Adapting the Mediterranean to climate change

MEDACC

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

LIFE12 ENV/ES/000536

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Development of an indicator-based methodology for the evaluation of climate change adaptation measures and their application to the LIFE MEDACC case study basins

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Executive summary

This report provides an in-depth description of the development of a methodology for evaluating pre-existing climate change adaptation measures based on a set of indicators. In this case, the adaptation measures considered were compiled from the three LIFE MEDACC project basins. Following the description of these indicators developed in the context of the project, they are applied to the project basins in a comparative case study.

Index

1. Introduction

The Catalonian Climate Change Adaptation Strategy Horizon 2013-2020 (ESCACC for its Catalan acronym), approved by the Catalonian government in November 2012[1], represents a step forward for reducing vulnerability to the impacts of climate change.

For its operational objectives, on one hand the ESCACC establishes the creation and transfer of knowledge on climate change adaptation, and on the other aims to increase the adaptive capacity of the most vulnerable Catalonian territories (Pyrenees, Ebro Delta, and coastal areas) and socioeconomic and natural systems of Catalonia: agriculture and livestock, biodiversity, water management, forest management, industry, commerce and services, mobility and transport infrastructures, fisheries and marine ecosystems, health, the energy sector, tourism, urbanism, and housing.

To achieve these objectives, the ESCACC proposes a total of 182 adaptation measures, 30 of which are generic, while the remaining 152 are specific to certain sectors and systems. One of the generic measures is the **establishment of a monitoring system and indicators of adaptation measures**, with the objective of evaluating whether adaptation to climate change has a positive impact in Catalonia. What is proposed is a monitoring scheme which will determine the appropriateness of adopted adaptation measures in order to face the impacts of climate change.

Along these lines of climate change adaptation policy in Catalonia, action B.1 of the project LIFE12 ENV/ES/000536, MEDACC, *Demonstration and validation of an innovative methodology for regional climate change adaptation in the Mediterranean area,* defines an action for the establishment of indicators which shall be used to evaluate climate change adaptation measures adopted in the project's three study basins. Essentially, Life MEDACC is to provide the definitions of new adaptation measures based on the evaluation of climate change impacts and vulnerability, and will also evaluate existing adaptation measures. Life MEDACC sub-action B.1.2. stipulates the compilation and review of methodologies using statistical methods and analysis of existing literature, all oriented towards the **development of a package of climate change impact adaptation indicators**.

2. How should adaptation be evaluated?

The evaluation of adaptation, or in other words, the analysis of whether the three study basins (Muga, Segre, and Ter) and by extension, Catalonia, advance in terms of adaptation to climate change impacts, requires the development of indicators which can be evaluated at three different levels of complexity: (1) an evaluation of effectiveness of the measure itself; (2) its effectiveness within each sector and system; and finally (3) its overall effectiveness encapsulating the whole region/basin.

[1] Acord de Govern GOV 115/2012, de 13 de novembre, DOGC núm. 6254

The development of an indicator has four basic requirements: (1) that the indicator is simple to achieve, in the sense that it is easy to access the necessary information; (2) that historical data allowing quantification of the indicators are available; (3) that the indicator is easy to interpret; and (4) that the information and data are specific to the basin.

The task of evaluation of the appropriateness of adaptation measures is not easy; this fact is recognized by the European Commission in the *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions about the European Climate Change Adaptation Strategy* (COM(2013) 216 Final 16.5.2016). The document affirms: "Monitoring and evaluating climate change adaptation policies are crucial. The emphasis is still on monitoring impacts rather than adaptation action and its effectiveness. The Commission will develop indicators to help evaluate adaptation efforts and vulnerabilities across the EU, using LIFE funding and other sources." In March 2014 the Commission proposed an Adaptation Preparedness Scorecard based on the evaluation of five distinct areas as an instrument for measuring the degree of progress in climate change adaptation policies of the EU Member States. One of these areas precisely refers to the monitoring and evaluation of adaptation measures by way of indicators, but without further indications about the mechanisms for their calculation.

2.1. Presentation of the indicators

With the context described above, both the novelty of the task required and the lack of examples have made the search for adaptation indicators in the three basins a difficult and complex undertaking. To some degree, this explains why some of the first indicators obtained are more developed than others, and also why some indicators may be applicable beyond the context of the three basins or may illustrate the incorporation of adaptation in sector-specific planning (water, forests). Therefore, after a first study consisting of data searches and compilation, a proposal is made consisting of a total of **22 indicators assessing adaptation measures in agriculture and livestock, water management, and forest management**, which are the areas of intervention of Life MEDACC. These 22 indicators are described in the data sheets in Annex 1.

The information contained in each of the indicator data sheets has been organized in the following manner:

Sectorial indicator - name of the indicator

Objective of the measure addressed by the indicator

Source - source of information

Methodology - explanation of the methodology followed and how numeric data is obtained

Data - numeric values of the indicator by year (table)

Graphical representation - of the data

Desired trend of adaptation - explanation of how the indicator should evolve for improved adaptation: increase, stability, or decrease

Relevance of the indicator - justification for why this indicator is useful for evaluating the specific measure. Also includes a description of how to interpret the data.

3. Qualitative evaluation of the indicators

In order to carry out a qualitative evaluation of the indicators, a table has been elaborated summarizing all of the information in the data sheets of each indicator. This table includes the following fields:

- **Basin to which it pertains or if it is general (all of Catalonia)**
- **Name of the indicator**
- **Sector**
- **Units in which the indicator is expressed**
- **Periodicity of the data**
- **Data years**
- **Desired trend:** how an indicator must evolve for an improvement in adaptation to the effects of climate change. In this field there are three options:
  - Increase: the desired trend of the indicator is that the values increase.
  - Stable: the desired trend of the indicator is that the values stay the same with little variation.
  - Decrease: the desired trend of the indicator is that the values decrease

- **Actual trend**: how the indicator has evolved since data became available. For each indicator, shown are the line of the linear trend, the equation of the regression, and the value of the coefficient of determination R^2. Based on the R^2 value and taking into account degrees of liberty (number of data points-2), it is determined if the trend is significant at the confidence level of 95% (shown with an asterisk * in the graphics of the indicators), 99% (shown with two asterisks **), 99.9% (shown with three asterisks ***), or if the trend is not significant (displaying ns in the indicator graphic). In this field there are three options:
  - Increase: the trend of the indicator values is an increase and is statistically significant at the 95% confidence level.
  - Decrease: the trend of the indicator values is a decrease and is statistically significant at the 95% confidence level.
  - No trend: there is no statistically significant trend.

- **Is progress being made?:** Comparison of the desired trend of the indicator with its

actual trend. This field is classified into one of three possible categories:

Improving
No significant trend
Worsening

4. Results

Next, the results of the qualitative evaluation of the indicators are presented for each of the studied sectors. Data from the municipalities, counties, and meteorological stations analyzed for the elaboration of the indicators for each basin are presented in Annex 2.

4.1. Results from the agricultural sector

In the agricultural sector a total of 6 indicators were calculated

Basin	Indicators	Sector	Indicator units	Periodicity	Data years	Desired trend	Actual trend	Is progress being made?
Muga	Crop productivity	Agriculture	kg/ha	Annual	2008-2014	No decrease	Increase	
	Crop diversity	Agriculture	Dimensionless	Annual	2008-2014	Moderate increase	Increase	
	Animal feed VS human food	Agriculture	Dimensionless	Annual	2008-2014	Decrease	Increase	
	Forest area VS agricultural area	Agriculture	Dimensionless	Annual	2001-2013	No increase	No trend	
	Water productivity	Agriculture	kg/ m^3	Annual	2008-2014	Increase	Increase	
	Surplus rainwater after agricultural use per kg produced	Agriculture	hm^3.Tg	Annual	2011-2014*	Remain same or increase	No trend	
Segre	Crop productivity	Agriculture	kg/ha	Annual	2008-2014	No decrease	Increase	
	Crop diversity	Agriculture	Dimensionless	Annual	2008-2014	Moderate increase	No trend	
	Animal feed VS human food	Agriculture	Dimensionless	Annual	2008-2014	Decrease	Increase	
	Forest area VS agricultural area	Agriculture	Dimensionless	Annual	2001-2013	No increase	Marginal increase	
	Water productivity	Agriculture	kg/ m^3	Annual	2008-2014	Increase	Increase	
	Surplus rainwater after agricultural use per kg produced	Agriculture	hm^3.Tg	Annual	2011-2014*	Remain same or increase	No trend	
Ter	Crop productivity	Agriculture	kg/ha	Annual	2008-2014	No decrease	Increase	
	Crop diversity	Agriculture	Dimensionless	Annual	2008-2014	Moderate increase	Increase	
	Animal feed VS human food	Agriculture	Dimensionless	Annual	2008-2014	Decrease	No trend	
	Forest area VS agricultural area	Agriculture	Dimensionless	Annual	2001-2013	No increase	No trend	
	Water productivity	Agriculture	kg/ m^3	Annual	2008-2014	Increase	Increase	
	Surplus rainwater after agricultural use per kg produced	Agriculture	hm^3.Tg	Annual	2011-2014*	Remain same or increase	No trend	

* The calculations (municipal level) for these indicators cannot show significant trends because data are only available for 4 years.

4.2. Results from the water management sector

In the water management sector a total of 5 indicators were obtained (two generic and three for each basin).

Basin	Indicators	Sector	Indicator units	Periodicity	Data years	Desired trend	Actual trend	Is progress being made?
General	Management Plan of the Catalonia River Basic District (2016-2021)	Water management	--					
	Water destined to irrigation in Catalonia	Water management	m^3/ha/year	Every 5 years	2007-2012	Decrease	No trend	
Muga	Municipal water utility	Water management	l/person/day	Annual	2008-2014	Decrease/Stable	Decrease	
	Volume of water used in urban systems	Water management	hm^3/year	Annual	2008-2014	Decrease	Decrease	
	Status and degree of compliance with planning objectives for surface water bodies	Water management	Number and %	Every 6 years	2008-2013	Increase (compliance with objectives)	Decrease	
Segre	Municipal water utility	Water management	l/person/day	Annual	2008-2014	Decrease/Stable	No trend	
	Volume of water used in urban systems	Water management	hm^3/year	Annual	2008-2014	Decrease	No trend	
	Status and degree of compliance with planning objectives for surface water bodies	Water management	Number and %	Every 6 years	2008-2013	Increase (compliance with objectives)	Increase	
Ter	Municipal water utility	Water management	l/person/day	Annual	2008-2014	Decrease/Stable	Decrease	
	Volume of water used in urban systems	Water management	hm^3/year	Annual	2008-2014	Decrease	Decrease	
	Status and degree of compliance with planning objectives for surface water bodies	Water management	Number and %	Every 6 years	2008-2013	Increase (compliance with objectives))	No trend	

4.3. Results of the forestry sector

For the forest management sector a total of 11 indicators were obtained (one generic and ten for each basin; it is noted that timber and firewood harvests are reported on the same datasheet, as are the indicators of stems and over bark volume).

Basin	Indicators	Sector	Indicator units	Periodicity	Data years	Desired trend	Actual trend	Is progress being made?
General	General Plan for Catalonian Forest Policy 2014-2024	Forest management	--					
Muga	Area with forest management plans on private property	Forest management	ha	Annual	2007-2014	Increase	Decrease	
	Relationship between forest area having undergone forest management practices and total area with forest management plans on private property	Forest management	%	Annual	2007-2014	Increase	No trend	
	Area of harvesting on private property	Forest management	ha	Annual	2007-2014	Increase	No trend	
	Timber harvested on private property	Forest management	tons	Annual	2001-2014	Increase	Increase	
	Firewood harvested on private property	Forest management	tons	Annual	2001-2014	Increase	Increase	
	Timber harvested on public property	Forest management	m^3	Annual	2006-2015	Increase	No trend	
	Density	Forest management	stems/ha	Every 10 years	IFN2 (1986- 1996) IFN3 (1997-2008)	Stable	No trend	
	Over bark volume harvested	Forest management	m^3/ha	Every 10 years	IFN2 (1986- 1996) IFN3 (1997-2008)	Increase	No trend	
	Area burnt by forest fires	Forest management	ha	Annual	2004-2014	Decrease	No trend	
	Head of sheep and goats	Forest management	number of animals	Annual	1999- 2007, 2009	Increase	Decrease	

Basin	Indicators	Sector	Indicator units	Periodicity	Data years	Desired trend	Actual trend	Is progress being made?
Segre	Area with forest management plans on private property	Forest management	ha	Annual	2007-2014	Increase	No trend	
	Relationship between forest area having undergone forest management practices and total area with forest management plans on private property	Forest management	%	Annual	2007-2014	Increase	No trend	
	Area of harvesting on private property	Forest management	ha	Annual	2007-2014	Increase	No trend	
	Timber harvested on private property	Forest management	tons	Annual	2001-2014	Increase	No trend	
	Firewood harvested on private property	Forest management	tons	Annual	2001-2014	Increase	Increase	
	Timber harvested on public property	Forest management	m^3	Annual	2006-2015	Increase	Increase	
	Density	Forest management	stems/ha	Every 10 years	IFN2 (1986- 1996) IFN3 (1997-2008)	Stable	No trend	
	Over bark volume harvested	Forest management	m^3/ha	Every 10 years	IFN2 (1986- 1996) IFN3 (1997-2008)	Increase	No trend	
	Area burnt by forest fires	Forest management	ha	Annual	2004-2014	Decrease	No trend	
	Head of sheep and goats	Forest management	number of animals	Annual	1999- 2007, 2009	Increase	Decrease	

Basin	Indicators	Sector	Indicator units	Periodicity	Data years	Desired trend	Actual trend	Is progress being made?
Ter	Area with forest management plans on private property	Forest management	ha	Annual	2007-2014	Increase	Increase	
	Relationship between forest area having undergone forest management practices and total area with forest management plans on private property	Forest management	%	Annual	2007-2014	Increase	Increase	
	Area of harvesting on private property	Forest management	ha	Annual	2007-2014	Increase	No trend	
	Timber harvested on private property	Forest management	tons	Annual	2001-2014	Increase	Increase	
	Firewood harvested on private property	Forest management	tons	Annual	2001-2014	Increase	Increase	
	Timber harvested on public property	Forest management	m^3	Annual	2006-2015	Increase	No trend	
	Density	Forest management	stems/ha	Every 10 years	IFN2 (1986- 1996) IFN3 (1997-2008)	Stable	No trend	
	Over bark volume harvested	Forest management	m^3/ha	Every 10 years	IFN2 (1986- 1996) IFN3 (1997-2008)	Increase	No trend	
	Area burnt by forest fires	Forest management	ha	Annual	2004-2014	Decrease	No trend	
	Head of sheep and goats	Forest management	Number of animals	Annual	1999- 2007, 2009	Increase	Decrease	

5. Conclusions

5.1. Agriculture and livestock

- **Crop productivity (kg/ha) increases in the three basins.** The Segre basin has smaller increases than the other two basins, probably because agriculture in this basin is much more established, with little recent change. From a productivity and/or economic perspective, this evolution of the indicator is compatible with the desired trend as related to agricultural sustainability.

- **The diversity of crops in the studied basins is not changing**, taking into account the current situation of low diversity. The Segre basin does not have a significant trend, probably due to the importance of major crops (winter cereals, olive trees, maize, fruit trees, almond trees) which are highly established in the local agricultural landscape; the fact that these crops are so fixed in local agricultural practices makes it unlikely that diversification will occur. This situation poses certain risks since it is possible that in the future certain crops will no longer be viable due to changing environmental conditions.

- **The ratio of crop production for animal feed vs. human food shows an upward trend in two of the three basins, the Muga and Segre.** In these basins, problems relating to contamination of surface and subterranean water and water quality have been increasing along with increases in GHG emissions. In the Ter basin, neither water quality nor this indicator in particular seemed to have changed much over the past few years, but the initial status of these were worse than the other two basins due to intensive pig livestock farming. Therefore, it appears that this is a good indirect indicator of surface and subterranean water quality.

- **The relationship between forest area and agricultural area** describes the balance between these two land uses, which has always been dynamic. **The indicator does not show any clear trend in the Muga and Ter basins, and shows a very slight increase in the Segre basin.**

- **Water productivity (kg produced/m^3 water consumed) increased significantly in the three basins, especially in the Ter (nearly 200 g/m^3/year) and the Muga (more than 100 g/m^3/year).** In the Muga basin this increase is basically due to increases in area of crops with high water productivity such as corn and fodder crops. In the Ter basin, the cause is both the increase in water productivity and area cropped to corn, together with an increase in area of other crops with high water productivity such as ryegrass, fodder crops, and oilseed rape. This overall increase in water productivity is a good sign from the perspective of climate change adaptation given the expected decrease in water availability.

- **The indicator of agricultural water conservation may be a good summarizing index** because it includes both conservation of water resources and effects on yield. However, at this time there are not enough data for the evaluation of trends of this indicator since some data necessary for its calculation are only available for the past few years. **To better understand how this and other indicators work, see Annex 3.**

- As a **general conclusion,** most of the indicators have trends in the desired direction with the exception of two: the indicator for agricultural conservation of water resources, and the

ratio of production of animal feed to human food. The first of these does not show any real trend due to insufficient data, while the second shows an undesirable trend in the Muga and Segre basins, and no significant trend in the Ter, albeit this basin has the highest values for this indicator. Also, **the Segre displays the least favorable situation of the three basins** since, in addition to the indicators discussed previously, it also shows undesirable trends in indicators such as crop diversity or forest area vs. agricultural area. This is probably due to the existence of a highly-established and relatively unchanging agricultural sector which is faced with **an exceptional opportunity to apply conservation measures which to date have not been adapted in a widespread manner.**

5.2. Water management

- Incorporation of **climate change adaptation in water policy** within the Management Plan of the Catalonia River Basic District (2016-2021) is evaluated as **positive** because the consideration of climate change impact has been included in evaluation of water resources within the different management systems in two distinct temporal phases, with the result that specific adaptation measures will now be adopted.

- Unfortunately, even now in the 21st century, evaluating real consumption of **water in agriculture** is a very difficult task to due to a chronic lack of water meters. This is why it is necessary to make estimations based on demand, based either on calculations involving the catchment infrastructures, calculations of water necessities of crops, or the volumes approved by the reservoir committees of the different basins. With this context, the data show a **reduction, however non-significant, in water provision in terms of annual volumes.**

- **The behavior of Catalonian citizens towards domestic water conservation is exemplary**. This is clearly shown in the values of domestic water provision in terms of volumes of water consumed in urban water systems of the **Muga and Ter** basins, showing a **clear, significant, decreasing trend.** Values in the **Segre**, on the other hand, **show stable values** through the data years analyzed without any trend.

- No trend was seen with the indicator measuring the **condition and degree of compliance with the planning objectives for surface water bodies** since only two data periods are available (2008 and 2013). Also, data is not available in 2008 for a large number of water bodies; at the same time, the indicators measuring the condition of water resources used by the Catalan Water Agency (water management authority in charge of the Muga and Ter basins) are more restrictive that those used by the Ebro Hydrographic Confederation (water management authority in charge of the Segre basin). However, based on the percentage of number of water bodies in good condition with respect to the total number of water bodies in 2013, we have arrived to a description of the actual trend for the three basins: a **decrease in the degree of compliance in the Muga**, **stability without trend in the Ter**, and an **increase in the Segre**, with the understanding that it will be necessary to wait until 2018 (the next evaluation year of the Monitoring and Control Program) to confirm these trends.

- Comparing the three basins, we have concluded that the current trends of the **Ter basin** are closest to those desired, displaying **an evolution towards improved adaptation to the impacts of climate change, followed by the Segre, and in last place, the Muga.** In all three cases, **adaptation of water management to climate change impacts** will first depend on

the establishment of the adaptation actions described in the Measures Program of the 2016-2012 Management Plan, and secondly on the **full integration of water management policies into agricultural and forestry policy**.

5.3. Forest Management

- The incorporation of **adaptation to climate change in sectorial policies** has been received positively following the approval of the General Plan for Catalonian Forest Policy 2014-2024. Though this planning tool was long-awaited by the sector, its approach incorporates updated guidelines in the area of climate change and, its application at the **regional level** equips the region with **new planning tools promoting multifunctional management of forests**.

- The **degree of forest planning** (area with IOF forest management plans) **varied between basins**: while in the **Ter basin the trend is towards increasing the area with planning**, Segre basin shows no trend, and finally, in the Muga basin the area with planning has decreased over the studied period. This is a direct indicator of the extent of forest planning in private forests within a given area, though it does not provide information about its implementation (if the planning is being executed or not). Designing an appropriate management scheme for the sustainable use and perpetuation of forests on private property is necessary, though not sufficient in itself, for its eventual adoption.

- The indicators designed to assess the **degree of implementation of forest planning** (relationship between planned and executed harvests and the total area of all harvests) **tended to improve in the Ter basin**, and remained **stable in the Muga and Segre**. This is a direct indicator of the degree of execution of planned activities in forests on private property, reflecting the effectiveness of forest planning in the basins.

- The indicators designed to evaluate **forest resource (firewood and timber) extraction** from forests on private property tended to **increase in the three basins**. High values of these indicators speak to the good status of exploitation of the forests' productivity. However, it is necessary to point out that in the case of the Muga, due to the Alt Empordà summer 2012 forest fire, the increased harvesting activities have remained significant, whereas this might not be the case were it not for that particular event.

- The indicators designed to evaluate **forest resources (timber) extraction** on public forest lands tended to **increase in the Segre basin** and remained stable in the Muga and Ter. It is necessary to comment that in the Segre basin public forests represent 43% of the total (for example, this value is over 60% in the Pyrenean zone of Alt Pirineu), while in the other basins public forests are not very representative (8.5% in the Ter basin and 1.1% in the Muga).

- The indicator describing the **evolution of regional impact of forest fires** (burnt area) show a **trend of stability** in the three basins.

- The indicators tied to measures for favoring **ranching**, and therefore with clear **benefits to forest fire prevention** (number of animals), show a **clear negative trend** throughout the data years.

- For the indicators "**Density**" and "**Over bark volume**", only two data sources are available (IFN2 and IFN3), and for this reason it is not possible to reach clear conclusions about whether the evolution is favorable or not. The field sampling campaign of the fourth inventory (IFN4) in Catalonia is near completion and it is hoped that new data will be available before the Life MEDACC project finalizes.

- Comparing the basins, we can conclude that the **Ter basin** has current trends which are closest to those desired, showing that it is **progressing towards a better adaptation to the impacts of climate change, followed by the Segre, and lastly the Muga.** In all three cases, **adaptation of forests to climate change** will depend on, firstly, the **application of adaptive forest management** favoring mature and healthy forest structures, and secondly, the **reduction of forest fire risk**, either through this existing forest management including preventive cutting, and/or by way of other options such as a **return to ranching and use of forest products** (biomass).

5.4. Overall conclusions

- It is difficult to resist the temptation to make a qualitative evaluation of the status or degree of adaptation of the three study basins based on the indicators developed here for the areas of agriculture, water management, and forest management. A summary table, according to the findings for each sector, places the basins in the following positions:

	Agricultural indicators	**Water indicators**	**Forest indicators**
First	TER	TER	TER
Second	MUGA	SEGRE	SEGRE
Third	SEGRE	MUGA	MUGA

6. ANNEX 1: Indicator Data Sheets

Agriculture and livestock

- Crop productivity (kg/ha)
- Crop diversity index (dimensionless)
- Ratio of production for animal feed VS human food (dimensionless)
- Ratio of forest area VS agricultural area
- Water productivity (kg/m^3)
- Agricultural conservation of water resources: Surplus rainwater from cultivated areas following agricultural use multiplied by yield (hm^3*Tg)

Water management

- Management Plan of the Catalonia River Basic District (2016-2021)
- Water destined to irrigation in Catalonia
- Municipal water utility
- Volume of water used in urban systems
- Status and degree of compliance with planning objectives for surface water bodies

Forest management

- General plan for Catalonian Forest Policy 2014-2024
- Area with forest management plans on private property (IOF by its Catalan acronym)
- Relationship between forest area having undergone forest management practices and total area with forest management plans on private property
- Area of harvesting on private property
- Forest resources (timber and firewood) harvested on private property
- Forest resources (timber) harvested on public lands
- Density and over bark volume harvested
- Area burnt by forest fires
- Head of sheep and goats

AGRICULTURE AND LIVESTOCK

Crop productivity (kg/ha)

1.- Objective of the measure addressed by the indicator:

Estimate the capacity for maintaining or improving food production (agro-food security) without the necessity of overexploiting the region. It is a measure of adaptation from the point of view of food sustainability.

2.- Source:

- Yield data (kg/ha) on the county level (2008-2014). Agricultural statistics from DARP. http://agricultura.gencat.cat/ca/departament/dar_estadistiques_observatoris/dar_estructura_produccio/dar_estadistiques_agricoles/dar_estadistiques_definitives

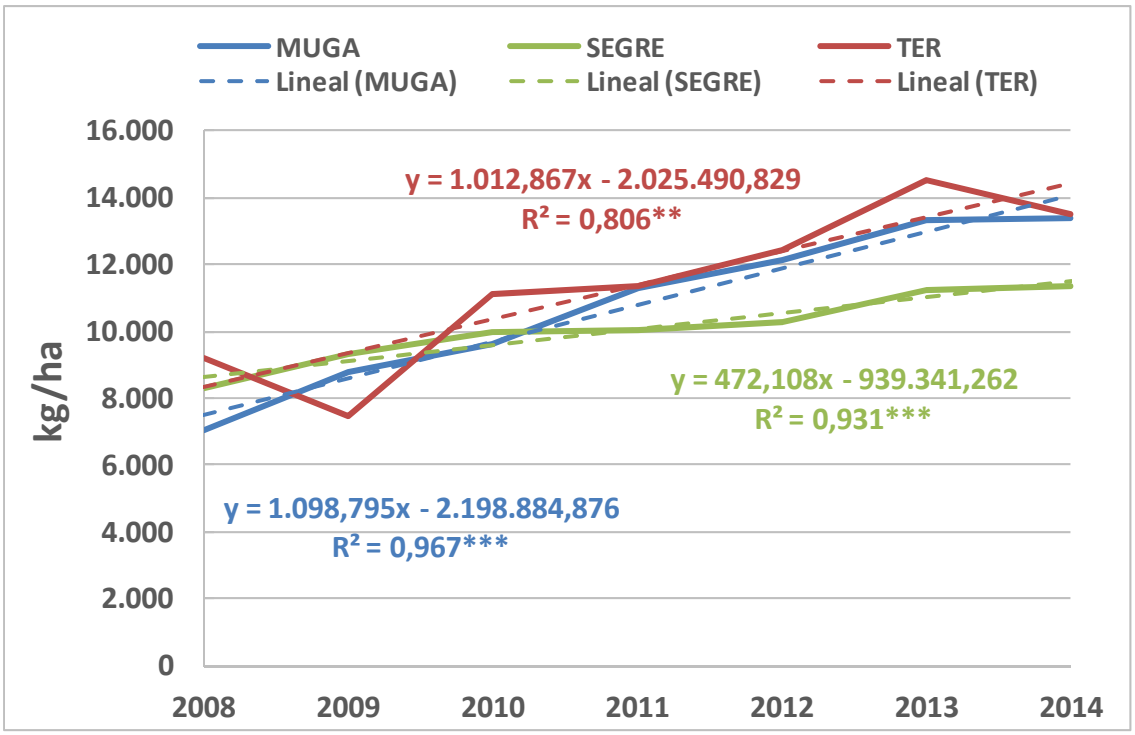
3.- Methodology:

In each basin the value of the indicator is the mean of data for productivity (kg/ha) in each county weighted by agricultural area. For each county, the mean for each crop is taken and weighted by area occupied by that crop. The counties within each basin used for the calculation of this indicator are defined in Table 1 of Annex 2.

4.- Data:

kg/ha	2008	2009	2010	2011	2012	2013	2014
MUGA	7.046	8.763	9.586	11.265	12.148	13.348	13.392
SEGRE	8.303	9.320	9.992	10.018	10.266	11.235	11.341
TER	9.223	7.474	11.114	11.369	12.454	14.525	13.529

5.- Graphical representation:



6.- Desired trend for adaptation: Not decreasing.

7.- Relevance of the indicator: This indicator allows evaluation of the evolution of crop productivity and therefore the profitability and the productive and/or economic aspect of agriculture. It allows the evaluation of agricultural and/or food sustainability of the region since it depends on yield within the available area.

Crop diversity index (dimensionless)

1.- Objective of the measure addressed by the indicator:

Estimate the potential resilience of the basin to the possibility that some current crop cannot be maintained due to changes in environmental conditions.

2.- Source:

For the indicator calculated with municipal-level data:

- Data on area of major crops on the municipal level (2011-2014). Agricultural statistics from DARP. http://agricultura.gencat.cat/ca/departament/dar_estadistiques_observatoris/dar_estructura_produccio/dar_estadistiques_agricoles/dar_estadistiques_definitives

For the indicator calculated with county-level data:

- Data on area of major crops on the county level (2008-2014). Agricultural statistics from DARP. http://agricultura.gencat.cat/ca/departament/dar_estadistiques_observatoris/dar_estructura_produccio/dar_estadistiques_agricoles/dar_estadistiques_definitives

3.- Methodology: The Shannon Index (H', dimensionless) was used, typically used for estimating biodiversity:

$$H' = -\sum_{i=1}^{S} p_i \log_2 p_i$$

Whereas *S* is the number of crops within each basin; P_i is the area (ha) of crop *i* (n_i) with respect to total area of crops (N), $P_i = n_i/N$.

For each year and basin, the maximum value which can be achieved for the indicator based on the number of different registered crops (S) was also calculated.

$$H'_{max} = -log_2 p$$

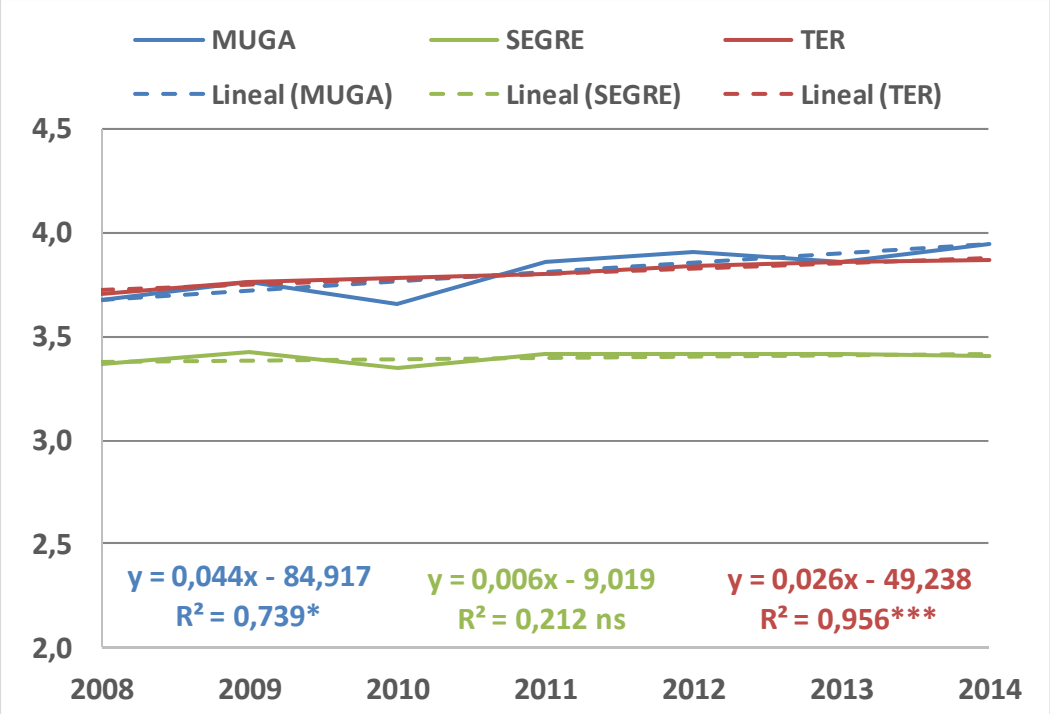
where $p=p_1=p_2=...=p_S = 1/S$ corresponds to a homogeneous distribution of the cultivated area among all crops present in the basin.

The list of counties and municipalities represented in the data used for calculating the indicator for each basin is shown in Tables 1 and 2 of Annex 2, respectively.

4.- Data:

	2008	2009	2010	2011	2012	2013	2014
MUGA	3.7	3.8	3.7	3.9	3.9	3.9	3.9
SEGRE	3.4	3.4	3.3	3.4	3.4	3.4	3.4
TER	3.7	3.8	3.8	3.8	3.8	3.9	3.9

5.- Graphical representation:



6.- Desired trend for adaptation: Moderate increase.

7.- Relevance of the indicator: This can be considered an indicator of adaptation in the sense that a more diverse agricultural landscape promotes a group of ecosystem services (positive biodiversity, water distribution, etc.) and facilitates changes of the agricultural system towards different crops and thereby adaptation to changes in a more general sense.

Ratio of production for animal feed VS human food (dimensionless)

1.- Objective of the measure addressed by the indicator:

Estimate progress towards reduced production of crops for animal feed due to the significant problems in the country associated with the use and quality of water and other environmental problems associated with the meat industry (contamination of aquifers, emission of GHGs, etc.).

2.- Source:

For the indicator calculated with municipal-level data:

- Data on productivity (tons/ha) on the county level. Agricultural statistics from DARP. http://agricultura.gencat.cat/ca/departament/dar_estadistiques_observatoris/dar_estructura_produccio/dar_estadistiques_agricoles/dar_estadistiques_definitives

- Data on area of major crops on the municipal level (2011-2014). Agricultural statistics from DARP. http://agricultura.gencat.cat/ca/departament/dar_estadistiques_observatoris/dar_estructura_produccio/dar_estadistiques_agricoles/dar_estadistiques_definitives

For the indicator calculated with county-level data:

- Data on production (tons) on the county level (2008-2014). Agricultural statistics from DARP. http://agricultura.gencat.cat/ca/departament/dar_estadistiques_observatoris/dar_estructura_produccio/dar_estadistiques_agricoles/dar_estadistiques_definitives

3.- Methodology:

This ratio is calculated as the proportion of production (tons) of major crops in each basin destined to animal feed and those destined to human food. In the case of cereals such as corn, wheat, barley and oats which could be destined to both human food and animal feed, European percentages on their allocation are used:

http://ec.europa.eu/agriculture/cereals/balance-sheets/index_en.htm

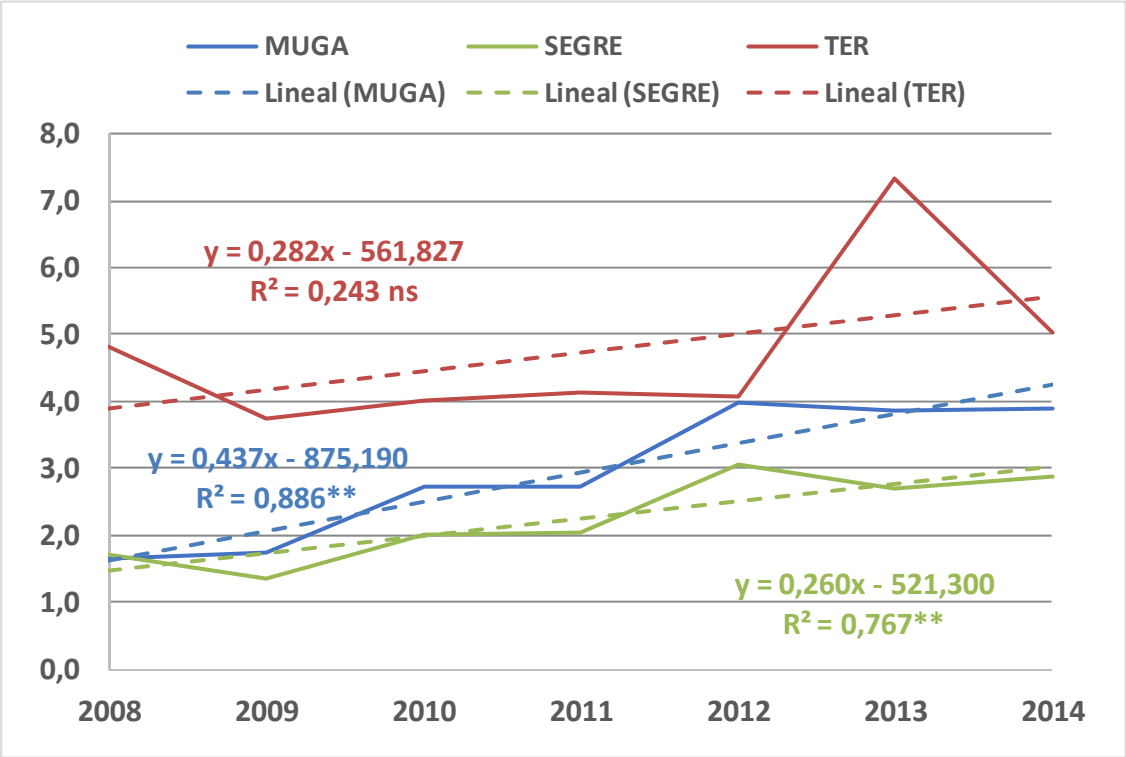
The list of counties and municipalities represented in the data used for calculating the indicator for each basin is shown in Tables 1 and 2 of Annex 2, respectively.

4.- Data:

		2008	2009	2010	2011	2012	2013	2014
Production for animal feed* (tons)	MUGA	142,078	175,026	198,206	245,182	284,312	344,452	368,571
	SEGRE	1,032,521	1,306,509	2,107,765	2,188,038	2,464,765	2,621,093	2,753,890
	TER	593,078	470,961	657,534	665,890	833,558	992,706	946,634
Production for human food* (tons)	MUGA	86,247	100,213	99,912	89,357	71,423	89,378	94,368
	SEGRE	1,761,222	1,752,346	1,052,409	1,064,731	805,415	968,170	958,724
	TER	123,090	125,678	164,221	160,889	203,913	135,308	188,312
Ratio of production for animal feed to human food (dimensionless)	**MUGA**	**1.6**	**1.7**	**2.7**	**2.7**	**4.0**	**3.9**	**3.9**
	SEGRE	**1.7**	**1.3**	**2.0**	**2.1**	**3.1**	**2.7**	**2.9**
	TER	**4.8**	**3.7**	**4.0**	**4.1**	**4.1**	**7.3**	**5.0**

*the kg of cereal for animal feed and human food are estimated (using European percentages on the allocation of each cereal, published annually at: http://ec.europa.eu/agriculture/cereals/balance-sheets/index_en.htm)

5.- Graphical representation:



6.- Desired trend for adaptation: Decrease.

7.- Relevance of the indicator: This ratio can be considered an indirect indicator of adaptation to climate change regarding the use and quality of water. Agriculture which is based mainly on crops destined to the livestock industry is a model of production which produces significant impacts on the use and contamination of water in the country.

Ratio of forest area VS agricultural area

1.- Objective of the measure addressed by the indicator:

Estimate the maintenance of environmental quality of the region

2.- Source:

- Data for agricultural and forest area (ha) on the county level (IDESCAT; land area and use, 2008-2013) *data published by IDESCAT for the years 2001-2007 are not comparable due to differences in the methodology used.
  http://www.idescat.cat/pub/?id=aec&n=202&t=2011

3.- Methodology:

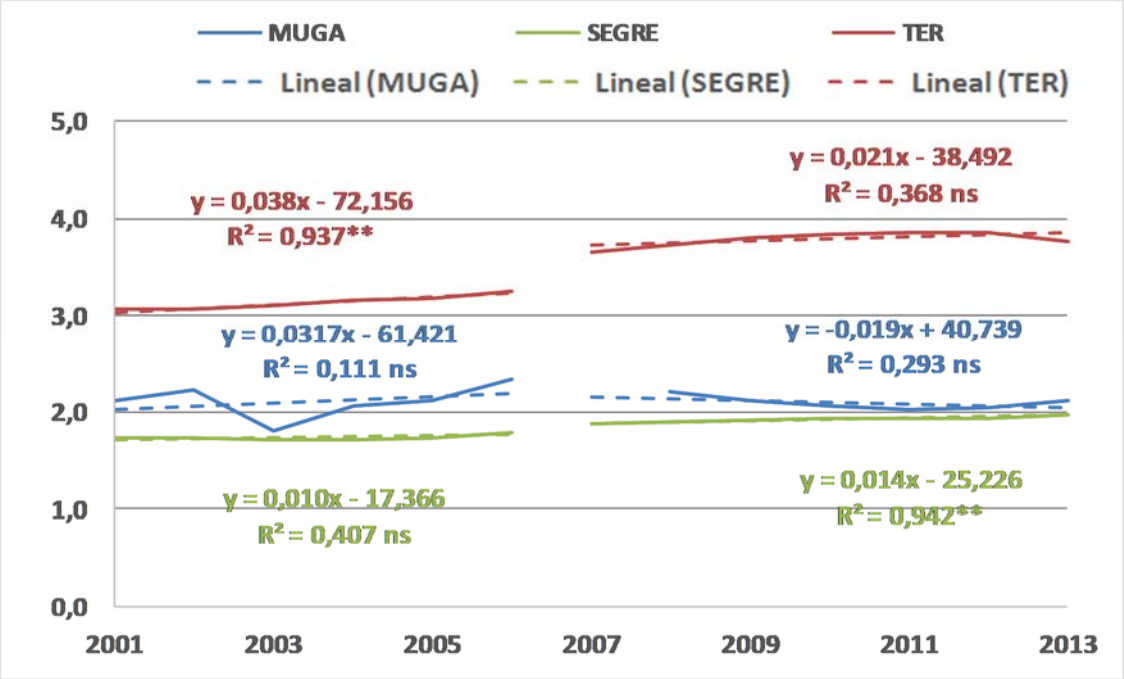
For each basin, forest area (ha) is summed and divided by agricultural area (ha) for counties within each basin (Table 1, Annex 2).

4.- Data:

	Forest area (hectares)			Agricultural area (hectares)			Ratio of forest area VS agricultural area (dimensionless)		
	MUGA	**SEGRE**	**TER**	**MUGA**	**SEGRE**	**TER**	**MUGA**	**SEGRE**	**TER**
2001	80,415	692,488	302,910	38,140	400,870	98,977	**2.1**	**1.7**	**3.1**
2002	81,652	688,075	302,935	36,839	399,834	98,975	**2.2**	**1.7**	**3.1**
2003	76,147	687,815	303,528	42,245	399,999	98,030	**1.8**	**1.7**	**3.1**
2004	81,526	687,141	306,665	39,448	400,725	97,301	**2.1**	**1.7**	**3.2**
2005	83,658	693,020	309,252	39,499	400,580	97,503	**2.1**	**1.7**	**3.2**
2006	86,605	717,635	310,503	37,064	400,987	95,664	**2.3**	**1.8**	**3.2**
2007	92,814*	729,547	320,477	30,642*	389,491	87,552		**1.9**	**3.7**
2008	84,995	731,454	322,431	38,524	386,361	86,545	**2.2**	**1.9**	**3.7**
2009	83,542	734,761	322,960	39,614	383,000	84,886	**2.1**	**1.9**	**3.8**
2010	82,664	734,464	323,572	40,318	381,090	84,156	**2.1**	**1.9**	**3.8**
2011	82,364	732,990	323,416	40,599	378,923	83,735	**2.0**	**1.9**	**3.9**
2012	82,382	732,864	323,090	40,328	378,106	83,981	**2.0**	**1.9**	**3.8**
2013	83,253	734,240	321,689	39,350	373,893	85,637	**2.1**	**2.0**	**3.8**

*data not considered in the indicator due to high uncertainty since they differ greatly from data in adjacent years. There was a change in methodology for data on area (ha) of forests and agriculture at the county level beginning in 2007 (IDESCAT; land area and use) and for this reason data from previous years are not comparable.

5.- Graphical representation:



6.- Desired trend for adaptation: Not increasing.

7.- Relevance of the indicator: This ratio can be considered as an indirect indicator of adaptation to climate change with regards to water consumption. An increase in forest area would cause an increase in water consumption in riparian and headwaters forests, and thereby a reduction in water resources downstream.

Water productivity (kg/m^3)

1.- Objective of the measure addressed by the indicator:

Estimate the capacity for maintaining yield under foreseeable conditions of reduced water availability based on the current trends of climate change and the increase in food demand.

2.- Source:

- Data on productivity (kg/ha) of each of the major crops on the county level (counties of each basin: Table 1 of Annex 2) for the period 2008-2014. Agricultural statistics from DARP. http://agricultura.gencat.cat/ca/departament/dar_estadistiques_observatoris/dar_estructura_produccio/dar_estadistiques_agricoles/dar_estadistiques_definitives

- Data on reference evapotranspiration (ET0) and precipitation from different regionally-representative meteorological stations within each basin (Table 3, Annex 2) for the years 2008-2014. The meteorological stations used belong to the Catalonia Meteorological Service and the Network of Agro-climatic Stations (XAC). http://www.ruralcat.net/web/guest/agrometeo.estacions

3.- Methodology: This indicator is calculated by dividing agricultural yield (kg/ha) for each type of crop by the water used (m^3/ha). This indicator has been calculated for each crop type and afterwards the weighted mean based on the area of each crop in the basin was calculated.

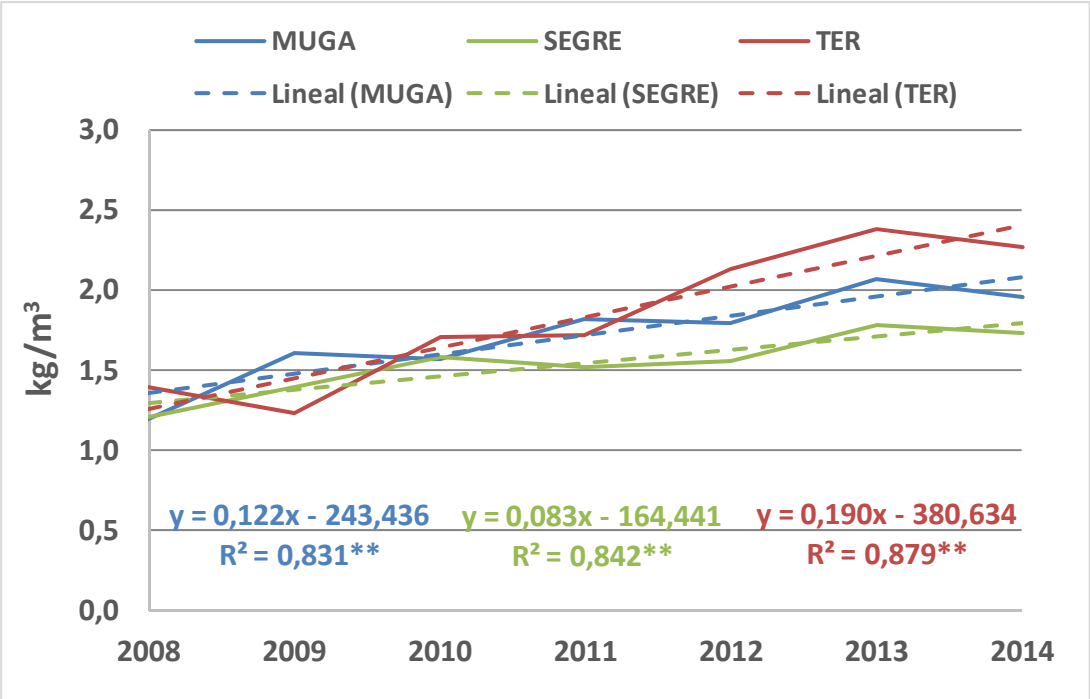
The quantity of water used for the resulting production is considered to be: for irrigated crops, ET_c; for dryland farming, the smaller quantity between ET_c and rainfall. For the estimation of potential evapotranspiration of each major crop (ET_c), for each basin, the methodology described in the document "Plan for the efficient use of water for agricultural irrigation" (ACA and IRTA, 2009)[2] was followed, using an average ET_0 of the meteorological stations for each basin.

4.- Data:

		2008	2009	2010	2011	2012	2013	2014
Average rainfall (mm)	MUGA	574	398	773	737	568	602	727
	SEGRE	604	540	595	436	439	571	631
	TER	780	608	843	918	523	725	870
Average ET_0 (mm)	MUGA	1,076	1,031	1,086	1,033	1,061	1,076	1,038
	SEGRE	975	1,053	999	1,071	1,086	1,015	1,015
	TER	946	1,034	959	1,008	1,034	961	939
Water productivity (kg/m^3)	**MUGA**	**1.2**	**1.6**	**1.6**	**1.8**	**1.8**	**2.1**	**1.9**
	SEGRE	**1.2**	**1.4**	**1.6**	**1.5**	**1.6**	**1.8**	**1.7**
	TER	**1.4**	**1.2**	**1.7**	**1.7**	**2.1**	**2.4**	**2.3**

[2] ACA and IRTA, 2009. Plan for the efficient use of water for agricultural irrigation [Pla per a l'eficiència en l'ús de l'aigua per a reg agrícola] (with the collaboration of the Catalonian Department of Agriculture, Food, and Rural Action).

5.- Graphical representation:



6.- Desired trend for adaptation: Increase.

7.- Relevance of the indicator: This indicator assesses the water efficiency of crops. In addition to the water efficiency of crops, this indicator is also influenced by small changes in area of crops with high water productivity.

Agricultural conservation of water resources: Surplus rainwater from cultivated areas following agricultural use multiplied by yield (hm^3*Tg)

1.- Objective of the measure addressed by the indicator:

Assess the conservation of water resources while maintaining food security (agro-food security, sufficient production).

2.- Source:

- Data on area (ha) of major crops on the municipal level (2011-2014). Agricultural statistics from DARP.
  http://agricultura.gencat.cat/ca/departament/dar_estadistiques_observatoris/dar_estructura_produccio/dar_estadistiques_agricoles/dar_estadistiques_definitives

- Data on reference precipitation evapotranspiration (ET0) from different regionally-representative meteorological stations within each basin (Table 3, Annex 2) for the years 2011-2014. The meteorological stations used belong to the Catalonia Meteorological Service and the Network of Agro-climatic Stations (XAC).
  http://www.ruralcat.net/web/guest/agrometeo.estacions

- Data on productivity (kg/ha) on the county level (2011-2014). Agricultural statistics from DARP.
  http://agricultura.gencat.cat/ca/departament/dar_estadistiques_observatoris/dar_estructura_produccio/dar_estadistiques_agricoles/dar_estadistiques_definitives

3.- Methodology: This indicator is calculated by subtracting the monthly evapotranspiration of each crop (ET_c) (m^3/ha) from the monthly precipitation (m^3/ha) and calculating the weighted mean for the area of each crop. Monthly precipitation is calculated as the mean of the meteorological stations in the basin (Taula 3 de l'Annex 2). For each crop, irrigated area is separated from dryland area. For dryland crops, if the ET_c of a crop is greater than the precipitation that it receives, the excess water is considered as zero.

Finally, the absolute excess water of each crop (hm^3) is multiplied by its absolute yield (Tg). Absolute yield at the municipal level for each crop is calculated by multiplying the municipal crop area for each basin (municipalities by basin: Table 2 of Annex 2) by the average county yield of the crop in each basin (counties by basin: Tab le 1 of Annex 2).

For the estimation of the specific evapotranspiration for each type of major crop (ET_c) in each basin, the methodology described in the document "Plan for the efficient use of water for agricultural irrigation" (ACA i IRTA, 2009)[3] was followed, using an average ET_0 of the meteorological stations for

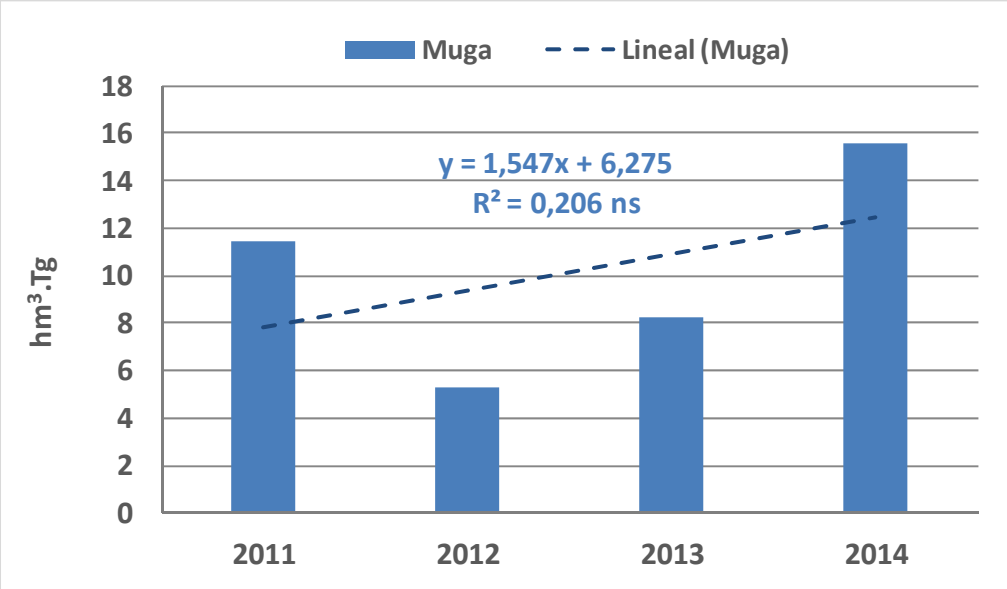
[3] ACA and IRTA, 2009. Plan for the efficient use of water for agricultural irrigation [Pla per a l'eficiència en l'ús de l'aigua per a reg agrícola] (with the collaboration of the Catalonian Department of Agriculture, Food, and Rural Action).

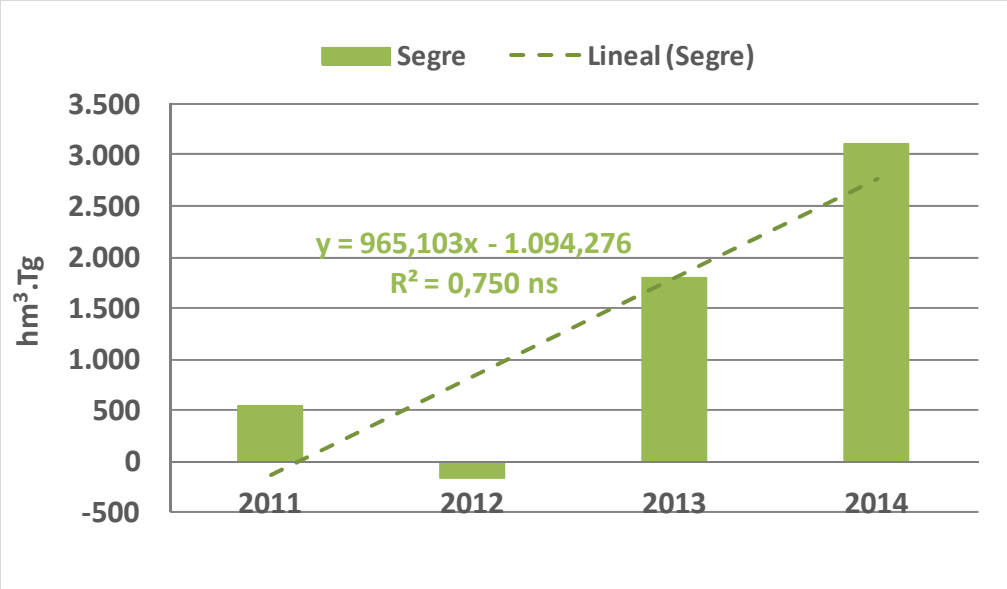
each basin.

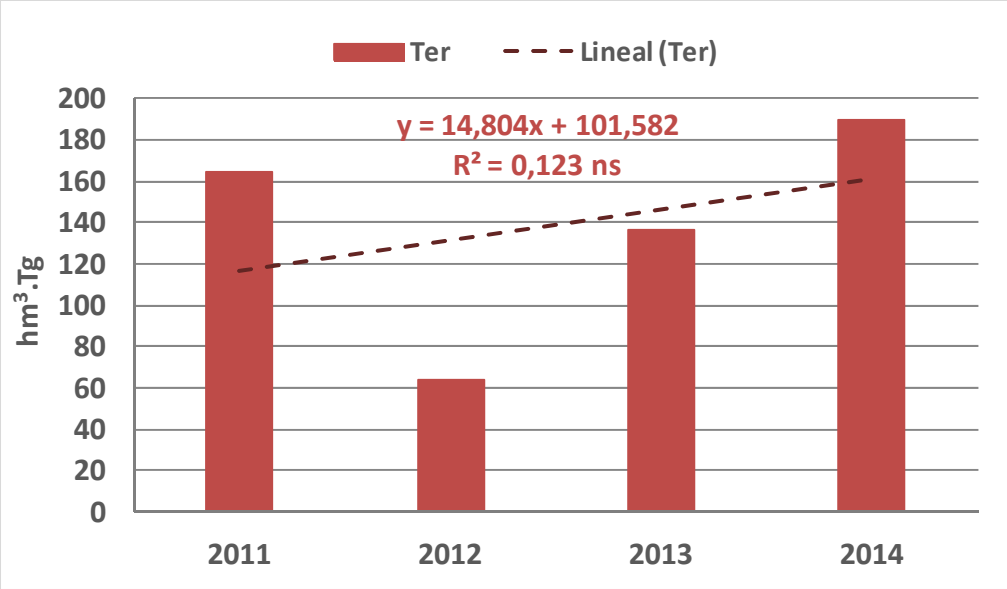
4.- Data:

		2011	2012	2013	2014
Absolute excess rainwater after agricultural use (Hm^3)	**MUGA**	64.175	26.889	33.826	61.561
	SEGRE	152.484	-47.002	469.654	789.659
	TER	276.737	101.052	162.010	250.683
Production(tons)	**MUGA**	177,888	196,924	244,911	253,032
	SEGRE	3,517,850	3,483,316	3,840,215	3,922,788
	TER	594,774	631,481	840,201	757,293
Excess agricultural water for production (Hm^3.Tg)	**MUGA**	**11.4**	**5.3**	**8.3**	**15.6**
	SEGRE	**536.4**	**-163.7**	**1.803.6**	**3.097.7**
	TER	**164.6**	**63.8**	**136.1**	**189.8**

5.- Graphical representation:







6.- Desired trend for adaptation: Remain the same or increase.

7.- Relevance of the indicator: This indicator reflects the absolute quantity of excess rainwater following agricultural use taking the production obtained into account.

WATER MANAGEMENT

Management Plan of the Catalonia River Basic District (2016-2021)

1.- Objective of the measure addressed by the indicator: Incorporation of climate change adaptation into sectorial policies.

2.- Source:

The document of the Management Plan, pending approval by the government of Catalonia, incorporates climate change impacts on water availability in two different temporal scenarios (pages 47 to 51):

http://aca-web.gencat.cat/aca/documents/Pla_de_gestio/2n_cicle/PdG/ca/03_pdg2_plagestio_dcfc.pdf

7.- Relevance of the indicator: The water management sector has included the climate change vector in its planning.

Water destined to irrigation in Catalonia

1.- Objective of the measure addressed by the indicator:

- Water conservation.
- Efficiency in water use.

2.- Source:

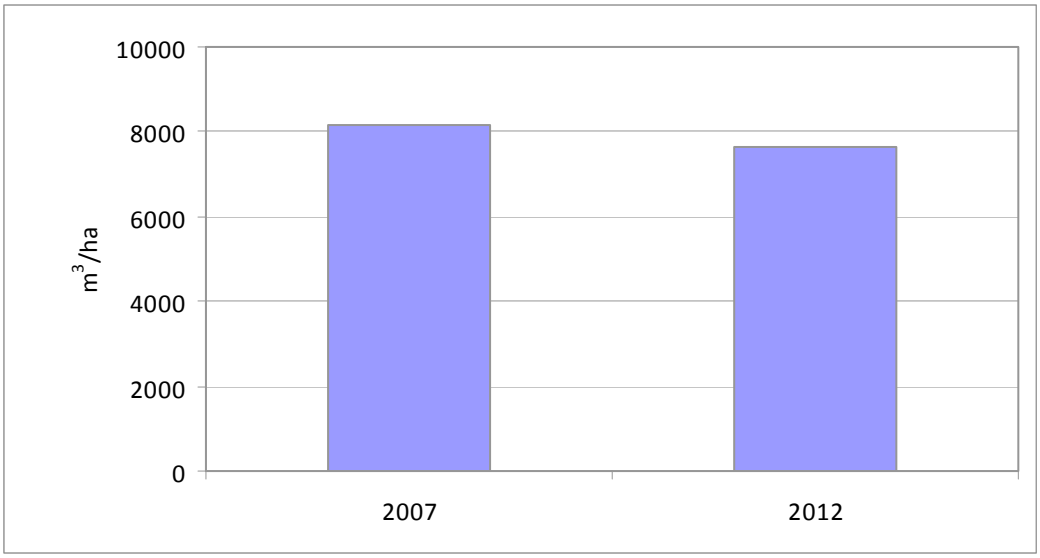
- Data from 2007: Estimation and prognosis of water demand in Catalonia. Technical guide [Estimació i prognosi de la demanda d'aigua a Catalunya. Bases tècniques] (2010). Catalan Water Agency [Agència Catalana de l'Aigua].
- Water demand for agricultural use in 2012: elaborated by the authors based on data from the 2013 EPTI document. Catalan Water Agency.
- Data on irrigated area in 2012: Catalonian Department of Agriculture, Livestock, Fisheries, Food, and Environment [Departament d'Agricultura, Ramaderia, Pesca, Alimentació i Medi natural]: http://agricultura.gencat.cat/ca/departament/dar_estadistiques_observatoris/dar_estructura_produccio/dar_estadistiques_agricoles/dar_estadistiques_definitives/

3.- Methodology: For calculating the demand for agricultural water use in 2012, overall data including agricultural irrigation and livestock consumption was used (2,073 hm^3/year) and water demand from the livestock sector from the year 2007 (41.37 hm^3) was subtracted from this value.

4.- Data:

	Water demand for agricultural use (m^3/year)	Irrigated area (ha)	Water destined to agricultural irrigation (m^3/ha/year)
2007	2,073,000,000	254,702	**8,139**
2012	2,035,000,000	266,500	**7,636**

5.- Graphical representation:



6.- Desired trend for adaptation: Decrease in allocated amount and annual volume: it is not only necessary to be more efficient - the same or better productivity with less water - but it is also necessary to reduce the annual volume of water destined to irrigation.

7.- Relevance of the indicator: This indicator allows the assessment of the evolution of efficiency in water use and total volumes of water destined to agricultural irrigation in Catalonia.

Municipal water utility (l/person/day).

1.- Objective of the measure addressed by the indicator: Water conservation.

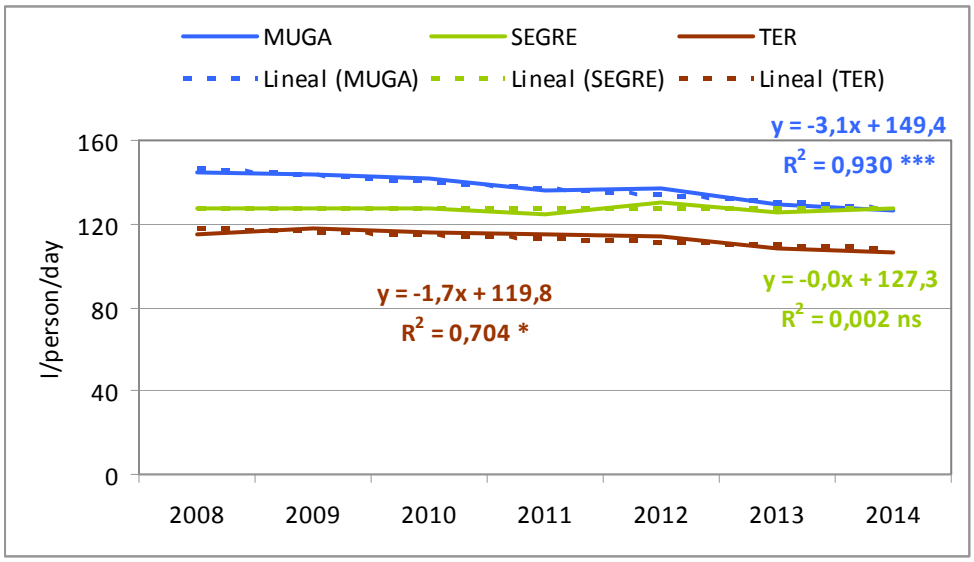
2.- Source consulted: Data on volumes consumed by the domestic sector: Catalonian Water Agency. City data: IDESCAT.

3.- Methodology: Compilation of annual data from the Catalonian Water Agency.

4.- Data: Allocation of water expressed in liters per habitant and day (l/person/day).

l/person/day	2008	2009	2010	2011	2012	2013	2014
MUGA	145	144	142	136	137	129	127
SEGRE	127	127	128	124	130	125	127
TER	115	118	116	115	114	108	106

5.- Graphical representation:



6.- Desired trend for adaptation: Decrease or stability (in some municipalities, domestic use has some values that are so low - below 100 l/person/d - that it is not recommended that they decrease further).

7.- Relevance of the indicator: This is a direct indicator of both water efficiency in homes (less consumption but the same or greater comfort) and conservation.

Volume of water used in urban systems (hm³/year)

1.- Objective of the measure addressed by the indicator: Water conservation.

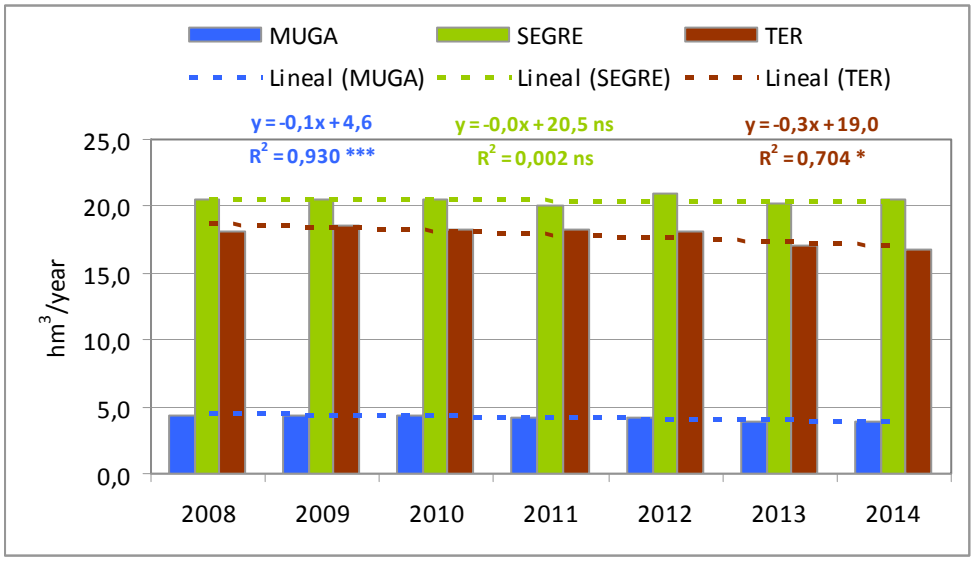
2.- Font: Catalonian Water Agency.

3.- Methodology: Recompilation of annual data from the Catalonian Water Agency.

4.- Data:

hm³/year	2008	2009	2010	2011	2012	2013	2014
MUGA	4.4	4.4	4.3	4.1	4.2	3.9	3.9
SEGRE	20.5	20.5	20.6	20.0	21.0	20.2	20.5
TER	18.2	18.6	18.3	18.3	18.1	17.1	16.8

5.- Graphical representation:



6.- Desired trend: Decrease.

7.- Relevance of the indicator: This is a good indicator since improved water conservation and efficiency will make urban areas more resilient to the impacts of climate change (decrease in water availability and more competition for the resource).

Status and degree of compliance with planning objectives for surface water bodies

1.- Objective of the measure addressed by the indicator: Water quality.

2.- Source: For the Muga and Ter:

- Data for 2008: Management Plan of the Catalonia River Basic District, Annex XVII, Status of Water Bodies (Catalonian Water Agency).
  http://aca-web.gencat.cat/aca/documents/Pla_de_gestio/1er_cicle/PdG/ca/Annex_XVII_PdG1cicle.pdf

- Data for 2013: Management Plan of the Catalonia River Basic District (2016-2021), Annex VIII, Status of water bodies and timeline for achievement of objectives, (Catalonian Water Agency).
  http://aca-web.gencat.cat/aca/documents/Pla_de_gestio/2n_cicle/PdG/ca/09_pdg2_annexVII.pdf

For the Segre:

- Data for 2008: Hydrological Plan for the Ebro Basin 2010-2015. Appendix 3: Status of water bodies within the hydrographic demarcation of the Ebro (Ebro Hydrographic Confederation).
  http://www.chebro.es:81/Plan%20Hidrologico%20Ebro%202010-2015/Memoria/4.-%20Apendice_3_Estado_masas_agua.pdf

- Data for 2013: Hydrologic plan for the Ebro Basin 2015-2021. Appendix 4.1: Environmental Objectives (Ebro Hydrographic Confederation).
  http://www.chebro.es:81/Plan%20Hidrologico%20Ebro%202015-2021/2%20Revisi%C3%B3n%202015-21%20del%20Plan%20Hidrol%C3%B3gico%20del%20Ebro/2.3%20Memoria/2.3.5.-%20Anexo%204/Anexo%204.1.-%20Objetivos%20medioambientales.pdf

3.- Methodology: Diagnosing the status of water bodies is carried out using the application of elements of quality defined in the respective Management Plans, and the data obtained from the application of the Monitoring and Control Program 2007-2012. Following the diagnosis, the results are compared with the objectives of planning. It is necessary to note that in the case of the Segre, the Ebro Hydrographic Confederation does not include fishery indicators for good quality, for this reason the obtained results must be interpreted with caution.

4.- Data:

MUGA

Status of 10 surface water bodies- MUGA

	Good	Less than good	Bad	n.d. (*)
2008	0	5	0	5
2013	2	0	8	0

(*)n.d.: Not analyzed

Degree of compliance of the 10 superficial water bodies 2013 MUGA

Good	Bad
20,0%	80,0%

SEGRE

Status of 100 superficial water bodies - SEGRE

	Good	Bad	n.d(*)
2008	37	26	37
2013	75	24	1

(*)n.d: not analyzed, many of them correspond to headwaters which in 2013 were in good status.

Degree of compliance of the 100 superficial water bodies 2013 SEGRE

Good	Bad	n.d(*)
75,0%	24,0%	1,0%

(*)n.d.: Not analyzed

TER

Status 42 superficial water bodies - TER

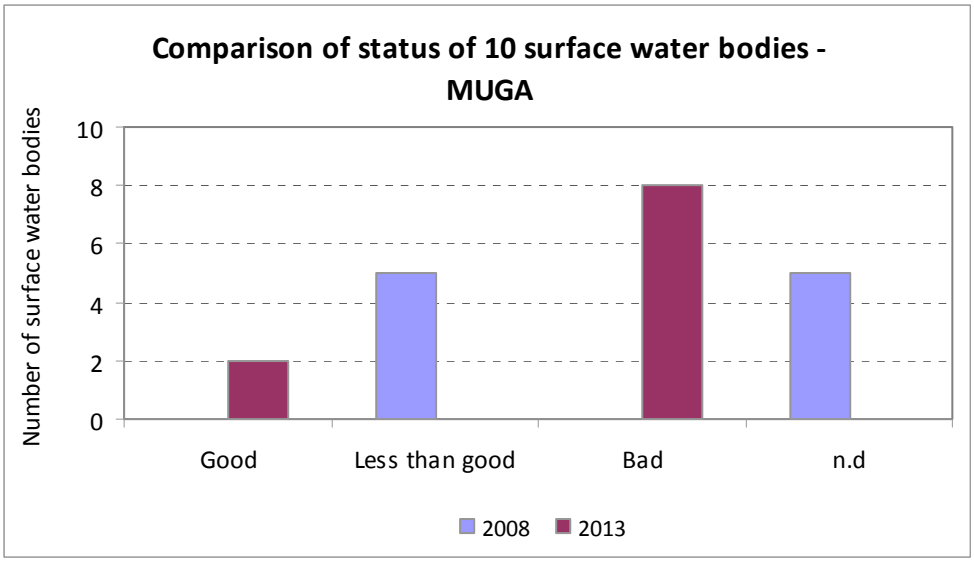
	Good	Less than good	Bad	n.d (*)
2008	15	14	0	13
2013	22	0	20	0

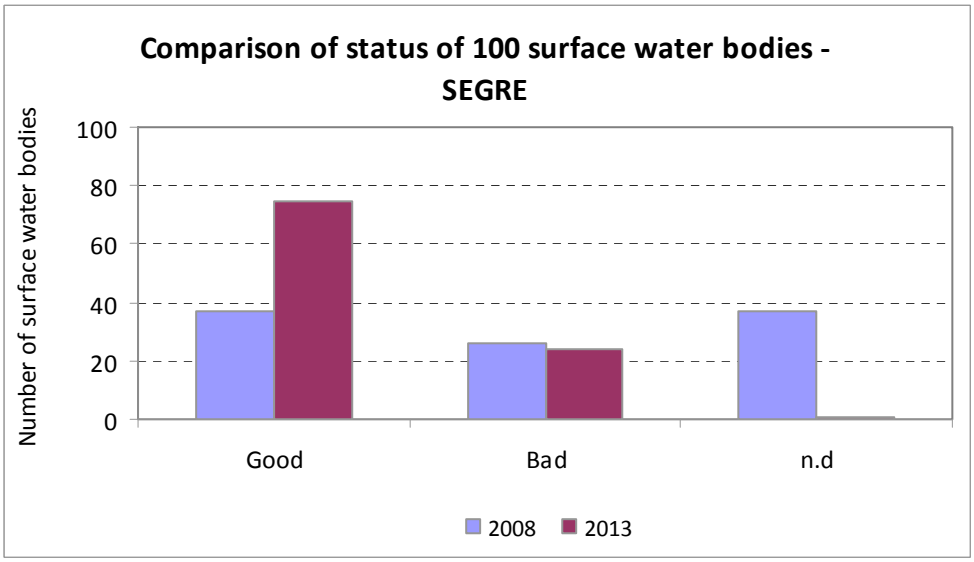
(*)n.d.: Not analyzed

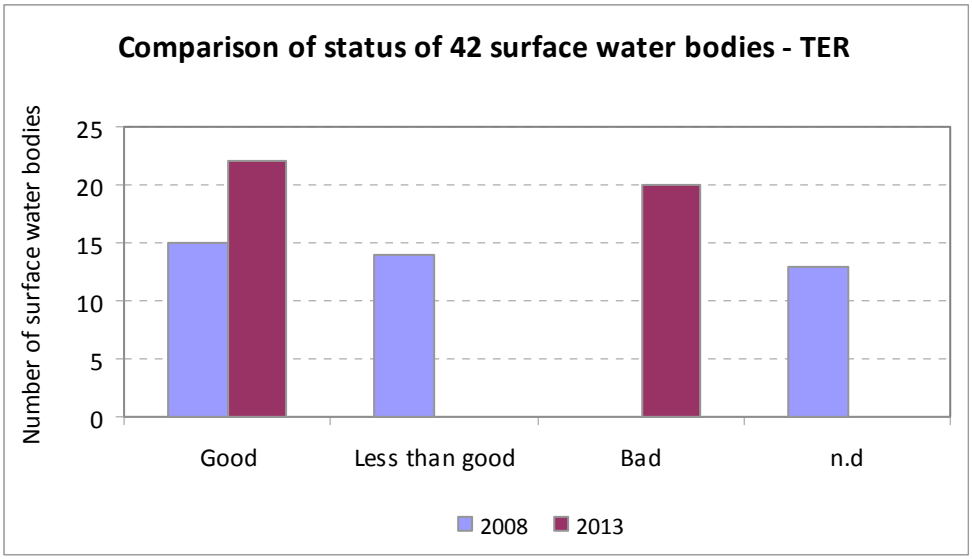
Degree of compliance of the 42 superficial water bodies 2013 TER

Good	Bad
52,4%	47,6%

5.- Graphical representation:







6.- Desired trend for adaptation: Increases, both in the number of water bodies which meet the objectives of planning, and as a result, the percentage.

7.- Relevance of the indicator: An improvement in the status of water bodies represents having good quality water both for ecosystems as well as the many other uses. Quality and quantity are inseparable, and therefore having quality means having quantity. In future planning horizons (2012, 2027) it will be necessary to be attentive to the degree of compliance of objectives and the sensitivity of these objectives to climate change impacts.

FOREST MANAGEMENT

General plan for Catalonian Forest Policy 2014-2024

1.- Objective of the measure addressed by the indicator: Incorporation of climate change adaptation into sectorial policies.

2.- Source:

http://www20.gencat.cat/portal/site/DAR/menuitem.3645c709047c363053b88e10b031e1a0/?vgnextoid=47ba883042529310VgnVCM2000009b0c1e0aRCRD&vgnextchannel=47ba883042529310VgnVCM2000009b0c1e0aRCRD&vgnextfmt=default

7.- Relevance of the indicator: The forestry sector has incorporated the climate change vector in its planning.

Area with forest management plans on private property (IOF by its Catalan acronym) (ha)

1.- Objective of the measure addressed by the indicator:

- Forest management and planning
- Sustainable and adaptive forest management

2.- Source: Data on area with IOF from the Forest Ownership Centre, Catalonian Department of Agriculture, Livestock, Fisheries, Food, and Environment [Centre de la Propietat Forestal, Departament d'Agricultura, Ramaderia, Pesca, Alimentació i Medi natural].

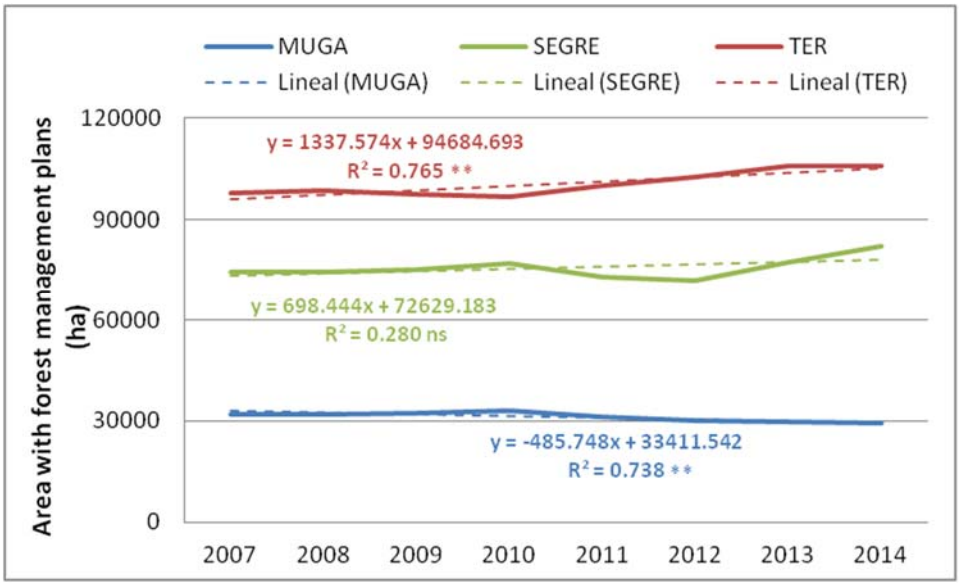
The area of forests on private property by basin has been estimated based on treed area in the Land Cover Map of Catalonia 2005 (MCSC 2005, CREAF) and cartography on public forests from the Department of Agriculture, Livestock, Fisheries, Food, and Environment.

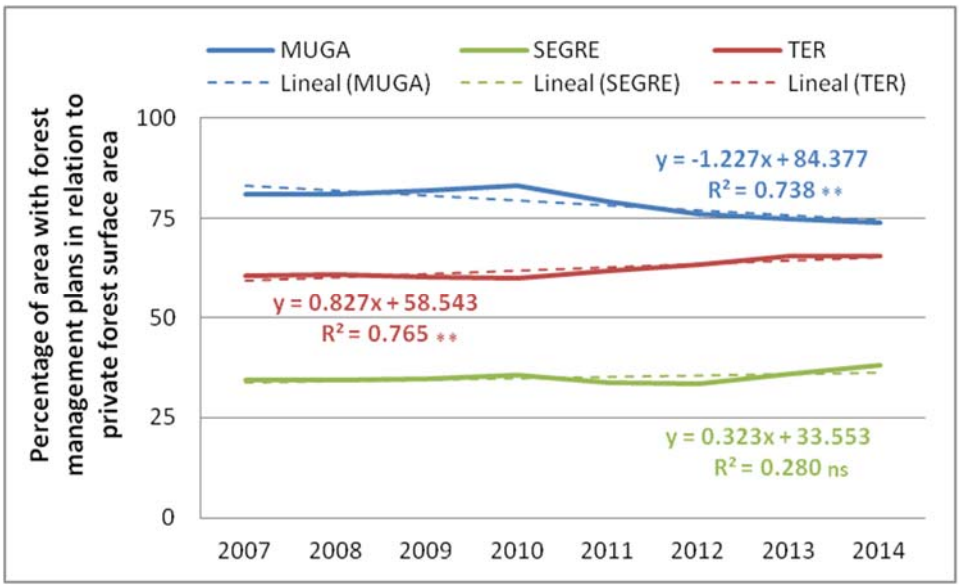
3.- Methodology: The data refer to forest area (in ha) on private property with management plans (IOF) in each basin, differentiating between 1) Simple forest management plan (PSGF), planning instrument for the management of forest estates with an area of less than 25 hectares; and 2) Technical plan for forest improvement and management (PTGMF) for forest estates with an area of 25 or more hectares. For estimating private forest area per basin the following procedure was followed: first, the treed area was estimated per basin based on the Land Cover Map of Catalonia 2005 level 5. Next, it was estimated what treed surface was within public forests based on cartography of the Department of Agriculture, Livestock, Fisheries, Food, and Environment. Finally, it was assumed that all forest surface not within a public forest is therefore private property. It is, therefore, an approximation of the forest area on private property.

4.- Data:

	Muga Basin				Segre Basin				Ter Basin			
	PSGF (ha)	PTGMF (ha)	IOF (ha)	% IOF/area private forest	PSGF (ha)	PTGMF (ha)	IOF (ha)	% IOF/area private forest	PSGF (ha)	PTGMF (ha)	IOF (ha)	% IOF/area private forest
2007	210.9	31,910.2	32,121.0	81.1%	217.1	74,137.6	74,354.7	34.4%	544.9	97,364.4	97,909.2	60.5%
2008	215.4	31,835.7	32,051.2	80.9%	294.5	74,042.2	74,336.7	34.3%	572.1	98,181.5	98,753.6	61.1%
2009	215.4	32,247.5	32,462.9	82.0%	294.5	74,949.1	75,243.5	34.8%	600.6	96,825.2	97,425.8	60.2%
2010	264.1	32,618.4	32,882.5	83.0%	329.7	76,781.9	77,111.6	35.6%	793.9	96,033.0	96,826.9	59.9%
2011	264.1	31,020.8	31,284.9	79.0%	339.4	72,792.4	73,131.8	33.8%	849.6	99,222.1	100,071.7	61.9%
2012	264.1	29,875.4	30,139.5	76.1%	339.4	71,750.1	72,089.5	33.3%	1,002.2	101,561.2	102,563.4	63.4%
2013	268.9	29,318.7	29,587.7	74.7%	434.0	77,110.7	77,544.7	35.8%	1,105.6	104,757.3	105,862.9	65.5%
2014	348.7	28,927.0	29,275.7	73.9%	684.8	81,680.1	82,364.9	38.1%	1,261.5	104,955.2	106,216.7	65.7%

5.- Graphical representation:





6.- Desired trend for adaptation: Progressively increasing values of area tending toward covering the private forest area in the basins (39,598 ha a la Muga, 161,737 ha al Ter i 216,460 ha al Segre). Progressively increasing percentage values approaching 100%.

7.- Relevance of the indicator: This is a direct indicator of the degree of forest planning in a given area, although it does not provide information about its execution (if the planning is being carried out or not).

Relationship (%) between forest area having undergone forest management practices and total area with forest management plans on private property

1.- Objective of the measure addressed by the indicator:

- Forest planning and management
- Sustainable and adaptive forest management

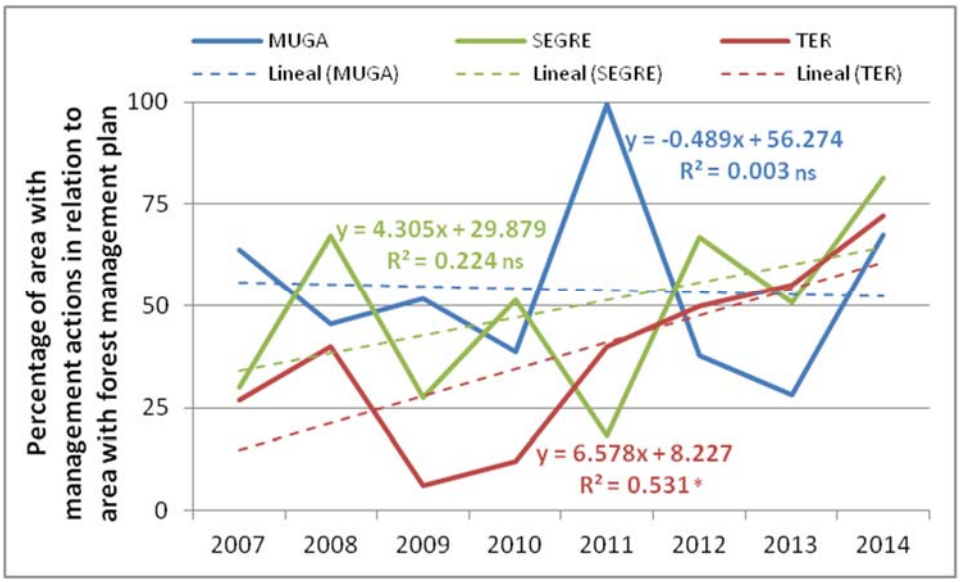
2.- Source: Forest Ownership Centre, Catalonian Department of Agriculture, Livestock, Fisheries, Food, and Environment

3.- Methodology: Information derived from the area having undergone management actions each year and crossed with planned area to undergo management corresponding to the Technical Plans for Forest Improvement and Management (PTGMF) on private property, not considering harvesting actions undertaken without planning due to their unexpected nature: cutting for forest health issues (forest fires, windfall, snow, etc.).

4.- Data:

	Percentage of area with management action / Planned area							
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Muga Basin	64%	46%	52%	39%	99%	38%	28%	67%
Segre Basin	30%	67%	28%	51%	18%	67%	51%	82%
Ter Basin	27%	40%	6%	12%	40%	50%	55%	72%

5.- Graphical representation:



6.- Desired trend for adaptation: Progressively increasing values approaching 100%. It is also desirable that the indicator value is relatively stable.

7.- Relevance of the indicator: This is a direct indicator of the degree of execution of planned management, showing the effectiveness of forest planning in a given area.

Area of harvesting (ha) on private property

1.- Objective of the measure addressed by the indicator:

- Forest planning and management
- Sustainable and adaptive forest management

2.- Source: Forest Ownership Centre, Catalonian Department of Agriculture, Livestock, Fisheries, Food, and Environment

3.- Methodology: The data refer to the area where authorized harvesting has been carried out in each basin within private land holdings.

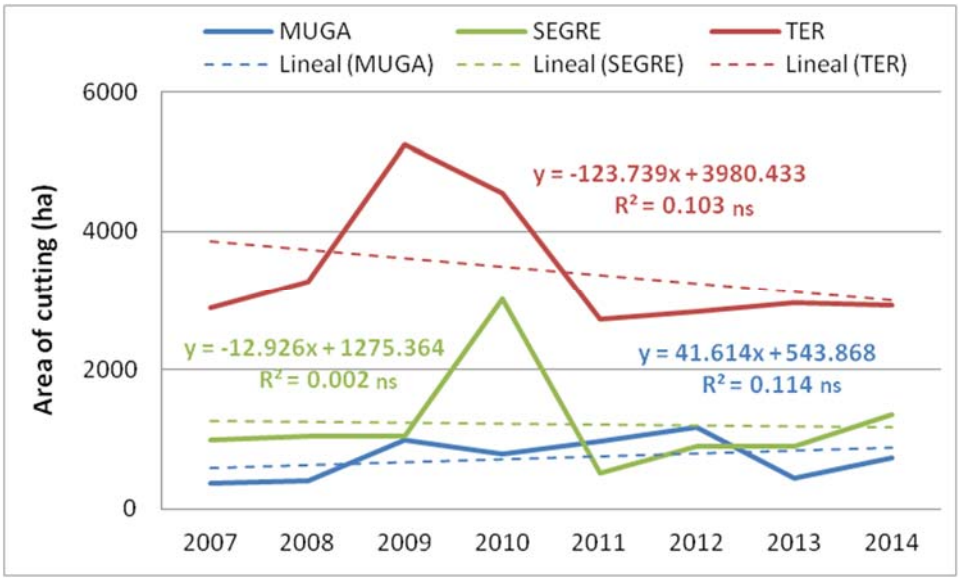
4.- Data:

	Area of harvesting (ha)								
Harvesting activities in Muga Basin	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**∑**
Thinning for stand improvement	23.9			85.2	90.0	44.8	25.1	12.6	**281.6**
Firewood harvesting	23.0	10.5	3.0	102.6	6.0	5.0	3.0	26.1	**179.1**
Clearcutting	0.4			4.7	2.0	37.5	1.6	15.5	**61.8**
Cutting of fire-affected vegetation					18.4	661.1	65.4	158.7	**903.6**
Cutting of snow-affected vegetation			25.7	48.4	16.5				**90.6**
Cutting of wind-affected vegetation		21.6	441.3						**462.9**
Final cutting	4.0	1.5			3.9	17.7			**27.1**
Shelterwood cutting	109.6								**109.6**
Forest health-promoting cutting		2.8			35.0			3.4	**41.3**
Selection cutting	200.5	371.4	522.2	535.9	796.5	397.6	352.6	515.0	**3,691.5**
∑	**361.3**	**407.8**	**992.2**	**776.9**	**968.3**	**1,163.7**	**447.6**	**731.3**	**5,849.0**

	Area of harvesting (ha)								
Harvesting activities in Segre Basin	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**∑**
Thinning for stand improvement	126.0	86.9	106.3	10.4	159.5	74.4	107.3	371.4	**1,042.1**
Firewood harvesting	22.0	23.0	31.0	1,092.7	37.0	30.0	28.0	40.0	**1,303.7**
Harvesting for thinning	10.0					1.8			**11.8**
Clearcutting	0.1	0.1				7.4		5.8	**13.3**
Cutting of fire-affected vegetation			254.6		50.9			28.0	**333.5**
Cutting of snow-affected vegetation			161.9	1,528.4	31.7				**1,722.0**
Cutting of deceased vegetation	1.5								**1.5**
Cutting of wind-affected vegetation			78.1				43.4		**121.4**
Final cutting		6.4				19.1			**25.5**
Shelterwood cutting	2.9				10.0		4.4		**17.4**
Forest health-promoting cutting	18.6	44.1					9.7		**72.5**
Selection cutting	806.1	875.1	412.1	383.7	227.3	753.7	705.6	909.4	**5,073.0**
∑	**987.2**	**1,035.5**	**1,043.9**	**3,015.2**	**516.4**	**886.4**	**898.4**	**1,354.5**	**9,737.6**

	Area of harvesting (ha)								
Harvesting activities in Ter Basin	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**∑**
Thinning for stand improvement	605.3	886.5	239.4	260.2	351.9	405.9	581.5	670.9	**4,001.5**
Firewood harvesting	66.9	37.9	20.0	155.2	27.0	41.0	38.0	26.0	**412.0**
Shelterwood cutting	28.6						20.5		**49.0**
Clearcutting	140.2	107.0	58.6	36.9	96.4	122.8	110.3	95.5	**767.7**
Seed cutting		11.0			19.0	2.4			**32.4**
Cutting of fire-affected vegetation				1.0			36.9		**37.9**
Cutting of snow-affected vegetation		2.2	3,059.1	2,688.5	692.5			13.0	**6,455.3**
Cutting of deceased vegetation	46.2								**46.2**
Cutting of wind-affected vegetation	16.8		404.6						**421.4**
Cutting of hailstorm-affected vegetation					1.0		2.0		**3.0**
Cutting of drought-affected vegetation	81.8	73.5	9.2	7.2			102.5	3.0	**277.3**
Seed cutting								46.6	**46.6**
Final cutting	77.4	7.2	27.2	16.5	46.5	141.1	15.8	36.4	**368.2**
Preparatory cutting	19.5		32.0	19.0	8.9	52.8		3.1	**135.2**
Forest health-promoting cutting	63.5	362.1	370.2	144.6	120.1	291.1	171.0	32.1	**1,554.7**
Selection cutting	1,745.5	1,776.9	1,027.5	1,226.3	1,350.3	1,776.7	1,883.9	1,993.5	**12,780.6**
∑	**2,891.6**	**3,264.3**	**5,247.6**	**4,555.5**	**2,713.6**	**2,833.9**	**2,962.4**	**2,920.0**	**27,388.9**

5.- Graphical representation:



6.- Desired trend for adaptation: With the current situation of sub-optimal exploitation (less than planned), it is desirable that this value increases to values close to the planned area for management actions in a given year. It is also desirable that the indicator value is relatively stable.

7.- Relevance of the indicator: High values indicate a good level of use of the productive function of the forest. Low values are indicative of neglect of this function.

Forest resources (timber and firewood in tons) harvested on private property

1.- Objective of the measure addressed by the indicator:

- Forest planning and management
- Sustainable and adaptive forest management

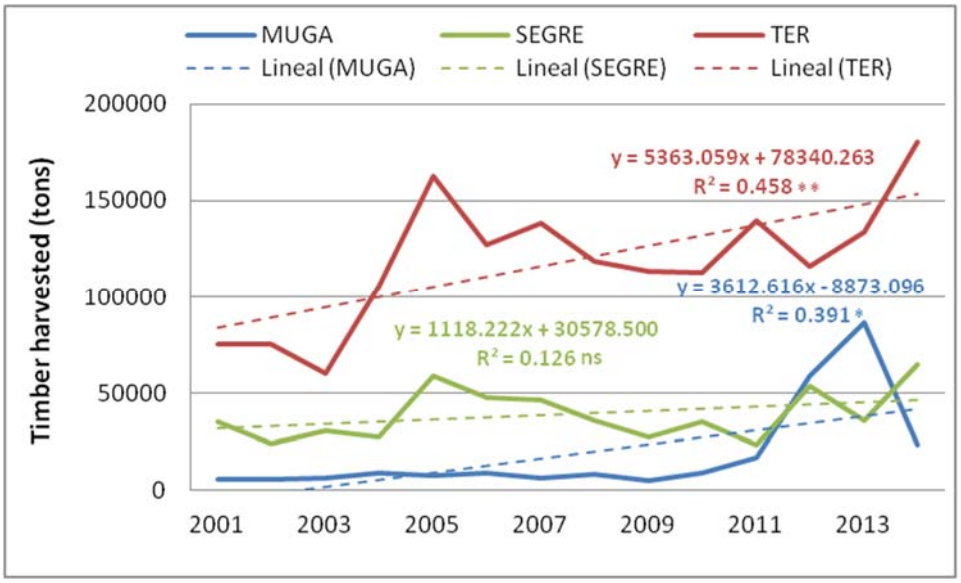
2.- Source: Forest Ownership Centre, Catalonian Department of Agriculture, Livestock, Fisheries, Food, and Environment

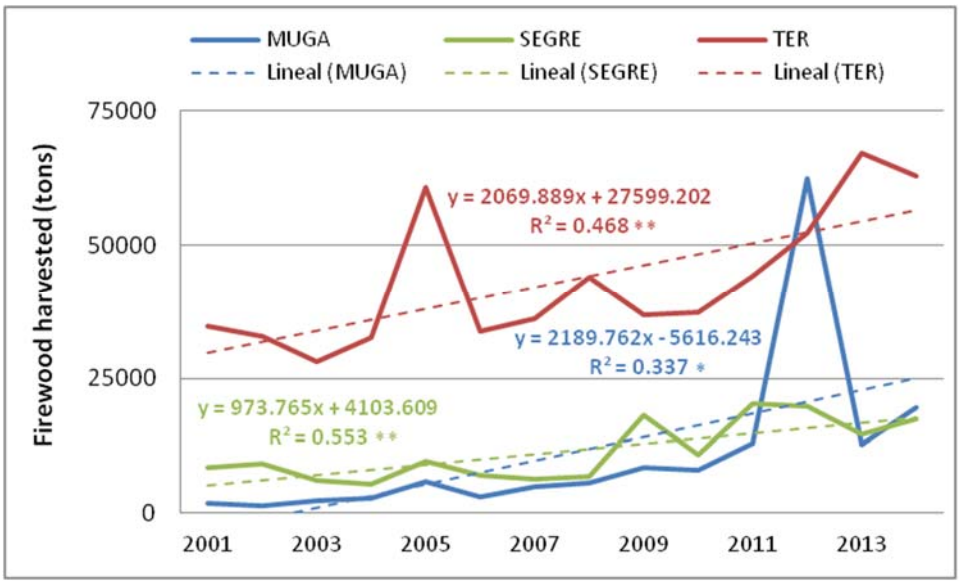
3.- Methodology: Data on harvesting of timber and firewood (in tons) carried out on private property, with and without management plans.

4.- Data:

	Muga		Segre		Ter	
Year	Timber harvested (t)	Firewood harvested (t)	Timber harvested (t)	Firewood harvested (t)	Timber harvested (t)	Firewood harvested (t)
2001	5,476.8	1,690.9	35,091.2	8,475.0	75,555.6	34,782.0
2002	5,335.2	1,376.1	23,687.5	9,233.1	75,235.6	32,890.8
2003	6,197.0	2,303.5	30,634.0	6,093.8	60,314.7	28,063.8
2004	8,766.8	2,740.5	27,545.8	5,307.8	105,612.5	32,669.8
2005	7,648.0	5,924.2	58,720.1	9,577.2	162,535.7	60,705.2
2006	8,759.2	2,908.4	47,802.6	7,070.4	127,111.0	33,658.7
2007	6,378.5	4,940.7	46,086.0	6,202.0	138,471.6	36,229.4
2008	8,205.6	5,512.5	35,813.2	6,719.2	118,727.2	43,923.7
2009	4,678.4	8,348.9	27,236.5	18,067.0	113,459.8	36,959.2
2010	8,646.0	7,890.8	35,372.1	10,835.2	112,544.5	37,335.5
2011	16,882.0	12,942.8	23,397.6	20,354.1	139,961.5	44,104.6
2012	58,731.6	62,529.7	53,268.8	19,759.5	115,931.8	52,330.0
2013	86,358.8	12,583.4	35,783.1	14,665.8	133,920.7	67,194.8
2014	23,037.4	19,605.1	65,073.9	17,335.7	180,502.7	62,879.6

5.- Graphical representation:





6.- Desired trend for adaptation: With the current situation of sub-optimal exploitation, it is desirable that this value increases progressively. It is also desirable that the indicator value is relatively stable.

7.- Relevance of the indicator: High values indicate a good level of use of the productive function of the forest. Low values are indicative of neglect of this function. Abnormal peaks in the data are due to extreme events such as wildfires.

Forest resources (timber in m^3) harvested on public lands

1.- Objective of the measure addressed by the indicator:

- Forest planning and management
- Sustainable and adaptive forest management

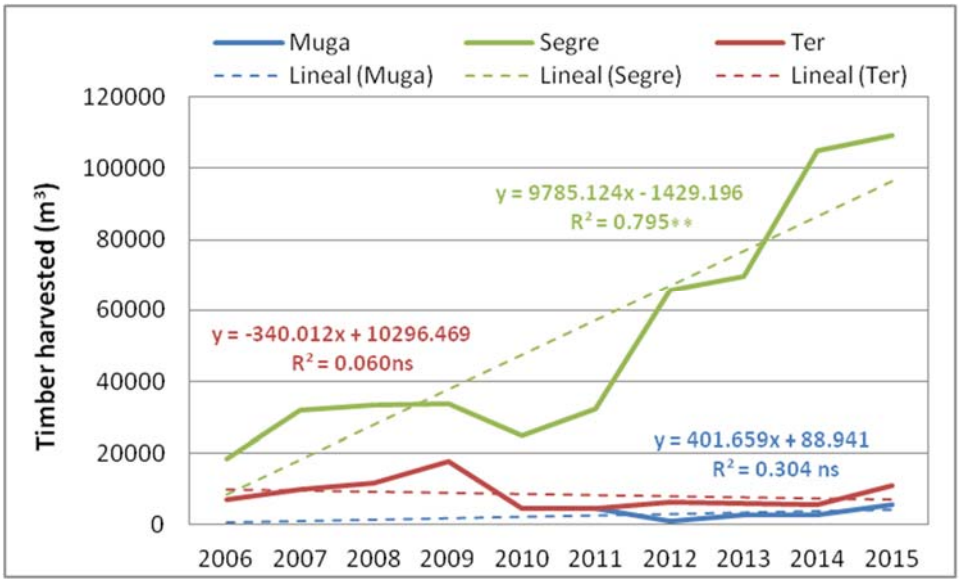
2.- Source: Head of the Public Forest Section, Directorate General for Forests, Department of Agriculture, Livestock, Fisheries, Food, and Environment

3.- Methodology: Annual data on planned harvestings to be undertaken in public forests at the municipal level. These are not data on actual harvests since those data are not available on the municipal level.

4.- Data:

	Muga	Segre	Ter
Year	Timber harvested (m^3)	Timber harvested (m^3)	Timber harvested (m^3)
2006		18,330.0	6,995.0
2007		31,869.2	9,838.0
2008	1,362.0	33,279.2	11,641.3
2009		33,895.6	17,860.0
2010		24,783.3	4,390.0
2011	4,400.0	32,154.3	4,511.5
2012	943.0	65,679.0	6,374.1
2013	2,700.0	69,684.4	6,071.1
2014	2,700.0	105,040.1	5,670.1
2015	5,700.0	109,174.7	10,912.8

5.- Graphical representation:



6.- Desired trend for adaptation: With the current situation of sub-optimal exploitation, it is desirable that this value increases progressively. It is also desirable that the indicator value be relatively stable.

7.- Relevance of the indicator: High values indicate a good level of use of the productive function of the forest. Low values are indicative of neglect of this function. Abnormal peaks in the data are due to extreme events such as wildfires.

Density (trees/ha) and over bark volume harvested (m^3/ha)

1.- Objective of the measure addressed by the indicator:

- Forest planning and management
- Sustainable and adaptive forest management

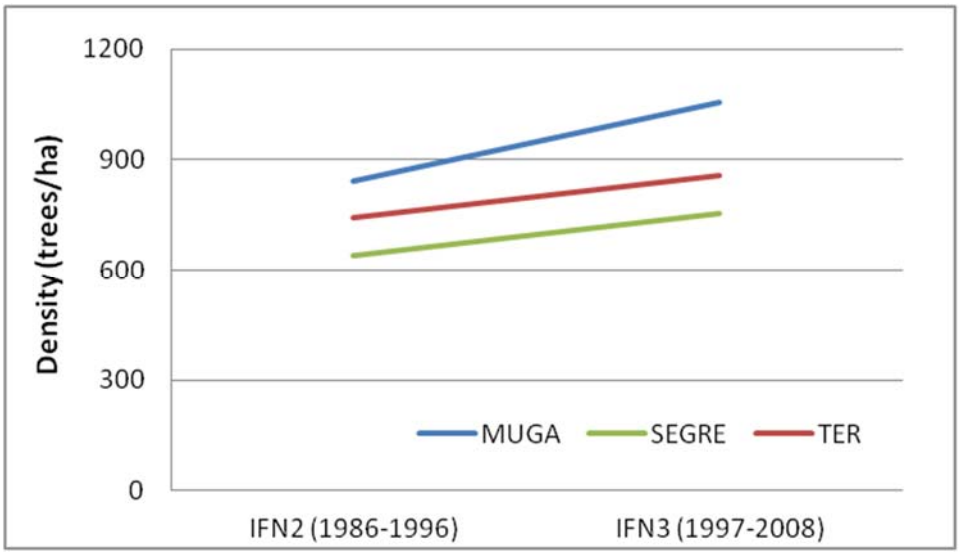
2.- Source: Elaborated by the authors based on data from the Spanish National Forest Inventory (IFN2 and IFN3).

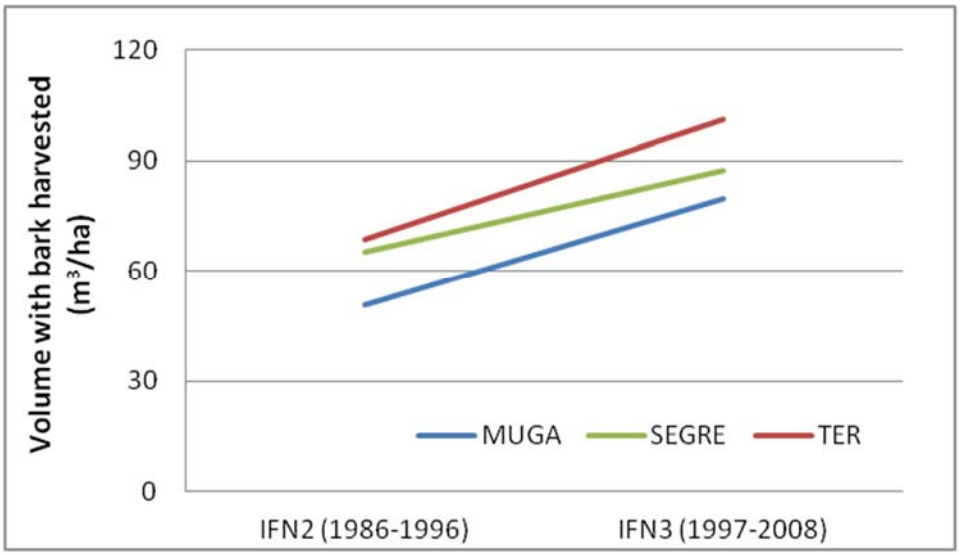
3.- Methodology: Mean values of all the IFN2 and IFN3 parcels within the basins: 354 in the Muga, 1,578 in the Ter and 3,321 in the Segre. The IFN2 data correspond to the 1986-1996 period and the IFN3 1997-2008.
The over bark volume is the volume of a trunk from the base to the apex, expressed per unit area. It is calculated by multiplying the basal area by the height and by the shape coefficient (which is the ratio of the actual volume of the trunk to the volume it would have if it were a cylinder whose base is equal to its real basal area and of the same height).

4.- Data:

	Density (trees/ha)		Over bark volume (m^3/ha)	
	IFN2	IFN3	IFN2	IFN3
Muga	840.6	1,056.1	50.8	79.6
Segre	638.9	753.9	65.0	87.2
Ter	744.4	858.9	68.6	101.0

5.- Graphical representation:





6.- Desired trend for adaptation: With the current situation of sub-optimal exploitation, it is desirable for density to trend toward stability and the harvested over bark volume to increase.

7.- Relevance of the indicator: Stable values for density and high values of harvested over bark volume indicate a good status of use of the productive function of the forest.

Area burnt by forest fires (ha)

1.- Objective of the measure addressed by the indicator:

- Fire prevention
- Sustainable and adaptive forest management

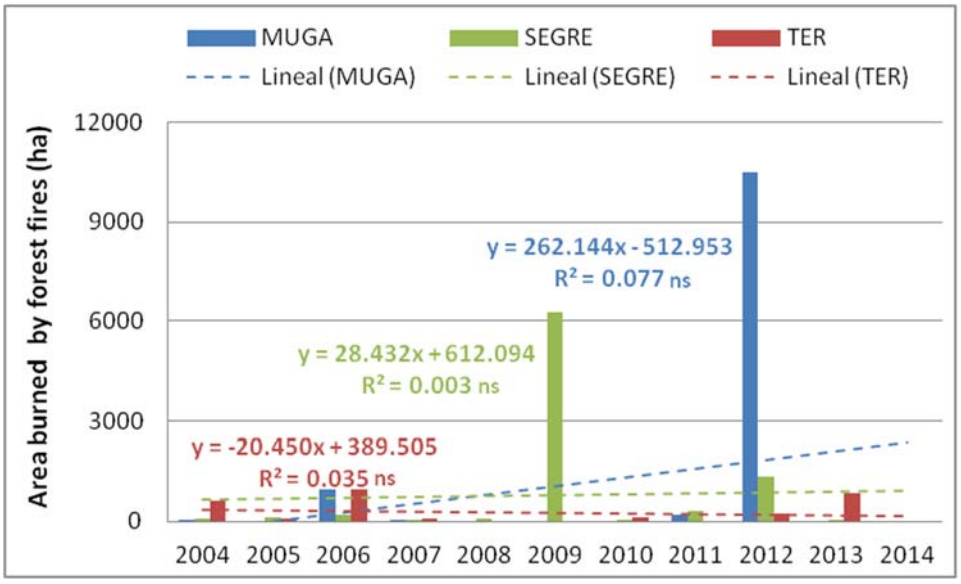
2.- Source: Created by the authors based on data from the Forest Ownership Centre (Department of Agriculture, Livestock, Fisheries, Food, and Environment).

3.- Methodology: Information on forest fires corresponds to total affected area (ha)

4.- Data:

	Area burnt by forest fires (ha)		
	Muga Basin	Segre Basin	Ter Basin
2004	24.3	84.6	633.5
2005	0.0	129.7	70.3
2006	949.6	201.3	952.0
2007	10.3	64.6	77.6
2008	0.0	104.1	0.0
2009	0.0	6,267.9	0.0
2010	0.0	35.3	124.4
2011	198.1	32.4	0.0
2012	10,476.8	1,361.2	222.8
2013	0.0	32.6	854.3
2014	0.0	0.0	0.0

5.- Graphical representation:



6.- Desired trend for adaptation: Decrease.

7.- Relevance of the indicator: The best prepared forests will be those which do not contribute to the propagation of large forest fires once a fire has begun.

Head of sheep and goats (number of individuals)

1.- Objective of the measure addressed by the indicator:

- Fire prevention
- Stimulus to ranching

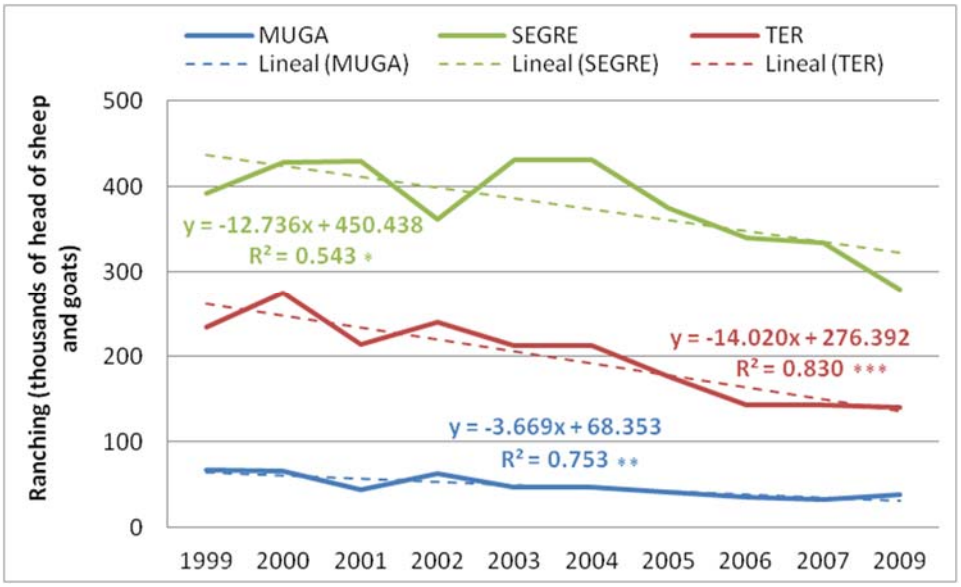
2.- Source: Elaborated by the authors based on data from IDESCAT (Catalonian Institute of Statistics): *Agriculture, Livestock / Animal Husbandry / Head of livestock. By species, counties, areas and provinces.* Data on sheep and goats in the region for the period 1999-2007 and 2009.
http://www.idescat.cat/pub/?id=aec&n=451&t=2001

3.- Methodology: The original data from IDESCAT correspond to number of sheep and goats by county. In order to estimate the number of livestock per MEDACC basin, the counties pertaining to each basin were first determined by consulting the relevant cartography (see Annex 2). Within each basin the number of livestock in the counties was summed for each year. This indicator is an estimation of ranching in the basins. It was not possible to include the number of horses (which are also included in ranching) because these data were not available at the county level (only available at provincial level).

4.- Data:

	Ranching (thousands of head of sheep and goats)		
	Muga Basin	Segre Basin	Ter Basin
1999	67.9	392.3	234.6
2000	65.7	428.8	275.0
2001	44.0	430.3	213.7
2002	62.8	362.5	240.1
2003	46.8	431.4	213.2
2004	46.8	431.4	213.2
2005	41.4	374.8	176.4
2006	35.4	339.7	142.5
2007	32.9	334.0	143.4
2009	38.0	278.8	140.7

5.- Graphical representation:



6.- Desired trend for adaptation: That it increases in a sustainable manner.

7.- Relevance of the indicator: "[...] Although much of ranching in Catalonia pertains to the beef sector, due to the fact that official figures do not distinguish between intensive and extensive beef livestock farming, this evaluation has been limited to subsectors that clearly correspond to [extensive] ranching..." (IEEEP, 2010). These subsectors are sheep, goats, and horses. The data are accompanied by unavoidable inaccuracies because such enterprises include housed animals, however these are relatively few in number.

7. ANNEX 2: Counties, municipalities, and meteorological stations analyzed

Table 1. Listing of counties within each basin. In the case of the Muga and Ter, selected counties are those which have more than 10% of their area within the basin; in the case of the Segre, this figure is 20%.

MUGA	SEGRE	TER
Alt Empordà	Pallars Sobirà	Ripollès
	Alt Urgell	Garrotxa
	Alta Ribagorça	Pla de l'Estany
	Cerdanya	Osona
	Solsonès	Gironès
	Pallars Jussà	Baix Empordà
	Noguera	Selva
	Segrià	
	Segarra	
	Pla d'Urgell	
	Garrigues	
	Urgell	

Table 2. Listing of municipalities in each basin (municipalities which have more than 10% of their area within the basin).

MUGA		SEGRE		TER	
INE code	Municipality	INE code	Municipality	INE code	Municipality
17001	Agullana	25001	Abella de la Conca	17002	Aiguaviva
17003	Albanyà	25002	Àger	08004	Alpens
17012	Avinyonet de Puigventós	25003	Agramunt	17007	Amer
17234	Biure	25038	Aitona	17008	Anglès
17029	Boadella i les Escaules	25005	Alàs i Cerc	17015	Banyoles
17026	Borrassà	25007	Albatàrrec	17020	Bescanó
17031	Cabanelles	25008	Albesa	17025	Bordils
17030	Cabanes	25010	Alcanó	17016	Bàscara
17041	Cantallops	25011	Alcarràs	17028	Brunyola
17042	Capmany	25012	Alcoletge	17033	Caldes de Malavella
17047	Castelló d'Empúries	25013	Alfarràs	08037	Calldetenes
17051	Cistella	25014	Alfés	17035	Camós
17060	Darnius	25015	Algerri	17036	Campdevànol
17005	el Far d'Empordà	25016	Alguaire	17037	Campelles
17064	Espolla	25017	Alins	17038	Campllong
17066	Figueres	25021	Almenar	17039	Camprodon
17086	la Jonquera	25022	Alòs de Balaguer	17040	Canet d'Adri

MUGA		SEGRE		TER	
INE code	Municipality	INE code	Municipality	INE code	Municipality
17014	la Vajol	17006	Alp	17044	Cassà de la Selva
17088	Lladó	25023	Alpicat	17049	Celrà
17093	Llers	25024	Alt Àneu	17050	Cervià de Ter
17100	Masarac	25027	Anglesola	08070	Collsuspina
17102	Maçanet de Cabrenys	25029	Arbeca	17055	Colomers
17106	Mollet de Peralada	25032	Arséguel	17056	Cornellà del Terri
17111	Navata	25033	Artesa de Lleida	17063	Espinelves
17115	Ordis	25034	Artesa de Segre	17065	Esponellà
17132	Peralada	25036	Aspa	17067	Flaçà
17135	Pont de Molins	08016	Bagà	17068	Foixà
17136	Pontós	25039	Baix Pallars	08083	Folgueroles
17143	Rabós	25040	Balaguer	17070	Fontanilles
17158	Sant Climent Sescebes	25041	Barbens	17071	Fontcoberta
17171	Sant Llorenç de la Muga	25044	Bassella	17073	Fornells de la Selva
17182	Santa Llogaia d'Àlguema	25046	Belianes	17079	Girona
17196	Terrades	25170	Bellaguarda	17080	Gombrèn
17214	Vilabertran	25047	Bellcaire d'Urgell	17081	Gualta
17221	Vilafant	25048	Bell-lloc d'Urgell	08100	Gurb
17228	Vilanant	25049	Bellmunt d'Urgell	17085	Jafre
		25050	Bellpuig	17087	Juià
		25051	Bellver de Cerdanya	17189	la Cellera de Ter
		25052	Bellvís	17130	la Pera
		25053	Benavent de Segrià	17195	la Tallada d'Empordà
		25055	Biosca	17096	les Llosses
		17024	Bolvir	08116	les Masies de Roda
		25060	Cabanabona	08117	les Masies de Voltregà
		25061	Cabó	17133	les Planes d'Hostoles
		08031	Calaf	17089	Llagostera
		08036	Calonge de Segarra	17090	Llambilles
		25062	Camarasa	17091	Llanars
		25904	Castell de Mur	17097	Madremanya
		25064	Castellar de la Ribera	08111	Malla
		25067	Castelldans	08112	Manlleu
		08060	Castellfollit de Riubregós	17107	Molló
		25068	Castellnou de Seana	08131	Montesquiu
		25069	Castelló de Farfanya	08129	Muntanyola
		25070	Castellserà	17112	Ogassa
		25071	Cava	08150	Orís
		25072	Cervera	17116	Osor
		25073	Cervià de les Garrigues	17123	Palol de Revardit
		25074	Ciutadilla	17125	Pardines

MUGA		SEGRE		TER	
INE code	Municipality	INE code	Municipality	INE code	Municipality
		25077	Coll de Nargó	17134	Planoles
		25161	Conca de Dalt	17137	Porqueres
		43046	Conesa	17142	Quart
		25078	Corbins	17043	Queralbs
		25079	Cubells	17145	Ribes de Freser
		17061	Das	17147	Ripoll
		25076	el Cogul	17150	Riudellots de la Selva
		25158	el Palau d'Anglesola	08183	Roda de Ter
		25168	el Poal	08901	Rupit i Pruit
		25030	el Pont de Bar	17155	Salt
		25173	el Pont de Suert	08195	Sant Agustí de Lluèanès
		25206	el Soleràs	17157	Sant Andreu Salou
		25253	el Vilosell	17183	Sant Aniol de Finestres
		25004	els Alamés	08199	Sant Bartomeu del Grau
		25153	els Omellons	08201	Sant Boi de Lluèanès
		25154	els Omells de na Gaia	17161	Sant Feliu de Pallerols
		25911	els Plans de Sió	17163	Sant Gregori
		25224	els Torms	17164	Sant Hilari Sacalm
		25082	Espot	08215	Sant Hipòlit de Voltregà
		25088	Estamariu	17167	Sant Joan de les Abadesses
		25085	Estaràs	17168	Sant Joan de Mollet
		25086	Esterri d'Àneu	17166	Sant Jordi Desvalls
		25087	Esterri de Cardós	17169	Sant Julià de Ramis
		25089	Farrera	08220	Sant Julià de Vilatorta
		25908	Fígols i Alinyà	17903	Sant Julià del Llor i Bonmatí
		25093	Fondarella	17172	Sant Martí de Llúmena
		17069	Fontanals de Cerdanya	17173	Sant Martí Vell
		25094	Foradada	17177	Sant Pau de Segúries
		43061	Forés	08233	Sant Pere de Torelló
		25097	Fulleda	08237	Sant Quirze de Besora
		25098	Gavet de la Conca	08241	Sant Sadurní d'Osormort
		17078	Ger	08265	Sant Vicent de Torelló
		25099	Golmés	08243	Santa Cecília de Voltregà
		25103	Granyanella	17181	Santa Cristina d'Aro
		25105	Granyena de les Garrigues	08246	Santa Eugènia de Berga
		25104	Granyena de Segarra	08247	Santa Eulàlia de Riuprimer
		17082	Guils de Cerdanya	08253	Santa Maria de Besora
		25109	Guimerà	08254	Santa Maria de Corcó
		25110	Guissona	17186	Sarrià de Ter

MUGA		SEGRE		TER	
INE code	Municipality	INE code	Municipality	INE code	Municipality
		25115	Isona i Conca Dellà	17187	Saus, Camallera i Llampaies
		17084	Isòvol	17191	Serra de Daró
		25112	Ivars de Noguera	17192	Setcases
		25113	Ivars d'Urgell	08269	Seva
		25114	Ivorra	08271	Sobremunt
		25910	Josa i Tuixén	08272	Sora
		25118	Juncosa	17194	Susqueda
		25119	Juneda	08278	Taradell
		25042	la Baronia de Rialb	08280	Tavertet
		25092	la Floresta	08275	Tavèrnoles
		25096	la Fuliola	08283	Tona
		25101	la Granadella	08285	Torelló
		25102	la Granja d'Escarp	17199	Torroella de Montgrí
		25903	la Guingueta d'Àneu	17201	Toses
		25136	la Molsosa	17204	Ullà
		25169	la Pobla de Cérvoles	17203	Ultramort
		25171	la Pobla de Segur	17170	Vallfogona de Ripollès
		25174	la Portella	17211	Verges
		25035	la Sentiu de Sió	08298	Vic
		25203	la Seu d'Urgell	17212	Vidrà
		25227	la Torre de Cabdella	17215	Vilablareix
		25043	la Vall de Boí	17216	Viladasens
		25909	la Vansa i Fórnols	17218	Vilademuls
		25006	l'Albagés	17220	Viladrau
		25009	l'Albi	17224	Vilallonga de Ter
		25037	les Avellanes i Santa Linya	08303	Vilanova de Sau
		25058	les Borges Blanques	17233	Vilobí d'Onyar
		25152	les Oluges	17232	Vilopriu
		25906	les Valls d'Aguilar		
		25239	les Valls de Valira		
		25081	l'Espluga Calba		
		25122	Linyola		
		25123	Lladorre		
		25124	Lladurs		
		25125	Llardecans		
		25126	Llavorsí		
		25120	Lleida		
		25127	Lles de Cerdanya		
		25128	Llimiana		
		17094	Llívia		
		25129	Llobera		

MUGA		SEGRE		TER	
INE code	Municipality	INE code	Municipality	INE code	Municipality
		43073	Llorac		
		25133	Maials		
		25130	Maldà		
		25131	Massalcoreig		
		25132	Massoteres		
		25134	Menàrguens		
		25135	Miralcamp		
		25137	Mollerussa		
		25139	Montellà i Martinet		
		25140	Montferrer i Castellbò		
		25138	Montgai		
		8133	Montmaneu		
		25142	Montoliu de Lleida		
		25141	Montoliu de Segarra		
		25143	Montornés de Segarra		
		25145	Nalec		
		25025	Naut Aran		
		25148	Odén		
		25149	Oliana		
		25150	Oliola		
		25155	Organyà		
		25156	Os de Balaguer		
		25157	Ossó de Sió		
		43101	Passanant i Belltall		
		25164	Penelles		

Table 3. Listing of meteorological stations in each basin, used for the calculation of indicators with direct relevance to water.

MUGA	SEGRE	TER
Cabanes d'Empordà	Aitona	Anglès
Castelló d'Empúries	Cervera	Banyoles
Espolla	Das	Cassà de la Selva
	el Poal	la Tallada d'Empordà
	el Pont de Suert	Muntanyola
	la Granadella	Orís
	la Seu d'Urgell	
	Lleida - Raïmat	
	Oliana	
	Oliola	

MUGA	SEGRE	TER
	Organyà Ós de Balaguer Pinós Sant Martí de Riucorb Vilanova de Meià	

8. ANNEX 3: Additional comments regarding the agricultural indicators

Detailed comments on the calculation and interpretation of some indicators

As with all indicators, those presented here have their own limitations and cannot be interpreted in isolation because, apart from what they attempt to estimate, they are influenced by other factors that often affect more than one indicator. It is important to point out these limitations, the importance of their joint interpretation, as well as external sources of information or new data which may improve the interpretation.

- The indicator, **productivity of crops (kg/ha)**, depends on the modernization (cropland intensification) or the substitution of current crops for other crops and/or varieties which may be more productive (better adapted to regional conditions or to conditions related with climate change). An increase in the indicator indicates improved productivity, but it is necessary to evaluate this together with the evolution of agricultural area. Regarding the desired trend of this indicator, in order to achieve adaptation to climate change, it would be acceptable to reduce negative impacts while maintaining crop productivity, and it is for this reason that the desired trend of the indicator is that it does not decrease. On the other hand, from the perspective of global change, it would be necessary that it increases in order to cope with increased population, though it is debatable whether this will be a problem in Catalonia or Europe, much less at the basin level. In this sense, from the point of view of agricultural sustainability and according to the European CAP, agricultural productivity should increase, and therefore the desired trend should be a "sustainable increase."

- **Crop diversity** is an indicator which is clearly adapted to the scale of this study (the basin): calculated over a large regional area such as Catalonia, the diversity of crops may be seen as quite large, but if each county, basin, or municipality tends towards monoculture, they are each vulnerable (if monocultures are affected by climate change, agriculture becomes vulnerable), and thus the whole country is also vulnerable. This speaks to the importance of regionalizing this indicator as has been explained previously. When evaluating this indicator, it is necessary to take into account that an extreme diversification of crops can increase carbon footprint (for example, due to the impossibility of sharing agricultural machinery in cooperative systems, resulting in transportation over larger distances, effectively increasing the carbon footprint). Since the initial levels of diversity are low, an increase is considered desirable. These levels of diversity are low as compared to maximum values of this logarithmic indicator that could be achieved with the number of crops present in each basin: with 70 to 100 crops per basin, maximum values would be between 6 and 6.5; the values which were obtained, falling between 3 and 4, represent a large difference in diversity (an eightfold difference, keeping in mind the use of the logarithm base 2). It would be necessary to evaluate (as the objective of a separate study) a maximum permissible level of fragmentation that does not increase the carbon footprint (through use of heavy machinery) under the conditions of climate change. This indicator of crop diversity was also calculated at the municipal level using areas of crops within municipalities having 10% or more of their area within the basin. Unfortunately, at the municipal level this information is only available for the period 2011-2014 (annual agricultural statistics from DARP), and this range of years is not sufficient for identifying significant trends. In order to have a longer data series, in the end the indicator was calculated at the county level (Annex 1). Figure 1 and Table 4 show that the values for years for which data is available for both scales are very similar.

Table 4. Crop diversity index data (dimensionless) calculated with municipal data.

	2011	2012	2013	2014
MUGA	3.9	3.9	3.8	3.9
SEGRE	3.4	3.4	3.4	3.4
TER	3.8	3.8	3.8	3.8

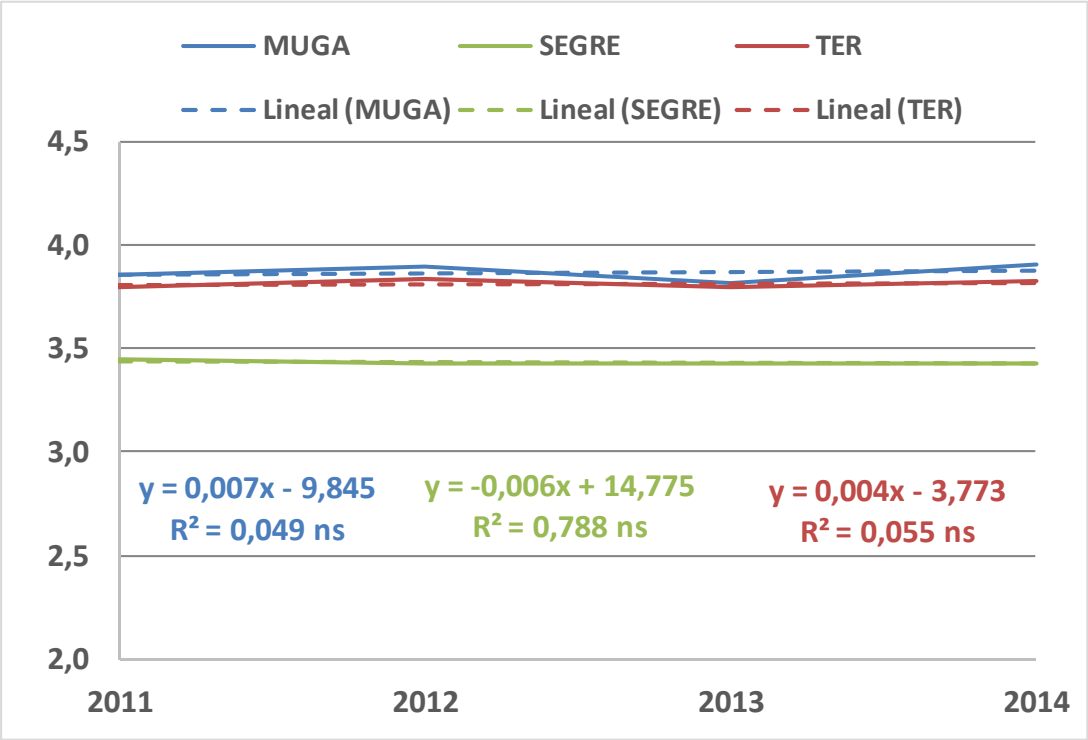


Figure 1. Evolution of the crop diversity index (dimensionless) calculated with municipal data.

- The ratio between crop production for **animal feed vs. human food** does not take into account possible interregional exchanges of animal feed products. It is also clear that the direct measure of surface and subterranean water would give a more appropriate measure, but this indirect indicator is faster and simpler since it is based on already-published data encompassing the entire geographical area of the basin, doing away with the problems of spatial and temporal representativeness of singular water samplings. The fact that this indicator has the same response as direct indicators of water contamination provides clues about the degree of adaptation of crops of the basin to the requirements of animal production. In addition, this indicator could provide information about changes in the production of animal protein as related to the dietary changes recently proposed by the EU and the FAO. For this indicator, the calculation was also made at the municipal level by multiplying municipal crop areas (annual DARP agricultural statistics for the 2011-2014 period) by county-level productivity values since there are no published data available for crop productivity at the municipal level. However, this indicator shows different results when calculated at the different levels (municipal and county), particularly for the Muga basin. Values at the municipal level are shown in Table 5 and Figure 2. Although it may be the case that the municipal-level indicator best suits the basin-level scale of the study, with the available data (four years: 2011-2014) no significant trends were seen in this case.

Table 5. Data for ratio of crops for animal feed vs. human food (dimensionless). Calculated with municipal data. Data for production for animal feed and human food (tons).

		2011	2012	2013	2014
Production for animal feed * (tons)	MUGA	145,707	163,836	208,263	219,376
	SEGRE	2,093,628	2,387,386	2,518,389	2,527,725
	TER	442,691	509,167	714,459	623,809
Production for human food* (tons)	MUGA	22,358	26,589	27,777	25,551
	SEGRE	1,214,287	958,495	1,107,872	1,238,910
	TER	116,260	99,931	98,086	109,484
Ratio of production for animal feed vs. human food (dimensionless)	**MUGA**	**6.5**	**6.2**	**7.5**	**8.6**
	SEGRE	**1.7**	**2.5**	**2.3**	**2.0**
	TER	**3.8**	**5.1**	**7.3**	**5.7**

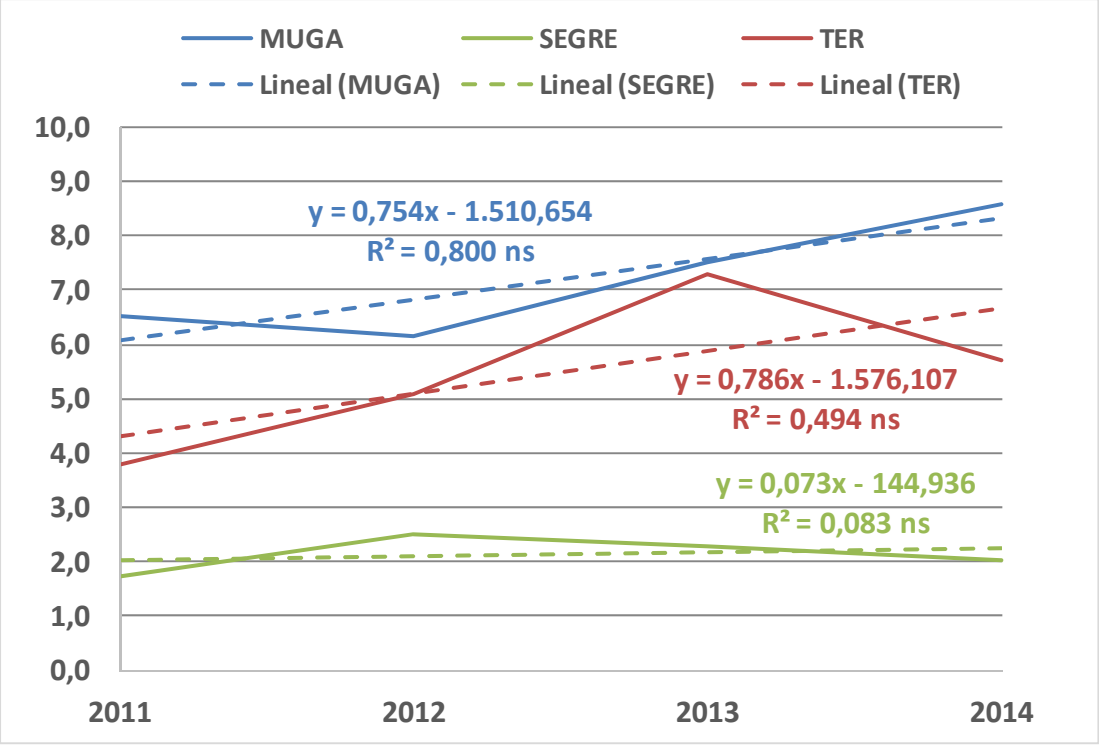


Figure 2. Evolution of the ratio of production of crops for animal feed VS human food (dimensionless). Calculated with municipal data.

- The relationship **between forest area and agricultural area** describes the balance that must exist between these two land uses, a relationship which has always been dynamic. Its interpretation is not direct: maintaining current values or slightly lower values would allow maintenance of the carbon sink capacity of the forest and water availability for different uses within the basin. Increasing forest area would increase water consumption as compared to dryland crops, but not necessarily as compared to irrigated crops, showing the necessity of

interpreting this indicator together with such information. To deal with this, the interpretation of forest area vs. agricultural area can be made together with the indicator, "surplus rainwater from cultivated areas following agricultural use multiplied by yield (hm^3*Tg)."

- **Water productivity** (kg produced/m^3 water used) indicates the capacity for maintaining yield under conditions of declining water availability. It must be evaluated together with the indicators of conservation of agricultural water resources (surplus rainwater from cultivated areas following agricultural use multiplied by yield, hm^3*Tg) in order to assess whether improvements in water productivity are due only to conversion to irrigation, which is not the only way to achieve this objective: conversions associated with reduced agricultural area and maintaining total yield (by conversion to crops with greater water productivity) would also lead to improvements in this indicator. It is necessary to take into account that, in addition to reflecting changes in water productivity of different crops, this indicator is also very sensitive to changes in crop area of crops with high water productivity. For example, in the case of the Muga no stable trend of change in the water productivity of any crop was seen (Fig. 3), though there was an upward trend in overall water productivity. This is due to the increased area of some crops with large water productivity such as corn and fodder crops (Fig. 4). With the circumstances under which these calculations were made, this indicator cannot reflect changes in crop water efficiency: improvements in irrigation management are not reflected because irrigation efficiency is not considered; improvements in management of drylands or changes in varieties affecting water use do not affect the indicator because the same Kc values are used for all agricultural management schemes and varieties of the same crop. The indicator does not consider soil water reserves.

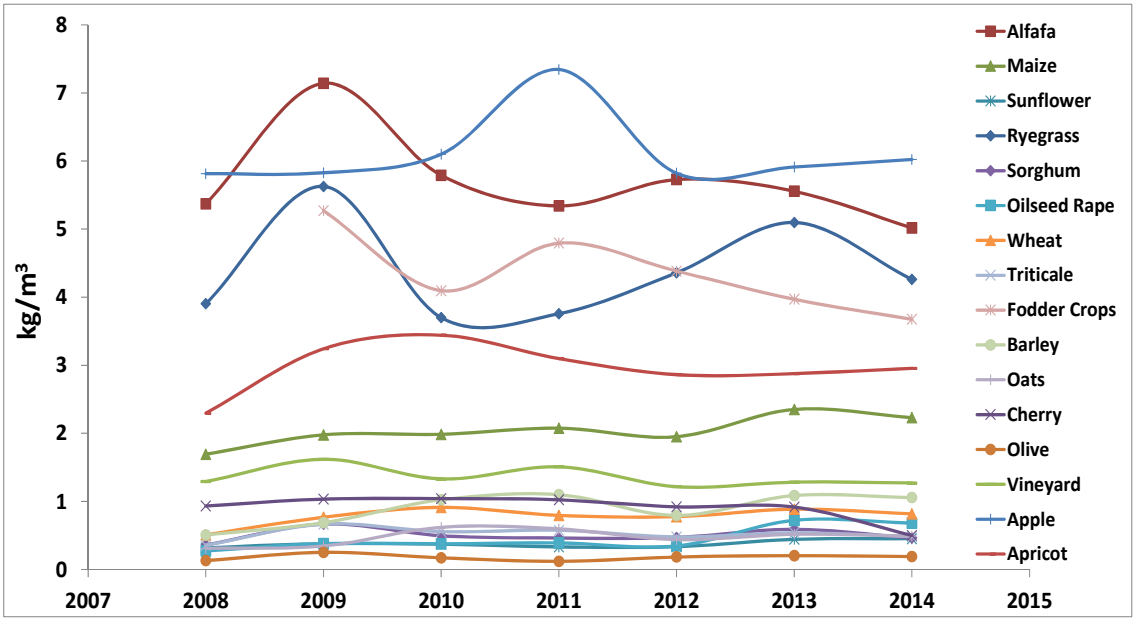


Figure 3. Evolution (2008-2014) of water productivity (kg/m^3) of crops in Muga basin.

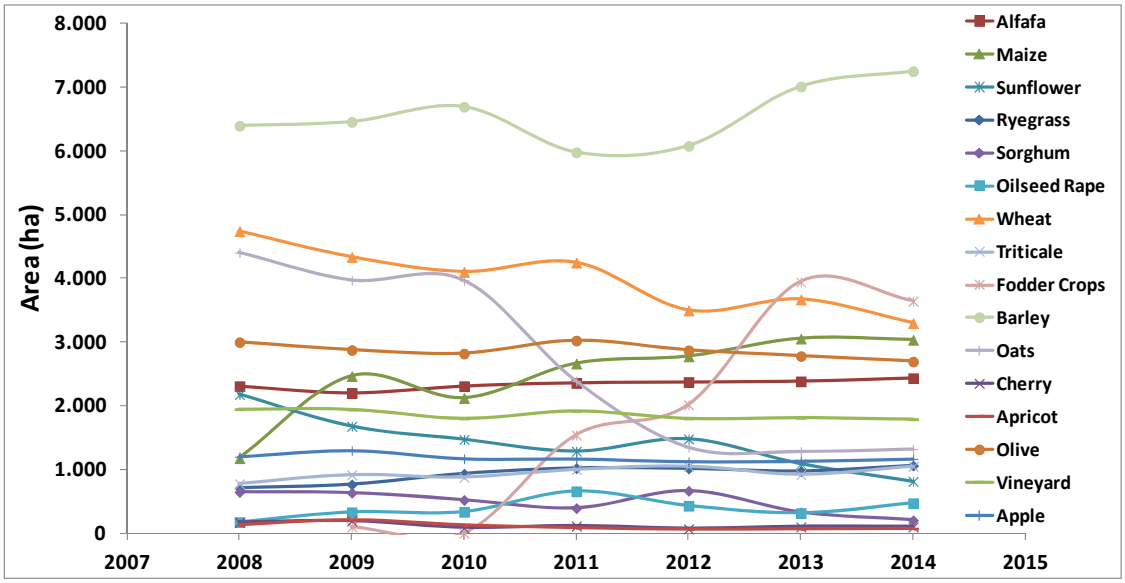


Figure 4. Evolution (2008-2014) of crop area (ha) in Muga basin.

- The indicator **agricultural water conservation**, which assesses water resource conservation and yield, can only increase if yield increases while maintaining water use (therefore also maintaining a surplus), or if surplus water increases while yield is maintained (improved water productivity). If yield increases at the cost of reduced surplus water, the indicator shows the relative magnitude of the two changes. The overall value of the indicator at the basin level indicates the balance between dryland crops with positive surplus rainwater (rain>ET_c), dryland crops without surplus rainwater (rain≤ET_C), and irrigated crops, which always have negative surplus. Therefore, this indicator will have negative or positive values in function of the areas of these different crop types. As with the indicator for water productivity, the agricultural water conservation indicator is basically sensitive to changes in the relative areas of crops with different water demands, and does not reflect changes in irrigation efficiency, dryland crop management, or changes in varieties or management of crops in terms of water use, nor does it consider the soil water reserve. Finally, this indicator only considers surplus rainwater and not water from other possible sources. This indicator is strongly influenced by yearly conditions, which affect both water use of the crop and its yield, and for this reason larger data series are necessary for its proper interpretation and in order to show significant trends; these drawbacks may limit the use of the indicator. Despite the above, it is a good synthesis indicator since it includes yield, thus summarizing water efficiency, crop area, and the efficiency of crop production.