A Satellite-Based Assessment of the 2001 La Crosse Flood

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ABSTRACT

April 2001 brought widespread flooding of the Mississippi River to La Crosse, Wisconsin. This study compared two Landsat ETM satellite images, taken in April and September of 2001, to assess the geographical impact of the flood in the La Crosse area. The September image was used as the normal case and the April image was used as the flood case in order to draw statistical and spatial comparisons. By combining multi-spectral and panchromatic bands through a Brovey Transform resolution merge, the images were pan-sharpened to reveal the necessary information to give a detailed description of the flood. A classification of the transformed images shows how the river grew during the flood. A matrix function was used to produce an image that shows where flood waters resided during the flood.

INTRODUCTION

The spring of 2001 brought widespread flooding of the upper Mississippi River and its associated tributaries. In La Crosse, WI, the National Oceanic and Atmospheric Administration (NOAA) recorded the third highest Mississippi River crest on record. From April 15 to May 18, the Mississippi River was over the 12-foot flood stage mark (Erickson, 2001). The river crested twice, first on April 18th at 16.41 feet and then on April 30th at 15.78 feet (Erickson, 2001). The causes of the flood included heavy rains in November of 2000, followed by higher than normal snow amounts in winter and unusually cold temperatures in March which delayed thawing, and an unprecedented April rainstorm that brought 3 to 6 inches to most of Minnesota (Hardie, 2001). The flood of April 2001 was a 50-year flood, representing a 2% probability of a flood that severe occurring in a given year (Erickson, 2001).

The goal of this research project was to examine how satellite data could be used to measure the spatial extent of flooding. If data could be collected from satellites and interpreted correctly, then the extent of the flood could be obtained quantitatively to describe the flood's extent. A report of the flood's impact could provide valuable information for disaster planning and future flood models, as well as providing a historical context.

DATA AND METHODS

The project began by obtaining two Landsat Enhanced Thematic Mapper (ETM) 7 images with multi-spectral and panchromatic bands. One image was taken April 18, 2001 at the time of the highest river stage, and another one on September 21, 2001 when the river stage had returned to normal conditions for the Mississippi River. The images cover the Mississippi River area between Wisconsin, Minnesota, and Iowa.

The processing of the raw data sets was done in ERDAS Imagine, a well-recognized GIS tool designed specifically for working with satellite images. The raw images were georeferenced into a UTM coordinate system. The process involved assigning coordinates and correcting for distortions, so that the images would be geographically accurate. Once the images were corrected, a subset of the full scene was defined to focus on the immediate La Crosse/Mississippi River area. The study area images show the La Crosse area from about I-90 to Goose Island and from La Crescent, MN to the bluffs east of La Crosse.

The study required high spatial resolution multi-band images in order to give accurate results. The Landsat ETM images have a multi-spectral spatial resolution of 30 meters, but also have a panchromatic band that has a spatial resolution of 15 meters. It is possible to combine the two resolutions to achieve the best resolution while maintaining the necessary bands to help classify the pixels. The process is called a *resolution merge*. A resolution merge is a compromise between spatial resolution and the number of bands for an image. After trying several different resolution merge algorithms including Principal Component, Multiplicative, and the Brovey Transform, it was decided that the Brovey Transform with the Nearest Neighbor resampling technique provided greatest enhancement of the multi-spectral and panchromatic bands. The resulting images had three bands, which enhanced different depths of water and had better spatial detail in the water areas. According to the ERDAS Field Guide, "The Brovey Transform was developed to visually increase contrast in the low and high ends of an image histogram (i.e. to provide contrast in shadows, water and high reflectance areas such as urban features)" (ERDAS, 2002, p.151).

The next step was to classify both image dates and identify the features that were important to the study. To study the extent of the flood, a water class and three land cover classes were used: pastures, forested areas, and urban areas. Using these land classes benefited the analysis by providing the spatial visualization that was required for maps showing affected areas. An unsupervised ISODATA classification algorithm was used to process both images. The results were two images showing the flood and non-flood conditions that could be compared to find where the flood water was and how much land area it covered.

For statistical comparison between the September and April 2001 images, a matrix function was used to identify spatial and numerical differences and similarities. The matrix function produced a new image that shows where water existed in both September and April. Using September as the normal case of the Mississippi River and April as the flood case, the difference between the water extent would represent the flooded areas.

RESULTS

The study area selected was centered on La Crosse and the Mississippi River and covered 65,766.62 acres. The flood waters in April 2001 covered 16,767.28 acres of the study area. During normal conditions, water would occupy around 4,700.00 acres. This means that roughly four times the amount of water was visible in the study area in April than in September.

The class breakdown (Table 1) shows the results of the matrix function. The September classes listed are the four classes used in the classification. In order to show the new flooded areas the April classification lists only the water class. The table shows that 4,646.59 acres of water appeared in both classifications as water. This represents the average river acreage for a normal river stage. Of the pasture/bare ground areas, 8,139.79 acres evident on the September image were under water in April. This is a significant area that includes many of the open marsh areas. The La Crosse River Marsh, north of the UW-L campus, retained a large amount of the floodwaters, possibly preventing flooding farther into town. The marsh is an excellent sponge for Mississippi River flooding. The La Crosse River Marsh not only provides a natural aide to stop flooding, but provides scenic and biological resources to La Crosse.

Table 1. Class Breakdown (September vs. April)

September Class	April Class	Pixel Count	Area (Hectares)	Area (Acres)
Water	Water	83,628	1,881.63	4,649.59
Pasture/Bare	Water	146,403	3,294.07	8,139.79
Forest	Water	57,656	1,297.26	3,205.59
Urban	Water	13,891	312.55	772.32
Totals		301,578	6,785.51	16,767.28

The results show that 3,205.59 acres of forest/wooded areas and 772.32 acres of urban or developed land were underwater. On French Island, many people were evacuated from their homes and entire blocks were underwater. Local emergency workers had to use small boats to travel into these neighborhoods. Riverside and Pettibone Parks, near downtown La Crosse, both experienced high waters covering most of their areas. The walkways and sidewalks along the river were underwater. The water came within feet of 2nd Street in downtown La Crosse during the highest river stages (Erickson, 2001).

Figure 1 was created by combining the April and September classification results using a matrix function. It gives a spatial perspective of the areas of normally dry land that were underwater during the April flood. Most of these are located on the Minnesota side of the Mississippi River and south of the city in the marsh areas. In addition to these areas, the flooding of the La Crosse River Marsh is clearly evident.

CONCLUSION

The flood of April 2001 represented a 50-year flood. As a result of the severe flooding, the Federal Emergency Management Agency (FEMA) was authorized to distribute federal aid to residents and businesses (Erickson, 2001). The estimated total cost to La Crosse County was $1 million dollars to help pay for the massive labor force, equipment costs, and clean up (Erickson, 2001).

With satellite images, this study was able to give numerical values to how much the flood impacted the City of La Crosse and surrounding areas. The image classifications also produced a map that shows the spatial extent of the flood and where these areas were during the highest river stage. Satellite image analysis could provide an effective way to plan for future floods and help asses their impact.

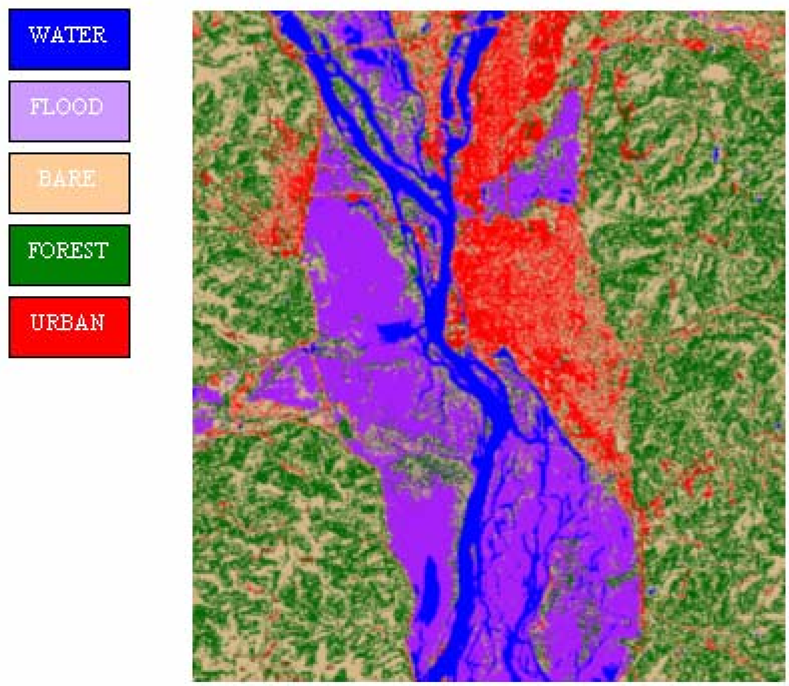

Figure 1. Map of Flooded Areas for La Crosse, WI.

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