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Geospatial analysis of Qadirabad-Baloki link canal in Pakistan

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Abstract

Water is an important input for achieving agriculture growth and is considered to be the lifeline of agriculture activities. In Pakistan, unlined canals in almost all irrigation districts loses water through seepage and occasional breaches resulting in water logging, salinity and cropland inundation issues besides reduced water availability for crops irrigation. Water resource managers wish to give seepage proof lining to these old canals, however, due to high price tag of construction and environmental mitigation, initiating such elephantine projects would be excessively expensive. Conventional techniques of seepage detection and identification of areas prone to canal breaches along irrigation canals are expensive, time consuming and labor intensive, and in addition are generally not very accurate. Recent technological advancements in geospatial techniques have made it possible to investigate irrigation canals for various water related anomalies including seepage and sites susceptible to breaches. The goal of this research was to map water related anomalies along a segment of Qadirabad-Baloki link canal in the province of Punjab, Pakistan using on high resolution SPOT-5 satellite imagery.

1. Introduction

Low cost supply of large quantities of water was one of the signs that launched the establishment of modern societies. Until recently, the approach of providing water for human related uses was simple: either locating close to water, as many cities did or store and transport the water to wherever it was required (Henry and Heinke 1996; Gleick 1996). Rapid population growth and industrial expansion initialized the need for increased water supply and distribution. Increasing water demand proposed new challenges for water resources planners and managers. To keep pace with the increasing population, irrigated agricultural production needs to be increased. It is possible through development of new water resource projects (supply management) or efficient water management of available resources (Khare et al. 2007). In line with efficient management of available water resources is to connect two basins through a link canal which is used to transfer water from one source where an adequate supply is available to another where additional supplies are desired.

In this context, the Qadirabad-Baloki Link canal in the province of Punjab, Pakistan was designed and built in 1967 to feed water from the Chenab River to Ravi River. The Qadirabad barrage on the Chenab River is 32 kilometers below the Khanki Headwork's. The other benefit of the Link Canal is to enhance drainage of the area by intercepting a number of drains and conveying their discharge to the Ravi River. Flood flows in excess of the capacities of the siphons were inletted into the link by means of drainage inlets (Binnie 1968).

2. Water Resources of Pakistan

Pakistan possesses around 31 x 10^6 ha of land suitable for agriculture. However, 131 x 10^9 m^3 of water available in the existing network of canal systems can hardly meet the irrigation needs of 14 x 10^6 ha of land. Roughly 4 x 10^6 ha of land is being irrigated through tube wells and other means of irrigation. An additional 9 x 10^6 ha of land can be brought under irrigated agriculture if water is available. The current water deficit is 14 x 10^9 m^3 which will increase to 37 x 10^9 m^3 by the year 2025.

The province of Punjab has very fertile land and possesses the largest network of irrigation system in Pakistan comprising nearly half of the total irrigated area producing more than 90% of the total food production (Panella 2005; Qureshi et al. 2008). Development of irrigation and water resources are key factors to Pakistan's growth (Panella 2005).

Much of the Pakistan's canal systems were developed before partition. Many irrigation systems containing unlined canals are losing water through seepage, resulting in cropland water-logging and salinity issues and also reduced water availability for extending the irrigation district.

Heavy monsoon rainfall causes flooding in canals and forces canal banks to give way at weak points (Washburn 2002; Klemas 2009). Another reason of canal breach may be illegal manmade activities especially in areas where canals are elevated above the surrounding terrain on one or both sides. Floods in the recent past in Pakistan have witnessed many cases of canal breaches, both natural and anthropogenic. These embankments require regular inspection for leakages because if leaks develop it could lead to complete collapse of embankments (Washburn, 2002). To make the canal banks and beds strong enough, water resource managers wish to give seepage proof lining to these old canals which could also save enormous amount of water for extending irrigation districts downstream. However, due to high price tag of construction and environmental mitigation, commencing such hefty projects would be excessively expensive.

Water resource managers are looking for quick methods to closely monitor large areas of irrigation canal systems for application systems, identifying seepage locations, and drainage ways (Nellis, 1982; Pickerill and Malthus, 1998). Conventional techniques of identifying seepage zones and areas prone to canal breaches along irrigation canals are expensive, time consuming and labor intensive, and in addition are generally not very accurate (Pickerill and Malthus, 1998).

3. Remote Sensing Techniques

Remote Sensing-derived information is critical to the successful modeling of numerous natural processes such as, water-supply estimation; eutrophication studies; and nonpoint source pollution (Walsh et al., 1999; Stow et al., 2003 as cited in Jensen, J. R., 2005). Remote sensing has the ability to collect information related to seepage and canal banks susceptible to breach over a large area in a short time and repeated time intervals, especially with recent developments in sensor functionality and both temporal and spatial image resolution (Ahmad et. al. 2011; Klemas 2009). To capture images of flooding and canal breaches, high resolution airborne and satellite remote sensors could be efficiently utilized. When extracting urban/suburban information from remotely sensed data, it is usually more important to have high spatial resolution (1–5 m) than a large number of spectral bands. Near-infrared spectral bands are very effective for discerning inundated urban or natural areas from dry ones. Although urban areas require high-resolution data, such as the 0.6–4-m resolution, many of the surrounding natural inundated areas, such as wetlands, are more efficiently monitored with medium-resolution satellite systems, such as the Landsat Thematic Mapper (TM) or SPOT, at 10–30-m resolution (Klemas 2009). The SPOT - 5 and other remotely sensed images may be successfully used to give water resource manager a clear view of inundated areas and help plan pumping and other recovery efforts. Remote sensing can be utilized successfully as a promising technique for the identification and mapping of various anomalies along irrigation canals (Arshad, M. 2008; Washburn, 2002; Pickerill and Malthus, 1998; Nellis, 1982). With the availability of higher spectral and spatial resolution sensors in the market, it is feasible to investigate and map seepage, canals breach and farmer's encroachment locations without interfering with the smooth flow of water in canals.

Land cover classification using satellite imagery is commonly based on spectral information in the individual pixels ignoring the information in the neighboring pixels. Spatial filtering techniques using information in neighboring pixels may however, contribute significantly to an improvement of the classification (de Jong 1993). In this study, spatial filtering and/or spectral ratioing techniques have been applied on SPOT-5 data to investigate and verify the above stated anomalies along the Qadirabad-Baloki link canal in the province of Punjab, Pakistan.

4. Study Area

The 527-cumec (527 m^3/s) Qadirabad-Baloki Link Canal (see Fig. 1) was taken out from the Barrage in 1967 (Water and Authority 1967). Its center lies at a latitude of 32.234 and longitude of 73.689 and it has an elevation of 203 meters above sea level. This link is fed by water from Jhelum River carried through the Rasul-Qadirabad Canal.

The flat plain is largely made of alluvium, over 300 m deep, deposited by the Indus River and its tributaries, which flow through the provinces of Punjab and Sindh to the Arabian Sea near Karachi (Akhtar 2003). The average annual temperature in the study area is estimated to be around 24 ^{0}C. The average annual rainfall in the area is recorded as 855 mm. Most of the rainfall occurs during the monsoon period (July –

September) which is estimated to be around 138 mm whereas, winter rainfall is 70 mm.

The canal head withdrawals in Kharif (April- September) 2012, decreased by 4 percent and stood at 71 x 10^8 m^3 as compared to 75 x 10^9 m^3 during the same period last year. During the second planting season, Rabi (October-March) 2012-13, the canal head withdrawals increased by 8 percent and stood at 40 x 10^9 m^3, compared to 29 x 10^9 m^3 during the same period of last year (Pakistan Economic Survey 2012-13).

5. Methodology

A SPOT-5 image (a bundle of panchromatic and multispectral bands) (Path 199, Row 286) dated 21-10-2008 was used in this study. SPOT-5 panchromatic (PAN) band (595.0 nm) has a spatial resolution of 2.5 meters, whereas, SPOT 5 multispectral sensor has four bands, band-1 is Green (545.0 nm), band-2 is Red (645.0 nm), band-3 is Near-Infrared (835.0 nm) and band-4 is Shortwave Infrared (1665.0 nm). Spatial resolution of Visible-near-infrared (VNIR) bands and Shortwave Infrared (SWIR) band are 10 meter and 20 meters respectively. Firstly raw images was calibrated using the Environment for visualizing images software (ENVI™ 4.7) on a DELL™ OPTIPLEX 960 platform and then visible-near-infrared (VNIR) and shortwave-infrared (SWIR) bands were converted to apparent reflectance using the commercially available atmospheric correction software "FLAASH™".

Pan sharpening is a technique that synthesizes a high spatial resolution multispectral image from a low spatial resolution multispectral image and a high-resolution panchromatic (PAN) image. The multispectral (VNIR) bands (in apparent reflectance) were pan-sharpened with the SPOT – 5 panchromatic band by the application of Graham-Schmidt technique to obtain a resolution of calibrated panchromatic band (2.5 m). According to (Du 2007) Gram Schmidt method generates good results as compared to Brovey and multiplicative methods. Spectral ratioing techniques were carried out on the pan-sharpened SPOT-5 image to further enhance visual interpretation of the target area. These methods helped in extracting maximum information from the derived products, minimizing the reliance on a *priori* or outside information.

6. Results and Discussion

According to Binnie (1968) "the link canal is situated in a badly waterlogged area with high sub-soil water levels. Although there are a great number of drainage channels in this area, none have adequate capacity to handle the runoff from major storms, and this area is perennially subjected to flooding with consequent heavy damages to crops and improvements.

From the 2.5 m pan-sharpened SPOT – 5 image, red band was ratioed with near-infrared band as depicted in figure 1.

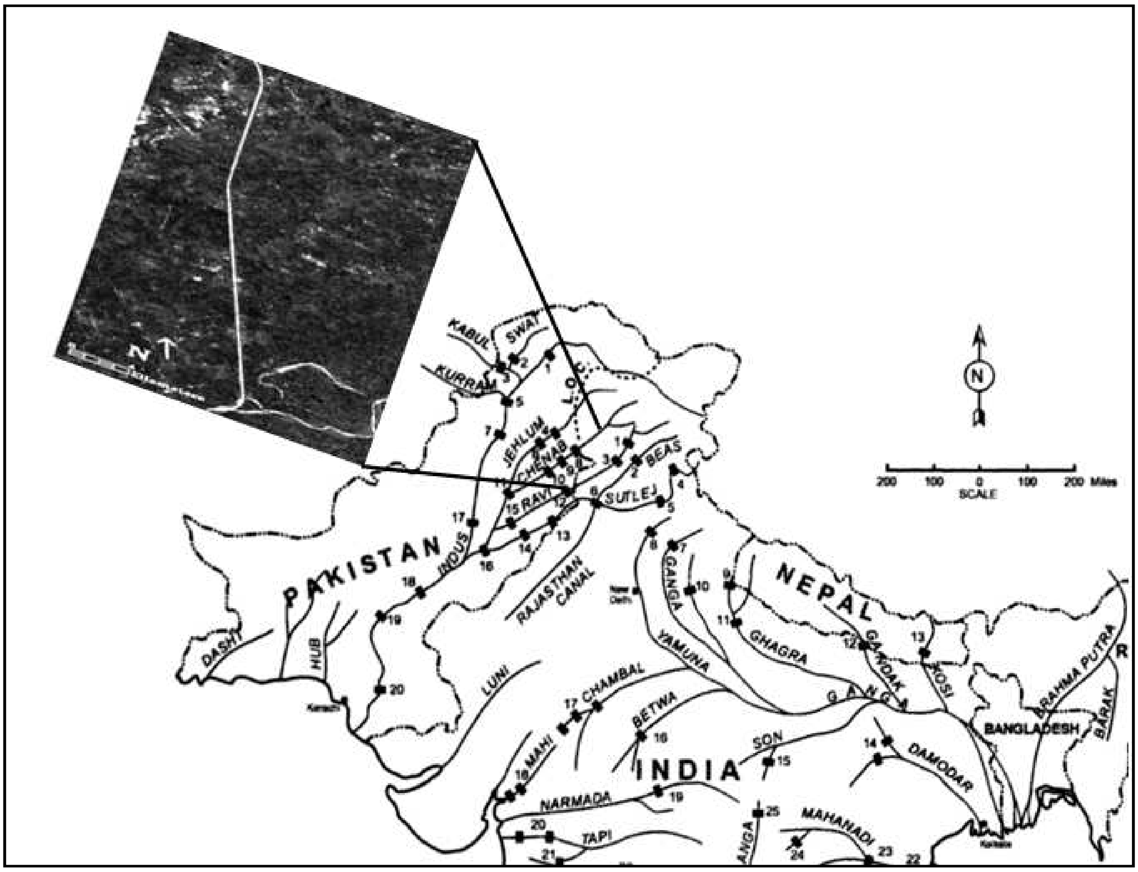


Figure 1. *A segment of the Qadirabad-Baloki Link canal bringing the water from River Chenab into River Ravi (Ratioed image of red to Near IR band).*

Such ratioing made features like water to reflect in lighter tones, whereas, features such as vegetation to appear in darker tones because of their relatively low reflectance in the red band and high reflectance in the near-infrared band (Lillesand, 2008). A false color composite image as depicted in figure 2 is generated by the combinations of two band ratios and a green band. Here the features of interest such as vegetation, water and the risk of canals breach is highlighted in this image.

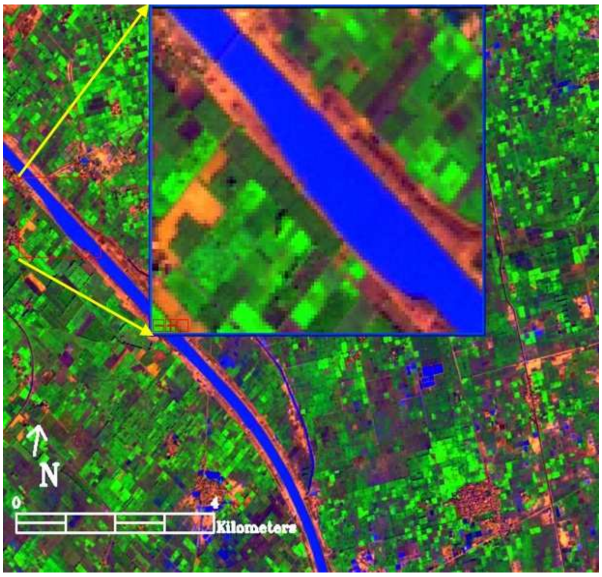


Figure 2. *A false color composite image highlighting vegetation, water and risk of canal breach.*

As shown in figure 3, a high pass spatial domain filter was applied to a single 2.5 meter high resolution panchromatic (PAN) band. In this scene, the vegetation is suppressed enhancing the visual interpretability of the canals breach risk.

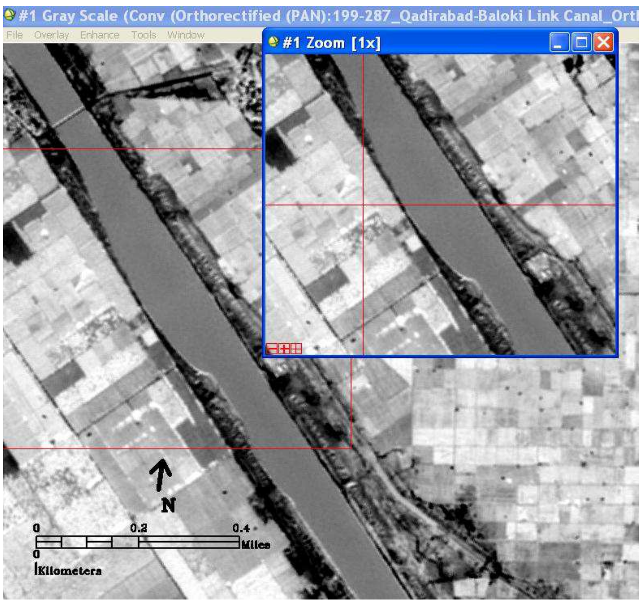


Figure 3. *An enhanced high pass image of the same area suppressing vegetation shows the risk of canal breach.*

Figure 4, highlights the thinning of canal bank due to soil erosion caused by canal water flow and encroachment by the farmers, thus, making the area susceptible to canal breach.

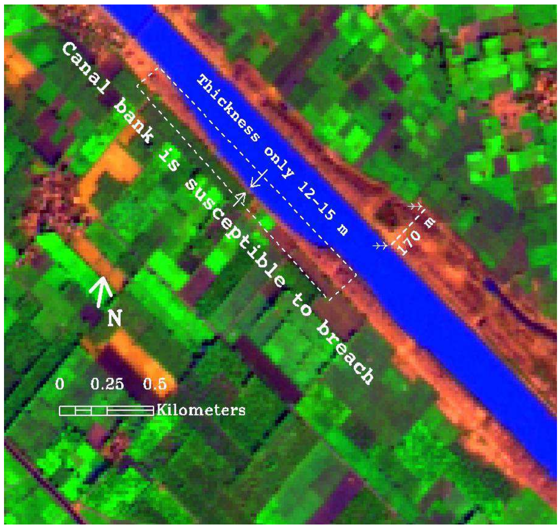


Figure 4. *Analysis of farmer's encroachment and canal breach risk.*

Figure 5 shows canal flooding and its aftereffects. The area on both sides of the canals seems to be flooded with canal water. The widespread damage to crops and property (village on the right side) can be clearly seen on this image. Such images can help determine the extent of flooding and can assist the disaster relief agencies in assessing the damages to the crops and property loss. One of the possible reasons causing this damage might be guessed as water overflow due to heavy down pouring exceeding the designed intake capacity of the canal and resulting in canal breaching on both sides.

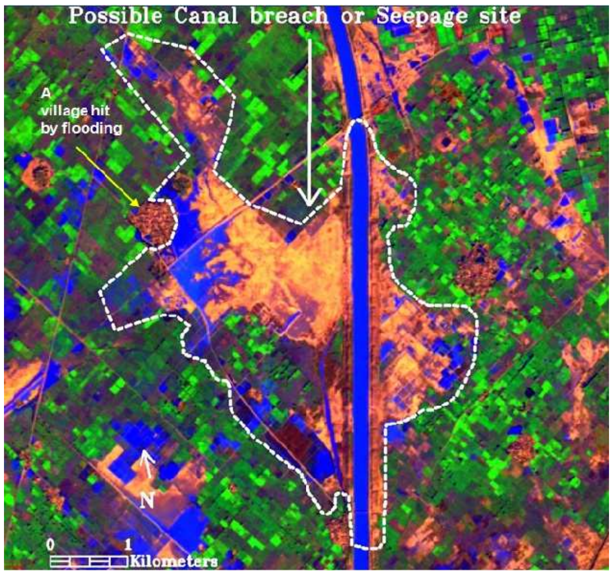
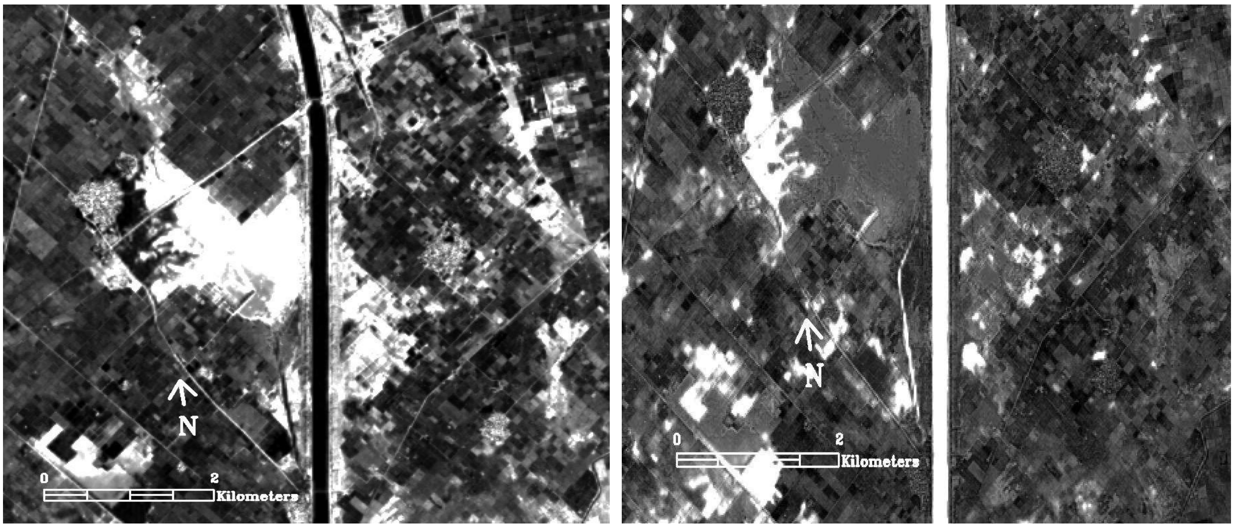


Figure 5. *A location suspected to be inundated by canal breach.*

Figure 6 (a) and (b) shows the same location in various ratioed images. Figures 7 (a, b & c) are composite, ratioed and high pass images showing another seepage or flooded area. Here also water can be seen on both sides of the canal. The possible reason might be the area is poorly drained.



(a) (b)

Figure 6. *Same area is shown in various ratioed images*

(a) (b) (c)

Figure 7. *Composite, ratioed and high-pass images of seepage and/or canal breach close to canal tail end.*

7. Conclusion

Many irrigation systems containing unlined canals are losing water through seepage resulting in water logging and salinity issues of surrounding croplands and loss of agriculture produce. Conventional corrective methods are expensive, time consuming, and labor intensive, especially when considering large irrigation districts.

Application of remote sensing techniques as shown above can be successfully utilized for the identification of water related anomalies along irrigation canals. By applying remote sensing techniques, the water resource managers can monitor the condition of canals for encroachments, risks of canals breach and suspected seepage sites and can promptly take corrective measures. In the near future, near real time monitoring of the irrigation canals would be possible with high resolution satellite sensors due to short revisit time of the target areas.

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