Impacts of Super Typhoon Nepartak (2016) on Southeastern Taiwan as Observed by Satellite(s)

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Abstract: This study focuses on the analysis of flood caused by typhoon Nepartak passing through Southern Taiwan (8-10 July 2016) by using satellite data with support of *in-situ* photos. Typhoon Nepartak had devastating impacts on residential and farmland areas. The objectives of the study include *(i)* determination of flood extent using satellite images; *(ii)* monitoring of changes in inundation areas; and *(iii)* estimation of flood depth using Sentinel 1 data. The satellite images were acquired by Landsat on 27 June (before typhoon) and 29 July 2016 (after typhoon), and Spot 6 data on 25 July 2016. Flood extent extracted from Landsat 8 images is slightly reduced in comparison with that derived from Spot 6 image, possibly due to two reasons: *(i)* resolution of Landsat data is lower than that of Spot 6 data and *(ii)* Landsat data was taken 4 days later than Spot 6 with hot and dry weather. In contrast, flood extent extracted from satellite data is much underestimated as compared with potential flood map released from the authority, suggesting that a further investigation on the difference between the two approaches is needed.

1. INTRODUCTION

Rising moisture in the air and abnormally distributed heavy rainfall are classic signals of climate change, which is assumed to result in an increase in the occurrence frequency of natural disasters all over the world. A pronounced increase in intense typhoons with heavier rainfall and stronger wind leading to an increase in flooding risk has been observed. This issue is significant in Taiwan since its seasonal typhoons and geographic features make many areas prone to inundation, likely affecting various fields and causing huge economic loss. The effectiveness of the instant disaster response efforts is contingent on accurate and timely information regarding the spatial location and impacts of the ongoing typhoon events. Decision of emergency aids and distribution of supplies should be based on insights where the impacts are and what nature of the impacts is.

Remote sensing and GIS have significantly contributed to environmental disaster management and mitigation by providing necessary information for rapid responses [1, 2]. Mapping flood extent aims to determine the magnitude of inundation for rapid response and supplies. Optical and radar satellite imagery with high spatial-temporal resolution that offer large coverage have been widely used to delineate inundation areas and flood depth [2]. This study intends to extend further applications of satellite images to manage and lessen damage of flood.

2. MATERIALS and METHOD

2.1 Typhoon Nepartak

Typhoon Nepartak made its first landfall as a super typhoon near Taitung City in Southeastern Taiwan as a Category 4 equivalent tropical cyclone shortly after 6:30 a.m. on 8 July 2016, Taiwan local time. Precipitation data shows that one week before typhoon: the amount of precipitation was insignificant (highest amount was about 12.8 mm/day on 28 June 2016); During the typhoon: the amount of precipitation was significant with highest amount approximately 241 mm/day on 8 July 2016; After typhoon: there was almost no rainfall with highest amount only 1.5 mm/day on 26 July 2016. Water measurement data indicates that water levels at Hsinwuhu and Dalun stations climbed by about 1.7 meters higher during typhoon event (from 316.1 to 317.8 meters at Hsinwuhu station; and from 370.3 to 371.6 meters at Dalun station). Then water levels declined slightly by about 0.4 meter at Hsinwulu station after typhoon and fluctuated slightly around 317 meters later on.

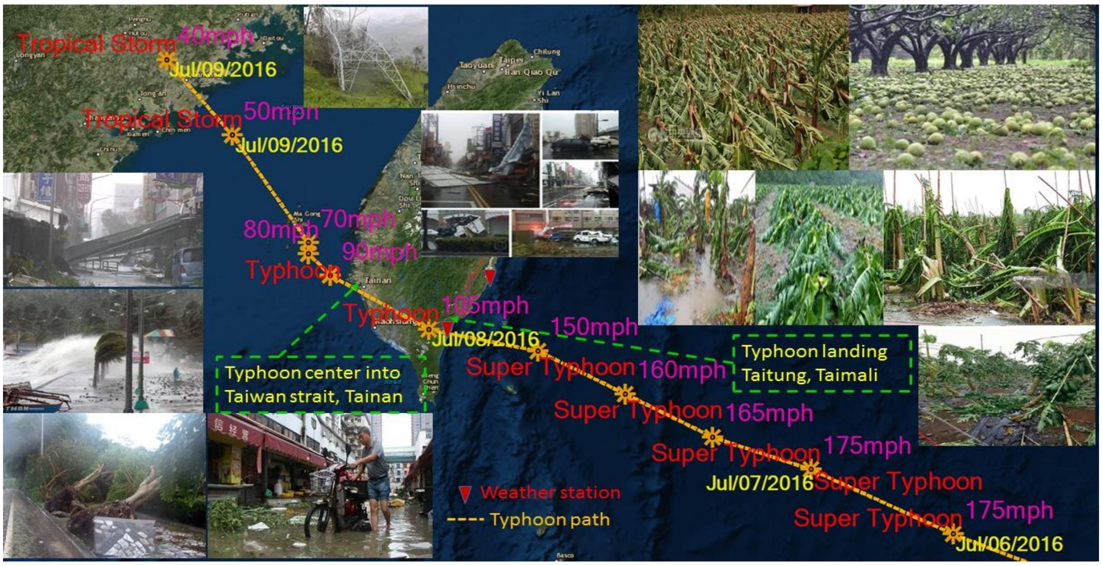

Fig. 1 Typhoon Nepartak and its impacts.

The casualty, damage, and impacts due to typhoon Nepartak are briefly described. The numbers of casualty, injured, evacuated, and accommodated were 3,142, 16,318, and 3,749, respectively. Infrastructure was damaged severely with 208 households destroyed by flood, 512.656 households out of electricity, and 24.280 households without water supply. Transportation system was significantly damaged, four highways were interrupted (data issued by the Central Weather Bureau (CWB) and the Central Emergency Operation Center). It is estimated that typhoon caused US$21.1 million of damage in Taiwan (**Fig. 1**).

2.2 Materials

Table 1 shows the list of data used in the current study. The data includes images acquired from the satellites and measurements taken by *in situ* sensors.

Table 1. Data used

Data	Date	Spatial resolution	Coordinate Projection	Source
Landsat 8 OLI	27 June 2016 29 July 2016	30 meters	WGS 84/UTM Zone 51N	USGS
SPOT 6	25 July 2016	6 meters	WGS 84/UTM Zone 51N	CSRSR
Sentinel 1	14 June 2016 19 July 2016	10 meters	Natural radar range observation coordinate	ESA
Precipitation data	daily			CWB
Water levels	daily			CWB

2.3 Method

This study focused on investigation of spatial characteristics of flood associated with typhoon Nepartak. It was implemented by three major steps: *(i)* delineation of flood extent using Landsat and Spot data; *(ii)* investigation of the spatial characteristic of flood in terms of land use; and *(iii)* estimation of flood depth using Sentinel 1 data. To delineate boundary of flood, Modified Nomarlized Difference Water Index (MNDWI) was calcuated by using the MIR band that can considerably enhance the open water features and efficiently reduce and even remove build-up land noise due to asphalt materials. Supervised classification method was applied to delineate landcover map into five categories (*vegetation, agricultural land, bareland, residential land,* and *static water*). Classification accuracy is 83.2% and Kappa is 0.754.

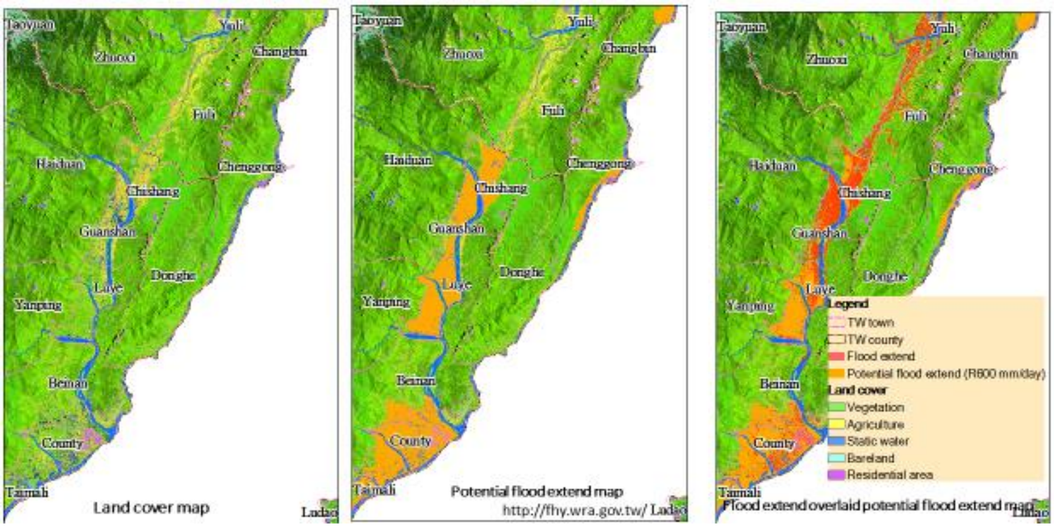

Fig. 2 Flood extent extracted from Landsat data and potential flood extent map.

3. RESULTS

The flood extent extracted from Landsat data is about 119,921,679 m^2 and the area of flood from potential flood map with rainfall 350 mm/day is about 216,204,063 m^2 (potential flood map source is http://fhy.wra.gov.tw/). Consistent rate between flood extent extracted from satellite image and potential flood is 0.55 with deviation between them around 96,297,092 m^2 (**Fig. 2**), indicating a further investigation on the deviation is required. Results show that flood generally occurred over the regions with elevation under 210 m, mainly in residential land and farmland with areas about 10,436,400 m^2 and 99,563,400 m^2, respectively. In terms of land use, the regions of plains are vulnerable to flood, such as Taitung, Taimali, Chenggong, Yuli, Changbin, Chishang, Guanshan, and Luye. **Fig. 3** shows that flood extent extracted from Landsat image acquired on 29 July 2016 is overlaid on Spot 6 image captured on 25 July 2016**.** Result indicates that the flood status on Spot image represented a slight expansion as compared with flood extent extracted from Landsat image. This may be due to the fact that SPOT image was taken 4 days after so that the flood extent was decreased under hot and dry weather conditions.

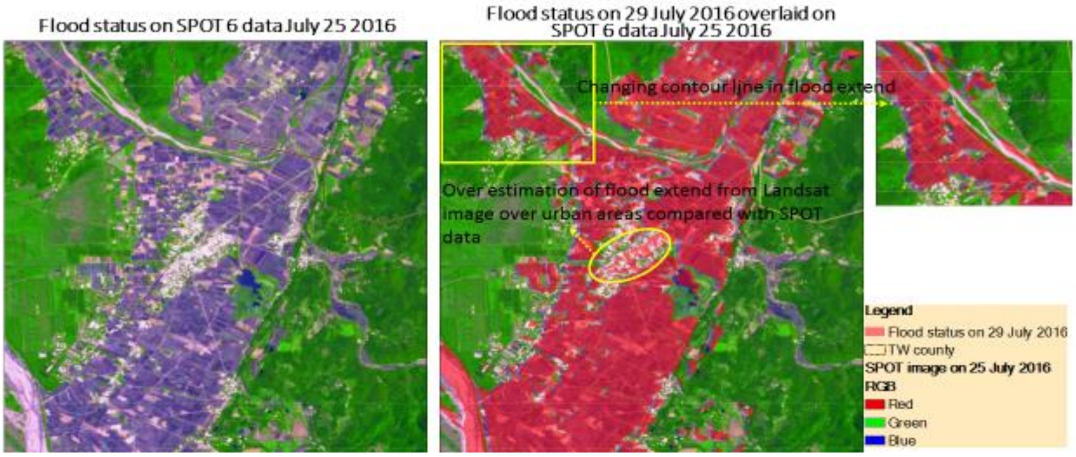

Fig. 3 Flood status on SPOT 6 image and its comparison with flood status on Landsat data.

4. DISCUSSION and CONCLUSION

Flood that is one of the most devastating natural disasters may cause severe casualty and economic loss. It depends on a number of factors, such as climate, topography, precipitation, land use,… etc. To monitor flood, two parameters are always concerned: *(i)* areas of flood; and *(ii)* flood depth. In this study, the flood extent is observed by Landsat, Spot and Sentinel data and compared with potential flood map. Water levels at the 9 stations at Peinan river (Hsinwulu , Dalun, Chishang Bridge, Dianguang Bridge, Luanshan Bridge, Ruiyuan, Yanping, Luming Bridge, Taidong Bridge) before, during and after typhoon is analyzed. Precipitation data at Taitung city is analyzed. This type of flood hazard map in digital form can be used as a database to be shared among the various government and nongovernment agencies responsible for the construction and development of flood defense.

There is a need to conduct the flowing future work: *(i)* Estimate of flood depth using Sentinel data; *(ii)* Linking information with vulnerabilities to humanitarian organizations such as Vulnerability Capacity Assessments (VCAs); and *(iii)* Collection of farming activities to get exact information of agriculture damaged due to flood extent.

5. ACKNOWLEDGMENTS

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6. REFERENCES

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