Journal of Rural Development, Vol. 38 No. (1) pp. 55-77
NIRDPR, Hyderabad.

# USE OF REMOTE SENSING AND GIS FOR IDENTIFYING TANKS AND REHABILITATION BENEFITS TO THE RURAL AREAS

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## ABSTRACT

*Water storage is crucial for water security (WS) in countries with monsoon-driven climates. Tanks significantly contribute to WS by augmenting water supply to agricultural production in parts of south and Southeast Asia. The present paper assesses the potential locations of small tanks for rehabilitation to enhance WS. The Bhadrachalam catchment from the Godavari river basin, India was selected for the study. Remote Sensing and Geographical Information Systems techniques were used to identify the small tanks and water spread areas for augmenting storage. The cost -benefit analysis was also carried out for the identified tanks with various scenarios, cropping pattern and management options. The returns from desiliting, increase in area under the tank command with paddy and cotton crops are found to be beneficial. It concludes that rehabilitation of small tanks should be considered a priority investment as it will not only enhance WS and financial benefits to local communities, but also augment river flows in the non-monsoon season.*

**Keywords**: Water Security, Geographical Information System, Remote Sensing, Cost-Benefit Analysis, Godavari River Basin.

## Introduction

Water storage is crucial for water security (WS) in the monsoon-driven climatic countries like India. The utility of storages will be more prominent with increasingly variable rainfall and climate change (Pachauri and Reisinger, 2007). The monsoon rains between June and September contribute to 80 per cent of the total precipitation in many Indian River basins. Many of the surface storages have been built since 1950's, mainly to meet the water requirements of irrigation, domestic and industrial sectors (Shah and Raju, 2002). In India, the net irrigated area is 63.6 million hectare (Mha), with water

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being supplied from multiple sources: from canals (26.4 per cent), tubewells (61.7 per cent), tanks (2.5 per cent) and other sources (9.3 per cent) (GoI, 2014). Although tank irrigated area is low, tanks are one of the most important and oldest traditional water harvesting structures. And traditional village tanks have sustained agricultural production and provided domestic water needs to millions of rural people over the past 2000 years (Nagarajan, 2013).

Village tanks, some of which were constructed by ancient kings and village communities, create buffer storage to mitigate the impacts of floods in the monsoon months and of droughts in the non-monsoon period (Rodrigues et al., 2012). Tanks in the Indian context are also inextricably linked to the socio-cultural aspects of rural life and have historically been an indispensable part of the village habitat, sustaining its socio-ecological balance. They play a major role in the livelihood of people and ecosystems services. However, it has been noted that tank storage has begun to decrease to less than half over the years due to various factors. Some of them include development of large-scale gravity irrigation systems, technology development in groundwater pumping, poor community participation and sedimentation. To enhance the WS at the village level in rural areas tanks need rehabilitation and restoration (Babu and Manasi, 2008).

Funding agencies also require accurate information of the present status of siltation, damages to link channels or tank bunds, etc., for investments. Hence, the present study uses geo-spatial techniques to identify small tanks that can enhance WS of the rural villages. It also analyses the present status of the water spread area of the tank using Remote Sensing and GIS technology (RS & GIS). Remote sensing data are efficient and can make precise measurement for delineating water bodies (Kääb et al., 2005). The water boundaries of tanks can be delineated with satellite remote sensing techniques (Frazier et al., 2000; Xu, 2006). Multi-temporal satellite imageries can be used to identify tanks and estimate storage potential in the catchments. In the following sections, the methodology followed in identification of such water bodies/tanks, study area details, review of literature on water security and benefits of tanks and rehabilitation are provided in detail.

## Literature Review

Water Security (WS) is defined as the reliable availability of an acceptable quantity and quality of water for health, livelihoods and production, coupled with an acceptable level of water-related risks (Grey and Sadoff 2007). WS is high in the global development agenda. Often, population expansion, economic growth and climate change increase water-related risks (Vörösmarty et al., 2010). WS requires attention in many dimensions: for food production and livelihoods, for good health of people, and for culture and environment (Falkenmark, 2001).

WS often depends on quantity and quality of water use, return-flows and interactions with upstream and down-stream users. The climate change and the rainfall variability also exacerbated the situation and lead to delayed cropping seasons and farmers finding themselves with no or less water for their farming activities. These dry seasons have ultimately affected the yields in the agriculture sector. Issues are further complicated with the resulting competition from the other sectors of water use: drinking and sanitation, energy, industries and environment. There has been tremendous increase in the amount of water required for irrigation, drinking and industry (Dwivedi and Ramana, 2005). So then, what is the solution to this vexing issue? Storing of water in water harvesting structures is one way of reducing the dependence of agriculture on being solely rain-fed. Interventions like development and rehabilitation of traditional tanks, farm ponds, Managed Aquifer Recharge (MAR) structures and climate change adaptation practices are essential to circumvent the WS issues(Dillon et al., 2009). The MAR is also used to address a wide range of water management issues which include storing water in aquifers for future use, smoothing out supply and demand fluctuations as part of an integrated water management for water security. Gale et al. (2006) describes Managed Aquifer Recharge (MAR) as intentional storage and treatment of water in aquifers.

However, the multiple uses and benefits of tank systems is playing a significant role in the country. Tanks are used as a source of water for irrigating crops and pisciculture. Silt from tank beds has been used for improving fertility of agricultural land and trees grown on tank bund are the source of small timber and domestic fuel (Dwivedi and Ramana, 2005). Tanks also play an important role in the ecological system and help maintain biodiversity.

Since the major irrigation system has reached its maximum potential and groundwater has been over-exploited, minor irrigation systems, which not only recharge groundwater but also eco-friendly, need to be developed. This calls for restoration and maintenance of the existing tanks that are in poor condition and construction of new tanks. The study dating back to the 11$^{th}$ and 12$^{th}$ centuries describe tank construction activities in Warangal district in Andhra Pradesh (Reddy, 1973). In southern India, under the Chola, Pandya, Pallava, Chera, Vakataka, Kakatiya and other dynasties, a vast network of tanks and canals was developed that served to irrigate crops and enhance agricultural production (ADB, 2006). For assessment of the potentials of irrigation tanks, maintenance and management of the existing tanks, information on number, spatial extent of water, storage capacity, land use/land cover in the anicuts and ayacuts, status of land degradation is a pre-requisite. An intimate knowledge of the spectral response pattern of water bodies is a key to detect small irrigation tanks using remote sensing data. Remote sensing has been found to be quite effective in finding water spread tanks and development of agriculture in tank command areas (Dwivedi and Ramana, 2005). The characteristic absorption feature of water bodies can be utilised for detection of water bodies from multi-spectoral measurements made by Lamdsat-MSS/TM and SPOT-MLA (Moore and North, 1974; Rose and Rosendahl, 1983; Pietroniro and Prowse, 1996). Krishnaveni et al. (2011) identified the drainage course problems in the tank cascade system using GIS. As many tanks are found in cascade form, they are hydro-geologically and socio-economically interlinked in terms of storing, conveying and utilisation of water. Previously, walk-through survey was conducted to identify the cascade drainage problems.The RS-GIS can now help the irrigation departments, policymakers and corporate sectors in decision-making for rehabilitation of the tanks based on the satellite imageries.

The very recent Mission Kakatiya programme taken-up by the Government of Telangana, India in 2014 is also recording the tank information by geo-tagging. In addition to identification of tank and rehabilitation, there is also a need to understand the costs and returns that can benefit the rural community. Studies have shown that the rehabilitation activities are benefiting the landlords and landless agricultural labourers marginally as wages.The per-capita income in the rural areas was able to increase by about 66 per cent due to rehabilitation (ADB, 2006).The investments on different tank management systems reveal that the net present worth to be positive and the BC ratio to be more than 1.5 (Amarnath and Raja, 2006). Application of silt also increases the yield, water recharge and enhanced livelihood options by and large (Anuradha and Ambujam, 2012). However, there is a gap in analysing different scenarios with alternative cropping patterns and benefits to derive. The present paper will bridge the gap with different scenarios and identifying the tanks by RS-GIS.

## Methodology

The focus area of the study is a small catchment in the downstream of the Godavari river basin.The Godavari is the third largest river basin in India, with 110 billion cubic metres (Bm3) of total renewable water resources. The catchment area of the basin—31,281,200 Ha (312,812 km$^2$)--spreads across seven States: Maharashtra, Telangana, Andhra Pradesh, Madhya Pradesh, Chhattisgarh, Odisha and Karnataka (CWC 2014). The basin is subject to seasonal climate with highly variable rainfall regimes. Floods and droughts within the same year are a recurrent phenomenon. The catchment area is reported to have many individual tanks but few tank cascades. A cascade system is formed by the interlinking of tanks, where the surplus runoff of upper tanks becomes a source of water for the lower tanks. They are managed generally by tank-based village communities (Sengupta, 2013). Many of these tank systems require rehabilitation and restoration.This study assesses the potential of small tanks, with a special focus on cascading tanks, for the purpose of enhancing WS in the Bhadrachalam Catchment (BC), which is situated in the Khammam district of Telangana State , India (Figure 1). The Khammam district is bounded by Krishna, East and West Godavari and Nalgonda districts from the east, south, west and north and by the State of Chhattisgarh borders towards the north. The area is situated on the banks of Godavari river and is about 312 kilometres (194 miles) to the east of State capital, Hyderabad. The BC encompasses approximately 322,300 Ha, which is about one per cent of the total area of Godavari basin (Table 1). The focus area of BC is the river section between Dummugudem tail pond and Bhadrachalam bridge. The major tributary within the BC is Kinnerasani river.

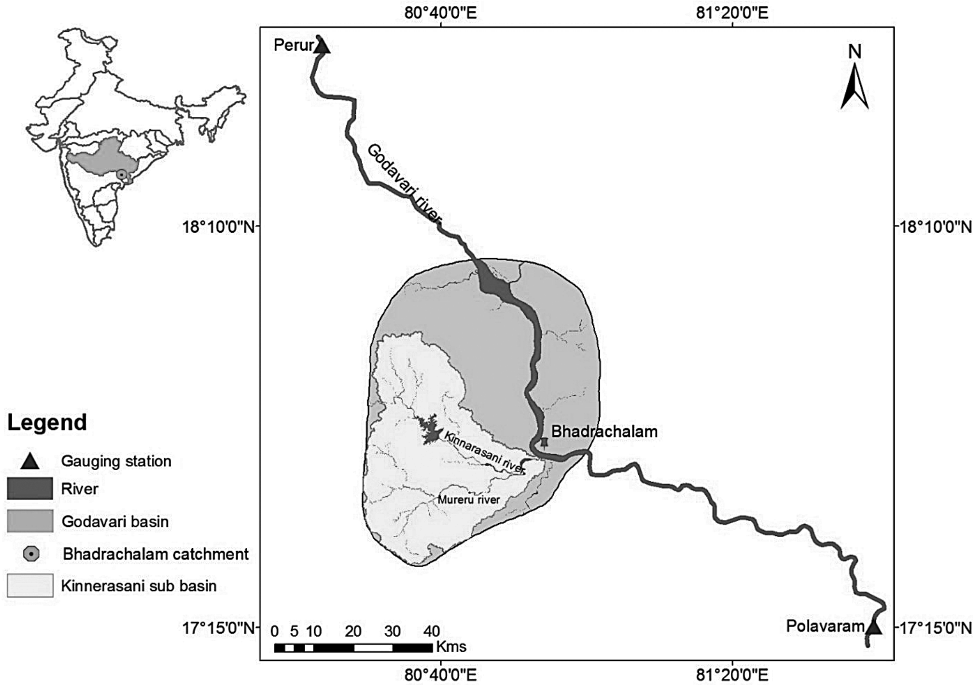


**Figure 1: Bhadrachalam Catchment in the Godavari basin**

**Table 1: Demography and Land Area**

| Factor | Units | Bhadrachalam catchment | Khammam district | Godavari river basin |
|---|---|---|---|---|
| Land area | Ha | 322,300 | 1,602,900 | 31,281,200 |
| Population in 2011 | 1000s | 1,027 | 2,797 | 70,510 |
| Rural population in 2011 | 1000s | 723 | 2,141 | 50,860 |

Sources: Population Census (GoI 2012)

The BC has a population of one million in 18 mandals in the Khammam district. Majority of the population (70 per cent) are rural, and depend on agriculture-based activities for their livelihoods. Overall, 17 per cent of the population of the Khammam district belong to Scheduled Castes (SC), and 27% belong to Scheduled Tribes (ST), of which the

Bhadrachalam revenue division has the largest ST population (51per cent), and the lowest SC population (12per cent) (GoAP 2012).

Rice, maize, pulses, cotton and tobacco are the major crops grown in the BC, of which rice, maize and tobacco are the major irrigated crops (Table 2). The BC depends mainly on groundwater, tanks and direct lift from the river for its agriculture water use.

**Table 2: Cropped and Irrigated Areas in 2010-2011**

| Sources of irrigation and major crops | Irrigated area (1000 Ha) | | Cropped area (1000 ha) | |
|---|---|---|---|---|
| | Bhadrachalam catchment | Khammam district | Bhadrachalam catchment | Khammam district |
| Major crops grown | | | | |
| Rice | 40.3 | 184 | 69.8 | 218.2 |
| Jowar | 0 | 0 | 1.8 | 2.5 |
| Maize | 6.1 | 22.6 | 6.6 | 35.1 |
| Gram | 0 | 0 | 14.4 | 45.0 |
| Cotton | 0 | 15.3 | 22.8 | 148.6 |
| Groundnut | 0.8 | 4.6 | 2.5 | 6.4 |
| Tobacco | 4.1 | 4.5 | 4.1 | 4.5 |
| Other food | 13.2 | 44.3 | 25.3 | 81.0 |
| Other non-food | 2.1 | 3.8 | 10.5 | 29.0 |
| Irrigated area by different sources | | | | |
| Canals | 7.6 | 89.3 | - | - |
| Tanks | 18.7 | 58.5 | - | - |
| Tube wells | 26.3 | 63.5 | - | - |
| Shallow wells | 0.9 | 44.2 | - | - |
| Lift irri. (river) | 12.5 | 18.8 | - | - |
| Others | 0.7 | 4.6 | - | - |
| Total area | 66.6 | 279.1 | 157.8 | 570.3 |

Source: Directorate of Economics and Statistics, Andhra Pradesh (GoAP, 2012).

**Data**

This study mainly focuses on the status of tank in the year 2013 using geospatial tools. It estimates the storage capacity and the actual storage. To obtain such data, processing of satellite images of pre- and post-monsoon seasons is required. This also helps in assessing the tank water spread areas of pre-monsoon rains (where tanks are almost empty), and post-monsoon rains (where tanks are almost full).

For the year 2013, pre and post-monsoon imageries of Landsat 8 were taken. The Landsat 8 satellite images the entire planet earth every 16 days and captures approximately 400 scenes a day, which can be downloaded online (http://earthexplorer.usgs.gov/). The image consists of six spectral bands with spatial resolution of 30m and a panchromatic band with a spatial resolution of 15m. Spatial resolution refers to the size of the smallest possible feature that can be detected from an image and spectral bands refer to the range of wavelengths that an imaging system can detect (Lillesand and Kiefer, 2000).

The study area was covered by two Landsat scenes per season. Therefore, the images of May 1 and May 24 were used for pre-monsoon season. November 9 and October 31 imageries were used for the post-monsoon season (Table 3). The two scenes of pre- and post-monsoon were mosaiced.

**Table 3: Description of the RS Images**

| Satellite | Year of data acquisition | Spatial resolution (m) | Spectral bands |
|---|---|---|---|
| Landsat 8 | 01-05-2013<br>24-05-2013<br>31-10-2013<br>09-11-2013 | 30/15 | 0.450 - 0.515 μm (Blue band)<br>0.525 - 0.600 μm (Green band)<br>0.63 - 0.680 μm (Red band)<br>0.845 - 0.885 μm (NIR band)<br>1.560 - 1.66 μm (SWIR band1)<br>2.10 - 2.30 μm (SWIR band2)<br>0.500 - 0.680 μm (Pan band) |

In order to identify links between tanks, topo sheets (scale 1:50000) of the study area were obtained from Survey of India, Hyderabad. Digital Elevation Model (DEM) for the study area was extracted from Advanced Space Borne Thermal Emission and Reflection Radiometer (ASTER) at 30m spatial resolution, which is a Japanese sensor and is one of five remote sensory devices on board the Terra satellite orbiting the earth.

## Methodology

The methodology adopted for processing the RS imageries for the identification of tanks is illustrated in Figure 2.The steps involved for the analysis are as follows:

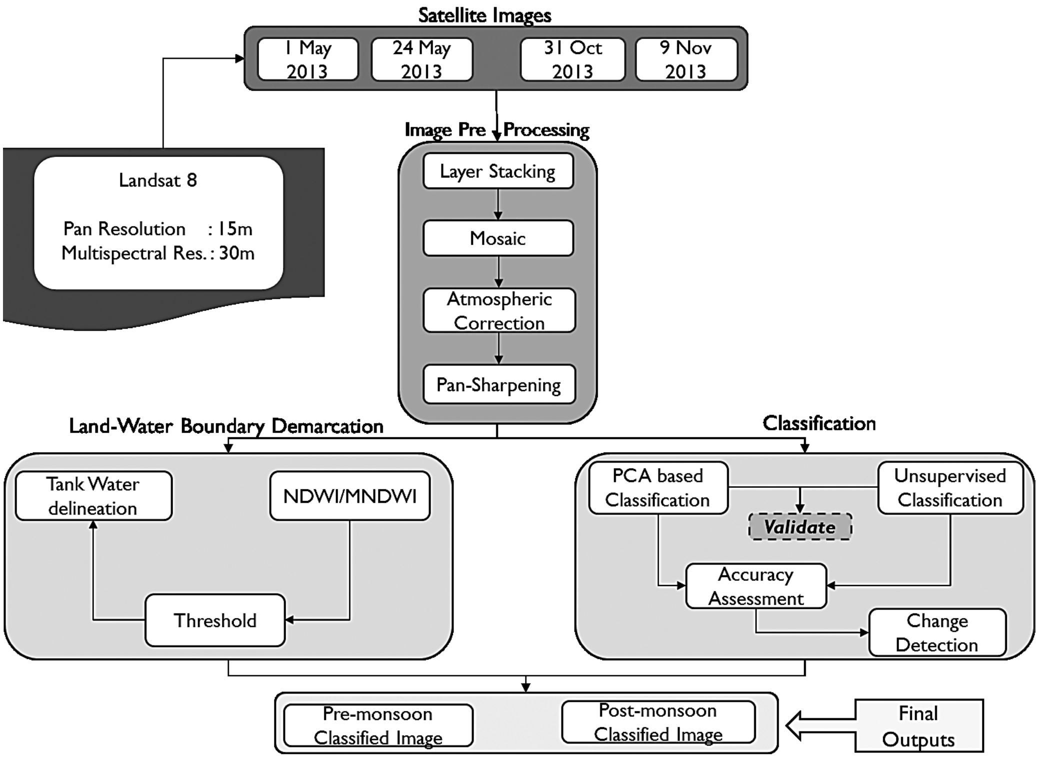


**Figure 2: Methodology for Identification of Tanks and Quantification**

***Image Pre-processing :*** The effects of the atmosphere are part of the signal received by the sensing device. It is, therefore, important to remove the atmospheric effects from the RS images. The dark object subtraction (DOS) method was used to remove the haze from the top of satellite images (Hadjimitsis et al., 2010). The DOS searches for the darkest pixel value and assumes that the dark objects reflect no light. Any value greater than zero must result from atmospheric scattering. The scattering was removed by subtracting this value from every pixel in the band.

The Landsat 8 images were pan-sharpened by the merging of high-resolution panchromatic with lower resolution multispectral bands, to create a single high-resolution colour image (Brower and Laben, 2000).

***Image Processing:*** Image processing and analysis techniques have been developed to interpret remotely sensed images and to extract as much information as possible from the images. The image processing techniques assist the analyst in the qualitative interpretation, i.e., visual interpretation as well as the quantitative interpretation of images, i.e., image classification.

**i. Area Delineation**

Extraction of the extent of the water body by using remote sensing is an important step in the methodology. There are various methods for the extraction of water information from remote sensing imagery. In this study area, MNDWI (modified normalised difference water index) enhanced the open water features (tanks) efficiently. A threshold was determined from bands to discriminate water from land. It has been analysed that the MNDWI enhanced tanks, by suitably suppressing the noise from land.

**ii. Image Classification**

Classification is used to assign corresponding classes with respect to groups with homogenous characteristics. The aim here is to discriminate multiple pixels within the image. The first method was subjected to a principal component analysis (PCA) and then applying clustering to the first principal component to classify and enhance the tank area. In the second method, original remotely sensed satellite images were classified using unsupervised ISODATA algorithm. And these two methods were used to validate and to quantify the tank area dynamics and to estimate tank area losses as well. Further two approaches were also analysed to choose the best method.

***(a) Unsupervised classification :***

One of the most widely used unsupervised clustering algorithms is the ISODATA (Iterative Self-Organising Data Analysis) technique (Tou and Gonzalez, 1974). The ISODATA procedure has also been used for tank water classification. This method uses a maximum-likelihood decision rule to calculate class means that are evenly distributed in the data space and then iteratively clusters the remaining pixels, using minimum distance techniques. Each iteration recalculates means and reclassifies pixels with respect to the new means. This process continues until the number of pixels in each class changes by less than a selected pixel change threshold or until a specified maximum number of iterations is reached.

In simple terms, unsupervised classification groups the pixels of the image into separate clusters depending on their spectral features. Each cluster will then be assigned a land cover type. Unsupervised classification (using ISODATA algorithm) is an effective method for extracting land cover information from the remotely sensed data.The ISODATA classifier provided a relatively quick and easy way to delineate landform elements and broadly seven major classes were identified.

***(b) PCA based classification:***

The PCA is an approach that transforms the remotely sensed data into a new set of uncorrelated variables that capture the essential information of the RS data. The PCA is essentially a mathematical technique for reducing the dimensionality of a data set (Jackson, 1983). In remote sensing (RS), it aims to reduce the number of bands to reorganise the information. PCA can be used as a change detection technique in remote sensing (Jensen, 1996; Fung and LeDrew, 1987; Muchoney and Haack, 1994). PCA is typically used to identify factors that describe spectral variance, to reveal the underlying dimensionality of multivariate data and to compress image data and concentrates almost all the information in the first two or three components (Mulla, 2013). The first principal component was classified using ISODATA algorithm to generate seven major land cover classes.

### 3.3 Tanks Interlinking

To identify the links between tanks - the stream network thematic layer, toposheet layer and Google Earth were overlaid on classified satellite images (Figure 3). ASTER (30m) DEM was used to generate stream network and the toposheets were geo-referenced. These layers were overlaid on Google Earth to identify the links between tanks.

The images were classified into different land use and land cover classes. This helps in identification of possible water bodies in the study area.

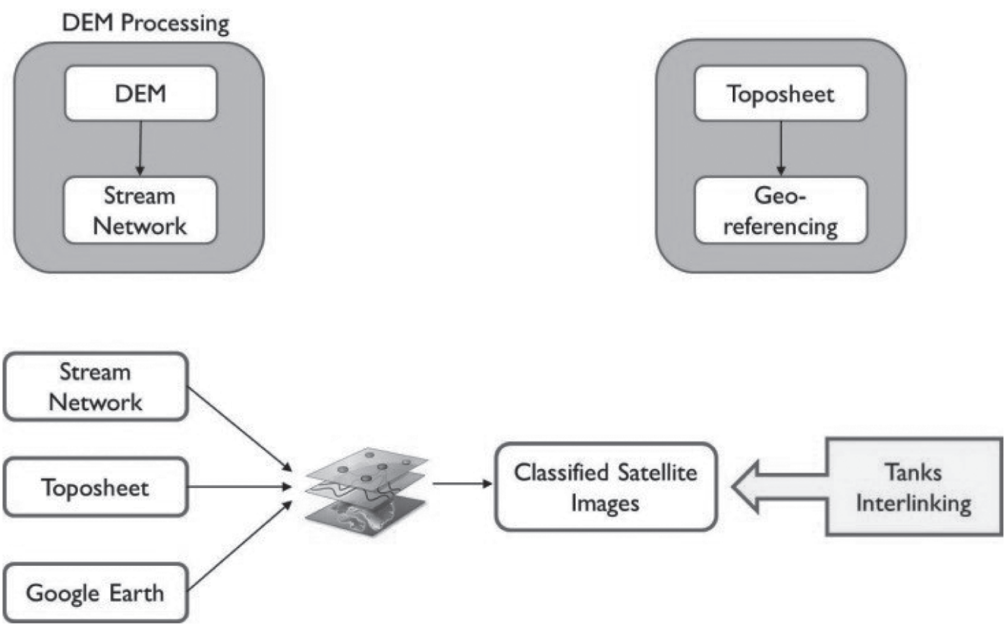


**Figure 3: Methodology for Identification of Linkages**

## Results

***Accuracy Assessment:*** Accuracy assessment was performed on classified images for validation. The overall user's accuracy (UA), producer's accuracy (PA) and kappa statistic were calculated on a classified image to evaluate the classification accuracy (Jensen et al., 1996). The PA is a measure of commission error indicating how well the training set pixels of the given land cover type have been classified, and the UA is the omission error indicating the probability that a pixel classified on a map actually exists on the ground. The kappa is a measure of agreement between the model's predictions and reality (Senseman et al., 1995).

It has been observed in this analysis that both methods provided almost the same result with more or less the same variations. The accuracy assessment of PCA-based classification shows that overall accuracy is 86 per cent and 92 per cent and Kappa coefficient is 0.78 and 0.86 for pre-monsoon and post-monsoon, respectively. From the assessment of unsupervised classification, overall accuracy is 88% and 96% and kappa coefficient is 0.73 and 0.86 for pre-monsoon and post-monsoon respectively.

The satellite imageries are classified into agriculture, forest and water bodies. The area under agriculture, forest and water bodies in the BC are 48.7per cent, 44.5 per cent and 3.8 per cent, respectively. Figure 4 shows the water spread area of tanks in the BC in pre-monsoon and post-monsoon seasons. There are approximately 13 major tanks in the BC within an area greater than 40 ha and approximately 370 small tanks within an area between 1 ha to 40 ha. The major tanks in the BC are Tummala, Sambai Gudem, Chandralagudem, Morampalle, etc.

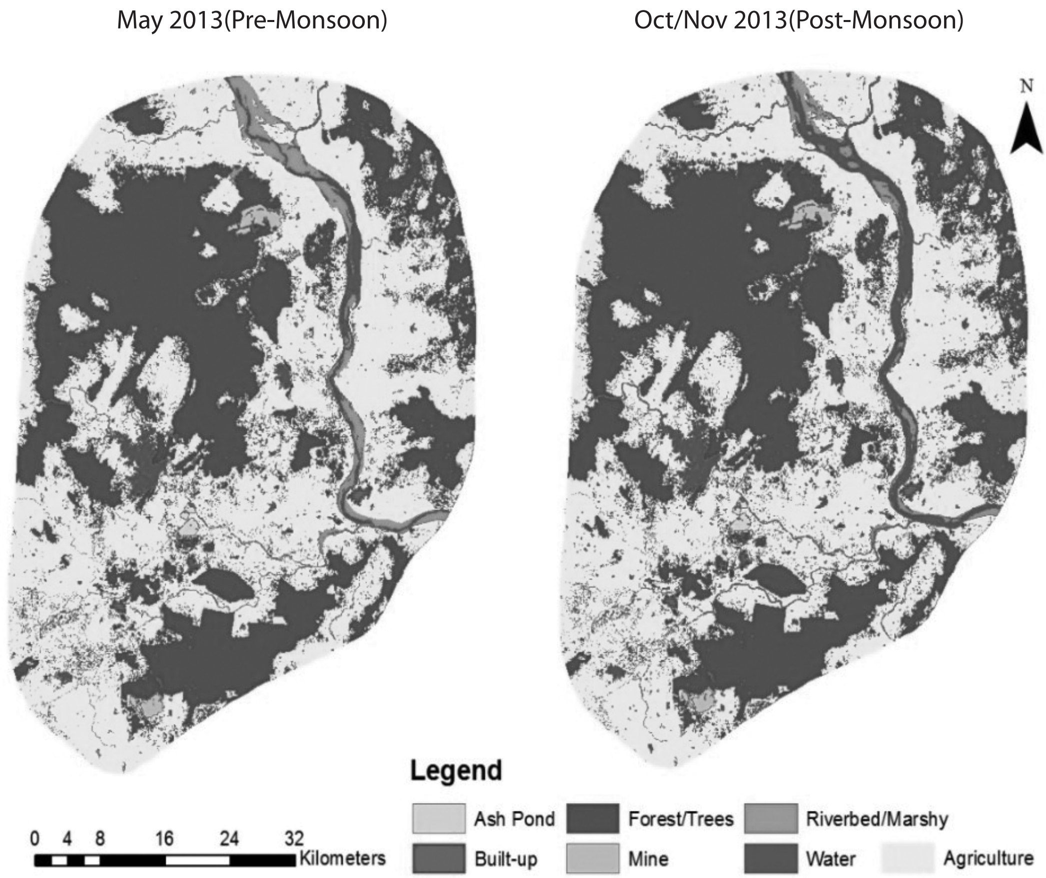


**Figure 4: Processed Images Before and After Monsoon**

***Selected Cascade and Individual Tanks:*** The cascades tanks systems are very limited in the BC. Therefore, two cascade systems and three individual tanks (Figure 5) were selected and links between tanks were identified for further analysis:

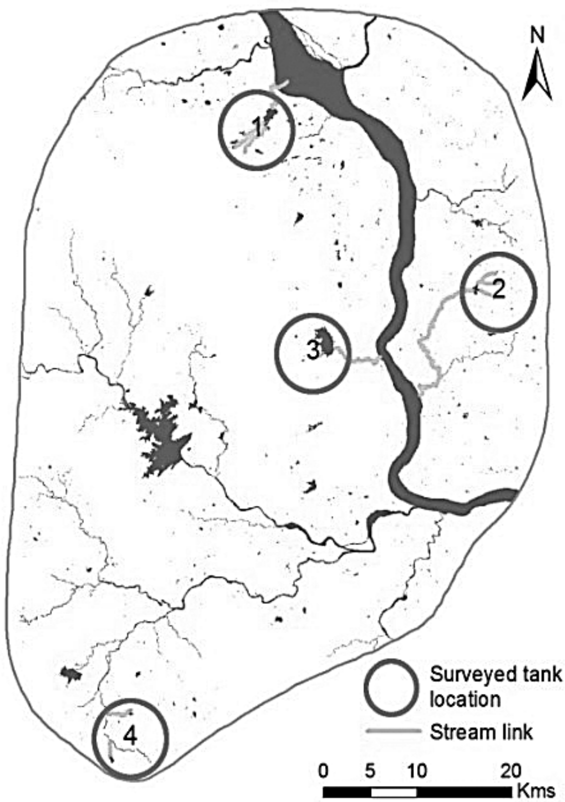


**Figure 5: Potential Locations for Tank Rehabilitation (1. Pagidaru Village Cascade, 2. Laxminagar Village Cascade, 3. Tummala Tank, 4. Ganugapadu and Thungaram tank)**

***Field Data Collection and Cost-benefit Assessment:*** Focus group discussions were carried out with a semi-structured questionnaire survey to assess the status and opinions of farming households on these tanks (Figure 6). Survey was focused on the tanks characteristics such as existence of technical information (area, depth, and command area) maintenance and present condition of the tanks (Tables 4 and 5). The selected tanks were visited and their specific pre-and post-monsoon depths were determined during the interviews.The approximate seasonal volume was determined by both depth and surface area of each tank. The survey has brought out the farmers' perception on WS and how to enhance it through tanks restoration. The respondents across all the villages proposed interventions to improve storage capacity of tanks by rehabilitation.

Rehabilitation of a tank's ecosystem is considered as one of the best options to improve the performance of irrigated agriculture. The cost of tanks desilting varies from 33 to 76 INR/$m^3$ (Palanisami, 2014). Past experiences show that physical modernisation alone improved irrigation efficiency by 32.25 per cent and subsequently increasing the yield by about 30 per cent (Sindhu, 2010). Deivalatha et al. 2014 also show that the crop yield has increased between 2 to 19 per cent (average 10 per cent) due to tank restoration. The authors also report that the area under tank restoration has increased from 19-107 per cent for large, middle, small and marginal farms. The European Economic Committee (EEC) had attempted to modernise irrigation tanks in Tamil Nadu during 1984-85 to 1994-95 periods. The approximate cost for the modernisation during the aforesaid periods was INR 21,000 per ha (Palanisami, 2008).

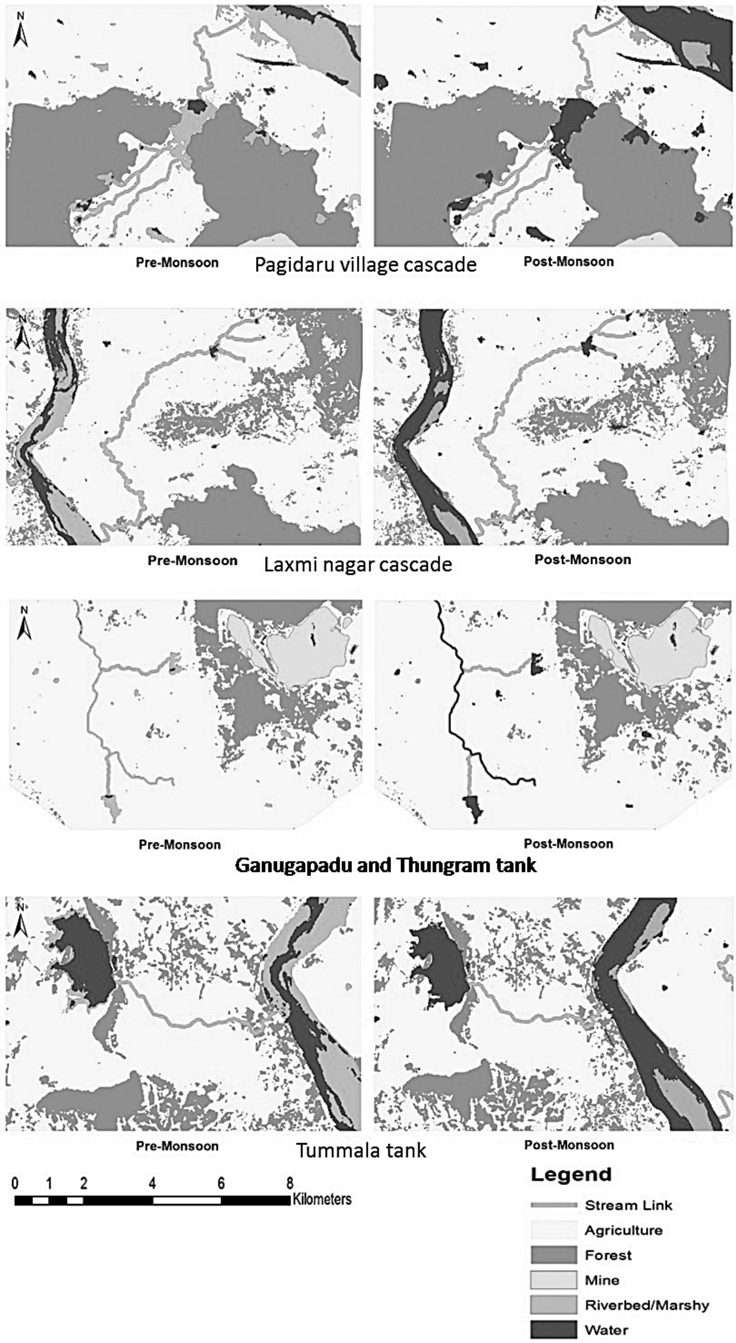


**Figure 6: Surveyed Tanks**

**Table 4: Farmers' Perception on Tank Statistics**

| Village | Tanks | Area under irrigation (ha) | Pre-monsoon volume (m3) | Post-monsoon volume (m3) | Proposed desiltation depth (ft) | Proposed increase in bund height (ft) | Sluice condition | Channel condition |
|---|---|---|---|---|---|---|---|---|
| Pagidaru | Sambai Gudem | 4000 | 327881 | 5559145 | 6 | 2 | Fine | Fine |
| | Ayyarkunta | 20 | 4443 | 37635 | 4 | 2 | Poor (no gates) | Fine |
| | Ippgadda | 80 | 9000 | 442508 | 3 | 3 | Not well | Not well |
| | Ponchampalli 1 | 240 | 175218 | 778130 | 5 | Not required | Not well | Fine |
| | Ponchampalli 2 | 20 | 22387 | 172986 | 3 | 2 | Not well | Fine |
| | Kodichala | 60 | 2643 | 39379 | 5 | 2 | Poor (not working) | Fine |
| | Chinna (individual) | 200 | 41681 | 827635 | 3 | 9 | Not well | No channel |
| Laxmi-nagar | Chinnarulagubal | 800 | 222750 | 1744887 | Full needed | 2 | Not well | Fine |
| | Kothuru | 40 | 43031 | 221085 | 4 | 2 | Fine | Fine |
| | Kamalapuram | 20 | 13331 | 77970 | Partial needed | 2 | Fine | Fine |
| | Rajupeta | 10 | Marshy | 30884 | Full needed | Not required | Not well | Fine |

**Table 5: Individual Tank Statistics**

| Tanks | Area under irrigation (ha) | Proposed increase in bund height (ft) | Pre-monsoon volume (million m3) | Proposed desiltation depth (ft) | Sluice condition |
|---|---|---|---|---|---|
| Ganugapadu | 120-160 | Not required | Less water (marshy) | Partial needed | Fine |
| Thungaram | 120 | 3 | Less water (marshy) | 10 | Fine |
| Tummala | 2000 | Not required | 7.5 | Required | Fine |

In the present study, the Pagidaru cascade from BC was identified for rehabilitation, i.e., desilting, strengthening tank bunds, canal and repairing sluices in the cascade. The area of the tank cascade is 272 ha with a total command area of 4,420 ha (Table 6). However, the actual area under cultivation in the cascade is only 3,536 ha, which is about 80 per cent of the actual command area. The area under the cascade was reduced due to siltation over the years. Farmers' perceptions through personal discussions also reveal that there is a need for rehabilitation of the existing tank cascade. Studies from various researchers also show that there will be an additional yield, water and area due to the rehabilitation of tanks (Deivalatha et al., 2014; Palanisami, 2008; Arumugam et al., 1997).

**Table 6: Pagidaru Cascade Area and Crop Details**

| Village | Tanks | Tank area (m2) | Depth (m) | Actual command area (ha) | Area under cultivation (ha) | Cotton (ha) | Paddy (ha) |
|---|---|---|---|---|---|---|---|
| Pagidaru | Sambai Gudem | 1,588,327 | 3.5 | 4,000 | 3,200 | 2,560 | 640 |
| Pagidaru | Ayyarkunta | 25,090 | 1.5 | 20 | 16 | 12.8 | 3.2 |
| Pagidaru | Ippgadda | 147,502 | 3.0 | 80 | 64 | 51.2 | 12.8 |
| Pagidaru | Ponchampalli 1 | 222,323 | 3.5 | 240 | 192 | 153.6 | 38.4 |
| Pagidaru | Ponchampalli 2 | 69,194 | 2.5 | 20 | 16 | 12.8 | 3.2 |
| Pagidaru | Kodichala | 19,689 | 2.0 | 60 | 48 | 38.4 | 9.6 |

Source: Field survey in the Bhadrachalam.

The major crops grown in the command area are paddy and cotton. Paddy is cultivated in 80 per cent (2,828.8 ha) of the area and the rest with cotton (707.2 ha). Based on the socio-economic study conducted in the area, paddy and cotton yields are found to be 58.25 and 20.5 qt/ha, respectively. The net income from these two crops are INR 7,175 and INR 10,708 per ha, respectively.

The total cost for tank rehabilitation was estimated to be INR 10.36 million (INR 50 per $m^3$ for desiltation, which is an average of 33-76 INR/$m^3$ as reviewed above). The estimates project that the cost of rehabilitation will be INR 29,300 per hectare. The desilted soil is also considered as a viable fertiliser for the main fields, and some farmers actually purchase it. Hence, the revenue generated due to the desilted soil was estimated to be INR 2.59 million (INR 5 /$m^3$).

With the available information and estimates, a cost-benefit analysis was carried out for different cropping and irrigation patterns. The lifespan of the tank rehabilitation is assumed to be 10 years at an interest of nine per cent. An annual maintenance cost of INR 30,000 was also considered for the analysis to maintain the cascade. Seven scenarios were considered for the cost-benefit analysis (Table 7).

Scenario one is assumed to have the same/actual irrigated area (A) (paddy - 80 per cent and cotton - 20 per cent) without any change in the area ($\Delta$ A) and yield ($\Delta$ Y). Cost of the tank rehabilitation is considered to be 50 INR/m3. The net benefits generated from the paddy area (80 per cent) and the cotton area (20 per cent) are the only ones considered for this analysis. In addition, soil desiltation revenue was also added to the benefits for the first year. In the following years, only crop benefits were considered for the analysis.

Scenario two is assumed to have the same yield (Y) but the area is considered to have increased by 20 per cent (Δ A), which covers the actual command area. The rest of the components remain similar to scenario one. The yield was increased by 30 per cent (Δ Y) in scenario 3 without having an increase in area. Scenario 4 was taken up with an increase of 20 per cent in area (Δ A) and a 10% increase in the yield (Δ Y). On the other hand, the cost of rehabilitation was also taken to the maximum amount of 76 INR/$m^3$ keeping the rest to the actual situations in scenario 5. In scenario 6, additional benefits (i. e., increase in area by 20 per cent and the yield generated from it) were also taken for analysis. The increased area was also allotted with the present cropping pattern of 80 per cent paddy and 20 per cent cotton. In scenario 7, additional benefits with the 50 per cent paddy and 50 per cent cotton were used for analysis.

**Table 7: Scenarios for the Cost-Benefit Analysis**

| S.No | Scenario | Particulars |
|---|---|---|
| 1 | S1 | Actual irrigated area+ desilt cost 50 INR/$m^3$+actual yield+ paddy area (80%)+cotton (20%)+revenue from desilted soil |
| 2 | S2 | Increased area by 20% + desilt cost 50 INR/$m^3$+actual yield + paddy area (80%)+cotton area (20%) + revenue from desilted soil |
| 3 | S3 | Actual irrigated area+ desilt cost 50 INR/$m^3$+increase in yield (30%) + paddy area (80%) + cotton area (20%) + revenue from desilted soil |
| 4 | S4 | Increase area by 20% + desilt cost 50 INR/$m^3$+Increase in yield (10%) + Paddy area (80%)+ cotton area (20%)+revenue from desilted soil |
| 5 | S5 | Actual irrigated area + desilt cost 76 INR/$m^3$+actual yield + paddy area (80%)+cotton (20%)+revenue from desilted soil |
| 6 | S6 | Additional benefits only due to increased area (20%) +desilt cost 50 INR/$m^3$+paddy area (80%) + cotton area (20%) |
| 7 | S7 | Only additional benefit due to increased area (20%) + desilt cost 50 INR/$m^3$ + paddy area (50%) + cotton area (50%) |

The results from the analysis show that with the present cropping pattern and net benefits (S1), the cascade would have a Benefit Cost Ratio (BCR) of 1.84 with an Internal Rate of Return (IRR) of 23 per cent (Table 8), assuming that the water supply would be sufficient for the actual cropped area due to desiltation. But the area can also be increaed due to rehabilitation. Hence, scenario 2 shows that with the increased area (20 per cent) under the cascade the BCR can have 2.21 with an IRR of 35 per cent (Table 6).

**Table 8: BCR and IRR for the Pagidaru Catchment**

| | S1 | S2 | S3 | S4 | S5 | S6 | S7 |
|---|---|---|---|---|---|---|---|
| BCR | 1.84 | 2.21 | 5.91 | 3.83 | 1.45 | 0.38 | 0.43 |
| IRR (%) | 23 | 35 | 740 | 115 | 12 | -19 | -17 |

Source: Authors' Estimations.

Increase in yield (Δ Y) by 30 per cent according to Sindhu 2010, would have further benefits in the command area with 5.91 BCR and 740 per cent IRR (S3). However, increase in yield by 30 per cent would depend on various factors such as variety and management activities on field (alternate wetting and drying, direct seeding of rice, BT cotton, etc.) Hence, increase in the yield is considered to be a minimum of 10 per cent in scenario 4 with sufficient water due to rehabilitation. The BCR for S4 is 3.83 with an IRR of 115 per cent.

In case, where the rehabilitation cost is at INR 76 per $m^3$, the BCR with the actual irrigated area will be 1.45 and IRR 12 per cent (S5). All the scenarios from S1 to S5 have higher returns with the rehabilitation. But, considering the additional revenue and area with the rehabilitation, (i.e., ? A and ? y) the BCR is 0.38 and IRR is -19 per cent, which is not feasible for investment (S6) due to the negative values. Similarly, with changes in the cropping pattern to 50 per cent paddy and 50 per cent cotton have increased returns over S6 with 0.43 BCR and -17 per cent IRR (S7). Nonetheless, considering the other ecological and environmental factors (groundwater recharge, agro forestry, fish culture, etc.,) the stabilised tank irrigation would have more benefits, which is beyond the scope of this study. But considering the benefits from the total command area in the catchment and with the increased area and yield, the cost-benefit and IRR have positive values (i.e. S3 and S4). The S4 is found to be a good investment option in the study areas when compared to the other options.

## Conclusion

In order to face the growing threat of water scarcity, it is required to rehabilitate and improve the existing irrigation systems resulting from deferred maintenance. This study is conducted towards the identification of water bodies/tanks and the rehabilitation of individual tanks and tank cascade systems. Remote sensing and GIS are found to be a suitable means to detect small tanks and accurately measure their surface areas. The combination of satellite-based measurements and field survey data has allowed for monitoring of tanks. Identifying such tank cascades or bigger tanks for rehabilitation to improve the water storage and making decision on the investment options can reduce water scarcity with increased benefits. The improved water security benefits would also help in improving the household livelihoods. The field surveys helped to assess villagers' perception of rehabilitating tanks for enhancing water security. The study provides information that there is substantial potential for augmenting the water supply by increasing the potential storage facilities. The State governments are also investing on the rehabilitation of irrigation tanks. For example, the State government of Telangana has initiated tank rehabilitation through Kakatiya Mission during 2014-15. Investment on desilting of tanks at INR 50/$m^3$ and increased yields have better economic feasibility as per the assumptions made in the study. Therefore, identifying the small tanks in the catchments and making investments for water security is the need of the hour.

## References

Amarnath, J.S., Karthik Raja, P. (2006), An Economic Analysis of Tank Rehabilitation in Madurai District of Tamil Nadu, *Agricultural Economics Research Review*, 19, 187-194.

Anuradha, B., Ambujam, N. K. (2012), Impact of Tank Rehabilitation on Improved Efficiency of Storage Structures, *International Journal of Engineering Research and Application,* 2(4), 1941-43.

Arumugam, N., Mohan, S., Ramprasad, R. (1997), Sustainable Development and Management of Tank Irrigation Systems in South India, *Water International,* 22(2), 90-97.

Asian Development Bank (ADB) (2006), Rehabilitation and Management of Tanks in India: A Study of Selected States, https://think-asia.org/bitstream/handle/11540/5073/rehabiliation-management-tanks.pdf?sequence=1 (Last accessed on December 17, 2017).

Babu, K.L., Manasi, S. (2008), Estimation of Ecosystem Services of Rejuvenated Irrigation Tanks: A Case Study in Mid Godavari Basin, http://agris.fao.org/agris-search/search.do?recordID=QL2012002254 (Last accessed on September19, 2016).

Brower, B.V., Laben, C.A. (2000), Process for Enhancing the Spatial Resolution of Multispectral Imagery Using Pan-sharpening, United States Eastman Kodak Company (Rochester, New York). US Patent 6011875.

CWC (Central Water Commission) (2014), Godavari Basin, http://www.india-wris.nrsc.gov.in/Publications/BasinReports/ Godavari%20Basin.pdfCWC, New Delhi: CWC.

Deivalatha, A., Senthilkumaran, P., Ambujam, N.K. (2014), Impact of Desilting of Irrigation Tanks on Productivity of Crop Yield and Profitability of Farm Income, *African Journal of Agricultural Research,* 9(24), 1833-1840.

Dillon, P., Pavelic, P., Page, D., Beringen, H., Ward, J. (2009), Managed Aquifer Recharge: An Introduction, Waterlines Rep No. 13, National Water Commission.

Dwivedi, R. S., Ramana, K.V. (2005), Remote Sensing in Inventorying and Monitoring Irrigation Tanks in Andhra Pradesh, Ed. Reddy, M. D (ed.) Proc. of Workshop on Agricultural Research and Demonstration under Tank Irrigated Areas of Andhra Pradesh, Acharya N G Ranga Agricultural University, Rajendranagar, Hyderabad.

Falkenmark, M. (2001), The Greatest Water Problem: The Inability to Link Environmental Security, Water Security and Food Security, *International Journal of Water Resources Development*, 17(4), 539-554.

Frazier, P.S., Page, K.J. (2000), Water Body Detection and Delineation with Landsat TM data, *Photogrammetric Engineering and Remote Sensing,* 66(12), 1461–1468.

Fung, T., Le Drew, E. (1987), Application of Principal Component Analysis to Change Detection, *Photogrammetric Engineering and Remote Sensing,*53, 1649 - 1658.

Gale (2006), Managed Aquifer Recharge: Lessons Learned from the Agrar Study, http://www.sahra.arizona.edu/unesco/allepo/Gale.pdf. (last accessed on December 29, 2014).

GoAP (Government of Andhra Pradesh) (2012), District Statistical Tables, Andhra Pradesh: Government of Andhra Pradesh.

GoI (Government of India)(2014), Annual Report 2013-14, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, http://agricoop.nic.in/Annualreport2013-14/artp13-14ENG.pdf, Last accessed on February 5, 2015.

GoI (Government of India) (2012), Population Census 2011, New Delhi: Government of India.

Grey, D. and Sadoff C. (2007), Sink or Swim? Water Security for Growth and Development, *Water Policy*, 9: 545–571.

Hadjimitsis, D.G., Papadavid, G., Agapiou, A., Themistocleous, K., et al. (2010), Atmospheric Correction for Satellite Remotely Sensed Data Intended for Agricultural Applications: Impact on Vegetation Indices, *Natural Hazards and Earth System Science,* 10(1), 89–95.

Jackson, B.B. (1983), Multivariate Data Analysis: An Introduction, Irwin, Homewood, Illinois, USA.

Jensen, J.R.,Lulla, K. (1996), Introductory Digital Image Processing: A Remote Sensing Perspective, Prentice-Hall Inc.

Kääb, A., Huggel, C., Fisher, L., Guex, S., Paul, F., Roer, I., et al. (2005), Remote Sensing of Glacier-and Permafrost-related Hazards in High Mountains: An Overview, *Natural Hazards and Earth System Science,* 5(4), 527–554.

Krishnaveni, M., Sankari, S., Rajeswar, A. (2011), Rehbailitation of Irrigation Tank Cascade System Using Remote Sensing GIS and GPS, *International Journal of Engineeering Science and Technology*, 3(2), 1624-1629.

Lillesand, T. M., Kiefer R. W. (2000), Remote Sensing and Image Interpretation, 4th ed. Wiley & Sons.

Moore, G. K., North, G.W. (1974), Flood Inundation in the Southeastern United States from Aircraft and Satellite Imaging, *Water Resources Bulletin* 10 (5), 1082-1097.

Muchoney, D.M., Haack, B.N. (1994), Change Detection for Monitoring Forest Defoliation, *Photogrammetric Engineering and Remote Sensing*, 60, 1243 - 1251.

Mulla, D. J. (2013), Twenty-five Years of Remote Sensing in Precision Agriculture: Key Advances and Remaining Knowledge Gaps, *Biosystem Engineering*, 114(4), 358-371.

Nagarajan, R. (2013), Tank Rehabilitation Index for Prioritization of Lakes in Semi Arid Regions-Geospatial Approach, *International Journal of Geomatics and Geosciences,* 3(3), 525–537.

Pachauri, R., Reisinger, A. (2007), IPCC Fourth Assessment Report, *IPCC, Geneva*.

Palanisami, K. (2014), Economics of Irrigation Investment Options in Dryland System: South Asia, IWMI Internal Report (not published).

Palanisami, K. (2008), Water Resource Management with Special Reference to Tank Irrigation with Groundwater Use, IWMI-CPWF report on Strategic Analysis of India's National River Linking Project, http://publications.iwmi.org/pdf/H042698.pdf (Last accessed on July 7, 2016).

Pietroniro, A., Prowse, T.D. (1996), Environmental Monitoring of the Peace-Athabasca Delta Using Multiple Satellite Data Sources, *In:* Applications of Remote Sensing in Hydrology, Proceedings of the Third International Workshop, NHRI Symp.No 17, National Hydrology Research Institute, Saskatoo, Canada.

Reddy, G. (1973), Agriculture under Kakatiya of Warangal, *Journal of Andhra Pradesh*, 1, 56-65.

Rodrigues, L.N., Edson, E.S., Tammo, S.S., Denilson, P.P., et al. (2012), Estimation of Small Reservoir Storage Capacities with Remote Sensing in the Brazilian Savannah Region, *Water Resources Management*, 26(4), 873–882.

Senseman, G.M., Bagley, C. F., Tweddale, S.A. (1995), Accuracy Assessment of the Discrete Classification of Remotely-Sensed Digital Data for Landcover Mapping, USACERL Technical Report EN-95/04.

Shah, T., Raju, K.V. (2002), Rethinking Rehabilitation: Socio-ecology of Tanks in Rajasthan, North-west India, *Water Policy, 2002,* 3(6), 521–536.

Sindhu, J. S. (2010), Water Pricing and Sustainable Surface Irrigation Management, *Indian Journal of Science and Technology,* 3 (8), 932-936.

Vörösmarty, C. J., McIntyre, P. B., Gessner, M. O., Dudgeon, D., Prusevich, A., Green, P., and Davies, P. M. (2010), Global Threats to Human Water Security and River Biodiversity, *Nature,* 467(7315), 555-561.

Xu, H. (2006), Modification of Normalised Difference Water Index (NDWI) to Enhance Open Water Features in Remotely Sensed Imagery, *International Journal of Remote Sensing,* 27(14), 3025–3033.

Tou, J.T., Gonzalez, R.C. (1974), Pattern Recognition Principles, Addison-Wesley, Reading, MA,377.