Monitoring Long-Term Topographic Changes in Badlands: a Natural Laboratory in the Southern Pyrenees

Damià Vericat
Fluvial Dynamics Research Group, University of Lleida, dvericat@macs.udl.cat

Aim

This project aimed at maintaining a long-term geomorphological monitoring program in a sub-humid badland located in the southern Pyrenees (the Upper River Cinca). The program was started in 2013 when High Resolution Topography was annually obtained at different spatial scales combining Laser Scanning Techniques and Digital Photogrammetry. Additionally, data on rainfall and time-lapse imagery were also registered. In particular, BSG funding allowed the **maintenance** of all these measurements and surveys between 2016 and 2017, and has also supported the acquisition of complementary equipment installed during this period, detailed below.

Methods

Data is obtained in 3 different sites: (a) A badland of 0.30 ha with a relief of 22 m and an East main aspect (**Badland 1**); (b) A badland of 0.45 ha with a relief of 23 m and a West main aspect (**Badland 2**), and (c) The outlet of the basin (10.13 km^2, **Outlet**). Badland 1 and 2 are within the Soto catchment and occupy the 0.03 and 0.04% of its catchment area, while both represent the 0.25 % of the percentage of badlands within the catchment (**Figure 1**). *Badland 2 and the Outlet of the catchment were set up in addition to the BSG project outlined initially*.

Data acquired in this natural laboratory include: (a) Topography: point clouds were obtained by means of multiple techniques, methods and platforms. A Leica C10 Terrestrial Laser Scanner System has been used in 5 occasions. Simultaneously and subsequently, digital photogrammetry or Structure from Motion Photogrammetry (hereafter SfM) has been applied (see **Table 1** for the specific details of all surveys). A 10 metre pole was acquired to take aerial photographs. In the last 4 surveys High Resolution Topography was acquired using pole-based SfM alone since preliminary results (unpublished data), suggest the accuracy and precision of SfM-based pint clouds are similar the TLS-based, while the time required to obtain the data is substantially less. (b) Air Temperature and Rainfall: changes in air temperature and rainfall through the year are monitored with a Campbell temperature sensor (model 107) and an ARG100 Campbell rainfall sensor located in the experimental Badland 1 (see **Figure 1**). Data are logged at 15 minute intervals. (c) Time-Lapse Imagery: a time-lapse Brinno camera is set up in each location (Badlands 1 & 2, and in the outlet of the Soto Catchment). Images are taken at 15 minute intervals. (d) Water Discharge & Temperature: a Trutrack capacitive sensor is installed at the outlet of the catchment. This sensor records water depth and air and water temperature at 15 minute intervals. (d) Water Turbidity: a McVann turbidimeter probe is installed at the outlet of the basin logging to a CR200 Campbell data-logger at 15 minute intervals. (e) Water Samples: a stage water sampler (following the initial model developed by Schick in 1967) is installed at the outlet of the catchment with the objective of calibrating the tubidimeter and to obtain samples when this is out of range. **Table 2** summarises the location of the sensors, the frequency for which data is registered and the period for which data is available. **Figure 2** shows some examples of the equipment installed. In addition to all field campaigns carried out to obtain topographic surveys, every 20 days a field visit is performed to check all instrumentation, download data and change batteries if necessary.

This BSG grant has supported part of the costs associated with field work and the materials obtained to improve and to extend the monitoring sites.

Main Findings

This project was submitted as a long-term geomorphological monitoring program with the objective to maintain and improve the program started in 2013. The main result is therefore that the number of data that are being acquired has been extended substantially by installing new sensors, adding two new sites (Baldand 2 & Outlet) and by increasing the temporal scale for which topographic surveys are acquired, making a natural laboratory offering the potential to become a considerable geomorphological resource. Additionally, a **new web site** has been prepared and published (https://sites.google.com/site/badlandscan/) to facilitate open-access sharing of the project data (work ongoing) communicate temporal and spatial resolution of available data, link to associated the publications, photographs and videos. At the present time, data is being processed routinely; however, since we aim for this to be a long term monitoring site, we seek to acquire further data over the next few years before main research findings are obtained. This monitoring program is providing field data beyond the timescale of normal research projects. The resolution and timescale of the data will allow studying processes and interactions controlling land degradation at multiple spatial scales and in relation to the frequency and magnitude of meteorological events. Additionally, the data will be very valuable to develop, calibrate and validate modelling approaches.

Figures & Tables

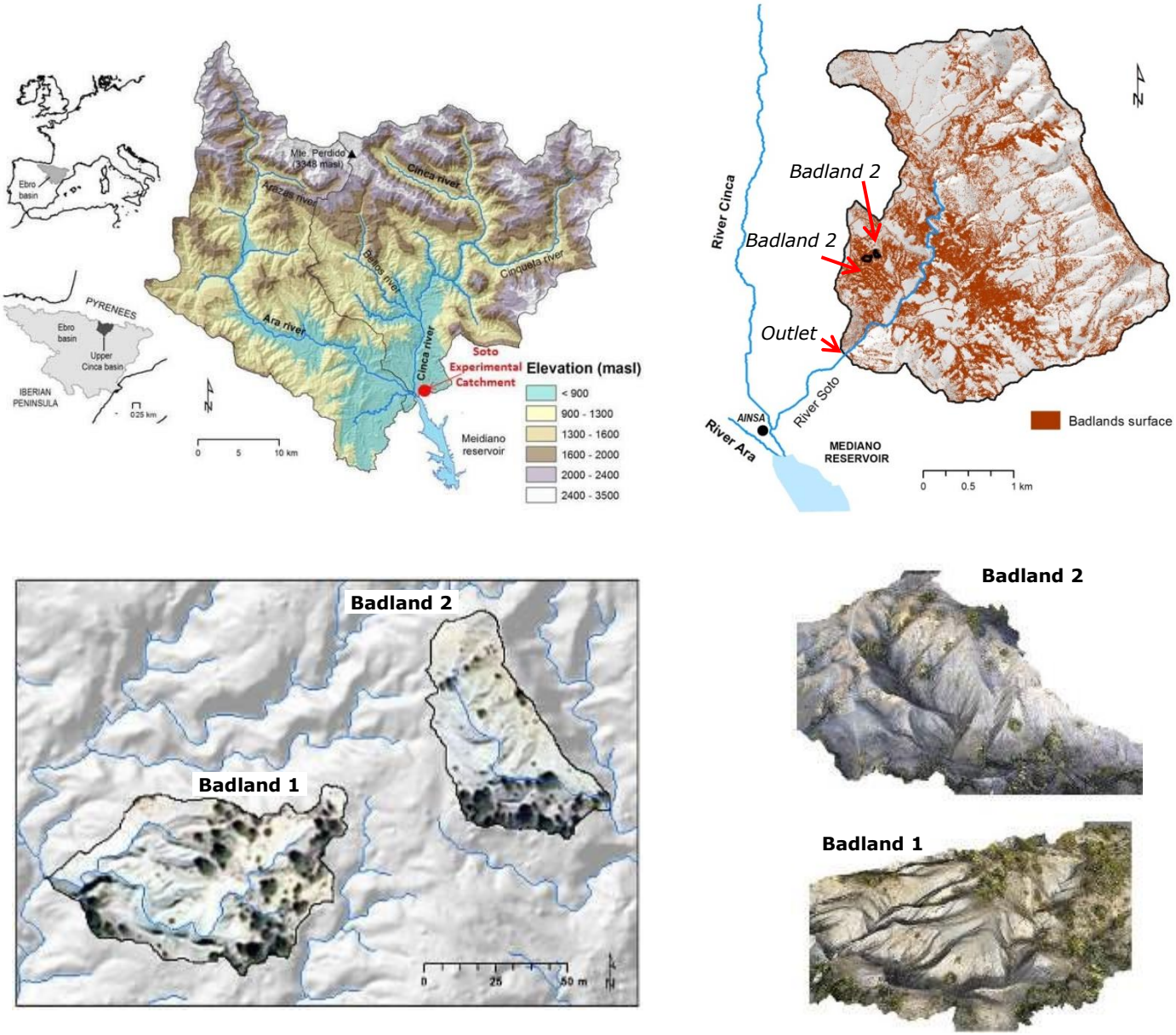

Figure 1. Location of the three monitoring sites in the Soto Experimental Catchment (southern Pyrenees; the Upper River Cinca: (a) Badland 1, (b) Badland 2 and (c) Catchment Outlet.

Figure 2. Some examples of data acquisition and instrumentation in the monitoring stations of the Soto Experimental Catchment (southern Pyrenees; the Upper River Cinca). Top: The outlet station. Middle: acquiring topographic data in Badland 1. Bottom: a new pole to acquire aerial imagery, the improved rainfall and air temperature station located in Badland 1, and an example of one of the time-lapse cameras installed, in this case, in Badland 1 (see Figure 1 for location).

Table 1. High Resolution Topographic Surveys obtained in the Soto Experimental Catchment (southern Pyrenees; the Upper River Cinca (see Figure 1 for location). Note that all surveys carried out in 2016 and 2017 were done in the background of this project.

Survey code	Date	Site	Survey Method
S01	26/06/2013	Badland 1	SfM and TLS
S02	02/12/2013	Badland 1	SfM and TLS
S03	29/5/2014	Badland 1	SfM and TLS
S04	04/8/2015	Badland 1	SfM and TLS
S05	19/7/2016	Badland 1	SfM and TLS
SOTO_1	20/08/2016	Gauging station (outlet)	SfM
S06	07/12/2016	Badland 1 and 2	SfM
S07	04/04/2017	Badland 1 and 2	SfM
S08	28/06/2017	Badland 1 and 2	SfM

Table 2. Data acquired in the Soto Experimental Catchment (southern Pyrenees; the Upper River Cinca (see Figure 1 for location). Note that all variables started being registered between 2016 and 2017 were acquired in the background of this project.

Environmental variables	Site	Frequency	Period
Rainfall	Badlands	5 minutes	05/08/2015 - Today
Air Temperature	Badlands	5 minutes	04/05/2016 - Today
Time-Lapse Imagery	Badlands and Outlet	5 minutes	26/06/2013 - Today
Topography	Badlands	Annual and seasonal	26/06/2013 - Today
Water discharge & Temperature	Outlet	5 minutes	04/05/2016 - Today
Water Turbidity	Outlet	5 minutes	20/08/2016 - Today
Water Samples	Outlet	-	20/08/2016 - Today