Quick Scan of Natural Water Retention Measures for tributaries of Rio Tajo near Toledo

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1. Introduction

Heavy rains poured down in the afternoon and evening of 3 September 2023 in central Spain. A slow-moving storm system (DANA) passed by, officially known as an upper-level isolated depression. The high intensity of the rainfall in combination with total precipitation rates exceeding 100 mm caused huge floods in the Madrid and Toledo region.

With sea temperatures rising due to climate change, rainfall patterns are changing all across Europe and this type of severe rainfall events is predicted to happen more frequently.

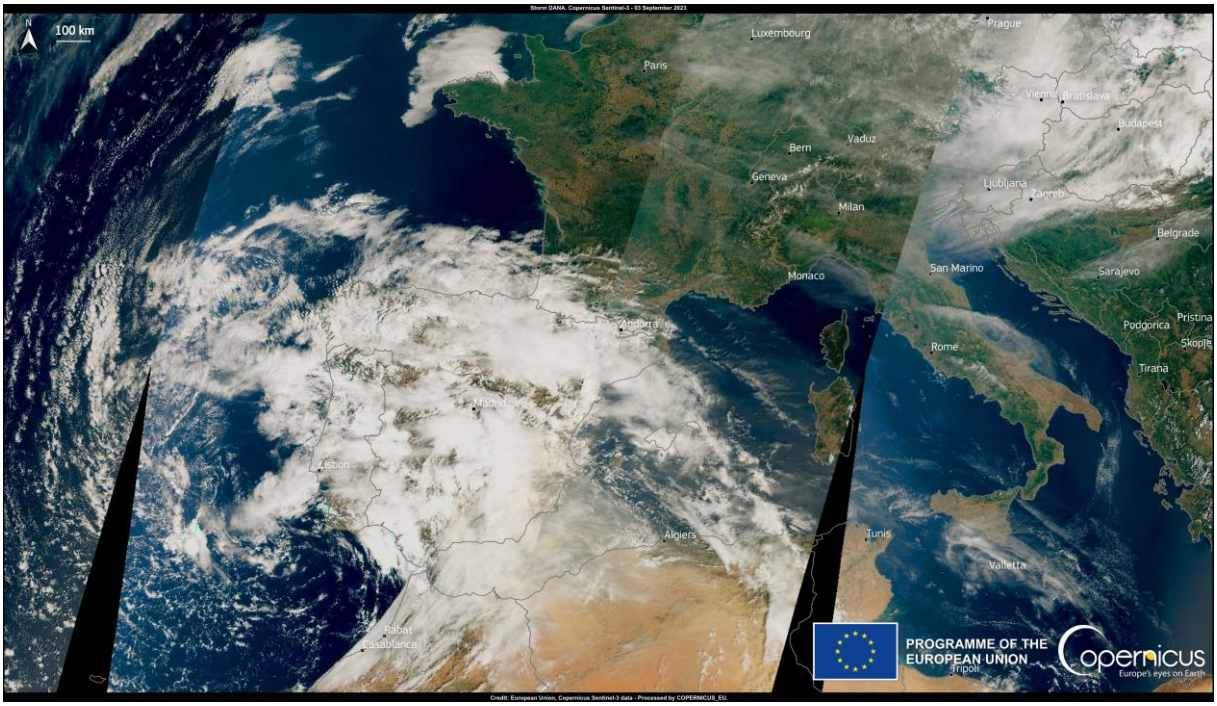


Figure 1: Storm DANA seen from Copernicus Satellite on 4 September 2023

This desktop study provides an overview of the present situation, the DANA rainfall event and the potential of Nature-Based Solutions (NBS) such as Natural Water Retention Measures (NWRM) and the use of “natural sponges” to delay the flow of water in tributaries of the river Tajo near Toledo.

The Quick Scan will focus on four tributaries of the river Tajo near Toledo: 1. Arroyo del Aserradero, 2. Arroyo de la Degollada, 3. Arroyo del la Rosa and 4. Arroyo de Ramabujas.

The study and analyses are included on the interactive site:
https://media.stroming.nl/toledo/#

2. Rain event DANA 3 September 2023

By analysing weather station network, https://www.wunderground.com, a precipitation pattern on 3 September in the Toledo region could be distinguished. The most reliable network stations are shown in the graphs below. Total precipitation rates increased from 75 mm in Cobisa (south) to almost 100 mm in El Beato (north). The rainfall followed roughly the same pattern, with rainfall intensity around 40 mm / hour during the afternoon and extremely high rainfall intensity (74 – 134 mm / hour) between 20:00 and 21:00 in the evening.

Rainfall intensity is an important factor for flood risk. Depending on soil conditions and land use, overland flow occurs when the intensity of rainfall increases.

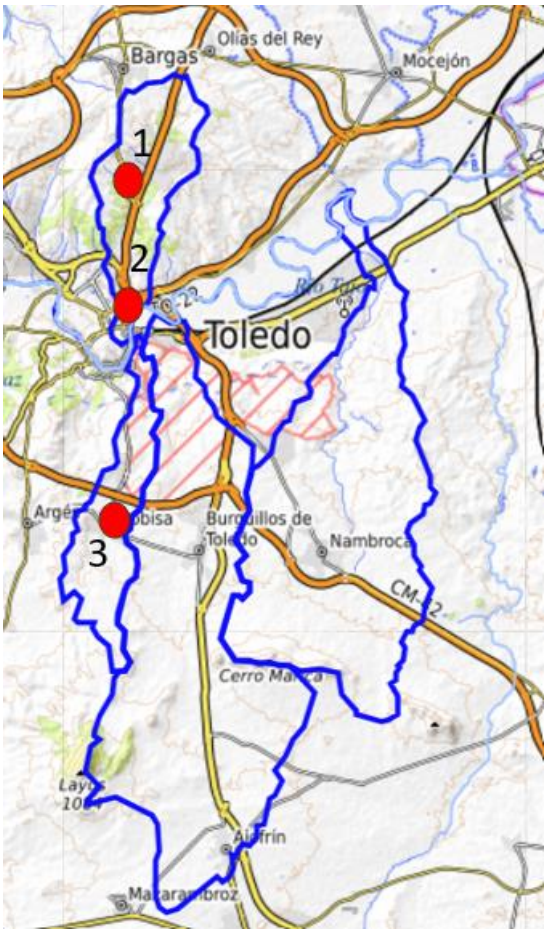
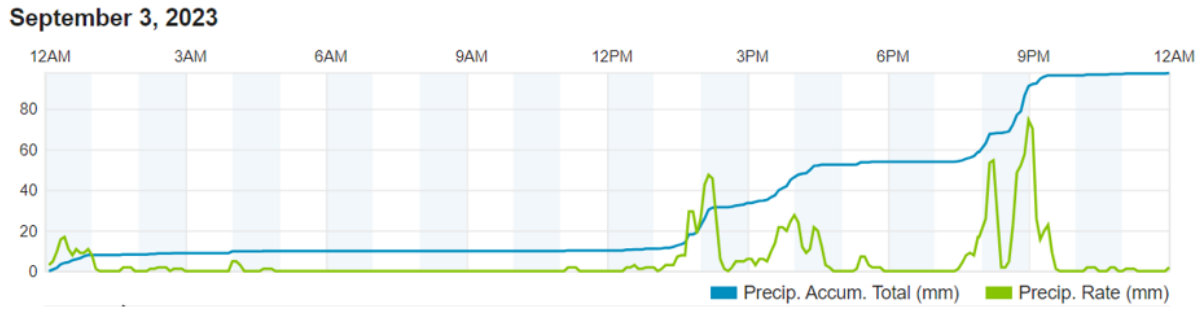
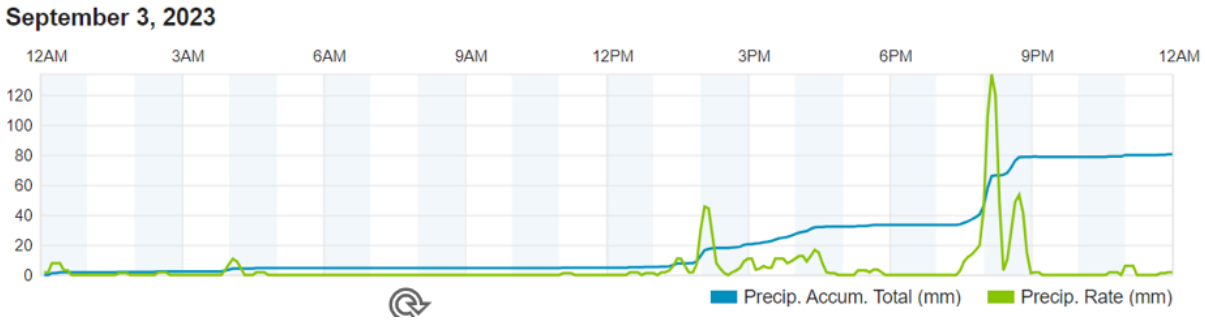


Figure 2: Catchments of the Tajo tributaries Arroyo del Aserradero, Arroyo de la Degollada, Arroyo del la Rosa and Arroyo de Ramabujas and the location of the private weather stations that are connected to Wunderground.

Arroyo del Aserradero, El Beato
Total Precipitation: 97 mm
Highest precipitation rate: 74 mm / hour



Arroyo del Aserradero, Toledo
Total Precipitation: 80 mm
Highest precipitation rate: 134 mm / hour



Arroyo de la Degollada, Cobisa
Total Precipitation: 75 mm
Highest precipitation rate: 82 mm / hour

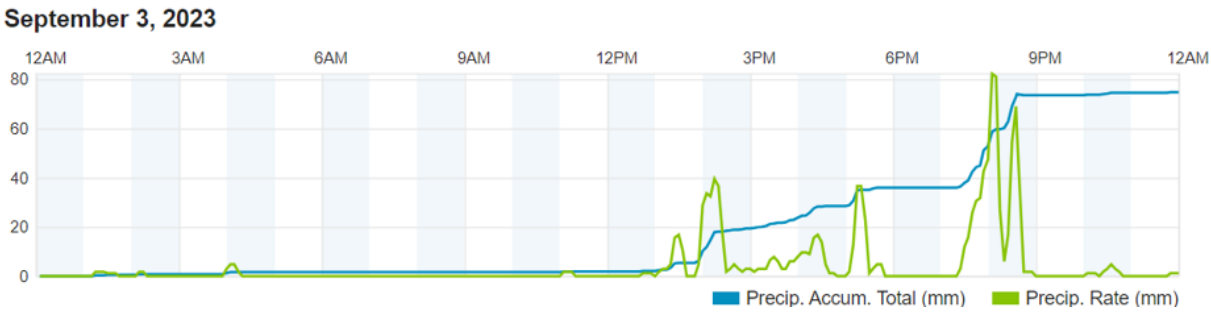


Figure 3: Precipitation graphs for three private weather stations in the Toledo region. The blue line shows the accumulated precipitation (mm) and the green line shows the precipitation rates (mm / hour)

3. Potential of natural water retention measures

In this chapter the most important topics regarding flood risk in these catchments will be highlighted and inventoried along with the potential for NBS related to NWRM which can delay the discharge and/or slow the flow of water as illustrated in the figures below.

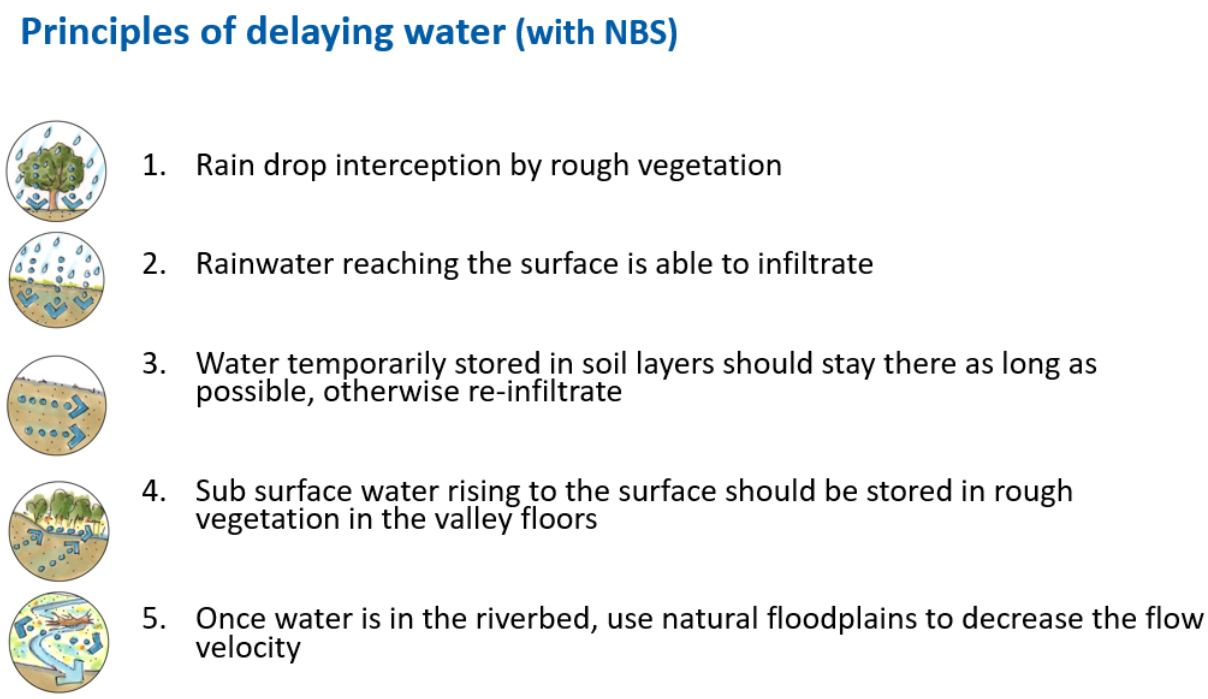


Figure 4: By following the raindrop on its journey to the river, the best measures to slow the flow of water with NBS can be determined.

3.1 Potential for natural sponges

To analyse the suitability for natural sponges as NWRM, a low slope of <10% is desirable for the best results to effectively slow flows. Using a GIS analysis, the following areas are potentially available:

- Arroyo del Aserradero: The available space is mainly occupied by urban settlements and highway A-42 to Toledo. The challenge in this catchment is to retain water discharging from roads and paved surfaces.
- Arroyo de la Degollada: A large percentage of the suitable area is unbuilt with the village of Cobisa as an exception. There are many chances to retain water.
- Arroyo de la Rosa: A large percentage of the suitable area is unbuilt and has enough space for NWRM, with the downstream urban settlement of Santa Barbara as the exception. There are many chances to retain water.
- Arroyo de Ramabujas: A large percentage of the suitable area is unbuilt and has enough space for NWRM, with the downstream urban settlement of Santa Maria de Benquerencia as the exception. There are many chances to retain water.

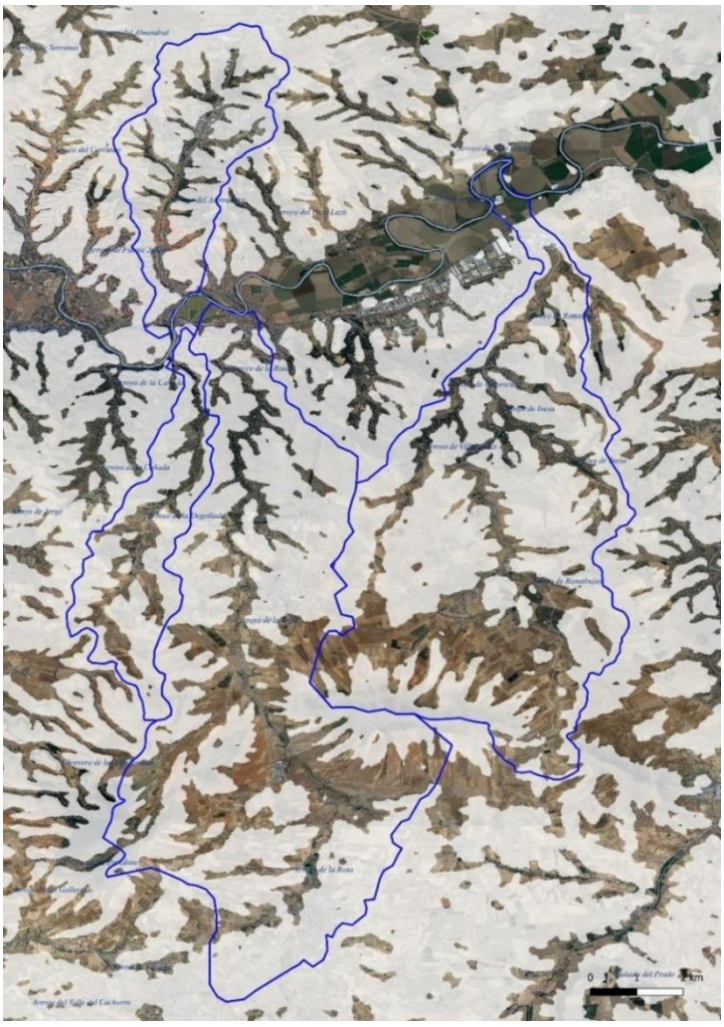


Figure 5: GIS analysis to determine low lying areas with a low slope gradient within the catchments. These are the areas potentially suitable for NWRM.
https://media.stroming.nl/toledo/#

3.2 Urban development

Runoff from paved surfaces contributes significantly to the maximum peak flows in the instance of a DANA type rain event. By creating NWRM and natural sponge areas, water discharges can temporally be stored and delayed, lowering flood peaks downstream.

Figure 6: Shopping centre (13 ha) next to the Arroyo del Aserradero. The DANA event with almost 100 mm rainfall caused a runoff potential of 13.000 m3 water from this shopping centre only.

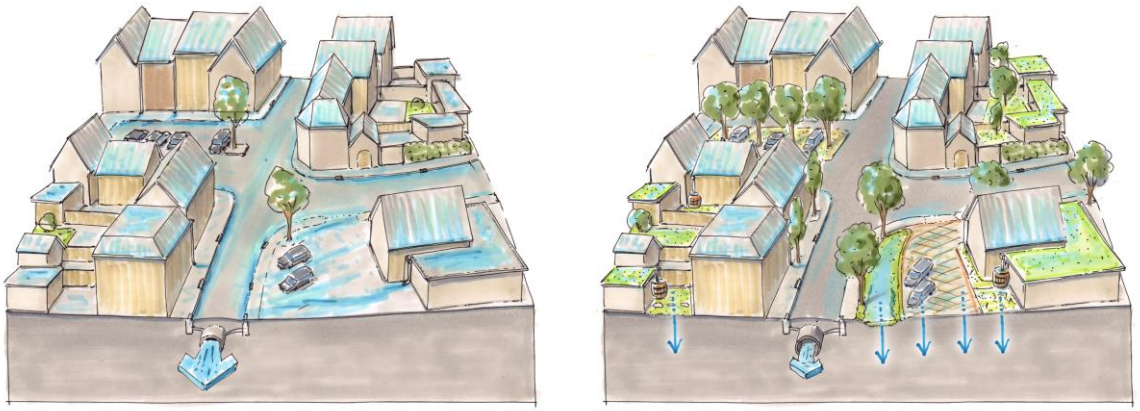


Figure 7: The development of NWRM and sponges within urban areas helps minimise the discharge from paved surfaces.

3.3 Spatial planning

In the past few decades, villages in the Toledo region, often situated next to streams, expanded their territory. The 1953 aerial photograph shows that the village of Cobisa was situated next to the Arroyo de la Degollada. In the current situation however, the new urban layout is situated in the original streambed. The expansion continues as new houses are being built north of the village within the course of the Arroyo de la Degollada. During the DANA event, the flood zones in Cobisa exceeded the 500 year return period. That's why for the sake of flood resilience it's important not to build over streams and give space to water.

Figure 8: The expansion of Cobisa in the past decades on top of the streambed (upper photos). The expansion continues as new houses are built within the course of the Arroyo de la Degollada (lower left). Flood zones in Cobisa with a 500 year return period (lower right). Water filled with sediments flowed through the village of Cobisa on 3 September (below).

The Arroyo de la Rosa and Arroyo de Ramabujas are both forced into small channels in the downstream village of Sante Barbara and the neighbourhood Santa Maria de Benquerencia, leaving little space for absorbing high peak discharges.

Figure 9: Arroyo de la Rosa goes underground in the village of Santa Barbara (left), Arroyo de Ramabujas is channelled while passing the neighbourhood of Santa Maria de Benquerencia.

Figure 10A: 2021 Flooding in Arroyo de la Rosa in the downstream village of Santa Barbara (source: El Público)

Figure 10B: 2023 flooding in Arroyo de Ramabujas at the bus parking area in the downstream village of Santa Maria de Benquerencia (source: ELDIGITALCLM)

The village Burguillos de Toledo, situated next to the Arroyo de la Rosa, expanded as well in the past few decades. The streambed was however respected and is still largely without buildings on its side. For flood resilience it's essential to protect floodplains outside the streambed.

Figure 11: Spatial development of the village Burguillos de Toledo between 1956 and 2023. The Arroyo de la Rosa largely kept its floodplain unbuilt despite the expansion of the village.

Figure 12: Protected floodplains are a prerequisite for flood resilience.

3.4 Water discharge from roads

Roads on slopes act like extended river channels in the case of DANA type rain event. They collect water from the surrounding areas, increase the flow velocity and discharge the collected water directly into the stream. Interception of the discharge from roads in low, dry valleys also known as “washes” or guiding it through natural vegetation can temporally store and delay the discharge of water.

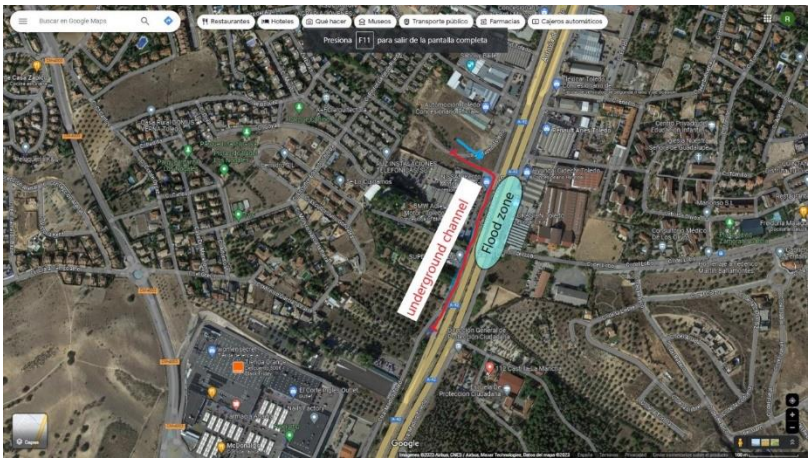


Figure 13: Next to the Arroyo de Aserradero lies the Autovida de Toledo. The Autovida roadway acts like an extended stream in case of a DANA type event.

Figure 14: Disconnecting roads from rivers. Water can temporarily be stored in dry valleys or flow slowly through natural vegetation.

3.5 Rural land use

In central Spain, rural areas are transformed from vegetated areas into bare fields after the harvesting of crops in early summer. In olive groves, soils remain largely uncovered year-round; they often lack undergrowth such as grasses and herbaceous plants. These bare soils have less capacity for water retention and infiltration than soils covered with vegetation, making them vulnerable to erosion and rapid surface run-off of water – which can contribute to higher peak discharges in the case of a DANA type rain event.

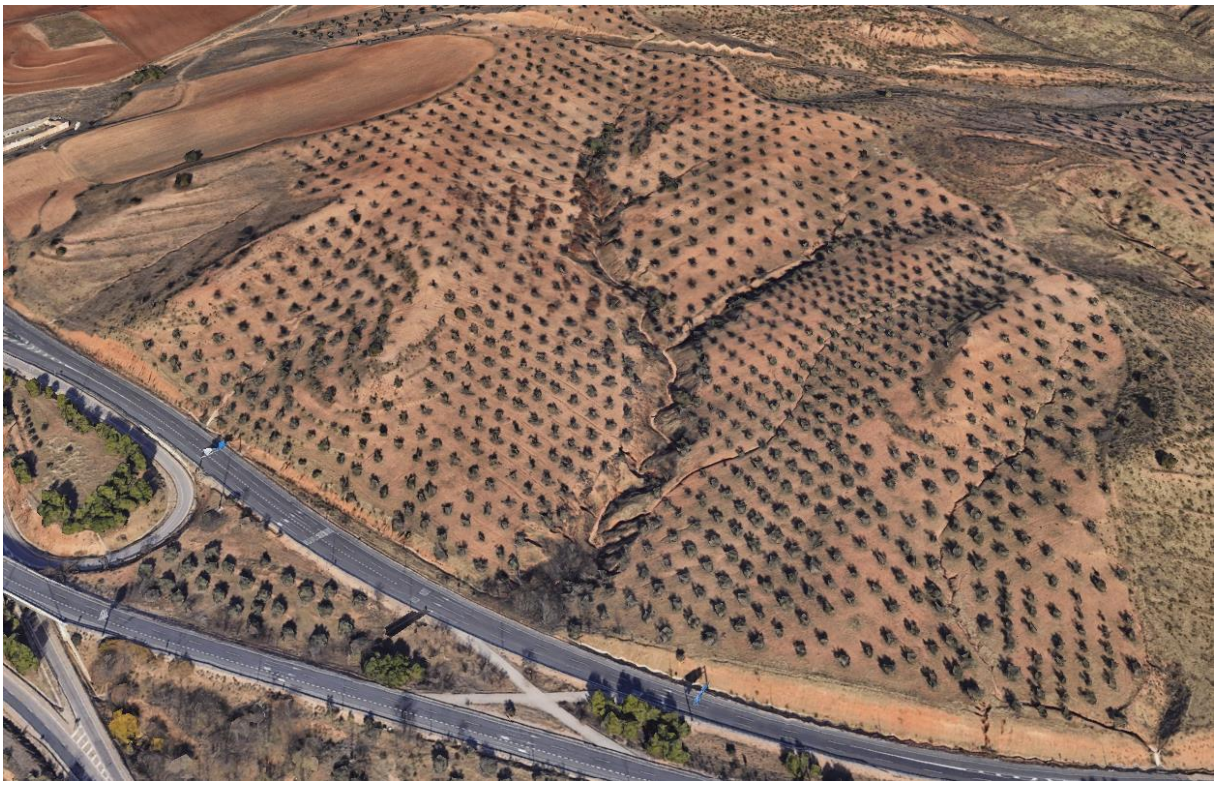


Figure 15: Gullies formed by erosion in an olive field in the Arroyo del Aserradero

Figure 16: Bare soils surrounding the village of Cobisa.

Figure 17: After the DANA event, Cobisa was covered with thick layers of mud from surrounding fields.

For example, the use of grasses and herbaceous plants as undergrowth between the olive trees protects soil fertility and increases the infiltration capacity and biodiversity.

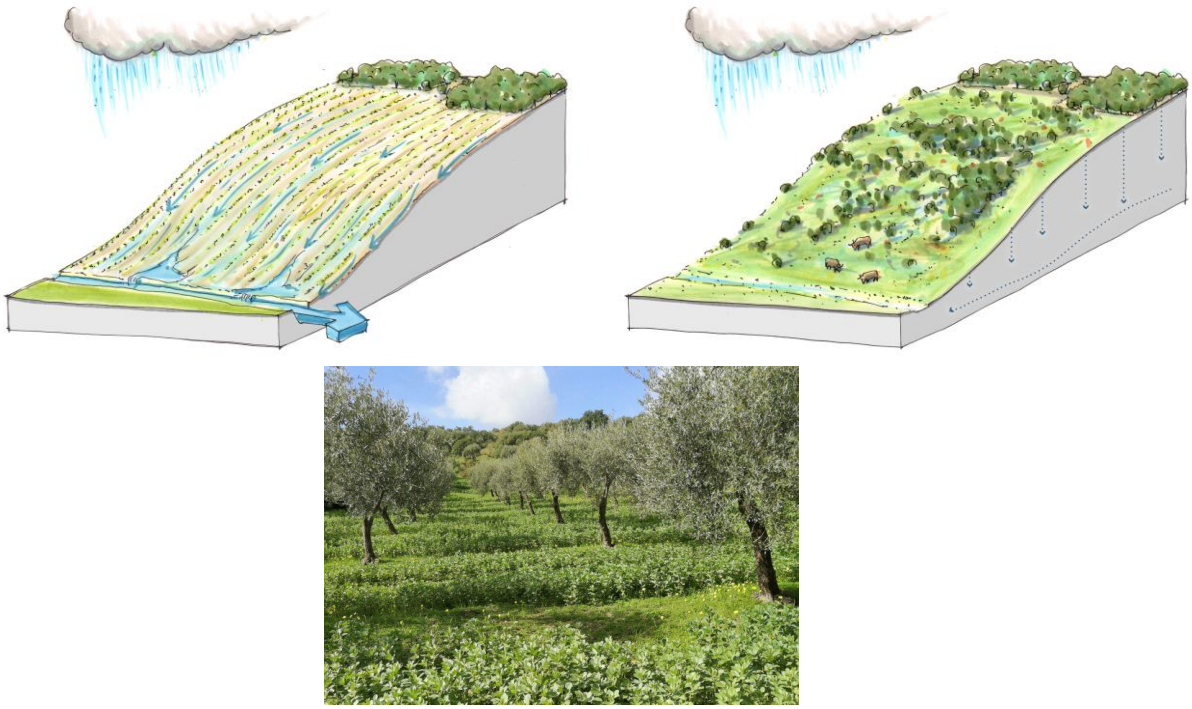


Figure 18: The transition of land use from bare to vegetated fields is an effective NBS measure for flood resilience.

3.6 Natural sponge valleys in upper catchments

In the three southern catchments enough space is available for the restoration and preservation of natural sponges in upstream valley bottom areas. Retaining more water in upstream natural sponges can create multiple benefits, reducing downstream peak flood discharges and increasing base flows of water in times of drought. This involves removing drainage channels and restoring infiltration capacity in the upper catchments. Another benefit of upstream sponge restoration is that there is often more undeveloped land available in upper catchments for landscape-scale measures that can retain water more effectively than in more built up environments. There are good examples of natural sponges in the three southern catchments which can be used as showcases to transform other parts of the catchments.

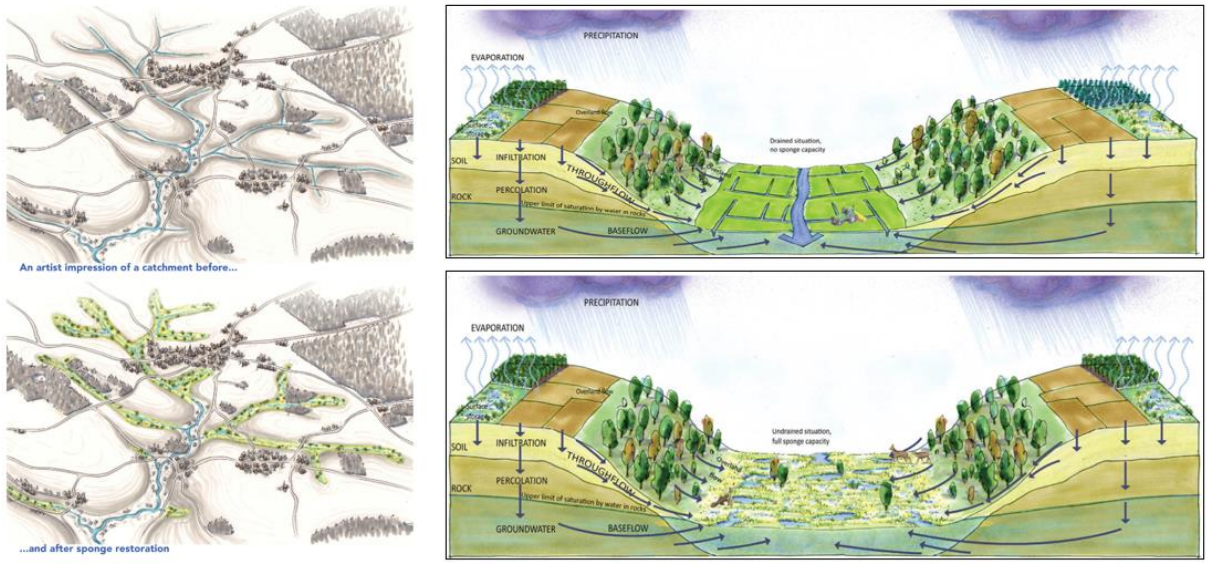


Figure 19: Illustrating the change from fast drainage in an upper catchment valley bottom (top) to a natural sponge (bottom) that retains and slows the flow of water downstream.

Figure 20: Example of a natural sponge valley in Arroyo del la Rosa. The natural vegetation delays the discharge of water, helping to reduce peak flows in floods and increase base flows in droughts.

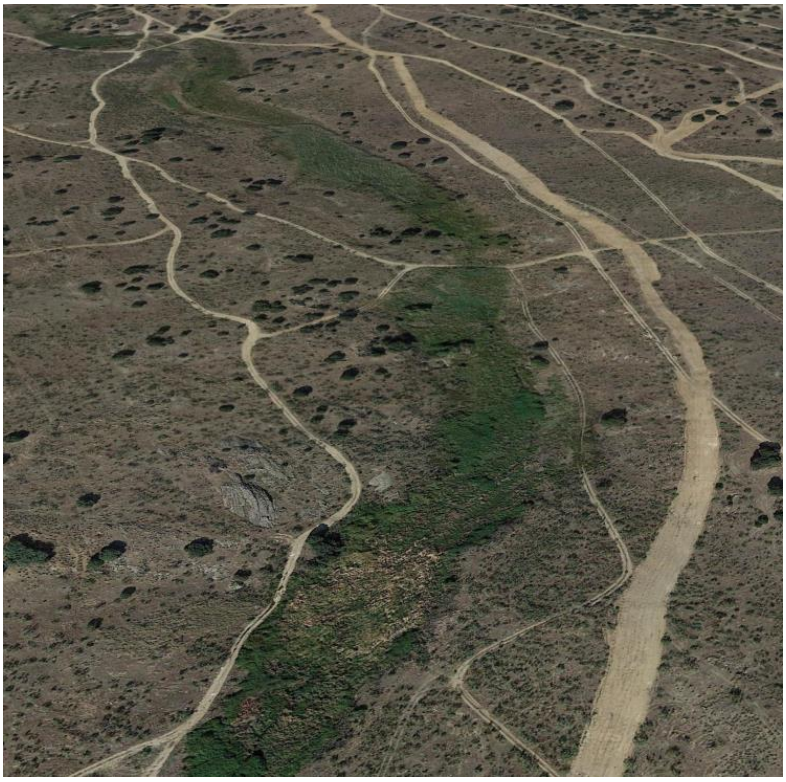


Figure 21: Natural sponge valley in Arroyo de la Degollada. The natural vegetation delays the discharge of water.

Figure 22: Natural sponge valley in Arroyo de Ramabujas. The natural vegetation slows the flow of water.

4. Initial recommendations for NBS measures

Within the landscape, there are many possibilities to increase nature-based flood resilience in the four analysed catchments. These include measures in urban and rural areas, spatial planning and land use changes and the restoration of natural sponge valleys.

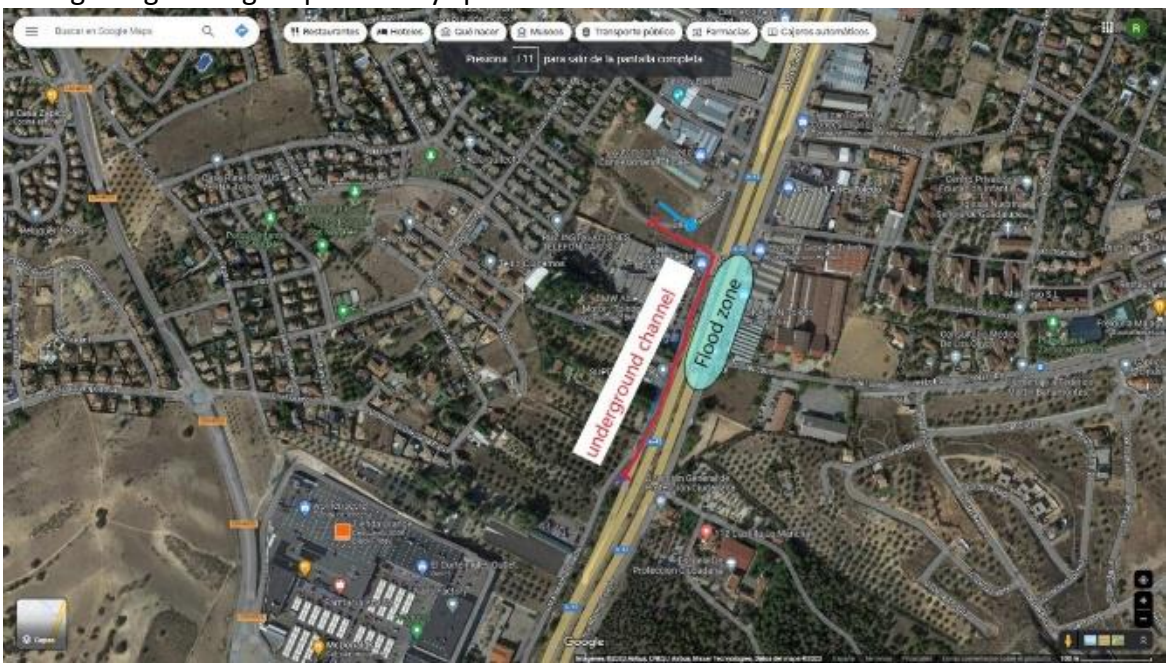
Disclaimer. The following are measures and locations that appear promising based on the initial GIS analysis and mapping. Further ground truthing and local knowledge are needed to validate the suitability of all of these areas for NBS.

1. Arroyo de Asseradero

Composite image of Arroyo de Asseradero

Enlarged left image – undeveloped area for potential sponge measures

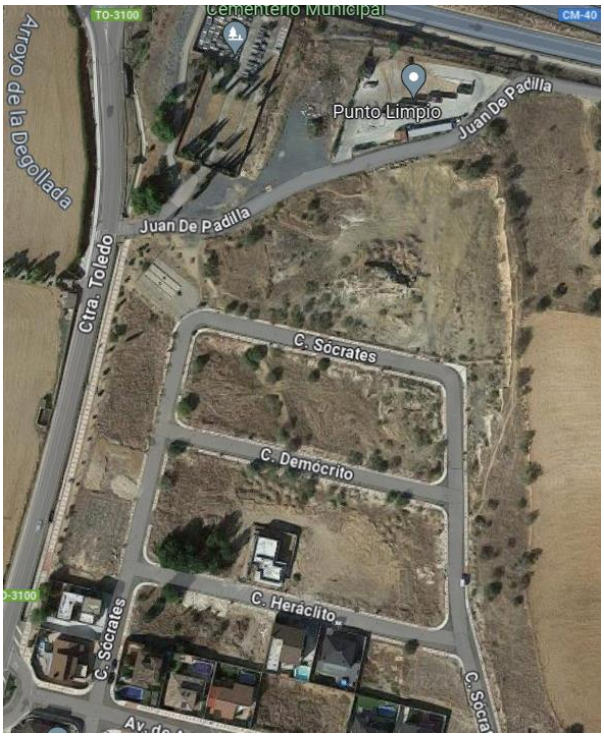
Enlarged right image – potentially space for measures at the location of the blue arrow



2. Arroyo de la Degollada

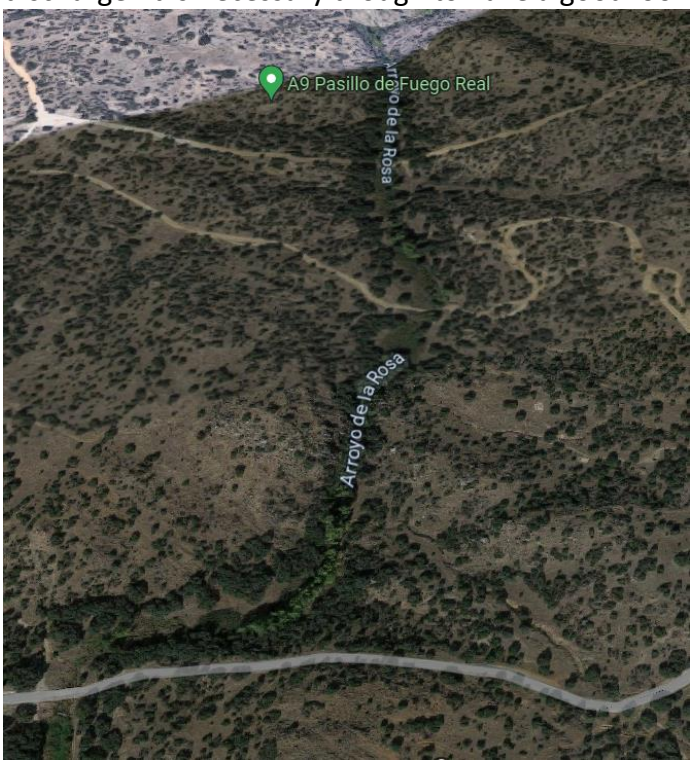
The village of Cobisa suffers great damage and costs as result of flooding. In the upstream area of Cobisa, it is advisable to look for opportunities for natural stream channels (wide natural valleys with rough vegetation) and a pilot for land use adjustments to prevent erosion. At the moment there is no natural water retention in the upstream area of Cobisa.

There may also be opportunities north of the city to implement water retention in the new residential area pictured below.



3. Arroyo de la Rosa

Look for water retention measures in natural, militarised zone upstream of Santa Barabara. It is difficult to get good images from these area, but there might be options to heighten the river bed so the water will flow on a wider floodplain with the ability to slow down discharge. It is necessary though to have a good look into the area with a field visit.



4. Arroyo de Ramabujas

Upstream area of the Santa Maria de Benquerencia neighbourhood, design a natural water retention area to protect the area. There are many chances to naturalise and heighten the streambeds and create natural floodplains. Also the protection of erosion is opportunity here.

In addition, the interactive website https://media.stroming.nl/toledo/# presents the history and present situation of development in the catchments and opportunities for a more flood resilient future.

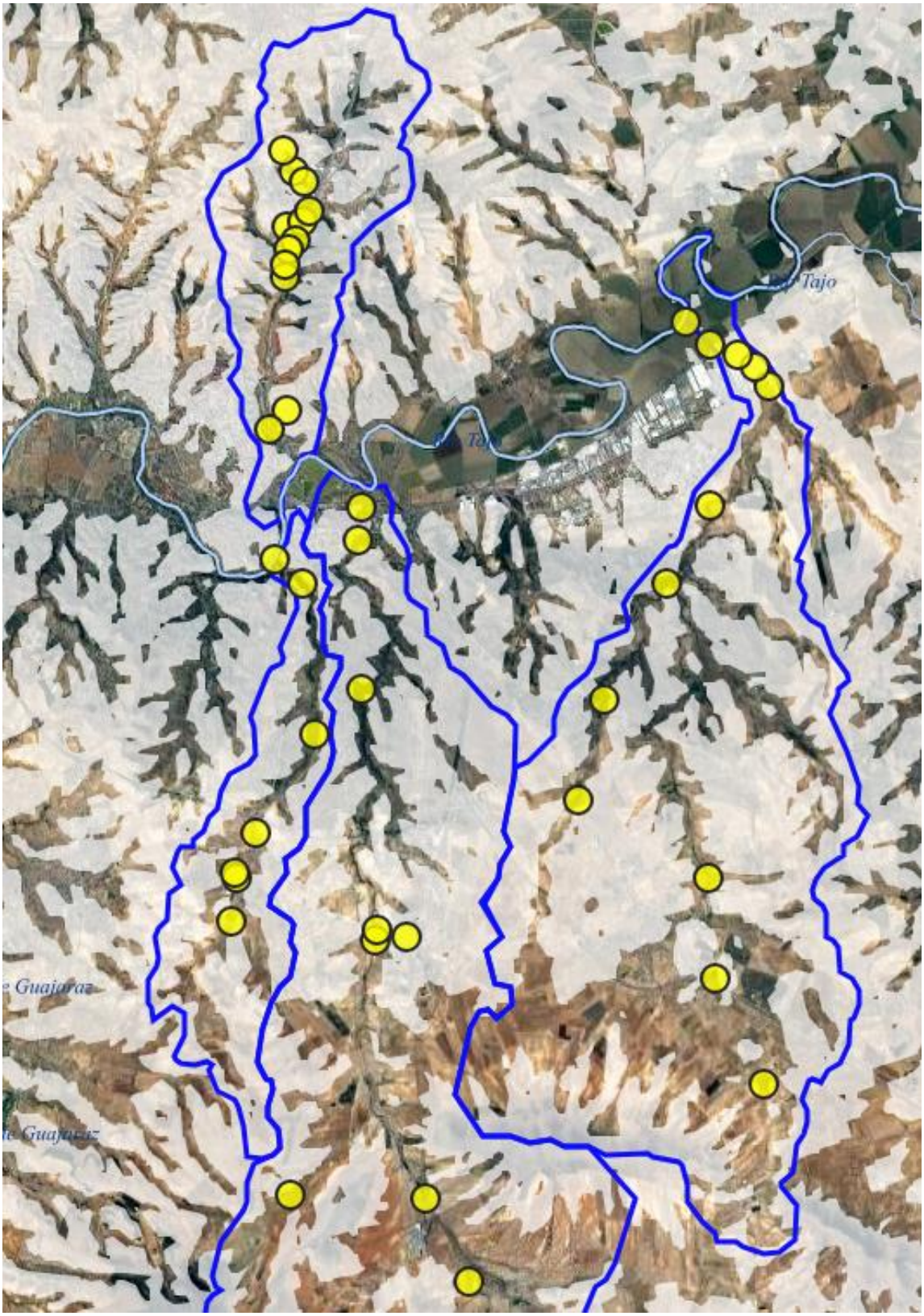


Figure 23: Interactive map of the valley floors in the catchment.