

Basis for a flood early-warning system approach in fast-flow Mediterranean catchments: The case study of Cala reservoir (Spain)

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Introduction

- Multipurpose dams are common over Mediterranean regions
- Optimal operation criteria are required to prevent damages linked to floods and droughts
- Difficulties in the optimization of decision making process

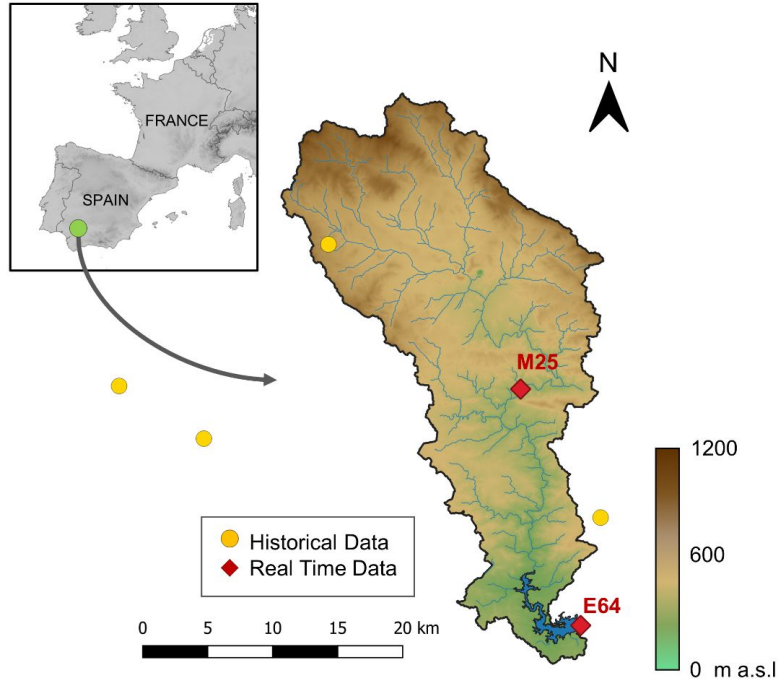
COMMON ISSUES

Meteorological forecasting systems not accurate due to the uncertainty associated to rapid response time of these watersheds

The insufficient number of control points with available real time measurement challenges the creation of early warning system

This study proposes the basis for the definition of an early warning system based on a limited number of real time in situ measurements in a characteristic Mediterranean catchment

Study Site and Available Data



Cala Reservoir (multipurpose)
Upstream catchment (535 km²)

Agroforestry uses

Quick response to intense precipitation due to steep slopes, shallow soils and groundwater redistribution, which does not favour the lamination of water

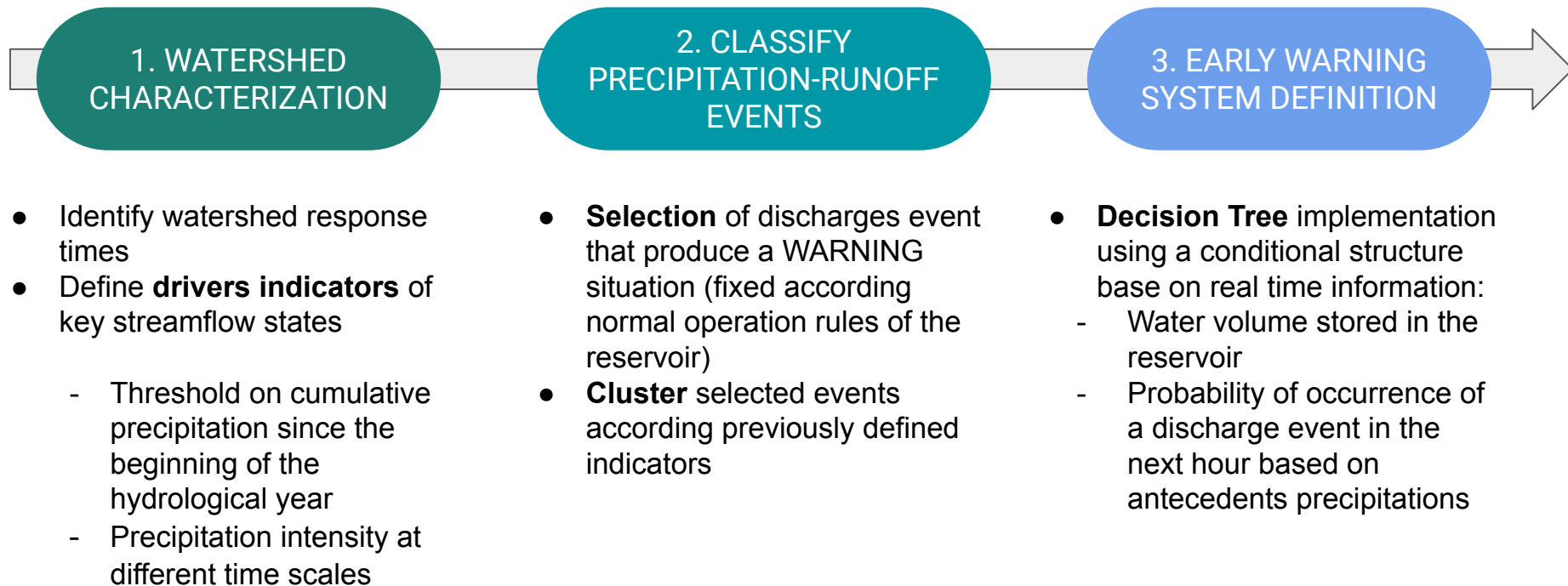
Real time data:

M25 - Water level and Precipitation (hourly)

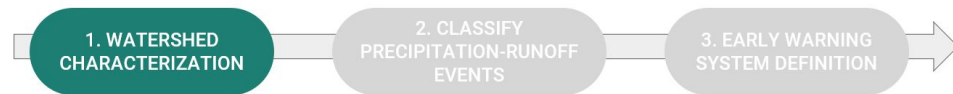
E64 - Water inflows and Precipitation (hourly)

Hydrological year	Watershed' Average Precipitation (mm/yr)	Reservoir Inflows (hm ³ /yr)
2009-2010	1089	238
2010-2011	845	176
2011-2012	338	13
2012-2013	625	150
2013-2014	496	33
2014-2015	488	42
2015-2016	649	49
2016-2017	527	39
2017-2018	646	86
2018-2019	380	9
Mean	608	83

Methods



Results (1/6)



Main Factors conditioning Watershed Hydrological

Response

- The watershed has a quick response to precipitation, with a maximum correlation between precipitation and runoff of 3 HOURS
- No WARNING events are identified before accumulating 100 mm since the beginning of the hydrological year.
- There exist many small pools and ponds use for irrigation with volumes that are unknown. They modified the natural regime during accumulation and release water for irrigation.
- Lack of groundwater measurements
- Different precipitation regimes between headwaters (steeper) and low areas (more flatten) in the watershed without hourly data.
- Non-control extraction from the reservoir.

Precipitation-Runoff Correlation

Shith	h (current hour)							
	h	h+1	h+2	h+3	h+4	h+5	h+6	h+7
R ²	0,038	0,084	0,152	0,294	0,273	0,272	0,215	0,163

Example of Indicator

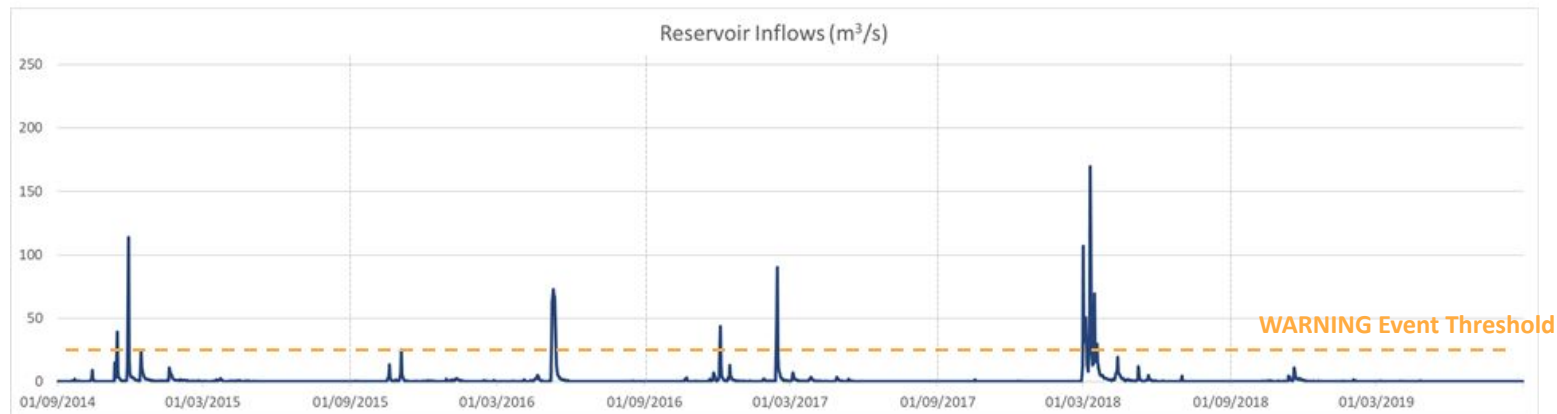
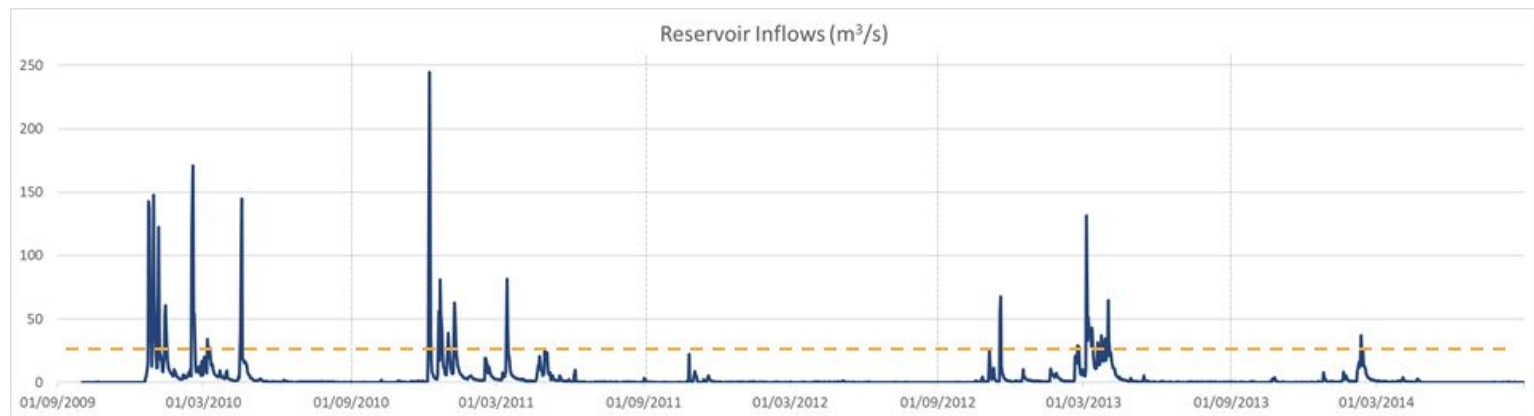
Hydrological year	P cum 1 st Q>WARNING event		
	M25 (mm)	E64 (mm)	Date 1 st Q>WARNING event
2009/2010	192,7	184,4	22/12/2009
2010/2011	171,9	221	06/12/2010
2011/2012	0,5	130,6	01/09/2011
2012/2013	114,8	185,9	04/11/2012
2013/2014	313,2	352,7	06/02/2014
2014/2015	14,1	107,3	22/09/2014
2015/2016	154,2	198,4	18/10/2015
2016/2017	123,3	237,6	26/11/2016
2017/2018	207,3	215,3	28/02/2018
2018/2019	-	-	-
2019/2020	150,3	138,4	19/12/2019
Mean	144,23	187,16	

Results (2/6)

1. WATERSHED
CHARACTERIZATION

2. CLASSIFY
PRECIPITATION-RUNOFF
EVENTS

3. EARLY WARNING
SYSTEM DEFINITION



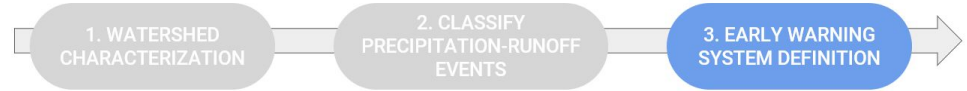
Results (3/6)



Example of Event Clustering (2019-2020)

Date	P-M25 h - 1 (mm/h)	P-E64 h - 1 (mm/h)	P-M25 h (mm/h)	P-E64 h (mm/h)	Water Level M-25 (m)	Q-E64 (m ³ /s)	P cum M25 (mm)	P cum E64 (mm)	Event Type
19/12/19 12:00	0	0,8	1,3	0,9	1,014	36,028	150,3	138,4	III
23/01/20 14:00	5,6	4,3	4,4	2,9	0,445	30,202	278,5	266,9	III
24/01/20 20:00	1,8	4,2	1,4	2,3	0,772	32,205	294,1	293	III
16/04/20 08:00	0	0	0	0	0,649	47,969	431,7	422,4	II
25/04/20 15:00	8,9	29,4	1,9	5,9	0,404	28,304	457,8	472,7	I

Results (4/6)



DISCHARGE EVENT TYPE I

- Events of heavy precipitation only in the control station in the reservoir (E64).
- Extremely quick response events
- Warning will be determined only using the precipitation values in E64 and the previous inflow values in the reservoir.

DISCHARGE EVENT TYPE II

- Events of precipitation in the headwater of the watershed but without precipitation in M25 or E64
- Slow response events
- Warning will be determined using and analysis in the streamflow in the 4 previous hours in M25, assigning probability occurrence depending on the discharge range (*) see Results (5/6)

DISCHARGE EVENT TYPE III

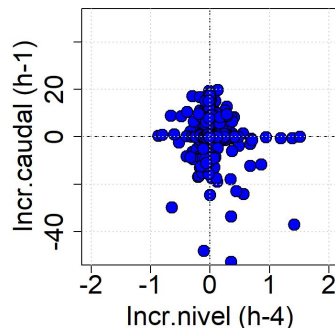
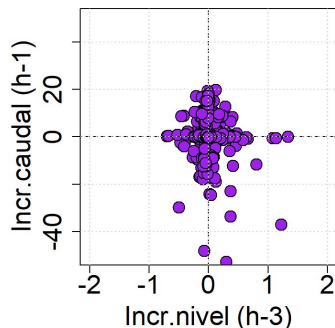
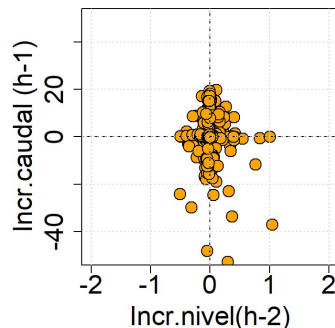
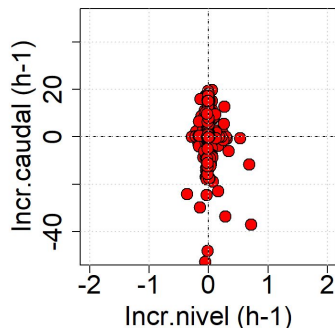
- Events of precipitation in both M25 and E64.
- Intermediate response events
- Warning will be determined due to a constant increase response in the inflow to the reservoir

Results (5/6)

1. WATERSHED
CHARACTERIZATION

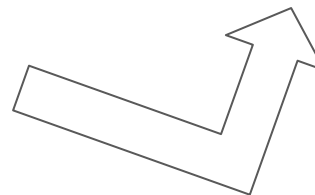
2. CLASSIFY
PRECIPITATION-RUNOFF
EVENTS

3. EARLY WARNING
SYSTEM DEFINITION



Probabilidad (%)

Incr. caudal (h-1)	-2	-1.5	-1	-0.5	0	0.5	1	1.5	2
-40	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
-30	0.000	0.000	0.000	0.025	0.025	0.000	0.000	0.000	0.000
-20	0.000	0.000	0.025	0.100	0.100	0.000	0.000	0.000	0.000
-10	0.000	0.000	0.025	0.624	0.674	0.050	0.000	0.000	0.000
0	0.000	0.000	0.050	3.745	2.197	0.250	0.025	0.000	0.000
10	0.000	0.025	0.300	9.064	5.368	0.624	0.200	0.125	0.000
20	0.000	0.025	0.449	14.607	7.191	0.874	0.250	0.150	0.000
30	0.000	0.025	0.599	16.355	7.840	0.999	0.275	0.150	0.000
40	0.000	0.025	0.624	16.554	7.965	0.999	0.275	0.150	0.000

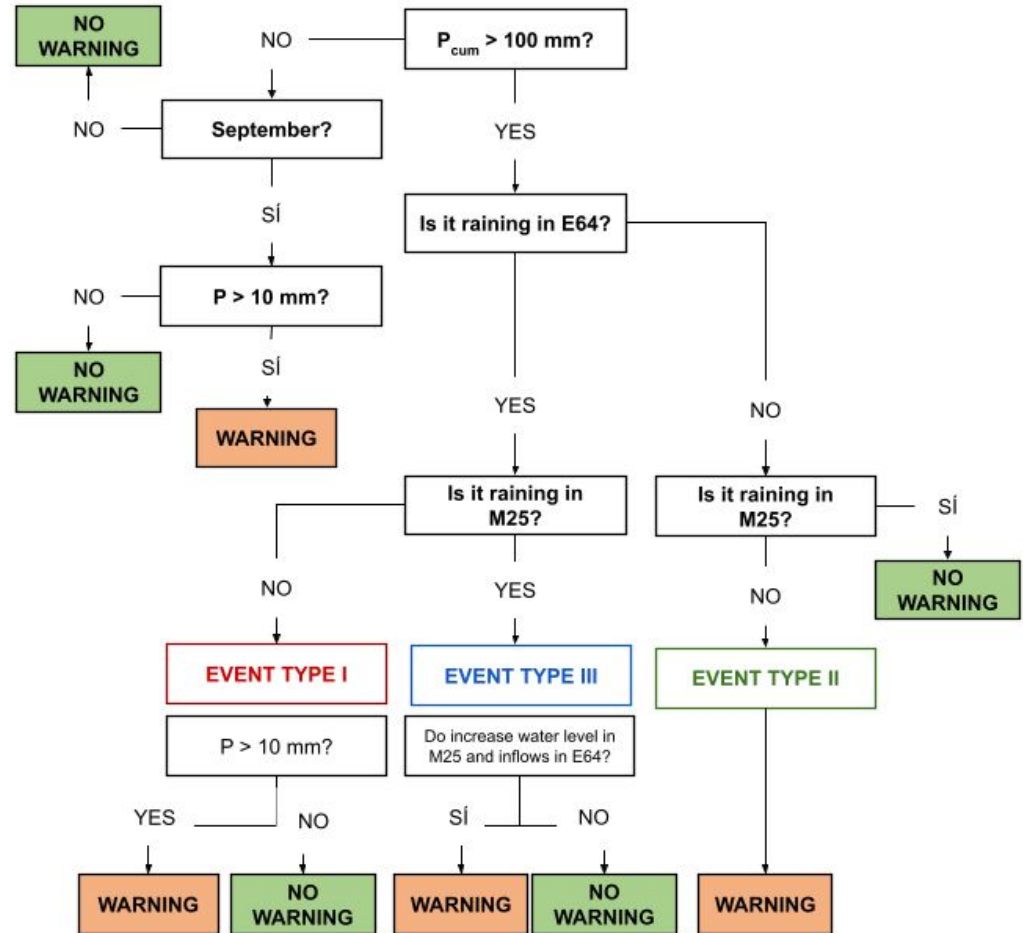


Results (6/6)

Decision

This scheme allows to identify the potential occurrence of a warning situation, which is fixed by the normal operational rules of the reservoir. Once the flood event is underway, the use of real time information about the water volume stored in the reservoir and the estimated probability of occurrence of an discharge event in the next hour based on antecedents precipitation, are the hydrological indicators to base the decision on together with the generation thresholds and requirements of the hydropower system. The approach is also validated based on historical information within a hindcast process during the validation period.

Tree



Conclusions

- Key hydrological indicators have been identified as the basis of an early warning system (i.e. threshold on cumulative precipitation since the beginning of the hydrological year, precipitation intensity at different locations within the catchment and time scales).
- Three main types of precipitation-runoff event have been defined according to the real time information available in the watershed.
- The results point out to the need of a more complete real time measurement network.
- The decision tree proposed allows to identify the potential occurrence of a warning situation, which is fixed by the normal operational rules of the reservoir.



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Thank you!



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