# MEDACC

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

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# Methodology to monitor the effects of the implementation actions in the LIFE MEDACC case-study basins

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# Executive summary

This deliverable explains the methodologies followed 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 methodologies followed by the project to monitor the effects of the implementation actions. The results, analysis of the results and conclusions of the application of these methodologies can be consulted at the *Deliverable 22. Effects of the implementation actions in 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 methodologies followed by the project to monitor the effects of the implementation actions. The results, analysis of the results and conclusions of the application of these methodologies can be consulted at the *Deliverable 22 Effects of the implementation actions in 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. Methodology

### *2.2.1. Accuracy of eco-hydrological calibrated models*

Two eco-hydrological models have been used in LIFE MEDACC project: RHESsys and SWAT models. A detailed description of the models are given in Pascual et al. (2016).

The evaluation of the accuracy of the models is done during the calibration. The calibration is done by comparing model results with observed data. In the case of LIFE MEDACC models, calibration implies to modify the model parameters to obtain stream flow values similar to those registered in the gauging station, especially in regard to peak flows and base flows.

The evaluation of the accuracy of the models is monitored with three indicators:

- the visual comparison of the simulated stream flow curves with observed stream flow curves;
- the numerical comparison of simulated mean stream flow values and total contributions between simulated and measured data; and
- the application of the statistics Nash-Sutcliffe efficiency (NSE) coefficient, the RMSE-observations standard deviation ratio (RSR) and the percent bias (PBIAS, %), following Moriasi et al. (2007). The NSE coefficient, the RSR ratio and PBIAS equations and the statistics performance ratios are shown in Table 1.

| **Performance rating** | $RSR = \left[ \frac{\sqrt{\sum_{i=1}^{n} \left(Y_i^{obs} - Y_i^{sim}\right)^2}}{\sqrt{\sum_{i=1}^{n} \left(Y_i^{obs} - Y^{mean}\right)^2}} \right]$ | $NSE = 1 - \left[ \frac{\sum_{i=1}^{n} \left(Y_i^{obs} - Y_i^{sim}\right)^2}{\sum_{i=1}^{n} \left(Y_i^{obs} - Y^{mean}\right)^2} \right]$ | $PBIAS = \left[ \frac{\sum_{i=1}^{n} \left(Y_i^{obs} - Y_i^{sim}\right) * (100)}{\sum_{i=1}^{n} \left(Y_i^{obs}\right)} \right]$ |
|---|---|---|---|
| Very good | 0.00 ≤ RSR ≤ 0.50 | 1.00 ≤ NSE < 0.75 | PBIAS < ± 10 |
| Good | 0.50 < RSR ≤ 0.60 | 0.75 ≤ NSE < 0.65 | ± 10 ≤ PBIAS ≤ ± 15 |
| Satisfactory | 0.60 < RSR ≤ 0.70 | 0.65 ≤ NSE < 0.5 | ± 15 ≤ PBIAS ≤ ± 25 |
| Unsatisfactory | RSR > 0.70 | NSE ≤ 0.5 | PBIAS ≥ ± 25 |

*Table 1. Equations for the statistics Nash-Sutcliffe efficiency (NSE) coefficient, RMSE-observations standard deviation ratio (RSR), Percent bias (PBIAS) and general performance ratings for the statistics for a monthly time step. Yiobs is the ith observation values sample for the constituent being evaluated, Yisim is the ith simulated sample for the constituent being evaluated, Ymean is the mean of observed data for the constituent being evaluated, and n is the total number of observations.*

The results of the evaluation of the accuracy of eco-hydrological calibrated models are available at *Deliverable 22 Effects of the implementation actions in LIFE MEDACC case study basins* (Pascual et al. 2018).

### *2.2.2. Inter-comparison of the climate and socioeconomic scenarios*

The following scenarios have been used in LIFE MEDACC project:

- Climate scenarios: RCP4.5 emissions scenario from the IPCC.
- Socioeconomic scenarios: Three land cover scenarios for the headwaters (afforestation, fire and forest management scenarios) and two water use scenarios for the medium and low basin courses (rational use of water resources and increased demand scenarios).

<u>Inter-comparison of climate scenario</u>

The RCP4.5 scenario is a stabilization scenario in which total radiative forcing is stabilized shortly after 2100, without overshooting the long-run radiative forcing target level (Clarke et al. 2007, Smith and Wigley 2006, Wise et al. 2009). The Representative Concentration Pathways (RCPs) are referred to as pathways in order to emphasize that their primary purpose is to provide time-dependent projections of atmospheric greenhouse gas (GHG) concentrations. In addition, the term pathway is meant to emphasize that it is not only a specific long-term concentration or radiative forcing outcome, such as a stabilization level of interest, but also the trajectory that is taken over time to reach that outcome. They are representative in that they are one of several different scenarios that have similar radiative forcing and emissions characteristics (Moss et al, 2008)

The RCP4.5 scenario used in LIFE MEDACC project has been developed by the GCAM modelling team at the Pacific Northwest National Laboratory, Joint Global Change Research Institute (JGCRI) in the United States. The downscaling of the scenario has been performed by Martín-Vide (2016), based on the Third Report on Climate Change in Catalonia (TICCC) until 2050.

The election of RCP4.5 scenario is not trivial. There are 4 new emission scenarios defined in the 5th IPCC Report with different forcing levels, from the very low level (RCP2.6) to a very high one (RCP8.5) with two stabilization scenarios (RCP4.5 and RCP6.0). Being considered the RCP4.5 as a scenario with medium values (equivalent to SRES B1 in terms of $CO_2$ concentration values), Life MEDACC considered this scenario as a median range scenario (Thomson et al., 2011). These scenarios can be defined as is explained below (Table 2):

- RCP2.6. Peak and decline. It is assumed a high decrease of greenhouse gasses emission and a 3.1 W/m2 radiative forcing values in 2050 and 2.6 in 2100. The temperature probably not exceed in 2ºC.
- RCP4.5. Stabilization without overshoot. The radiative forcing is expected to stabilize after 2100 and temperature probably exceed in 2ºC.
- RCP6.0. Stabilization without overshoot. The radiative forcing is expected to stabilize after 2100 and temperature probably exceed in 2ºC. It was developed by the application of a range of technologies and strategies for reducing greenhouse gas emissions (Fujino et al. 2006; Hijoka et al. 2008)
- RCP8.5. Rising. Increase of greenhouse gasses emissions. Temperature probably not exceed in 4ºC.

| Name | Radiative forcing | Concentration(p.p.m.) | Pathway | Model providing RCP* |
|---|---|---|---|---|
| RCP8.5 | >8.5 W $m^{-2}$ in 2100 | >1,370 $CO_2$-equiv. in 2100 | Rising | MESSAGE |
| RCP6.0 | ~6 W $m^{-2}$ at stabilization after 2100 | ~850 $CO_2$-equiv. (at stabilization after 2100) | Stabilization without overshoot | AIM |
| RCP4.5 | ~4.5 W $m^{-2}$ at stabilization after 2100 | ~650 $CO_2$-equiv. (at stabilization after 2100) | Stabilization without overshoot | GCAM |
| RCP2.6 | Peak at ~3 W $m^{-2}$ before 2100 and then declines | Peak at ~490 $CO_2$-equiv. before 2100 and then declines | Peak and decline | IMAGE |

*Table 2. Characterization of different RCP scenarios. (*) MESSAGE, Model for Energy Supply Strategy Alternatives and their General Environmental Impact, International Institute for Applied Systems Analysis, Austria; AIM, Asia-Pacific Integrated Model, National Institute for Environmental Studies, Japan; GCAM, Global Change Assessment Model, Pacific Northwest National Laboratory, USA (previously referred to as MiniCAM); IMAGE, Integrated Model to Assess the Global Environment, Netherlands Environmental Assessment Agency, The Netherlands.*

These new scenarios consider the effects of the policies against the climate change on the past century, as an innovation in comparison with the scenarios described in the former IPCC Reports, called SRES. Thus, each RCP contains several socioeconomic, technologic and biophysic assumptions. Figure 1 shows the differences between the RCP2.6 and RCP8.5 what illustrates the range of temperature change around the world.

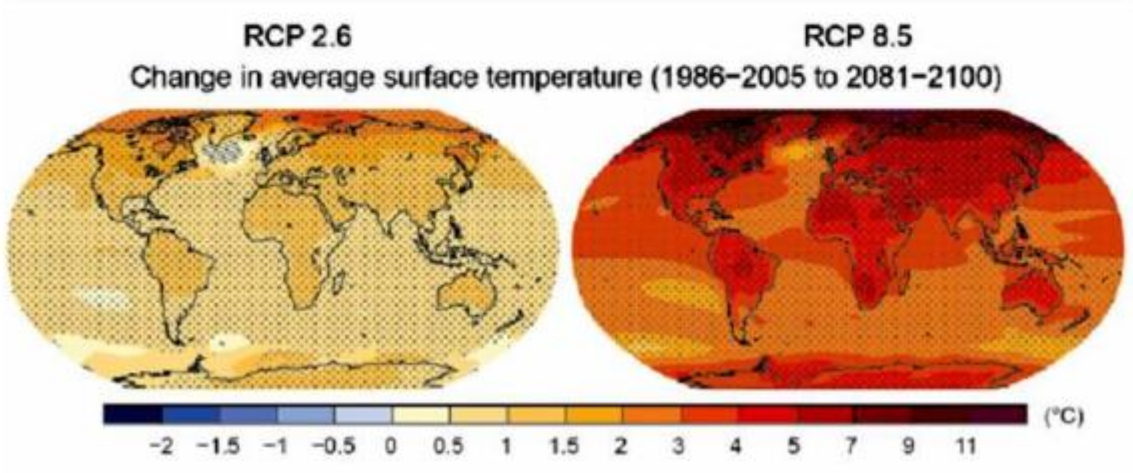


*Figure 1. Changes in average surface temperature (RCP 2.6 and RCP 8.5)*

Table 3 is just an example about differences on annual maximum temperature changes projected by different scenarios in Catalonia. The RCP4.5 and RCP6.0 do not show great differences, until 2050, being greater by the end of 21st century (Figure 2).

| Period | RCP4.5 | RCP6.0 | RCP8.5 |
|---|---|---|---|
| 2021-2030 | 1.2 | 1.2 | 1.4 |
| 2031-2040 | 1.5 | 1.4 | 1.7 |
| 2041-2050 | 1.7 | 1.7 | 2.1 |

*Table 3. Projected changes (ºC) in maximum temperature for Catalonia in different scenarios and periods (AEMET).*

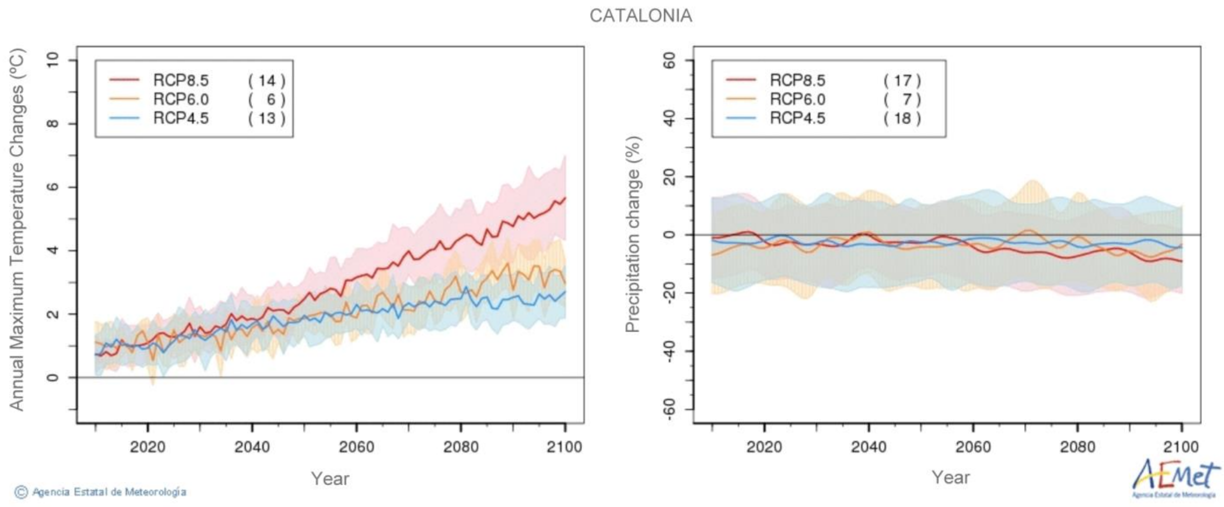


*Figure 2. Changes in average surface temperature and precipitation.*

The results of the inter-comparison of climatic scenarios are available at *Deliverable 22 Effects of the implementation actions in LIFE MEDACC case study basins* (Pascual et al. 2018).

Inter-comparison of socioeconomic scenarios

Socioeconomic scenarios represent socioeconomic changes occurring in a territory that include, among others, land use and land cover changes, demographic changes or changes in resource (water, energy, food) uses. The scenarios draw alternative plausible options for different future socioeconomic developments (narrative storylines). Many international organizations and projects make use of scenarios that help them to plan an uncertain future.

In LIFE MEDACC project, we planned to use land use change projections (2050) and demography and water demands projections (2050) based on scenarios developed in other European, national or local projects. Nevertheless, it was impossible to find existent scenario that took into account the characteristics and dynamics of the case-study basins or that had enough spatial resolution to be appropriate for the project objectives. For this reason, we decided to develop socioeconomic scenarios designed ad hoc for the project, based on experts' knowledge on main socio-economic sectors. The socioeconomic scenarios were materialised in two ways: the spatial distribution of future land covers (raster) and a prevision of future water demands, for 2050. Five scenarios were developed, three land cover scenarios for the headwaters (afforestation, fire and forest management scenarios) and two water use scenarios for the medium and low basin courses (rational use of water resources and increased demand scenarios).

On the other hand, the majority of the socioeconomic scenarios found in the literature review of international organizations and projects represent the scenarios in the form of narrative storylines or numerical data (demographic changes or migrations, changes in climatic variables), but just a few provide spatial distribution of future land covers, as the scenarios generated in LIFE MEDACC project. Some of the scenarios reviewed were:

- IPCC emissions scenarios. The Representative Concentration Pathways (RCPs) of the IPCC describe four different 21st century pathways of greenhouse gas (GHG) emissions and atmospheric concentrations, air pollutant emissions and land use. The scenarios are represented as changes in main climatic variables (air temperature, water cycle-precipitation), emissions, ocean temperature, sea level, carbon cycle and biogeochemistry, among others (http://www.ipcc.ch/report/ar5/).
- Scenarios from the Global Environment Outlooks 5 developed by the United Nations Environment Programme. Two alternative sustainable world scenarios to 2050 are compared to a conventional world scenario: scenario A focuses entirely on additional investments in transforming technology and production to achieve the goals; scenario B focuses on how

adding lifestyle change reduces those investments (UNEP 2012). The scenarios are represented as changes in the economic sector (GDP, additional investment …), social sector (population, calories per person and day, employment …), environmental sector (forest area, waste generation, renewable energy …) (http://www.unep.org/geo/assessments /global-assessments/global-environment-outlook-5).

- Scenarios from the Millennium Assessment Reports proposed by the United Nations. Four consistent scenarios are proposed for 2050 that explore aspects of plausible global futures and their implications for ecosystem services: Global orchestration, Order from strength, Adapting mosaic, TechnoGarden. The scenarios are represented narratively, describing changes in population, income, size of economies, agriculture area, trade, among others (http://www.millenniumassessment.org/en/Scenarios.html)
- ET2050 - Territorial Scenarios and Visions for Europe (ESPON). ESPON uses the SASI model, a simulation model of socio-economic development of regions in Europe subject to exogenous assumptions about the economic and demographic development of the European Union as a whole and transport and other spatial policies scenarios. Three exploratory scenarios area proposed: MEGAs Scenario A (large European metropolitan areas are promoted in the interest of global competitiveness and economic growth), Cities Scenario B (secondary European cities are promoted in order to strengthen the balanced polycentric spatial structure of the European territory, and Regions Scenario C (rural and peripheral regions are promoted to advance territorial cohesion between affluent and economically lagging regions). The scenarios are represented narratively and quantitatively, showing changes in EU structural funds expenditure, accessibility, GDP, population, CO2 emissions by transport, among others. Some spatial information is provided but not referring to future land uses (maps on future accessibility of roads, GDP, population …) and with a coarse spatial distribution (regions) (https://www.espon.eu/programme/projects/espon-2013/applied-research/et2050-territorial-scenarios-and-visions-europe).
- PRELUDE scenarios from the European Environment Agency. Five different scenarios (2035): Great Escape - Europe of Contrast, Evolved Society - Europe of Harmony, Clustered Networks - Europe of Structure, Lettuce Surprise U - Europe of Innovation, Big Crisis - Europe of Cohesion. PRELUDE use a 10-minutes grid spatial resolution (10 km approximately) for scenario calculation but displayed the results with no further spatial delineation (http://www.eea.europa.eu/media/audiovisuals/interactive/ prelude-scenarios).
- IMAGE 3.0 scenarios. IMAGE is an ecological-environmental model framework that simulates the environmental consequences of human activities worldwide. IMAGE represent the RCPs scenarios of the IPCC in different spatial formats, including the spatial distribution of land uses /covers from 1970 to 2100 (every five years) at 5-minutes grid spatial resolution (5 km approximately) (http://themasites.pbl.nl/models/image/index.php, https://data.knmi.nl/ datasets?q=PBL).

As we have seen in the previous review, the majority of scenarios are generated at coarse spatial resolution or / and are represented in the form of narrative storylines or numerical data, but just a few provide spatial distribution of future land covers. For this reason, the inter-comparison has not been an easy or trivial issue. We only have been able to perform the inter-comparison with the IMAGE 3.0 scenarios, concretely with the RCP4.5 scenario (the same used as climate scenario).

The results of the inter-comparison of socioeconomic scenarios are available at *Deliverable 22 Effects of the implementation actions in LIFE MEDACC case study basins* (Pascual et al. 2018).

# 3. Monitoring the effects of Action B2

### 3.1. Introduction

The Action B2 has as objective to perform all necessary tasks to implement pilot experiences in the selected watersheds 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 saved water or reused water.

### 3.2. Methodology

The procedure to monitor the demonstrative activities of Action B2 is included in the field protocols defined at Savé et al. (2015) *Deliverable 6*.

The field protocols detail the management objectives, the type of treatments, the variables monitored continuously in each plot, the frequency of the monitoring and the methodology employed to measure the variables.

#### *3.2.1. Monitoring agricultural demonstrative actions*

The monitoring of the agricultural demonstrative activities is done by measuring different variables on the field and comparing the changes of the variable's values among treatments (control and management treatment) and along the time (annual campaign of 2015-2016-2017).

Weather conditions of all experimental plots were continuously monitored by means of permanents weather stations of Catalan Weather Service (XEMA; acronym in Catalan of network of automatic weather stations of Catalonia, http://www.meteo.cat/), or weather field stations (Vantage Pro2 Station; Davis Instruments, Hayward, California, USA) located at Bodegas Miguel Torres, Raimat and Mas Badia.

Table 4 defines per each watershed and crop, the objectives of the pilot experience, the treatments accomplished and the variables monitored to assess the effects of the demonstrative activity.

| Watershed | Crop | Objectives | Treatments | Monitored variables |
|---|---|---|---|---|
| Muga | Maize<br>Apple | Implement an irrigation advice system for farmers to increase water use efficiency | **C plot**: control plot with a traditional gravity irrigation system<br>**T1 plot**: plot with an irrigation advice system and drip irrigation | Crop evapotranspiration<br>Precipitation<br>Soil water content<br>Water use<br>Growth and productivity |
| | | Asses acceptability and impact of *GIROREG Maize* and *GIROREG Apple on local growers* | Surveys addressed to local growers | Crop type<br>Water source<br>Main water-related issues (quality, quantity, etc.)<br>Irrigation scheduling<br>Perception about GIROREG recommendations<br>Other comments |

| Watershed | Crop | Objectives | Treatments | Monitored variables |
|---|---|---|---|---|
| Ter | Maize<br>Apple | Implement an irrigation advice system for farmers to facilitate the savings in irrigation water without reducing crop production | **C plot**: control plot with a traditional gravity irrigation system<br>**T1 plot**: plot with an irrigation advice system and drip irrigation | Crop evapotranspiration<br>Precipitation<br>Soil water content<br>Water use<br>Growth and productivity |
| | | Asses acceptability and impact of *GIROREG Maize* and *GIROREG Apple on local growers* | Surveys addressed to local growers | Crop type<br>Water source<br>Main water-related issues (quality, quantity, etc.)<br>Irrigation scheduling<br>Perception about GIROREG recommendations<br>Farmer's acceptation of water save technology<br>Legal and functional limitations for the implementation of GIROREG |
| Segre | Vineyard | Reduce water use and consumption using a mulching treatment in a new vineyard plantation in RAIMAT assay | **C plot**: control plot with no mulching<br>**T1 plot**: vineyard with organic compost mulching<br>**T2 plot:** vineyard with BASF mulching film | Soil water content<br>Plant survival and growth |
| | | Reduce water use and consumption using a mulching treatment in an adult vineyard plantation in RAIMAT assay | **C plot**: control plot with no mulching<br>**T1 plot**: vineyard with organic (straw) mulching<br>**T2 plot**: vineyard with BASF mulching film | Soil water content<br>Productivity<br>Basic grape quality parameters at harvest time<br>Pruning weight |
| | | Evaluation of vineyard movements to high altitudes in Bodegas Miguel Torres assay | **C plot**: control plot at low altitude<br>**T1 plot**: vineyard at 950m altitude (Tremp) | Productivity<br>Basic grape quality parameters at harvest time<br>Phenological changes |

*Table 4. Objectives of the pilot experience, treatments accomplished and variables monitored to assess the effects of the demonstrative activity.*

Table 5 describes the monitored variables, specifying the indicators selected to monitor the variables, the frequency of the monitoring and the methodology used.

| Monitored variable | Monitoring indicators | Frequency | Methodology |
|---|---|---|---|
| Crop evapotranspi-ration | Evapotranspiration | Daily | Daily measurements over the last 15 days (XEMA's permanent weather stations) and also including a week's prediction (estimate with expected temperature, rain probability and general forecast). |

| Monitored variable | Monitoring indicators | Frequency | Methodology |
|---|---|---|---|
| Precipitation | Precipitation | Daily | Last 15 days (XEMA's permanent weather stations) and 7 days prediction (Rain probability according Weather Channel prediction) |
| Growth and productivity | Relative growth rate in different plant parts related to productivity<br>Crop quality | Monthly or more depending on crop life span and seasonality | Relative growth rate: Measuring crop diameter in the case of woody crops, and height in the case of herbaceous crops.<br>Relative growth rate: Measuring fresh/dry weight of fruits collected in the plot depending on crop life span.<br>Crop quality: Using quality standards for fruits (size and colour). |
| Water use | Volume of water used | Annual or seasonal | Using water meter of the plot pipe system. |
| Soil water content | Soil water content | Weekly | Using three volumetric water content sensors distributed in every replication of each treatment |

*Table 5. Monitored variables, indicators, frequency of the monitoring and methodology used.*

The results of the monitoring of the agricultural demonstrative activities are available at *Deliverable 22 Effects of the implementation actions in LIFE MEDACC case study basins* (Pascual et al. 2018)

### *3.2.2. Monitoring forest demonstrative activities*

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

Table 6 defines per each watershed and kind of forest, the objectives of the pilot experience, the treatments accomplished and the variables monitored to assess the effects of the demonstrative activity.

| Watershed | Objectives | Treatments | Monitored variables |
|---|---|---|---|
| **Muga**<br>Holm oak forest (*Quercus ilex*) | Reduce forest water stress and fire risk | **C plot**: control plot with no intervention.<br>Initial situation: over 2,000 trees/ha, basal area 30 $m^2$/ha and irregular coppice forest structure.<br>**T1 plot**: low thinning to adapt the forest to a regular structure.<br>Results: 15-25% reduction of basal area affecting primarily the diametric classes 5 and 10. 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.<br>**T2 plot**: selection treatment to adapt the forest to an irregular structure and to stimulate forest regeneration.<br>Results: 40-50%-reduction of basal area, causing a higher opening of the forest canopy (leaving a final 60% cover) in order to stimulate resprouting. | Forest structure<br>Forest fuel continuity<br>Fuel moisture<br>Soil moisture<br>Stand temperature and relative humidity<br>Site meteorological conditions |

| Watershed | Objectives | Treatments | Monitored variables |
|---|---|---|---|
| **Ter**<br>Scots pine forests (*Pinus sylvestris*) | Improve tree health status<br>Increase wood production / carbon sequestration<br>Scots pine replacement by oak under conditions of climate change | **C plot**: control plot with no intervention.<br>Initial situation: over 1,000 trees/ha, basal area 21 $m^2$/ha and regular structure for the Scots pine, basal area of 7 $m^2$/ha for oak (*Quercus pubescens*) and 3 $m^2$/ha for other escort species. Average forest canopy cover 65 %.<br>**T1 plot**: understory clearing to reduce resources competition.<br>Results: 50%-reduction of basal area of oak and other escort species. Pine trees were not removed.<br>**T2 plot**: low thinning and understory clearing to reduce tree competition. Elimination of escort species and dominant Scots pines.<br>Results: 30%-reduction of basal area of Scots pine, total elimination of oak and other escort species.<br>**T3 plot**: elimination of Scots pine to accelerate the replacement by oak and evaluate oak's future development.<br>Results: total elimination of Scots pine and promotion of escort species maintenance. | Forest structure<br>Forest health status<br>Soil moisture<br>Stand temperature and relative humidity<br>Site meteorological conditions |
| **Segre**<br>European black pine forests (*Pinus nigra*) | Reduce forest fire risk<br>Increase wood production / carbon sequestration | **Llobera site**<br>**C plot**: control plot with no intervention.<br>Initial situation: over 1,700 trees/ha, basal area 38.6 $m^2$/ha, 60-80 years, canopy cover over 75 %.<br>**T1 plot**: selective understorey clearing and low thinning.<br>Results: 10%-reduction of basal area of European black pine.<br>**T2 plot**: selective understorey clearing and intensive low thinning.<br>Results: 40%-reduction of basal area of European black pine.<br>**Madrona site**<br>**C plot**: control plot with no intervention.<br>Initial situation: over 1,100 trees/ha, basal area 29 $m^2$/ha, 80-100 years, canopy cover 75 %.<br>**T1 plot**: selective understorey clearing.<br>Results: 0%-reduction of basal area of European black pine (only no inventoried).<br>**T2 plot**: selective understorey clearing and intensive low thinning.<br>Results: 30%-reduction of basal area of European black pine. | Forest structure<br>Forest fuel continuity<br>Fuel moisture<br>Soil moisture<br>Stand temperature and relative humidity<br>Site meteorological conditions |

*Table 6. Objectives of the pilot experience, treatments accomplished and variables monitored to assess the effects of the demonstrative activity.*

Table 7 describes the monitored variables, specifying the indicators selected to monitor the variables, the frequency of the monitoring and the methodology used.

| Monitored variable | Monitoring indicators | Frequency | Methodology |
|---|---|---|---|
| Forest structure | Tree density (trees/ha)<br>Diametric class distribution<br>Tree height (m)<br>Understorey biovolume<br>Resprouting | Initial, following treatment and yearly survey | Forest inventory: In each treatment and control, three circular plots (radius 10 m) are defined. Plot location in each treatment area is uniformly distributed and pre-assigned in a map. The central point of these plots remains marked for periodic surveys. In each plot, the number of trees/resprouts of each species is counted and the diameter at breast height (DBH) and the height of each tree is measured. In addition, one/two strip biomass transects (10 m) to estimate understorey biovolume are defined in each plot. In each transect, the maximum height and cover of shrubland species are measured in 50x50 cm quadrat plots. |
| Forest fuel continuity | Fuel type cover (%)<br>Fuel height (m)<br>Distance between fuel types (m) | Initial, following treatment and yearly survey | Fuel identification and classification: Using a field key, forest fuel cover, height and the distance between fuel types are estimated. The key determines the role of surface fuel, ladder fuel and aerial fuel in the vertical/horizontal fuel continuity in the stand. This method is based on CVFoC Manual (Piqué et al. 2011). |
| Forest health status | Mortality (%)<br>Defoliation (%)<br>Foliage discoloration (%) | Initial, following treatment and yearly survey | Forest decline identification key: Using a field key, stand decline status is assessed through visual estimation of tree mortality percentage (dried crowns), defoliation percentage (non-present leaves in relation of leaves present on a healthy tree) and foliage discoloration percentage (non-green leaves in relation of green leaves on a healthy tree). This field identification method is based on the DEBOSCAT project (Banqué et al, 2013) and the Spanish Forest Monitoring Network (Level II www.magrama.gob.es). |
| Fuel moisture | Relative water content (RWC) | Seasonal and twice a month (summer) | Forest fuel sampling: A sample of branches from 5 random trees and shrubs is collected through a Fiberglass Pruning Pole (Jameson JE). The samples are conserved in a cool-box until processing in the laboratory. In the laboratory samples are weighed to obtain fresh weight (W). Samples are then oven dried at 80 ºC for 24h and weighed to determine dry weight (DW). This allows the determination of relative water content. |
| Soil moisture | Soil water content (SWC) | Seasonal and twice a month (summer) | Soil water content (SWC) is assessed every season and twice a month (during summer period) using a time-domain reflectometry (TDR) device (Tektronix 1502C, Beaverton, Oregon, USA) (Gray & Spies, 1995). Three stainless steel cylindrical rods, 15 cm long, are permanently left fully driven into the soil at five selected points uniformly distributed in each treatment area (15 sensors per area). The time domain reflectometer is connected to the ends of the rods in each measurement |
| Stand temperature and relative humidity | Temperature and relative humidity | Continuous | Sensor measurements: In each monitored treatment area, 5 temperature and relative humidity data loggers (HOBO Pro v2 (U23-001) by Onset Computer Corporation) are installed to register data from TDR sensors. These HOBO loggers are located 130 cm above the ground. The recording interval was set to 60 |

| Monitored variable | Monitoring indicators | Frequency | Methodology |
|---|---|---|---|
| | | | min. |
| Site meteorological conditions | Maximum temperature, minimum temperature, rainfall and radiation | Continuous | Meteorological station: Daily values of meteorological variables, including maximum temperature, minimum temperature, rainfall, radiation and wind speed are calculated through hourly data recorded by an automatic weather station, a Vantage Pro2 Station (Davis Instruments, Hayward, California, USA). |

*Table 7. Monitored variables, indicators, frequency of the monitoring and methodology used.*

Three more analysis have been done to monitor forest demonstrative activities:

- An economic evaluation of their implementation based on the subcontracting costs.
- An analysis of soil of each demonstrative activity to evaluate the influence of main soil variables into the evolution of the different plots.
- An aerial image created by a Remotely Pilot Aircraft System (RPAS, drone) of the 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 tasks included in Table 5. For this reason, an aerial image of the area was taken and digitalised to quantify the forest surface affected by droughts in each treatment.

The results of the monitoring of the forest demonstrative activities are available at *Deliverable 22 Effects of the implementation actions in LIFE MEDACC case study basins* (Pascual et al. 2018)

# 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

The project website was launched on December 2013 and lately redesigned on November 2015. The changes included in the second version responded to the necessities identified by project partners according to the requests of the stakeholders and the European.

The project platform was launched on September 2015. The platform was implemented in the website of the project in order to disseminate and make profitable the information system. The information was uploaded in six different classes according with the main areas in the project: 1) Adaptation measures, 2) Agriculture and Soils, 3) Climate and Hydrology, 4) Forest, 5) Networking activities and 6) Pilot Experiences. More than 100 items are currently uploaded in the platform.

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. Methodology

Two opinion polls has been produced along the project:

- The first opinion poll launched on 17$^{th}$ 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. The poll was distributed among participants with the objective of knowing the degree of satisfaction of the information received and about the project website. Table 8 includes the questions and values included in the first opinion poll.

| | **Questions** | **Values** |
|---|---|---|
| Type of user | Choose the type of user | Level A: beneficiaries and desk officer's Commission<br>Level B: project stakeholders interested in technical information<br>Level C: other project stakeholders<br>Level D: general public |
| Platform information | Quality of the information | 0-10 |
| | Utility of the information | 0-10 |
| Medium used to access to platform information | Value the quality of the mean used to access to the information | 0-10 |
| Received assistance | Have you had direct contact with some beneficiary of the LIFE MEDACC project | Yes / No |
| | Value the received assistance | 0-10 |

| | | |
|---|---|---|
| LIFE MEDACC website | Quality of the information | 0-10 |
| | Utility of the information | 0-10 |
| Observations | | Free text |

*Table 8. Questions and values included in the first opinion poll.*

The results of the first opinion poll are analysed at *Deliverable 22 Effects of the implementation actions in LIFE MEDACC case study basins* (Pascual et al. 2018)

### *4.2.2. Final opinion poll*

The final opinion tool was launched on March 2018. Table 9 includes the questions and values included in the final opinion poll.

| | Questions | Values |
|---|---|---|
| Platform design: about structure, organization, accessibility. | Quantity of information | Yes/No |
| | Download method | 1 to 5 |
| | Type of information | Yes/No |
| | Useful data | Yes/No |
| | Formats | Yes/No |
| | Suggestions | Free text |
| Use of Platform | Quantification | 1 to 5 |
| | Nº of downloads | 1 to 4 |
| | Usefulness of Platform | Yes/No |
| | Suggestions | Free text |
| Socio-demographic data | Age | |
| | Academic background | |
| | Labour sector | |

*Table 9. Questions and values included in the final opinion poll.*

The results of the final opinion poll are analysed at *Deliverable 22 Effects of the implementation actions in LIFE MEDACC case study basins* (Pascual et al. 2018)

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