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Exploratory analysis of climatic data, fire occurrences and water regimes in a Mediterranean watershed.

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Exploratory analysis of climatic data, fire occurrences and water regimes in a Mediterranean watershed.

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Summary

Trend results from climate data (precipitation and temperature) were analysed in relation to trends in water flow and forest fire occurrence over a 30 year time span in the Ebro watershed in Spain. An important part of the study was dedicated to data selection and preparation. Water and climate data are notorious for containing gaps and therefore artificial neural networks (ANN's) were tested and proved to be reliable to fill up those gaps, but were unfortunately too time consuming. After the selection of unaltered gauging stations (i.e. no influence by dams or irrigation, etc.) and climate stations with data availability from 1976 – 2006, linear regression analysis was applied to the evaluation of changes in water flow regime, climate and forest fires. The results confirmed that there were changes in those variables, however limited to some locations (very few for forest fire occurrence). To identify regionalization of the compounded regimes a cluster analysis was performed based on a principal component analysis (PCA) of the slope estimates (trends). A clear regionalization could not be delineated but some locations showed remarkable changes in water flow and climate over time. The spatial overlay of trend areas indicated that climate change could be related to water flow regime change, to some extent, in some of the locations where gauging and climate stations indicated the highest rate of change over time.

1 Introduction

Global changes are a major issue in the 21st century and attention to this subject is growing steadily (e.g. the Climate Congress in Copenhagen, Denmark in March 2009). The possible effects are widespread and could have very serious implications on human society and the environment (Arthington et al. 2010, Bales and Pope 2001, NASA 2010, Poff et al. 1997, Vorosmarty et al. 2000, Woodward and Diament 1991).
The possible effects on the environment have been discussed by many researchers (Alquilar 2009, Arnell 1999a, Bates et al. 2008, Dios et al. 2007, EPA 2010, NASA 2010, Woodward and Diament 1991), but uncertainties about global change and especially climate change remain, particularly in regions most expected to encounter changing climate patterns, like the Mediterranean area. This region is known for its warm summer periods with low precipitation so a further increase of temperature and decrease of precipitation could have serious impacts on the water availability. Also forest fire occurrence could be influenced by climate change and in turn have an indirect influence on water flow (i.e. through loss of vegetation). The absence of vegetation causes a faster water runoff which means that there is a larger input after a rainfall event but no gradual input of water over the following days.
Since water availability and forest fire prevention are important issues in Spain we focused in this study on the relationships between climate change, fire occurrence patterns and water resources distribution and availability in a Mediterranean watershed (figure 1).

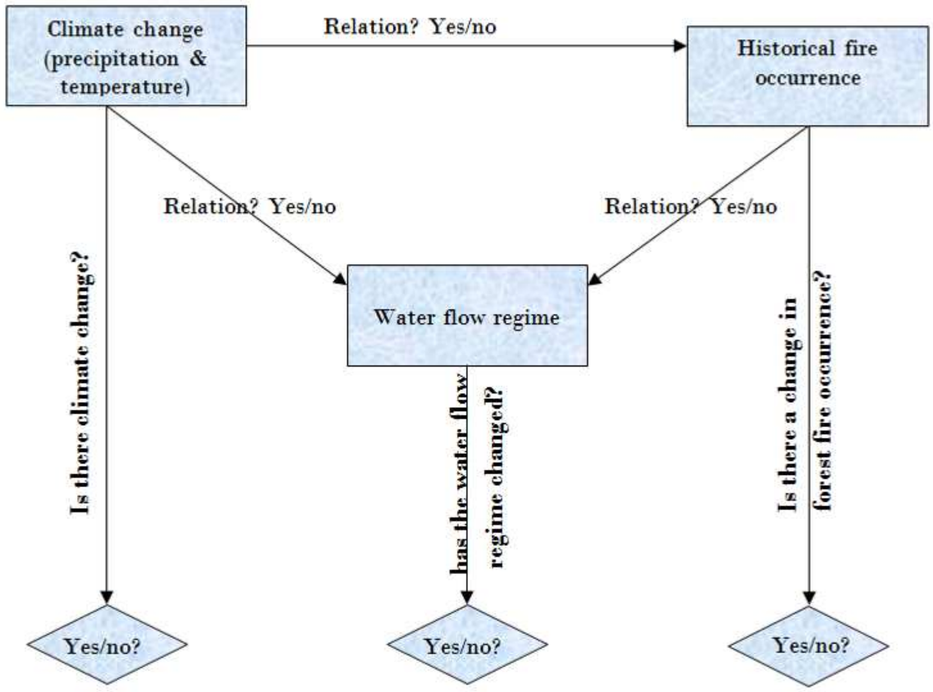

Figure 1: Flow chart of the variables used in this study

Effect of climate change on hydrology
Various climate models developed over the last years show consistent results in a reduction of water availability with increasing temperature and a reduced precipitation, which are supported by observed studies (Arnell 1999a, Arnell 1999b, Poff et al. 1996, Vorosmarty et al. 2000). It is a fact that during the last decades an increase in climate extremes has been observed. Precipitation patterns have changed, and currently the ice caps on the North Pole are melting at a high rate. Many previous studies suggest that freshwater supplies are

diminishing, especially in countries located in the southern latitude from 10°S to 30°N (Bates et al. 2008).
In Europe this seems to translate in reduced water availability and increased forest fires in the Southern part (which is the case in Spain) and a higher occurrence of floods in the Northern part of Europe, where reduced snowfall and snow melt has shifted towards an earlier period in the season (Arnell 1999a, Bates et al. 2008, Cuadrat et al. 2007, Poff et al. 1996).
Many studies in the Mediterranean show trends towards increasing temperature and decreasing precipitation which indicates a general decrease in annual runoff (Arnell 1999a, Bates et al. 2008, Cuadrat et al. 2007, Poff et al. 1996, Vorosmarty et al. 2000). There are also indirect consequences of climate variability to consider; the urban water consumption increases, more irrigation is needed and the constructions of new dams adds to the ecological impacts (Batalla et al. 2004). All these factors will likely further decrease the already scarce available water in the Mediterranean region.

Effect of climate change on forest fires
Climate change also may have a high influence on forest fire occurrence. Climate directly influences fuel conditions, ignition and spread of fires and the lack of water in summer months will make fires even more frequent and severe. Anthropogenic pressure (range management, agricultural burning, recreation, demand for irrigated lands, etc.) is an important factor when evaluating forest fires in Spain (Diaz-Delgado et al. 2004), a factor that caused increasing trends in human-caused fires in the last decades. Also in past years, shrublands, woodlands and forests have increased in rural Spain due to land abandonment. Climate change in combination with rural abandonment and high human risk will cause more favorable conditions for fires on the short-medium term (Dios et al. 2007, Vega-Garcia and Chuvieco 2006, Vega-Garcia et al. 2010) because abandoned regions are likely to be dominated by fire prone shrub and pine communities (secondary vegetal succession). On the long term, expected impacts are unfathomable, and a cause for concern given that forested areas in the Mediterranean are likely to be even more reduced in the future due to harder drought conditions. Furthermore, forests could become more susceptible to pathogens. Normally trees and pathogens are in balance and only weak trees will die, but because unfavorable environmental conditions a larger number of trees will be at risk (Dios et al. 2007). This increases the amount of highly flammable dead wood material.

In order to explore the hypothesized effects of climate change on fire occurrence and on water resources distribution and availability, the following research questions are formulated:
1) Are there indications that climate has changed in the Ebro watershed over the past 30 years?
2) Are there indications of hydrologic alteration in the Ebro watershed in the past 30 years and if so, is it possible to find a relationship between hydrologic alterations (water flow) in the Ebro watershed and climate change parameters?
3) Are there indications that the fire regime has changed in the Ebro watershed in the last 30 years, and if so, is there a relationship between fire occurrence and climate change parameters? Is there a relationship between fire occurrence and water flow parameters.
This study mainly focused at temporal trends in climate, water resources data and forest fire occurrence's, but also an analysis of the spatial patterns was included to observe if changes had a local or regional character.

2 Materials and methods

Figure 2 shows an overview of the methods used in this explorative study to answer the research questions and will be explained in detail in this chapter.

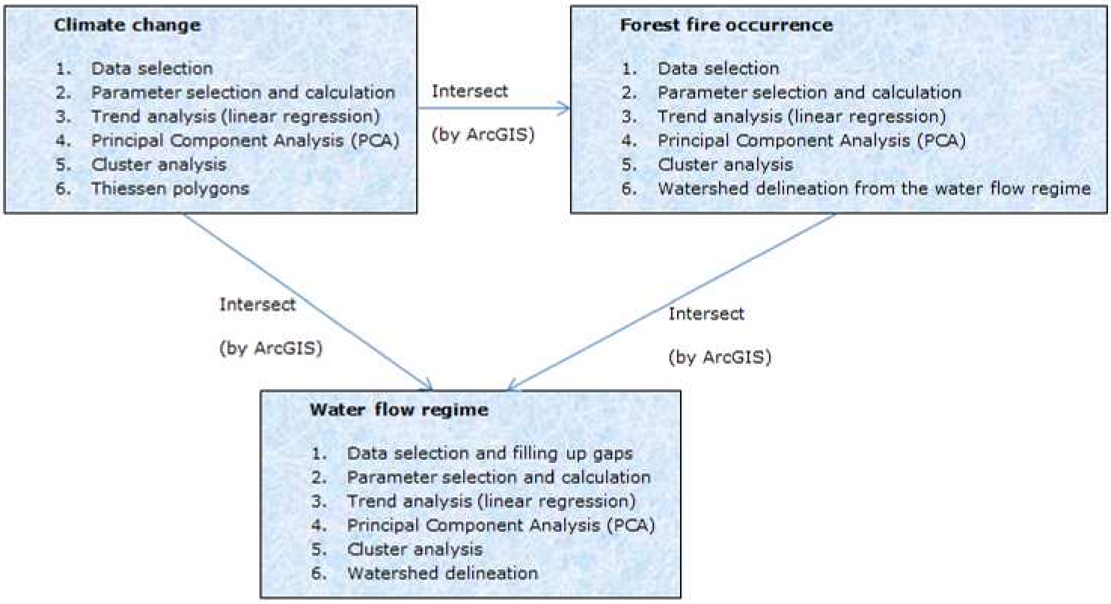

Figure 2: Overview of the methods used in this study.

2.1 Database

The selected study area is the Ebro River Basin in Spain which is located at the northeast of the country and has an approximate area of 85550 km² (Alcazar et al. 2008) (Figure 3). It is the largest river in Spain, having a total length of 910 km, and the foremost in terms of flow, with an average water discharge of 430 m³/s. The Ebro river is of major importance for ecological and human purposes, holding heavy demands from hydropower generation, irrigation of agricultural fields, recreation and urban uses (Alcazar and Palau 2010). Within the watershed there are a total of 240 gauging stations (GS's) that record daily water flow levels of tributaries and 1700 climate stations (CS's) with temperature and precipitation recordings.

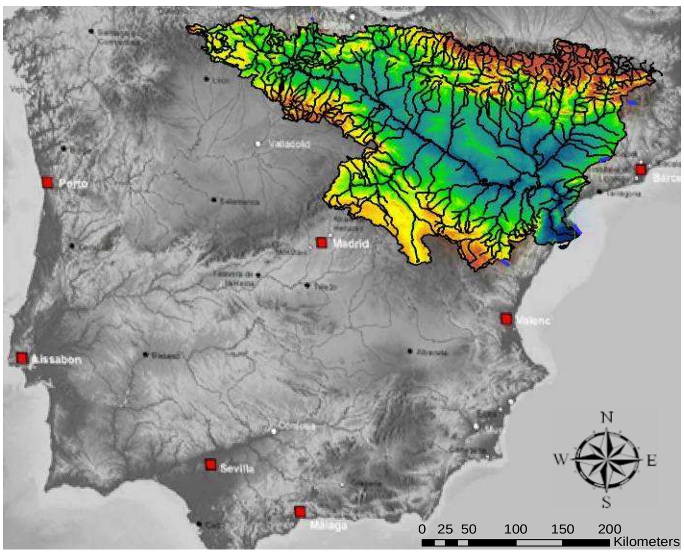

Figure 3: The Ebro watershed - highlighted (source: based on figure of Wikipedia 2007)

The water flow data are freely available at the ‘Confederación Hidrográfica del Ebro’ from the Spanish Government (source: http://www.oph.chebro.es). They have online data containing daily water flow records (m^3/s) and digital maps with the locations of a.o. GS’s (point data) without known accuracy, river branches (line data) with a scale of 1:50000, the delineation of the study area (polygon data) and the digital elevation model (DEM) with a grid size of 100m.
Climate data with daily temperature and precipitation records were ordered from AEMET (Agencia Estatal de Meteorología) from the Spanish government. The data were stored in a Microsoft Excel file and contained several climate parameters and also the xy – coordinates which allowed adding the CS’s as point data in ArcGIS 9.3. No information about accuracy was available.
The fire history records are collected from the EGIF Wildland Fire National Statistics of the Protection against Forest Fires Area (ADCIF) of the General Directorate for Environment and Forestry Policy (DGMNPF) (Ministerio de Medio Ambiente y Medio Rural y Marino). The Spanish Government data provides individual fire reports from 1988 till 2008. The data are stored in a Microsoft Access database and contains a.o. location (xy – coordinates), frequency and the burned area on several administrative levels. No information about accuracy was available.

2.2 Data Preparation

2.2.1 Filling gaps in water flow and station selection

First a selection of suitable GS’s has been made because within the Ebro watershed many rivers have altered regimes due to dams, hydro power plants, irrigation channels and urban consumption. Therefore, all GS’s in rivers with altered/variable water flows were excluded from further analysis in order to keep out any human-caused influence. Only stations without sudden alteration or very low variability in water flow were selected and if they had also reliable data from 1976 till 2006.
The selection of the CS’s was based on the availability of a long enough registry (i.e. data available from 1986 to 2006), data quality and on their proximity to the selected GS’s.
Water flow and climate data are notorious for containing missing data periods, especially when considering a 30 year time span. Depending on the positioning of the gap (e.g. at the beginning of the time series) the analysis could be less reliable, therefore double mass analysis (Brooks et al., 1991 and Ponce, 1994) was used for small gaps and if nearby GS’s or CS’s were available.

Also artificial neural networks (ANN) were tested for filling up the gaps of water flow data. ANNs are universal approximation functions, robust and data distribution-independent mathematical models that are especially useful when statistical models cannot be applied. In this case, climate variables would be expected to be highly correlated spatially and temporally, violating assumptions required for statistical model building. Over the last 10 years forecasting models based on artificial neural networks (ANNs) have been increasingly applied in many fields of hydrology and have proven their reliability (Alcazar et al. 2008, Besaw et al. 2010, Dastorani et al. 2010a, Dastorani et al. 2010b, Kuo et al. 2010, Decuyper, 2011). There are many types of networks, but a specific multilayered feed-forward type of ANN was used in this study, the cascade-correlation model defined by Fahlman & Lebiere (1990), which has the advantage of optimizing network architecture in the so called ‘training’ or ‘learning’ process (Alcázar et al. 2008). By using historical data it is possible to fit the ANN models to the patterns in the data (Besaw et al. 2010, Dastorani et al. 2010a, Dastorani

et al. 2010b, Kuo et al. 2010, Decuyper 2011). The database for analysis is split in training[1], test[2] and validation[3] groups, and the iterative learning algorithm was set to improve the correlation (Pearson R) between observed and predicted outcomes: the known flow values (average daily water discharge in m^3/s) and the output of the net.
To predict daily water flow in GS's nearby CS's (precipitation records) were used. A preliminary study was done for five GS's with each one or two nearby CS's. They were selected because all of them presented unimpaired, natural flow regimes with a reliable data range of 30 years (1976 – 2005) of daily climate and flow records (average daily water discharge in m^3/s), and no more than three gaps. The selected GS's showed a mainly rainfall-dominated hydrological regime. The database presented a total of 10 gaps or discontinuities ranging from 17 to 272 days (nine months). The variables used for completing gaps in the database were Julian day, the precipitation (mm) on the day of the missing value, and the precipitation up to five days before the date of the missing value. Given the small size of the watersheds, that was considered time enough for water from the watershed divide to reach the watershed outlet (time of concentration) regarding the particularities of shape, topography, vegetation and soil characteristics of the watersheds studied.
Several transformations were applied to the independent variables and tested through a genetic algorithm provided by Predict® software (Neuralware 2009) previously to model building. The cases were randomly shifted between groups at least three times for each model, and we built 5 replicas with different sets of random weights for each grouping at the beginning of training. Correlation was used to rate performance, but convergence of the 15 trials for each model (each gap) to a same or similar structure was also considered a trait of robustness of the solution. A sensitivity analysis of the variables in the best model through partial derivatives was used to rate their relative importance in the models.
Six different approaches (scenarios) were defined to optimize the predictive models of water flow for each gap in any gauging station. They were required because the natural variability of flow regime (inter and intra-annual variability) is a key aspect in defining the functioning and structure of a river (i.e. Ritcher et al. 1996, Poff et al. 1997, Stewardson and Gippel 2003, Poff and Zimmerman 2010), especially in Mediterranean ecosystems. But this high variability of the streamflow database could induce large errors when developing prediction models from large time spans (30 years, Scenario 1). Consequently, several scenarios were proposed to reduce errors induced by a high inter and intra-annual daily flow variability while keeping the observations for model building representative (Scenarios 2, 3, 4, 6). We also considered that the hydrological response of watersheds is influenced by the basin characteristics that regulate runoff, such as geomorphology, geology and vegetation cover. Changes in land cover over time due to either natural causes or human activities may influence the hydrological behaviour of the watershed, i.e. the relationship between precipitation and runoff. Then, the accuracy of streamflow prediction models based only on precipitation data over a long period of time may be decreased by errors related to vegetation cover changes, for instance. Scenario 5 tried to reduce this possible source of error by reducing the time span of the observations used for modelling.
Scenario 1 (S_{all}): we used the whole range of 30 years of weather and flow data.
Scenario 2 (S_{out}): we removed extreme years (outliers) if present, only when the gap was not located within those years.
Scenario 3 (S_{inter}): we looked at inter-annual variability of flow regimes. All available years were classified into three types, Wet, Normal and Dry year, based on the characterization of

[1] Training data is used for learning/fitting the parameters (weights) of the classifier (Ripley 1996).
[2] Validation data is used to tune (transform) the parameter of the classifier (e.g. to choose the number of hidden units in the ANN) (Ripley 1996).
[3] Test data is used to assess the performance of a fully specified classifier (Ripley 1996).

the regime's inter-annual variability, and according to the following criteria (Martínez Santa-María and Fernández Yuste 2010):

• A year was considered to be 'Wet' if its annual volume in natural regime is greater than the volume corresponding to the 25% exceedance percentile.

• A year is considered to be 'Normal/Average' if its annual volume in natural regime lies between the volume corresponding to 25% and 75% exceedance percentile.

• A year is considered to be 'Dry' if its annual volume in a natural regime is lower than the volume corresponding to the 75% exceedance percentile.

Water flow data were divided in Wet, Normal and Dry years, and only years of the same type as those where the gaps were occurring were used for the corresponding analysis.

Scenario 4 (S_{intra}): we looked at intra-annual variability of flow regimes. Annual flow regimes were divided in Low, Medium and High flow periods based on an analysis of seasonal flow variability, and only data of the same period as that where the gaps were located were used for the analysis.

Scenario 5 (S_{4years}): we selected short periods of time where the basin characteristics could be considered invariable and therefore the hydrological response of the watershed did not change. Only data of the two years before and after the gap were used for the analysis.

Scenario 6 ($S_{4\text{-}5}$): Combined scenarios 4 and 5. Only data of the same seasonal flow period of the two years before and after the gap were used for the analysis.

When gaps were too big (i.e. several gaps of a few years) and no nearby GS's were available (in the same river and unaltered), the GS was discarded. The same applied for CS's.

2.2.2 Watershed delineation

Watersheds are the unit of analysis since the water flow regime and the possible effect of climate change on water runoff is not affected at the location of the GS but the whole upstream area until the GS. To create the exact area of influence (i.e. the watershed area until the GS) a 'watershed delineation' was drawn by using Digital Elevation Models (DEM's) in ArcGIS.

2.2.3 Fire occurrences

The fire records were added as point data in ArcGIS by using the xy -coordinates, but had some positional inaccuracies (e.g. some points were located in the Mediterranean Sea and no information about accuracy was available). This problem was solved by summing up the fire records for each townships (the lowest administrative level) since the forest fire database relates each ignition to the townships. To assign the forest fire data to the watersheds an overlay with the areas of the townships was made in ArcGIS and only those which had an overlay of more than 50 percent were assigned to the corresponding watershed.

2.3 Parameter selection

2.3.1 Water flow

After a thorough literature review a selection of aspects (i.e. magnitude, frequency, variability and rate of change) was made based on the work of Richter et al. (1995; 1996; 1998), Brizga et al. (2001) and Clausen and Biggs (2000). In order to describe those aspects a number of parameters was selected based on Martínez Santa-María and Fernández Yuste (2010) which resulted in a reduced selection of parameters based on the work of Ritcher et al. (1995; 1996; 1998), but covering a wider range of environmental aspects (including seasonality) that made them more specific and appropriate to the characteristics of Mediterranean river flows (see overview in table 1). These aspects/parameters were studied for ordinary and extreme conditions (habitual and extreme values components). The list with all parameters and the description and the calculation of the less common ones can be found in appendix I.

Components of the natural regime		Aspect	Parameter
Habitual values	Yearly values	Magnitude	- Average annual water discharge
		Variability	- Difference between monthly min. and max. water discharge per year - Difference between $Q_{10\%}$ and $Q_{90\%}$
	Monthly values	Magnitude	- Average monthly water discharge
		Variability	- Difference between daily min. and max. water discharge per month
		Seasonal nature	- Month with the min. and max. water discharge per season
Extreme values	Maximum values (floods)	Magnitude & frequency	- Max. daily flow per month - Average monthly max. flow per year (based on max. daily flow) Qc - Bankfull flow/effective discharge (Q_{ED}) - Flushing floods ($Q = Q_{5\%}$) - Month with the lowest flood frequency ($Q \geq Q_{5\%}$)
		Variability	- Coefficient of variation of the max. daily flow per year
		Rate of change	- Increasing rate of change - Decreasing rate of change
	Minimum values (droughts)	Magnitude	- Average of the min. daily flow per year - Flows corresponding to droughts ($Q = Q_{95\%}$) - Month with the lowest flood frequency ($Q \leq Q_{95\%}$)
		Variability	- Coefficient of variation of the min. daily flow per year

Table 1: Overview of the components, aspect and parameters for water flow included in this study

2.3.2 Climate change

To study climate change the same components as in water flow were used. The selection of aspect and parameters was based on the study of Vicente-Serrano and Cuadrat-Prats (2006) and Cuadrat-Prats et al. (2007) and on data availability (e.g. daily or monthly data), which resulted in: magnitude, seasonality and frequency (see overview in table 2). The list with all parameters can be found in appendix I.

Components for precipitation (P) and temperature (T)		Aspect	Parameter
Habitual values	P	Magnitude	- Total annual P
		Seasonality	- Total seasonal P
	T	Magnitude	- Average annual T
		Seasonality	- Average seasonal T
Extreme values	P (high values)	Magnitude & Seasonality	- Max. seasonal P in one day (24 hours) - Max. seasonal P per year
	T (high values)	Magnitude	- Average of the Max. monthly T
		Seasonality	- Max. seasonal T per year
		Frequency	- # of days with T ≥ 30°C (seasonal & annual) - # of days with T ≥ 25°C (seasonal & annual)
	P (low values)	Seasonality	- Min. seasonal P per year
		Frequency	- # of days without P (seasonal & annual)
	T (low values)	Magnitude	- Average of the Min. monthly T
		Seasonality	- Min. seasonal T per year
		Frequency	- # of days with T ≤ 5°C (seasonal & annual) - # of days with T ≤ 0°C (seasonal & annual)

Table 2: Overview of the components, aspect and parameters for climate included in this study

2.3.3 Forest fires

The database of the forest fire records contained many parameters not used in this study (e.g. the person who detected the fire, firefighting technique, wind direction, etc.). Some parameters are also susceptible to the interpretation of the observers like the type of fire (e.g. canopy –or ground fire) and the location of ignition is not always very accurate. To solve the latter problem we summed up the fire occurrences per township (see 'data preparation').
Only the reliable (physically measurable) and for our study important parameters were selected, which resulted in forest fire occurrence (number of fires per township) and the total amount of burned area (km²) over a time span of 17 years (1988-2005). An example of a fire occurrence form (in Spanish) can be found in appendix III.

2.4 Modelling/ analysis

2.4.1 Temporal analysis

Once the parameters of the different variables were calculated they were subjected to a linear regression analysis (single linear structure) which for each parameter indicated if there was a change in water flow regime (per watershed), climate change (per CS) and forest fire occurrence (per watershed) over the 30 years' time span. The significant slope estimate values indicated the amount of change or trend of each specific parameter over the study period (an example of a non-significant trend can be found in figure 4). The parameters where the plot of the residuals showed a under – or over –estimation were re-analysed after exclusion of the outlier(s) (an example can be found in figure 5).

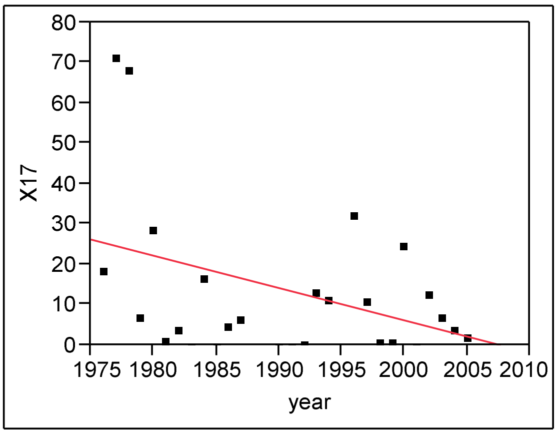

Figure 4: The average water flow of august (X11) - Slope estimate = -0.80; SE= 0.37549; P=0.0430*, but after removal of the two outliers: P>0.05 and slope estimate was set to zero .

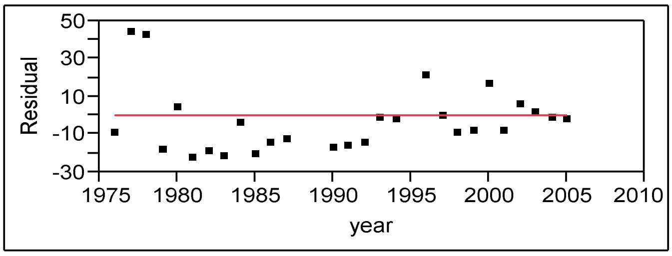

Figure 5: The residuals of the average water flow in August – an overestimation in the first years due to two high values

2.4.2 Spatial patterns

In order to identify spatial patterns in GS/CS and forest fire occurrence with similar characteristics (regimes), a non –spatial cluster analysis was performed based on the slope estimate values (non-significant values were assigned the value zero). A prior Principal Component Analysis (PCA) was done to convert the potentially correlated parameters (avoiding then problems of collinearity) into a set of values of uncorrelated parameters. For the water flow and precipitation principal components were used which range of eigenvalues contributed up to 85% of the variance (otherwise the division between clusters was too vague), while for temperature and fire occurrence all principal components were used to perform the cluster analysis.
A hierarchical cluster analysis using Ward´s procedure (Ward, 1963) was performed to sort the GS's, CS's and forest fire occurrences and group them by their relatively similar regimes. The loadings of the original data on the principal component axes were used as the new variables in the cluster analysis.

The next step was to build a spatial data base in ArcGIS to find spatial relationships within (regionalization) and between the variables, based on the cluster analysis and with the use of the stations' XY -coordinates. Water flow regimes and forest fire occurrences were assigned to the watersheds as mentioned before. CS's (point data) could not be assigned to the watershed database because of multiple CS's with a different regime within or near a watershed or there was a lack of a close-by CS. Furthermore, in some cases several CS's influenced the same watershed, but were situated just outside the watershed perimeter and averaging the original data (i.e. before the parameter calculation) of the CS's would result in the loss of the local characteristics. Therefore the 'Thiessen Polygon' function in ArcGIS 9.3

was used to create a spatial database of climate variables. Due to the lack of data, not all CS's had both temperature and precipitation data. This created a difference in location (different CS's) and amount of stations between the two climate variables, so one layer for each was made.

Once all coordinates systems were adjusted to a common reference the datasets were overlaid by using the 'intersect' function.

We could not pair temperature or precipitation regime (cluster) to water flow regime one-on-one because one watershed (unit for water flow) could be influenced by several temperature or precipitation regimes and averaging trends is not possible. The problem with averaging the original data was mentioned above. A solution was found by making contingency tables which were a result of overlaying the data layers in ArcGIS 9.3. These tables show how much the area of each cluster of variable A is influenced by the clusters of variable B which enables us to identify the relationships between the regimes (clusters) of the two variables.

The tables were analyzed in a descriptive way since the contingency tables have many classes (i.e. clusters) per variable and more than five values were below five, which makes it easy to get highly significant results in the chi square analyses when there are actually not very big differences (type II error).

3 Results

3.1 Data preparation

The best models for each GS or the best outcome out of 15 runs for each scenario and gap are presented in Tables 3 to 7. An overview of the most important results for the three gaps in GS-7 can be examined in Table 3. The results of GS-7 were based on climate stations 354 and 350A, but in some models a whole station's variables were left out. Models for scenarios S1, S2 and S3 all had R < 0.50. S4 was the best for the longer 1988 spring gap (87 days). S5 was best for the shorter 91' summer gap (17 days). Best results were achieved for the 55-days gap in summer 1984 in which the S6 model reached R= 0.76 for the trained dataset and R= 0.82 for the test and validation datasets.

Table 3: Results of ANN for GS-7 (the best performance is marked)

GS	CS	S	Excluded variables	Training R	Test R	Validation R	Date and size of gaps.
7	354 and 350A	1		0.4719014	0.385536	0.3784908	All gaps
7	354 and 350A	2		0.4719014	0.385536	0.3784908	All gaps
	354 and 350A	3		0.2882581	0.2095485	0.2187318	All gaps
7	354 and 350A	4		0.5701082	0.5369969	0.5279167	18/06/1991-04/07/1991 (17days) & 30/06/1984-23/08/1984 (55days)
7	354 and 350A	4		0.7340653	0.6200938	0.5217793	16/02/1988-12/05/1988 (87days)
7	354	4		0.5043471	0.2386446	0.2549841	All gaps
7	350A	4		0.4065346	0.2188785	0.4683616	All gaps
7	354 and 350A	5		0.6012151	0.6022697	0.6238819	18/06/1991-04/07/1991 (17days)
7	354 and 350A	5		0.6163394	0.560811	0.6639273	18/06/1991-04/07/1991 (17days)
7	354 and 350A	5		0.7177097	0.5450608	0.470026	16/02/1988-12/05/1988 (87days)
7	354 and 350A	5		0.6955229	0.6019796	0.6586597	30/06/1984-23/08/1984 (55days)
7	354 and 350A	5		0.689842	0.6715547	0.6962118	30/06/1984-23/08/1984 (55days)
7	354 and 350A	5		0.6429316	0.6091658	0.6707178	18/06/1991-04/07/1991 (17days)
7	354	5		0.7044174	0.7002445	0.6189693	18/06/1991-04/07/1991 (17days)
7	354	5		0.680967	0.6477133	0.6456955	18/06/1991-04/07/1991 (17days)
7	354 and 350A	5	Not PP4&5	0.7026513	0.5626603	0.6545003	18/06/1991-04/07/1991 (17days)
7	354	5	Not PP4&5	0.6547109	0.6457863	0.6335687	18/06/1991-04/07/1991 (17days)
7	350A	5	Not PP4&5	0.6745606	0.5540947	0.603172	18/06/1991-04/07/1991 (17days)
7	354 and 350A	5	Not PP3 (354) & Not PP4&5 (350A)	0.6087984	0.6064831	0.6026835	18/06/1991-04/07/1991 (17days)
7	354 and 350A	6		0.7052527	0.49416	0.4851857	18/06/1991-04/07/1991 (17days)
7	354 and 350A	6		0.5950004	0.5866454	0.4648952	16/02/1988-12/05/1988 (87days)
7	354 and 350A	6		**0.7608629**	**0.8187535**	**0.8166268**	30/06/1984-23/08/1984 (55days)
150	279	1		0.5749629	0.5448159	0.564397	All gaps
150	279	5		0.6622621	0.6625042	0.6096148	26/07/1986-12/09/1986 (49days)
150	279	5		0.7390342	0.75811	0.7175101	24/02/1994-11/05/1994 (77days)
150	279	5		0.7108593	0.7723696	0.8088687	16/10/2004-16/11/2004 (32days)
150	279	5		0.8238573	0.5427486	0.7622485	16/10/2004-16/11/2004 (32days)

Station GS-57 was nearby the same climate stations as GS-7 were used. Analysis of the water flow curves over all the years based on the average monthly volume showed no extreme years. No homogenous period within the year could be identified (heterogeneous data over all months), so scenarios S2, S3, S4 and S6 could not be applied. The other scenarios gave unsatisfying correlation values R < 0.50 for all replicas. An overview of the best results can be found in Table 4.

Table 4: Model results for GS-57 (best performance is marked)

GS	CS	S	Excluded variables	Training R	Test R	Validation R	Date and size of gaps.
57	350A	1	None	0.4182885	0.4326839	0.4296383	All gaps
57	354 and 350A	5	None	**0.5577001**	**0.4061961**	**0.3932632**	11/06/1991-30/06/1991 (20days)

Station GS-78 water flow did not show any extreme years. The two gaps present overlapped the periods with homogenous very low water flow and the period with high heterogeneous water flow so also here S2, S3 and S6 could not be used. S1 and S4 gave low R values. The S5 model produced the best results for the 28-day 92' winter gap with an R=0.60 for the trained dataset and an R=0.69 for the validation dataset (Table 5).

Table 5: Model results for GS-78 (best performance is marked)

GS	CS	S	Excluded variables	Training R	Test R	Validation R	Date and size of gaps.
78	245-I	1	None	0.4711653	0.3314248	0.475306	All gaps
78	245-I	5	None	**0.6018427**	**0.5472923**	**0.6962058**	17/11/1992-14/12/1992 (28days)
78	245-I	5	None	0.3342236	0.2539122	0.5499468	08/03/2004-19/07/2004 (134days)

GS-86 shared climate station with GS-78. In this GS all scenarios could be applied for modelling, but none of them gave good results (R values ≤ 0.50). An overview of the most important results can be found in Table 6.

Table 6: Model results for GS-86 (best performance is marked)

GS	CS	S	Excluded variables	Training R	Test R	Validation R	Date and size of gaps.
86	245-I	1	None	**0.5085366**	**0.4283653**	**0.4445611**	All gaps
86	245-I	5	None	0.4348041	0.5139971	0.3255738	01/10/1992-29/06/1993 (272days)
86	245-I	4	None	0.4058686	0.3707844	0.4223284	01/10/1992-29/06/1993 (272days)
86	245-I	6	None	0.4185559	0.5047016	0.3755853	01/10/1992-29/06/1993 (272days)

GS-150 was modelled with independent weather variables from climate station 279. S1 showed R values close to 0.56 for training, test and validation data for all three gaps. S2, S3 and S6 could not be applied to the longer gaps (49-days and 77-days) because the gaps overlapped both High and Low flow periods. Models for the gap in the High period (32-days) gave bad correlations in general (R values ≤ 0.50), except for S5. S5 provided reasonably good results for all the gaps, with R=0.66-0.60 (training-validation datasets) in the 49- days 86' summer gap, R values above 0.71 for the 77-days 94' winter spring gap and R= 0.71-0.80 for the shorter autumn 32-days 2004' gap (Table 7).

Table 7: Model results for GS-86 (best performance is marked)

GS	CS	S	Excluded variables	Training R	Test R	Validation R	Date and size of gaps.
150	279	1	None	0.5749629	0.5448159	0.564397	All gaps
150	279	5	None	0.6622621	0.6625042	0.6096148	26/07/1986-12/09/1986 (49days)
150	279	5	None	0.7390342	0.75811	0.7175101	24/02/1994-11/05/1994 (77days)
150	279	5	None	**0.7108593**	**0.7723696**	**0.8088687**	16/10/2004-16/11/2004 (32days)
150	279	5	None	0.8238573	0.5427486	0.7622485	16/10/2004-16/11/2004 (32days)

In most models, structures were parsimonious and solutions converged. The difference between the R values of the training, test and validation datasets were well balanced indicating good reliability in the best models. The variables excluded from most models or with partial derivatives that did not indicate relevant contribution were usually the precipitation values 4-5 days before the daily gap.

Despite the good results in some stations the ANN method was considered too time consuming because there was not one single scenario suitable for filling up gaps in all GS's. Only four GS's could be filled up using the double mass technique. After the selection procedure and filling up gaps a total of 56 GS's, 53 CS's for precipitation and 35 CS's for temperature were selected and used for analysis. Each of the 56 GS's were assigned to a watershed (area of influence) and based on these watersheds forest fire occurrence has been determined, so also this variable has 56 records.

3.2 Waterflow

The detailed results from the general trends and the cluster analysis can be found in appendix II.

3.2.1 General trends

Habitual values

Most of the gauging stations (GS's) (~79%) did not show changes in most magnitude related parameters. Some GS's showed a decrease in average water flow (WF), especially in the months February, May, June and the annual data (X5, X8, X9 and X13). The annual data in particular showed more decrease in WF (~36%) then the monthly data (~18%), but also in this parameter the majority of the GS's did not show changes (~63%). GS's where an increase in WF was noted were negligible (~1%).

All of the variability related parameters, the difference between the min. and max. daily and monthly discharge and between Q10 and Q90 - percentile (X14-X27, X30), did not show many changes over the years, only in ~12% of the GS's this difference became smaller and those with a higher variability were negligible (~1%). When separating the monthly and annual parameters, respectively ~10% and ~21% of the GS's had less variability.

Also in the seasonal data the same trends were found: mainly no change (~94%) in the number of the month with the lowest and highest water discharge (X28, X29), only one GS (~2%) for low water flow and ~7% of the GS's for high water flow indicated a shift of towards an earlier time in the season. GS's that had a shift in low and high water flow towards a later period in the season were absent or negligible.

Extreme values (floods)

The magnitude and frequency related parameters, the maximum daily flow and average maximum monthly flow - Qc (X31-X57, X59), did not show significant changes in ~62% of the GS's and respectively a decrease and increase of ~24% and ~13% in the remaining GS's. However the monthly data of the effective discharge (Q_{ED}) (X44-X55) had many significant trends, ~39% of the GS's had a lower maximum WF(based on the previous 10 years, but over a 30 year time span) and ~34% a higher maximum WF. Especially the months December & September had a higher maximum WF (in 51% of the GS's) and November, April and May had a lower maximum WF (in 58% of the GS's). On an annual base the effective discharge or bankfull flow (X56) summarizes the monthly results, no changes in ~34% of the GS's, a lower maximum WF in ~36%, and a higher maximum WF in ~30% of the GS's. Flushing floods (X57) had known a reduction in maximum WF in ~25% of the GS's, but other stations did not show changes. The maximum daily flow (X31-X42) did not show so many changes (~88% of the GS's) and an increase in maximum daily flow did not occur.

There were also no changes in variability (coefficient of variation of the monthly maximum flows - X58) over time (~96% of the GS's), only in ~4% of the cases a higher variability was observed.

There was mainly no variation in the increasing rate of change (X76) over time (~86% of the GS's), while the remaining ~13% GS's showed a slower change in hydrological conditions (water level). GS's with fast change (~2%) were negligible. The same trend is confirmed by the decreasing rate of change (X77): ~82% of the GS's did not changed significantly over the years, while the remaining GS's (~16%) showed a fast change of daily WF. GS's with slow change in daily WF (~2%) were negligible.

Extreme values (droughts)
The magnitude and frequency related parameters; the minimum daily flow and the average minimum monthly flow per year and the annual ordinary drought discharge (X60-X73, X75), did not show a significant trend in ~77% of the GS's and a further reduction of minimum flow in ~22% of the GS's. An increase in the minimum flow was negligible. The same results were obtained when only looking at the minimum daily flow and the average minimum monthly flow per year separately. The differences between months taught us that the autumn months and January did not show any changes in minimum daily water flow, while in the other months ~30% of the GS's a decrease was found. Only the annual ordinary drought discharge showed a slightly larger amount of GS's with a lower minimum annual discharge (~33% of the GS's).
There were almost no changes in variability (X74) over time in the GS's (~88%). Of the remaining only ~5% of the GS's had a smaller and ~ 7% had a larger difference between the minimum monthly WF's.

3.2.2 Cluster analysis

The dendrogram was divided into eight clusters based on the dotted line in figure 6. A lower number of clusters was nearly impossible because we would have only one cluster, while a higher number of clusters was undesirable since it would make regionalization and relations with other variables (e.g. precipitation) very difficult. Since the distinction between clusters was not the same over all parameters, the characteristics or different water flow regimes were described per parameter or group of parameters in this section (see below). The differences between clusters could range from many changes over time to no changes at all.

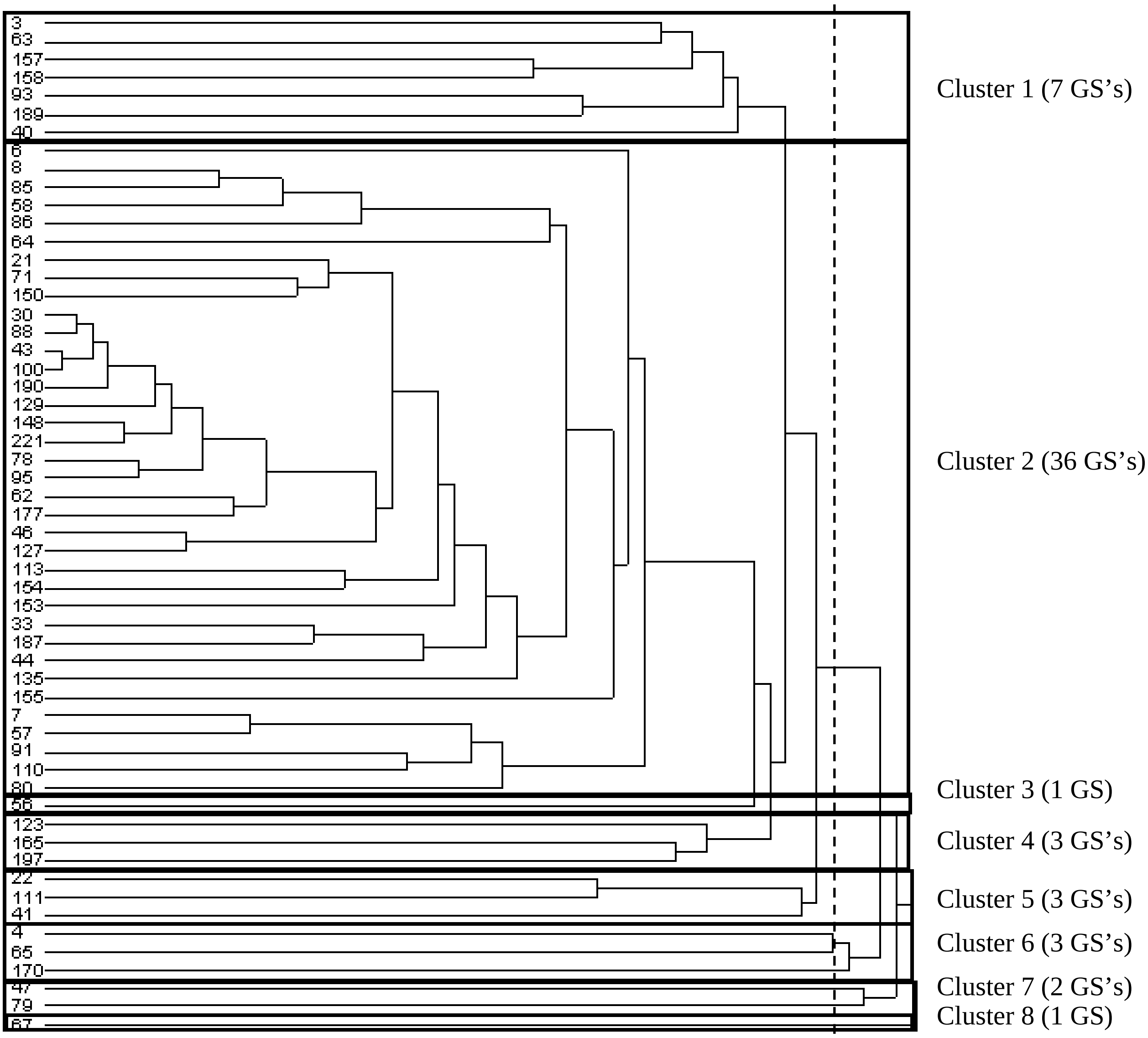

Figure 6: Dendrogram for the GS's. The dotted line indicates where the dendrogram was split into clusters

Analysis of the dendrogram clearly showed very unequal cluster sizes (i.e. the number of GS’s per cluster) (see figure 6).

Habitual values

With regards to the magnitude related variables, the cluster analysis did not show completely different behaviors among clusters. The minor differences indicated that the WF in the GS’s of C4 and C5 did not changed a lot over time, but in C4 the annual WF became lower.

In C6, followed by C1, most changes towards a decrease in average WF could be observed, while the other clusters were comparable to each other and a further hierarchy was difficult. One exception was found in GS153 of C2, which showed an opposite trend, an increase in average WF.

The variability related parameters were lacking sufficient significant changes to see a difference between clusters. Only in C6 more changes could be observed (i.e. less difference between the minimum and maximum WF’s) in the months February, May and June. When looking at the annual data there were (almost) no changes in variability for C6 and the other clusters, only C4 tended towards a decrease in difference between minimum and maximum

WF. The monthly difference between the minimum and maximum WF and difference between the Q_{10} and Q_{90} percentile had similar results, except C5, C6 and C8 where the majority of the GS's showed smaller variation over the years, all other clusters were mainly dominated by GS's without changes. Only GS153 had an opposite trend in the last two parameters.

Extreme values (floods)

From the general trends it was indicated that only the end of spring (May), summer (June and July) and February somewhat larger amount of GS's had a significant reduction in maximum daily WF. Within these months C6 and C1, followed by C5 had a majority of GS's with changes. When generalizing towards annual data, only C4 had a majority of GS's with a reduced maximum WF. Other clusters had only few changes, but with the same trend.

The bankfull flow or effective discharge per month (X44-X55) showed many significant trends. There was a lot of variation within groups, especially the months October, January, March, June, July and August showed positive, negative and no trends depending on the GS. December and September were dominated by GS's with a higher maximum flow or bankfull flow over the 10 years' return period (positive trend) and November, April and May had mainly GS's with a lower maximum flow or bankfull flow (negative trend). The trends based on annual data (X56) showed the same variation between positive, negative and no trends within groups. Because of this high variability within groups no difference between clusters could be made.

The reduction in WF of flushing floods (X57) was mainly found in C5, C6 and C8, where in other clusters no changes were noted (only GS153 had again an opposite trend).

In the variability related parameters, the coefficient of variation (CV) of the maximum monthly flows per year (X58) and the month with the highest flood frequency (X59), there were almost no changes in any of the clusters and therefore it was not possible to divide the clusters.

The same accounted for the increasing rate of change (X76), only the decreasing rate of change (X77) had some changes towards a lower rate of change (positive trend), but not sufficient for making a division between cluster characteristics.

Extreme values (droughts)

The minimum daily WF (X60-X71) did not show enough changes in the months from October to April to find differences between the clusters. In the other months (from May to September) however a distinction between C1, C3, C6 and C8 with a large amount of GS's showing a decrease in minimum daily flow and the other clusters with mainly no changes. In C2 a sub-cluster could be distinguished (GS 78, 85 and 86) which had a majority of GS's with a reduction in minimum WF. Also in C2, GS 153 was again the outlier with an opposite trend.

The generalized annual data (X72) showed fewer changes; only in C1, C3, C8 and the previously mentioned sub-group of C2 a decrease in minimum daily flow was observed. The ordinary drought discharge (X73) had very similar results than X72, so the same distinction between clusters was made.

Almost no changes in the variability related parameters (X74 and X75) occurred, so no difference between clusters could be inferred based on variability of drought extreme values.

3.2.3 Spatial distribution

The mapping of the water flow regimes did not indicate a differentiated spatial pattern between the clusters (figure 7). Some clusters appeared only in the north and one only in the south, but they were mainly clusters with one single watershed. Some semi-large clusters (ranging from 3 to 7 GS's) showed spatial patterns; C1 was only present in the Northwest and C4, C6, C7 in the North. Contrariwise, the GS's corresponding to C2 were spread over the map, not showing any spatial pattern.

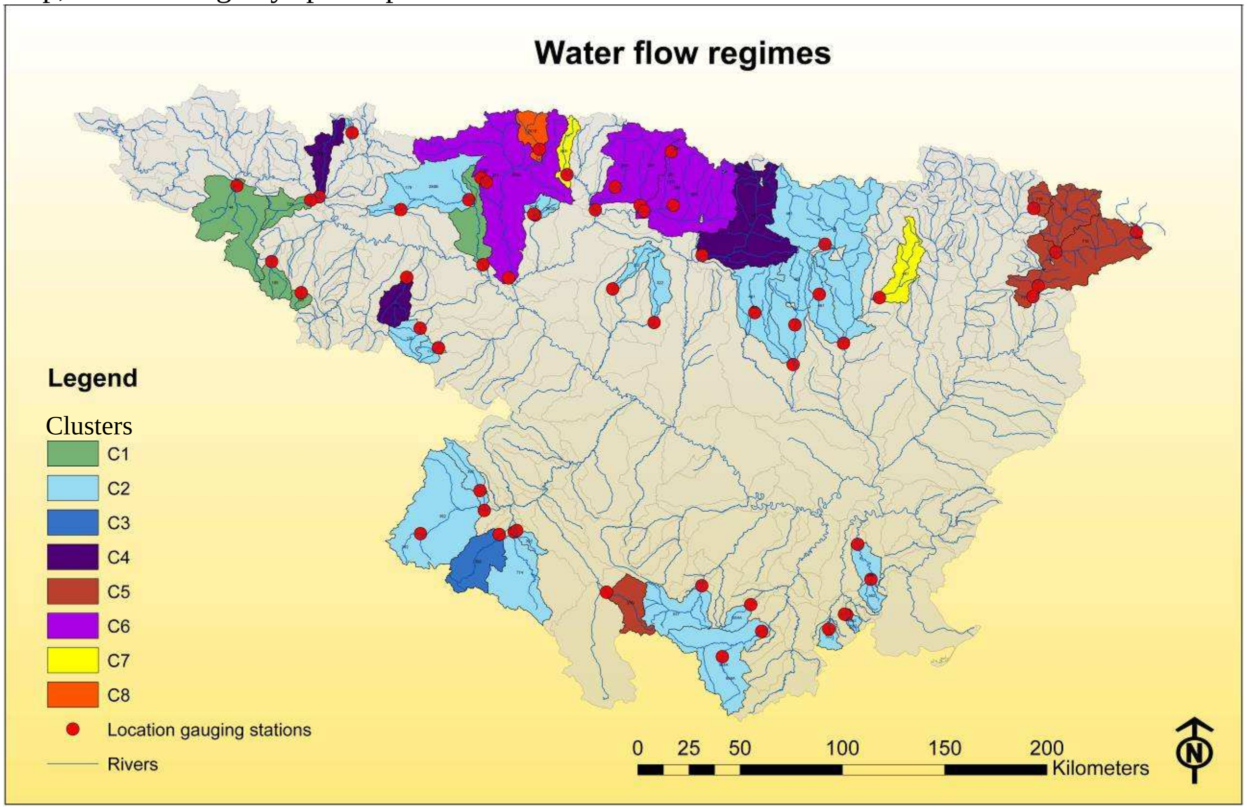

Figure 7: Spatial distribution of the water flow regimes (C: cluster)

3.3 Climate - Precipitation

The results from the general trends and the cluster analysis can be found in appendix III.

3.3.1 General trends

Habitual values

Most of the CS's (~83%) did not show a significant trend in the magnitude related parameters total and average precipitation (Y5, Y6). The CS's that showed a change indicated mainly a reduction in the amount of precipitation (~13%).

The same trends were found in the seasonality related parameters, the total precipitation per season (Y1-Y4), where ~90% of the CS's did not show a trend. CS's indicating a decrease and increase in precipitation were negligible, respectively ~6% and ~4%.

Extreme values (high rainfall)

The maximum seasonal precipitation per year (Y7) did not show a significant trend in ~91% of the GS's and respectively a lower and higher amount of rain in ~7% and ~2% in the remaining CS's. Also the seasonality related parameters, the maximum precipitation within 24 hours, did not indicate many changes over time (93% of the CS's). CS's indicating a decrease and increase in maximum precipitation were negligible, respectively ~2% and ~5%.

Extreme values (low rainfall)

The minimum seasonal precipitation (Y8) did not indicate changes (~96% of the CS's), with only a few CS's showing an increase in minimum rainfall (~4%).

The frequency related parameters; the number of days without precipitation per season (Y18-

Y22) did not show a significant trend in ~79% of the CS's and a decrease in ~13% of the CS's. An increase of rain free days was observed in only ~8% of the CS's. There was a high variation in trends between the seasons. Winter and summer hardly showed any changes, but in spring the number of days without precipitation decreased (~41% of the CS's against ~59% without change), while autumn had more days with precipitation (~19% of the CS's against ~78% without change). The more general annual data summarized the seasonal data, ~72% of the CS's without change, ~17% had less days with precipitation and ~11% had more days with precipitation.

3.3.2 Cluster analysis

The dendrogram was divided into eight clusters based on the vertical dotted line in figure 8. A lower number of clusters was nearly impossible because the relationships between CS's would become too vague, while a higher number of clusters was undesirable since it would make regionalization and relations with other variables (e.g. water flow) very difficult. Each cluster had its own characteristics or precipitation regime per parameter ranging from many changes to no changes and were explained in detail in this section.

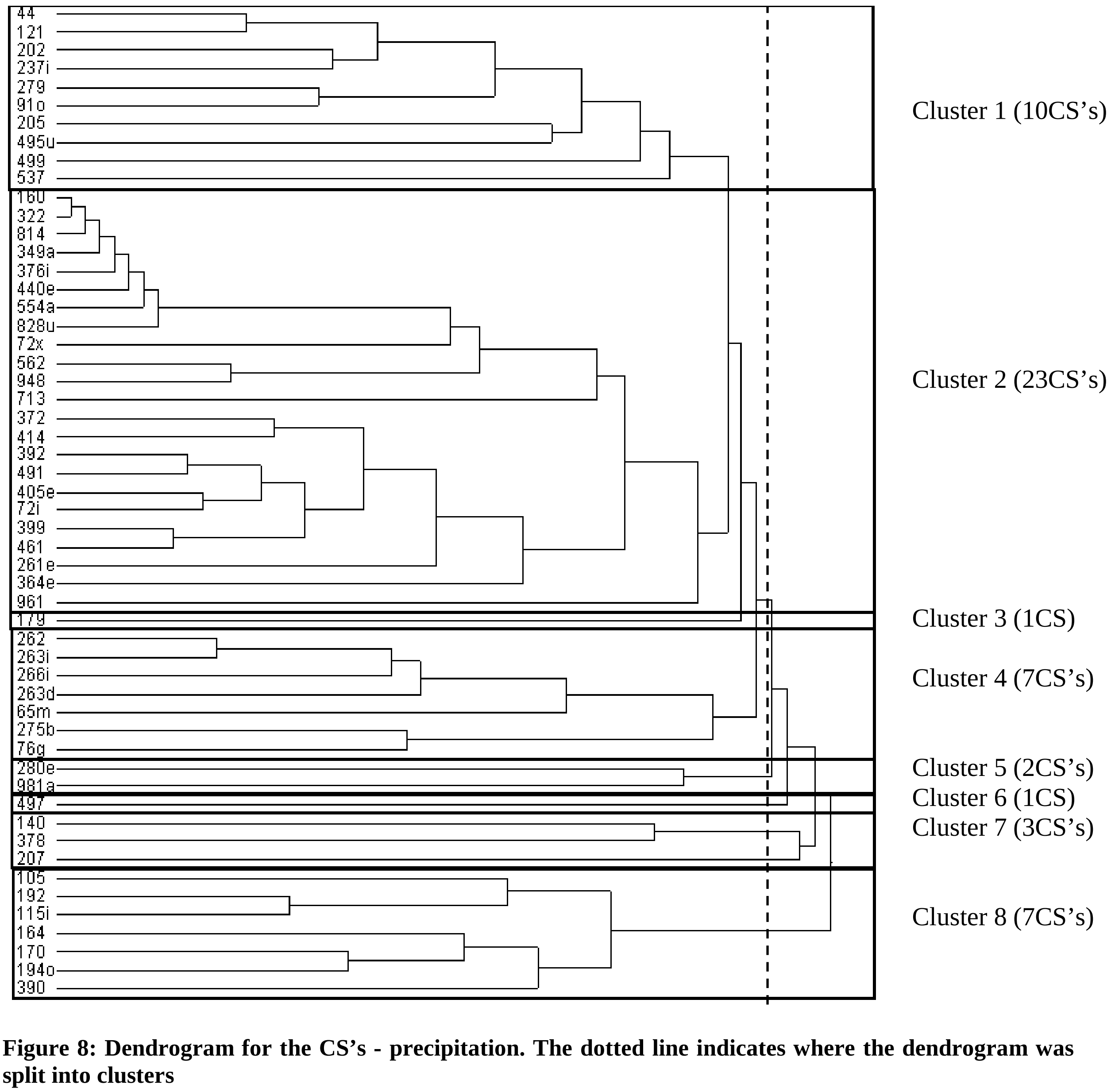

Figure 8: Dendrogram for the CS's - precipitation. The dotted line indicates where the dendrogram was split into clusters

Habitual data
The total and average precipitation (Y5-Y6) showed similar results; C4, C7 were characterized by lower precipitation values over the years, as did few stations of C1. In C2, C6 and C8 no changes occurred and in C5 there was a trend towards more precipitation.
In winter (Y1) and summer (Y3) there was no difference between the clusters since there were only very few changes. In spring (Y2) only in C4 a majority of the CS's showed a decrease in precipitation. In other clusters very few changes were found; besides C1, C2 and C7 where some CS's showed also a decrease in precipitation (except 1 CS's in C2 which had a positive trend), all other clusters did not show any changes.

Extreme values (high rainfall)
Making a distinction between clusters based on the results of the maximum seasonal precipitation (Y7) was difficult since almost all clusters had very few or no changes. Only C7 tended towards a lower maximum precipitation and in C2 one GS had the same and one an opposite trend. The maximum precipitation in one day (Y14-Y17) did not show many changes within the seasons to make a separation between clusters, only in autumn (Y17) there was an increase in maximum precipitation in most of the CS's of C8.

Extreme values (low rainfall)
The minimum seasonal precipitation (Y8) did not show sufficient trends and also the number of days without rain did not show changes for the winter (Y18) and summer (Y20) season. Only spring (Y19) and autumn (Y21) had enough changes to find a difference between clusters by their changing regimes. In spring C4, C7 and C8 showed a clear trend towards a reduction of days with precipitation, while other clusters had no or very few CS's with changes. In autumn the opposite trend (more days with rain) was found for C1 and C3 and quite some CS's in C2 and C8, while other clusters had no or few changes. In the annual data there was a quite large variation between the clusters: C5 and especially C1 and C3 had CS's with an increase in days with rain, while C4, C8 and especially C7 were characterized by a decrease in days with rain.

3.3.3 Spatial distribution

A spatial pattern that could be recognized was that the largest cluster (C2) is mainly situated in the North –and Southeast, but in this area CS's are scarce. Furthermore only C4 and C8 show a clear pattern (all are situated in the Northwest), but all other clusters (precipitation regimes) had spread stations (see figure 9).

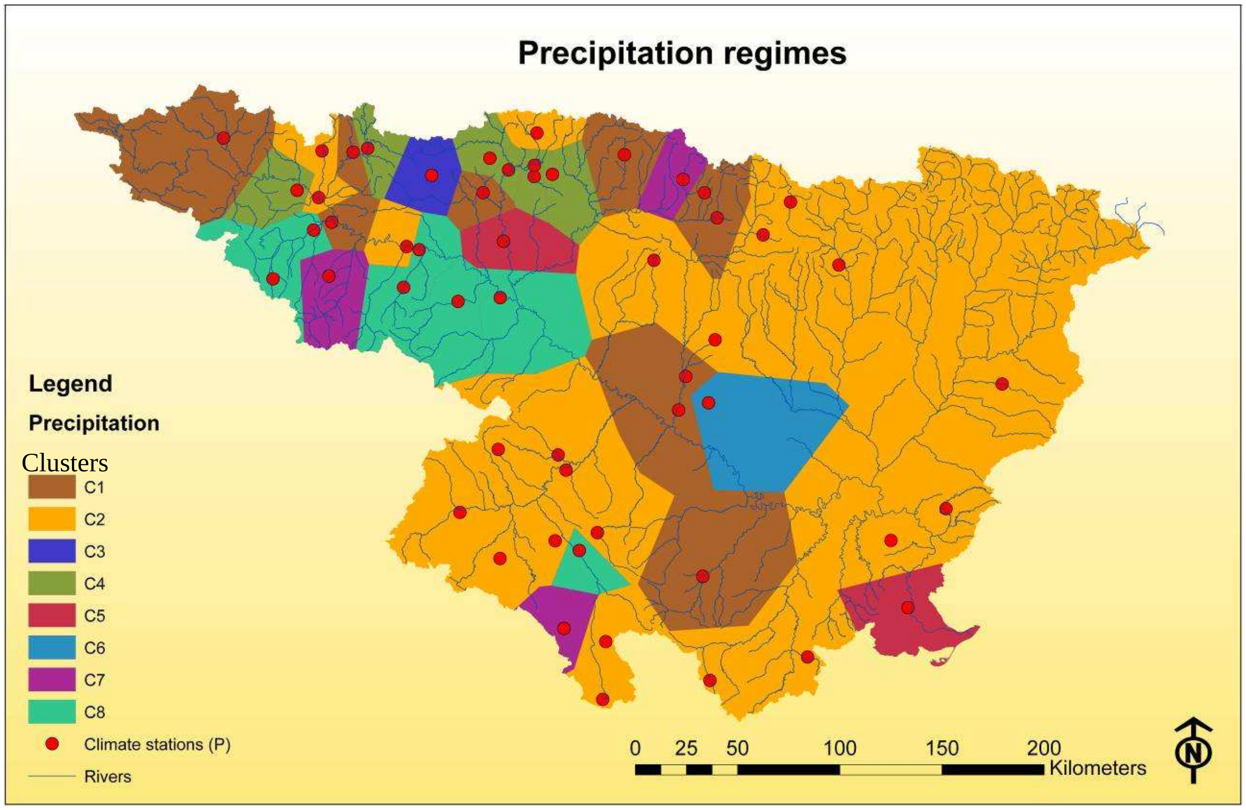

Figure 9: Spatial distribution of the precipitation (C: cluster)

3.4 Climate - Temperature

The results from the general trends and the cluster analysis can be found in appendix III.

3.4.1 General trends

Habitual values

The average annual temperature (Y27) showed a trend towards an increase in temperature in ~49% of the CS's and except two CS's declining, all other stations did not had a change over time.

Also the seasonal trends indicated a raise in temperature, especially in spring (Y24) and summer (Y25) with ~69% of the GS's. In winter and autumn very few changes were noticeable (~13% of the CS's). CS105 was an exception, showing in all seasonal and annual averages a decrease in temperature.

Extreme values (high T)

The average of maximum monthly temperatures (Y28) had no trend in (~46%) of the CS's, ~9% had a lower temperature and quite some CS's (~46%) showed an increase in maximum temperature.

Maximum seasonal temperature (Y30) was dominated by CS's without change (~86%) and the small amount of CS's that showed a trend (~14%) were all indicating a decrease.

The frequency related parameters; the number of days with a temperature higher than 30°C and 25°C per season and per year (Y32-Y39) did not show a significant trend in ~59% of the CS's and a decrease of days with high temperature in ~6% of the CS's. The most remarkable was a considerable amount CS's (~35%) with a tendency towards an increase in days with high temperature. There was no difference when separating seasonal and annual data.

Extreme values (low T) – Magnitude, seasonality and frequency

In ~57% of the CS's there was no change in the average monthly minimum temperatures (Y29), while the rest of the CS's showed an increase (~40%). The CS's with a tendency towards lower minimum temperatures were negligible.

The seasonal minimum temperature (Y31) was not influenced over time (~94% of the CS's did not show a trend), because CS's with an increase or decrease in minimum temperature were negligible.

The frequency related parameters; the number of days with a temperature lower than 5°C and 0°C per season and per year (Y40-Y47) did not show a significant change in ~72% of the CS's and a lower number of days with low temperature in ~28% of the CS's. Especially winter and spring showed a decrease in number of days below 0°C, with respectively ~66% and ~31% of the CS's. The same pattern is found in the annual data, with a lower number of days with low temperature in ~60% of the CS's. Stations with an increase in days with low temperature were absent.

3.4.2 Cluster analysis

The dendrogram was divided into seven clusters based on the vertical dotted (see figure 10). A lower number of clusters was not made because the relationships between CS's would become unclear, while more clusters will complicate the regionalization (clusters will be too small to make conclusions). Similar to the previous variables, also in this case each cluster had its own characteristics or temperature regime per parameter ranging from many changes to no changes and were explained in detail in this section.

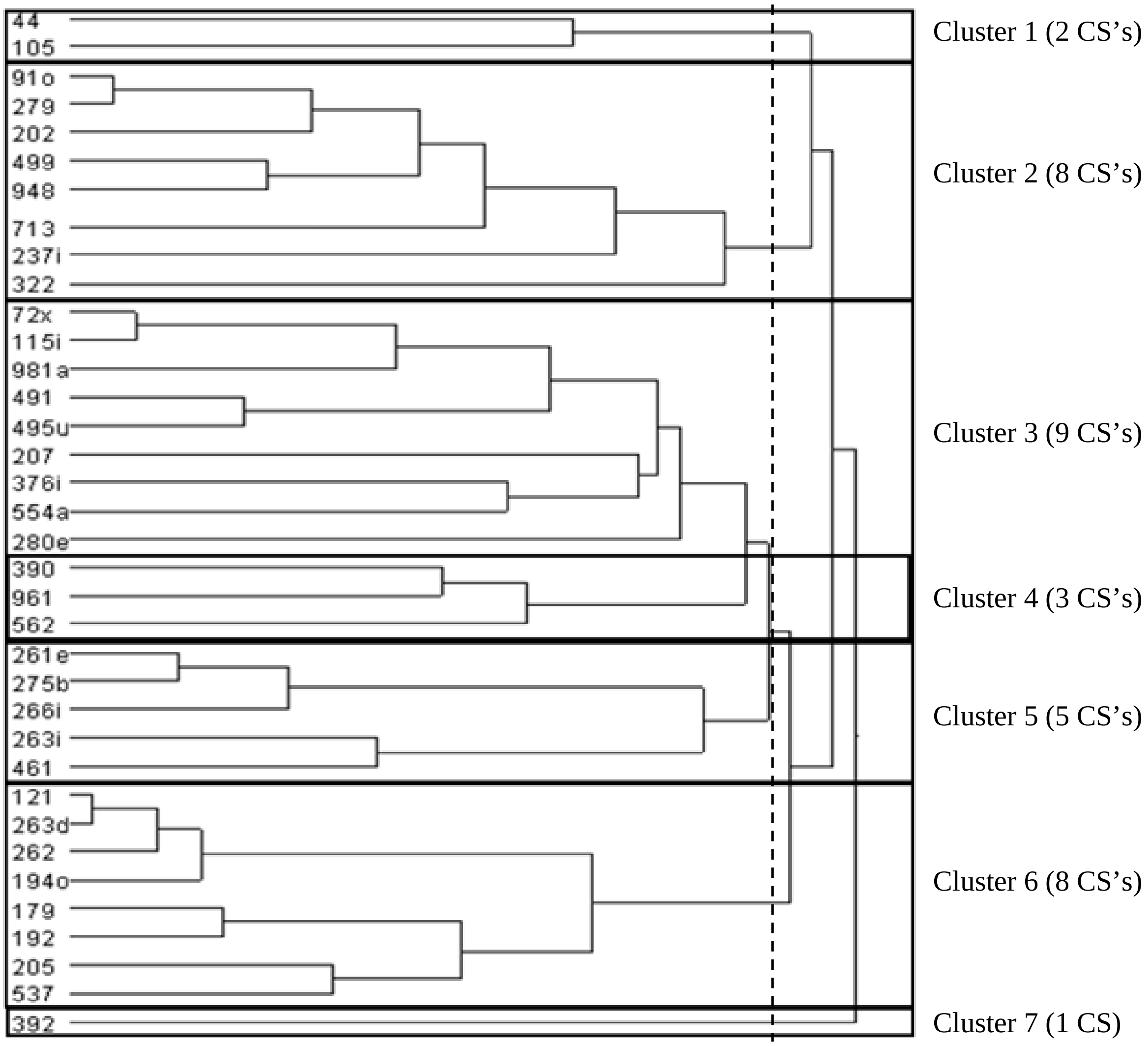

Figure 10: Dendrogram for the CS's – temperature. The dotted line indicates where the dendrogram was split into clusters

Habitual data

The average seasonal temperature in winter (Y23) and autumn (Y26) and the annual results (Y27) showed very few trends, only in C4 there was a majority of CS's with an increase in average temperature. In spring (Y24) and summer (Y25) many significant increases in average temperature can be observed for all clusters so it was not really possible to make large distinctions between clusters for the habitual data. The only CS that had a decrease in average temperature was GS105 of C1.

Extreme values – high temperatures

The average of maximum monthly temperatures (Y28) knew an increase in most of the CS's in C2, C3, C4 and C6 but no change in C5 and C7. Also in this parameter some GS's showed a decrease in temperature (i.e. CS322 of C2, CS280 of C3 and CS105 of C1).

The maximum seasonal temperature (Y30) indicated very few trends in all clusters, so in this case no difference between clusters could be found.

Number of days with a temperature ≥ 30°C (Y32-Y34) occurred more over the years, especially in spring many clusters (i.e. C2, C4, C5, C6 and C7) had a majority of CS's, but also C1 and C3 showed many CS's with the same trend. Also in summer the same tendency was found, but only C3 and C6 this was the majority and in C7 no changes were found. Again some CS's had an opposite trend, i.e. CS105 of C1 and CS322 of C2. In autumn only a few significant increases were found, especially in C2. When looking at the summed up annual data (Y35) it was mainly C4 and C6 that had more days with a temperature over 30°C, while C1 and C7 showed no changes. The number of days with a temperature ≥ 25°C (Y36-Y38) has similar results as in Y32-Y34, but in this case mainly C3-C6 were characterized by these changes. Only C1 and C7 in spring and C7 in summer had no changes. In autumn only C5 and C7 were affected by these changes. The more general annual data (Y39) showed an increase in days with a temperature above 25°C in C3 and C4, while in C1 and C5-C7 no changes were perceptible. In C2, CS322 had an opposite trend (decrease).

Extreme values – low temperatures

The number of days with a temperature ≤ 5°C did not have sufficient significant trends during all seasons (Y40-Y42) to mark a difference between cluster characteristics for these parameters. Only when looking at the more general annual data (Y43) a distinction could be made between C4 and C7, which had a decrease in number of days below 5°C, but the other cluster remained indistinct for extreme variables. The number of days with a temperature ≤ 0°C per season (Y44-Y46) did show negative slope estimates, especially in winter almost all clusters (except C7) had CS's with fewer days below 0°C. In spring only C4 had a majority of CS's with this trend. In other clusters mainly no changes occurred, but all of them had some CS's with the same decreasing trend. In C1 again CS 105, and in C2 CS91o showed an increase in days with frost. In autumn there were only few changes, so cluster differences were absent for this season. Annual data had similar results than winter so the same cluster characterization could be used.

3.4.3 Spatial distribution

Some clusters followed spatial patterns; C3 only appeared in the Southern region. C4 was placed in the North (Pyrenees) and C6 was located in the Northwest. C7 had only one CS, so no pattern could be inferred. All other clusters, including the largest, are disaggregated over the map (see figure 11).

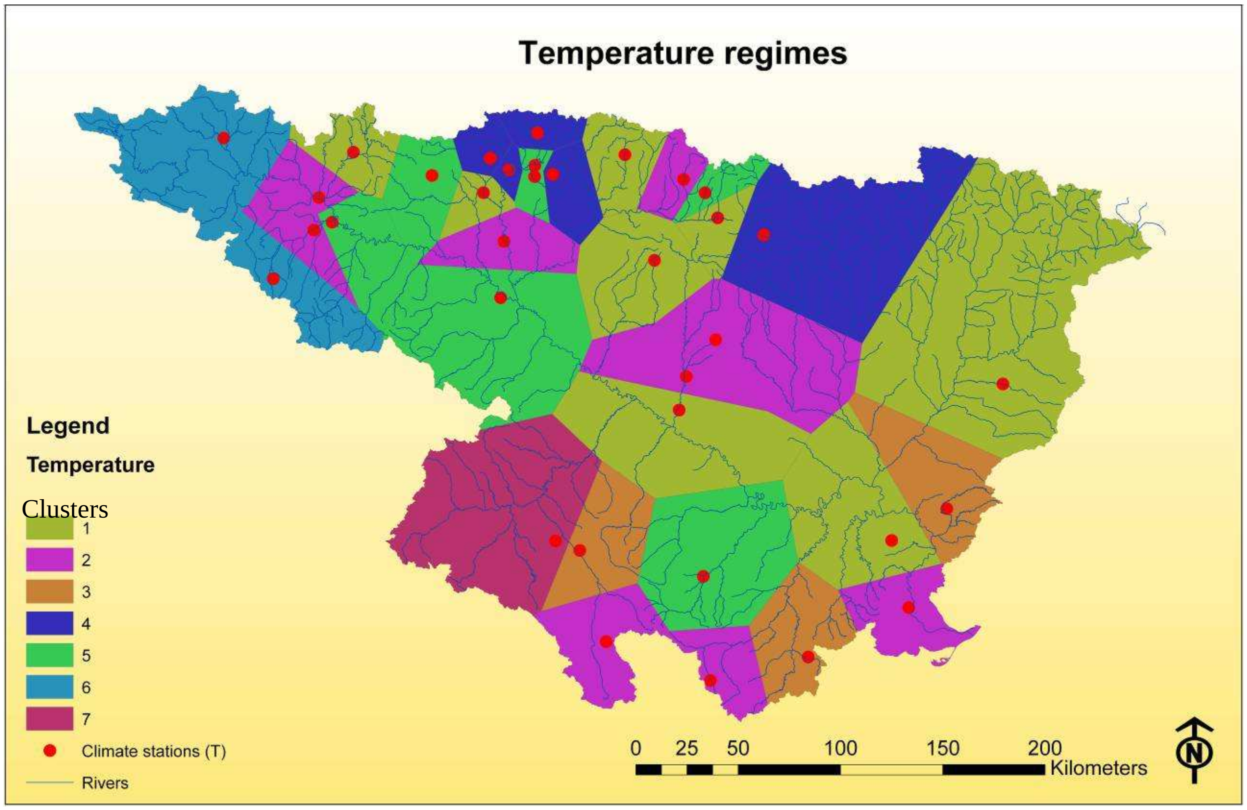

Figure 11: Spatial distribution of the temperature regimes (the numbers are standing for the clusters)

3.5 Forest fire occurrence

3.5.1 General trends

The forest fire occurrence did not change over time in ~73% of the watersheds, while there was more occurrence in ~21% of the watershed areas and a lower occurrence in ~7% of them. The burned area was about constant over time; ~95% of the watersheds exhibited no trend.

3.5.2 Cluster analysis

The dendrogram was divided into six clusters based on the vertical dotted (see figure 12). A lower number of clusters was not made because the relationships between CS's would become indistinct and a larger number would make the clusters too specfic and too small which would obscure regional patterns and make relations with other variables (e.g. temperature) very difficult.

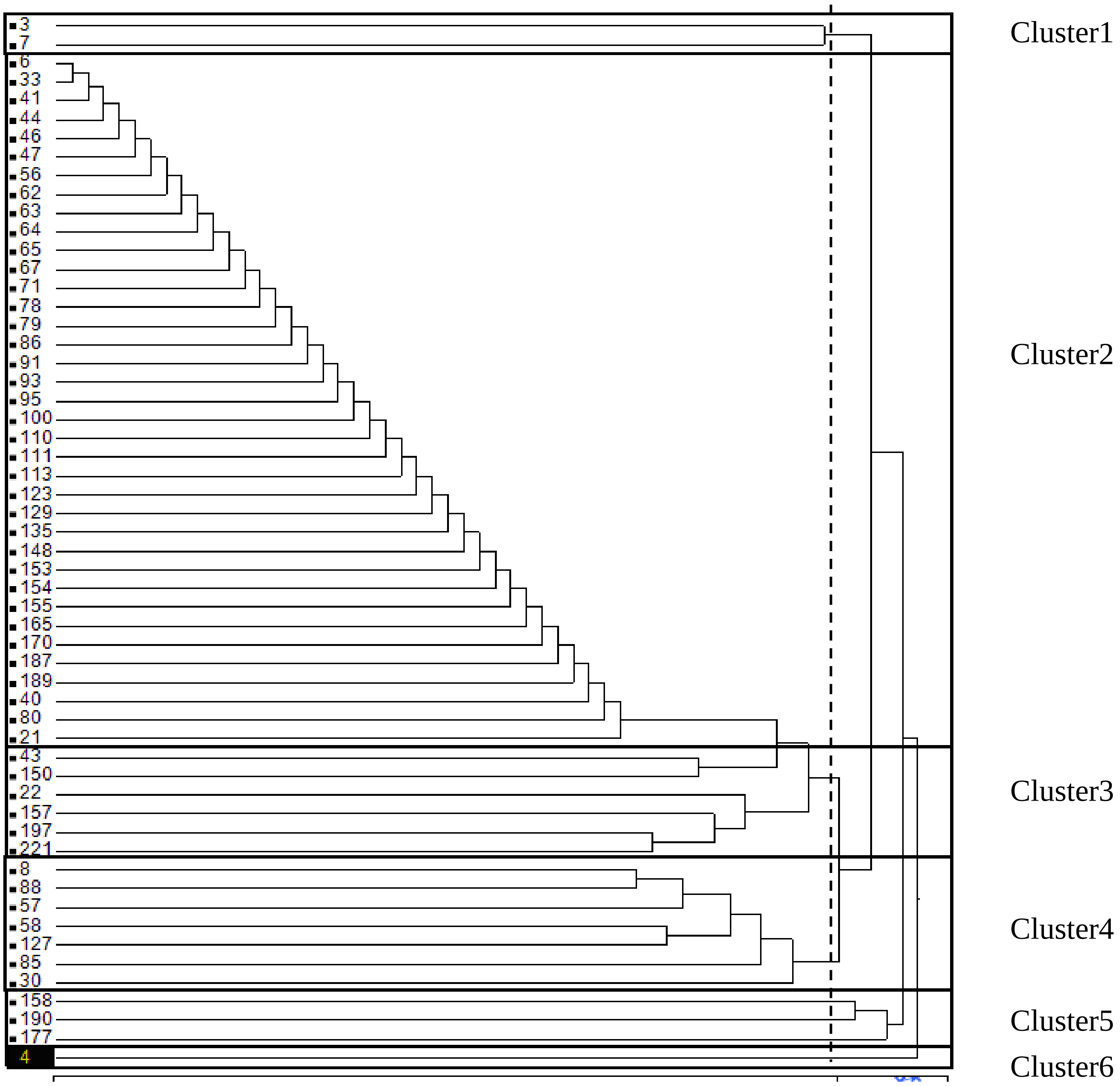

Figure 12: Dendrogram for the forest fire occurrence. The dotted line indicates where the dendrogram was split into clusters

The forest fire occurrence clusters had clear deviations from each other since there were only two parameters included, i.e. frequency and burned area. C6 had the highest increase of occurrence over time, followed by C4 and C3, but these clusters had no change in burned area trends. In C2 there was no change in occurrence or burned area and in C5 there was only a change towards a decrease in burned area.

3.5.3 Spatial distribution

The map of the forest fire occurrences did indicate a spatial pattern for some clusters; C4 was only located in the South, while the largest cluster (C2) was mainly present in the Northern part. Other clusters did not show patterns or were too small to assume patterns (see figure 13).

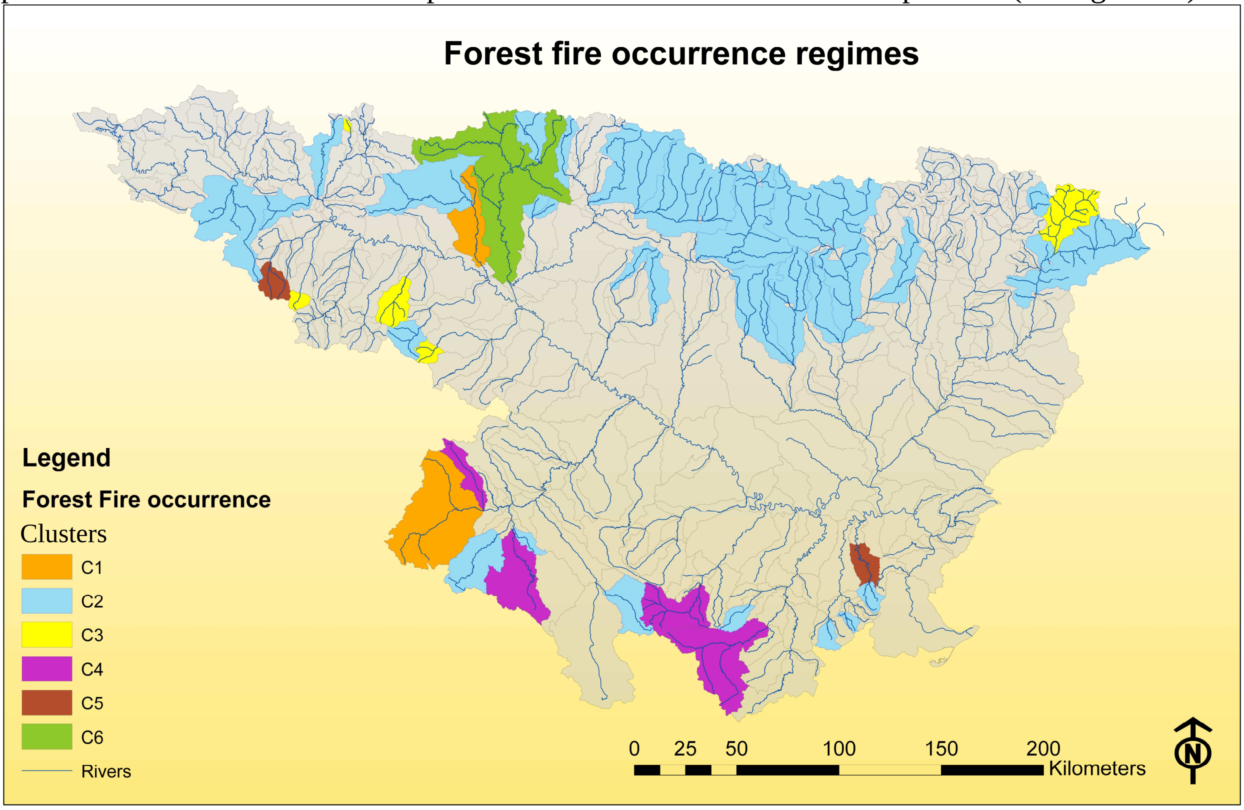

Figure 13: Spatial distribution of the forest fire occurrence regimes (C: cluster)

3.6 Relationships between the variables

In this section the relations (the amount of spatial overlap in km^2) between the regimes of the variables are shown as indicated by 'intersect' in figure 2.

3.6.1 Relations between water resources and climate data

From table 8 and figure 14 it is possible to discern that WF1 is mainly related to P1 although in some cases they also appear to be related to P2, P3 and P5. Also WF6 is related to P1, but this WF regime has some additional relations, mainly with P2, P4 and P7. All other water flow regimes are mainly related with P2.

Table 8: Relations between water resources (WF + cluster number) and precipitation (P + cluster number). The values are indicating the overlapping areas (km^2).

WF/P	1	2	3	4	5	6	7	8
1	1068	814	707	576	211	0	230	733
2	1338	10159	675	310	293	0	401	329
3	0	558	0	0	0	0	0	0
4	494	1150	0	1	0	0	0	284
5	16	2948	0	0	0	0	0	30
6	2572	787	217	1284	482	0	1470	62
7	0	521	0	108	0	0	0	0
8	0	235	0	30	0	0	0	0

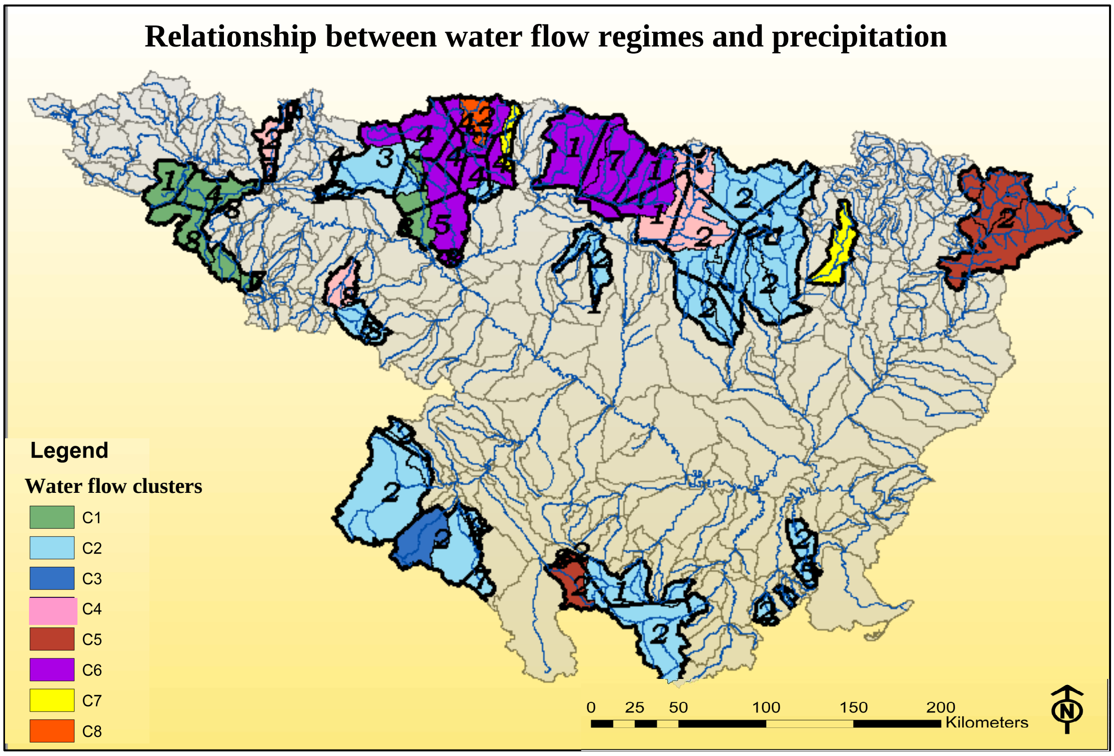

Figure 14: Relation between water flow regimes (indicated by C in the legend) and precipitation (the clusters of precipitation are indicated by the number within the map)

From table 9 and figure 15 it can be noticed that WF1 is mainly related to T6, although there is also a relation with T1, T2, T4 and T5. WF2 is mainly related to T4, but also a large area of T2, T3 and T7 is overlapping with this water flow regime. WF3 is only related to T7 and WF4 to T2 and T4. WF5 and WF6 are mostly related to T1, but in the latter WF regime also T2, T4 and T5 are related. WF8 was mainly related to T4.

Table 9: Relations between water resources (WF + cluster number) and temperature (T + cluster number). The values are indicating the overlapping areas (km²).

WF/T	1	2	3	4	5	6	7
1	678	787	0	703	928	1244	0
2	265	1877	2843	3943	1927	0	2786
3	0	0	0	0	0	0	559
4	0	873	97	824	134	0	0
5	2617	310	49	0	17	0	0
6	2015	1952	0	1452	1456	0	0
7	139	0	0	0	0	0	0
8	0	0	0	235	30	0	0

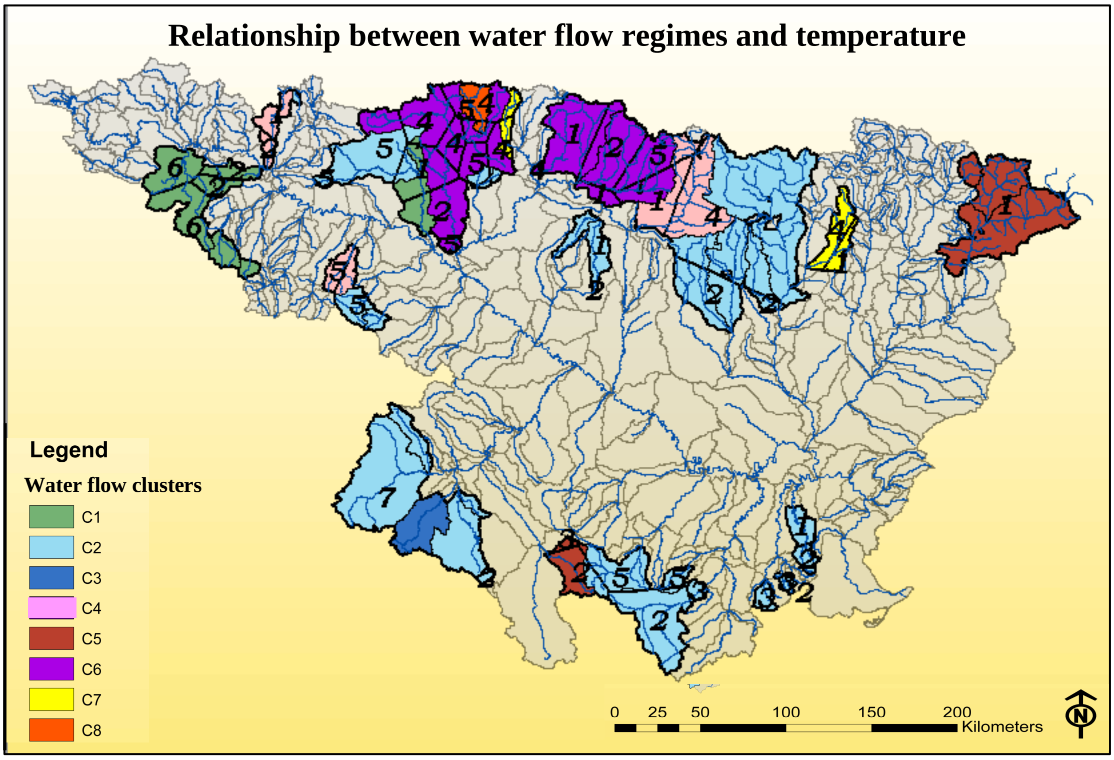

Figure 15: Relation between water flow regimes and temperature (the clusters of temperature are indicated by the number within the map)

3.6.2 Relations between water resources and forest fire occurrence

The influence of forest fire occurrence on the water flow regimes is mainly related to FF2, although in some cases (WF1, WF2 and WF6) there is respectively also quite some overlap with FF1, FF4 and FF6 (see table 10 and figure 16).

Table 10: Relations between water resources (WF + cluster number) and forest fire occurrence (FF+ cluster number). The values are indicating the overlapping areas (km²).

WF/FF	1	2	3	4	5	6
1	1455	2615	75	0	196	0
2	1590	8046	153	3287	564	0
3	0	559	0	0	0	0
4	0	1645	284	0	0	0
5	0	2447	546	0	0	0
6	0	4079	0	0	0	2796
7	0	623	0	0	0	0
8	0	266	0	0	0	0

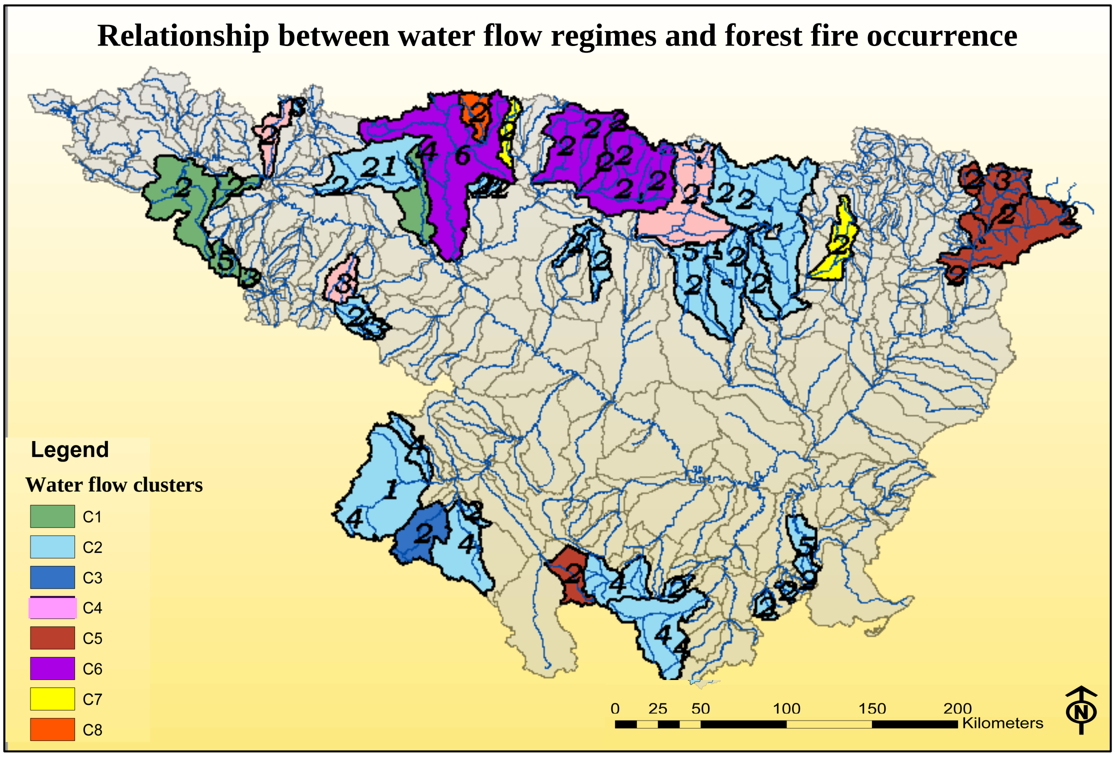

Figure 16: Relation between water flow regimes and forest fire occurrence (the clusters of forest fire occurrence are indicated by the number within the map)

3.6.3 Relations between forest fire occurrence and climate change

Table 11 and figure 17 show that all forest fire occurrence regimes, except FF6, are mainly related to P2. FF6 is mostly overlapped by P4. Some other precipitation regimes that also have a considerable amount of overlap are P1 on FF2 and P8 for FF3.

Table 11: Relations between forest fire occurrence (FF+ cluster number) and precipitation (P + cluster number). The values are indicating the overlapping areas (km²).

FF/P	1	2	3	4	5	6	7	8
1	371	1669	675	98	211	0	0	20
2	4305	11437	707	868	168	0	2075	724
3	31	546	0	20	0	0	26	436
4	528	2566	0	57	0	0	135	0
5	0	438	0	0	126	0	0	196
6	252	516	217	1266	482	0	0	62

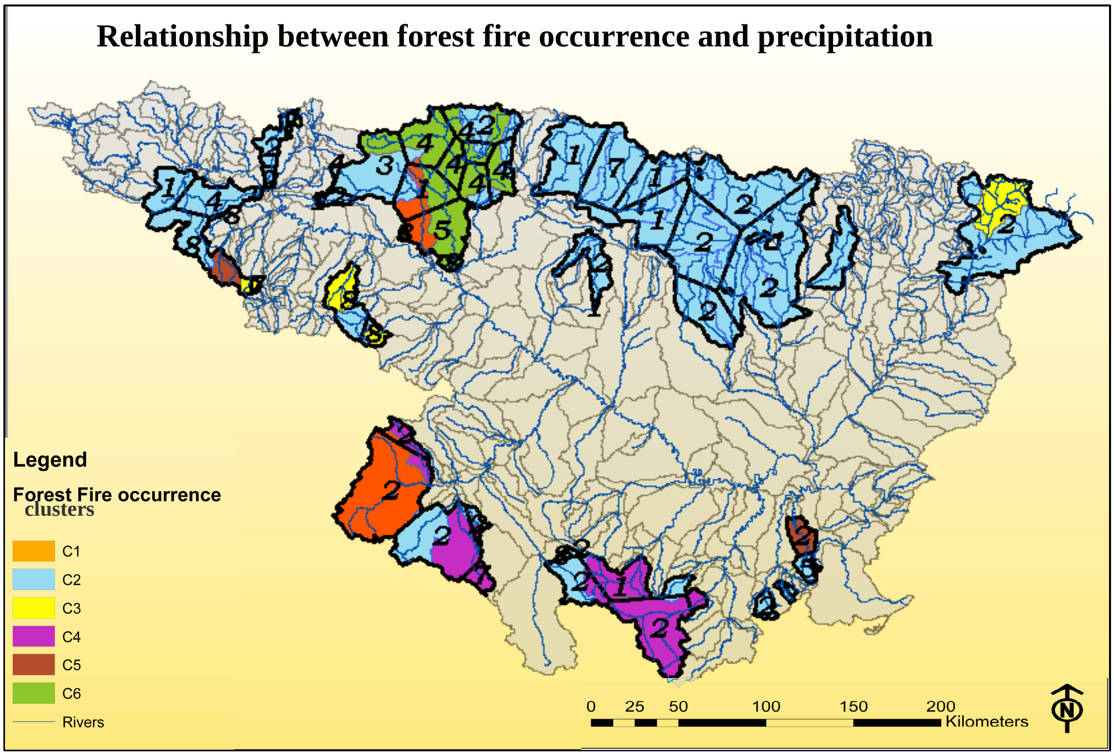

Figure 17: Relation between forest fire occurrence and precipitation (the clusters of precipitation are indicated by the number within the map)

From table 12 and figure 18 one can see that FF1 is mostly related to T7, FF2 is mainly related to T1 and T2, FF3 to T1, but also to T5 and FF4 mainly to T4 and T1. FF5 is mainly overlapped by T1, while FF6 is mostly related to T4.

Table 12: Relations between forest fire occurrence (FF+ cluster number) and temperature (T + cluster number). The values are indicating the overlapping areas (km²).

FF/T	1	2	3	4	5	6	7
1	361	228	0	70	795	0	1590
2	6186	3935	226	5952	2370	973	643
3	577	0	0	20	387	75	0
4	589	97	0	824	134	0	0
5	1280	310	49	0	17	0	0
6	252	482	0	1434	628	0	0

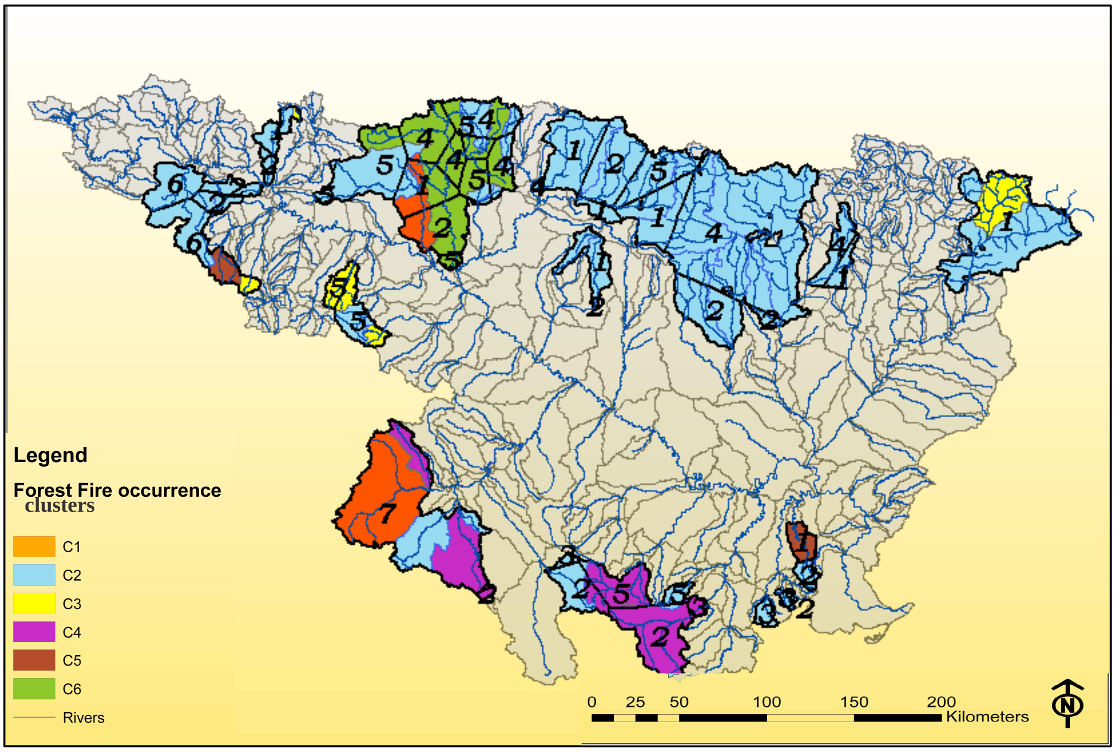

Figure 18: Relation between forest fire occurrence and temperature (the clusters of temperature are indicated by the number within the map)

4 Discussion

4.1 Data preparation

Natural and rainfall-dominated flow regime watersheds with a reliable data range of 30 years of daily weather and flow records were not abundant in the Ebro river watershed. These conditions were not easily met and consequently, the data used in this study was limited to five GS's. Nevertheless, the selection of the gauging stations spread North and South of the main stream and include paired, nearby gauging stations. Ten gaps were modelled under different conditions of inter and intra-annual flow variability. The variables used to build the models were purposely few, because Julian day and precipitation data are considered the most important variables to make predictions on streamflow (Besaw et al. 2010; Cuadrat et al. 2007; Wu and Chau 2011), and they are usually available within the area of interest. Data availability is always an issue in this type of studies. Existing data at GS's nearby, either upstream or downstream of the same watercourse, are rarely available. Complex rainfall-runoff models can be built, but they also require many data, and watershed characteristics (shape, soil, elevation, vegetation) are not always easily acquired. Instead, we tested simple models based on generally available weather data with a view to use them for filling gaps in water flow series. In many instances the artificial neural network models (ANNs) further reduced the amount of variables in order to improve training results (as in Vega-García et al. 1996; Klutowski and White 1993), mainly precipitation values delayed 4-5 days from the gaps. This fact backed the assessment of the small size of the watersheds and the selection of precipitation variables (previous 1-5 days) based on time of concentration.
Like in other hydrological problems (Alcázar et al. 2008, Araujo et al. 2011, Besaw et al. 2010, Poff et al. 1996, Wu and Chau 2011), ANNs have proven their potential value for modelling complex processes with limited data, but the variability of the Pearson R correlation values between observed and predicted outcomes under different scenarios and GS's indicate that procedures cannot be generalized. Not all models performed well enough for their intended filling gaps application.
The results of the study suggested that there was not one single scenario suitable for filling up gaps in all gauging stations, but S4, S5 and S6 gave the best results. Different scenarios would have to be tested, if applicable, but this approach seemed promising if seasonal variability is accounted for and short periods before and after the gap are considered. Using the full 30 years of data did not give satisfactory results which probably were related to changes in water flow over the years, more likely with longer time spans. Gaps in Low water flow periods gave better modelling results, probably caused by a lower variability in the data typical of these periods. High heterogeneity in the water flow data negatively influenced the training of suitable models, like in case of GS-57 and GS-86 gauging stations, where no suitable model was found for any scenario or gap. Future work may have to look into neural network algorithms better suited to identify extreme values instead of general trends.

4.2 Waterflow

4.2.1 General trends

The habitual parameters to determine if there was a change in water flow regime during the 30 years' time span indicated that on an annual base there was a decrease in water discharge in a considerable amount of rivers (GS's), but in the majority of rivers no change was noticeable. Summarizing the monthly results resulted in leveling out most of the seasonal

influence because in most months almost no changes were appreciated, but it is remarkable that the decrease found in annual data is mainly influenced by the month's spring (May and June) and the beginning of summer (July). This could be an indication that the period of drought, normally taking place in summer, is extending towards spring and could maybe cause more severe drought stress in summer. Summer itself is already dry so that is possibly the reason why in August and September no significant changes were noted. A somewhat strange observation in the results is the decrease in water flow in February which was not in line with the expectations. GS153 was an exception since it is the only river with an increase in water discharge. No explanation could be found by looking at the trend results of other variables at this location or topography. Including factors such as vegetation or soil could maybe have explained more but were out of the scope of this research.
The variability had not changed in most of the months, except in February, May and June some changes towards a lower variability were found. This was also the case for the annual data. This could be explained by the fact that a reduction in maximum water flow reduces the difference between the minimum and maximum flows. Also the difference between the Q10 and Q90 percentile of the flow duration curve confirms these observations.
Seasonality was included to see if climate change could cause a shift in the water flow regime. Maybe an increase in temperature could had an influence on the snow melt, causing a shift in high water flow towards an earlier period in the year and affecting the water availability later in the year (Bates et al. 2008, Arnell 1999a, Arnell 1999b, Cuadrat et al. 2007, Poff et al. 1996). However both the months with maximum and minimum water discharge presented very few changes.

Trends similar to those in habitual data were found in the maximum values or floods. The monthly maximum in most GS's did not change over time, only in the months February, May, June and July some changes towards a lower maximum water flow were apparent, similar to the trends in the monthly average data. Also the average maximum monthly discharge had similar results. The effective discharge or bankfull flow enabled us to see if the peaks in water flow, measured over a period of 10 years (return period from the year of interest till 10 year before), decreased or not. In general it seems that the effective discharge was very site specific because the monthly data showed, besides some stations without change, stations with decrease and increase within the each parameter. Only for the months September and December there was a tendency towards higher peaks in water discharge and in the months November, April and May towards lower peaks. The lower peaks could be the result of a generally lower water discharge over the years as found in the average and maximum flows. The increase in peak flows is probably caused by extreme weather events (heavy rainfall) in some days although it could be the case that the rest of the time precipitation was reduced (Arnell 1999a, Bates et al. 2008, Cuadrat et al. 2007, Poff et al. 1996). The results of the flushing floods over time indicated a reduction in floods, which supports the decreasing trends in bankfull flows.
There was no change in the variability of maximum flows. That could be because lower peaks in winter and lower peaks in summer level each other out, but it is also possible that there are no changes in variability. Also the months with the highest flood frequency did not show any changes, which means no shifts occurred in floods from one month to another over time.
The increasing and decreasing rate of change (a measure for how rapidly a flow raises or falls from day to day) did not show many changes. The GS's in which a change was observed were indicating rate of change became lower, probably caused by the reduction in water flow.

The reduction of water availability is also found in some of the GS's when looking at the minimum daily flows per month. This trend is mainly observed in spring, summer and in

February, strengthening the earlier findings in habitual and maximum data. The ordinary drought and the average minimum monthly –discharge confirms previous results. Similar to the maximum values there was almost no variability in minimum values, probably because annual data is too general.

4.2.2 Cluster analysis

The temporal results of the habitual data had a majority of stations without change which somewhat complicated the comparison between the different clusters (few differences) However as described in the general trends some parameters had still many GS's indicating a change, enabling us to distinguish the differences in characteristics between clusters and thus the type of water flow regime. Unfortunately the dissimilarities in characteristics that separate these clusters are different from parameter to parameter which makes it impossible to make a clear division into clusters with many changes to those with no changes. Therefore the characteristics had to be explained per parameter and it has to be noted that this is an explorative study. Nevertheless it was possible to denote that the clusters which seemed to have changed most over the 30 years' time span in the months with sufficient changes were C1 and C6, while the GS's of C2 and C4 indicated the lowest amount of changes. This was not the case for C4 when looking at the annual data.
In the variability related parameters with fewer changes, C6 was again the most remarkable cluster showing a decrease in variability in the months with sufficient changes (as found in the general trends). These trends were also found in the annual data and the in the difference between the Q_{10} and Q_{90} percentile for C6, together with C5. In most of these (latter) parameters C2 and C4 were indicating only very few changes. C3, C7 and C8 were too small (1 or 2 GS's) to categorize them as having many or few changes, especially because within those clusters with 2 GS's the results were mixed (no change and decreasing trend) and this was also the case when looking over all the parameters of the habitual data. In general C6, followed by C1 were the clusters with their water discharge most affected, and C2 and C4 less affected over time.

The same patterns as in the average water flow were found for the maximum values; C1 and C6, and in some extent C5 had lower maxima. However this was not found in the annual data of maximum water flows, probably the other months disguise the effects found in some months. In this case only C4 was indicated as being most affected. The effective discharge was, as mentioned before in the results, very site specific and could not be used on a cluster level because of the large variability within each cluster. From all other parameters only the 'flushing floods' had sufficient changes and also in this case C6, and C5 were characterized by lower peak flows. In general the maximum values (floods) had similar clusters which had been affected by changes (C1 and C6), but in this aspect also C5 had many changes.

The months in which there was an influence on the minimum daily discharge (see 'general trends') indicated that these changes mainly occurred in C1 and C6. The annual data had similar results, but in this parameter no changes were found in C6. This could be because the other months disguise the effects found in some months (as found in the 'maximum values'). What was also remarkable was C8; despite this cluster had only one GS, this station had a change in minimum water flow in all of the monthly and annual parameters. When looking at the results of the annual drought discharge, only C1 had a majority of GS's which showed a decrease in minimum discharge. In general this aspect also indicated C1 and C6 as the clusters most affected by changes.

The map of the water flow regimes did not indicate a spatial pattern between the clusters (figure 7). Some clusters only appear in the north and one only in the south, but they are mainly clusters which comprise only one single watershed and their uncertainty is too high to speak of pattern (i.e. it is not sure that if there would be more stations in this cluster, they would be near each other. Nevertheless for some semi large clusters (ranging from 3 to 7 GS's) we could say with some confidence that they indicate a spatial pattern; C1 was only found in the Northwest and C4, C6, C7 in the North. However, the GS's corresponding to C2 in the contrary were spread over the map, not showing any spatial pattern

4.2.3 Spatial distribution

When looking at the location of the clusters and taking into account the results from the cluster analysis it can be clearly found that both C1 and C6 have rivers which had a change in water flow regime over time and both are located in the North to Northwest. C8 which showed changes in the minimum values is also located in the North but this cluster, together with C3 and C7 is actually too small to speak of patterns. The cluster containing the GS's with the least change was C2 and is spread over the map.

4.3 Climate – precipitation

4.3.1 General trends

The annual data did not indicate changes in precipitation, only in a small amount of stations there was less rainfall over the years and the division into seasonal data did not show different results. Only in spring there was a slight decrease in rainfall and in autumn an increase which to some extent could indicate wetter autumns and drier springs. Maybe the effects in summer could increase the already dry summer period and cause problems regarding drought.

Also the extreme events of high (maximum) rainfall were mainly not influenced over time. It is possible that over the 30 years' time span habitual (average) rainfall events were occurring less frequently, but their intensity remained the same (that could explain the drop in water flow in some rivers, but not their maximum flows). Maybe including parameters, which did not look at the absolute maximum values, but for example the amount of days with a rainfall above a certain threshold or the average of the 10 largest rainfall events per season would maybe reveal more changes.

Similar results were observed for the minimum values (droughts), but in this regard some remarkable trends were found in autumn, tending towards more days of rainfall and spring tending to fewer days with rain as indicated by Bates et al. (2008), Arnell (1999a) and Arnell (1999b). Especially the changes in the spring season are important; as mentioned before this could be an indication towards an extension of the characteristic dry summer which could maybe cause water stress (for vegetation) and shortage of water availability (e.g. irrigation). Overall it would have been useful to look at more specific monthly data in addition of seasonal and annual data. Annual data often seems too general and therefore not always shows the changes that occur on a seasonal level. Specifically, opposite trends in the seasonal data causes annual data to be non-significant (trends are disguised).

4.3.2 Cluster analysis

Since for habitual data the majority of CS's were not indicating changes, it was difficult to separate the cluster characteristics. However seasonal data, and especially spring and autumn enabled us to select clusters with different characteristics such as C4 and C7 which had a lower total precipitation in spring and C8 with increased total precipitation in autumn. C2 displayed the least changes.

Similar patterns were found in the maximum values; C7 indicated a decrease in maximum precipitation in the annual data, while C8 showed an increase in autumn.

Also the minimum rainfall parameters were supportive of previous findings. The annual data seems too general (as mentioned in the general trends), but the seasonal data indicates that spring had more days without rain in C4, C7 and C8. In autumn the trend was opposite in C1 and C3 and to some extent in C2 and C8. In summary, C4, C7 and to some extent C8 indicated a decrease in precipitation events in spring, while in autumn an opposite trend was found in C8 especially, but also in C1, C2 and C3.

4.3.3 Spatial distribution

Figure 9 indicates that C4 is only located in the Northwest, while C7, the other cluster with a decreasing precipitation regime, is more dispersed. C8, which showed an increase in rain in autumn and a decrease in spring, was also located in the Northwest. The other clusters existing only out of one CS could not be considered as having a pattern because with so little stations we cannot speak of groups. Another remarkable pattern is that C2 (least changes) is mainly located East, but this is a less reliable assumption since in that area only very few stations were useful for analysis (due to lack of data).

4.4 Climate - temperature

4.4.1 General trends

When compared to the other two variables, temperature showed most changes over time. Habitual data indicated clearly that in many locations an increase in temperature occurred which was especially discernible in spring and summer.

Also in the averages of maximum monthly temperature per year an increase was found, but when looking at the absolute peaks in temperature over time there were only few changes. This indicates that although temperature raises and maybe temperature peaks are more frequent, they are not becoming more severe. Frequency related parameters supported the trend results of the habitual data: the increase in temperature was also found in the number of days above 25°C and 30°C during spring and summer. Annual frequencies were showing less significant results but that could be caused by the inclusion of autumn.

To explore if these trends were also taking place in and around the winter season, maybe influencing snowfall and/or snow melt (regarding the shift in water flow), the frequency of days below 0°C and 5°C were analysed. The results indeed indicated a decrease in days with low temperature, mainly in the days below 0°C in winter and spring, which are the most important months regarding snow melt and the effect on water discharge. These results are also supported by Bates et al. (2008), Arnell (1999a), Arnell (1999b), Cuadrat et al. (2007) and Poff et al. (1996). Despite the small amount of CS's one can still conclude with some certainty that there is a tendency towards an increase in temperature in almost all parameters, although this does not seem true in all areas.

4.4.2 Cluster analysis

Since the habitual values the annual data and the autumn season did not show a sufficient amount of changes (see general trends) for dividing the clusters by their characteristics the emphasis lays on the increase in temperature in winter, spring and summer. In the habitual data only C4 stuck out (significant increase in temperature in all parameters) and this was also

the case for the number of days above 30°C in spring. In the last mentioned parameter also C2, C6, C7 and especially C5 had a majority of CS's with an increase in days with high temperature. In summer this was the case for C3 and C6, while C7 had no changes at all. Also for the days with a temperature above 25°C C3 and C6 were the clusters with most changes towards an increase in days with high temperature, while the CS's C1 and C7 had no changes.
The trends in low temperatures in winter indicated a difference between C7 (no change) and all other clusters (especially C3, C4 and C5) which had a decrease in days with low temperature (0°C). In spring only C3 had a majority of CS's with a decrease in the last mentioned parameter, while in C7 again no changes occurred.
Overall one can conclude that C3, C4, C5 and in some extent in C6, most changes towards an increase in temperature. This was not the case for C7 and other clusters could be found as intermediate.

4.4.3 Spatial distribution

The location of the clusters suggested that most clusters which showed a change towards an increasing temperature had a spatial pattern: C3 was situated in the Southern part of the Ebro watershed, C4 only in the northern part and C6 in the Northwest. Only the CS's of C5 were scattered. The cluster with few or no changes (C7) had only one CS, so here one cannot speak of a pattern. In general the number and extent of the CS's was poor because of the lack of data. However regarding the relationship with the other variables (water flow and forest fire occurrence) the reliability is quite high since most CS's are situated within or near the watersheds.

4.5 Forest fires

4.5.1 General trends

In most watersheds forest fire occurrence did not change over the 30 years' time span, but some areas suggested an increase. The amount of burned area did not change, and it has been speculated this is due to improvement in monitoring and technological advancement in techniques for firefighting. Also, the awareness of the danger of fires increased during the years which lead towards preventive measures against fire spread (fire roads, hazard reduction through fuel treatment). To be able to fully understand the trends regarding forest fires, though, more parameters are needed, especially regarding vegetation type and structure, amount of dead wood, shrubs/understory, but also land management is important.

4.5.2 Cluster analysis

Since only two parameters were included in the cluster analysis the cluster division of the dendrogram is very clear, showing mainly watersheds where no fires occurred (C2). C6, followed by C4 had the highest changes over time. As mentioned before more parameters are needed to have a full understanding and more complete and reliable cluster division.

4.5.3 Spatial distribution

The clusters indicating most change towards an increase in fire forest fire occurrence, C6 and C4 were respectively located in the North and the South. However C6 only had one watershed so it is difficult to make any hard conclusions regarding its location. Since C4 and C6 had a similar regime, we would expect them to be located near each other if there was a spatial pattern, but this was not the case. Therefore there is a high uncertainty regarding any spatial relationship.

4.6 Spatial relationships between the variables

4.6.1 Relations between water resources and climate change

The main interest is on the clusters with the most affected water flow regime and if there is a relation with to the most affected clusters of precipitation. This was found for the water flow regime of C1, which was mainly related to the precipitation regimes in C4 and C8 (see figure 14). This was to some extent also the case for C6 which was mainly related to C4 and C7 together, although the precipitation regime in C1 covered most area (see table 8). Other relations were found in water flow C2 (characterized by 'no changes'), which is mainly related to C2 of precipitation (also characterized by 'no changes'). However in the latter case one needs to be aware that the relation is also partly due to the large size of the clusters of both variables as indicated in the dendrogram (figure 8). Other relations were not found because they are not clear (i.e. clusters with only some changes and/or overlapped by multiple clusters with different regimes or the cluster is too small).

The decreasing water flow regime in C1 is mainly related to the increasing temperature in the CS's of C6, but there was also an overlap with C2 and C5 from which C2 had only few changes. Water flow C6 (decrease in water discharge) is mainly related to C1 and C2 and in some extent to C4 and C5, so in this case temperature had not much influence on the water discharge. C8 (decrease in water discharge) was mainly related to C4, but this is only a small area, not enough for making hard assumptions. This was also the case for C7 (no changes in temperature) covering C2 (no changes in water discharge). Other relations were not found because they are not clear (i.e. clusters with only some changes and/or overlapped by multiple clusters with different regimes).

4.6.2 Relations between water resources and forest fire occurrence

Forest fire occurrence did not have any influence on the water flow regime besides the relation between C6 of both variables with water flow showing a decrease in water flow and a higher forest fire occurrence. This one relation could be coincidence, but a more plausible assumption is that this was mainly the effect of precipitation and temperature changes in this area. Forest fire occurrence is actually an indirect influence, i.e. replacing the effect of vegetation on water flow (they cause removal of some of the vegetation).
More important is the effect the last mentioned variables on the water flow regime (see above) and forest fire occurrence (see below).

4.6.3 Relations between forest fire occurrence and climate data

The area where most forest fires occurred (C6) was mainly influenced by C4 which showed most decrease in precipitation. Other relevant relations were not found.
In the case of temperature the area where most forest fires occurred (C6) was mainly influenced by C4, characterized by many trends of increasing temperature.
This means that there is a probability that the increase forest fire occurrence in that area is related to a combination of more droughts and an increase in temperature over time. However we need to keep in mind that this is an explorative study and this means that also other variables could cause an increase in forest fire occurrence.
This is only the case for forest fire C6, but other clusters did not show these relationship. To thoroughly analyze forest fire occurrence more parameters are needed. Especially vegetation, land management (abandonment) and the amount of dead wood (fuel) as also mentioned in Diaz-Delgado et al. (2004), Dios et al. (2007) and Vega-Garcia & Chuvieco (2006).

5 Conclusions

The artificial neural network modeling part (ANNs) in this study was a stepping stone used for the estimation of daily water flow in five gauging stations with rainfall dominated natural hydrological regime located in watersheds of the Ebro River. We concluded that no general rule applied to all stations and gaps investigated, but if seasonal variability is accounted for and short periods before and after the gap are considered this approach may be useful. Models for low water flow periods apparently performed better, probably because of the lower variability in the data typical of these periods.

The main goal of this study was to explore effects (relations) of climate change on fire occurrence and water regimes in a Mediterranean watershed. Before the relations could be made between climate change, water flow regime and historical forest fire occurrence, the change in climate, water flow regime and forest fire occurrence had to be tested to see if there were changes in the first place:

- Are there indications of hydrologic alteration in the Ebro watershed in the past 30 years and are there spatial patterns?

Changes in water flow occurred, but the majority of rivers (GS's) did not show changes over the 30 year time span. The stations with changes all pointed towards a reduced water discharge which was most detectable during the spring. The reduction of water flow in spring was an important observation because it could extent the characteristic dry summer period which could cause ecological problems. Most changes are grouped in the clusters located in the North to Northwest, but in general we cannot make a regionalization of the water flow regimes since most gauging stations and/ or clusters are widespread.

- Are there indications that climate has changed in the Ebro watershed over the past 30 years and are there spatial patterns?

The variables of the climate analysed, precipitation and temperature, both indicated changes. The changes in precipitation were limited to some locations, showing a decrease in precipitation mainly discernible in spring. There was also an increase in precipitation in autumn. Especially the number of days without rain highlighted these changes. Also in this case two of the three clusters with most changes were located in the Northwest of the Ebro watershed.
Temperature was the variable with most changes over time, displaying an increase in almost all parameters. The main seasons showing an increase in temperature were spring and summer, in the habitual data and the high temperature data. But also around the winter period some remarkable changes were found; there was a considerable decrease of days with frost which could have a large effect on the water flow. The assumption of a reduction of snow or earlier snow melt could cause a shift in water discharge towards an earlier period in the year, causing reduction of water flow later on and maybe even shortage.

- Are there indications that the fire regime has changed in the Ebro watershed in the last 30 years and are there spatial patterns?

To measure the changes in forest fire occurrence only two parameters were included, but the most important parameter, the occurrence, showed an increase in fires in some (few) locations. Except for the cluster with most changes, located in the North, no other spatial patterns were evident.

- Is it possible to find a relationship between the variables?

When testing the relations between the variables we noticed that there is a considerable amount of overlap between the clusters most affected by changes, but not everywhere. Despite the fact that this part of the study is only descriptive and explorative we can say that there are quite some indications that there is a relation between water flow and climate change (combination of precipitation and temperature). The effect of climate change on forest fire occurrence (despite some relation with the cluster characterized by a decrease in rainfall) could not be proved. Forest fire ignition is mainly caused by humans (but also influenced by climate) and therefore is very complex to model.

Even though some quite clear trends and some indications of spatial relationships were found, this is an exploratory report and we concluded further analysis were needed to improve the reliability of our findings by including other important variables as vegetation and soil characteristics.

References

Alcazar J, Palau A (2010) Establishing environmental flow regimes in a Mediterranean watershed based on a regional classification. Journal of Hydrology, 388:41-51

Alcazar J, Palau A, Vega-Garcia C (2008) A neural net model for environmental flow estimation at the Ebro River Basin, Spain. Journal of Hydrology, 349:44-55

Alquilar JP (2009) Historic changes of ecologically relevant hydrologic indices of unregulated Kansas streams. Kansas State University. Doctoral dissertation

Andreassian V (2004) Waters and forests: from historical controversy to scientific debate. Journal of Hydrology, 291:1-27

Arnell NW (1999a) The effect of climate change on hydrological regimes in Europe: a continental perspective. Global Environmental Change-Human and Policy Dimensions, 9:5-23

Arnell NW (1999b) A simple water balance model for the simulation of streamflow over a large geographic domain. Journal of Hydrology, 217:314-335

Arthington AH, Olden JD, Balcombe SR (2010) Multi-scale environmental factors explain fish losses and refuge quality in drying waterholes of Cooper Creek, an Australian arid-zone river. Marine and Freshwater Research, 61:842-856

Bales JD, Pope BF (2001) Identification of changes in streamflow characteristics: Journal of the American Water Resources Association, v. 37 no. 1, February 2001, p. 91-104

Batalla RJ, Gomez CM, Kondolf GM (2004) Reservoir-induced hydrological changes in the Ebro River basin (NE Spain). Journal of Hydrology, 290:117-136

Bates BC, Kundzewicz ZW, Wu S (2008) Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva, 210 pp.

Besaw LE, Rizzo DM, Bierman PR (2010) Advances in ungauged streamflow prediction using artificial neural networks. Journal of Hydrology, 386:27-37

Brizga S, Arthington A, Choy S, Craigne N, Mackay S, Poplawski W, Pusey B, Werren G (2001) Environmental Flow Report: Pioneer Valley. Water Resource Plan. Department of Natural Resources and Mines, Brisbane. 2 Volumes

Brooks KN, Folliott PF, Gregersen HM, DeBano LF (1991) Hydrology and the management of watersheds. Iowa, Iowa State University Press

Chuvieco E, Cocero D, Riano D (2004) Combining NDVI and surface temperature for the estimation of live fuel moisture content in forest fire danger rating. Remote Sensing of Environment, 92:322-331

Clausen B, Biggs BJF (2000) Flow variables for ecological studies in temperate streams: groupings based on covariance. Journal of Hydrology, 231(2000)184-197

Cotillas M, Sabaté S, Gracia C, Espelta JM (2009) Growth response of mixed Mediterranean oak coppices to rainfall reduction Could selective thinning have any influence on it?. Forest Ecology and Management, 258: 1677–1683

Cuadrat JM, Saz MA, Vicente-Serrano SM and González-Hidalgo JC (2007) Water Resources and Precipitation Trends in Aragon. International Journal of Water Resources Development, 23: 107-123

Dastorani M, Moghadamnia A, Piri J et al (2010a) Application of ANN and ANFIS models for reconstructing missing flow data. Environ. Monitoring Assess., DOI: 10.1007/s10661-009-1012-8

Dastorani M (2010b) Using neural networks to predict runoff from ungauged catchments. Asian Journal of Applied Sciences, 3:399-4 10

Decuyper M (2011) Applying artificial neural networks to complete gaps in discontinuous daily flow data series. Presentation on the congress ‘Managed Forests in Future Landscapes: Implications for water and carbon cycles. Santiago de Compostela, Spain.

Diaz-Delgado R, Lloret F, Pons X (2004) Spatial patterns of fire occurrence in Catalonia, NE, Spain. Landscape Ecology, 19:731-745

Dios VRd, Fischer C, Colinas C (2007) Climate change effects on Mediterranean forests and preventive measures. New Forests, 33:29-40

EPA (United States Environmental Protection Agency) (2010) Climate Change Indicators in the United States. In: http://www.epa.gov/climatechange/indicators.html. Accessed November 17 2010

Fahlman S.E., Lebiere C. (1990) The cascade-correlation learning architecture, Advances in neural information processing systems 2, Morgan Kaufmann Publishers Inc., San Francisco, CA.

Fotheringham AS, Brunsdon C, Charlton ME (2002) Geographically Weighted Regression: The Analysis of Spatially Varying Relationships. Wiley, Chichester

Kuo CC, Gan TY, Yu PS (2010) Seasonal streamflow prediction by a combined climate-hydrologic system for river basins of Taiwan. Journal of Hydrology, 387:292-303

Martínez Santa-María C, Fernández Yuste JA. (2010) Índices de Alteración Hidrológica en ecosystemas fluviales. Ministerio de Fomento y de Medio Ambiente. Spain.

NASA (National Aeronautics and Space Administration) (2010) Global climate change: NASA's eyes on the earth. In: http ://climate.nasa.gov/. Accessed November 17 2010

Poff NL, Allan JD, Bain MB (1997) The natural flow regime. Bioscience, 47:769-784

Poff NL, Tokar S, Johnson P (1996) Stream hydrological and ecological responses to climate change assessed with an artificial neural network. Limnology and Oceanography 41, 857-863.

Poff NL, Zimmerman JKH (2010) Ecological responses to altered flow regimes: a literature review to inform the science and management of environmental flows. Freshwater Biology, 55:194-205

Ponce VM (1994) Engineering Hydrology: Principles and practices. New Jersey, Prentice Hall

Plutowski M, White H (1993) Selecting Concise Training Sets from Clean Data. IEEE Trans Neural Networks, 4:305-318

Richter BD, Baumgartner JV, Braun DP, Powell J (1998) A spatial assessment of hydrologic alteration within a river network. Regulated Rivers: Research & Management, 14: 329-340

Richter BD, Baumgartner JV, Powell J, Braun DP (1996) A method for assessing hydrologic alteration within ecosystems. Conservation Biology, 10: 1163-1174

Richter BD, Baumgartner JV, Wigington R, Braun DP (1997) How much water does a river need? Freshwater Biology, 37: 231-249

Ripley BD (1996) Pattern Recognition and Neural Networks, Cambridge Univ. Press, Cambridge, UK. pp.403. ISBN 0 521 46086 7

Searcy JK (1959) Flow-duration curves: U.S. Geol. Survey Water-supply Paper 1542-A, pp.1-33

Stewardson MJ, Gippel CJ (2003) Incorporating flow variability into environmental flow regimes using the flow events method. River Research and Applications, 19: 459-472

Vega-Garcia C, Tatay-Nieto J, Blanco R (2010) Evaluation of the Influence of Local Fuel Homogeneity on Fire Hazard through Landsat-5 TM Texture Measures. Photogrammetric Engineering and Remote Sensing, 76:853-864

Vega-Garcia C, Chuvieco E (2006) Applying local measures of spatial heterogeneity to Landsat-TM images for predicting wildfire occurrence in Mediterranean landscapes. Landscape Ecology, 21:595-605

Vicente-Serrano SM, Cuadrat-Prats JM (2006) Trends in drought intensity and variability in the middle Ebro valley (NE Spain) during the second half of the twentieth century. Theoretical and Applied Climatology, 88: 247−258

Vorosmarty CJ, Green P, Salisbury J (2000) Global water resources: vulnerability from climate change and population growth. Science (Wash) 289:284-288

Ward JH, (1963). Hierarchical grouping to optimize an objective function. J. American. Statistical. Association, 58, 236-244

Woodward FI, Diament AD (1991) Functional Approaches to Predicting the Ecological Effects of Global Change. Functional Ecology, 5:202-212

Wu CL, Chau KW (2011) Rainfall–runoff modeling using artificial neural network coupled with singular spectrum analysis. Journal of Hydrology, 399:394-409

Appendix I: Parameters for water flow and climate data

Parameters WaterFlow Data	
Par. nr.	Name
X1	Average discharge – m^3/s (oct)
X2	Average discharge – m^3/s (nov)
X3	Average discharge – m^3/s (dec)
X4	Average discharge – m^3/s (jan)
X5	Average discharge – m^3/s (feb)
X6	Average discharge – m^3/s (mar)
X7	Average discharge – m^3/s (apr)
X8	Average discharge – m^3/s (may)
X9	Average discharge – m^3/s (jun)
X10	Average discharge – m^3/s (jul)
X11	Average discharge – m^3/s (aug)
X12	Average discharge – m^3/s (sept)
X13	Average discharge – m^3/s (annual)
X14	Difference between the min. and max. daily discharge – m^3/s (oct)
X15	Difference between the min. and max. daily discharge – m^3/s (nov)
X16	Difference between the min. and max. daily discharge – m^3/s (dec)
X17	Difference between the min. and max. daily discharge – m^3/s (jan)
X18	Difference between the min. and max. daily discharge – m^3/s (feb)
X19	Difference between the min. and max. daily discharge – m^3/s (mar)
X20	Difference between the min. and max. daily discharge – m^3/s (apr)
X21	Difference between the min. and max. daily discharge – m^3/s (may)
X22	Difference between the min. and max. daily discharge – m^3/s (jun)
X23	Difference between the min. and max. daily discharge – m^3/s (jul)
X24	Difference between the min. and max. daily discharge – m^3/s (aug)
X25	Difference between the min. and max. daily discharge – m^3/s (sept)
X26	Difference between the min. and max. daily discharge – m^3/s (annual)
X27	Difference between the min. and max. average monthly discharge – m^3/s (annual)
X28	Month with the max. water discharge – number of the month (annual)
X29	Month with the min. water discharge – number of the month (annual)
X30*	Difference between $Q_{10\%}$ and $Q_{90\%}$ – m^3/s (flow duration curve)
X31	Max. daily discharge – m^3/s (oct)
X32	Max. daily discharge – m^3/s (nov)
X33	Max. daily discharge – m^3/s (dec)
X34	Max. daily discharge – m^3/s (jan)
X35	Max. daily discharge – m^3/s (feb)
X36	Max. daily discharge – m^3/s (mar)
X37	Max. daily discharge – m^3/s (apr)
X38	Max. daily discharge – m^3/s (may)
X39	Max. daily discharge – m^3/s (jun)
X40	Max. daily discharge – m^3/s (jul)
X41	Max. daily discharge – m^3/s (aug)
X42	Max. daily discharge – m^3/s (sept)
X43	Qc - Average max. monthly discharge – m^3/s (annual)
X44**	Q_{ED} - effective discharge – m^3/s (oct)
X45	Q_{ED} - effective discharge – m^3/s (nov)
X46	Q_{ED} - effective discharge – m^3/s (dec)
X47	Q_{ED} - effective discharge – m^3/s (jan)
X48	Q_{ED} - effective discharge – m^3/s (feb)

X49	Q_{ED} - effective discharge – m³/s (mar)
X50	Q_{ED} - effective discharge – m³/s (apr)
X51	Q_{ED} - effective discharge – m³/s (may)
X52	Q_{ED} - effective discharge – m³/s (jun)
X53	Q_{ED} - effective discharge – m³/s (jul)
X54	Q_{ED} - effective discharge – m³/s (aug)
X55	Q_{ED} - effective discharge – m³/s (sept)
X56	Q_{ED} - effective discharge – m³/s (annual)
X57***	$Q_{5\%}$ - flushing flood – m³/s (annual)
X58	Coefficient of variation of the max. monthly discharges (annual)
X59****	$Q \geq Q_{5\%}$ - Month with the highest flood frequency - number of the month (annual)
X60	Min. daily discharge – m³/s (oct)
X61	Min. daily discharge – m³/s (nov)
X62	Min. daily discharge – m³/s (dec)
X63	Min. daily discharge – m³/s (jan)
X64	Min. daily discharge – m³/s (feb)
X65	Min. daily discharge – m³/s (mar)
X66	Min. daily discharge – m³/s (apr)
X67	Min. daily discharge – m³/s (may)
X68	Min. daily discharge – m³/s (jun)
X69	Min. daily discharge – m³/s (jul)
X70	Min. daily discharge – m³/s (aug)
X71	Min. daily discharge – m³/s (sept)
X72	Qs - Average min. monthly discharge – m³/s (annual)
X73*****	$Q_{95\%}$ - ordinary drought discharge – m³/s (annual)
X74	Coefficient of variation of the min. monthly flows (annual)
X75	$Q \leq Q_{95\%}$ - Month with the lowest flood frequency - number of the month (annual)
X76	Increasing rate of change (annual)
X77	Decreasing rate of change (annual)

Remark: the stars * indicate that this parameter has an explanation/formula below

Explanation/formula of the less common parameters:

** Difference between $Q_{10\%}$ and $Q_{90\%}$ – m³/s (X30)*

Explanation: Is a measure for variability and is based on the flow duration curve.

Calculation: This curve is a cumulative frequency curve that shows the percentage of time that a discharge is equaled or exceeded (Searcy 1959). The percentiles are derived by rescaling the number of days (365) to 100% and the discharges (Q) are obtained by sorting the daily data descended for each year. For this parameters is that Q10% - Q90%, with:

10% exceedance (Q10), as flow which on average, is only equaled or surpassed during 10% of the year, i.e., ~37 days. Similarly, 90% exceedance (Q90) indicates flow which on average is equaled or surpassed during 90% of the year, i.e., in daily terms, on ~329 days (Martínez Santa-María and Fernández Yuste, 2010).

*** Effective discharge or Q_{ED} (X44-X56)*

Explanation: The effective discharge is the water flow with a geomorphological significance of peak flows, as the flow that shapes the channel and they represent the aspects magnitude and frequency (Martínez Santa-María and Fernández Yuste, 2010)

Calculation: The maximum of the year of interest and the nine year before.

****Flushing flood – m³/s or Q5% (X57)*
Explanation: flushing flood is the flow that will transport small particles within the river bed.
Calculation: Also based on the flow duration curve (see above) and is the 5% exceedance), as flow which on average, is only equaled or surpassed during 5% of the year, i.e., ~18 days.

***** Q≥Q5% - Month with the highest flood frequency - number of the month (X59)*
Explanation: Is used to find if there is a shift in peak flows towards an earlier or later period in the year over the 30 year time span.
Calculation: The same as the above parameter but now the month with the highest frequency (related to the values of the 5% exeedance) is selected.

****** Q95% - ordinary drought discharge – m³/s (X73)*
Explanation: This is the flow representing the most common low flow periods.
Calculation: The flow corresponding to the 95% exceedance based on the flow duration curve (see above).

Parameters Climate Data	
Par. nr.	Name
Y1	Total P – mm (winter)
Y2	Total P – mm (spring)
Y3	Total P – mm (summer)
Y4	Total P – mm (autumn)
Y5	Total P – mm (annual)
Y6	Average P – mm (annual)
Y7	Max. seasonal P – mm (annual)
Y8	Min. seasonal P – mm (annual)
Y14	Max. P in 24hour – mm (winter)
Y15	Max. P in 24hour – mm (spring)
Y16	Max. P in 24hour – mm (summer)
Y17	Max. P in 24hour – mm (autumn)
Y18	# of days with P=0 (winter)
Y19	# of days with P=0 (spring)
Y20	# of days with P=0 (summer)
Y21	# of days with P=0 (autumn)
Y22	# of days with P=0 (annual)
Y23	Average T – ℃ (winter)
Y24	Average T – ℃ (spring)
Y25	Average T – ℃ (summer)
Y26	Average T – ℃ (autumn)
Y27	Average T – ℃ (annual)
Y28	Average of monthly max. values – ℃
Y29	Average of monthly min. values – ℃
Y30	Max. seasonal T – ℃ (annual)
Y31	Min. seasonal T – ℃ (annual)
Y32	# of days with T≥30℃ (spring)
Y33	# of days with T≥30℃ (summer)
Y34	# of days with T≥30℃ (autumn)
Y35	# of days with T≥30℃ (annual)
Y36	# of days with T≥25℃ (spring)
Y37	# of days with T≥25℃ (summer)
Y38	# of days with T≥25℃ (autumn)
Y39	# of days with T≥25℃ (annual)
Y40	# of days with T≤5℃ (winter)

Y41	# of days with T≤5℃ (spring)
Y42	# of days with T≤5℃ (autumn)
Y43	# of days with T≤5℃ (annual)
Y44	# of days with T≤0℃ (winter)
Y45	# of days with T≤0℃ (spring)
Y46	# of days with T≤0℃ (autumn)
Y47	# of days with T≤0℃ (annual)

Appendix II: Slope estimates indicating the change within each parameter. Zero values mean no significant

Water flow

GS #	Cluster #	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X17	X18	X19	X20	X21	X22	X23	X25	X26	X27	X28	X29	X30	X31
3	1	0	0	0	0	0	0	-0.41	-0.33	-0.34	0	-0.07	0	0	0	0	0	0	0	0	-1.54	-2.02	0	0	0	0	0	0	0	0
63	1	0	0	0	0	-0.97	0	0	-0.43	-0.21	0	-0.04	0	-0.25	0	0	-2.23	-3.42	0	0	-2.06	-1.52	0	0	-3.17	-0.72	0	0	-0.49	0
157	1	0	0.06	0	0	-0.06	0	0	0	-0.04	0	0	0	0	0	0.25	0	-0.17	0	0	0	0	0	0	0	0	0	0	0	0
158	1	0	0	0	0	-0.12	0	0	0	-0.08	-0.04	-0.04	-0.02	0	0.13	0.30	0	0	0	0	0	0	0	0	0	0	0	0	0	0
93	1	0	0	0	0	0	0	-0.31	-0.24	-0.24	-0.09	-0.06	0	-0.13	0	0	-0.80	0	0	-0.89	-0.62	0	0	0	-1.33	-0.32	0	0	-0.25	0
189	1	0	0	0	0	0	0	0	-0.04	-0.06	-0.02	-0.02	-0.01	0	0	0	-0.71	0	0	-0.81	-0.15	0	0	0	-1.37	0	0	0	0	0
40	1	0	0	0	0	-0.38	0	0	0	0	-0.38	-0.18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	2	0	0	0	0	-0.02	0	0	0	-0.03	0	-0.01	-0.01	-0.02	0	-0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	2	0	0	0	0	-0.10	0	0	-0.14	-0.19	-0.07	0	0	0	0	0	0	-0.33	0	0	0	0	-0.12	0	0	0	0	0	0	0
30	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46	2	0	0	0	0	-0.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.10	0	0	0	0	0	0
58	2	0	0	0	0	0	0	0	0	0	0	0	-0.01	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
62	2	0	0	0	0	-0.23	0	0	-0.15	-0.14	0	0	0	-0.05	0	0	0	-0.61	0	0	0	0	0	0	0	0	0	0	0	0
64	2	0	0	0	0	-0.80	0	0	-0.22	0	0	0	0	-0.13	0	0	-2.14	-3.22	0	0	-1.76	0	0	0	-2.24	-0.48	0	-0.03	0	0
71	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1.00	0	0	0	0	0	0	0	0	0
78	2	0	0	0	0	0	0	0	-0.01	-0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.05	0	0
85	2	0	0	0	0	0	0	-0.17	-0.13	-0.07	-0.02	-0.01	-0.01	-0.04	0	0	0	0	0	0	-0.44	0	0	0	-0.26	0	0	0	0	0
86	2	-0.01	0	-0.01	-0.02	0	0	0	-0.01	-0.01	-0.01	0	0	-0.01	0	0	-0.08	0	0	0	0	-0.03	0	0	-0.24	-0.04	0	0	-0.03	0
88	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.08	0	0	0	0	0	0	0	0	0	0	0	0
95	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
127	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04	0	0	0	0	0	0
129	2	0	0	0	0	0	-0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
148	2	0	0	0	0	-0.02	0	-0.02	0	-0.02	0	0	0	0	0	0	0	0	0	0	0	-0.07	0	0	0	0	0	0	0	0
150	2	0	0	0	0	0	0	-0.01	-0.01	-0.01	0	0	0	0	0	0	0	0	0	0	-0.02	0	0	0	0	0	0	-0.06	0	0
177	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
190	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
221	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
57	2	0	-0.01	0	0	0	-0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.06	-0.01	0	0	-0.01	0
80	2	0	0	0	0	-0.08	0	0	-0.10	-0.06	-0.03	0	0	-0.03	0	0	0	-0.20	0	0	0	0	0	0	0	0	0	0	0	0
91	2	0	0	0	0	-0.26	0	0	0	0	0	0	0	0	0	0	-1.52	0	0	0	0	0	0	0	-1.60	0	0	0	0	0
110	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44	2	0	0	0	0	0	0	0	0	0	-0.02	-0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
113	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.15	0	0
135	2	0	0	0.04	0.03	0	0	0	0	-0.11	-0.04	0	0	0	0	0	0.24	0	0	0	0	-0.12	-0.09	0	0	0	0	0	-0.07	0
153	2	0	0	0	0	0.07	0.11	0	0.18	0.07	0	0.01	0.02	0.07	0	0	0	0	0	0	0	0	0	0	0	0.21	0	0	0.18	0
154	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
155	2	0	0	0	0	0	0	0	0	-0.03	0	0	0	0	0	0	0	0	0	0	0	-0.10	-0.01	0	0	0	0	0	0	0
187	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	2	-0.01	0	-0.01	0	-0.02	-0.03	0	0	0	0	-0.01	-0.01	-0.02	0	-0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56	3	-0.02	-0.02	0	0	-0.06	0	0	0	-0.07	-0.05	-0.03	-0.03	-0.04	0	0	0	-0.10	0	0	0	0	-0.05	0	0	0	0	0	-0.05	-
123	4	0	0	0	0	-0.97	0	0	0	0	0	0	0	0	0	0	0	-1.98	0	0	0	0	0	0	0	0	0	0	0	0
165	4	0	0	0	0	0	0	0	0	-0.25	0	0	-0.03	-0.10	0	0	-2.21	0	0	0	0	0	0	0	-3.95	0	0	0	0	0
197	4	0	0	0	0	0	0	0	-0.19	0	0	0	0	-0.05	0	0	0	0	0	0	-2.42	-1.84	0	0	-3.90	-0.24	0	0	0	0
22	5	0	0	0	0	0	0	0	0	-1.37	-0.39	0	0	-0.19	0	0	0	0	0	0	-1.12	-2.16	-0.64	0	-1.68	-0.87	0	0	-0.52	0
111	5	0	0	0	0	0	0	0	-0.72	-1.60	-0.61	0	0	0	0	0	0	0	0	0	-1.31	-2.22	-1.05	0	0	-0.89	0	0	-0.67	0
41	5	0	-0.01	-0.01	-0.02	-0.02	-0.02	0	0	0	0	0	0	-0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.03	0
4	6	0	0	0	0	0	0	-1.57	-1.52	-1.00	-0.38	0	0	0	0	0	0	0	0	0	-4.82	-4.29	0	0	0	0	0	0	0	0
65	6	0	0	0	0	-1.70	0	0	-1.10	-0.55	0	0	0	-0.59	0	0	-8.96	-7.04	0	0	-6.79	-3.10	0	0	0	-1.36	0	-0.05	-1.39	0
170	6	0	0	0	0	-2.19	0	0	-1.28	-1.75	-0.52	0	0.31	-0.65	0	0	0	-6.85	0	0	0	-4.30	0	0	0	-1.24	0	0	-1.33	0
47	7	0	0	0	0	-0.23	0	0	0	-0.18	0	0	0.08	0	0	0	0	-1.01	0	0	0	0	-0.24	0.41	0	0	0	0	0	0
79	7	0	0	0	0	-0.33	0	0	-0.11	-0.07	-0.02	0	0	-0.12	0	-1.79	-3.73	-1.67	0	-0.75	-1.44	0	0	0	-4.80	-0.54	-0.16	-0.05	-0.15	0
67	8	0	0	0	-0.45	-0.42	-0.35	-0.30	-0.35	-0.12	0	0	0	-0.22	0	0	0	-1.50	-2.09	0	-1.80	0	0	0	0	-0.55	0	0	-0.46	0

GS #	Cluster #	X32	X33	X34	X35	X36	X37	X38	X39	X40	X41	X42	X43	X44	X45	X46	X47	X48	X49	X50	X51	X52	X53	X54	X55	X56	X57
3	1	0	0	0	0	0	0	-1.67	-2.19	0	0	0	0	0	-2.35	3.31	0	0	-8.38	-2.26	-4.51	-7.25	1.61	-1.25	0.21	-6.02	0
63	1	0	0	-2.21	-3.58	0	0	-2.21	-1.59	0	0	0	-3.19	0	-10.28	-3.42	-6.35	-6.48	-1.88	-3.11	-6.09	-3.22	0	0	2.00	-6.93	-1.04
157	1	0.24	0	0	-0.20	0	0	0	0	0	0	0	0	0.49	0.69	3.57	0.85	0	1.20	0.24	0.29	0.18	0.87	0.70	0.14	0	0
158	1	0.30	0	0	-0.29	0	0	0	0	0	0	0	0	0.49	0.50	2.71	0.95	-0.54	0	0	0.70	0.88	0.43	-0.86	-0.19	0.71	0
93	1	0	0	-0.81	0	0	-1.00	-0.74	-0.96	0	0	0	-1.34	0	-2.10	2.73	0	0	0	-2.66	-2.62	0	0.31	-1.91	-0.13	0	-0.46
189	1	0	0	-0.70	0	0	-0.82	-0.16	0	-0.03	0	0	-1.37	0	-0.38	-0.88	-2.87	0	-0.86	-4.19	-0.64	-1.58	-0.08	-1.05	-0.16	-3.46	0
40	1	0	0	0	0	0	0	0	0	0	0	0	0	-11.42	-28.08	17.57	14.13	0	0	0	-14.13	0	0	0	0	0	0
8	2	-0.02	0	0	-0.05	0	0	0	0	0	0	0	0	-0.22	-0.05	0.01	1.32	-0.21	0	0	0	-0.69	0	-0.03	0	1.11	0
21	2	0	0	0	-0.34	0	0	0	-0.32	-0.16	0	0	0	-0.61	-2.05	2.34	1.14	-0.91	0.36	0.48	0	-0.49	-0.48	-0.20	0	1.57	0
30	2	0	0	0	0	0	0	0	0	0	0	0	0	1.78	-1.87	0	-1.46	-0.75	0	0	0	0	0	-0.03	0	0	0
43	2	0	0	0	0	0	0	0	0	0	0	0	0	0.08	-0.15	0.19	-0.19	0	0	0	0	0	-0.08	0	0.07	0	0
46	2	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.95	1.35	0	0	0	-0.74	0	0.56	0.39	0.16	0.09	0	0
58	2	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0.03	0.17	0	-0.12	0	0	0.04	0	-0.05	-0.03	0	-0.22	0
62	2	0	0	0	-0.66	0	0	-0.37	-0.34	0	0	0	0	1.93	-0.52	1.49	0	-1.03	0.51	-0.54	-0.69	0	0.34	0	0.62	1.30	0
64	2	0	0	0	-3.30	0	0	-1.81	0	0	0	0	-2.24	3.94	-7.09	0	-3.53	-4.75	0	0	-4.04	0	1.86	0.60	1.20	-1.97	-0.74
71	2	0	0	0	0	0	0	-1.06	0	0	0	0	0	2.23	0	0	0	-3.30	-2.13	0	-1.41	-1.70	0	-2.94	0	0	0
78	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.18	0	0.34	0	-0.42	-0.03	-0.13	0.01	0	0.08	0.28	0
85	2	0	0	0	0	0	0	-0.47	-0.28	0	0	0	-0.27	0	-0.53	-0.42	-0.36	-0.26	-0.27	-0.44	-0.74	-0.40	0.25	-0.98	-0.23	-0.37	0
86	2	0	0	-0.08	0	0	0	0	-0.04	-0.01	0	0	-0.24	-0.61	-0.37	-0.20	0	0	-0.22	-1.30	0.26	-0.13	-0.07	0.20	0.03	-0.77	-0.04
88	2	0	0	0	-0.08	0	0	0	0	0	0	0	0	0.45	-0.36	0	0	-0.19	0	0	0	0	-0.19	0.07	0.07	0.50	0
95	2	0	0	0	0	0	0	0	0	0	0	0	0	0	-1.36	3.21	1.25	1.15	-0.36	-0.96	0.36	1.16	0	-1.45	0.60	2.00	0
100	2	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.05	0	-0.05	-0.01	0	0	0.28	0.23	-0.03	0	0	0.24	0
127	2	0	0	0	0	0	0	0	0	0	0	0	0	-0.35	-0.20	0.37	-0.17	-0.11	0	-0.41	0	0.31	0	0.19	0	0	0
129	2	0	0	0	-0.01	0	0	0	0	0	0	0	0	0	0	0	0	-0.03	0	0	0	-0.11	-0.08	-0.01	-0.02	0	0
148	2	0	0	0	0	0	0	0	-0.08	-0.01	0	0	0	0.49	0	0	1.15	0.17	-0.16	-0.15	-0.18	-0.17	-0.05	0	-0.01	0.46	0
150	2	0	0	0	0	0	0	-0.03	-0.02	0	0	0	0	-0.01	0.03	0.07	0.10	0.15	0	-0.05	-0.12	-0.05	-0.02	0.04	-0.01	0.11	0
177	2	0	0	0	0	0	0	0	0	0	0	0	0	7.59	-1.23	0	-0.68	0.49	0	0	1.06	0.52	0	0.60	0	6.22	0
190	2	0	0	0	0	0	0	0	0	0	0	0	0	-0.07	-0.13	1.45	1.07	0.99	0.20	0	0	0.30	0	0.32	0.34	0	0
221	2	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.20	0	-0.26	0.58	0	0	0	0.09	0.19	-0.58	-0.09	0.23	0
7	2	0	0	0	0	0	0	0	0	0	0	0	0	0.10	0.91	1.01	0	0.71	0	-0.12	0	0.54	1.03	0.83	0.55	0	0
57	2	-0.05	-0.01	-0.01	0	-0.02	0	0	0	0	0	0	-0.06	-0.02	-0.19	0	0	0	-0.06	-0.01	0	-0.19	0.04	-0.11	0	-0.25	-0.01
80	2	0	0	0	-0.23	0	0	0	0	0	-0.04	0	0	-0.59	-1.04	0.59	0	-0.40	0.27	-0.15	-0.10	0.68	0.32	0	0.59	-0.72	0
91	2	0	0	0	0	0	0	0	0	0	0	0	-1.61	-2.63	-3.59	3.74	0	0	-1.16	-0.38	0	1.36	1.01	-0.87	0.24	0	0
110	2	0	0	0	0	0	0	0	0	0	0	0	0	-0.67	-0.58	0.12	-0.39	0	0	-0.42	1.37	0.10	0	0	0	0	0
33	2	0	0	0	0	0	0	0	0	0	0	0	0	0	-4.79	10.90	4.40	0	0.41	0	0	1.75	0	-0.47	0	11.02	0
44	2	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.77	2.06	0.45	0	0.11	0	0.62	0	-0.25	0	0	1.37	0
113	2	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0	0.01	0	0	0	0	0.01	0.01	0	0	0	0.15	0
135	2	0	0	0.24	0	0	0	0	-0.17	-0.10	0	0	0	-0.19	0	0.91	0.92	0.77	0.34	-1.94	-2.24	-0.39	-0.48	0.09	0.13	-2.02	-0.10
153	2	0	0	0	0	0	0	0	0	0	0	0	0	9.13	-6.78	0	-1.02	0	1.15	-2.19	0	1.11	0.16	0.29	-0.61	0	0.24
154	2	0	0	0	0	0	0	0	0	0	0	0	0	10.07	-0.51	0	-0.09	0.12	0	-0.38	0	0.27	0	-0.10	0.04	0	0
155	2	0	0	0	0	0	0	0	-0.11	-0.01	0	0	0	0	-0.30	0	-1.01	0	0	-0.14	-0.34	-0.19	0	0	0.27	-0.73	0
187	2	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.43	0.87	-0.08	0.73	0.25	-0.18	-0.20	0.53	-0.41	0	0.24	0.80	0
6	2	-0.02	-0.02	0	-0.04	0	0	0	0	0	-0.01	0	0	-0.21	-0.05	0.01	1.27	-0.21	0	0	0.33	-0.66	-0.17	-0.03	0	0.86	0
56	3	0	0	0	-0.14	0	0	0	0	-0.08	-0.04	0	0	-0.18	-0.09	0.69	0	-0.32	0	0	0	-0.26	-0.38	-0.10	0	0	-0.08
123	4	0	0	0	-2.27	0	0	0	0	0	0	0	0	-4.44	-14.02	8.40	2.56	-6.57	1.27	-3.56	-17.29	-9.85	-5.21	0	0	-12.75	0
165	4	0	0	-2.22	0	0	0	0	-2.31	0	0	0	-3.96	6.95	-2.96	-6.88	-10.50	0	0	0	-5.70	-7.20	0	-18.38	-1.11	-6.57	-0.44
197	4	0	0	0	0	0	0	-2.44	-1.87	0	0	0	-3.90	0	-0.45	0.28	-0.56	0	-1.01	-2.73	-12.82	-6.39	0	-0.92	0	-12.37	0
22	5	0	0	0	0	0	0	0	-2.55	-0.79	0	0	-1.65	-1.47	4.85	4.03	1.97	-1.82	2.50	0	-2.08	-2.61	-1.19	-0.84	0	0	-1.02
111	5	0	0	0	0	0	0	-1.49	-2.96	-1.24	0	0	0	0	0	28.08	24.89	0	3.56	8.89	0	-6.14	-1.72	-0.16	0	14.87	-1.02
41	5	0	0	0	0	0	0	0	0	0	0	0	0	-0.19	-0.04	0.02	-0.19	-0.10	0	-0.06	-1.16	0	-0.25	-0.21	-0.61	-0.95	0
4	6	0	0	0	0	0	0	-5.55	-4.76	0	0	0	0	12.53	0	12.41	0	0	0	0	-13.41	-7.67	-2.31	-18.42	-1.27	0	0
65	6	0	0	-8.95	-7.41	0	0	-7.12	-3.30	0	0	0	0	17.61	-9.82	0	-19.43	-11.10	0	-10.70	-17.99	0	0	6.45	4.99	0	-2.32
170	6	0	0	0	-7.48	0	0	0	-5.17	0	0	0	0	0	-17.23	10.82	0	-18.01	7.79	0	-22.76	-5.88	0.80	0	4.68	-17.88	-1.67
47	7	0	0	0	-0.97	0	0	0	0	-0.26	0	0.41	0	0	0	9.43	0	-1.93	0	0	-1.55	0.61	-0.56	0.15	1.38	7.93	-0.36
79	7	-1.78	-2.75	-3.71	-1.71	0	-0.75	-1.46	0	0	0	0	-4.80	-10.55	-8.94	-12.74	-14.72	-4.19	-3.29	-2.94	-7.27	0	0	0.46	0	-12.30	-0.46
67	8	0	0	0	-1.65	-2.21	-1.37	-1.89	0	0	0	0	0	0	-2.69	0	19.48	-3.09	-1.88	-0.05	-6.56	0	0	-6.50	0	20.26	-0.72

GS #	Cluster #	X58	X59	X60	X61	X62	X63	X64	X65	X66	X67	X68	X69	X70	X71	X72	X73	X74	X75	X76	X77	X78
3	1	0	0	0	0	0	0	0	0	0	-0.13	-0.16	-0.07	-0.05	0	0	-0.05	0	0	0	0	0
63	1	0	0	-0.03	0	0	0	-0.16	-0.11	0	-0.15	-0.07	-0.03	-0.03	-0.02	-0.02	-0.03	0	0	0	0	0.05
157	1	0	0	-0.01	0	0	0	0	-0.03	0	0	-0.04	-0.02	-0.01	0	-0.01	-0.01	0	0	0	0	0
158	1	0	0	-0.02	0	0	0	0	0	0	-0.07	-0.05	-0.04	-0.03	0	-0.02	-0.02	0	0	0	0	0
93	1	0	0	-0.02	0	0	0	0	0	-0.11	-0.12	-0.12	-0.05	-0.03	0	0	-0.01	0	0	0	0	0
189	1	-0.03	0	0	0	0	0	0	0	0	0	-0.03	-0.01	0	-0.01	0	-0.01	0.01	0	0	0	0.04
40	1	0	0	0	0	0	0	0	0	0	0	0	-0.22	0	0	0	0	0	0	0	0	0
8	2	0	0	0	0	0	0	-0.02	-0.02	-0.02	0	-0.02	-0.02	-0.02	-0.02	0	-0.01	0	0	0	0	0
21	2	0	0	0	0	0	0	0	0	0	0	-0.11	-0.04	0	0	0	0	0	0	0	0	0
30	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43	2	0	0	0	0	0	0	0	0	-0.01	0	0	0	0	0	0	0	0	0	0	0	0
46	2	0	0	0	0	0	0	-0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0
58	2	0	0	-0.01	0	0	0	0	0	0	0	0	0	0	-0.01	-0.01	-0.01	0	0	0	0	0
62	2	0	0	0	0	0	0	-0.04	0	0	-0.09	-0.06	-0.01	-0.01	0	0	0	0	0	0	0	0
64	2	0	0	0	0	0	0	0	0	0	-0.05	0	0	0	0	0	0	0	0	0	0	0.04
71	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
78	2	0	0	0	0	0	0	0	0	0	-0.01	0	0	0	0	0	0	0	0	0	0	0
85	2	0	0	-0.01	-0.01	0	0	0	-0.02	0	-0.03	-0.02	-0.01	-0.01	-0.01	0	0	0	0	0	0	0.03
86	2	0	0	0	0	0	-0.01	-0.01	-0.01	0	-0.01	0	0	0	0	0	0	0	0	0	0	0.05
88	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
95	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
127	2	0	0	0	0	0	-0.01	-0.02	-0.02	0	0	0	0	-0.01	0	0	0	0	0	0	0	0
129	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.03
148	2	0	0	-0.01	0	0	0	-0.01	-0.01	0	0	-0.01	0	0	0	0	0	0	0	0	0	0
150	2	0	0	0	0	0	0	0	0	-0.01	0	-0.01	0	0	0	0	0	0	0	0	0	0.03
177	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
190	2	0	0	0	0	0	0	0	0	0	0	-0.01	0	0	0	0	0	0	0	0	0	0
221	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
57	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
80	2	0	0	0	0	0	0	-0.03	0	-0.03	-0.06	-0.04	0	0	0	0	0	0	0	0	0	0.03
91	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
110	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.12	0	0	0
33	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44	2	0.01	0	0	0	0.02	0	0	0	0	0	0	-0.01	-0.01	0	0	0	0	0	0	0	0
113	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
135	2	0	0	0	0	0	0	0	0	0	0	-0.05	0	0	0	0	0.01	-0.02	0	0	0	0
153	2	0	0	0	0	0	0	0	0.05	0	0.08	0	0	0.01	0.01	0	0.01	0	0	0	0	0
154	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.03	0	0	0	0
155	2	0	0	0	0	0	0	-0.03	-0.02	0	-0.01	-0.01	0	0	0	0	0	0	0	0	0	0.04
187	2	0	0	0	0.01	0.01	0.02	0	0	0	0	0	0	0	0	0	0	-0.03	0	0	0	0
6	2	0	0	-0.01	0	0	0	-0.02	-0.02	-0.02	0	0	-0.01	-0.02	-0.02	-0.01	-0.01	0	0	0	0	0.04
56	3	0	0	-0.02	0	0	0	-0.03	0	0	-0.04	-0.05	-0.03	-0.03	-0.03	-0.02	-0.02	0	0	0	0	0
123	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
165	4	0	0	0	0	0	0	0	0	0	0	-0.04	0	-0.02	0	0	-0.01	0.01	0	0	0	0.03
197	4	-0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	5	0	0	0	0	0	0	0	0	0	0	-0.39	-0.14	0	0	0	0	0.01	0	0	0	0.03
111	5	0	0	0	0	0	0	0	0	0	0	-0.74	0	0	0	0	0	0	0	0	0	0.04
41	5	0	-0.19	0	-0.01	-0.01	-0.01	-0.01	-0.02	-0.01	0	0	0	0	0	0	-0.04	0	0.38	0	0	0
4	6	0	0	0	0	0	0	-0.94	-0.58	-0.67	-0.73	-0.46	-0.24	-0.23	0	0	0	0	0	0	0	0.03
65	6	0	0	0	0	0	0	-0.38	-0.41	-0.27	-0.33	-0.20	0	0	0	0	0	0	0	0	0	0.04
170	6	0	0	0	0	0	0	-0.63	0	-0.40	-0.50	-0.87	-0.17	0	0	0	0	0	0	0	0	0.04
47	7	0	0	0	0	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
79	7	0	0	0	0	0	0	0	0	0	-0.02	-0.02	-0.01	-0.01	-0.01	-0.01	-0.01	0.01	0	0	0	0.05
67	8	0	0	0	-0.08	-0.11	-0.10	-0.15	-0.12	-0.10	-0.09	-0.05	-0.02	-0.01	-0.01	-0.01	-0.01	-0.01	0	0	0	0.05

Precipitation

CS #	Cluster #	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11	Y12	Y13	Y14	Y15	Y16	Y17	Y18	Y19	Y20	Y21	Y22
44	1	0	-34.45	0	0	0	0	0	0	0	0	0	0.66	0	0	0	0	0	0	0	0	-0.66	0
91o	1	0	-30.10	0	0	-50.17	-12.54	0	0	0	0	0	0.68	0	0	0	0	0	0	0	0	-0.68	0
121	1	0	-42.63	0	0	0	0	0	0	0	0	0	0.67	0	0	0	0	0	0	0	0	-0.67	0
202	1	0	0	0	0	0	0	0	0	0	0	0	0.65	0	0	0	0	0	0	0	0	-0.65	0
205	1	0	0	0	0	0	0	0	0	0	0.35	0	0.55	1.02	0	0	0	0	0	-0.35	0	-0.55	-1.01
237i	1	0	0	0	0	0	0	0	0	0	0	0	0.87	1.54	0	0	0	0	0	0	0	-0.87	0
279	1	0	0	0	0	-78.44	-19.61	0	0	0	0	0	0.60	0.96	-5.51	0	0	0	0	0	0	-0.60	-0.96
495u	1	0	0	0	0	0	0	0	0	0.49	0.30	0	0.68	1.56	0	0	0	0	-0.49	0	0	-0.68	-1.55
499	1	0	0	-16.02	0	0	0	0	0	0	0	0	0.57	0	0	0	0	0	0	0	0	-0.57	0
537	1	0	0	0	0	0	0	0	0	0	0.32	0.27	0.49	1.33	0	0	0	0	0	-0.32	-0.27	-0.49	-1.33
72i	2	0	0	0	0	0	0	0	0	0	0	0	0.65	0	0	0	0	0	0	0	0	0	0
72x	2	0	-43.48	0	0	0	0	-21.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
160	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
261e	2	0	-26.68	0	0	0	0	0	0	0	0	0	0.47	0	0	-7.15	0	0	0	0	0	-0.47	0
322	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
349a	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
364e	2	0	0	0	0	80.79	20.20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
372	2	0	0	0	0	0	0	0	0	0	0	0	0.49	0.73	0	0	0	0	0	0	0	-0.49	-0.73
376i	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
392	2	0	0	0	0	0	0	0	0	0	0	0	0.36	0	0	0	0	0	0	0	0	-0.36	0
399	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.42	0
405e	2	0	0	0	0	0	0	0	0	0	0	0	0.30	0	0	0	0	0	0	0	0	-0.30	0
414	2	0	0	0	0	0	0	0	0	0	0	0	0.32	0.76	0	0	0	0	0	0	0	-0.32	-0.76
440e	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
461	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
491	2	0	0	0	0	0	0	0	0	0	0	0	0.38	0	0	0	0	0	0	0	0	-0.38	0
554a	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
562	2	0	0	0	0	0	0	45.22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
713	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8.88	0	0	0	0	0	-0.66
814	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
828u	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
948	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
961	2	0	55.62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
179	3	0	0	0	0	0	0	0	0	1.15	0	0	0.81	2.34	0	0	0	0	-1.15	0	0	-0.81	-2.34
65m	4	0	0	0	0	-80.53	-20.13	-32.94	0	0	-0.57	0	0	-1.09	0	0	0	0	0	0.57	0	0	1.10
76g	4	0	0	0	0	-112.39	-28.10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
262	4	0	-39.68	0	0	0	0	0	0	0	-0.43	0	0	0	0	0	0	0	0	0.43	0	0	0
263d	4	0	-33.99	0	0	-75.11	-18.78	0	0	0	-0.47	0	0	0	0	0	0	0	0	0.47	0	0	0
263i	4	0	-32.95	0	0	0	0	0	0	0	-0.43	0	0	0	0	0	0	0	0	0.43	0	0	0
266i	4	0	-73.30	0	0	0	0	0	0	0	-0.42	0	0	-0.86	0	0	0	0	0	0.42	0	0	0.86
275b	4	0	-36.90	0	0	-156.84	-39.21	0	0	0	0	0	0.50	0	0	0	0	0	0	0	0	-0.50	0
280e	5	0	0	0	0	111.65	27.91	0	26.22	0	0	0	0	1.44	6.27	0	0	0	0	0	0	0	-1.43
981a	5	0	0	0	0	0	0	0	19.24	0	0	0	0	0	0	15.13	0	0	0	0	0	0	0
497	6	0	0	-32.22	0	0	0	0	0	0	0	0	0	0	0	0	-11.58	0	0	0	0	0	0
140	7	0	-21.92	0	0	-93.20	-23.30	-51.44	0	0	-0.58	-0.32	0	-1.23	-5.65	0	0	0	0	0.58	0.32	0	1.24
207	7	-91.03	0	0	0	0	0	0	0	-0.83	-0.44	0	0	-1.49	0	0	0	0	0.83	0.44	0	0	1.49
378	7	0	0	0	0	0	0	-28.66	0	-0.33	0	-0.42	0	-1.29	0	0	0	0	0.34	0	0.42	0	1.30
105	8	0	0	0	38.22	0	0	0	0	0	-0.47	0	0.50	0	0	0	0	0	0	0.47	0	-0.50	0
115i	8	0	0	0	26.80	0	0	0	0	0	-0.35	0	0	-0.54	0	0	0	6.44	0	0.35	0	0	0.55
164	8	0	0	0	29.50	0	0	0	0	0	0	0	0.45	0	0	0	0	0	0	0.34	0	-0.45	0
170	8	0	0	0	29.42	0	0	0	0	0	0	0	0.38	0	0	0	0	3.84	0	0	0	-0.38	0
192	8	0	0	0	24.64	0	0	0	0	0	0	0	0	0	0	0	0	5.87	0	0	0	0	0
194o	8	0	0	0	28.94	0	0	0	0	0	0	0	0	0	0	0	0	6.42	0	0	0	0	0
390	8	0	0	0	16.47	0	0	0	0	-0.32	0	0	0	0	0	2.24	1.89	3.58	0.33	0	0	0	0

Temperature

CS #	Cluster #	Y23	Y24	Y25	Y26	Y27	Y28	Y29	Y30	Y31	Y32	Y33	Y34	Y35	Y36	Y37	Y38	Y39	Y40	Y41	Y42	Y43	Y44	Y45	Y46	Y47
202	1	0.54	0.98	0.86	0	0.57	0.74	0.40	0	0	0.07	0	0	0	0.32	0.64	0	0	0	0	0	-0.41	-0.79	-0.46	0	-1.12
279	1	0	0.74	0.52	0	0.29	0.53	0	0	0	0.08	0.48	-0.20	0	0.32	0.60	0	0.68	0	0	0	0	0	0	0	0
322	1	0	0	0	-0.95	0	-0.75	0	-1.98	0	0	-1.16	-0.46	-1.50	0	0	-0.95	-1.54	0	0	0	0	-1.72	-0.41	0	-2.35
499	1	0	0.37	0.62	0	0	0.27	0	0	0	0.14	0	-0.29	0	0	0	0	0	0	0	0	0	0	0	0	0
713	1	0	0	0	-0.72	0	0	0	-1.18	0	0	0	0	0	0	0	0	0	0	0	0	0	-1.64	0	0	-1.67
948	1	0	0	0	0	0	0	0	0	0	0	0.73	-0.33	0	0	0	0	0	0	0	0	0	-0.78	0	0	0
237i	1	0	0.91	0.92	0	0.53	0	0.73	0	0	0.08	0	0	0	0	0	0	0	0	0	0	-0.75	-1.92	-0.75	0	-2.66
91o	1	0	0.57	0.81	0	0.36	0.89	0	0	0	0.11	0.76	0	0.78	0.38	0.73	0	1.04	0	0	0	0	0	0.08	0	0
207	2	0	0.84	1.28	0	0	0	0.60	0	0	0	1.10	0	1.51	0	1.10	0	1.55	0	0	-0.16	0	0	-0.83	-0.51	-2.14
491	2	0	0.92	0.75	0	0.51	0.49	0.53	0	0	0.10	0	0	0	0.34	0.34	0	0	0	0	0	0	0	-0.20	0	0
115i	2	0	0.68	0.82	0	0.44	0.42	0.39	0	0	0.06	0.54	0	0.57	0.27	0.68	0	0.77	0	0	0	0	-0.76	0	0	-0.97
280e	2	0	0	0	-1.11	-0.46	-0.51	-0.50	0	-1.24	0	0	-0.48	0	0	0	0	0	0	0	0	0	0	0	0	0
376i	2	0	0.74	1.09	0	0.42	0.52	0.30	0	0	0	0.81	0	0.76	0.22	0.82	0	0.71	0	0	0	0	-0.92	-0.45	0	-1.33
495u	2	0	0.59	0	0	0	0	0	0	0	0.22	0	0	0	0.43	0	0	0	0	0	0	0	0	0	0	0
554a	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-2.81	0	0	-4.32
72x	2	0	0.89	0.76	0	0.45	0.55	0	0	0	0.07	0.76	0	0.78	0.33	1.01	0	1.15	0	0	0	0	0	0	0	0
981a	2	0	0.62	0.77	0	0.41	0.55	0	0	0	0	1.03	0	0.96	0.80	0	0	1.27	0	0	0	0	-0.37	0	0	-0.39
390	3	0.69	1.19	0.95	0.62	0.86	0.92	1.03	0	1.38	0.12	0.75	0	0.74	0.44	0.53	0	0.87	-0.38	0	-0.07	-0.47	-1.53	-0.49	-0.53	-2.55
562	3	0.90	1.33	0.70	0.16	0.80	0.70	0.88	-1.31	0	0	0	0	0	0	0.75	0	0.61	-0.26	0	-0.06	-0.37	-1.60	-0.65	0	-2.35
961	3	0	0.76	0	0	0.52	1.03	0	0	0	0.11	0	0	0.68	0.36	0	0	0	0	0	0	0	-0.82	0	0	-0.78
461	4	0	0.76	0	0	0	0	0	0	0	0	0	0	0	0.24	0	0	0	0	0	0	0	-1.65	-0.62	0	-2.00
261e	4	0	0.38	0.61	0	0	0	0	0	0	0.05	0.50	0	0.45	0	0.44	-0.31	0	0	0	0	0	-0.64	0	0	0
263i	4	0	1.01	0	0	0	0	0	-1.05	0	0.10	0	0	0	0.30	0.58	0	0	-0.29	0	0	-0.32	-1.42	-0.57	0	-2.06
266i	4	0	0.49	0.41	0	0	0	0.31	0	0	0.07	0	-0.25	0	0	0	-0.45	0	0	0	0	0	-0.71	0	0	-0.93
275b	4	0	0.58	0.61	0	0	0	0	0	0	0	0	0	0	0	0	-0.32	0	0	0	0	0	-0.62	0	0	-0.71
121	5	0	0.90	0.94	0	0.59	0.55	0.60	0	0	0.09	0.56	0	0.51	0.25	0.54	0	0	0	0	0	0	-0.69	0	-0.19	-0.90
179	5	0	0	0	0	0	0	0	0	0	0	0.59	0	0	0.34	0.62	0	0	0	0	0	0	-1.23	0	0	0
205	5	-0.42	0	0	0	0	0	0	0	0	0	0	0	0	0.17	0	0	0	0	0	0	0	-1.14	0	0	-1.55
262	5	0	0.91	0.85	0	0.35	0.50	0.23	0	0	0.09	0.71	0	0.58	0.28	0.59	0	0	0	0	0	0	0	0	0	0
537	5	0	0	0.49	0	0	0	0	0	0	0.06	0.62	0	0.66	0.32	0	0	0	0	0	0	0	0	0	0	0
194o	5	0	0.87	0.95	0	0.57	0.65	0.45	0	0	0.13	0.95	0	1.02	0.56	0.69	0	0	0	0	0	0	-0.72	0	0	-0.86
263d	5	0	1.04	0.96	0	0.61	0.68	0.54	0	0	0.10	0.66	0	0.57	0.26	0.61	0	0	0	0	0	0	-0.57	-0.24	0	-0.85
44	6	0	0.99	0.62	0	0.54	0	0.52	0	0	0.10	0	0	0	0	0.56	0	0	-0.44	0	0	-0.55	-1.64	0	0	-1.69
105	6	-0.94	-0.53	-0.53	-1.47	-0.66	-0.87	0	-0.89	0	0	-0.49	-0.42	0	0	0	-0.80	0	0	0	0	0	0	0.42	0.47	0
392	7	0	0.86	0	0	0	0	0	0	0	0.13	0	0	0	0	0	-0.48	0	0	0	0	-0.77	0	0	0	0

Appendix III: Forest fire occurrence report

PARTE DE INCENDIO FORESTAL

Nº de parte

DATOS GENERALES DEL INCENDIO

1. Localización:

Comunidad Autónoma ____ Provincia ____

Comarca o isla ____ Término Municipal (origen) ____

Entidad menor ____ Paraje ____

Cuadrícula Mapa militar 1:250.000 .... Hoja ____ Cuadrícula ____

U.T.M: Huso ____ X ____ Y ____

2. Tiempos: Día / Mes / Año Hora Minutos

2.1. Detección ....

2.2. Llegada primeros medios por tierra ....

2.3. Llegada primeros medios aéreos de extinción ....

2.4. Llegada de la primera brigada helitransportada ....

2.5. Incendio controlado ....

2.6. Incendio extinguido..

3. Detección:

3.1. **Detectado por:** Vigilante fijo (____) Cod. V. Fijo
Agente forestal Vigilante móvil Aeronave Llamada particular 112 Otros

3.2. **Iniciado junto a:** Carretera Pista forestal Senda Casas
Lugares con afluencia de excursionistas Vías férreas Cultivos Urbanizaciones
Vertederos Otros lugares del monte ....

4. Causa del incendio Cierta Supuesta

Rayo Días desde la tormenta

Negligencias y Causas accidentales

Quema agrícola ____ Quema de matorral ____

Quema para reg. pastos ____ Ferrocarril

Trabajos forestales Líneas eléctricas

Hogueras Motores y máquinas ____

Fumadores Maniobras militares

Quema de basuras Otras ____

Escapes de vertedero

Intencionado Motivación (sólo intencionado) ____

Causa desconocida **Incendio reproducido**

Causante: ____ Identificado No identificado

Clase de día: Festivo Sábado Laborable víspera festivo Laborable

5. Condiciones de peligro en el inicio del incendio

5.1. Datos meteorológicos: Estación meteorológica ____ Hora :

Días desde la última lluvia Temperatura máxima °C.

Humedad relativa % Viento: Velocidad Km/h. Dirección

5.2. Modelos de combustibles en la zona de incendio:

Pastizales Matorrales Bosques Restos

5.3. Prob. Ignición % Peligro: Prealerta Alerta Alarma Alarma extrema

6. Tipo de fuego: De superficie De copas De subsuelo

Codificar las casillas sombreadas según la clave

Rellenar los datos a mano

7. Medios utilizados en la extinción:

7.1. Transporte de personal terrestre: Vehículos ○ Helicópteros ○ .... ▢

Distancia aproximada a pie (metros).. ▢▢▢▢

7.2. Personal: Núm. de personas

	Núm. de personas
Técnicos	▢▢▢▢
Agentes forestales	▢▢▢▢
Combatientes de cuadrillas y brigadas..	▢▢▢▢
Bomberos profesionales..	▢▢▢▢
Voluntariado organizado..	▢▢▢▢
Otro Personal civil	▢▢▢▢
Guardia Civil, Policía Autonómica y otras..	▢▢▢▢
Fuerzas del Ejército...	▢▢▢▢

7.3. Medios pesados: Autobombas ▢▢ Bulldozer ▢▢ Tractores agrícolas ▢▢ Otros ▢▢

7.4. Medios aéreos:

	Núm.	Brigadas transportadas	Descargas
Aviones anfibios	▢▢		▢▢▢
Aviones de carga en tierra	▢▢		▢▢▢
Helicópteros de extinción (depósito ventral)	▢▢	▢▢	▢▢▢
Helicópteros para transporte de cuadrillas (con o sin helibalde)	▢▢	▢▢	▢▢▢
Aeronave coordinación	▢▢		

Retardantes: Amónicos ○ Espumantes ○ Viscosantes ○ .... ▢

8. Técnicas de extinción:

8.1. Ataque directo ○ Ataque indirecto ○ .... ▢

8.2. Ataque indirecto: Apertura de cortafuego o líneas de defensa ○ Contrafuego ○ .... ▢

9. Pérdidas:

9.1. Víctimas... Muertos ▢▢ Heridos ▢▢

9.2. Superficies afectadas por el fuego:

9.2.1. Superficie forestal (Hectáreas)

	Arbolada	No Arbolada
Montes Utilidad Pública..	▢▢▢▢▢,▢▢	▢▢▢▢▢,▢▢
Montes del Estado - CCAA...	▢▢▢▢▢,▢▢	▢▢▢▢▢,▢▢
Montes en Consorcio / Convenio................................	▢▢▢▢▢,▢▢	▢▢▢▢▢,▢▢
Montes Públicos no Catalogados................................	▢▢▢▢▢,▢▢	▢▢▢▢▢,▢▢
Montes particulares..	▢▢▢▢▢,▢▢	▢▢▢▢▢,▢▢
TOTALES..	▢▢▢▢▢,▢▢	▢▢▢▢▢,▢▢

9.2.2. Superficie no forestal (Hectáreas).. ▢▢▢▢▢,▢▢

9.3. Efectos ambientales: Estimación de impacto global.. ▢▢

9.3.1. Superficie arbolada autorregenerable:	60-100% ○		30-59% ○		< 30% ○		▢
9.3.2. Efecto en la vida silvestre:	Inapreciable ○		Pasajero ○		Permanente ○		▢
9.3.3. Riesgo de erosión:	Bajo ○		Moderado ○		Alto ○		▢
9.3.4. Alteración del paisaje y valores recreativos:	Inapreciable ○		Pasajera ○		Permanente ○		▢
9.3.5. Efecto en la economía local:	Inapreciable ○		Pasajero ○		Permanente ○		▢

9.4. Incidencias de Protección Civil:

Cortes de carreteras ▢ Cortes de líneas férreas ▢ Cortes de suministro eléctrico ▢

Cortes de teléfono ▢ Desalojo de viviendas ▢ Daños en viviendas o naves industriales ▢

9.5. ¿Afectó a Espacio Natural Protegido? Sí ○ No ○ ▢

9.6. ¿Afectó a Reforestación de Tierras Agrarias? Sí ○ No ○ ▢

10. Nº de parte asociado: ▢▢▢▢▢▢▢▢▢▢