Kolleru lake revisited: the post 'Operation Kolleru' scenario

Kolleru, the largest freshwater lake along the east coast of India in Andhra Pradesh (AP) had been encroached, mainly for aquaculture, to such an extent that most of the lake area was highly compartmentalized by 3–4 m high embankments of hundreds of fish tanks that had sprung up in the lake bed. In 2004, Nageswara Rao *et al.*[1], based on an analysis of the satellite image from 2001 coupled with field observations in 2003, reported the existence of more than one thousand fish tanks occupying about 42% of the lake area while the rest of it was either covered by dense weed or paddy cultivation. Subsequently during 2005–06, the AP Government under the Supreme Court's directive undertook the task of what was termed as 'Operation Kolleru'. This was aimed at removing all encroachments within the designated wildlife sanctuary of the lake. Even dynamites were used to blast off the imposing earthen embankments of the fish tanks. The Operation was conducted over several months from September 2005 to June 2006 amidst stiff resistance from the locals[2]. The success of this operation and return of migratory birds to the lake have been widely acclaimed[2–5]. But the ground reality does not seem to be as delightful as what one would expect after government action. We made an attempt to investigate the extant conditions in the lake through analysis of recent satellite images and field observations.

Sandwiched between the Krishna and the Godavari deltas (Figure 1), lake Kolleru is a sprawling shallow coastal wetland with a maximum depth of about 2.0 m. It was initially formed as a coastal lagoon about 6000 years ago, as is evident from the presence of a series of relict sandy beach deposits of mid-Holocene origin right up to the seaward margin of the lake which is about 35 km inland from the present coast[6]. The lake survived for millennia, even after a younger lagoon seaward of it formed and subsequently dried out[6]. This, apparently, is due to its location over a deep-seated tectonic depression[1], known as Gudivada sub-basin or graben[7,8]. As the deltas on both sides prograded, the overall shoreline advanced seaward leaving the lake stranded inland. With a number of streams such as Tammileru and Budimeru, and a host of minor drains discharging into it, the lake turned into a freshwater body. However, the lake is still connected to the Bay of Bengal through Upputeru, a 60 km long highly meandering tidal channel.

Wetlands constitute the largest sector of ecosystem service providers, contributing to flood mitigation, water-quality improvement, habitat biodiversity and landscape aesthetics[9]. Kolleru is one such wetland in a low-lying deltaic setting acting as an important flood-balancing reservoir, a haven for migratory and resident birds, and a source of livelihood for traditional fishermen. However, large-scale encroachments for aquaculture during recent decades, even into the core area of the lake, have disturbed the ecosystem to such an extent as to almost completely efface the lake's identity. Concerned about the situation, the AP Government in 1999 had declared the lake area within the 5-foot (≈ 1.5 m) contour above mean sea level as a wildlife sanctuary, banning all types of encroachments.

We examined the post-Operation Kolleru scenario through analysis of the Indian Remote Sensing (IRS) satellite LISS III images from 2004 and 2008. The Kolleru lake comes in two adjacent images. The western part of the lake is covered in the image of the Path 102/Row 61, the cloud-free image of which was available from 17 April 2004. The eastern part of the lake comes in Path 103/Row 61, for which the cloud-free image from 17 January 2004 was used. These two images were geo-referenced (a process of assigning the Earth's coordinate system to the digital images of the Earth's surface) and combined to create a mosaic of the two images, through image processing techniques. Similarly, the two images of the adjacent paths dated 3 March 2008 (covering the western part of the lake) and 8 March 2008 (covering the eastern part of the lake) were combined. In addition, the map prepared in 1966 by the Irrigation Department of the Government of AP, showing the important contours around the lake, was scanned and geo-referenced to make it compatible with the satellite images. The 3-foot (≈ 0.9 m) and 5-foot (≈ 1.5 m) contours were digitized from this map. The polygon representing the 5-foot (≈ 1.5 m) contour was overlaid on both the image mosaics and the sub-images representing the area of the Kolleru Wildlife Sanctuary were extracted. These sub-images after digital enhancement, following Nageswara Rao *et al.*[1], clearly showed the condition of the lake in the respective years. The image from 2004 (Figure 2 *a*) shows that out of

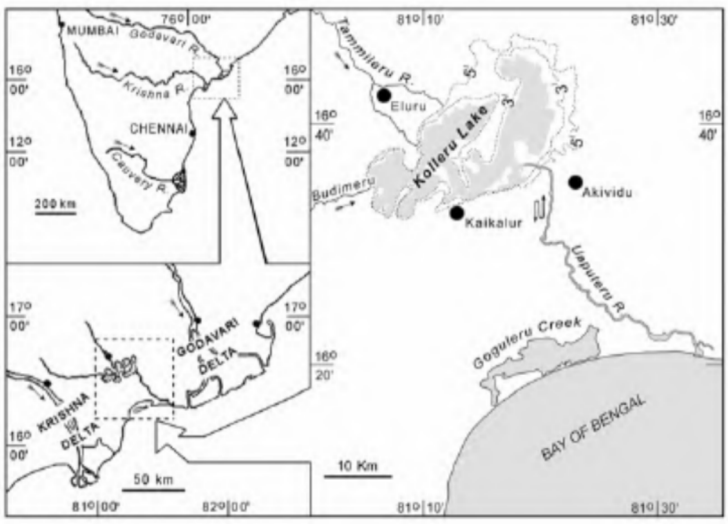

Figure 1. Location of the Kolleru lake between the Krishna and Godavari deltas. Note the 3 foot (≈ 0.9 m) and 5 foot (≈ 1.5 m) contours shown as dotted lines around the water spread area of the lake. (Contours traced from the map entitled 'Kolleru Lake with important contours' prepared by the AP Government Irrigation Department in 1966.)

the total of ≈493 km^2 area of the sanctuary, fish tanks occupied 313 km^2 (about 64%), while another 49 km^2 area (10% of the total) was occupied for paddy cultivation. This was before Operation Kolleru. The 2008 image representing the post-Operation Kolleru scenario (Figure 2 *b*) also shows fish tanks occupying an area of 138 km^2 (28% of the total area) and another 91 km^2 under paddy cultivation. Although the area under pisciculture has decreased owing to the Operation, this activity still persists in the sanctuary. Moreover, parts of the area where fish tanks were demolished are still under human occupation for paddy cultivation, as is evident from the increased paddy area within the sanctuary from 49 km^2 in 2004 to 91 km^2 in 2008.

The AP Government recently decided to downsize the extent of the Kolleru Wildlife Sanctuary, limiting it to the zone within the 3-foot (≈0.9 m) contour (as a concession to the local farmers' demands, although it is subject to the final verdict of the Supreme Court[10]). So, we analysed the sub-images of the area within the 3-foot (≈0.9 m) contour as well, extracted from both the 2004 and 2008 satellite images. The 2004 image shows that out of the total area of ≈339 km^2 within the 3-foot (≈0.9 m) contour (yellow coloured dotted line in Figure 2 *a*), fish tanks occupied about 194 km^2 (57% of the total) followed by paddy covering another 10 km^2 (3%) area. Even in the post-Operation scenario, fish tanks persisted in 63 km^2 (18% of the total area) within the 3-foot (≈0.9m) contour, as the 2008 image revealed (within the area enclosed by the yellow coloured dotted line in Figure 2 *b*). The paddy area increased to 33 km^2 (9% of the total).

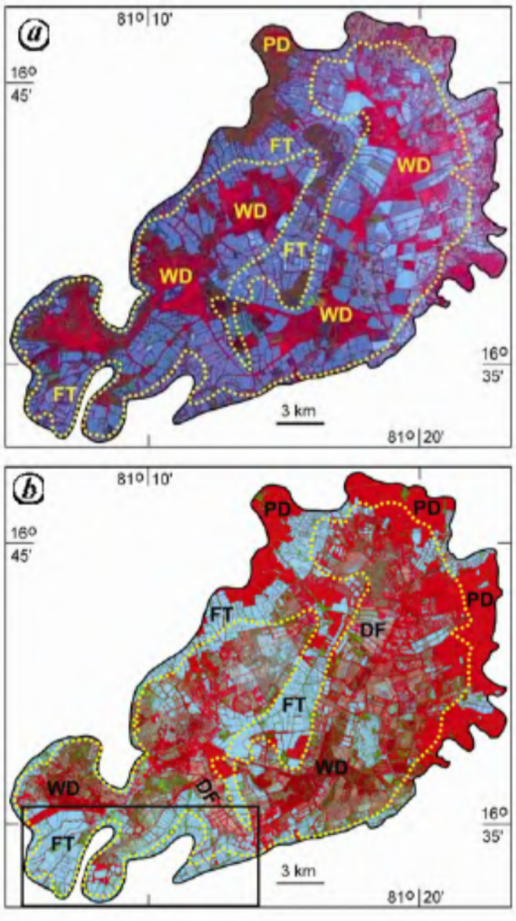

Figure 2. Status of the Kolleru lake area in 2004 (***a***) and 2008 (***b***) within the 5 foot (≈1.5 m) contour. Yellow coloured dotted line in both (***a***) and (***b***) represents the 3 foot (≈0.9 m) contour. FT: Fish tanks in blue colour with characteristic embankments; PD: Area under paddy cultivation; WD: Weed in mottled brownish-red; DF: Drained fish tanks with their embankments still intact, in red colour due to weed growth. Area enclosed in black rectangle in (***b***) is enlarged in Figure 3.

Finally, we tried to limit the core area of the lake bed (which Nageswara Rao *et al.*[1] considered in their study) confining the boundary only to the water spread of the lake depicted in the Survey of India topographic map from the 1930s (when the lake area was free from any type of encroachments). This zone covers an area of ≈245 km^2, about 42% of which was occupied by fish tanks as noted from the 2001 satellite image[1]. The aquaculture activity has been further intensified to cover 50% of this area as is revealed by the 2004 image in the present study. Even after the Operation Kolleru, the 2008 image shows that fish tanks still exist within the core area of the Kolleru lake bed covering about 11 km^2, i.e. over 4% of the area.

Our study also revealed that in spite of the Operation Kolleru, some fish tanks remained undisturbed even in the core area of the lake bed and their number and extent are increasing by the day. Apparently, the fish tank construction activity has again picked up momentum in recent months. For instance, the extreme south-eastern corner of the lake as appearing in the 2004 image (Figure 3 *a*) had fish tanks, some of which were apparently demolished during the Operation Kolleru, as is evident from the IRS AWiFS (Path 103/Row 59) image dated 23 February 2006 (Figure 3 *b*). However, fish tanks reappeared in the area as seen from the 2008 image (Figure 3 *c*). Hectic digging using heavy machinery is still going on at many locations in the lake bed, as recently as June 2009, to rebuild the fish tanks.

A determined approach is called for to restore the lake to its pristine condition. In this direction, several ambiguities perpetuated for long need to be sorted out, including demarcation of the lake boundary itself. At present, a lot of uncertainty prevails in this regard. For instance, the Kolleru lake over an area of 901 km^2, the outer boundary of which tentatively follows the 10 foot (≈3 m) contour, has been declared in 2002 as a Ramsar site[11]. Prior to that, in 1999, the AP Government declared the Kolleru area within the 5-foot (≈1.5 m) contour as a wildlife sanctuary. Even today, there is no agreement among the various government

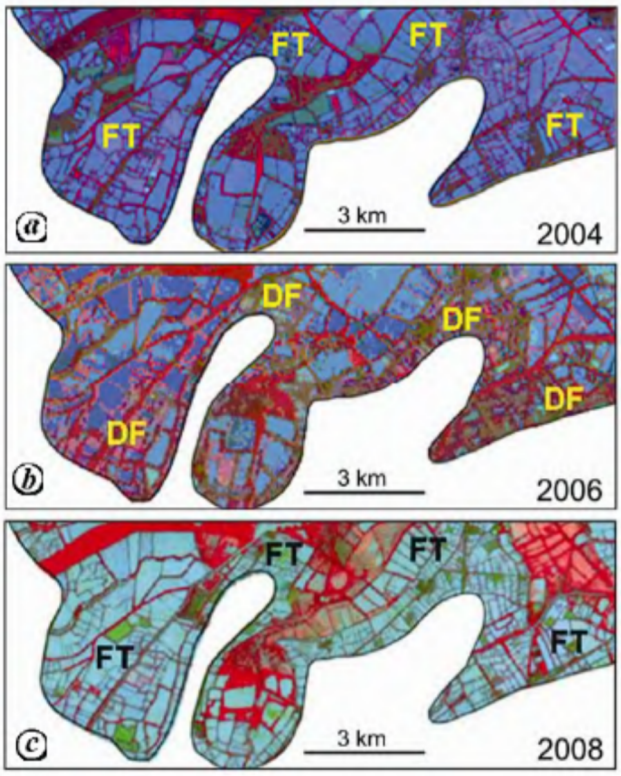

Figure 3. Southeastern part of the Kolleru lake. (See its location in Figure 2 *b*.) Fish tanks (FT) in the 2004 image (***a***) were later drained during Operation Kolleru and hence appeared in the 2006 image (***b***) in red colour (drained fish tank (DF)) due to weed growth. FT reappeared in the area as seen in the 2008 image (***c***).

departments concerned over the location of the 5 foot (≈ 1.5 m) contour[10]. The contour map prepared by the State Irrigation Department in 1966 (which was used in this study) is now being disputed by the State Revenue and Forest Departments[10]. Adding to all this, the AP Government is now proposing to shrink the boundary of the sanctuary to the 3 foot (≈ 0.9 m) contour. In any case, once the boundary of the sanctuary is properly fixed, through rigorous survey using modern techniques like LiDAR (Light Detection And Ranging) altimetry or high-resolution satellite stereo image analysis coupled with fine resolution DGPS (Differential Global Positioning System) control points and total station surveys, the encroachments are to be cleared totally from the zone. There is a catch here. Mere breaching of the fish-tank embankments to drain off the water, as was done in many cases during the Operation Kolleru (note the drained fish tanks with their embankments almost intact from the 2008 images shown in Figures 2 and 3), will not restore the lake environment. Our field observations during June 2009 revealed that some of the partially demolished fish tanks have already been repaired and put to use again by locals. In other parts, the lake area appeared as dry land with decayed vegetation giving one an impression, although ironically, that fish tanks with full of water throughout the year might have been better than the lake's dried up condition (for several months). Removal of encroachments should be aimed at eliminating the embankments in the entire length and breadth of the demarcated area. It is worthwhile to deepen certain parts of the lake and pile up the excavated earth as scattered islands where vegetation can grow, to provide resting/nesting grounds for avian tourists[12]. Concerted efforts should be made to prevent sedimentation from the catchment; pollution from industries; pesticide residues from the surrounding cropland, and urban sewage from entering the lake through the innumerable streams and drains that now decant into the lake. It seems a long way to go, if at all, to save the Kolleru lake, an important coastal wetland ecosystem in the country.

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