RESEARCH

Exploring the Potential of a Landsat-8 Satellite Image in Mapping the 2013 Flood Extent over Calgary, Alberta

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The authors have conducted this study under the leadership of Dr. Hassan at the Earth Observation Laboratory in the Schulich School of Engineering of the University of Calgary.

Introduction

In 2013, Alberta experienced an unprecedented flooding event. This flooding was primarily observed in southern Alberta (known as the Bow River basin). Calgary was the largest city within the affected region with a population of approximately 1.1 million. This particular event not only forced approximately 100,000 residents to evacuate but also resulted in billions of dollars in damages. Here, our aim was to use available remotely sensed Landsat-8 satellite image/data in order to generate a flood extent map. Schnebele et al. (2014) emphasised that because of extensive cloud cover and revisit limitations, remote sensing data of the Calgary flooding in June 2013 was extremely limited. However, the nearest usable pre-flood image was on Sept 20, 2011. This was almost 2 years before the June 2013 flood, which was definitely not ideal, as this might detect land use change rather than change in terrain wetness. Therefore, this study was limited to the use of one post-flood Landsat-8 image, which was acquired 16 days after the peak flood time on June 21, 2013.

Methods

Here, we considered our study area as a 1 km buffer (Fig. 1) along the Bow and Elbow Rivers around the City of Calgary. From our experiences and available information, we learned that the flood extent did not go beyond the 1 km buffer. In order to delineate the flood extent, we obtained a single post-flood Landsat-8 data/image acquired on July 7, 2013.

Using the 1 km buffer zone as shown in Fig. 1, we subset the Landsat image. Subsequently, we implemented a widely used unsupervised classifier to generate 50 spectral classes. Upon the classification, we divided the study area into two halves, using the left half for calibration and the right half for validation purposes. Our calibration phase consisted of two steps: (i) distinguishing of "wet" classes from the unsupervised classification image, and (ii) enhancing the classification accuracy through the application of majority filters with several window sizes. The resultant image was then compared against the City of Calgary flood extent map by means of $\widehat{K}$.

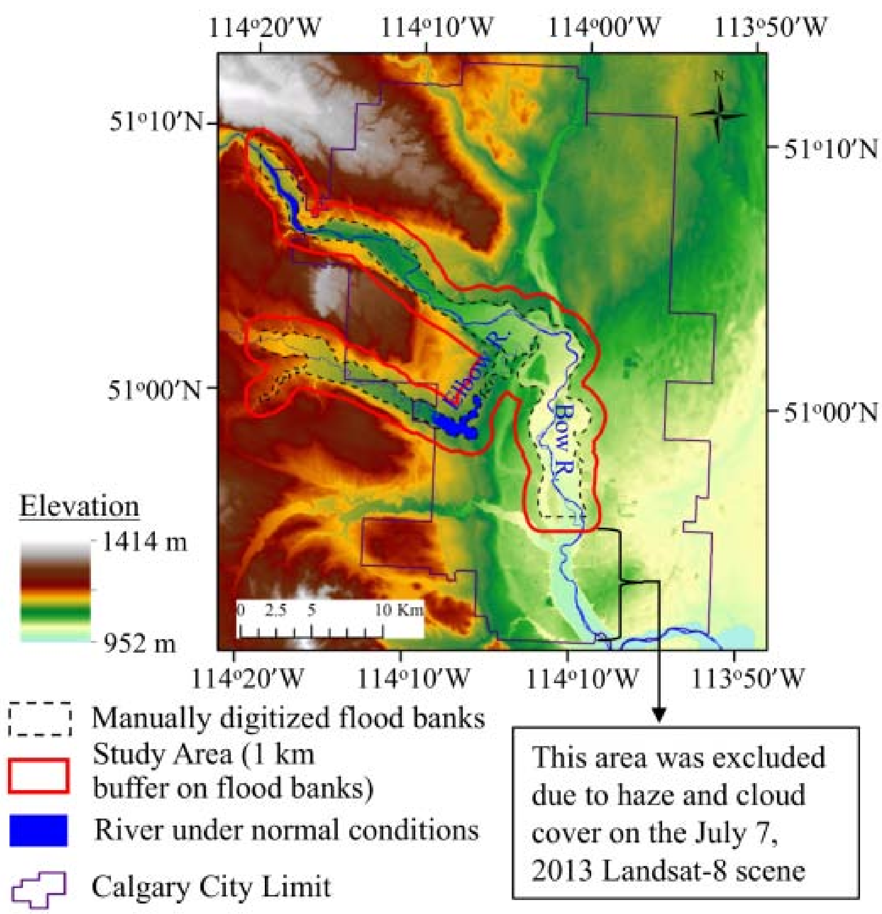

Fig.1 Study area for the flood extent estimation

Results and Discussion

Fig. 2 shows the Landsat-8 derived flood extent maps over the left half of our Landsat-8 image (i.e., calibration dataset) by use of the ISODATA clustering technique, and then the implementation of a majority filter with several windows sizes in the range 3x3 to 11x11. We found that the majority filter was effective: e.g., a simple 3x3 pixel majority filter increased the $\hat{K}$ (or agreement relative to the actual ground data) by approximately 5 percent from the original estimated flood extent (i.e., with a $\hat{K}$ of 0.50). Overall, we observed that 7x7 and 9x9 majority filters proved to be most effective, since they both gave the highest $\hat{K}$ of 0.59. Thus, both the 7x7 and 9x9 window sizes were selected for implementation over our validation dataset (i.e., right half of the image);

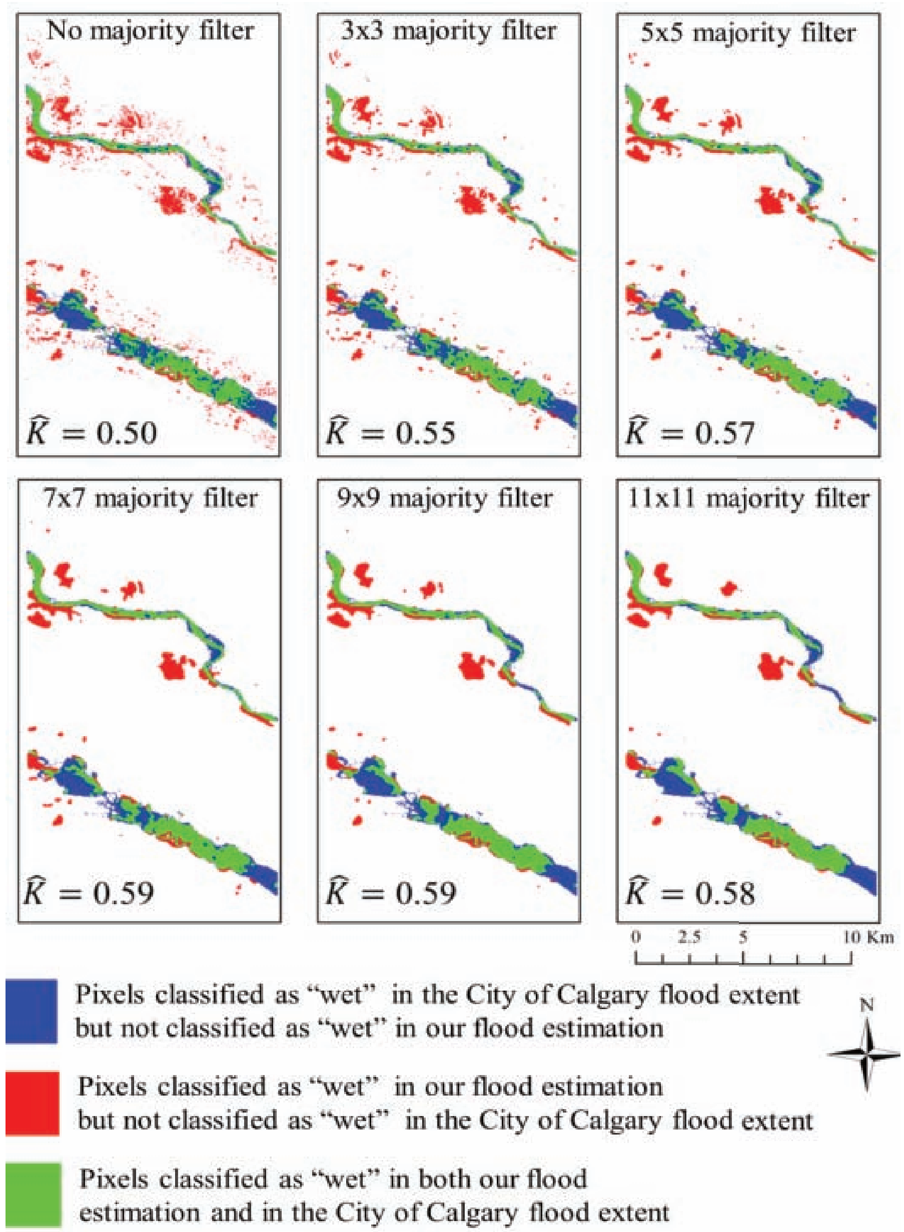

Fig. 2 Comparison between estimated flood extents from Landsat-8 image with that of the City of Calgary. To improve the agreement a majority filter with several window sizes was used.

Useful resources: by Lily Yumagulova

A comprehensive and informative resource, Floods in a Changing Climate from the International Hydrology Series, a collaboration between the International Hydrological Program, UNESCO, and Cambridge University Press, addresses critical dimensions of flood science and management:

Floods in a Changing Climate: Extreme Precipitation by Ramesh Teegavarapu,
Floods in a Changing Climate: Hydrological Modelling by P. P. Mujumdar and D. Nagesh Kumar,
Floods in a Changing Climate: Inundation Modelling by Giuliano Di Baldassarre,
Floods in a Changing Climate: Risk Management by Slodoban Simonović

Informative, packed with methodological guidance and international data, these books offer valuable insights for researchers in the related fields. Sections of the books could inform flood management professionals and policy-makers working in hazard mitigation, risk management and planning.

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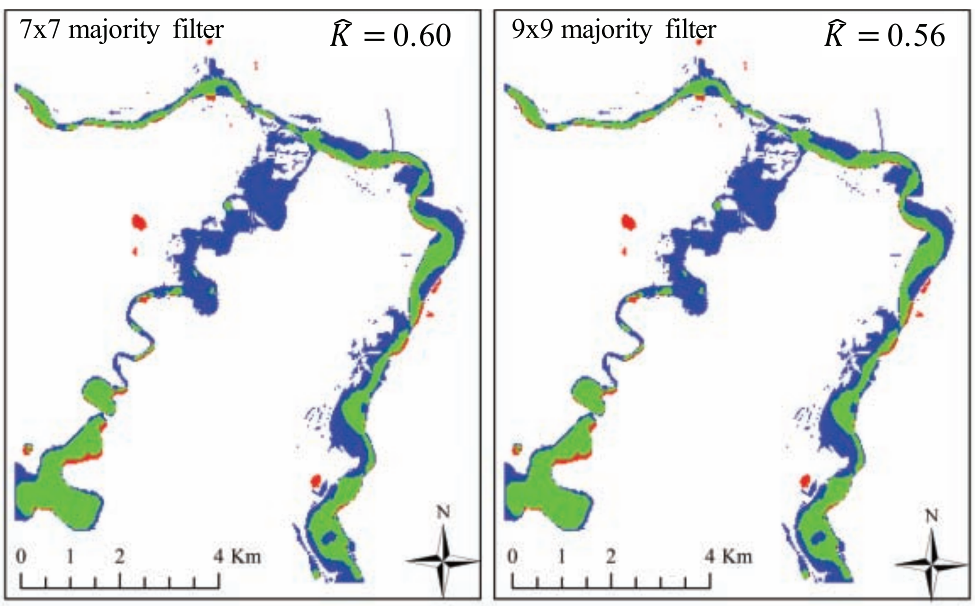
and such outcomes are shown in **Fig. 3**. It revealed that the $\hat{R}$ were 0.6 and 0.56 upon implementing the majority filters with a window size of 7x7 and 9x9 filters, respectively. Overall, the 7x7 majority filter proved to be more optimal than the 9x9 majority filter, since it gave a better outcome relative to the validation dataset. In addition, our hypothesis of having a smaller 7x7 window size for the majority filter proved to be correct, as this avoided over generalization of the classified areas.



Pixels classified as "wet" in the City of Calgary flood extent but not classified as "wet" in our flood estimation

Pixels classified as "wet" in our flood estimation but not classified as "wet" in the City of Calgary flood extent

Pixels classified as "wet" in both our flood estimation and in the City of Calgary flood extent

Fig. 3 Validation of our estimated flood extent derived from Landsat-8 image in comparison with the City of Calgary flood extent.

Ideally, our result in terms of $\bar{R}$ should have been closer to 1. However, the major limiting factor for detecting the June 2013 flood extent was the lack of available Landsat data at a closer date to the flood event. In the scope of **Fig. 4**, we overlaid our Landsat-8 derived flood extent map on top of a land-use map consisting of two major classes, such as built-up or vegetated areas.

Figure 4 demonstrates that in areas where the River is surrounded by vegetation and water has a longer retention time, our method worked well and there were plenty of correctly classified flooded pixels. However, where the Elbow River meets with the Bow River (i.e., the area in **Fig. 4** highlighted by a black circle) the classification of the flooded pixels was the worst.

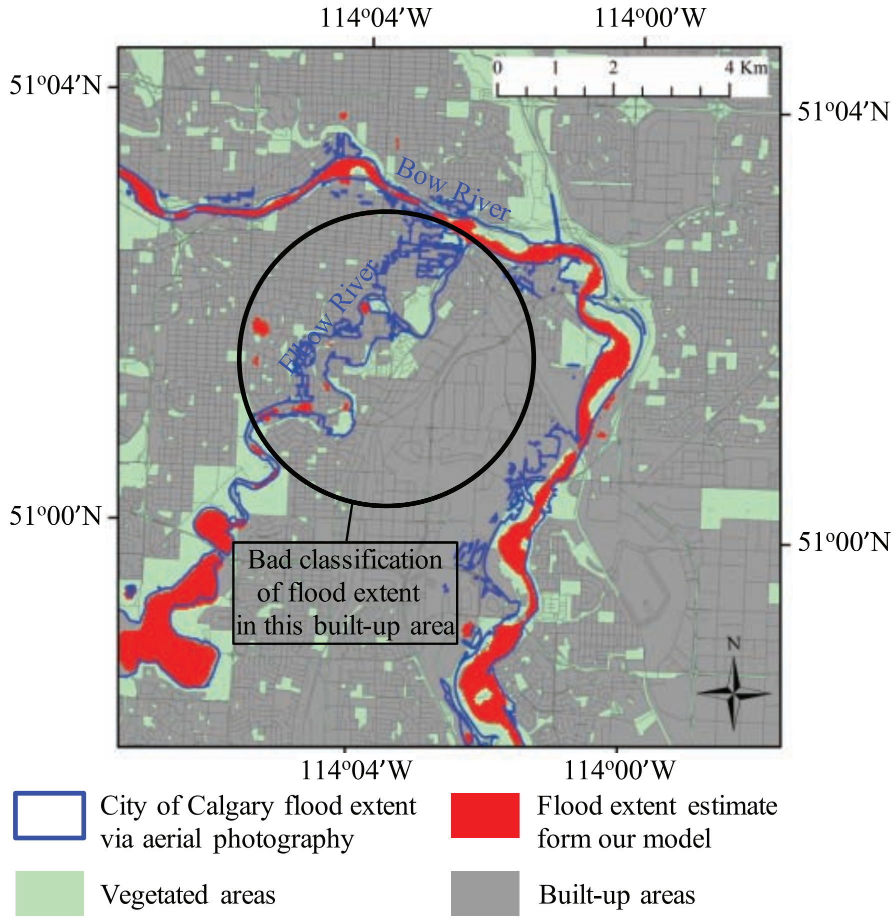


Fig. 4 Estimated flood extent over vegetated and built-up land-use areas

Remarks

In this article, we demonstrated a simple method to estimate the extent of flooding in the City of Calgary during the June 2013 flood event. This estimation relied primarily on unsupervised classification, using an ISODATA clustering technique of 6 total bands (i.e., blue, green, red, near infrared, shortwave infrared1, and shortwave infrared2) from the Landsat-8 satellite. We believe that remote sensing-based techniques and their application in flood management via extent mapping can help decision/policy makers to act quickly with necessary evidence to increase resilience in communities.

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• **Gianinetto, M., Villa, P. & Lechi, G., 2006,** Postflood damage evaluation using Landsat TM and ETM+ data integrated with DEM. IEEE Trans. Geosci. Rem. Sens., 44(1), 236–243.

• **Schnebele, E., Cervone, G., Kumar, S., & Waters, N., 2014,** Real time estimation of the Calgary floods using limited remote sensing data. Water, 6(2), 381–398.