PART V

PUBLICATIONS

Part V

Publications

This part contains a list of publications, acceptance letters of the papers that are due for publication, and photocopies of the abstracts and the papers that are not included in the earlier parts of the thesis.

Appendix I

List of publications

List of published / accepted / communicated research papers

	Title	Source	Page No.
1	Impact of urbanization on the water resources and their management in Pondicherry	The Proceedings of Tenth National Symposium on Hydrology, July 2000, new Delhi, Indian Association of Hydrologists, Roorkee.	486 – 495
2	Plankter community dynamics of a shallow fresh water lake of Oussudu	The Proceedings of Third Asia Pacific Conference on sustainable Energy and Environmental Technologies, Hong Kong, Dec 2000 (APSCEET).	201 – 206
3	Assessing landuse / landcover of Kaliveli watershed using Remote Sensing and GIS: implications for conservation	The Proceedings of Spatial Information Technology: Remote Sensing and GIS, 2001, Vol II, BS Publications, Hyd, India	331 – 336
4	Application of GIS in ecorestoration planning of a typical suburban area	The Proceedings Spatial Information Technology: Remote Sensing and GIS, 2001 Vol II, BS Publications, Hyd, India	573 – 578
5	Environmental conditions of Oussudu watershed, Pondicherry, India: an integrated geographical assessment	The Indian Geographical Journal, 2001, Vol 75, No.2	81 – 94
6	Studies on Environmental Management of Pondicherry – I : The Water and Air Resources	Journal of the Institution of Public Health Engineers, Vol 2002 (3)	20 – 24
7	Primary productivity of Kaliveli – a rare estuarine wetland of south Indian peninsula	Proceedings of the Conference on Hydraulics, Water Resources and Ocean Engineering – HYDRO 2002	497 – 501
8	Environmental assessment of Oussudu watershed using GIS and remote sensing: inputs for micro-level planning	The Proceedings of National level Seminar on Application of GIS at Micro-level Planning, NIRD, Hyd, Feb' 2002	25 - 33
9	Identifying similarity among the vector based GIS maps using *LANDSTAT*	The Proceedings of National Level Seminar on Application of GIS at Micro-level Planning, NIRD, Hyd, Feb' 2002	62 - 67
10	Kaliveli – a typical bulwark against draught	Proceedings of the Recent Trends in Drought Assessment, Monitoring, and Management, IIT Mumbai, June 2002	In Press

...contnd

	Title	Source	Page No.
11	Ecology, habitat and bird community structure at Oussudu lake: developing a Geographic Information System for conservation	Aquatic Conservation, John-Wiley & Sons	In press
12	GIS (Geographical Information System) : A Versatile Tool for Environmental Impact Assessment	Journal of the Institution of Public Health Engineers	In press
13	A study on the fish fauna of Oussudu - a rare fresh water lake of South Indian peninsula	Indian Journal of Fisheries, Vol 50(1)	In press
14	Using GIS to assess the implications of landuse on the plankter community of a shallow fresh water lake of South Indian peninsula	Chemical and Environmental Research	Communi cated
15	GIS and Micro-level planning of wetland conservation	The Proceedings of National Conference on Application of GIS in Micro-level Planning, NIRD, Hyd, Aug' 2002	32
16	*LandStat* - a new analytical tool for the vector based GIS maps	Landscape and urban planning	Communi cated

Appendix II

Letters of acceptance

Office of the Managing Editor,
Indian Journal of Fisheries,
Central Marine Fisheries
Research Institute, PB No.1603,
Tatapuram P.O., Cochin-682 014.
Kerala. India.

No.1-96/IJF/ 747 Dated: 10 12 2002

To Prof S A Abbasi,
Senior Professor & Director,
Centre for pollution Control &
Energy Technology,
Pondicherry University, R. Venkataraman Nagar, Pondicherry.
PIN - 605 014

Sir/~~Madam~~,

Your paper entitled "A study on the fish ..... bearing Reg. No. 747 ..... is accepted for publication in the journal, Vol. 50 No. 1 ..... of year. You may kindly inform by return of post the number of copies of reprints you may require extra, apart from the 50 gratis due to you (to be shared among the authors if the paper has more than one author.

Yours faithfully,

(Dr.N.G.Menon)
Editor
For Managing Editor.

cks/1512001.

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26 October 2000

Professor S.A. Abbasi
Centre for Pollution Control & Energy Technology
Pondicherry University, Kalapet
Pondicherry 605 014
INDIA

Paper Title: PLANKTER COMMUNITY DYNAMICS OF A SHALLOW FRESH WATER LAKE OF OUSSUDU
Author(s): K.B. CHARI AND S.A.ABBASI

Dear Professor S.A. Abbasi,

On behalf of the Organising Committee of the 3rd Asia Pacific Conference on Sustainable Energy and Environmental Technologies (APCSEET) to be held in Shangri-La Hotel, Hong Kong, 3-6 December 2000, I am pleased to inform you that your above paper has been accepted for ORAL presentation at APCSEET and included in the conference proceedings published by World Scientific Publishers. For your special case, the registration fee has been reduced from US$500 to US$250.

We look forward to meeting you in Hong Kong in December 2000, and on behalf of the organising committee I thank you for your kind contribution. If you have further inquiries, please do not hesitate to contact me or the Secretariat by fax (+852 2358 0054) or email (apc2000@ust.hk).

Sincerely yours,

Professor Po Lock Yue
Chairman
Organising Committee, APCSEET 2000

THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY
DEPARTMENT OF CHEMICAL ENGINEERING

CENTRE FOR SPATIAL INFORMATION TECHNOLOGY

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Jawaharlal Nehru Technological University
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Phones +91 (40) 3308825

ICORG - 2000

Date:16th August, 2000.

To
K.B.Chari
Center for Pollution Control & Energy Technology
Pondicherry University, Kalapet
PONDICHERRY 605 014

Ref:- Your Paper: Application of GIS in Ecorestoration Planning of a Typical Suburban Area.

K.B.Chari, T.Senthil Murugan, and S.A. Abbasi

Dear Colleague,

Sub:- **International Conference on Remote Sensing and GIS/GPS (ICORG 2000)- Letter of Paper Acceptance.**

The ICORG organizing committee has great pleasure in informing you about the acceptance of the above referred paper for ICORG – 2000. The list of papers accepted for ICORG is displayed on web site **www.icorg.org**. Please send the hard copy of the full paper/s before 15 September, 2000 along with soft copy and registration fee of Rs.2000. The authors instructions for full paper preparation, registration form and details of accommodation are available on ICORG web site **www.icorg.org**. You can mail us your requirement of hotel accommodation with all details. Looking forward to see you during ICORG.

IV Muralikrishna
Program Director

Appendix III

Abstracts and papers

Studies on Environmental Management of Pondicherry–I : The Water and Air Resources

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Abstract

Pondicherry is a unique city in several respects It was under French occupation when the rest of India (expect Goa, Daman and Due) was under British rule As a result the city bears several features of the French way of town planning, architecture, and public administration Due to vagaries of history the city does not occupy a single contiguous territory of land but has several pockets interspersed with Tamil Nadu These features, not to speak of several others besides the unique spiritual dimension bestowed upon it by Sri Aurobindo, makes Pondicherry a very interesting as well as challenging city for environmental managers

We have begun a major programme of studies aimed at assessing the natural resources of Pondicherry, the extent of their pollution, and devising ways and means of sustainable development of the city This paper presents the first of this multi-pronged ongoing programme of investigations

WATER RESOURCES

Surface Water Resources

Compared to the nearby (140 km towards North) metropolitan city of Chennai and many parts of the neighbouring Tamil Nadu, Pondicherry has been wellendowed in terms of water resources It has two major lakes – Oussudu and Bahour – besides 86 lakes of smaller size in a catchment of 6765 ha (Figure 1) Two non-perennial rivers, Gingee and Ponnaiyar, feed some of these water bodies The rainfall is intense during the North-East monsoon (October – December) but significant precipitation also occurs during the South - West monsoon (Figures 2 & 3) In some years, scattered rains come in other seasons as well (Table 1)

The Ousteri Lake

This is the largest and the most important lake of Pondicherry It also happens to be one of the most important wetlands of Asia (IUCN, 1986)[1] as it is a major wintering spot for a large number of migratory birds and is a rich source of inland fisheries The lake also plays a crucial role in recharging the underground aquifers of the region (Abbasi, 1997)[2]

Unfortunately, during the last few decades the lake did not seem to have received the care and attention it deserves The ever-increasing mats of terrestrial and aquatic weeds in Oussudu indicate the degradation of its cathment Recent studies by Chari and Abbasi (2000)[3] have quantitatively documented the growing eutrophication of Ousteri

The other threat to this lake is from industrial pollution Some industries have been found dumping huge piles of obnoxious substances at the periphery of the lake One such foul smelling waste analyzed by us (Table 1) was highly acidic and had seared the grass and the earth through which it has passed through on way to the lake

The Bahour Lake

Bahour lake is not as big as Oussudu (Table 2), but is maintained more efficiently by the local people This has saved it from eutrophication and industrial pollution The water of this lake is extensively used for irrigation

Table 1— Characteristics of Industrial waste dumped at the bank of Ousteri

Characteristic	Value
Odour	Offensive, caused dizziness
Colour	Dark, dingy
pH	0 3 units
Conductivity	45 00,00 mμ
Sulphate	23,00,00 mg/l
Nickel	700 mg/l
Cobalt	380 mg/l
Mercury	110 mg/l

Table 2— Some features of Oussudu and Bahour Lakes

Particulars	*Ousteri*	*Bahour*
Full tank level (FTL) (mm)	14 12	10 77
Depth of water level upto FTL (m)	3 50	3 60
Capacity at FTL (m)	15 30	5 60
Number of sills	7	8
Length of feeder channel from anicut (km)	12 80	14 0
Area of ayacut (ha)	15 68	33 9

* Department of Science, Technology and Environment, Government of Pondicherry, Pondicherry 605 010

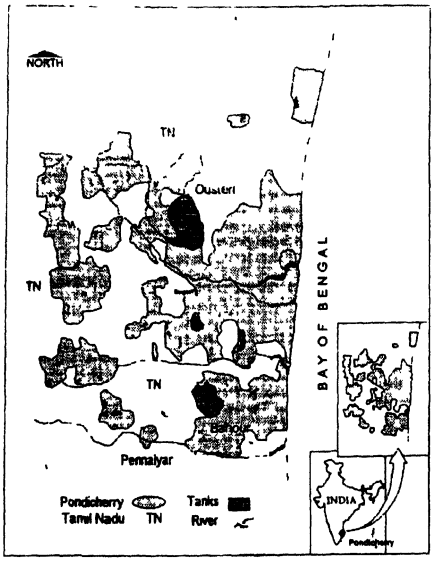


Fig 1 Location map of Pondicherry region

Table 3—Mode of Groundwater utilisation in Pondicherry

Purpose	*Percentage utilised*
Industry	4%
Drinking	9%
Agriculture	87%

Table 4—CL /HCO_3^- ratios in water samples

Location	*Value*
Keerapalayam	1.59
Periya Mudaliarchavadi	1 27
Pillaichavady	1 13
Purnakuppam	1.54
Pannithittu	3 1
Nallavadu	4 84
Virampatnam	1 7
Ariyankuppam	1 8

Smaller Lakes and Large Ponds

Apart from the two major lakes there are several smaller lakes and large ponds But most of them are besieged with siltation and eutrophication Some of the lakes/ ponds situated close to agricultural areas are found to be contaminated with organochlorine pesticides The levels of such pesticides has been found to be in the range of 29 3 µg/l to 402 µg/l

Ground Water Resources

Upto the 1960s, surface bodies had played a significant role in supplying water for irrigation in Pondicherry However, from the early 1970s there has been increasing encroachment upon wetlands for agriculture, silting up of the wetlands, and blockage in the upper reaches of the catchment areas This has hampered most wetlands Now the bulk of irrigation water requirement is met by tubewells As a result, there has been heavy demand on groundwater for agriculture, industry and domestic purposes (Table 3) leading to a rapid decline in groundwater table (Selvanathan, 1997)[9]

The potential aquifers of Pondicherry are

The Alluvium This is a shallow aquifer which has the groundwater potential of 64 mcm Areas tapping the alluvial aquifers have been classified under grey category by the government signaling cautious approach in further development of this aquifer system

Cuddalore formation Approximately 50-60% of Pondicherry is under this formation. This aquifer was

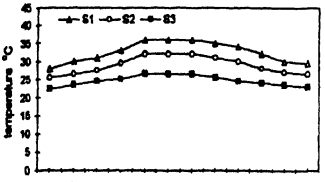
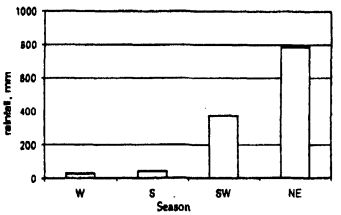


Fig. 2 Annual patterns of the minimum (S1), average (S2) and maximum (S3) temperature in Pondicherry

earlier recommended as the one with most potential for future development. However at present because of the overexploitation no further tapping of this aquifer is officially allowed.

Vanur Ramanathapuram formation : This formation is located in the north eastern part of Pondicherry, on both sides of the Gingee river. The recharge of these aquifers is mainly from the seepage of precipitation falling over cultivated fields and water bodies.



W : Winter (Jan & Feb) S : Summer (March - May)
SW : South west monsoon (Jul-Sept) NE : North east monsoon (Oct-Dec)
(10 Year average : 1975-84)

Fig. 3 : Rainfall in Pondicherry across different seasons (10 Year average : 1975-84)

Depth of Water Table

The water table map of the region was prepared on the basis of the water level data of the network hydrograph stations monitored by State Ground Water Dept (Figure 3). It is seen that in major part of the region the water table is 15m below ground level (BGL). The deepest water table (30m BGL) can be seen at Thirukkannur, P.S. Palayam, Sorapet, Lingareddypalayam and Katterikuppam. The shallowest water table (within 10m BGL) occurs along the coast.

Due to improper management of surface water bodies there has been a total dependence on ground water which has caused a steep decline of water levels in most parts of Pondicherry. It has been estimated that the water levels have declined by 4 to 20 m, from east to west in the past 18 years (Reddy, 1996)[5].

In a study conducted by M. S. Swaminathan Reasearch Foundation it has been found that in Pillaiyarkuppam the water table has fallen by as much as 13 m between May (19m) to May 1991 (32m). The tremendous increase in the population in recent years, and the mounting use of groundwater for industrial and agriculture activities are said to be directly responsible for the pressure exerted on the aquifer system of ground water resources in this region in terms of their quantity and quality.

The other important reason for the decline in water table is the expansion of the lignite mining activities at nearby Neyveli and the exploitation of groundwater in the upper reaches of Pondicherry especially in South Arcot district as the tertiary aquifer extends from Neyveli to Kalapet (Pondicherry) area (Reddy, 1996)[5]. The hydrographs (Figure 4 and 5) support this prognosis.

Salt Water Intrusion

In the coastal areas salinization of groundwater is an increasingly menacing problem. It can be attributed to tidal water ingress in the upper aquifers, sea water ingress in lower aquifers, besides over exploitation and decreasing natural recharge of groundwater. It has been estimated that the most serious of the adverse impacts of salinity is the spread of salt water over farms causing a loss of agricultural lands and drinking water quantity (Abbasi and Vineethan 1997)[1].

Borewells constructed to tap the deeper aquifers along the Pondicherry coast show signs of increasing salinity. There is a reversal of groundwater gradiant,

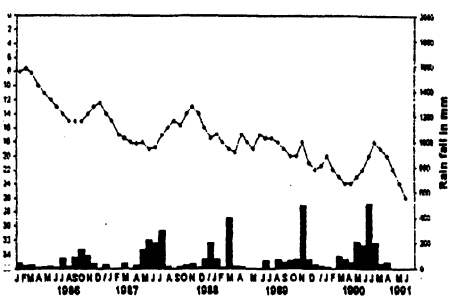


Fig. 4 : Hydrograph of Karayambuthur.

resulting in salt water intrusion in several areas specially in Kalapat, Muthialpet, Mudaliarpet, Kirumampakkam and Pannithittu (Reddy, 1996)[5].

Sea water has higher fractions of chlorides and magnesium than fresh water which is richer in bicarbonates and calcium. So Cl^-/HCO^{3-} and Mg^{2+}/Ca^{2+} values in a water sample are good indicators of salt water intrusion; when these ratios are greater than one, intrusion is indicated. Several regions in Pondicherry (Table 4) have values of this ratio greater than one (Biswas 1998)[4].

A study by Gopikrishna (1998)[4] using the saturated transport model (SUTRA) reveals that salt water has intruded upto a maximum distance of 14 km from the coast towards land in this region.

AIR RESOURCES

Air pollution has become an increasingly greater concern in Pondicherry. The main sources of pollution are automobiles and industries.

Automobiles

The automobile population, that was steadily increasing during the first half of the previous decade (Table 5), has suddenly spurted from 1996 onwards as opening of Indian economy made it possible to buy and brand across-the-counter. Today the roads and bylanes of Pondicherry are chocked with two-wheelers, cars, and station wagons.

The most noxious of emissions are provided by tempos. These are fuelled with diesel, often mixed with kerosene. In a recent emission check conducted by DSTE for diesel-driven vehicles, only about 10% of the tempos showed smoke density levels less than the standards of 65 HSU. The rest had more than 90 HSU. Tempos also contribute to noise pollution-reaching even 85 dB levels. Overloading of passengers in tempos and private buses, adulteration of petrol, bad roads, and improper maintenance of vehicles–all contribute greatly to the air pollution, directly or indirectly.

Monitoring of ambient air by territory's Department of Science, Technology, and Environment (DSTE) has revealed a sharp increase in the SPM (Suspended Particulate Matter) levels in Pondicherry. Vehicular emissions, and dust are main contributors to SPM, some of which can be extremely hazardous (Abbasi 1998)[3].

Table 5— Number of Vehicles registered in Pondicherry

Type	*1992*	*1993*	*1994*	*1995*
Trucks and Lorries	1,607	1,765	1,926	2,632
Buses	669	741	766	816
Cars & station wagons	9,943	8,415	8,912	11,424
Three wheelers	673	762	775	843
Two wheelers	60,272	65,654	71,414	78,731

Air Pollution by Industries

Pondicherry has witnessed rapid industrialisation over the past one and half decades. This has brought about economic prosperity but has also stressed the environment (Abbasi & Vinithan, 1997)[1].

There are 5 major industrial estates presently existing and plans are on to establish a few more (Figure 5). The impact of these on air pollution is summarised below.

Mettupalayam Industrial Estate

This is the biggest of all industrial estates in pondicherry and its contribution to environmental pollution is as great as its size. This estate has 122 units mainly comprising of leather, electrical, chemical, food processing, rubber, and plastic industries.

The residents in and around this region often complain of objectionable odours. The air quality in this region is bad in terms of all the three parameters studied — SPM, NO_x and SO_x. The levels of these pollutants are well above the limits applicable to residential areas (Table 6). No wonder there is frequent public outrage against the pollution in this region, with people living close to the industrial boundries the principal sufferers. Further, the data in Table 6 does not truly reflect the gravity of the situation as only SO_x, NO_x and SPM are monitored whereas contributions from chlorine, metallic particulate, and organic could be of much greater concern.

Pillaiyarkuppam-Kirumampakkam Area

This area which constitutes one of the major industrialised pockets in Pondicherry has witnessed an outburst of industrial growth over the past decade.

A detailed study (Abbasi and Vinithan 1997)[1] has shown that the air quality in this area is grossly polluted all through the year. The samples collected from the industrial, residential and sensitive areas have brought to light the critical situation prevailing in this area as most of the samples showed levels of NO_x, SO_x and SPM were above the limits set by the relevant standards. The seriousness of the situation can be gauged from the fact that whereas the norms set by CPCB require that

Table 6— Number of Vehicles registered in Pondicherry

Location	*SPM*			*NO_x*			*SO_x*		
	Min	*Mean*	*Max*	*Min*	*Mean*	*Max*	*Min*	*Mean*	*Max*
Industrial area (PIPDIC)	71	197	346	12.2	37.8	144.4	36	30.8	194
Mettupalayam	81	238	407	21.8	62.6	130.6	11.3	55.9	183.8

(all in microgram/m³)

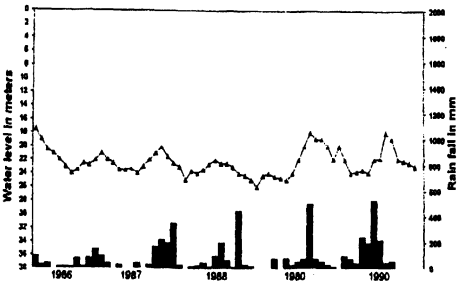


Fig. 5 : Hydrograph of Kalapet.

not more than 2% of the samples taken over an year should cross the permissible levels, this limit is exceeded in all the months (Table 7).

The Industries in most of the estates consume large quantities of water which end up as effluents. These untreated effluents are let off in a general drain which carries sewage from the nearby residential areas. In many situations the effluents are disposed on land. A typical set of results – this one pertaining to Pillaiyarkuppam-Kurumampakkam estate - is presented in Table 8. The data indicates higher-than-permissible levels of several metals. The most alarming is the presence of excessively high levels of arsenic cadmium, and mercury.

Table 7— Air samples found polluted in Pillaiyarkuppam– Kirumampakkam area

Location	*Polluted Sample*	
	Day	*Night*
Residential I	40%	70%
Residential II	63%	81%
Residential II	20%	60%
Sensitive area (Primary School)	100%	100%
Industrial area (PIPDIC)	43%	59%

Table 8— Heavy metal and metalloids in the water samples drawn from Pillaiyarkuppam – Kirumampakkam area

S. Metals No.	Months sampled				
	Apr. 94	May 94	Jun 94	Oct 94	Jan 95
	Ground Water				
1. Arsenic	0.125	0.334	0.125	0.182	0.377
2. Cadmium	0.102	0.109	0.236	0.181	0.085
3. Iron	7.825	4.985	6.251	0.969	0.707
4. Manganese	0.184	0.216	—	0.272	0.630
5. Mercury	0.384	0.360	0.473	0.530	0.263
6. Nickel	0.109	0.119	0.081	0.174	0.020
7. Zinc	0.330	0.474	1.652	1.032	0.380
	Surface Water				
1. Arsenic	0.125	0.228	0.192	0.242	0.314
2. Cadmium	0.082	0.098	0.251	0.150	0.094
3. Iron	1.663	1.238	3.021	0.455	2.073
4. Manganese	0.554	0.608	—	0.208	0.883
5. Mercury	0.293	0.165	0.284	1.116	0.946
6. Nickel	0.080	0.091	0.057	0.104	0.153
7. Zinc	0.197	0.147	0.398	0.398	0.298

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GIS AND MICROLEVEL PLANNING OF WETLAND CONSERVATION

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Abstract

India has been endowed with a very large number of wetlands. Baring exceptions, most wetlands serve the need of the rural poor who depend on the wetlands for water, fishery, reeds, and recreation.

Sadly, over the last few decades, most wetlands have been under serious threat of extinction due to pollution and encroachments.

In most urban and suburban settings, the wetlands have all but perished.

Considering the overwhelming importance of wetlands as harvesters of rainwater and rechargers of ground water, besides their myriad other uses, it is a thrust of national importance to develop strategies for conserving wetlands and finding ways to utilize them sustainably.

The quality of any wetland is directly influenced by the quality of its catchment. Hence wetland management is, de facto, catchment management. It is in this context that GIS acquires tremendous significance because most catchments are large – covering hundreds of Km^2 – and comprise of very diverse land use which may encompass agriculture, forests, human dwellings, highways, industry etc.

The authors have been studying several wetlands and their catchments with the help of GIS. In this paper the potential of GIS in micro-level planning of wetland conservation has been discussed. A few case studies from the author's work are also presented.

APPLICATION OF GIS IN ECORESTORATION PLANNING OF A TYPICAL SUBURBAN AREA

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ABSTRACT

The paper describes the application of land-use surveys supported by GIS in a) assessing the present status of land-use and environmental degradation and b) identification of integrated ecorestoration measures in a typical suburban area: the campus of Pondicherry University.

The various solid-waste and liquid-waste disposal sites, and patterns of soil erosion, denudation, and rainwater loss were identified. Simultaneous surveys were done to assess the present and likely modes of physical development. The flora, especially the tree species and the more common of the lower vegetation was monitored and mapped.

The various maps thus prepared were utilized by McHarg's method, with the aid of the GIS tool MapInfo Professional v5.5, to assess not only the present status of environmental degradation but also future trends. Finally the information was integrated with the concepts of ecorestoration to develop a management strategy aimed at reversing the harmful trends in a cost-effective manner.

1. INTRODUCTION

Geographical Information System (GIS) is finding increasing application in the monitoring, impact forecasting, and management of environment (USEPA, 1995). The applications range from wildlife management to flood forecasting and restoration of degraded lands to development of early warning systems for forest fires or water-borne diseases.

In this paper we present the application of GIS in extensive mapping and monitoring of a typical garden-land area in an India suburb which is now being increasingly developed and populated. The GIS has been used to set up the present 'bench-marks' of land-use, flora, fauna, and topography. This information-base shall serve as a frame of reference for identifying the patterns of change in future and assessing the impact of each change. This GIS has also been used to outline an ecorestoration strategy for the study area.

2. THE STUDY AREA

The study area is a 300 ha (~2.91 km^2) located in the Kalapet suburb, 11 Km North of downtown Pondicherry (Figure 1). The area is characterized by neem, cashew, palm, and phoenix as principal natural vegetation, and a terrain that gently slopes from West to East towards the sea cost (Bay of Bengal).

The area was taken over by Pondicherry University in 1987. It was then bounded and extensively planted with acacia (Acacia sp.), casuarina (Casuarina sp.), teak (Tectona grandis), coconut (Cocos nucifera), being the preferred trees, along with lesser number of several other species.

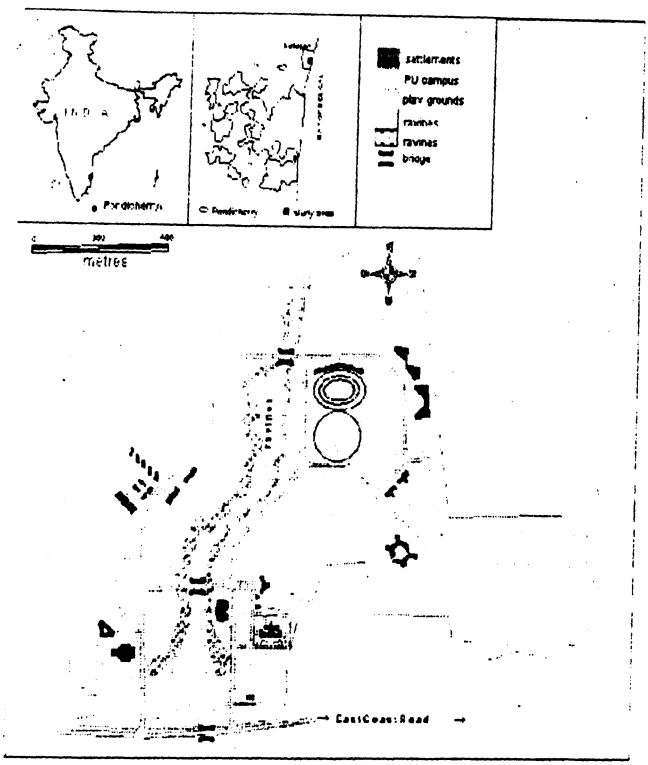

Figure 1 Location map of Pondicherry University campus

The area has since been slowly developed and at present has 8.09 km of macadamized roads, and approximately 0.108 km² of built area. Another 0.064 km² have been utilized for play-fields, and compounds accompanying building. The portions thus developed constitute a mere 7.8% of the total area; yet the signs of ecodegradation are already emerging loud and clear in the form of a) land erosion, b) fall in groundwater table, (c) solid waste accumulation, (d) water pollution, and (d) air pollution.

3. METHODOLOGY

The study area was notionally divided by a grid into 18 units. Each unit was then extensively surveyed for (a) vegetation (b) developmental features such as roads, buildings, playgrounds, water tanks etc., and (d) topography. For each unit five or more maps were generated to accommodate all essential details.

The topography of the area was studied with the specific objective of indentifying potential sites for rainwater harvesting and groundwater recharge. The emphasis of rest of the survey was to identify and quantify sites for ecorestoration.

For about 13 sites elevation contours were determined using dumpy level. Each such site measuring about 16 m^2 were split into grids of 2m^2 and readings were taken diagonally.

The maps were scanned with HP Scanjet 6300 colour scanner. All the subsequent processing for GIS was done with the tool MapInfo Professional v5.5. The terrain contours were done by Vertial Mapper v2.5, an accessory tool of MapInfo Professional.

4. RESULTS AND DISCUSSION

4.1 Topography

The study area has a gently undulating and net sloping terrain, falling from its western peak height of 36m above the sea level to the eastern boundary 7m above the sea level, some 500m from the sea.

The whole area has been split down the middle by a ravine (Figure 1). The catchment ravine has sharp undulations for a few meters, on either side of the ravine - the southern flank more prominent in this respect. These undulations provide relief in an otherwise predominately flat terrain.

Due to its eastward slope, the area is prone to sheet and gully erosion. The gradual and uniform peeling away of the soil surface by the action of flowing water renders the soils infertile due to the loss of soil humus and nutrients. As the finer particles are carried away the water holding capacity of the soil is affected severely.

The precipitation intensity, duration and frequency, especially during the southwest monsoons (Abbasi et.al., 2000), seem to accelerate the loss of topsoil. Rather than checking the runoff, the campus engineers have provided cobbled channels to facilitate draining of rainwater out of the campus. As a result not only priceless water is lost to the sea, there is a concomitant loss of the top soil. There is also a tendency to clear the grounds of all vegetation on the premise of keeping off scorpions and snakes, and reducing mosquitos. These factors have combines to make the study area very sensitive to devegetation. Indeed, clearing of even small patches of land for residential quarters and play-grounds, without concomitant attention to watershed pattern, has caused rapid erosion of top-soil. Some of the macadamized portions of the roads have been totally covered with thick layers of eroded topsoil, so much so that they look like mudtracks rather than pukka - roads.

4.2 Vegetation

The flora of the study area represents diverse habits and habitations. As the trees are isolated by the abundant presence of shrubs (Figure 2), the vegetation can be classified as woodlands (Scot, 1995).

The species Azadirachta indica, Pongamia sp., and Borassis flabellifer, representing the natural vegetation form about 62.11% of the green cover. Among the natural vegetation 34% species belong to scrub jungle, and 17% to wastelands. The presence of species such as Lucas aspera, Dodonea viscosa, and Tridax procumbens, consisting about 13.6% of the total vegetation, indicate substantial disturbance of the existing natural vegetation. Further, the species selected for plantations - such as Acacia and Eucalyptus - which are very effective in restoring or utilizing degraded lands, are not appropriate in the study area because the study area has good soil and can easily support less dominant and more varied flora.

Table 1 Habitat distribution of various species in the study area

Habitat	% species
Natural	62.11
Scrub jungle	21.21
Waste lands	10.30
Others	30.30
Distributed lands	34.80
Garden land	7.6
Cultivated land	13.6
Fallow land	13.6
Others	3.03
Total	100.00

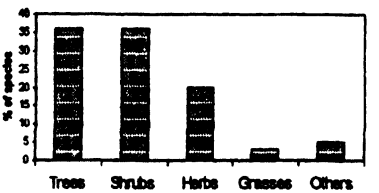

Figure 2 Habitat distribution of the vegetation

4.3 Other features

The study area urgently needs to device an integrated and ecologically compatible strategy for handling it's liquid and solid wastes as this is already becoming an increasingly menancing problem Inspite of very low population density.

5. IMPERATIVES

The campus urgently needs extensive measures to improve ground water recharge, contain soil erosion, and treat its solid and liquid wastes. On the basis of the GIS we have developed for the study area, the following imperatives emerge :

- There are numerous sites, for example the one depicted in Figure 3, where run-off management can enormously help in ground water recharge. The management actions include contour bunds, sand traps and other mechanical measures to delay run-off and facilitate ground water recharge.
- Rain water harvesting : diverting the rain water collected over roof-tops into percolation pits can help not only in recharging the ground water aquifers but also reduce the run-off. The same roof top water if stored can supplement the water requirement.
- Disposal of liquid waste: The study area is ideal for waste water treatment based on constructed wetlands.
- Disposal of solid waste: Sorting out solid waste at site and conversion of biodegradable waste into either compost/vermicompost.
- More careful choice of species to be planted for ecorestoration.

6. ACKNOWLEDGEMENTS

The authors thank the Ministry of Water Resources, Govt of India, for support.

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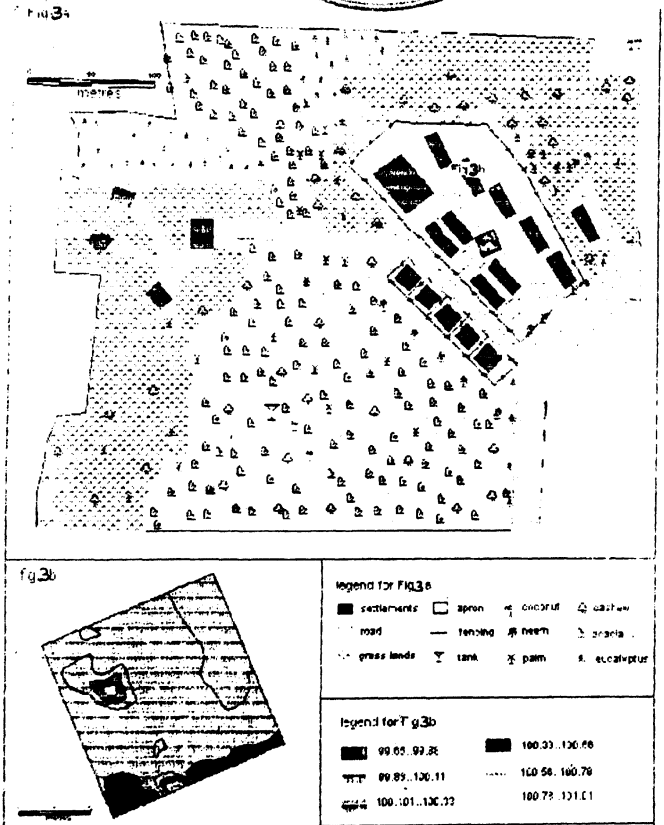

Figure 3 a) Digitized map of one of the units of the study area
b) Detail of contours studied for catchment management