

Evaluating the Impact of Flood Hazard Caused by Tropical Cyclones on Land Use Using Remote Sensing and GIS in Wadi Uday: Sultanate of Oman

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Abstract-Two severe tropical cyclones hit the Sultanate of Oman; Gonu in June 2007 and Phet in June 2010. Wadi Uday passes through the main urban areas of Muscat, the capital city, which was among the most affected areas. This paper aims to evaluate the impact of flood hazards on land use, in Wadi Uday lower basin, using Remote Sensing (RS) and Geographical Information Systems (GIS) techniques. The Wadi basin was captured using 40 meter Digital Elevation Model (DEM), while total damage were examined using Ikonos images which acquired in 12/6/2007, coupled with land use dataset for 2003, and rainfall record of the past 20 years. The analysis showed that the highly affected land use categories were the recreation and residential areas with a ratio of 31% each. Roads, agriculture and public buildings were moderately affected. Further research will compare these results to that of Phet (June 2010) on the same area.

Keywords: floods, hazards, GIS, Geomorphology, land use

1-OBJECTIVES

The main objectives of the study are:

- 1- To evaluate, Wadi Uday floods and their effect on land use.
- 2- To determine the flood hazard size on the vulnerable areas, especially at the wadi lower part.
- 3- To prepare the risk map for the lower part area.

2-STUDY AREA

Wadi Uday extends at the northeastern part of Sultanate of Oman, in Muscat Governorate, the capital of Oman. The Wadi basin is bounded by latitudes 23° 20' 00" to 23° 40' 00" N., and longitudes 58° 20' 00" to 58° 35' 00" E. The Wadi upstream extends over the easternmost portion of Al Hajar AshSharqi Mountains and flows to the Sea of Oman. Figure (1).

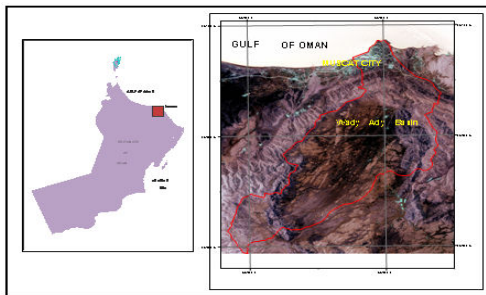


Fig.1 Location of Wadi Uday

3-METHODOLOGY

The paper was accomplished using GIS & RS techniques. To create risk, identify damages areas, assess the impact and flood risk management for Wadi Uday. In order to achieve the study objectives, the following data sources have been used:

1. DEM with high resolution (40 m).
2. IKONOS images with 1 m spatial resolution acquired after few days after GONU and Phet.
3. Land use data for 2003
4. Rainfall data.

The basin of Wadi Uday with its streams has been derived from 40m DEM by using ArcHydro tool in ARCGIS. The flood areas after cyclone Gonu have been derived from IKONOS images by ER-Mapper software using spectral signature. The land use and the rainfall data, in addition to the above created layers (Wadi Uday basin and the flood areas after cyclone Gonu) have been used statistically in ARC GIS to identify the total damages areas and to classify these damages (Brayant, 2005; Cooke et al. 1985).

4-HYDROGRAPHIC SETTINGS

According to the rainfall data from the Ministry of Regional Municipalities and Water Resources (MRMWR, 2005) the mean annual rainfall in Wadi Uday is about 67 mm. Table 1 and figure 2, summarize, the rainfall regime of wadi Uday during the period 1987-2007. It's worth to note that this rainfall regime does not include the precipitation associated with Gonu cyclone estimated around 610mm (Hermann et al., 2010). The available records showed that there are prolonged periods of drought, which may persist several years, and at the same time there are years in which rainfall exceeds the mean annual many times. Furthermore, rainfall in the area is random and unpredictable, most of which falls in winter months and associated with thunderstorms. Sometimes during summer (June to August), orographic lifting causes local rain which covers limited areas. Furthermore, the country is subject to the influence of tropical cyclones that develops, from time to time, in the Arabian Sea causing heavy rain and flood (Saleh and Al-Hatrushi, 2009).

Table 1 Wadi Uday rainfall analysis characteristics

No of falling	83
Mean (mm)	17.5
Std. Deviation	34.40
Variance	1183.63
Range (mm)	145
Minimum (mm)	0.20
Maximum (mm)	145.20
Sum (mm)	1456

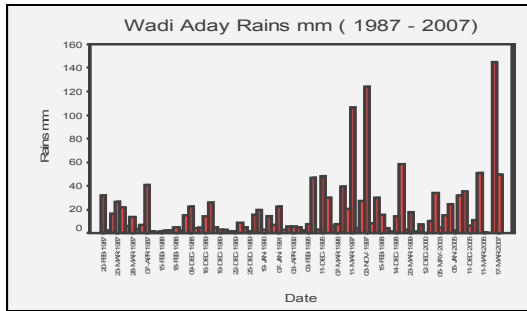


Fig.2 Wadi Uday Rains mm. (1987 – 2007)

Flood record at the main stream of Wadi Uday for the same period showed that 54 floods were happened in the Wadi main stream as shown in (Fig.3) in 20 years, with frequency of about 2.7 floods per year, while flood frequency of a large volume is one per year. Flood usually ends up in the sea or dispersed on the streets between buildings and other land use areas causing damages and destruction to properties.

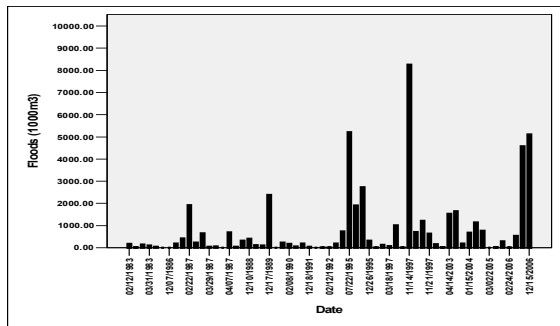


Fig.3 Wadi Uday floods (1987 – 2007)

Correlation between rainfall and floods (Fig.4) showed that rains more than 20 mm may cause extreme floods in the Wadi which may persist for some hours to one day, depending on the drainage basin and network characteristics.

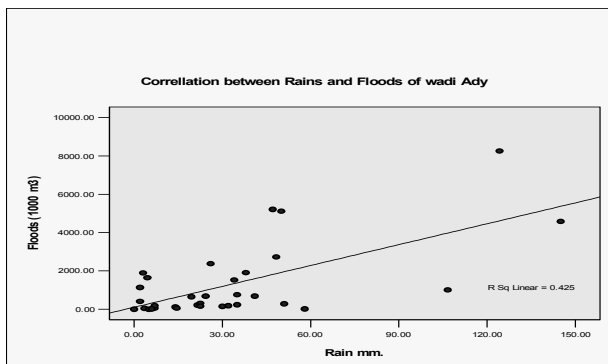


Fig.4 the correlation between rainfall and floods of Wadi Uday Area

5-LAND USE STATEMENT AND RISK ASSESSMENT

The urban extension covers most of the lower part of the Wadi including the urban area of El Qurm, where the Wadi course cuts a number of residential, commercial, recreational, transportation (roads) public buildings, industrial and agricultural. Land use and risk assessment maps at the lower

part of the wadi, shown in Fig. 5 and 6, have been developed taken into account the following criteria:

- 1- Land use
- 2- The floods magnitude
- 3- The floods frequency
- 4- Floods duration

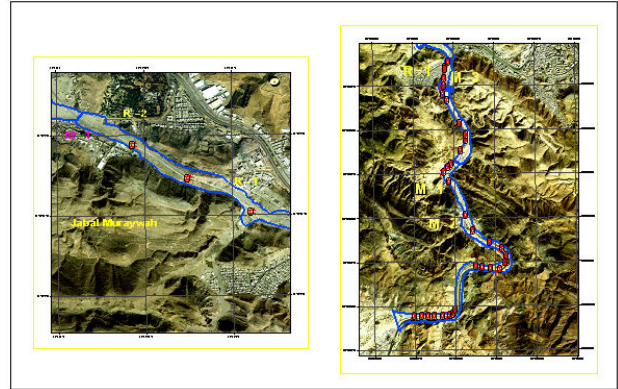


Fig.5 Land use situation and risk assessment at the lower part of Wadi Ady

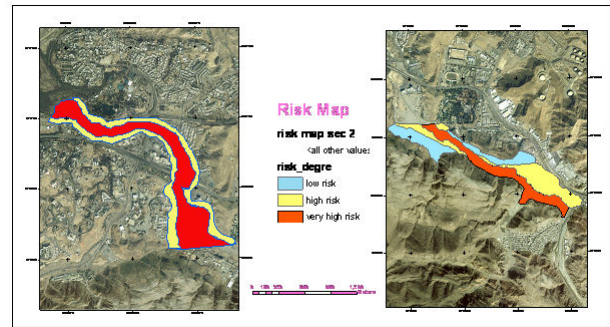


Fig.6 Risk Map of Wadi lower part sections

6-RESULTS

From the analysis of hydrographic data, hydrological characteristics of the wadi basin, land use data and Ikonos satellite images acquired immediately after the tropical cyclone Gonu, the assessment of the affected area by the flood in Wadi Uday areas based on the damage caused by Cyclone Gonu is shown in figure 7 and table 2, and can be extracted as follows:

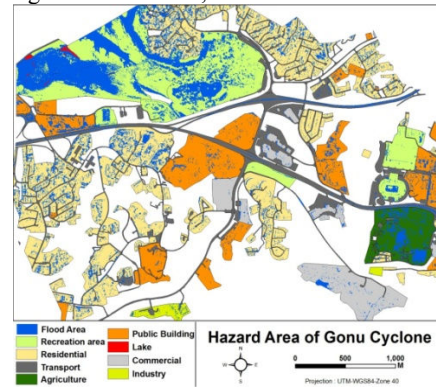


Fig.7 Part of the affected area by the flood in Wadi Uday - 12/6/2006

Table 2 the area and the present of the affected area by the flood in Wadi Uday - 12/6/2006

Description	Floods Area (m2)	Floods Area (%)
Recreation Area	647799.14	31.91
Residential	630824.84	31.08
Transportation	208915.00	10.29
Agriculture	206611.71	10.18
Public Building	144810.19	7.13
Lake	80098.34	3.95
Commercial	79391.59	3.91
Industry	31444.70	1.55
total	2029895.51	100

- Most of the damage happened in both recreation and residential land use, where about one third of its total area (31.91% and 31.08% respectively). This explains why the total damage from cyclone Gonu was more than US \$ 4 billion (Ministry of National Economy).
- In the second rank, transportation and agriculture land uses with 10.29% and 10.18% respectively. It is important to emphasize that, while the affected area of transportation use was relatively small but it had a great impact on the life of population who live in the city in terms of transport moving flow because of the damaged roads.

With regards to the tropical cyclone Phet, which hit the Sultanate with its peak intensity in June 4th 2010, was the third named cyclone of the 2010 North Indian Ocean cyclone season. As figure 8 shows, heavy rains drenched Oman's eastern coastal region as strong winds uprooted trees and signboards and number of people were killed. Heavy rainfall exceeded 600mm occurred on the Arabian Sea, and approximately 450mm on the eastern.

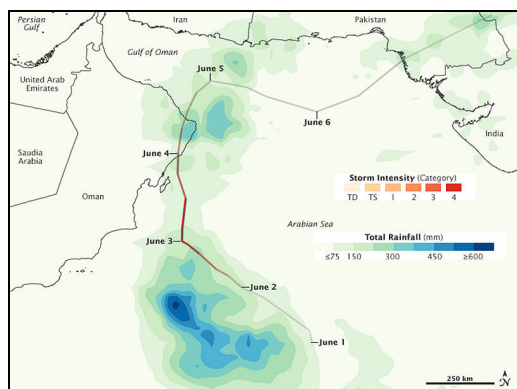


Figure (8) TRMM satellite rainfall estimate map (The colored line indicates storm track and intensity according to the Saffir-Simpson hurricane scale)

Damage from Phet in Oman was estimated to have exceeded \$780 million most of which is in the eastern coastal region. IKONOS satellite images of Wadi Uday area acquired few days after Phet were utilized to investigate flood impact on the same area. The preliminary results of image analysis showed no severe damage compared to that caused by Gonu. For example, figure 8, shows the main road connecting Muscat and Quryat was completely destroyed after Gonu, however, the temporary road

constructed after Gonu was intact and not much effected after Phet. The same was observed in Al-Quram urban area, where complete destruction of roads and silt covering most of urban features after Gonu, while after Phet slight destruction and silting occurred on the urban features as shown in figure 9.



Figure 8. Main road connecting Muscat and Qurayat (a) after Gonu and (b) after Phet



Figure 9. Al-Quram urban area (a) after Gonu and (b) after Phet

The less damage caused by the tropical cyclone Phet, in the study area, compared to that caused by Gonu is due to the fact that Phet affected severely the eastern coastal region and Muscat was affected slightly. The reconstruction of the infrastructure after Gonu according to new indices of civil engineering, which is still going on, helped in preventing further damages.

CONCLUSION AND RECOMMENDATIONS

Wadi Uday floods, either flash flood or flood caused by tropical cyclones, threaten the urban area, human activities, and infrastructure networks at an important part of Muscat. The hazards risk on land use are going to increase, especially, with fast growing of population, expanding of human activities and tropical cyclones intensity. To mitigate the problem, the following action processes are needed:

- Long term hydro- meteorological record
- Floods measurement record, which is very limited
- Modeling inland flooding due to tropical cyclones
- Infrastructure capable to stand against all types of floods

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