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Consideration of cloud covered pixels for the estimation of flooded area using NOAA AVHRR data

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1. Introduction

Remote sensing (RS) techniques is very promising tools for determination of flooding areas. Image data from National Oceanographic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) with Geographic Information System (GIS) were used in this study. Flood inundation mapping is based on the fact that water will normally appear in black in a NOAA image. This principle has provided the helpful guidelines for mapping of flooding area (Islam and Sado, 1998a; Islam and Sado, 1998b). Cloudy skies often occur during the big floods, and visible and infrared ray observed by NOAA AVHRR cannot penetrate cloud cover. So, the presence of cloud limits the study. We therefore used images taken during low cloud cover period during the flood, and here we proposed a technique for classifying cloud covered pixels into water or non-water categories. The results of the analysis of cloud covered pixels show the distribution of cloud covered pixels into the water and non-water pixels. Our proposed technique will provide the helpful guide line for make a decision of cloud covered pixels while the analysis of flooded areas using RS data.

2. Study area

Bangladesh is south Asian country surrounded on three sides by India, which lies to the east, north, and west, and shares a small part of its southeastern boarder with Myanmar. To the south lies the Bay of Bengal. The whole area of Bangladesh is an immense river basin crisscrossed by a network of 230 rivers, including three major rivers - the Ganges, Brahmaputra and Meghna - which ripped the country. Flood occurs very frequently in Bangladesh and floods are one of the most devastating environmental hazards in the country. Floods are normally occur in rainy season during the monsoon months between July and October.

3. Data selection and processing

The full scenes of NOAA AVHRR covering the whole area of Bangladesh and the parts of neighboring countries were considered for this study. Vector data for the boundary of Bangladesh was prepared by ARC/INFO software by using an existing geographic map. After geometric correction, sub-scenes corresponding to the whole area of Bangladesh were extracted from the full scenes by using a vector layer for the country. Geometric correction was carried out by using ERDAS Imagine software, and root mean square errors were less than one pixel. Both the length of one pixel and of one line for NOAA AVHHR images represented 1.1 km on the ground surface. This is the ground resolution for NOAA AVHRR data.

One NOAA AVHRR dry season image, taken Jan. 20, 1988, and three images taken during the flood (on Sept. 18 & 24 and Oct. 8, 1988, respectively) were analyzed under different vegetation, land cover and water content conditions. Among the NOAA AVHRR images the dry season image was free of clouds.

4. Landcover classification

There are not any tools or any direct system in ERDAS IMAGINE software to distinguish directly between water pixels and non-water pixels. To differentiate between water and non-water pixels, unsupervised land cover classification (ISO-DATA clustering) were performed for the four images. Initially three images of Sept. 18 & 24 and Oct. 8, 1988 were categorized into sixty clusters by ISO-DATA clustering, then the sixty clusters were divided into three categories: non-water, water and cloud. The occupied area percentage of three categories are shown in Table 1 and the three class images are shown in Fig. 1. The image of Jan. 20, 1988, was also categorized initially into sixty cluster then divided into two categories of water and non-water, because it was cloud free. Table 1 shows that water covered areas are 36.59%, 29.30% and 29.57% without recovery of cloud covered areas while cloud coverage are 15.00%, 15.40% and 5.51%, respectively, for the images taken Sept. 18 & 24 and Oct. 8, 1988.

Table 1 Water, non-water and cloud covered area (%) for three different images

	18.9.88	24.9.88	8.10.88
Water	36.59	29.30	29.57
Non-water	48.41	55.30	64.92
Cloud	15.00	15.40	5.51
Total	100.00	100.00	100.00

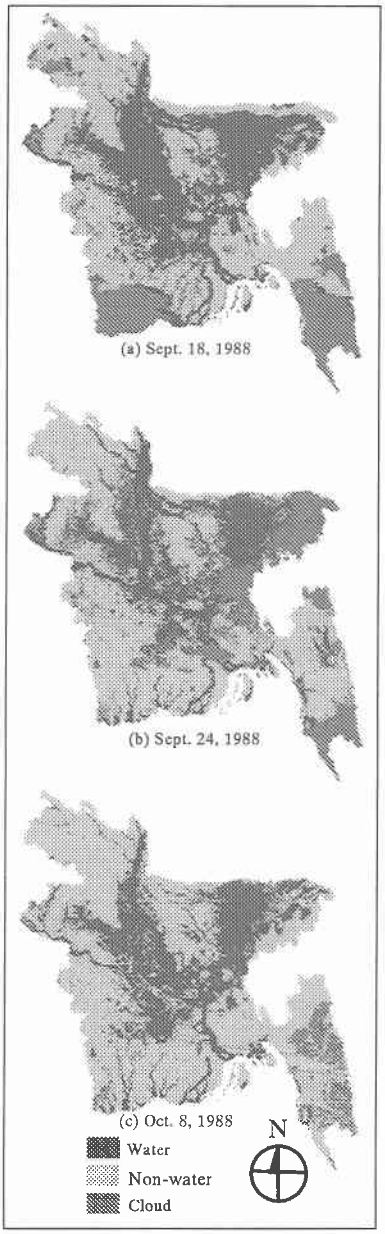

Figure 1. Three classes of water, non-water and cloud covered areas

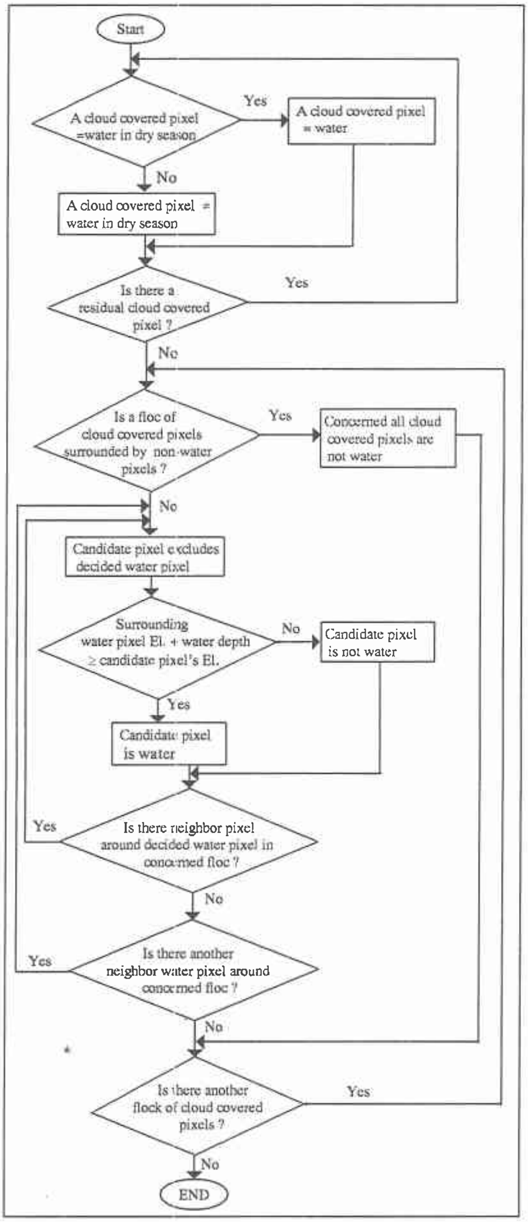

Figure 2. Flowchart for recovery of cloud pixels

5. Consideration of cloud covered pixels

5.1 Process of the recovery of cloud covered pixels

Cloudy skies are expected during big floods, and NOAA AVHRR data is not cloud penetrating data, so, the presence of clouds over the damaged areas after an event limits the usefulness of this data and difficulty arises with the interpretation of whether a given area beneath the clouds is dry or covered by water for the study of flooding. We employed low cloud covered images (cloud coverage for the images taken Sept. 18 & 24 and Oct. 8 were

15.0%, 15.4% and 5.5%, respectively) and an algorithm was used to interpret these cloud covered pixels. The flowchart of the algorithm is shown in Fig. 2.

After differentiating all of the pixels into three categories (non-water, water and cloud) using land cover classification this algorithm was used to estimate what lay beneath the cloud covered pixels. The shadow of a cloud was included with the cloud covered area. Cloud covered pixels for the flood images which had represented water in the dry season image were interpreted as water, but the remaining cloud covered pixels were divided into two types through the use of digital elevation data. A floc of cloud covered pixels, which was surrounded by non-water pixels was considered to be non-water, while cloud covered floc surrounded by water pixels was compared with neighboring water pixels. If the elevation of a cloud covered candidate pixel was less than the land surface elevation of a neighboring water pixel plus water depth then the candidate pixel was considered to be a water pixel (it was assumed that the flow of water from a pixel to a pixel occurs across the common perimeter only), otherwise it was considered to be a non-water pixel. For cloud covered pixels initially determined to be non-water in the same floc, however, these procedures were repeated to compare them with neighboring water pixels in all directions until the decision was finalized for the floc. On the other hand, pixels that were initially determined to be water were not allowed to be changed to non-water pixel status.

This procedure was used for all flocs in the image. We did not consider the water depth in our study because water depth data were not available. Results would be more accurate if the water depth could also be considered. Some studies and mathematical modeling have been done in Bangladesh to estimate flood water depths (Paudyal, 1996).

5.2 Distribution of cloud covered pixels

Cloud covered pixels were distributed among the water and non-water categories. It is seems that cloud covered pixels have an affect on both the water and non-water areas. The area of 15.00%, 15.40% and 5.51%, occupied by cloud covered pixels of the image of Sept. 18 & 24 and Oct. 8, 1988, were converted into the water and non-water by 1.74% & 13.26%, 6.06% & 9.34%, and 0.75% & 4.76%, respectively. After recovering the areas of cloud covered pixels, the total water and non-water areas are shown in Table 2. Fig. 3 represents the total water and non-water areas while the cloud covered pixels were converted into water and non-water areas. Comparing between the Fig. 1 and Fig. 3 one can easily identify the areas those were converted into the areas of water or non-water.

Table 2 Water, non-water area (%) for three different images

	18.9.'88	24.9.'88	8.10.'88
Water	38.33	35.36	30.32
Non-water	61.67	64.64	69.68
Total	100.00	100.00	100.00

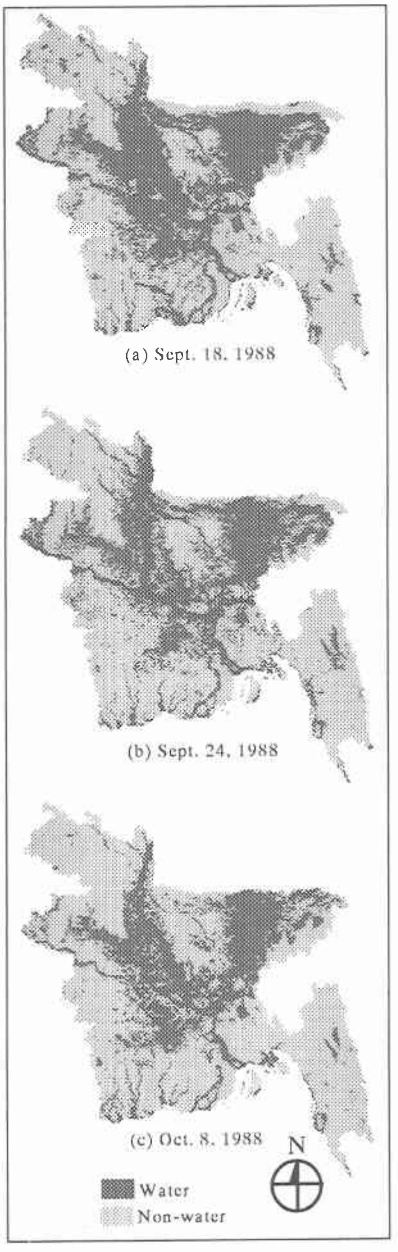

Figure 3. Water and non-water areas after recovering cloud covered pixels

6. Estimation of flooded area through three images

Inundated and land areas estimated by ISO-DATA clustering for the three days during the flood (Sept. 18, 24 and Oct. 8, 1988) are shown in Table 3. The columns of Table 3 show the results for the dry season while the rows show results for the flood season on by date. The elements representing water and non-water areas both during the flood and dry season are considered to be normal water (rivers, lakes, ponds, etc.) in the dry season and land area during the flood, respectively. An element that represents a water area during the flood but a non-water area during the dry season is considered to be an inundated area, and an element that represents a non-water area during the flood but a water area during the dry season is considered

Table 3 Estimated flooded area percentage for three different dates (Sep. 18 & 24 and Oct. 8, 1988) while considering cloud covered pixels

(a) Flooded area (%) for 18.9.'88

		20.01.'88		
		Water	Non-water	Total
18	Water	3.65	34.68	38.33
9	Non-water	1.67	60.00	61.67
'88	Total	5.32	94.68	100.00

(b) Flooded area (%) for 24.9.'88

		20.01.'88		
		Water	Non-water	Total
24	Water	3.76	31.60	35.36
9	Non-water	1.56	63.08	64.64
'88	Total	5.32	94.68	100.00

(c) Flooded area (%) for 8. 10.'88

		20.01.'88		
		Water	Non-water	Total
8	Water	3.61	26.71	30.32
10	Non-water	1.71	67.97	69.68
'88	Total	5.32	94.68	100.00

Table 4 Estimated flooded area percentage for three different dates (Sep. 18 & 24 and Oct. 8, 1988) while not considering cloud covered pixels

(a) Flooded area (%) for 18.9.'88

		20.01.'88		
		Water	Non-water	Total
18	Water	2.63	33.96	36.59
9	Non-water	1.17	47.24	48.41
'88	Cloud	1.52	13.48	15.00
	Total	5.32	94.68	100.00

(b) Flooded area (%) for 24.9.'88

		20.01.'88		
		Water	Non-water	Total
24	Water	3.29	26.01	29.30
9	Non-water	1.34	53.96	55.30
'88	Cloud	0.69	14.71	15.40
	Total	5.32	94.68	100.00

(c) Flooded area (%) for 8. 10.'88

		20.01.'88		
		Water	Non-water	Total
8	Water	3.39	26.18	29.57
10	Non-water	1.62	63.30	64.92
'88	Cloud	0.31	5.20	5.51
	Total	5.32	94.68	100.00

to be an error pixel. Flooded area percentage can be estimated by the following equation:

$$\text{Flooded area percentage} = a/(a+b) \qquad (1)$$

where a = inundated area, b = land area during the flood. Using this equation, the estimated flooded area for Sept. 18 & 24 and Oct. 8, 1988 are 36.63%, 33.38% and 28.21%, respectively.

Table 4 shows the inundated and land area while cloud covered pixels were not considered. Comparing between the Table 3 and 4, distribution of cloud covered areas among the land, normal water and flooded areas can be understood.

7. Conclusions

Nowadays remote sensing data is being widely used to monitor catastrophic floods occurring over large areas, but the presence of cloud limits the study. In this study, we proposed a technique to recover the cloud covered pixel for flood study. By using this technique one can estimate whether a given area beneath the clouds is dry or covered by water. We estimated the flooded area without and with considering cloud covered pixels, the results described in this paper demonstrate that cloud covered pixels have a significant contribution to increase flooded, normal and land areas.

References

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