ESTIMATION OF LARVAL PRODUCTION IN SANJAY LAKE AND ITS SURROUNDING PONDS IN DELHI, INDIA USING REMOTE SENSING TECHNOLOGY

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Abstract. A feasibility study to use remote sensing techniques for estimation of mosquito production in Sanjay lake in east Delhi was carried out. Besides the Sanjay lake, larval production for 12 surrounding remote sensing identifiable ponds was also estimated. Inspite of some limitations the technique is very useful for rapid mapping of major breeding sites, recording temporal changes and estimation of larval production in a cost effective manner in terms of survey cost and time.

INTRODUCTION

Remote sensing (RS) is the science of collection of information about an object without physical contact. Remote sensing technology uses the visible, infrared red and microwave regions of the solar radiation to collect information about the various objects on the earth's surface. The response of objects to different regions of the electromagnetic spectrum is different, and are used to distinguish objects. Starting with the US Television and Infra-Red Observation Satellite (TIROS) in 1960, remote sensing technology has now reached a state where application of satellite remote sensing has been made operational in many countries in different disciplines. For example RS applicability have been seen in mapping of the environmental parameters, *viz*, vegetation patterns, rainfall pattern, forest cover, flow rate of the river, water collections, humidity, etc (Jovanovic, 1985; Hayes *et al* 1985; Bos, 1989). American landsat satellite and aircraft data have been used (Washino *et al*, 1987), to monitor rice fields, water quality and mosquito larval abundance in North California. Linthicum *et al* (1990) used NOAA (National Oceanic and Atmospheric Administration) data to estimate ground moisture and rainfall pattern, monitor resultant flooding and mosquito habitats which support the breeding of *Aedes* and *Culex* mosquitos.

Mosquitos breed in a variety of aquatic habitats but larval breeding surveys are always very expensive, time consuming and cumbersome. Therefore a feasibility study to use remote sensing imageries in assessing mosquitogenic potential was carried out. Sanjay lake and its surrounding area within a radius of 3 km was selected for study. Imageries of study sites were obtained from Indian Remote Sensing Satellites (IRS) 1A and 1B. The feasibility of this technique in assessing mosquitogenic potential is discussed here.

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MATERIALS AND METHODS

Sanjay Lake is located within east of the National Capital Territory of Delhi. Length of the lake is about 600 m and width about 150 m, the perimeter of the water area was 1,500 m during the survey period. The lake is used for fish culture and is surrounded by city forest and residential colonies. Most of the time, shore line is polluted and full of Pistia plant. The neighboring areas have mosquito menace due to *Culex quinquefasciatus*. In houses surrounding the lake *Cx. quinquefasciatus* breed in coolers, over head tanks (OHTs), cisterns, earthern pots, etc. In the peridomestic areas the breeding is encountered in drains, ponds, pools, lake with and without vegetation. *Cx. quinquefasciatus* feed throughout the night on both man and animals.

In India, the National Remote Sensing Agency (NRSA) at Hyderabad is the operating earth station for receiving data from IRS - 1A and B satellites. The IRS satellite passes over Delhi at about 10 : 30

at 22 day intervals. During the study period the Regional Remote Sensing Services Centre (RRSSC) of ISRO located at Bangalore collected cloud free and good quality LISS II data only for 7 dates in 1 year. The first satellite data was rectified with respect to topomap on 1 : 50,000 scale by generating a second order polynomial transformation model using necessary ground control points. The rectified data was re-sampled to 30 × 30m ground pixel size. On other dates the data were rectified with respect to the above rectified scene using similar procedures. Masking of the study site was performed by registering the circular boundaries defined on to the topomap with a radius equivalent to 3 km from the central point located at the major water bodies. The masked image data of different dates corresponding to the study site were considered for analysis. Digital classification was performed on the sun elevation angle corrected data using a maximum likelihood algorithm. Data of unacceptable quality because of hazy conditions were excluded from the classification. Care was taken to identify homogeneous and evenly distributed training samples all over the scene. The images were analyzed on a 512 × 512 pixel frame, where each pixel corresponds to 30 × 30 m after resampling. Location accuracy of sattelite data after rectification was around 1.5 pixels, equivalent to 60 m. Sanjay lake shoreline was divided into 50 segments each of 30 m to match with the size of one pixel (Fig 1). Ground information was collected on each satellite pass. One dip at every 6 m was taken and pooled up according to the length of vegetation/non-vegetation area in each segment for estimation of average larval density. The type of vegetation and its width on the surface of the water

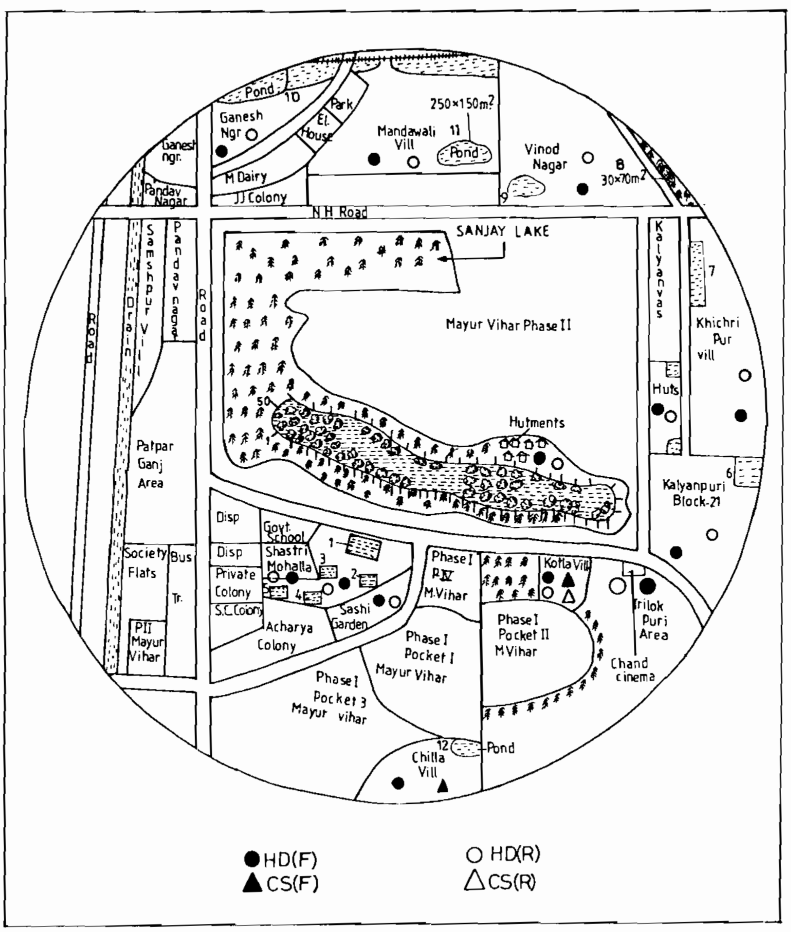

Fig 1–Sanjay Lake and its surrounding area.

in each segment was also recorded. Adults were also collected from its nearby situated human dwellings, cattlesheds and man hour density was calculated.

Besides the data collected from Sanjay lake, larvae from 12 ponds and adults from human dwellings and cattle sheds situated in the surrounding area within 3 km radius were also collected throughout the study period. The size of selected ponds was more than 30×30 m^2. Ground information was also recorded to monitor temporal changes in water bodies, vegetation and agricultural pattern. Land use classes, *viz* water, vegetation, urban, etc, were identified using the ground information. The classification was done by selecting training sets. The area under different classes was calculated as $30 \times 30 \times$ no. of pixels and the quantified data was correlated with ground information. Statistics were generated by RRSSC, Bangalore on a VAX 11/780 computer.

To estimate mosquito production per m^2 in the lake and its surrounding 12 ponds, a multiplication factor was estimated. It was assumed that while taking a dip, the dipper moved a horizontal distance of 0.3 m. If 'r' is the radius of the dipper, 2r will be the width of the area swept by the dipper. Hence the actual area as shown below is that from which larvae has been collected in each dip.

$$\begin{aligned} \text{Total area} &= \text{area (ABCD + APD + BQC)} \\ &= 2r\,(0.3) + \pi r^2 \\ &= r\,(0.6 + \pi r) = 0.0378 \text{ m}^2 \end{aligned}$$

The larval/dip is actually larvae per 0.0378 m^2. Hence larvae per m^2 = 1m^2/0.0378

= 26.5 (multiplication factor (mf) for larval production)

The vegetation area for each segment was calculated by multiplying the width of the vegetation on the surface of the water with the length of the vegetation in segments.

RESULTS AND DISCUSSION

Output maps depicting the spatial distribution of different categories on seven dates were generated. One enhanced false color composites along with classified output of remote sensing image is given in Fig 2. The land area of 27.7 km was classified into 7 main classes namely water, weed, plantation, agriculture vegetation, agriculture fallow barren, urban and barren. Seasonal changes in the area of landuse classes are given in Table 1.

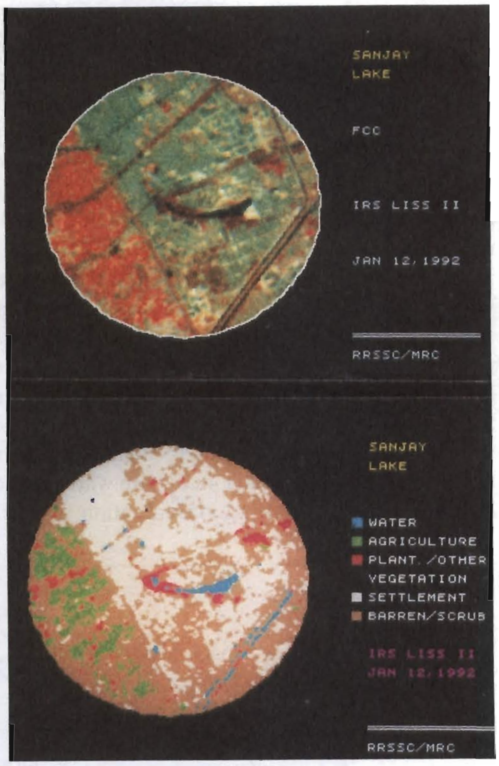

Fig 2–IRS LISS II false color composite and classified image of Sanjay Lake.

Out of seven land use classes the water is an important class for this study as it supports mosquito breeding. Water area varies from season to season as shown in the Table 1. Maximum water area was recorded in February 1992 (3.7%) followed by November 1991 (3.5%) and October 1991 (3.25%). This water area was further classified into 2 sub classes, *viz* lake water and water in surrounding ponds. Datewise water area in lake and in surrounding ponds are given in Table 2. Maximum areas covered by lake water was 261,900 m^2 during July 1991 and minimum area was 146,700 m^2 in October 1991. Maximum area covered by other water bodies in February 1992 was 798,300 m^2 and minimum in April 1992 was 228,600 m^2.

Larval density per dip of Sanjay lake varied from 0.13 (February 1992) to 13.54 (November 1991). The number of pixels classified as lake water and the larval density showed a negative correlation. In nature also an increase in water in a reservoir decreases the larval density due to either

Table 1

Estimated area of land use classes at Sanjay Lake and surrounding area using IRS LISS II data.

Land use classes	Area (km^2) of land use categories on different dates						
	9.7.91	5.10.91	27.10.91	7.11.91	12.1.92	25.2.92	20.4.92
Water	0.864	0.910	0.383	0.974	0.504	1.033	0.453
	3.119	3.285	1.384	3.516	1.819	3.730	1.635
Weed	0.316	1.985	0.616	0.764	0.260	0.157	0.595
	1.141	7.166	2.222	2.758	0.939	0.565	2.148
Plantation	5.756	1.618	1.671	1.616	1.048	1.922	1.994
	20.780	5.841	6.034	5.832	3.782	6.940	7.198
Aq veg	1.514	4.192	3.389	4.326	1.881	2.308	3.326
	5.466	15.134	12.236	15.618	6.791	8.331	12.007
Aq/fallow barren	1.467	4.704	4.462	4.093	7.287	2.558	4.425
	5.296	16.982	16.109	14.777	26.308	9.234	15.975
Urban	11.414	8.778	10.032	7.571	10.120	9.788	11.086
	41.206	31.690	36.218	27.331	36.533	35.337	40.022
Barren	3.646	3.216	5.625	7.588	5.671	8.090	5.635
	13.162	11.610	20.307	27.393	20.473	29.206	20.343
Unclassified	2.723	2.297	1.522	0.768	0.929	1.844	0.186
Area	9.830	8.292	5.490	2.775	3.354	6.657	0.672

PS : (i) Total area : 27.7 km^2

(ii) Lower figures indicate the % of the total area

Table 2

Classification of water bodies based on IRS LISS II data of Sanjay Lake and surrounding areas.

Date	Total no. of water pixel	No. of water pixel in lake	No. of water pixel other than lake	Total water area (m^2)	Total water area in lake (m^2)	Water area other than lake (m^2)
July 9 '91	960	291	669	864,000	261,900	602,100
Oct 5 '91	1,011	191	820	909,900	171,900	738,000
Oct 27 '91	426	163	263	383,400	146,700	236,700
Nov 7 '91	1,082	217	865	973,800	195,300	778,500
Jan 12 '92	560	232	328	504,000	208,800	295,200
Feb 25 '92	1,148	261	887	1,033,200	234,900	798,300
Apr 20 '92	503	249	254	452,700	224,100	228,600

1 Pixel = 30 × 30 m^2

flushing of breeding or increase in depth of water or by disturbing food reserve and shelter at the shore line (Table 3). Whereas decrease in water increases breeding potential by creating numerous pits and pools on the shore line.

Table 4 gives the vegetation area and total larval production from Sanjay lake in different dates. The maximum vegetation area was calculated in October 1991 (3,126.9 m^2) and minimum during July 1991 (154.5 m^2). During January 1992 there was no vegetation. Maximum mosquito production was also observed in October and minimum in July 1991 and January 1992. The correlation of the vegetation area with larval production was found to be significant ($p < 0.05$).

Mosquito production in the segments of lake with no vegetation revealed maximum production in November 1991 and minimum in October 1991 (Table 5). The area was estimated as the product of length of the segment and 1 m as it was found that breeding takes place in the shallow water *ie* up to 1 m. Total larval production and man hour density of adult mosquitos (number of mosquitos/man/hour) collected from the nearby cattlesheds and human dwellings were found to have correlations of 0.97 ($p < 0.05$) and 0.88 ($p < 0.05$), respectively, with density per dip (Table 6).

Table 3

Larval density on different dates in Sanjay lake.

Date	Total water area in lake	Total no. of larvae	Den/dip
July 9 '91	261,900	289	1.156
Oct 5 '91	171,900	1,143	4.572
Oct 27 '91	146,700	151	0.604
Nov 7 '91	195,300	3,385	13.54
Jan 12 '92	208,800	219	0.876
Feb 25 '92	234,900	34	0.136
Apr 20 '92	224,100	74	0.296

Total no. of segment = 50
Perimeter of the lake = 1,500 m
Total no. of dip on each date = 250 (one dip in 6 m)

Besides the total larval production of Sanjay Lake, total production for 12 surrounding remote sensing identifiable ponds was also estimated. Total larval production of Sanjay lake and its surrounding ponds revealed that ponds were more conducive for mosquito production in general as compared to Sanjay lake except in early October and November 1991 (Table 7).

These data revealed that estimated larval production using RS imageries has a correlation with man hour mosquito density in that area. This verifies the entomological findings through remote sensing data by ground realities.

In general, large water bodies do not support mosquito breeding except at shallow margins because of the absence of food and shelter, but vegetation allows a greater area for mosquito breeding. This is also revealed from the results obtained when the vegetation area in October, 91 was 3,127 m^2 and larval production was 148/m^2 as compared to April

Table 4

Larval production in segments with vegetation in Sanjay Lake.

Date	Vegetation area (m^2) X1	No. of segments	No. of dips	Den/dip X2	Total larvae production X3	Larvae production/m^2
July '91	154.5	1	5	0.0	0.0	0.0
Oct 5 '91	3,126.9	40	200	5.6	464,031.96	148.4
Oct 27 '91	2,545.2	37	185	0.8	53,958.24	21.2
Nov '91	263.6	5	25	2.6	18,162.04	68.9
Jan '92	0.0	0	0	0.0	0.0	0.0
Feb '92	872.6	11	55	1.2	27,748.68	31.8
Apr '92	754.5	23	115	0.1	1,999.42	2.65

r(X1, X3) = 0.789, $p < 0.05$
Total larvae production = vegetation area * (density/dip) *MF (= 26.5 see MM)
Vegetation area = l_j * W_j where l_j and W_j is the length and width of the vegetation on jth segment
Lengthwise 1 pixel = 1 segment

Table 5

Larval production in segments without vegetation.

Date	Breeding area without vegetation (m^2)	No. of segments	No. of dips	Total larvae production	Larvae production/m^2
July 9 '91	735	49	1.2	23,373.0	31.8
Oct 5 '91	150	10	0.6	2,385.0	15.9
Oct 27 '91	195	13	0.1	516.75	2.65
Nov 7 '91	675	45	14.8	264,735.0	392.2
Jan 12 '92	750	50	0.9	17,887.5	23.85
Feb 25 '92	585	39	0.1	1,550.25	2.65
Apr 20 '92	405	27	0.5	5,366.25	13.25

Table 6

Relationship per man hour density from density/dip and total larval production.

Date	Den/dip X1	Total larvae production X2	Man hour density X3
July 9 '91	1.2	28,286.1	97.5
Oct 5 '91	4.6	399,454.11	375.3
Oct 27 '91	0.6	43,569.18	48.2
Nov 7 '91	13.5	335,784.15	412.02
Jan 12 '92	0.9	17,887.5	85.4
Feb 25 '92	0.1	3,862.64	35.3
Apr 20 '92	0.3	9,218.03	42.7

r (X2, X3) = 0.97, ($p < 0.05$)
r (X1, X3) = 0.88, ($p < 0.05$)

Table 7

Larvae production per m^2 in 12 surrounding ponds and Sanjay lake.

Date	Larvae production/m^2 in	
	12 Ponds	Sanjay Lake
Oct 5 '91	72.1	121.9
Oct 27 '91	27.1	15.9
Nov 7 '91	36.3	357.75
Jan 12 '92	34.2	23.85
Feb 25 '92	12.5	2.65
Apr 20 '92	20.9	7.95

92 when the vegetation area was 754.5 m^2 and larval production was 3/m^2. Therefore it is possible to predict mosquito production areas and seasons of high abundance. Since the area under each class can be quantified with the help of pixels, temporal changes in each class can be quantified and resulting mosquito production can be estimated. Breeding sites of > 36.25 × 36.25 m^2 (IRS L2 resolution) can easily be identified and rapidly mapped, thus the old data can easily be updated.

The technique provides fast production of data at low cost without security regulations at low ground control/logistics but the major constraint is non-availability of satellite images during clouds. Spatial resolution constraints resist the identification of smaller water bodies which are prolific mosquito production sites, particularly for anophelines. The technique is good for mosquitogenic stratification but needs to be integrated with Geographical Information Systems which can integrate multidate satellite data and data from other sources, *eg* landuse maps, survey data, meterological data.

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