SUSTAINABLE DEVELOPMENT AND MANAGEMENT OF SURFACE AND GROUNDWATER IN COOUM SUB BASIN OF CHENNAI BASIN USING REMOTE SENSING AND GIS

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ABSTRACT

Water is the most valuable renewable natural resource for preserving all forms of living on earth. It is an economically productive resource and it is the main source of economic structures. In recent decades the surface water resources are fully utilized in the 17 most important river basins of Tamil Nadu and this is a main problem in the State. Sub-basins located near East Coast, face seawater intrusion problem. Cooum sub-basin of Chennai basin located in Thiruvallur and Chennai districts suffer due to pollution, saltwater intrusion problems. Hence, a study was undertaken in the Cooum subbasin. Collateral data on groundwater level, quality, soil, geology, drainage, rainfall and as maps were generated using GIS software in digital format. By interpreting high-resolution remote sensing satellite data, thematic layers as land use, geomorphology and waste lands were prepared. Existing anicuts, reservoirs were also marked with details. Water potential assessment was analyzed and sectoral demands were estimated. Degraded areas were distinctly marked. Favorable zones for further development were chosen and the map was prepared. Remedial measures were also suggested. The potential, draft, balance of water were derived scientifically by utilizing modern remote sensing and GIS techniques.

Keywords: sustainable development, surface and groundwater, remote sensing, GIS, Cooum subbasin, Chennai Basin

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INTRODUCTION

The human essential and economic development are important for sustainable development of conservative environment with the resourceful use of natural resources, that make sure substitution between preferred production and consumption levels.

Due to rapid growth (i.e.,) Most of the wetlands in the study area are converted to Information Technology (IT) industries and residential apartments⁸ and its suburbs and also due to population growth the river is highly deteriorated in every aspect. Water Resources are increasingly threatened by:

- Poor maintenance of irrigation tanks and their supply channels due to its loss of water conservation.
- Over utilization and Inefficient use of surface water for agriculture,
- Over utilization of groundwater for agriculture and rural water supply and
- Excessive use of chemical fertilizers and pesticides for agriculture

The groundwater cultivation yields are high compared to those in the canal irrigated areas⁶. In India, the groundwater-irrigated area accounts for about 50 percent of the total irrigated area and up to 80 percent of the country's total agricultural production may, in one form or another, be dependent on groundwater¹. Still, the availability of groundwater for irrigation only cannot make sure augmented yields as recognized around the world. The availability of groundwater is essential as a part of a complementary and commonly strengthens the set of other technologies. Surface water resources are fully utilized and due to

overuse of groundwater in the 17 most important river basins of Tamil Nadu is a very big problem in the State. Remote Sensing (RS) and Geographical Information Systems (GIS) now play a major role in inventorying and observing of natural resources.

The main problems encountered in Cooum sub-basin are:

- Sub-basins located near East Coast, face seawater intrusion problem.
- Cooum sub-basin of Chennai suffer due to pollution, saltwater intrusion problems

This paper deals with the possibility of releasing minimum water flow in the Cooum river for keeping the river clean in Chennai City from the savings of water in upper reaches in the Agriculture sector water utilization by adopting modern technology and better water management technologies.

Study Area

In earlier days the Cooum is also called as Triplicane river. Cooum name is derived from Tamil literature. The Cooum River originates from Cooum tank in Thiruvallur district of Tamil Nadu and flows towards the east for a distance of 65 km. The river confluences with the Bay of Bengal at Chennai City. The length of the river in Chennai City limits is 16 km. The Cooum Sub-basin is in Chennai Basin. The area of the subbasin is 682 sq.km. It is situated between latitude 12° 54'30" and 13° 9' and longitude 79° 36'30" and 80° 19'. Kosasthaliyar subbasin is in the north, Palar basin and Adayar sub basin lies in the south and Bay of Bengal in the eastern side. The location map is shown in Fig.-1.

The Korattur Anicut constructed in 1879 across Cooum in the middle reach of Cooum diverts water to Chembarampakkam tank through New Bangaru channel and surplus from Chembarampakkam tank flows into Adayar river.

Objectives

The main objectives of the study on sustainable development and management of surface and groundwater in Cooum sub-basin of Chennai basin are

- To prepare different themes such as land use, Geomorphology and wastelands using remote sensing and GIS.
- To generate the collateral data on groundwater level, quality, soil, geology, drainage, and rainfall using GIS software in digital format.
- To access the water potential and sectoral demands in Cooum sub basin.
- To prepare favorable zones for the study area.
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EXPERIMENTAL

Our country mostly depends on two main resources such as land and water resources. Due to overpopulation, the resources are in exhaustion. So there is more essential to deal with these resources. The integration of remote sensing and GIS is now more effective for the analysis to obtain sustainable development. The satellite datasets which is used for the current study are IRS LISS-II 2005 & IRS LISS-III 2013 of 1:50,000 scale were classified visually for preparation of thematic layers such as land use/land cover, hydrogeomorphology and soil.

With the help of characteristics of the satellite image like location size, shape, shadow, tone/colour, texture, pattern, height/depth and site/situation/association were carried out interpretation of photo-image and layouts were prepared for the above-specified themes All these layouts were checked with ground truth verification using field surveyed through Global Positioning System (GPS) and finalized the maps. To categorize the name of villages in the study area, latitude and longitudes with diverse reference points had plotted on the satellite images which is based on the 1:50,000 scale of Survey of India (SOI) toposheet. The overlay analyses (all thematic layers) were processed for land irrigation and for natural resource evaluation purpose.

Recommendations are given with the base study and availability of resources and conditions which are observed in the field, an alternative livelihood sustainability as cultivating like forestry, horticulture and

plantation and also brief given for more efficient water resource methods and practices for harvesting surface water.

Fig.-1: Location Map for the study

RESULTS AND DISCUSSION

Land Use

The base for any type of research in the land is mainly focused on mapping land use and the land cover information is essential for local to the regional level of study. In this research paper, this base study such as land use /land cover plays a vital role in sustainable development/management of the local community. In the Cooum sub-basin Chennai is Located. There is pressure for land for all the sectors such as housing, industries, agriculture etc. Urbanization and expansion of Industries encroach on the agriculture land. The statistical data of land use and land cover is given in Table-1 and the spatial distribution of the same is shown in Fig.-3.

Agricultural Area

Agriculture is the major use of the land, water and biological resources in the World. This is the main occupation of this area. In the current study the observation with the help of the image interpretation

reveals that the area under study is predominantly an agricultural region. In study area, maximum areas come under cultivation and it occupies 183 sq. km (27%) of the total study area.

Built-up land (Rural, Town/Cities)

It is classified as an urban area and is categorized by urban morphology as settlements; road & rail networks and rural areas are classified as villages of human habitation. The classification of urban area in satellite imagery was based on tone, color and location with the association. The settlement is demarcated in the satellite image which is seen as grayish & light bluish color. The total area of urban classification are occupied in the study area is 123 sq km (18%) and the rural area occupied the total area of 12 sq km (2%).

Fig.-2: Methodology for sustainable development and management of surface and ground water in Cooum Sub Basin of Chennai Basin

Water Bodies

It includes natural water bodies and manmade water features like lakes, ponds, tanks and reservoirs which flowing as rivers, streams and canals. These features in satellite data are represented tone as light blue to dark blue with a smooth texture. Due to the absorption of IR radiation, the water bodies are seen dark blue in the satellite imagery. The total geographic distribution of water bodies like tanks /reservoirs and river/streams are 32 sq km and 26 sq km respectively and the same is given in Table-1.

Other Categories

This category is included other uncultivated land, excluding the current fallows. In our study, the other category is classified as aquaculture pond and it occupies the very negligible area.

Soil Type

Mapping the soil information constitute a visualization of soil types and their specific areas of distribution. The following orders of soils are found in the sub basin as per remote sensing data is shown in Table-2 and Fig.-4.

Fig.-3: Land Use Map

Table-1: Land use Pattern in Coovum Basin, Chennai

Land use	Area –km ²	Percentage (%)
Crop	183	27
Plantation	296	43
Tanks and Reservoirs	32	5
Streams and River	26	4
Rural Settlement	12	2
Town and City	123	18
Others	10	1
Total	682	100

Alfisols are arable soils with water content adequate for at least three consecutive months of the growing season. In the study areas which are occupied are 154 sq km (23%).

Entisols are described as they don't show any development in the profile other than an A horizon. In this study entisols are occupied of about 118 sq km (17%) of the total area.

Inceptisols are the type which is weakly developed, but they are more developed than entisols. This type can be mostly seen in steep slopes or wet areas. These types of soils are occupied in the study area of about 331 sq km (49%). Vertisols are the soils which are clayey with the less organic matter, can be mostly seen in wet and dry seasons. Wetness substance differs in the study area and occupies a negligible area.

Geology

The sub-basin is underlined by the formation of Archaean to recent age. Crystalline rocks of Archaean age comprising granite gneisses, charnockite and associated basic and ultra basic igneous and metamorphic rocks cover the west. Sedimentary formations of Gondwana, tertiary, quaternary and alluvial deposits cover the east. They contain shale, clay, sandy clay, gravels, pebbles and fine to coarse sand.

Fig.-4: Soil Map

Table 2. Soil type in Cooum Basin, Chennai

Order	Area –km ²	Percentage (%)
Alfisols	154	23
Entisols	118	17
Inceptisols	331	49
Vertisols	1	0
Settlement	78	11
Total	682	100

Hydro Geology

Ground water occurs under confined and unconfined conditions. Yield in boreholes varies from 45 to 454 lpm.

Geomorphology

Chennai area mainly consists crystalline rocks, which spread out right to the coast to the South Chennai. Mostly this area topography shows wide topographic high in the central part of Chennai sector. Alluvial, coastal plains, flood plain and sedimentary high ground landforms are noticed in the study area are shown in Table-3. This area occupies various geomorphologic features in the study area is shown in Fig.-5.

Alluvial Plain

Alluvial Plain is a gentle form of slope or this type will be slightly undulating land surface and almost which results in the deposition of alluvial materials by running water and they are related with main rivers and streams that were recognized by sparse surface drainage. This type occupies the second main component of the sub basin. The alluvium plain which consists of silt, clay, sand, gravel as well as organic matter. The thickness of alluvium ranges from area to area and the highest of 28 m. The alluvial plain covered about 150 sq km (22%).

Coastal Plain

Chennai is the flat coastal plain and which is known as eastern coastal plains. This type of plains and seas are mostly rich in taxonomy. The coastal plains occupy an area of 95 sq km (14%) of the total area.

Flood Plains

This type is an area which occupies the land adjacent to the river/stream stretches from the bank. The flow of water may join nor other drainage channels to develop separate channel or incase this flow of water does not develop the channel fully and it drops and dumps full of sediment and these occupy of about 68 sq km (10%).

Sedimentary High Ground

In the study the main substance is sediment formation of about 54% from the total area was occupied and the area occupied Tertiary age, consisting of laterite, sandstone, clay, silt, sand, etc. The left over 46% of the area is occupied by soil type like river alluvium, coastal alluvium and flood plain.

Hydrometeorology

Rainfall

The rainfall data for 34 years from 1971 were analysed for 7 stations in Cooum sub basin. The 50% and 75% dependable rainfall are given below. (Table-4.1 and 4.2). The annual and monthly variations of rainfall for Kesavaram, Korattur and Nungampakkam are given in chart (Fig.-6).

Climatological Features

Maximum monthly average temperature-33.4 deg C (May)

Minimum monthly average temperature-24.4 deg C (December)

Maximum wind velocity (km/Hr)-9.1 (June)

Minimum wind velocity (km/Hr)-3.7 (October)

Maximum average sunshine (Hrs/day) -10.0 (April)

Table -3: Geomorphology Characters in Cooum Basin, Chennai

Type	Area-km ²	%
Alluvial plain	150	22%
Coastal plain	95	14%
Flood plain	68	10%
Sedimentary High ground	368	54%
Total	682	100%

Astronomical Tidal Analysis

Based on the data provided by the Chennai Port Trust analysis were made on 100 years tidal levels at Chennai and the mean tidal levels have been calculated and shown in Table-4.3. The water level at Napier bridge, Periyar bridge and Quid-e-millath bridge were observed during 27 may 2007 to 2 June 2007.

Surface Water Hydrology

The Cooum sub basin has linkage with Kosasthaliar sub basin and Adyar sub basin because of Chembarampakkam tank and Chennai City water supply schemes. In olden days Chembarampakkam tank was an important tank for Agriculture activities serving an ayacut of 5429 Ha.

To feed water to this tank an anicut was constructed across Kallar the tributary of Kosaathaliyar river in 1879 and water was diverted to Cooum river through old Bangaru channel and then below this Korattur Anicut was constructed further downstream of Cooum to divert water to Chembarampakkam tank through New Bangaru channel (Table-5.1).

Fig.-5: Geomorphology Map

Fig.-6: Rainfall Variation

Table-4.1: Rainfall for 75% dependability in mm

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Kesavaram Anicut	9	7	4	15	41	74	95	111	144	173	226	117	1015
Thiruvallur	13	14	3	16	46	80	116	130	155	216	277	118	1184
Korattur Anicut	16	12	2	8	43	73	93	125	141	232	270	126	1141
Poonamalli	16	14	1	10	41	68	122	145	144	281	369	149	1363
Chembarampakkam	29	25	3	18	54	93	129	168	163	291	409	168	1550
Nungampakkam	28	20	3	9	49	80	106	136	141	288	386	170	1416
Chepakkm	25	17	4	7	44	71	100	127	126	262	339	163	1283

Source: IMD, Chennai

Table-4.2: Rainfall for 50% dependability in mm

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Kesavaram Anicut	7	6	3	11	31	57	73	85	110	132	173	89	777
Thiruvallur	10	11	3	13	38	66	95	107	127	177	227	97	971
Korattur Anicut	15	11	2	8	40	68	86	116	131	215	251	117	1060
Poonamalli	14	12	1	9	36	59	106	125	125	243	319	128	1176
Chembarampakkam	24	21	2	14	44	76	104	136	133	236	332	137	1259
Nungampakkam	22	15	3	7	37	61	81	104	108	220	295	130	1082
Chepakkm	20	14	3	6	37	59	83	104	104	216	279	134	1058

Source: IMD, Chennai

Table-4.3: Mean Tidal Range at Chennai

Description	Water level (m Asol)
Mean Highest High Water	0.55
Mean Lowest Low Water	-0.23
Mean Highest Water Spring	0.77
Mean Highest Water Neap	0.41
Mean Lowest Water Spring	-0.35
Mean Lowest Water Neap	-0.06

Minimum average sunshine (Hrs/day)	-5.7 (July)
Maximum ETo mm/month	-251.1 (May)
Minimum ETo mm/month	-117.0 (November)
Average ETo mm/month	-175.7
Maximum monthly evaporation mm	-277.8 (May)
Minimum monthly evaporation mm	-105.2 (December)
Average annual evaporation mm	-2161

Poondi reservoir was constructed across Kosasthaliyar river for Chennai City water supply. Additionally, Cholavaram and Red hills tanks were also connected with Poondi reservoir to store water for Chennai. Now Chembarampakkam and Porur tanks of Adayar sub-basin are also used for Chennai city water supply. The other important canals are Buckingham canal, Otteri Nalla, Captain cotton canal and Arumpakkam odai. Integrating groundwater and surface water management could enable the more sustainable use of both pursues a holistic approach to these various types of water resources³.

Table 5. 1 Chennai City water supply Reservoirs

Name of Reservoirs	Gross Capacity (Mcm)	Live Capacity (Mcm)	Dead Storage (Mcm)	Catchment Area (Sq.km)	Water spread Area (Ha)
Chembaram pakkam	88.30	87.80	0.50	77.00	350
Porur	1.04	1.00	0.04	22.44	320
Poondi	77.90	77.40	0.50	2704.00	3230
Red Hills	80.75	80.25	0.50	59.57	2087
Cholavaram	25.63	25.43	0.20	28.33	2258

Source: Central Ground Water Board (CGWB)

The Existing Hydraulic Structures

Anicuts

As above the important anicuts in Cooum sub-basin are Kesavaram anicut and Korattur anicut. The hydraulic particulars of these anicuts are given in table 5.1 and 5.2. The other anicuts are below

1. Aranvoil anicut.
2. Ayalachery anicut
3. Paruthipattu anicut
4. Ayanampakkam anicut.

City Water Supply Reservoirs

The details of storage reservoirs for Chennai are given below:

Irrigation Tanks

In the upper and middle reach of this sub basin Agriculture is the main activity. Irrigation provides crucial water for agricultural production⁴. Tanks are the only source for surface water irrigation. The details of tanks are given in Table-5.2.

Table-5.2: Irrigation Tanks

Location	No of Tanks	Capacity (Mcm)	Ayacut (Ha)
System Tanks			
Above Cooum	26	11.40	5314
Non System Tanks			
Above Cooum	15	4.17	1803
Above Aranvoil	26	17.15	3784
Below Aranvoil	10	4.93	2167
Total	51	26.25	7754
Panchayat Union Tanks			
Above Cooum	4	0.50	97
Above Aranvoil	20	2.50	533
Total	24	3.00	630
Total Tanks			
In sub basin	101	40.65	13698

Source: Central Ground Water Board (CGWB)

Surface Water Potential

Institute for Water Studies Report

In this sub basin the contribution of runoff is mainly during the north east monsoon period and it is less during south-west monsoon period.

The surface water potential was worked out for the 75% dependable rainfall and 50% dependable rainfall for the Southwest monsoon, Northeast monsoon and annual by runoff coefficient method. The run off coefficient adopted is 0.15. The monthly rainfall of Thiruvallur, Korattur, Nungampakkam and

Chepaukkam had been taken for a period of 19 years from 1974 to 1993. The surface yield is furnished below in Table-5.3.

Table-5.3: Surface water Potential in Mcm by Run off Coefficient method.

	South west	North east	Annual
50% dependability	45.56	78.31	127.32
75% dependability	38.46	51.63	105.38

Source: Chennai River Basin Report

Ground Water Hydrology

Annual Groundwater Potential

The annual average groundwater potential has been assessed blockwise by the State Ground and Surface water Resource Data Centre using Groundwater Estimation Committee norms. From this assessment, the annual average Ground water potential for Cooum sub-basin has been worked out furnished under Table-6.1.

Table-6.1: The annual average Groundwater Potential in Mcm

Block	Area Sq.km	Area in Sub basin Sq.km	% in Sub basin	Total Potential Mcm	Potential in Sub basin Mcm
Walajabad	356	101	28%	117.07	33.21
Sriperumbudur	372	58	16%	120.62	18.81
Kadambathur	266	181	68%	88.03	59.90
Thiruvallur	195	62	32%	70.14	22.30
Poondamalli	178	109	61%	64.80	39.68
Villivakkam	211	75	36%	54.59	19.40
Puzhal	127	18	14%	31.39	4.45
Chennai		78			78.00
Total		682			275.75

Source: State Ground and Surface water Resource Data Centre

Well Census

As per the good census by the State Ground and Surface water Resource Data Centre, the following category wells are in the Cooum sub basin. Irrigation wells are 9349 and non irrigation wells are 78094 is shown in Table-6.2 and 6.3.

Table-6.2: Irrigation wells

Taluk	Open wells	Bore wells	Dug cum Bore wells	Tube wells	FP wells	Total	Ayacut (ha)
Arakonam	682	791	293	2	0	1770	1905
Kancheepuam	751	568	288	174	1	1782	1421
Sriperumbudur	300	123	33	184	0	640	645
Thiruvallur	1110	1143	530	574	100	3457	4395
Poondamalli	514	558	1	87	1	1161	909
Ambathur	93	40	0	23	0	156	74
Total	3452	3223	1145	1044	102	8966	9349

Source: State Ground and Surface water Resource Data Centre

Table- 6.3: Non-irrigation Wells

Taluk	Domestic	Industrial	Commercial	Total
Arakonam	195	7	4	206
Kancheepuam	122	1	3	126
Sriperumbudur	195	1	1	197
Thiruvallur	3689	55	48	3892

Poonamalli	2550	92	31	2673
Ambathur	70786	129	85	71000
Total	77637	285	172	78094

Source: State Ground and Surface water Resource Data Centre

Ground water level variations

The water level fluctuations have been observed during the period of five years from 2002 to 2006. The ground water level in Chennai City is going down in the past years is shown in Table-6.4.

Ground water quality

The State Ground water and Surface water data centre have observed water quality in the wells⁵. Quality of groundwater is equally important to its quantity owing to the suitability of water for various purposes⁹. In the coastal area the salinity in terms of Electrical conductivity values is found to be high due to sea water intrusion. The ground water pollution has been observed in Ambatur area due to industrial effluent discharges. The ground water quality has been furnished in Tables-6.5 and 6.6.

Table-6.4: The average annual variations in m

Year	Avadi	Govindavadi	Thandalam	Purisai
2002	4.6	19.4	3.0	14.9
2003	3.9	20.1	2.4	16.2
2004	6.0	20.7	2.6	16.6
2005	8.1	22.2	2.0	16.7
2006	4.7	19.8	2.8	12.9

Source: State Ground and Surface water Resource Data Centre

Table-6.5: Ground water quality

Contents	Arumpakkam	Vepery
Date	16-7-2003	16-7-2003
Ca	52	80
SO ₄	67	720
Cl	131	262
NO ₂ +NO ₃	16	4
TDS	645	1919
Hardness	255	1150
Conductivity	1040	8100
pH	8.6	7.8

Source: State Ground and Surface water Resource Data Centre

Table-6.6: Ground water quality

Contents	Govindavadi	Thandalam	Purisai	Avadi
Date	13-7-2006	13-7-2006	13-7-2006	13-7-2006
Ca	44	68	76	40
Mg	63	71	24	107
Na	246	110	191	357
K	9	3	65	5
HCO ₃	354	165	342	256
CO ₃	0	0	12	0
SO ₄	117	177	144	672
Cl	347	347	191	284

NO ₃	4	0	18	4
F	0	0	0	0
TDS	1021	859	954	1611
Hardness	370	460	290	540
Conductivity	1760	1880	1470	2540
pH	7.5	8.0	8.7	8.6

Favorable Zonal Map for Surface and Groundwater

With all the thematic layers, it has been finalized the main zones for sustainable development for surface and groundwater in Cooum Basin of Chennai Basin is shown in Fig.-7.

Fig.-7: Cooum Zones

CONCLUSION

The significance of integrated geospatial technology has clearly proved its usefulness in understanding the factors dependable for maintaining the hydrological cycle mainly the vegetation cover, surface water bodies, litho types and landforms. The groundwater prospects maps form a very good database and help in classifying the favorable zones (prospective zones) around the narrowing down the target areas. Recharge is the most important factor in groundwater studies. If sufficient recharge is not there, the most favorable aquifer zones will also become dry. The multi-parametric method of the technique is lucrative and this technique is better than the conventional method. This type of research is useful for analysis of influencing factors to identify the groundwater potential recharge sites.

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