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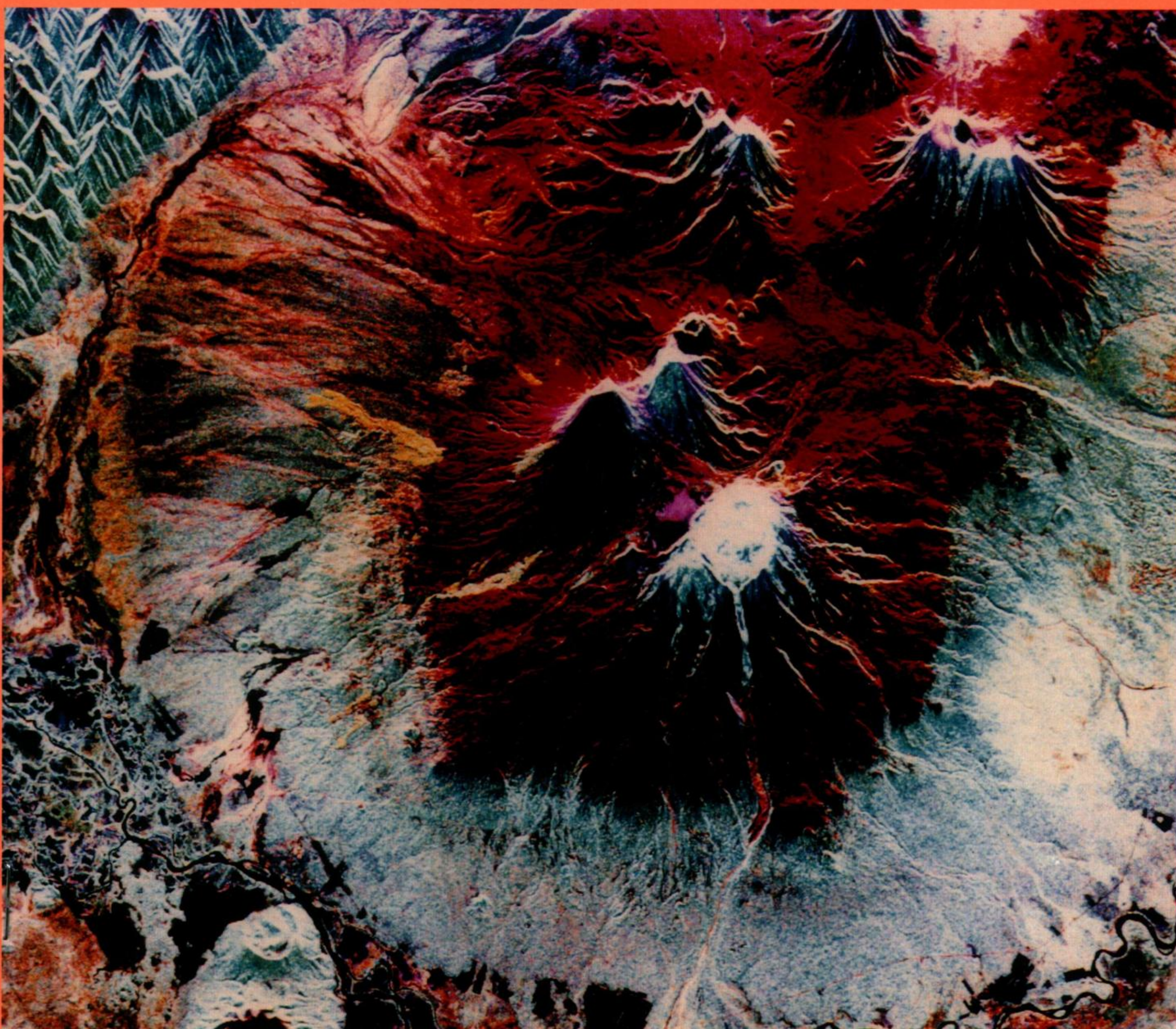
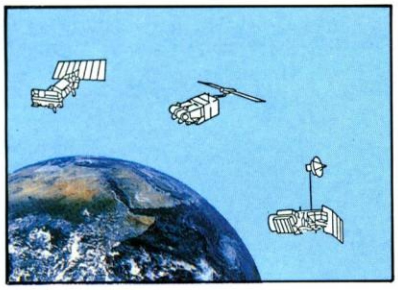


NASA SPACEBORNE RADAR IMAGE of Kliuchevskoi Volcano area of Kamchatka, Russia. The Spaceborne Imaging Radar-C/X Band Synthetic Aperture Radar-(SIR-C/X-SAR) is part of NASA's Mission to Planet Earth Initiative. Colors: Red=L Band (HH), Green=L Band (HV), Blue=C Band (HV).

NASA/JSC Photo S94-45024, 25 October 1994. Courtsey of Earth Science Branch at Johnson Space Center, Houston, Texas, USA.



Remote Sensing Images & Technical Notes

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Two Digital Approaches for Calculating the Area of Regions Affected by the Great American Flood of 1993

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Large sections of the upper Mississippi River Basin experienced major flooding during the summer of 1993. Many small communities and local governments throughout the region were faced with providing immediate assistance and emergency services to the flooded areas. In the flood's aftermath these same governments were requested to help the flood impacted areas to recover with aid from the state governments and federal agencies. To receive aid, in many cases the government units were required to delineate the amount of area flooded. This paper outlines two rather simple approaches, using satellite imagery and inexpensive software, to identify the amount and location of the flooded areas. Major floods occur every year throughout the world impacting hundreds of communities. The approaches presented in this paper might help these communities with respect to future floods as well as those communities dealing with the recovery problems associated with the 1993 Mississippi flood.

Study Area

False color (RGB = TM 7, 4, 3) images of the study area for July 4, 1988 and July 18, 1993 are presented in Figures 1 and 2. Map 1 shows the extent of the images and the regional context of the drainage network. Water surfaces appear dark blue, vegetated surfaces in tones of green, and urban and barren surfaces in shades of pink. The Missouri River runs through the center of the images with St. Charles, a city of 50,000 people (U.S. Bureau of Census 1990), located in the southwest corner. St. Charles is approximately 32 kilometers from St. Louis. The runways of the Lambert-St. Louis International Airport can be detected in the southeast corner of the images. The arcuate pattern of the Missouri River flood plain is apparent in the 1988 image; whereas, the 1993 image shows the extent of the flooding. On the morning of July 16, 1993, two days before the image was taken, the flood waters poured over the top of a railroad embankment being used as a levee just north of St. Charles and linked the Missouri and Mississippi to form a 32 kilometer wide body of water.

Software and Data

The purpose of this paper is to present the two methodologies used to determine the regions directly affected by floodwater as part of the Great American Flood of 1993, and to calculate the area of effected landscape. Both methodologies employ change

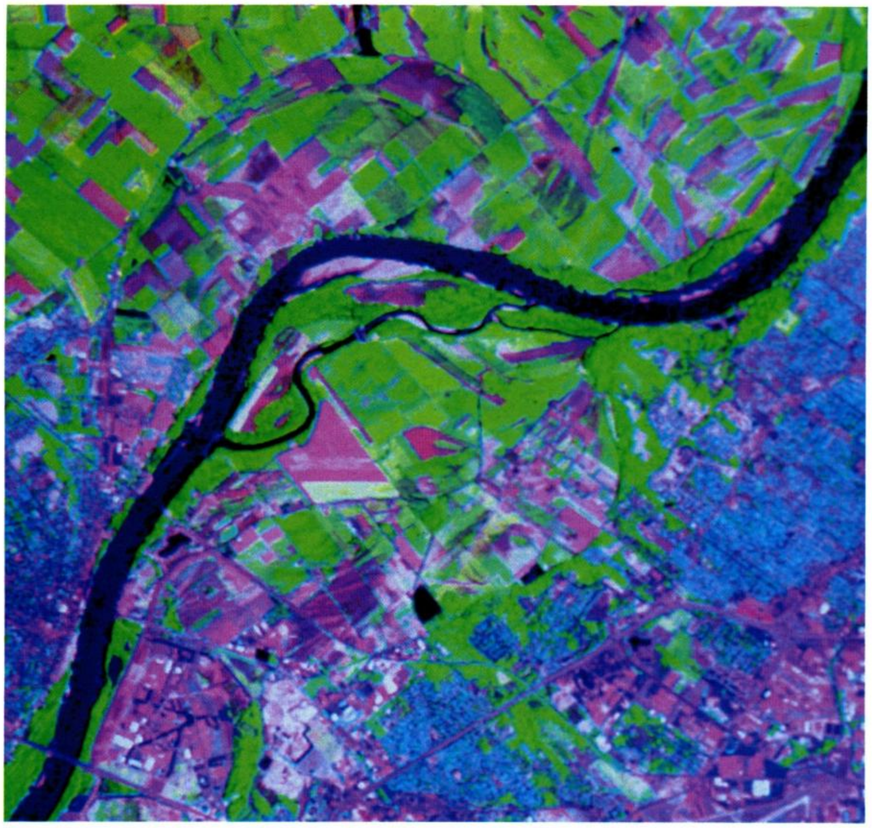
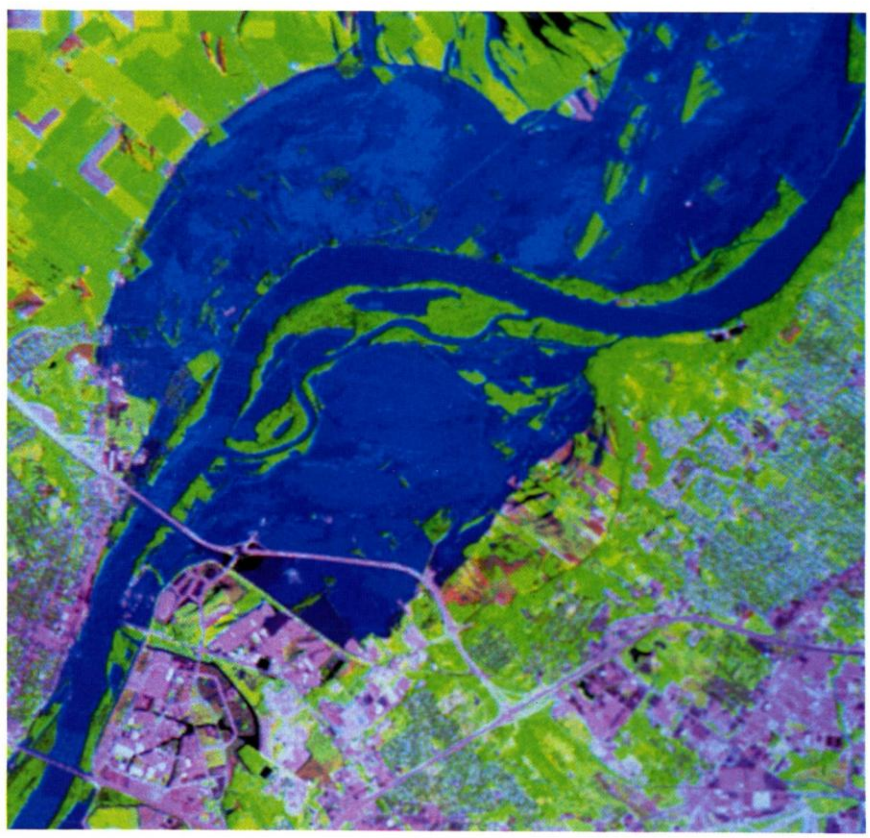
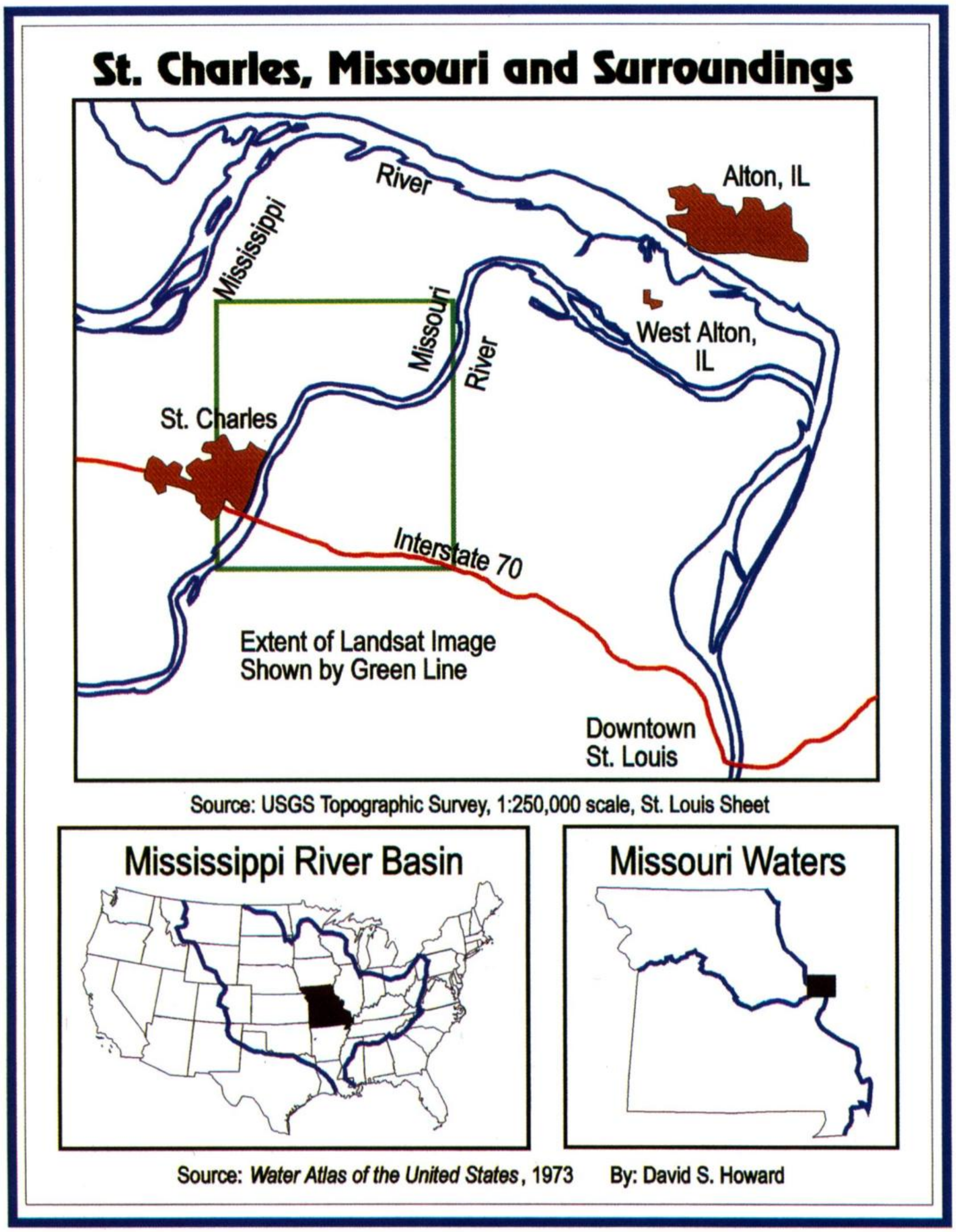


Figure 1 July 4, 1988 false color (RGB = TM 7, 4, 3) Landsat Thematic Mapper image of the St. Charles, Missouri region.

Figure 2 July 19, 1993 false color (RGB = TM 7, 4, 3) Landsat Thematic Mapper image of the St. Charles, Missouri region.





Map 1 Landsat thematic mapper coverage area and surrounding regional drainage network.

detection requiring a base image data set and an image during the flood period. All analysis presented in this article was accomplished with the inexpensive (e.g. U.S. $395.00) RSVGA microcomputer-based image processing software package available from Eidetic Digital Imaging Ltd (Eidetic Digital Imaging Ltd. 1993). This package operates on an IBM or compatible machine with 640K memory, a VGA monitor, and a math coprocessor, a hardware configuration which many small communities and local governments should have available. RSVGA can accommodate data sets as large as 8160 by 8160 pixels. The two Landsat thematic mapper data sets used in this study cover an area of 512 by 512 pixels. Landsat digital image data can be obtained from the Earth Observation Satellite Corporation (EOSAT) in Lanham, Maryland (EOSAT 1993). EOSAT geocorrected the two data sets creating twenty-five meter pixels.

Principal Component Approach

The principal component approach uses the second principal component created by using 8 spectral bands, four from each of the two data sets. These spectral bands include 1, 3, 4, and 7 from the 1988 base year data set and bands 1, 3, 4, and 7 from the 1993 data set. The RSVGA software performs a principal component analysis upon a maximum of eight image bands. Spectral bands 2 and 5 for each date were deleted from the analysis since band 2 exhibits surface reflectance patterns very similar to band 3, and band 5 exhibits surface reflectance patterns similar to band 4. Band 6 was not used from both data sets due to its larger spatial resolution and relatively little relevant information provided by the thermal emittance patterns within the scene. The second principal component image is often cited in the literature as a good tool to use for change detection (Jensen 1986). Indeed the second principal component image, Figure 3, does a good job of identifying newly flooded land. A significant difference in gray tone is obvious for water surfaces present in both 1988 and 1993, land inundated with flood water in 1993, and land not affected in either year. A density slice of this second principal component image resulted in an image which shows 1988 existing water bodies in red, 1993 flooded regions in green, and relatively dry land in blue (See Figure 4). The density slice ranges were: 39-56 (permanent water), 57-83 (flooded areas), and 84-255 (dry land). The number of 25 meter pixels and associated area of each land cover is presented in Table 1. One advantage of this analysis technique includes the fact that natural

Table 1 Area of 1993 Flooded Land Determined Through an Eight Band Principal Component Analysis

Surface	pixels*	acres	hectares	km^2
Permanent Water	13734	2121	858	8.58
Flooded Land	84787	13095	5299	52.99
Dry Land	163623	25270	10226	102.26

* Each pixel = 0.15444 acres
= 0.0625 hectares
= 0.000625 square kilometers

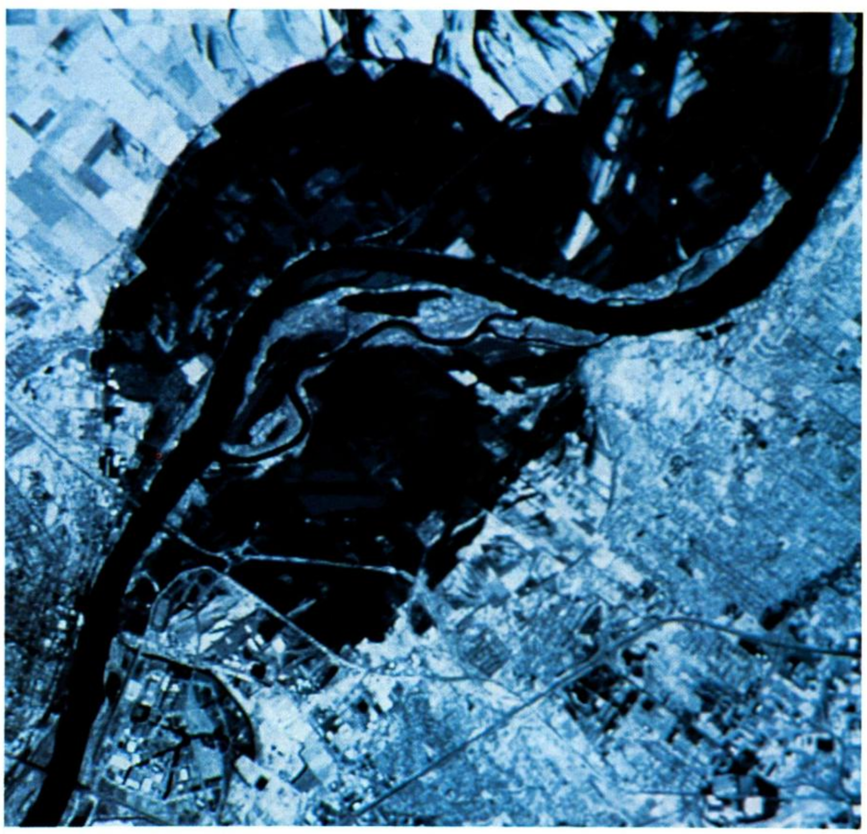


Figure 3 Second principal component of eight geocorrected digital image files, including Thematic Mapper bands 1, 3, 4 and 7 from July 4, 1988 and Thematic Mapper bands 1, 3, 4, and 7 from July 18, 1993.

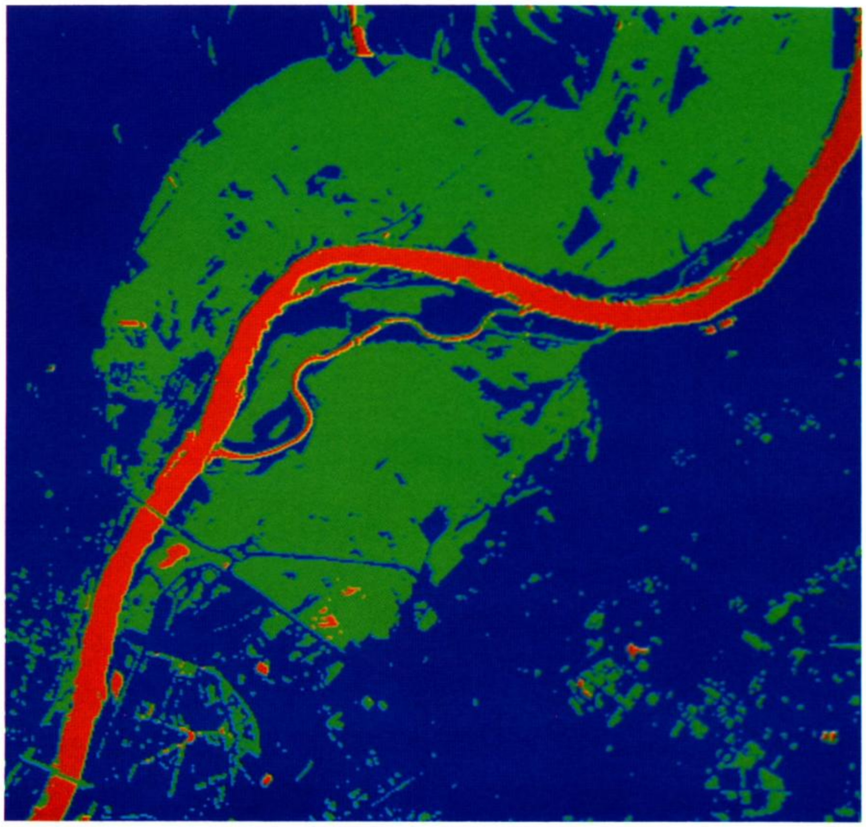


Figure 4 A colored density slice of Figure 3. The Missouri River and other permanent water is colored in red and represents a 5.24 percent of the image. Flooded areas are colored in green and represent 32.34 percent of the image. The rest of the image is colored in blue and represents 62.42 percent of the total area.

water surfaces from the first image are not included in the calculation of 1993 flooded land. Also, this technique requires a minimum of knowledge about the surface environment since the various surfaces were separated statistically. The reader is cautioned, however, that some knowledge of the surface environment, at least in some small sample areas, is required to accurately check the utility of this procedure.

Mathematical Approach

The mathematical approach deals with first identifying which image bands relate best toward solving the environmental hazards problem and secondly determining how mathematically to merge spectral bands into one final image from which the needed information can be obtained. Starting with the 1988 data set as the base year, the initial step was to find one band which clearly separated water areas from land surfaces. The visible bands, as often is the case, showed variation within water bodies but did not provide sharp differentiation between water and other surfaces (Campbell 1987). The three reflected infrared bands did detect water areas as solid bodies with little reflective variation which is the normal condition when working in the near and middle infrared portions of the spectrum. Comparing these three bands to the St. Charles United States Geological Survey 7.5 minute topographic map, band 4 related extremely well to the water features displayed on the map. The map was originally prepared in 1954 and photorevised in 1968 and 1974. Even though the U.S. Midwest suffered through a severe drought during the 1988 summer, the water level of the Missouri River and adjacent smaller water bodies within the study area did not vary significantly between what is indicated on the map and the band 4 image. The data ranges for bands 5 and 7, the other two infrared bands, were too clustered making it difficult to separate water from a variety of other surfaces. Band 4 did possess a problem in that its lower data values, which were used to indicate water areas, were also identifying the tops of commercial and industrial buildings. This problem will be addressed later. Band 4 was selected as the base year image.

Basically, for the same considerations used in choosing band 4 from the 1988 image, band 4 from the 1993 data set was selected to identify the flood conditions. To enhance both bands, they were stretched to make full use of the absolute data range (0-255). Rather than automatically using the minimum and maximum values associated with the bands to stretch the data, the bands' histograms were examined to select values that reduce the effect of the extreme conditions within the data. The minimum and maximum values used to stretch the data generally grouped the lower and upper .5 percent of the dynamic data range at the lower and upper levels of the absolute data range respectively.

The two stretched images were added together and scaled to produce a new image. Water had low reflectance values in both of the stretched bands. By adding the permanent (river channels and ponds) water surfaces as shown in the 1988 band to the same areas in the 1993 band, low values were generated which made it possible to separate the permanent water areas from the flooded areas. The flooded areas in the 1993 band also had low reflectance values but when added to the high values associated with the land condition in the 1988 band, the flooded areas had higher values than the permanent water areas. The high land reflectance values in both images created values higher than those related to the permanent water or flooded areas. This approach worked well except for certain commercial/industrial areas which were being identified as permanent water of flooded areas in the new image. To correct this problem a third band, band 7 of the 1993 data, was added to the new image. An examination of this band showed little reflectance confusion between permanent water areas and commercial/industrial areas. Like the other two bands, this band was also stretched. Figure 5 shows the final image scaled between values of 1 and 255. A density slice of these values enabled a separation between permanent water, flooded areas, and dry land surfaces (Figure 6). The density slice ranges were: 1-20 (permanent water), 21-100 (flooded areas), and 101-255 (dry land). Table 2 provides a numerical break down of the three classes.

Conclusions

As an environmental hazard, annual flooding impacts hundreds of communities throughout the world. For government relief efforts to be effective the

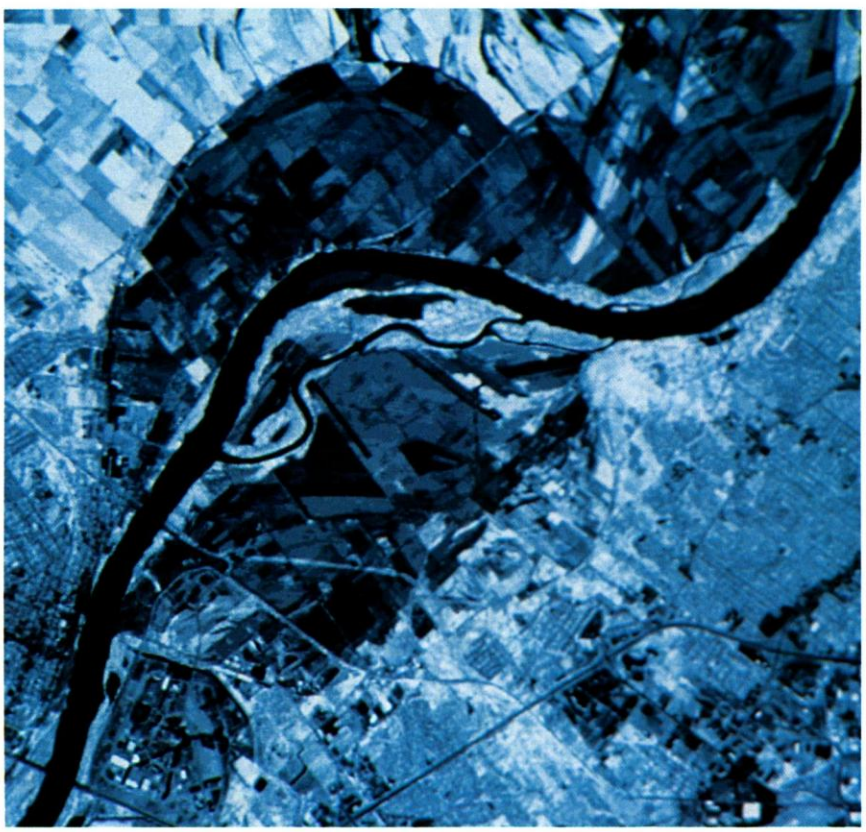


Figure 5 Mathematical approach image by adding together TM band 4 (1988), TM band 4 (1993), and TM band 7 (1993).

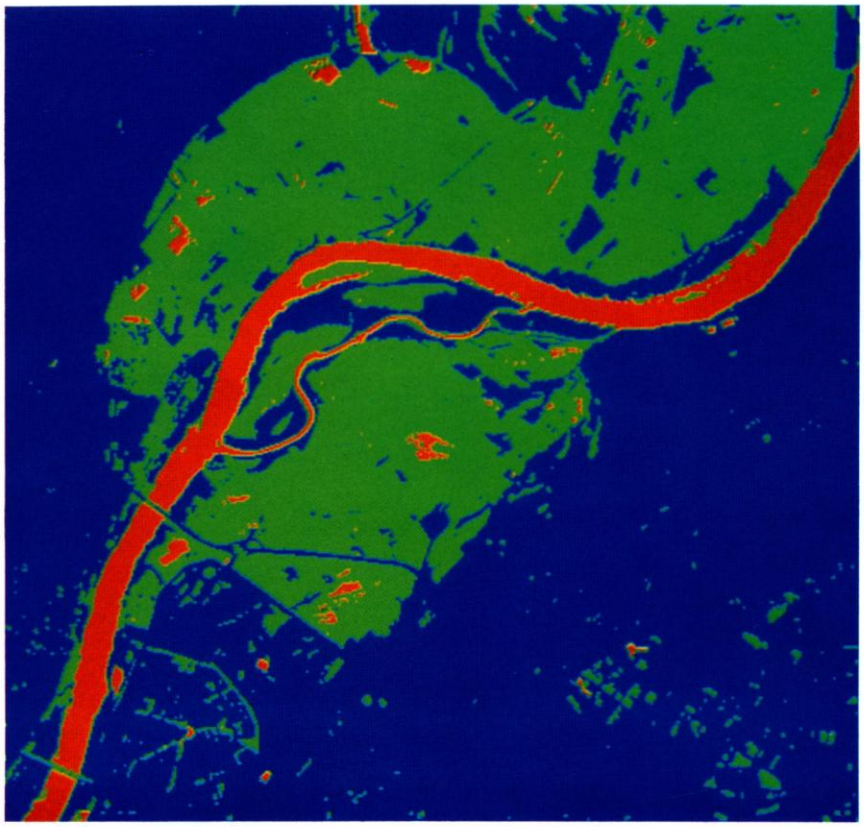


Figure 6 A colored density slice of Figure 5. The Missouri River and other permanent water is colored in red and represents 5.56 percent of the image. Flooded areas are colored in green and represent 30.82 percent of the image. The rest of the image is colored in blue and represents 63.61 percent of the total area.

Table 2 Area of 1993 Flooded Land Determined Through A Three Band Mathematical Approach

Surface	pixels*	acres	hectares	km²
Permanent Water	14578	2251	911	9.11
Flooded Land	80813	12480	5050	50.50
Dry Land	166753	25753	10422	104.22

* Each pixel = 0.15444 acres
= 0.0625 hectares
= 0.000625 square kilometers

rapid location and extent of flooding must be determined. Through relatively simple digital image processing approaches (principal comments analysis and other mathematic image merging approaches), with Landsat thematic mapper data sets, the extent of flooding in the St. Charles, Missouri area was effectively and accurately mapped. Such approaches offer local communities opportunities for gathering such information in a rapid and inexpensive manner.

Acknowledgement

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