FLASH FLOODS IN WADI SYSTEMS AND THEIR IMPACT ON INFRASTRUCTURE

A CASE STUDY OF THE UPPER DRAA WADI SYSTEM IN MOROCCO

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ABSTRACT

Flash floods are the dominant form of flooding in semi-arid areas. They significantly impact the population and livelihoods of vulnerable settlements within Wadi systems. This study aims to evaluate the characteristics of flash floods, including sediment transport and channel changes, in a Wadi system in southeastern Morocco using the rainfall-sediment runoff (RSR) model and the depth-averaged 2-D model. The basin sediment transport analysis reveals that most erosion and sediment supply occur in the steep slope areas in the northwestern part of the catchment. The 2-D model computation results indicate that while the channel bed is eroded, sediments are deposited on the banks, highlighting the need to implement slope protection and sediment control measures tailored to this context.

Keywords: Wadi system, Flash floods, suspended sediment, channel change

INTRODUCTION

The study area is a Wadi system in southeastern Morocco. Figure 1 shows the study area, and Figure 2 shows the basin map. In the last 10 years, a recurrent number of traffic interruptions were reported due to flash floods as shown in Figure 3. The Infrastructure and Water department intervened by conducting repair and replacement works to damaged bridges and roads. However, the poor understanding of the process of the Wadi Flash floods does not allow effective solutions. Therefore, this study aims at building hydrological, and sediment transport models which can identify the key parameters in this process as well as the most vulnerable areas, to implement evidence-based policies.

The catchment of Upper Draa area is approximately 22,938km2, and is home to a population of 228,600. As a Wadi system, the land cover is extremely poor, and the soil is mostly sand, with a shallow depth, and occasional exposed bedrock as shown in Figure 4. Another important characteristic is the slope, as the upstream is a mountainous area where the elevation reaches 3,800m as shown in Figure 5.

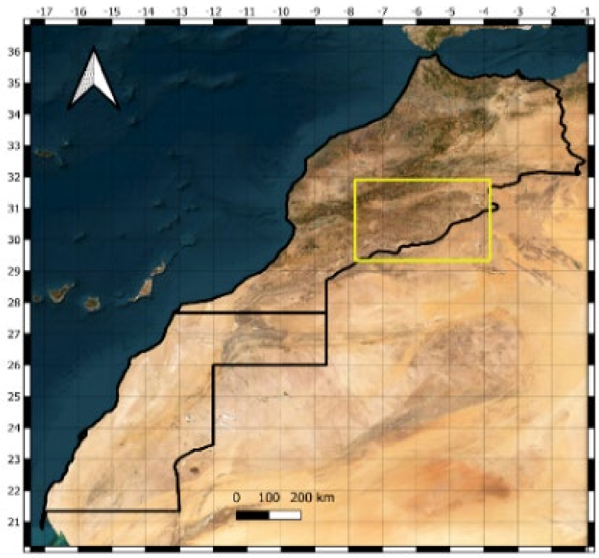

Figure 1: Location of study area

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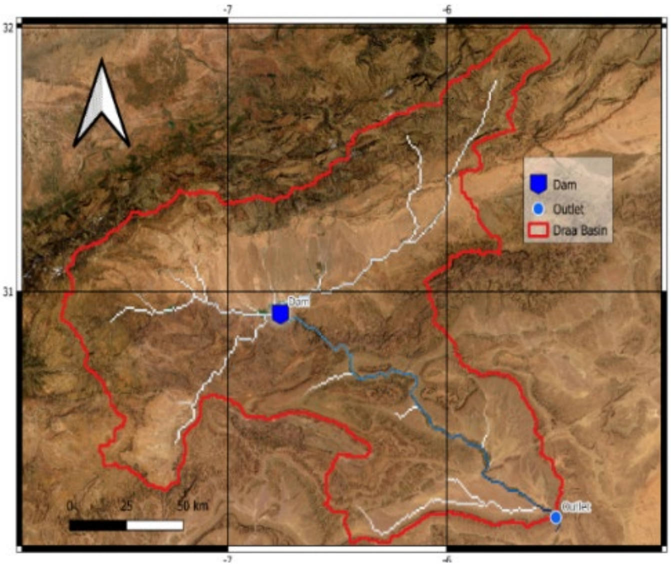

Figure 2: Satellite view of study area.

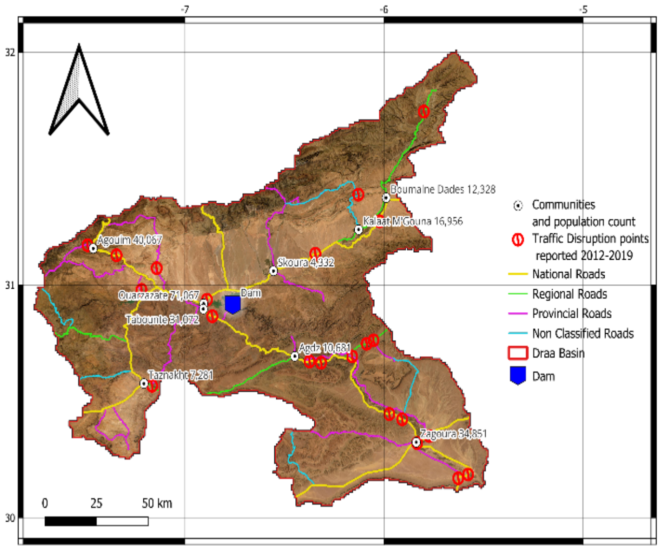

Figure 3: Traffic interruptions due to flash floods.

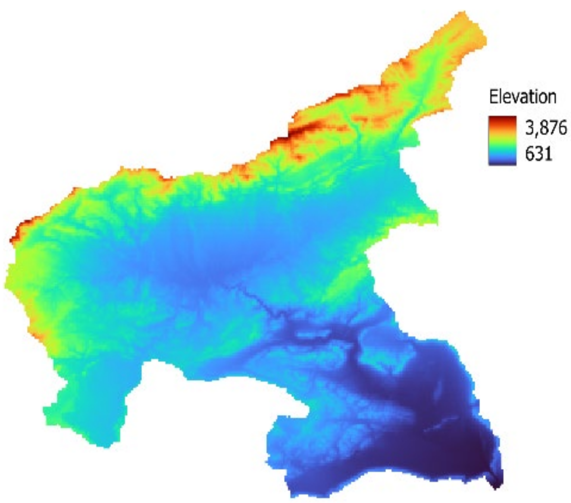

Figure 5: Elevation, Hydrosheds

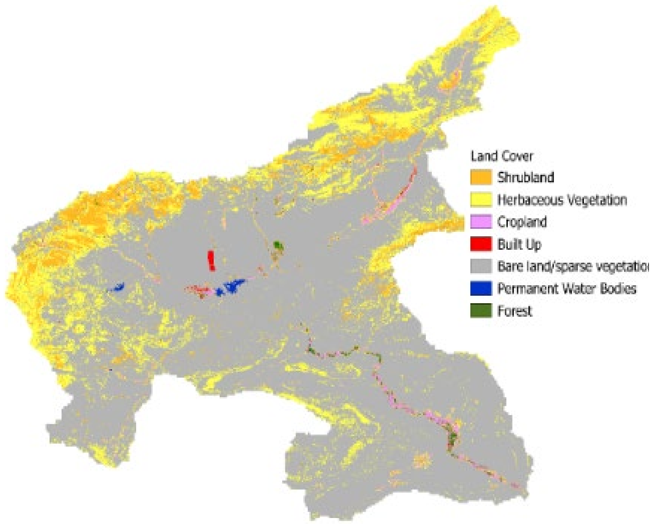

Figure 4: Landcover, from Copernicus

THEORY AND METHODOLOGY

Hydrological modeling was conducted using the Rainfall Runoff inundation (RRI) model. The aim of this study is to determine the parameters that reflect the physical characteristics of the basin. These parameters were then used to run a one-dimensional (1D) simulation for sediment transport on a catchment scale, which allowed the analysis of the characteristics of sediment transport in the Wadi system spatiotemporally. Subsequently, a two dimensional (2D) local sensitivity analysis was conducted to investigate how channel change is sensitive to the flow condition, and how it affects the inundation area. The workflow of this study is shown in Figure 6.

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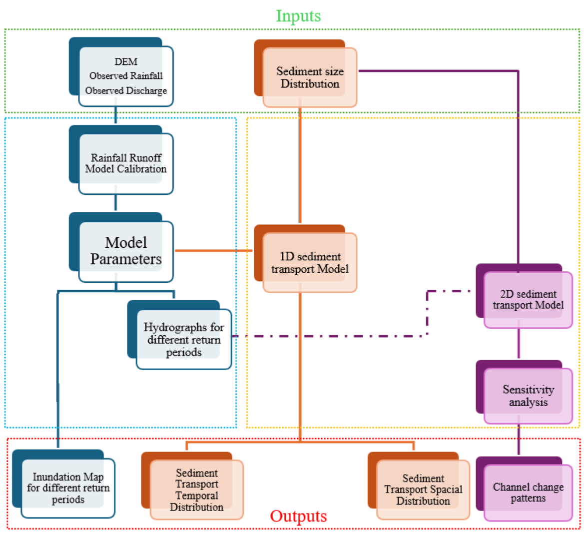

Figure 6: Workflow.

DATA

The analysis was conducted based on data from a significant event that occurred in November 2014, shown in Figure 7. The rainfall and the discharge were controlled daily at the dam. For the sediment model, the average annual sediment deposition is known. In addition, a record of traffic interruption points between 2012-2019 was used to confirm inundation locations.

Figure 7: Flash flood of November 2014

RESULTS AND DISCUSSION

Because of the unavailability of hourly rainfall, which could have enabled a much more accurate model for flash floods with rapid a rise time, daily rainfall was used, to obtain an hourly output, which was injected into the daily observed discharge. Figure 8 shows the results of the comparison.

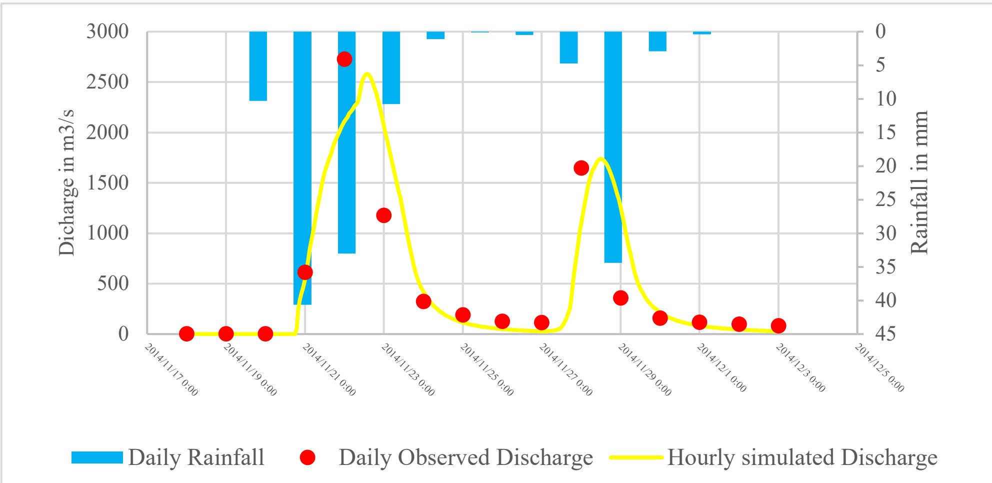

Figure 8: Model calibration

Two areas were considered for the parameters: the hillslopes and the Wadi channel. The hillslopes primarily consist of bare land. Infiltration was considered for both of them but with different sets of parameters. The parameters are shown in the following table.

Model Parameters		Hillslopes	Wadi channel
Channel roughness		-	0.03
Slopes roughness		0.2	-
Soil depth		0.35	0.5
Porosity		0.3	0.475
Green-Ampt infiltration Parameters	Hydraulic conductivity	10^{-7}	$6.54\ 10^{-5}$
	Wetting Front Suction Head	0.12	0.0495

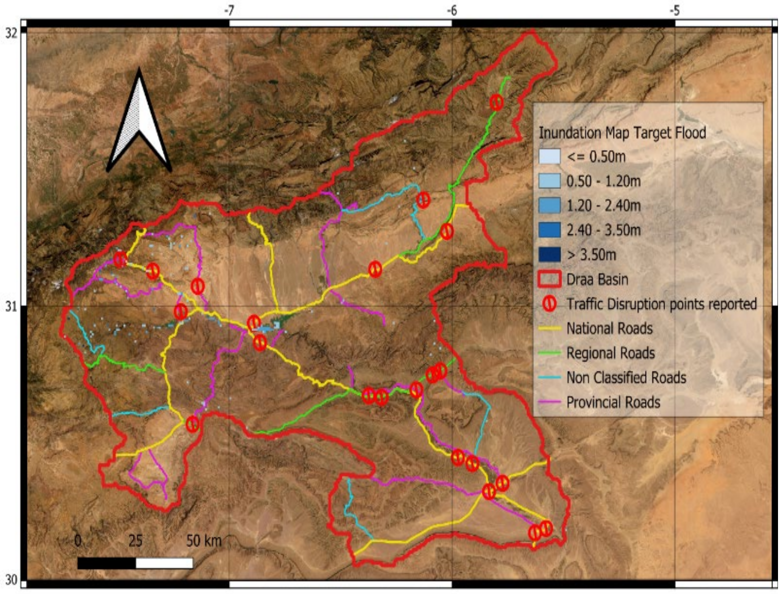

Figure 9: Inundation Map overlayed with history of traffic interruptions.

The comparison between the resulting inundation map and the record of traffic interruption points in figure 9 shows that the two areas vulnerable to inundation are upstream with steep slopes and the area immediately upstream of the dam.

These parameters were used to construct a rainfall sediment runoff model. Locations upstream and downstream showns in Figure 10 were selected to investigate the characteristics of the transported sediment. In figure 11, the sediment transport rate closely follows that of the hydrographs. Suspended sediment dominates the bedload, more significantly upstream than in the downstream, where the dam is an obstacle to sediment transportation.

Figure 11: Location for sediment Model.

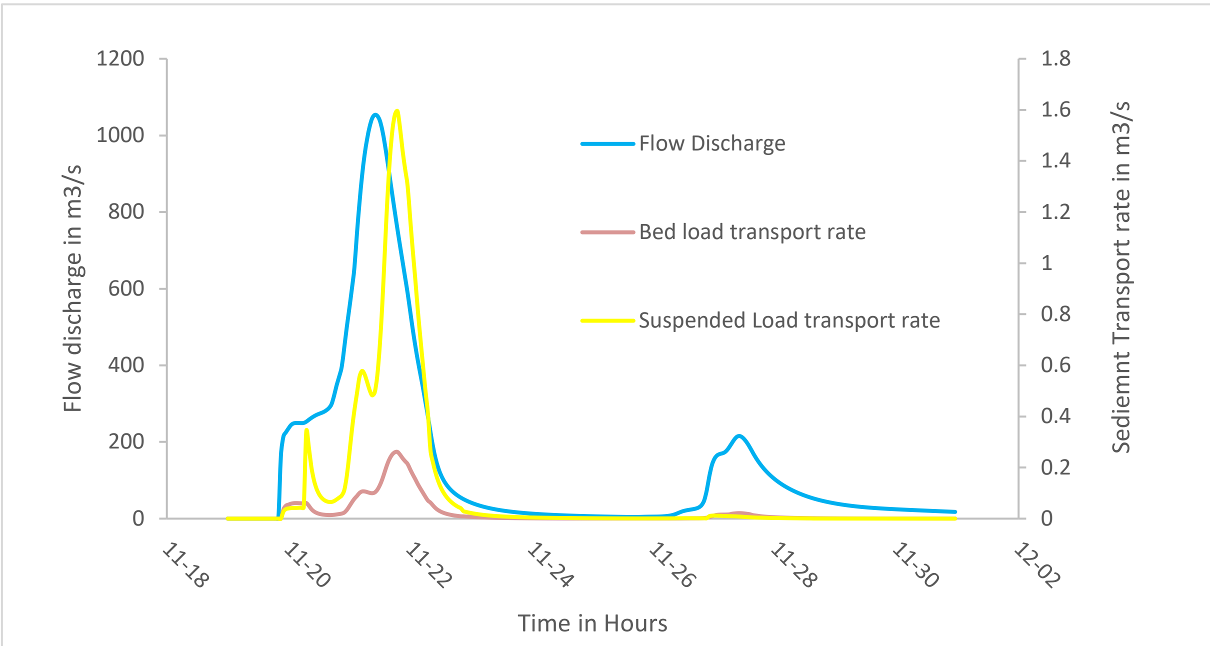

Figure 10: Sediment transport rate and hydrograph in the upstream

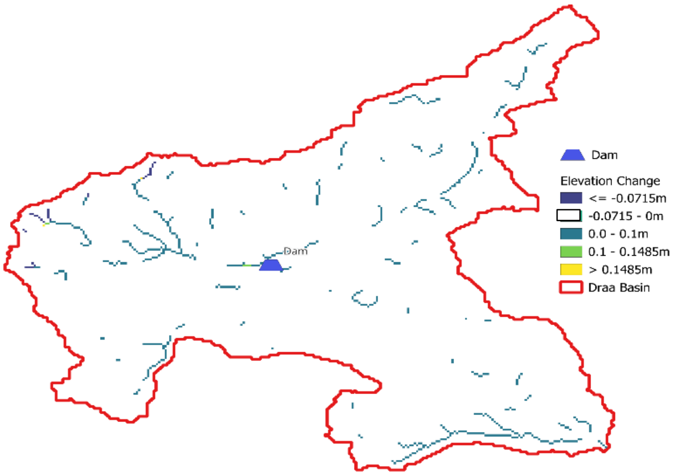

Figure 12: Elevation change in the study area.

Sediment supply from the slopes dominates the sediment supply as shown in Figure 12, wherias erosion and deposition in the upstream Wadi tributaries show that the sediment is not transported over a long distance, which is the same area affected by inundation. Therefore the role of sediment transport is to be investigated in a 2D local model upstream of the dam.
The target flood event contributed to 62% of the annual average sediment deposition in the dam.

Upstream of the dam was affected by inundation and sediment transport, therefore it was chosen as a location for a 2D model in order to investigate inundation and channel change. The simulation showed the area most affected by the inundation during the target flood. Figue 13 shows that under the 100-year return period the water level increases but not the extent of the inundation.

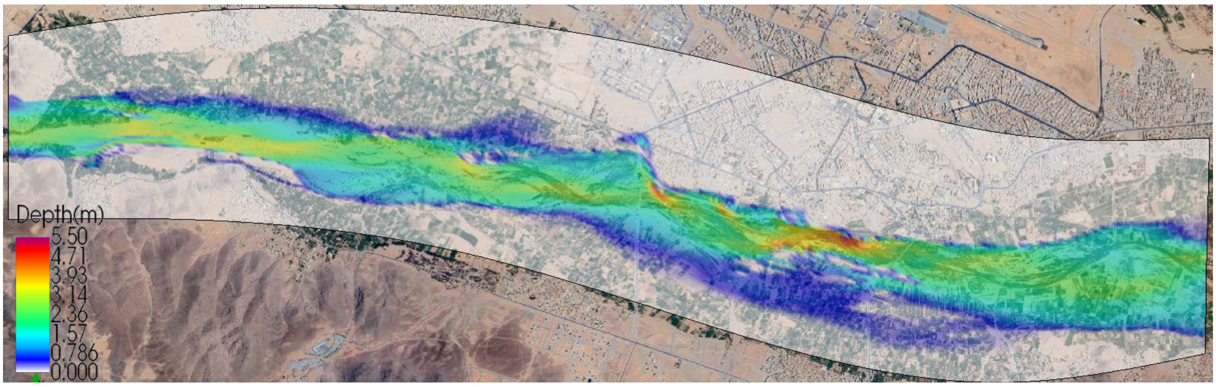

Figure 13: Inundation of the 100-year return period flood.

For the channel change, the Wadi bed is eroded while the sediment is deposited on the banks for both target flood and 100-year return flood as shown in figures 14 and 15. Due to the short timespan of flash floods, the sediment is not transported over a long distance.

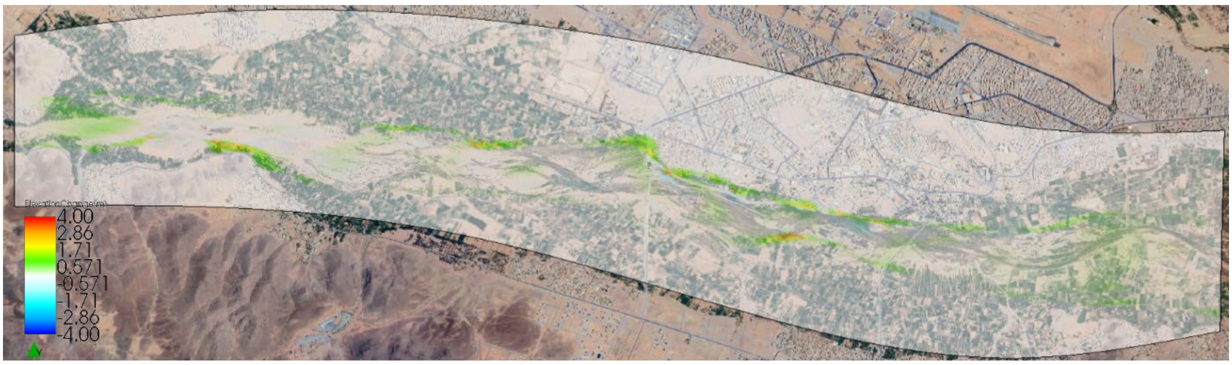

Figure 14: channel change during the target flood.

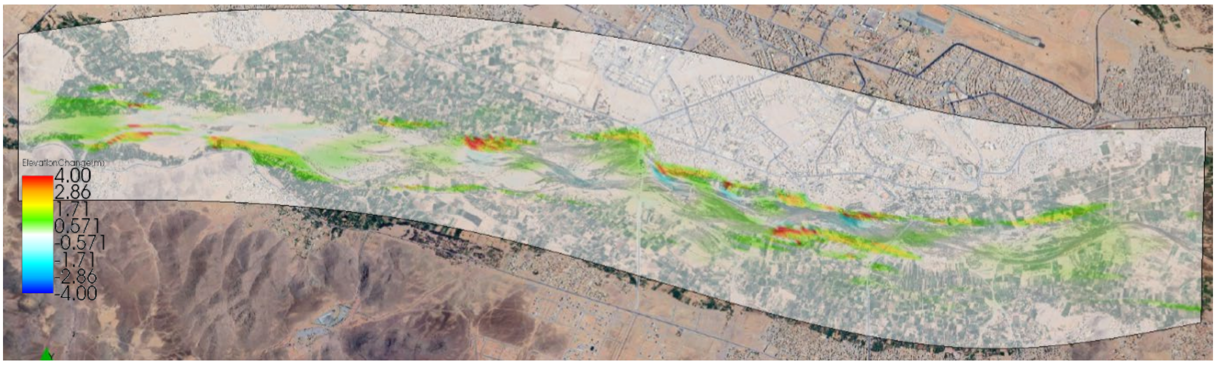

Figure 15: Channel change during the 100-year return period flood.

RECOMMENDATIONS

The upstream area, which has a steep slope, is where inundation, erosion, and deposition were concentrated. Flash floods are sensitive to the slope. The reduction of this impact can be adressed by implementing measures for slope protection and sediment control in this area. Although the discharge was low the effects of slope and topography increased the inundation risk and channel change impact. However, any sediment control measure must be adapted because the sediment transport is dominated by suspended sediments rather than bed load. For the dam, an increase in its flood control capacity provides greater safety downstream in the case of extreme events. Measues for to monitore and control channel change must be implemented near urban areas to reduce the impact of scouring on bridges and the decrease of the cross section leading to inundation.

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