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MONITORING AND SPATIAL MAPPING OF SMALL WATER BODIES USING GIS AND REMOTE SENSING

K. M. Shariful Huda[*]
D. N. M. Donoghue[**]
P. J. Atkins[**]

Abstract: Bangladesh is a low-lying flood prone deltaic plain. Excavations are needed to create raised land for safe flood-free homesteads and water bodies for irrigation, and these result in the creation of doba, pukur, dighi and jola. All of these types of small water bodies are almost equally distributed all over the country, except for the beel, which is a natural, saucer shaped depression. For every eight people there is approximately an acre of small water bodies, which range in size from 25-400 sq.m. (doba), 150-1000 sq.m. (pukur), >750 sq.m. (dighi), >2000 sq.m. (jola) and >1000 sq.m. (beel). These small water bodies are commonly used for drinking, bathing and washing, fisheries and aquaculture, duck raising, irrigation, cattle feeding and washing. Despite the importance of small water bodies to the local economy there is no up to date inventory.

This paper investigated the suitable methods for monitoring and mapping spatial distribution of SWB and visibility pattern using Remote Sensing and GIS. This was at a regional scale in four mouzas of Shahjadpur Thana. The data sources were different aerial photographs and satellite images. An integrated RS-GIS was employed to examine the visibility pattern. Results show that the doba, pukur and dighi, when these are not obstructed by surrounding vegetation, can be detected easily in high resolution panchromatic CORONA satellite photography, IRS-ID Panchromatic image and aerial photography. Comparatively large pukurs, dighis and all jolas and beels are detected in all other optical sensors and the SIR-C radar imagery. Multi-temporal images are helpful for identifying the different types of small water bodies as well separating those from other seasonal large water bodies and flooded areas.

INTRODUCTION

The water management systems in many parts of Asia such as Bangladesh are complex and diverse. Agriculture and aquaculture are often the dominant activities in rural life and both are dependent on successful water management. Access to adequate and safe domestic water and sources of water for the maintenance of livestock for at least

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[*] Associate Professor, Department of Geography and Environment, Jahangirnagar University, Dhaka, Bangladesh.
[**] Reader, Department of Geography, Durham University, Durham DH1 3LE, England.

subsistence purposes are part and parcel of rural life. Vital sources of water are the small water bodies (doba, pukhur, dighi, jola and beel) common in rural areas. A researchable constraint in understanding the role of small water bodies in the lives of poor rural parts of south Asia is an appreciation of the dynamic nature of human-environment interaction. Experience has shown that there is a fundamental problem with any developmental work that invests without an up-to-date inventory of resources. Therefore the aim of the paper is to demonstrate the capability of commercial Remote Sensing visibility pattern of spatial distribution of small water bodies to produce a reliable inventory of this important resource.

RATIONALE AND OBJECTIVES

An estimate by the Bangladesh Bureau of Statistics, through the Non-Crops Statistics Section of its Agricultural Statistics Wing, indicated 1.86 million ponds in 1982 (BBS 1984. The Second Phase Agricultural Census Project (1985-90) also carried out a survey, in 1989, and found 1.95 million (BBS, 1994). Since the national-level work was completed, there have been two main developments that call for a new inventory, (i) the number of SWB has increased dramatically, and, (ii) more appropriate remote sensing data is now available and the techniques for interpreting, analyzing and classifying these data also have improved. Thus, there is a persuasive rationale for developing and demonstrating appropriate techniques for conducting a new inventory specifically to see the visibility pattern of SWB at the mouza level. This paper has following objectives.

1. Identification of small water bodies using different Remote Sensing imegery.
2. Validation of the results using a ground survey.
3. Looking at the socio-economic context of results for management planning.

DATA SOURCES

Multi-spectral and panchromatic satellite data with the highest available resolution were used for this research. Previous studies have identified the need for high spatial resolution sensors for SWB detection (Vonders and Clevers, 1999). Based upon this requirement and the availability of images, a range of different satellite photos, images and aerial photography were evaluated (Table 1). An on screen visual interpretation was performed to assess manual on-screen digitizing methods for identifying and mapping the spatial extent of SWB. In addition, the images were classified, using various methods, to identify the water bodies in the area. The classified images were verified using available GIS data and data on the size of the water bodies to derive the potential SWB. Finally, the results were compared with ground truth data collected during the fieldwork.

Table 1: Remote Sensing Data.

Platform name	Sensor	Year	Mode	Media	Resolution/Scale
CORONA	KH-4B	1972	Panchromatic	Film	6 feet
Aerial Photography	–	1974	Black and White	Printed	1:30,000
Aerial Photography	–	1983	B&W-Infrared	Printed	1:30,000
Aerial Photography	–	1990	B&W-Infrared	Printed	1:40,000
SPOT-3	HRV	1989	Panchromatic	Digital	1:50,000
ERS-1	SAR	1993	C-Band	Digital	12.5 metre
SIR-C	SAR	1994	X-Band	Digital	30 metre
X SAR	SAR	1994	C-Band	Digital	25 metre
Landsat 5	TM	1997	Band 2-4	Digital	30 metre
Landsat	TM	1998	Band 2-4	Digital	30 metre
IRS	ID	1999	Panchromatic	Digital	6 metre
IRS	ID	2003	Panchromatic	Digital	6 metre
IRS	LISS	2003	XS	Digital	23 metre

Source: Huda, 2002-2003.

METHODS

The integrated methodology in terms of practical steps was as follows:

1. The remote sensing data was collected from different commercial agencies and analysed as described.

2. Paper maps were collected, dizitised and used for the identification of land use and boundaries, which enabled the location and identification of individual SWB in the field.

3. Surveyed each SWB in getting the spatial extent of the water body and an idea of the surrounding land use context.

4. Each SWB was then surveyed via participatory observation (taking different measurements, finding the creation year and understand the processes and causes of creation using the CORONA image and aerial photographs as a guide for local people to orientate themselves.

5. All of the SWB in each of the four *mouzas* were then mapped and tabulated.

6. The precise boundary identification for each SWB including and not including bank were then performed using different ground observation methods.

7. The in-depth manual image interpretation methods are used for identifying and measuring spatial extent of each SWB in the imagery. The survey was carried out during the dry season when the SWB were not completely filled with water. The remote sensing techniques were used to estimate the SWB area. The field data contained information on both the total of SWB area as well as the water area. The relation between SWB area from groundtruthing and obtained from remote sensing techniques was examined.
8. The result was then possible to compare this with the participatory and direct observational data, the local people's historical perceptions, and the GPS data.

RESULTS AND DISCUSSION

The field survey of four mouzas found 287 SWB. The largest SWB surveyed was 34,812.8 sq metres and, at the lowest end, the minimum doba size is about 1 decimals (40.48 sq metres). 20 SWB were reported as dry during the field survey and of these, ten were also dry during December 2001.The distribution pattern over the different class sizes follows more or less the pattern as observed for the whole study area.

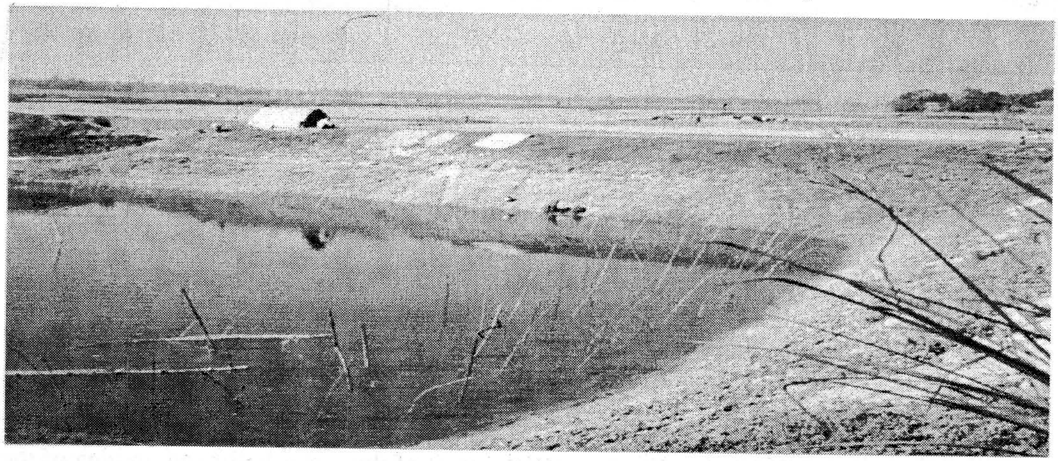
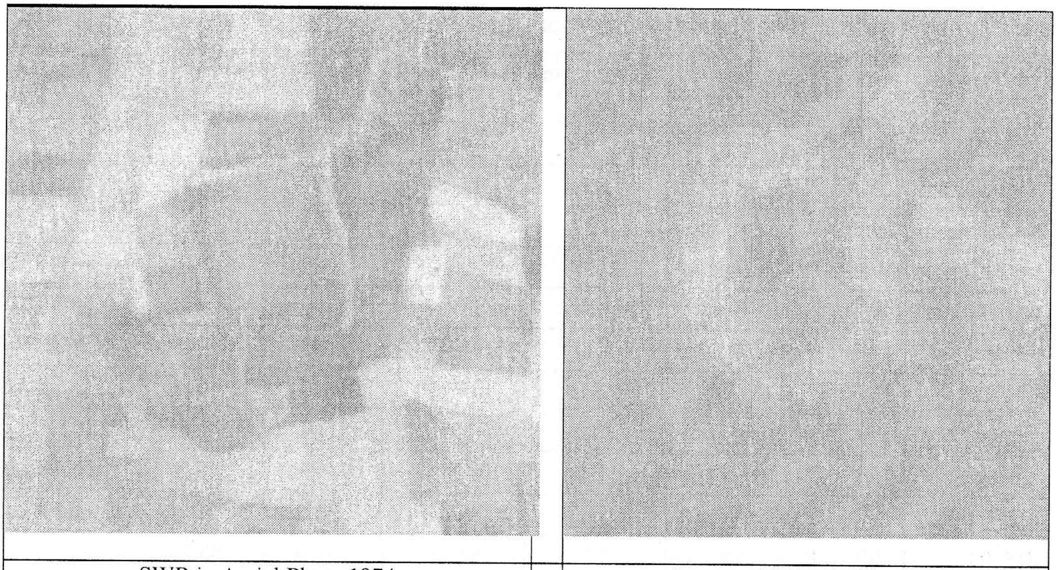


Figure 1: Baoikhola Dighi 1

The digital images were processed to derive a SWB map of the study area. From the preliminary assessment of the images it was observed that there was often a confusion between vegetation in the settlements and water of the SWB. Haze also significantly influenced the spectral properties of the image and had an effect on the results. Surrounding hazes are confused as embankment. The months from December to March are normally the middle stage of the irrigated paddy cultivation and ideally low and medium high lands are covered with paddy. These irrigated paddy fields added big clusters of scattered water pixels to the croplands.



SWB in Aerial Photo 1974

Same SWB in IRS pan 2003

SWBs present in Aerial Photo 1974

Same SWBs changed in IRS pan 2003

Figure 2: An Example of the Identification and Change Detction of SWBs in Shahjadpur.

Table 2 summarises the results of the remote sensing interpretation in terms of the smallest SWB that was detected, in square metres. The reader will immediately notice the wide variation of the total and for the individual mouzas. This is the result of the different resolution of the sensors and their ability to distinguish SWB from surrounding noise. The smallest SWB were detected by the IRS ID for 1999 and 2003, although we must remember that SWB are continually being created or re-excavated and the surrounding vegetation grows or is cut, and comparing sensors through time therefore has the disadvantage that the set of targets is not stable.

Table 2: The smallest water body detected in each mouza (sq. m.)

Platform	Year	Sensor	Resolution (m.)	BaoikholaSq. m	DayaSq. m	Narayandaha	PaschimKharua
CORONA	1972	Panchromatic	2.0	79.62	93.94	83.22	129.35
Aerial photo	1974	AP	1.5	75.28	n/a	n/a	n/a
Aerial photo	1983	AP	1.5	74.37	n/a	n/a	n/a
SPOT, HRV	1989	Panchromatic	16.0	2631.2	3643	4048	26717
Aerial photo	1990	AP	1.5	78.82	n/a	n/a	n/a
ERS1	1993	RADAR	16.0	1173.92	3643	4048	7934
SIR-C	1994	RADAR	13.0	1173.92	1619	4048	7934
Landsat TM	1997	Multispectral	30.0	2631.2	3643	4048	26717
Landsat TM	1998	Multispectral	30.0	2631.2	3643	4048	26717
IRS-ID	1999	Panchromatic	5.8	85.91	73.62	86.44	86.13
IRS-ID	2003	Panchromatic	5.8	84.69	78.73	85.22	87.36
IRS- LISSIII	2003	Multispectral	23.0	800.31	812.65	865.23	833.96

Source: Fieldwork 2001-2003.

Table 2 also shows the interpreted visibility pattern of the remotely sensed data from aerial photographs for 1974, 1983, and 1990; CORONA satellite images for 1972; and IRS images for 1999 and 2003. They are all panchromatic (black and white) images and their resolutions range from 1.8 metres up to 5.8 metres. The IRS-ID Pan sensor results are consistent between both image data sets used apart from one SWB. IRS shows similar capability to1:30,000 scale air photography. However, it is important to note that this visibility is often compromised by surrounding vegetation and therefore precision of aerial measurement is problematic.

Another important caveat should be entered for the aerial photography of 1990. This only covered Baoikhola mouza and is therefore not as full as the other years. Also, with the IRS for 1999 and 2003, it should be remembered that many new SWB have been created in recent years and therefore comparison with the other platforms is not strictly possible in terms of the numbers of features that are in/visible.

The lower resolution optical sensors like SPOT 3 HRV Pan 1989; Landsat TM 1997; and Landsat TM 1998 detected larger SWB (such as beels and jolas but were less successful with dighis, dobas and pukurs. The resolution of SPOT images has now improved (5m Pan) and they will therefore become more useful for this kind of study, not least because the unit price of a SPOT image is less than other high resolution equivalents.

Synthetic aperture RADAR imagery; ERS-I July 1993; ERS-I August 1993 and NASA SIR-C 1994. RADAR also shows poor detection capability for the smaller SWB. It can be concluded that these sensors cannot identify all the types reliably. However, they may be helpful for understanding changes especially the larger water bodies e.g. above 1000

m^2. Particularly, in the case of RADAR data which can be acquired day or night and through cloud. Two further points may be mentioned. First, acquiring the necessary skills for the interpretation of RADAR images is difficult because relatively little relevant literature exists by way of example. Second, the technology of RADAR is including its ground resolution likely to improve to the extent that it may become appropriate for this type of study in future. e.g. RADARSAT-2.

CONCLUSION

This paper has used visual interpretation and digital processing of remotely sensed imagery combined with the participatory field observation to develop a reliable, efficient and cost effective integrated method for detecting, inventorying and finally showing the visibility pattern of SWB in the four mouzas of Shahjadpur. The study used the spectral, spatial and multi-temporal properties of remotely sensed data to differentiate SWB from the other land surface features with the support of information and knowledge acquired from fieldwork under GIS-RS environment.

Successful visual interpretation needs concentration and adequate knowledge of the feature on the real world. Here as much as ancillary knowledge has used can in the interpretation problem and considered the various types of evidence together to identify and detect the SWB. The mentioned integrated method gives full control and knowledge over the visual interpretation of the SWB in the study area. The spatial resolution of the imagery plays vital role in interpreting and identifying the SWB. From Figure 1 we can get an idea of visibility according to size distribution. About two-thirds of the number of SWB has an area that is less than 800 sq. m. The study showed that the remote sensing methods are not suitable for the inventory of SWB with a size of less than 200 sq metres and are not capable of detecting more than a portion of SWB with size less than 80 sq metres. SWB signatures have the tendency to get mixed up with other land surface features. Surrounding homestead vegetation is the noisiest element for detection. The date and season when the remote sensing data are obtained is also important. In the early dry season SWB are full of water and a minimum number of SWB will be dry. More SWB were found to be dry while revisiting the SWB later February and begin of March 2001.

During this study a relationship was found between the derived SWB and the actual SWB area found in the ground. It is only valid for the images and field data used in this study. The smallest SWB area measured based on the screen digitized AOI SWB polygon which not represent the exact extends of those SWB on the field. Visual interpretation method gave nearly as accurate results as the ground observation. The influence of the resolution was very noticeable; higher resolution image resulted in a more accurate visual interpretation. Percentages of successful identification can be improved using as much as ancillary information.

Since the completion of the field work and image analyses of this study, the new era of very high resolution, commercially available satellite images has begun. The IKONOS and Quickbird satellites launched and transmitting high-quality imagery with 1 m panchromatic resolution and 4m multispectral resolution. Using the merging techniques with very high-resolution imagery should provide a method to identify most of the SWB in Bangladesh. However, the listed price for this high resolution imagery and the computer storage processing resources are to be taken under consideration. It is expected that the cost of these data will be reduced as other high-resolution satellites begin operating in the coming years.

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