀ D'ACCÉS (puntueu de 0 a 10)

Valoreu el mitjà utilitzat per accedir a la informació	8

ATENCIÓ REBUDA

Sí / No		(puntueu de 0 a 10)	
Heu tingut contacte directe amb algun soci del projecte MEDACC?	10	Valoreu l'atenció	10

WEB MEDACC (puntueu de 0 a 10)

Qualitat de la Informació	9
Utilitat de la Informació	8

OBSERVACIONS

ENQUESTA SOBRE EL GRAU DE SATISFACCIÓ DE LA INFORMACIÓ REBUDA I SOBRE EL WEB LIFE MEDACC

INFORMACIÓ REBUDA (puntueu de 0 a 10)

Qualitat de la Informació	6
Utilitat de la Informació	6

MITJÀ D'ACCÉS (puntueu de 0 a 10)

Valoreu el mitjà utilitzat per accedir a la informació	N/A

ATENCIÓ REBUDA

Sí / No		(puntueu de 0 a 10)	
Heu tingut contacte directe amb algun soci del projecte MEDACC?	NO	Valoreu l'atenció	N/A.

WEB MEDACC (puntueu de 0 a 10)

Qualitat de la Informació	7
Utilitat de la Informació	7

OBSERVACIONS

ENQUESTA SOBRE EL GRAU DE SATISFACCIÓ DE LA INFORMACIÓ REBUDA I SOBRE EL WEB LIFE MEDACC

INFORMACIÓ REBUDA (puntueu de 0 a 10)

Qualitat de la Informació	9
Utilitat de la Informació	8

MITJÀ D'ACCÉS (puntueu de 0 a 10)

Valoreu el mitjà utilitzat per accedir a la informació	7

ATENCIÓ REBUDA

Sí / No		(puntueu de 0 a 10)	
Heu tingut contacte directe amb algun soci del projecte MEDACC?	SI	Valoreu l'atenció	7

WEB MEDACC (puntueu de 0 a 10)

Qualitat de la Informació		?
Utilitat de la Informació		?

OBSERVACIONS

ENQUESTA SOBRE EL GRAU DE SATISFACCIÓ DE LA INFORMACIÓ REBUDA I SOBRE EL WEB LIFE MEDACC

INFORMACIÓ REBUDA	(puntueu de 0 a 10)	
	Qualitat de la Informació	8
	Utilitat de la Informació	6

MITJÀ D'ACCÉS	(puntueu de 0 a 10)	
	Valoreu el mitjà utilitzat per accedir a la informació	8

ATENCIÓ REBUDA	Sí / No		(puntueu de 0 a 10)	
	Heu tingut contacte directe amb algun soci del projecte MEDACC?	Sí	Valoreu l'atenció	10

WEB MEDACC	(puntueu de 0 a 10)	
	Qualitat de la Informació	8
	Utilitat de la Informació	8

OBSERVACIONS

ENQUESTA SOBRE EL GRAU DE SATISFACCIÓ DE LA INFORMACIÓ REBUDA I SOBRE EL WEB LIFE MEDACC

INFORMACIÓ REBUDA

(puntueu de 0 a 10)

Qualitat de la Informació	8
Utilitat de la Informació	8

MITJÀ D'ACCÉS

(puntueu de 0 a 10)

Valoreu el mitjà utilitzat per accedir a la informació	7

ATENCIÓ REBUDA

Sí / No		(puntueu de 0 a 10)	
Heu tingut contacte directe amb algun soci del projecte MEDACC?	No	Valoreu l'atenció	

WEB MEDACC

(puntueu de 0 a 10)

Qualitat de la Informació	8
Utilitat de la Informació	8

OBSERVACIONS

A la reunió els gots ~~del~~ l'esmorzar podrien ser reutilitzables no de plàstic

ENQUESTA SOBRE EL GRAU DE SATISFACCIÓ DE LA INFORMACIÓ REBUDA I SOBRE EL WEB LIFE MEDACC

INFORMACIÓ REBUDA (puntueu de 0 a 10)

Qualitat de la Informació	7
Utilitat de la Informació	7

MITJÀ D'ACCÉS (puntueu de 0 a 10)

Valoreu el mitjà utilitzat per accedir a la informació	6

ATENCIÓ REBUDA Sí / No (puntueu de 0 a 10)

Heu tingut contacte directe amb algun soci del projecte MEDACC?	No	Valoreu l'atenció	

WEB MEDACC (puntueu de 0 a 10)

Qualitat de la Informació	6
Utilitat de la Informació	6

OBSERVACIONS

ENQUESTA SOBRE EL GRAU DE SATISFACCIÓ DE LA INFORMACIÓ REBUDA I SOBRE EL WEB LIFE MEDACC

INFORMACIÓ REBUDA (puntueu de 0 a 10)

Qualitat de la Informació	8
Utilitat de la Informació	8

MITJÀ D'ACCÉS (puntueu de 0 a 10)

Valoreu el mitjà utilitzat per accedir a la informació	8

ATENCIÓ REBUDA Sí / No (puntueu de 0 a 10)

Heu tingut contacte directe amb algun soci del projecte MEDACC?	Sí	Valoreu l'atenció	10

WEB MEDACC (puntueu de 0 a 10)

Qualitat de la Informació	8
Utilitat de la Informació	7

OBSERVACIONS

ENQUESTA SOBRE EL GRAU DE SATISFACCIÓ DE LA INFORMACIÓ REBUDA I SOBRE EL WEB LIFE MEDACC

INFORMACIÓ REBUDA (puntueu de 0 a 10)

Qualitat de la Informació	8
Utilitat de la Informació	8

MITJÀ D'ACCÉS (puntueu de 0 a 10)

Valoreu el mitjà utilitzat per accedir a la informació	9

ATENCIÓ REBUDA Sí / No

		(puntueu de 0 a 10)	
Heu tingut contacte directe amb algun soci del projecte MEDACC?	Sí	Valoreu l'atenció	9

WEB MEDACC (puntueu de 0 a 10)

Qualitat de la Informació	9
Utilitat de la Informació	8

OBSERVACIONS

ENQUESTA SOBRE EL GRAU DE SATISFACCIÓ DE LA INFORMACIÓ REBUDA I SOBRE EL WEB LIFE MEDACC

INFORMACIÓ REBUDA (puntueu de 0 a 10)

Qualitat de la Informació	8
Utilitat de la Informació	

MITJÀ D'ACCÉS (puntueu de 0 a 10)

Valoreu el mitjà utilitzat per accedir a la informació	9

ATENCIÓ REBUDA Sí / No

		(puntueu de 0 a 10)	
Heu tingut contacte directe amb algun soci del projecte MEDACC?	NO	Valoreu l'atenció	

WEB MEDACC (puntueu de 0 a 10)

Qualitat de la Informació	9
Utilitat de la Informació	

OBSERVACIONS

ENQUESTA SOBRE EL GRAU DE SATISFACCIÓ DE LA INFORMACIÓ REBUDA I SOBRE EL WEB LIFE MEDACC

INFORMACIÓ REBUDA (puntueu de 0 a 10)

Qualitat de la Informació	9
Utilitat de la Informació	8

MITJÀ D'ACCÉS (puntueu de 0 a 10)

Valoreu el mitjà utilitzat per accedir a la informació	8

ATENCIÓ REBUDA

Sí / No		(puntueu de 0 a 10)	
Heu tingut contacte directe amb algun soci del projecte MEDACC?	sí	Valoreu l'atenció	8

WEB MEDACC (puntueu de 0 a 10)

Qualitat de la Informació	7
Utilitat de la Informació	7

OBSERVACIONS

ENQUESTA SOBRE EL GRAU DE SATISFACCIÓ DE LA INFORMACIÓ REBUDA I SOBRE EL WEB LIFE MEDACC

INFORMACIÓ REBUDA	(puntueu de 0 a 10)
Qualitat de la Informació	10
Utilitat de la Informació	10

MITJÀ D'ACCÉS	(puntueu de 0 a 10)
Valoreu el mitjà utilitzat per accedir a la informació	10

ATENCIÓ REBUDA	Sí / No		(puntueu de 0 a 10)
Heu tingut contacte directe amb algun soci del projecte MEDACC?	Sí	Valoreu l'atenció	10

WEB MEDACC	(puntueu de 0 a 10)
Qualitat de la Informació	9
Utilitat de la Informació	9

OBSERVACIONS

ENQUESTA SOBRE EL GRAU DE SATISFACCIÓ DE LA INFORMACIÓ REBUDA I SOBRE EL WEB LIFE MEDACC

INFORMACIÓ REBUDA	(puntueu de 0 a 10)	
	Qualitat de la Informació	8
	Utilitat de la Informació	8

MITJÀ D'ACCÉS	(puntueu de 0 a 10)	
	Valoreu el mitjà utilitzat per accedir a la informació	7

ATENCIÓ REBUDA	Sí / No		(puntueu de 0 a 10)	
	Heu tingut contacte directe amb algun soci del projecte MEDACC?	Sí	Valoreu l'atenció	9

WEB MEDACC	(puntueu de 0 a 10)	
	Qualitat de la Informació	7
	Utilitat de la Informació	8

OBSERVACIONS

ENQUESTA SOBRE EL GRAU DE SATISFACCIÓ DE LA INFORMACIÓ REBUDA I SOBRE EL WEB LIFE MEDACC

INFORMACIÓ REBUDA (puntueu de 0 a 10)

Qualitat de la Informació	10
Utilitat de la Informació	10

MITJÀ D'ACCÉS (puntueu de 0 a 10)

Valoreu el mitjà utilitzat per accedir a la informació	10

ATENCIÓ REBUDA Sí / No (puntueu de 0 a 10)

Heu tingut contacte directe amb algun soci del projecte MEDACC?	Sí	Valoreu l'atenció	10

WEB MEDACC (puntueu de 0 a 10)

Qualitat de la Informació	10
Utilitat de la Informació	10

OBSERVACIONS

TIPUS D'USUARI	TÈCNIC

INFORMACIÓ REBUDA

Qualitat de la Informació	10
Utilitat de la Informació	10

MITJÀ D'ACCÉS

Valori el mitjà utilitzat per accedir a la informació	10

ATENCIÓ REBUDA

Ha tingut contacte directe amb algun soci del projecte MEDACC?	si	Valori l'atenció	10

WEB MEDACC

Qualitat de la Informació	10
Utilitat de la Informació	10

OBSERVACIONS

TIPUS D'USUARI		STAKEHOLDER B		
INFORMACIÓ REBUDA				
	Qualitat de la Informació	8		
	Utilitat de la Informació	8		
MITJÀ D'ACCÉS				
	Valori el mitjà utilitzat per accedir a la informació	9		
ATENCIÓ REBUDA				
	Ha tingut contacte directe amb algun soci del projecte MEDACC?	SI	Valori l'atenció	8
WEB MEDACC				
	Qualitat de la Informació	9		
	Utilitat de la Informació	8		

OBSERVACIONS

TIPUS D'USUARI		Adm. Pública		
INFORMACIÓ REBUDA				
	Qualitat de la Informació	Molt bona, amb rigor tècnic i científic		
	Utilitat de la Informació	Adequada, tot i que en alguns dels àmbits de les nostres competènci		
MITJÀ D'ACCÉS				
	Valori el mitjà utilitzat per accedir a la informació	Molt positiu i adequat		
ATENCIÓ REBUDA				
	Ha tingut contacte directe amb algun soci del projecte MEDACC?	Sí	Valori l'atenció	Positiva, amb la informació n
WEB MEDACC				
	Qualitat de la Informació	Bona		
	Utilitat de la Informació	Adequada, amb els continguts penjats		

OBSERVACIONS

es i actuacions no és tan necessària per als nostres projecte (per exemple els tees forestals)

ecessària rebud adequadament (tema de l'efecte del canv climàtic als nostres rius, en especial en relació al Ter i els seus cabals).

7.3. Annex 3. General Audience report

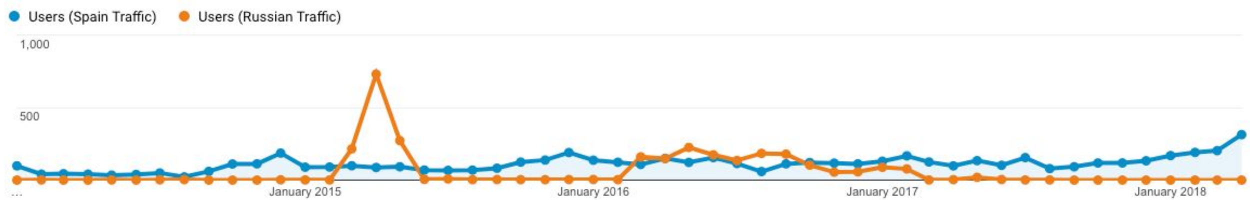
General Audience report medacc-life.eu

*Covering the period between **Jan 1st 2014** to **Apr. 30th 2018**.*

Introduction: the issue with Russian and USA traffic

During the project lifetime, there were two *audience peak* moments.

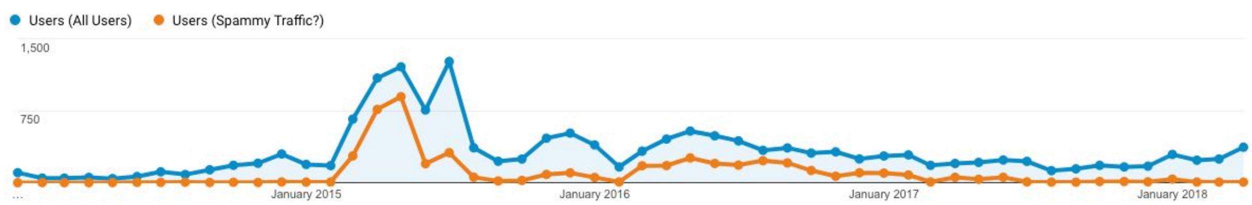
A big one in 2015 and another way more subtle in 2016.



Going deep into traffic sources, languages and geographic info we found out a surprisingly high volume of users coming from Russia and the United States during this peaks.

Of course, Russian people may be interested in *mediterranean basin* but sounds a bit nonsense when no specific actions were taken to communicate the project there.

That pointed us to spam/bot traffic on the website, so we've added some filters to exclude this traffic from being tracked to get the most accurate trendline picture possible.

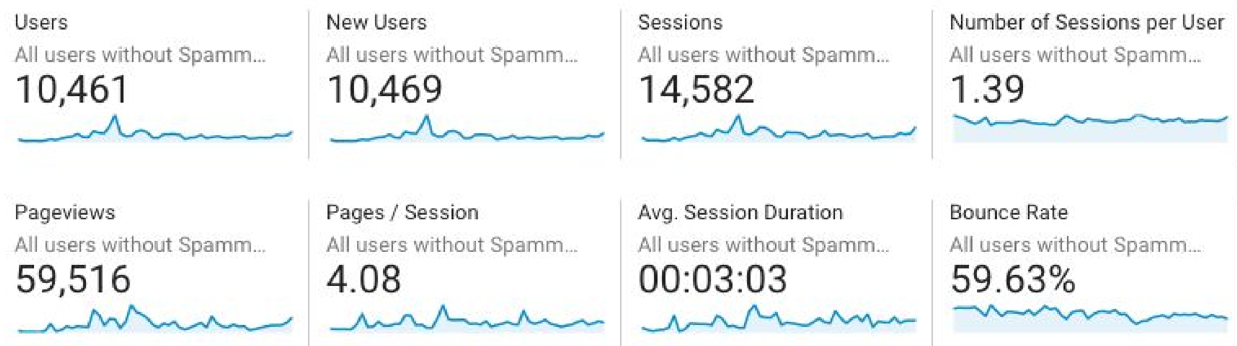


In this report, *spammy traffic* has been excluded.

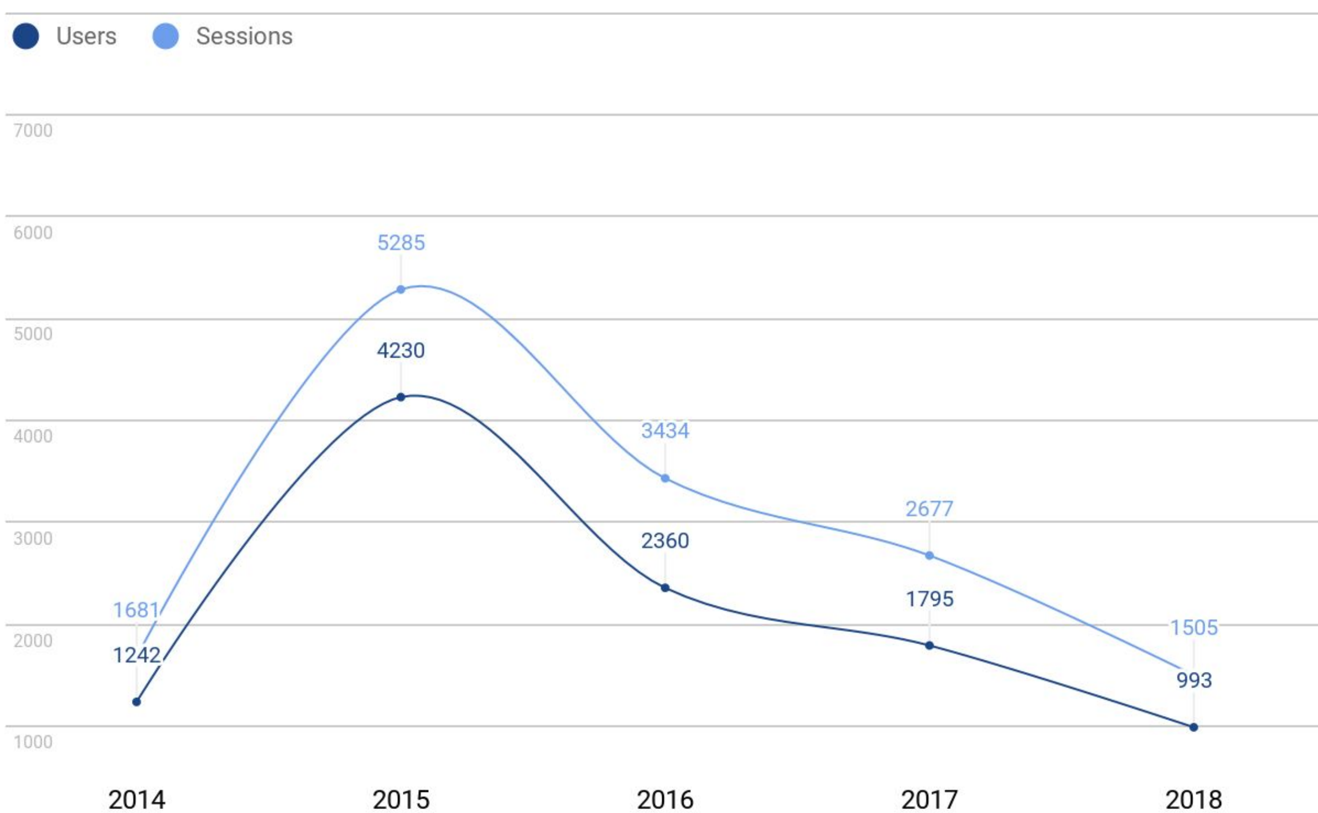
General audience

How many people has visited medacc-life.eu?

During this period, **10.461 distinct users** made a total of **14.582 sessions**, viewing **59.516 pages** in the website.



Audience distribution per year



Geographic distribution

Where is this audience coming from?

Once we've excluded russian traffic, most of medacc-life.eu website comes from Spain. We find *(not set)* as second location, which can also include some spam/bot traffic.

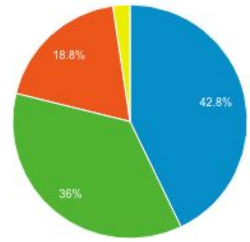
1.	Spain	4,801	46.04%
2.	(not set)	1,093	10.48%
3.	Brazil	615	5.90%
4.	United Kingdom	440	4.22%
5.	China	386	3.70%
6.	Italy	249	2.39%
7.	Germany	234	2.24%
8.	France	185	1.77%
9.	Japan	176	1.69%
10.	Canada	157	1.51%

Most *valid traffic* comes from Spain.

Traffic sources

How does audience reach medacc-life.eu?

1.	Referral	4,606	42.85%
2.	Organic Search	3,872	36.02%
3.	Direct	2,019	18.78%
4.	Social	253	2.35%



Referral traffic

Referral is the first source of traffic, with **43% of the audience coming from this source**.

Top 5 referring sites are:

- canviclimatic.gencat.cat
- ec.europa.eu
- www20.gencat.cat
- creaf.cat
- elpais.com

Organic search

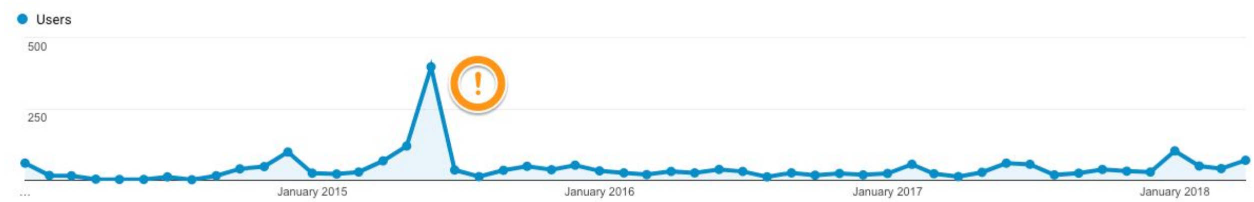
In second term, we find **organic search**, with **36% of the audience**.

Top 5 search queries are:

- life medacc
- medacc
- ectadapt
- climate change adaptation platform
- agricultural plots

Direct traffic

Direct traffic is the third source with near **20% of the audience**.



In 2015, we will find a peak in the same period of spam/bot activity against the site. We've not been able to filter it at this point.

According to this data, **we can't identify offline actions from the project affecting to website traffic**.

Social traffic

Social traffic may look a bit low, just 2% of overall.

That makes sense, since the website even when it has tools to share content has no *content marketing strategy* defined.

Most social traffic is coming from **Twitter** (81%) with **212 users**.

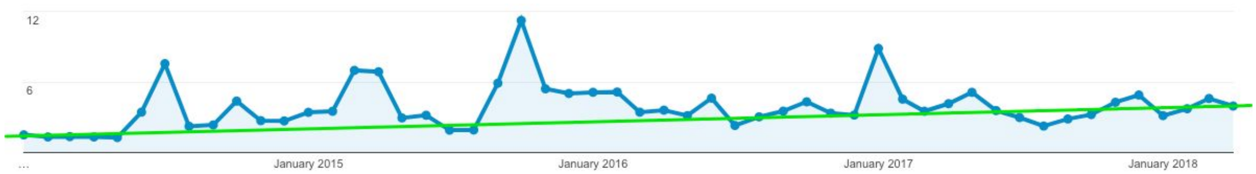
Facebook takes the second place, with 35 users.

Audience behavior

How users interact with our site

An average user visits 4 pages on every session. In the period, we've served almost 60.000 pages to 10.450 users.

Pages per session detail



Number of pages/session gets better over time, with **1.5 at the beginning of the project** and **3.95 in april 2018**..

Peaks shown in the graphic may not be related with spam/bot activity but with publication of project results.

By the end of 2015 we did some improvements in the website to increase user engagement.

Audience fequency

Most visitors get into the homepage, the lifeline and the project information page.

Near 10.500 of the 14.500 visitors are one-time users. Cookies usually expire every 60 days, so that does not mean necessarily that came once and never came back in 4 years.

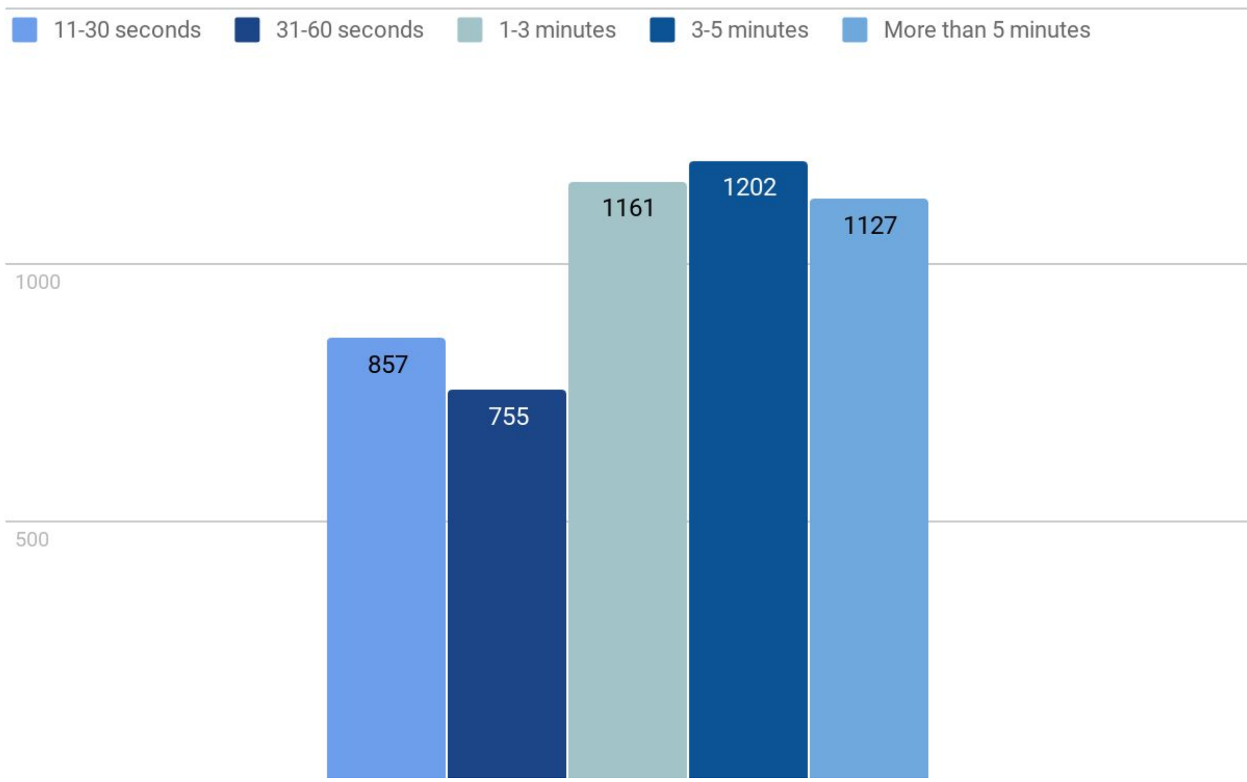
Going deeper, we find 4 relevant groups of sessions tracked:

- Those who come to the website twice (1.097)
- Those who come to the website 3 times (456)
- Those who come to the website between 15 and 25 times (397)
- Those who come to the website between 26 and 50 times (407)

Audience engagement

9500 out of 14000 sessions are less than 10 seconds long.

Taking the rest of sessions, we find the following 5 relevant groups of engagement:



Most visited content

The homepage is the most visited page in the project. Aggregating all three languages, we get **13.743 pageviews**, which represents a **23%** of the total.

In second term as a single page we find **the about page**, with **4,85% of the traffic**.

The rest of the content is distributed between **lifeline**, **documents** and **data**.

The lifeline gets **6,46%** of traffic with **3.977 pageviews.**

Document pages, aggregating both the landing page and document detail get **6,34%** of all the audience with **3.910 pageviews**.

Platform data reaches **2,58%** of all audience, with **1.589 pageviews**.

This trend is mostly consistent during all project time.