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Contents

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IDENTIFICATION, CATEGORISATION AND PROTECTION OF GEOHERITAGE SITES OF THE CAUVERY BASIN, SOUTH INDIA, FOR EDUCATIONAL, RESEARCH AND GEOTOURISM PURPOSES

Ramkumar Mu.[1], Kumaraswamy K.[2], Jyotsana Rai[3] and Menier D.[4]

[1]Department of Geology, Periyar University, Salem - 636 011
[2]Department of Geography, Bharathidasan University, Tiruchirappalli - 620 024
[3] Birbal Sahni Institute of Paleosciences, 53 University Road, Lucknow - 226 007
[4]GMGL UMR CNRS 6538, Université de Bretagne Sud, Vannes Cedex 56017
E-mail: muamkumar@yahoo.co.in

Abstract

Geoheritage sites are those sites identified and protected for their value in geoscience and aesthetics. Worldover, serious efforts are being made to identify, categorise and to protect such sites. A more or less complete stratigraphic record of Barremian-Danian along with diverse fossil, sedimentary structural and other features occur in the region bound between Vellar and Coleroon in South India. With the pace of rapid urbanisation developments and the mining activities in the vicinity, it is of public knowledge that the geologically important, unique archives of the past are being unscrupulously plundered and unless systematic documentation and sincere efforts of protection are initiated, these geological treasure troves will be lost forever. Given cognizance to all these, propose identification, protection and establishment of field museum sites under six categories, namely, sites of fossil locations, sites of natural exposures, sites of stratigraphic importance, sites of unique facies types, sites of excellent traverses and sites of newly excavated mine and other sections. We also propose to establish an online catalogue of important locales according to these six categories, creation of Web-GIS enabled interactive and informative kiosk containing basic information on these sites and making this resource an open-source model. Finally, this study suggests that the proposed field-museum encompassing the six-category sites may be named after Dr. M.S. Krishnan, the illustrious geologist of Geological Survey of India.

Keywords: Geoheritage, Geo-hotspots, Geotourism, Cauvery basin, Conservation, India

Introduction

Geoheritage sites are being identified worldover, in order to preserve geologically important sites and naturally or antropogenically well-exposed sections for the purposes of posterity, education, research and also for aesthetic values. While the importance of preserving and protecting these sites are being realised and efforts are made by governmental and non-governmental agencies all over the world, India lags behind and this poses serious threat to the valuable information and the utility value of these sections and sites contain within them. The earliest presence of mankind and tools used from Palaeolithic age in the Northern India are found in literary sources (Koushic, 1963). With the bludgeoning population, liberalisation of economy and free-licensing policies, the urbanisation and industrialisation exert additional pressures on these very geological treasures that contain archives of past environment-climate and biological events, which in turn may be lost forever, due to unplanned excavation-construction activities, indiscriminate mining of mineral deposits. These activities also invariably deprive the geologically important information that may be unearthed by researchers in future (Krishnan, 1943). In this paper, an attempt is made to impress upon the reader the importance of identification, categorisation and protection of geoheritage sites in and around Ariyalur, Cauvery Basin, South India.

Exposures in and Around Ariyalur - The Treasure Trove of Geological Information

The Cauvery basin of South India, formed during the break-up of the Gondwanaland, contains more than 5,500 m thick pile of sediments (Ramkumar, 2004). A more or less complete stratigraphic record of Barremian-Danian is found exposed in the Pondicherry-Ariyalur sub-basin of the Cauvery basin. More particularly, the region bound between Vellar in the North and Coleroon in the South (Figure 1) has been commented as a 'veritable field museum of the Cretaceous' (Ramkumar, 1997).

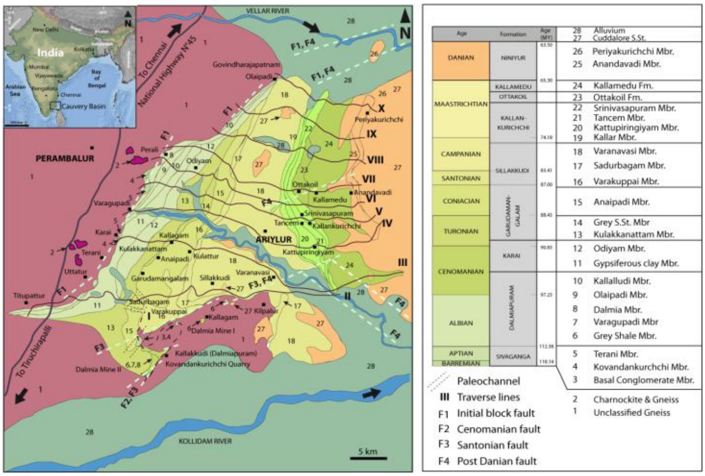

Fig. 1. Geology of the Cauvery Basin Exposed in the Pondicherry - Ariyalur Sub-Basin *(After Ramkumar et al. 2004)*

Since the first report during the year 1843, extensive documentation by Blanford and chronicles by Stolizca, the area is being visited by hundreds of researchers and thousands of students and hobbyists every year from every corner of the world, which in turn speaks of the importance of this area for geologists, paleontologists, stratigraphers, paleoclimatologists, mineralogists, sedimentologists, geochemists and general public. Despite the extensive documentation by professional organisations, every year many international and national level publications, masters and doctoral theses, that document newer fossils, geological information, depositional and diagenetic phenomena, sedimentary mechanisms, paleo-environmental and climatic events, sea level oscillations, etc., the area has not received the required attention with special emphasis on its conservation and protection for future studies.

Table 1. Barremian-Danian Geodynamics of the Cauvery Basin

Age	Fm.	Mbr.	Faunal and floral composition	Paleoenvironmental, biotic, sea level and tectonic dynamics
Danian	Niniyur	Periyakurichchi biostromal	Shark, algae, coral, bivalve, *amphibia*, pisces, gastropod and *Hercoglossa danica*	Short-term cycles of sea level fluctuations marked by marl-limestone alternations, preserving significant macro and micro faunal diversity and populations. While marl intervals document lesser diversity and population, the limestone intervals show abundance of population and species diversity.
		Anandavadi arenaceous	Coral, algae, serpulid, bivalve, gastropod and *Hercoglossa danica*	Typical coral-algal reef environment due to offshore protected environment. Isolated patch reefs represented by diverse coral colonies and associated algal and foraminiferal populations. Isolated bivalve shell banks also present with extremely rich populations.
Maastrichtian	Kallamedu		*Abelisauridae, Troodontidae, Sudamericidae, Bruhatkayosaurus matleyi, Megalosaurus sp. cf. Simosuchus sp., Crocodylia , Kurmademys kallamedensis, Anura , Lepisosteidae , Aquilapollenites bengalensis, Cranwellia cauveriensis, Araucariacites australis, Tricolpites microreticulatus, Triporopollenites minimus, Discorhabdus ignotus, Eprolithus floralis , Pseudomicula quadrata, Holococcolith sp., Prediscosphaera sp., Uniplanarius sp., Petrobrasiella? bownii, Eprolithus sp., Corollithion exiguum, Ottavianus terrazetus, Lucianorhabdus cf. L. maleformis, Calculites obscurus, Ceratolithoides pricei, and Biantholithus cf. B.sparsus*	A mix of estuarine and lagoonal nannofossil taxa and absence of marine communities.
	Ottakoil		*Pachydiscus otacodensis, Stigmatophygus elatus, Nautilus, Gryphaea, Alectryonia, Thalassinoides, Ophiomorpha, Dactyloidites Durania mutabilis, G. gansseri, Arkhangel-skiella cymbiformis, Braarudosphaerabigelowii, Ceratolithusaculeus, Chiastozyguslitterarius, Cyclagelosphaera deflandrei, Cribrosphaerella ehrengergii, Cribrosphaera sp., Eiffelithusgorkae, E. parallelus, E. turriseiffeli, Microrhabdulusundosus, Macula decussata, M. staurophora, M. swastika, Petrobrasiella? bownii, Prediscosphaeracretacea, P. spinosa, Stradneriacrenulata, Staurolithitescrux, Zygodiscus minimus* and *Z. spiralis, and Agerostrea ungulata*	Dwindling of faunal diversity and population in a waning sea. Coastal communities of macro and ichnofauna amid rich nannofossil assemblage.

		Srinivasapuram gryphean L.St.	*Gavelinopsis bembix, Gyroidinoides globosa, Lingulogavelinella, Cibicides, Siderolites, Pecten, Onychocellida, Hauriceras rembda, Perustrombus indicus, Gryphaea*, *Alectryonia*, *Terebratulida*, bryozoa, ostracoda, and sponge	Extremely favorable environmental parameters such as warm, clear, turbid free, and circulated waters that were sustained for a long duration by stable sealevel. These provided for diverse and rich fauna and floral composition. Toward top, reduction of sea level accompanied by increase of siliciclastic influx is noted, together with dwindling of fossil diversity and population
		Tancem biostromal	*Stigmatophygus, Planolites, Ophiomorpha irregularia,* and *Megaloolithus cylindricus*	A significant regression and increase in episodic high energy conditions. Opportunistic colonizers, coastal communities of body and ichno taxa thrived.
		Kattupiringiyam inoceramus L.St.	*Gavelinopsis bembix, Gyroidinoides globosa, Lingulogavelinella,* Agerostrea ungulata, *Ceratostreon pliciferum Planospirites ostracina, Pycnodonte (Phygraea) vesicularis, Rastellum (Arcostrea) pectinatum,* and bryozoa	Flooding of the depocenter and prevalence of stable, relatively deeper middle shelf conditions allowed predomination of inoceramus population, followed by formation of exogyra, alectryonia dominant shell banks and associated diverse macro and microfauna
	Kallankurichchi	Kallar arenaceous	*Gavelinopsis bembix, Gyroidinoides globosa, Lingulogavelinella, Cibicides, Siderolites, Gryphaea, Alectronia, and Pecten Eubaculites Orbitoides* spp. and *Goupillaudina daguini*	A major transgression covering partly the former shelf. Prevalence of turbulent energy conditions accompanied by very high rate of lithoclastic influx into the depocenter thwarted hospitable conditions during initial duration, which in turn was gradually transformed into hospitable during later part and allowed colonization by gryphea and alectryonia
Campanian	Sillakkudi	Varanavasi S.St.	Inoceramid, serpulid, *Turritella*, *Ophiomorpha, Thalassinoides, Karapadites karapadense, Globotruncana arca*, *Globigerinelloides, Marginotruncana marginata*, *Whiteinella baltica, Archaeoglobigerina, Bolivinoides culverensis, B. decorates, Globotruncana elevata , and G. ventricosa, Ostrea zitteliana*	Stable shelf, episodically inundated by high-energy events. Warm, stable, normal marine conditions on a widest shelf conditions promoted thriving of organisms and their preservation.
		Sadurbagam pebbly S.St.	Algae, *Rhynchonella, Terebratulid, Nautilus*, *Inoceramus balitus,* echinoid, crinoid, and bivalve	Fewer coastal communities and others often transported from offshore and accumulated. High energy siliciclastic environments restricted the diversity and population.
Santonian		Varakuppai lithoclastic conglomerate	*Thalassinoides, Marginotruncana Coronate, and Dicarinella asymmetrica*	Fluvial and fluvio-marine environments. Remains of only coastal/estuarine organisms and infauna are preserved in an otherwise tectonic-fluvial dominated depocenters. Toward top, marine influence increases.

Coniacian	Garudamangalam	Anaipadi S.St.	*Dravidosaurus blanfordi, Rhynchonella, Marginotruncana, Kosmaticeras* gr. *theobaldianum, Kossmaticeras theobaldianum crassicostata, Puzosia* sp., *Damesites* aff. *Sugata, Exogyra* (Costagyra) fausta, *Lopha* (Actinostreon) *diluviana*, *Proplacenticeras tamulicum, Nautilus*, Bored wood, encrusting oysters, and mollusca	Subtidal to relatively deeper environments and associated fauna, often preferred locales of nektobenthic accumulation as well as terrestrial/coastal wood clasts.
		Grey S.St.	*Teredolites, Thalassinoides*, oyster, gastropod and mollusca	High energy subtidal to supratidal environments. Predomination of coastal communities.
Turonian		Kulakkanattam S.St.	Abundant wood fragments encrusted by oysters, *Pinna*, *Testudines*., *Exogyra haliotoidea*, *Lewesicereas anapadense,* mollusca.Skolithos, *Diplocraterion, Ophiomorpha* and *Thalassinoides*	Shallow intertidal to below storm weather wave base environments and subtidal shell banks. Dynamic depocenter as a result of high-frequency RSL. It also favored mixed siliciclastic-carbonate deposition and accordingly the faunal composition.
	Karai	Odiyam Sandy clay	*Exogyra*, *Alectryonia, Pecten*, *Whiteinella Arahaeocretacea, Gyrochorte comosa, Thalassinoides suevicus, Ophiomorpha nodosa, Palaeophycus tubularis, Scolicia isp. Taenidium Serpentinum, Skolithos isp., Arenicolites isp., Rhynchostreon suborbiculatum, Pycnodonte vesiculosa*, Shark, *Mantelliceras Mantelli, Mortoniceras rostratum, Pseudaspidoceras footeanum,* foraminifer, and serpulid, radiolaria	A mixed shallow marine environmental setting, probably resulted by change in provenance, and tectonic stability.
Cenomanian		Gypsiferous clay	*Rotalipora Subticinensis, Tubulostrum, Praeglobotrancana Helvetica, Hedbergella, Preaglobotruncana, Whiteinella, Pycnodus sp., Lycoclupea menakiae, Thalassinoides suevicus, Palaeophycus tubularis, Planolites isp., Chondrites isp, Rosselia isp., Taenidium isp. Palaeophycus tubularis and Rosselia isp. Macaronichnus isp., Ophiomorpha isp., Ophiomorpha nodosa, O. borneensis, Thalassinoides suevicus, Exogyra* (Costagyra) *costata, Squalicorax Baharijensis, Platypterygius, Gladioserratus,* Ptychodus decurrens, *Eucalycoceras pentagonum* and radiolaria	Flooding of marine shelf, sediment influx highly influenced by seasonal fluctuations, dominated by humid climate, resulting in abundant siliciclastic supply. It also thwarted sustenance and proliferation of carbonate dominated environment and associated fauna. Faunal proliferation and dwindling were dependent on environmental parameters.
	Dalmiapuram	Kallakkudi Calcareous S.St.	*Rotalipora appenninica, Rotalipora cushmani, Exogyra*, *Alectryonia,Tetrabelus seclusus*, *Parahebolites, blanfordi, Neohibolites* sp., *Pycnodonte* sp., Phyloceratid, echinoid, bryozoa, and *Platypterygius indicus*	Establishment of typical coastal marine siliciclastic shelf associated with luxuriant, warm, normal marine waters and adjacent relatively deeper marine environments.
		Olaipadi conglomerat e	Reworked fauna namely: belemnite, rudist, coral and serpulid	Destruction of reef environment and predomination of tectonic-gravity, fluvial influenced sediment supply, resulting in only recycled faunal remains.

Albian		Dalmiya biohermal L.St.	Red algae, coral, bryozoa, gastropod, bivalve, echinoid, ostracoda, foraminifera, sponge, *Anomalinoides, Gavelinella plummerae, Gyroidinoidesglobosa, Lenticulina, Melobesioideae, Melobesioideae*, *Lithophyllum alternicellum, Pseudoamphiroa propria Quadrimorphina, Rastellum* (Arcostrea) carinata, *and Ostrea sp*.	Typical reef forming organisms and associated fauna and algae.
		Varagupadi biostromal L.St.	Bivalve, rudist, coral, algae, foraminifera, ostracoda, bryozoa, echinoid, *Melobesioideae*, *Melobesioideae*, *Lithophyllum alternicellum* and *Pseudoamphiroa propria Turrilites costatus, Acanthoceras sp., Mammites conciliatus, Nautilus, huxleyanus, Parachaetetesas vapattii, Sporolithon sp., Lithothamnion sp., Lithophyllum sp., Pseudoamphiroapropria, Neomeriscretaceae, Salpingoporella verticelata and Agardioliopsis cretaceae*	Establishment of shallow, relatively stable, normal marine depocenters and development of reef-reef associated environments. Reef forming organisms and reef dwellers thrived.
		Grey shale	Palynoflora, *H. planispira, Parachaetetes asvapattii, Sporolithon* sp., *Lithothamnion* sp*., Lithophyllum* sp., *Pseudoamphiroa propria, Neomeris cretaceae, Salpingoporella verticelata, Agardioliopsis cretaceae*, Ostracoda, bryozoa, and gastropoda	Marine flooding and resultant creation of deeper oxygen poor environments located adjacent to highly productive regions. Very-high frequency oscillations of oxygen poor-normal conditions as a result of RSL fluctuations. The durations of normal conditions increase toward top. Very high abundance of planktic and recycled benthic fauna.
Aptian	Sivaganga	Terani clay	*Ptilophyllum, Gymnoplites, Pascoeites, Microcachyidites, Cooksonites, Aequitriradites* and inoceramid	Coastal freshwater lakes, inundated as a result of marine incursion. Freshwater environment supported only microfauna, while the marine incursion resulted in accumulation of recycled bioclastic components.
		Kovandan-kurichchi S.St.	Early Cretaceous palynoflora	Creation of subaqueous fan deltaic environments dominated by siliciclastic deposition and turbid conditions, as a result of which, only drifted and or extra-basinal palynofloral remains are preserved.
Barremian		Basal Conglomerate	*Globigerina boteriveca*	Initiation of basin and coastal marine deposition under very high energy conditions; only deeper regions contain certain microfauna.

Categories of Geoheritage Sites to be Identified and Protected

With the pace of rapid urbanisation, developments and the mining activities in the vicinity, it is of public knowledge that the geologically important, unique archives of the past are being unscrupulously plundered and unless systematic documentation, sincere efforts of protection are initiated, these geological treasures troves will be lost forever. Given cognizance to all these, we intend impress upon the geologists, administrators, planners and general public about the following that need to be addressed immediately, if not soon.

We propose identification, protection and establishment of field museum sites under six categories.

- *Sites of fossil locations:* The faunal and floral diversity (Plate I, II, III, IV) and population of the Ariyalur area is insurmountable (Table 1). From the rate and quantum of publications on these, it can be perceived that the Ariyalur area is akin to modern analogue of rainforest, i.e., a storehouse of rich biological, ofcourse, ancient life (geobiodiversity) and the complete documentation is yet to be made satisfactory. Hence, it is of first priority that important fossil locations (perhaps apt to be termed geo-hotspots) need to be protected for conservation, examination by future researchers and education for students.

Plate I

A: *Ptillophyllum* – Late Aptian Terani Clay member; **B:** Petrified tree trunk measuring 18 m long and ca. 2m diameter – Middle Turonian Kulakkanattam S.St. member; **C:** Petrified wood fragments of various sizes strewn in silty sand – Early Turonian Odiyam sandy clay member; **D:** Well preserved shark teeth in the Cenomanian Gypsiferous clay member; E, F: Trace fossils (*Zoophycus*) in the Albian Biostromal limestone member; **G:** Trace fossil found in the upper part of Santonian Varakuppai lithoclastic conglomerate member; **H:** Colonial serpulids in the Middle-Late Campanian Varanavasi sandstone member; **I:** Thick population of *Gryphea* in the Early Maastrichtian Srinivasapuram gryphean limestone member.

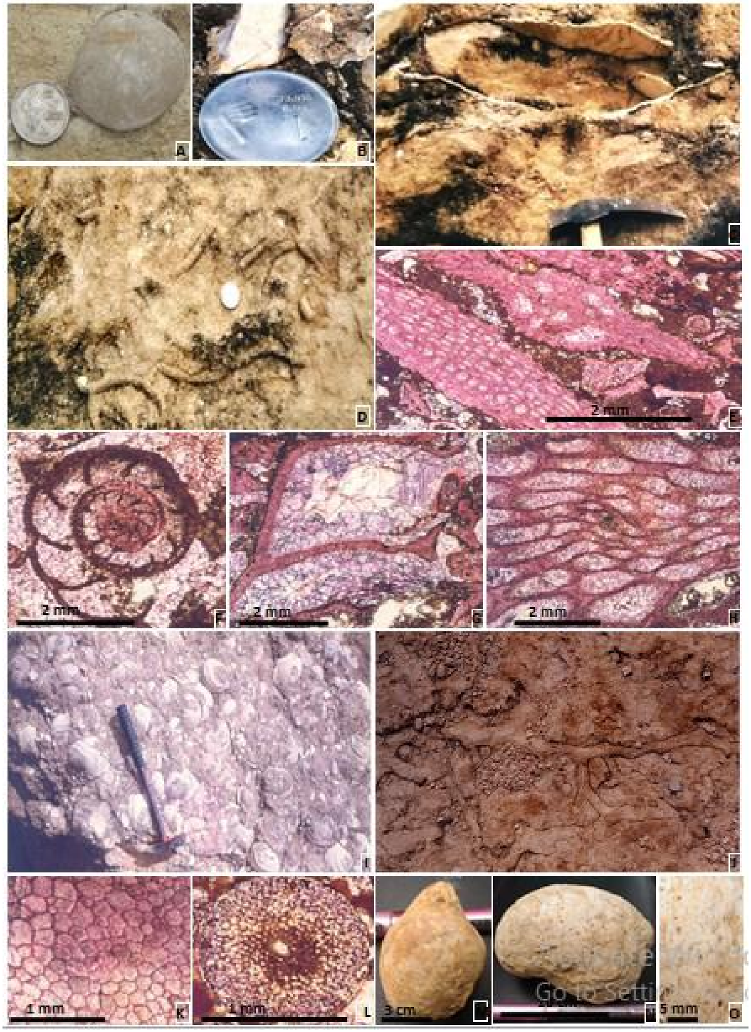

Plate II

A: *Stigmatophygus elatus* – Early Maastrichtian TANCEM biostromal limestone member; **B:** Fenestrate bryozoa – Early Maastrichtian TANCEM biostromal limestone member; **C:** Meter scale large clam in the Early Maastrichtian TANCEM biostromal limestone member; **D:** *Planolites Nicholson* found in rocks below storm deposits of the Early Maastrichtian TANCEM biostromal limestone member. Occurrence of trace fossils below the storm deposits and their absence in the aftermath of storm (in beds above the storm deposits) indicates catastrophic devastation of natural habitat due to sudden sea level change. **E:** *Orbitoid* found in the tidal channel deposits of the Early Maastrichtian TANCEM biostromal limestone member; **F:** Cross section of foraminifera found in the Early Maastrichtian Kattupiringiyam Inoceramus limestone member; **G, H:** Microphotographs of bryozoa – Early

Maastrichtian Kattupiringiyam Inoceramus limestone member; **I:** Thick population of *Inoceramus* in the Early Maastrichtian Kattupiringiyam Inoceramus limestone member; **J:** Thick population of *Ophiomorpha irregulaire* occurring over the storm deposits of TANCEM biostromal limestone member. Their occurrence and thick population suggest opportunistic colonization of ecospace vacated by native species in the aftermath of catastrophic event and sudden sea level change; **K:** Microphotograph of *Inoceramus* shell – Early Maastrichtian Kattupiringiyam Inoceramus limestone member; **L:** Microphotograph of echinoderm plate – Early Maastrichtian TANCEM biostromal limestone member; **M:** *Terebratula* – Early Maastrichtian Srinivasapuram gryphean limestone member; **N:** *Gryphea* – Early Maastrichtian Srinivasapuram gryphean limestone member; **O:** Close-up view of the gryphean shell depicted in 'N' showing sponge boring.

- *Sites of natural exposures:* Though the area houses 5,500 m thick sedimentary record of barremian-danian age, owing to the structural alteration, low dip angle and sandwiched between two mighty rivers, most of these deposits are covered under alluvium, kankar and mio-pliocene Cuddalore sandstone and hence, only scattered exposures are available for detailed study. These natural exposures (shown along the traverselines in Figure 1) are of paramount importance for educating the students and for documentation and correlation of their characteristics by future researchers. Thus, enlisting these locations, fencing and protecting the sites from any construction and or alteration are to be enforced strictly without slight deviations or exemptions. Sites of this category include all the natural exposures in the vicinity of Ariyalur and its environs regardless of other categories listed above and here under.
- *Sites of stratigraphic importance:* Studies abound on documenting the occurrence of lithostratigraphic, biostratigraphic sequence and chemostratigraphic boundary surfaces and sections (Ramkumar et al. 2011). From the published literature and in-house reports of Geological Survey of India (GSI), Oil and Natural Gas Corporation (ONGC) and other professional organisations, a list of important stratigraphic sections need to be prepared, with special emphasis on type sections and stratotypes, their importance and location details, etc. Based on the information, the sites need to be identified and protected. Protecting such sites not only would help making future stratigraphic correlation easier, but also may help finetune the existing stratigraphic models and classifications, that may in turn correlate these sections with regional and global counterparts.

1. *Braarudosphaera bigelowii* (Gran & Braarud) Deflandre, 1947; **2A-D, 3A-B.** *Arkhangelskiella cymbiformis* Vekshina, 1959; **4.** *Eiffellithus turriseiffeli* (Deflandre in Deflandre & Fert) Reinhardt, 1965; **5A-B.** *A. cymbiformis* Vekshina, 1959; **6A-B, 7A-B.** *E. parallelus* Perch- Nielsen, 1973; **8-9.** *E. turriseiffeli* (Deflandre in Deflandre & Fert) Reinhardt, 1965; **10A-B.** *E. gorkae* Reinhardt, 1965; **11A-B.** *Micula swastika* Stradner & Steinmetz, 1984; **12.** *M. murus* (Martini) Bukry, 1973; **13A-C, 14-16.** *M. decussata* Perch-Nielsen, 1973; **17A-B, 18A-C, 19A-C.** *Stradneria crenulata* (Bramlette4 & Martini) Nöel, 1970; **20-21.** *Microrhabdulus undosus* Perch- Nielsen, 1973; **22A-B.** *Ceratolithoides* *kamptneri* Bramlette & Martini, 1964; **23-24.** *Watznuaeria barnesae* (Black) Perch- Nielsen, 1968; **25.** *Cribrosphaerella ehrenbergii* (Arkhangelsky) Deflandre in Piveteau, 1952; **26.** *Cribrosphaerella* sp.; **27A-B, 28A-B.** *Prediscosphaera cretacea* (Arkhangelsky) Deflandre, 1968; **29.** *P. ponticula* (Bukry) Perch- Nielsen, 1984; **30.** *P. spinosa* (Bramlette & martini) Gartner, 1968; **31.** *Prediscosphaera* sp.; **32A-B, 33A-B.** *Zygodiscus spiralis* Bramlette & martini, 1964; **34A-B.** *Staurolithites crux* (Deflandre & Fert) Caratini, 1963; **35A-B.** *Z. minimus* Bukry, 1969; **36A-B.** *Ahmuellerella octoradiata* (Górka) Reinhardt, 1966; **37A-B.** *Pseudomicula quadrata* Perch- Nielsen in Perch- Nielsen *et al*. 1978; **38A-B.** *Cyclagelosphaera deflandrei* (Manvit) Roth, 1973; **39.** *W. barnesae* (Black) Perch- Nielsen, 1968; **40A-C.** *Petrobrasiella? Bownii* Burnett, 1998; **41A-B.** *Chiastozygus litterarius* (Górka) Manivit, 1971; **42A-B.** ***A.*** *regularis* (Górka) Reinhardt & Górka, 1967. (Source: Rai et al. 2013; All forms are magnified to 2000 times)

Plate III

A: Close up view of the fossilized bone fragment of presumed dinosaur – Late Maastrichtian Kallamedu Formation; **B:** Closer view of a bone fragment found embedded in coarse grained sandstone of the Kallamedu Formation; **C:** Presumed egg casts of sauropod – Late Maastrichtian Kallamedu Formation; **D:** Closeup view of the egg cast; **E:** SEM image showing the oblique cross sectional view of egg shell depicting the spherulite units separated by pores (indicated by arrows). The calcitization process has differential stability of the spherulitic units and pore fills in which the latter are often found to get lost; **F:** SEM photograph showing the cross sectional view of egg shell. Radiating spherulites of calcitic crystals are visible in the photograph. Black arrows at the bottom of the photograph indicate the nucleation sites; **G:** *Nautilus* in the Danian Anandavadi arenaceous member; **H:** Brain coral fossil in the Danian Anandavadi arenaceous member; **I:** (Source: Ramkumar et al. 2010; All the forms are to 2000 times). **1A-C, 15.** *Discorhabdus ignotus* (Górka, 1957) Perch-Nielsen, 1968; **2A-B.** *Eprolithus floralis* (Stradner, 1962) Stover, 1966; **3-4.** *Pseudomicula quadrata* Perch-Nielsen *in* Perch-Nielsen *et al.*, 1978; **5A-B.** Holococcolith sp.; **6.** *Prediscosphaera* sp.; **7.** *Uniplanarius* sp.; **8A-B.** *Petrobrasiella? bownii* Burnett, 1998b; **9.** *Eprolithus* sp.; **10.** *Corollithion exiguum* Stradner, 1961; **11A-B.** *Ottavianus terrazetus* Risatti, 1973; **12A-B.** *Lucianorhabdus* cf. *L. maleformis* Reinhardt, 1966; **13A-B.** *Calculites obscurus* (Deflandre, 1959) Prins and Sissingh *in* Sissingh, 1977; **14A-C.** *Ceratolithoides pricei* Burnett, 1998a; **16, 17A-B.** *Biantholithus* cf. *B. sparsus;* **J:** Tabulate coral colony in the Danian Anandavadi arenaceous member; **K:** Bivalve shell casts in the Danian Anandavadi arenaceous member.

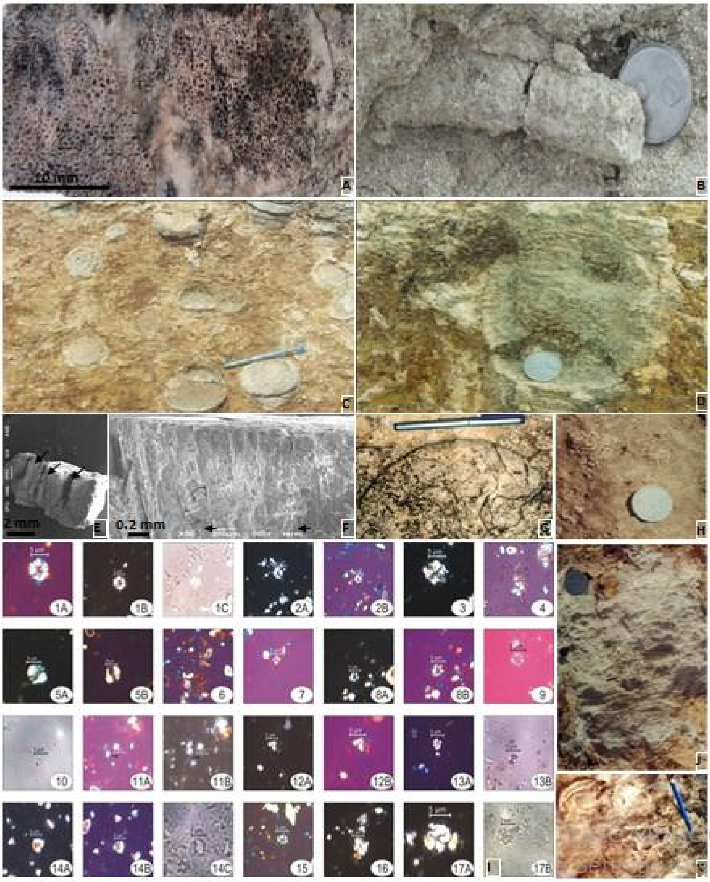

Plate IV

- *Sites of unique facies types:* The sedimentary deposits of Ariyalur area house many unique facies types. For example, the turbiditic deposits near Tirupattur (Ramkumar, 2008), boulder-rich ripple imbricate structures and contact between middle-shelf deposits and continental fluvial deposits near Kallagam (Ramkumar et al. 2005), hummocky-cross stratified paleo-tsunami deposits near Kallankurichchi (Ramkumar 2006), paleo-gas hydrate/hydrocarbon venting site near Reddipalaiyam (Ramkumar, 2007), cretaceous-paleogene contact (Ramkumar et al. 2010), black shales near Dalmiapuram (Ramkumar et al. 2004), etc. are unique to this region and need to be protected for future studies and education. In addition, documentation of lithofacies and associated characteristics of these sites may help to understand paleoclimatic and other important geological events more precisely. Hence, identification of similar sites and protecting them is essential.
- *Sites of excellent traverses:* Ariyalaur area is known for many traverses exposing rock records of important time-slices and fossil occurrences. For example, Karai-Kulakkanattam, Kunnam-Mungilpadi, Kallagam-Sadurbagam, Kilpalur-Sillakkudi can be sited as most visited, yet not protected traverses from pilferage and plundering by unscrupulous elements. Though visited by thousands of researchers and students every year, each time, new and newer information are being documented and hence, such traverses have unique educational and research purposes and need to be protected.
- *Sites of newly excavated mines and other sections:* With the accelerated infrastructure development and mining activities, newer exposures of road-cutting sections, mine sections and abandoned mine floor exposures are becoming available during recent times. These not only provide access to hitherto unknown and or little-known rock records of important time-slices, but also provide important clues and evidences to sedimentary structural, stratigraphic relationship, facies types, fossil occurrences and their biotic interactions. Selected sections of these newer exposures have to be documented and protected for future studies and education.

Establishment of Field Museum and Honouring Dr. M.S. Krishnan

Through this paper, we propose to establish an online catalogue of important locales according to the categories listed above, creation of Web-GIS enabled interactive and informative kiosk containing basic information on these sites and making this resource an open-source model, so that whoever has additional information, can contribute to enrich the online database for the benefit of all those who are interested. Such an effort would not only help protect the natural geological resource, but would also promote geotourism. It is to be noted that the State government of Tamil Nadu has already started taken few initiatives in the identification of geologically important locations and protecting them and commenced infrastructure development such as construction of approach road, provision of basic amenities, fencing, etc., near to such sites. However, systematic documentation of sites according to the six categories as listed in this paper, making similar infrastructure and other amenities to all of these sites are essential.

Considering the importance of geoscientific contribution to the Ariyalur and other areas of India by Dr. M.S. Krishnan, the illustrious geologist of GSI, we suggest that the proposed field-museum encompassing the six-category sites discussed in this paper, may be named after him. This will be a fitting tribute to him both for his vast research contribution to Ariyalur region and also as the Former President of the Indian Geographical Society, in 1947, when he was the Superintending Geologist, GSI, Madras Circle, Bheemasena Gardens, Mylapore, Madras and contributed enormously for the development of the Society.

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GROUNDWATER CHARACTERISATION OF ARIYALUR AND PERAMBALUR DISTRICTS EMPLOYING AQUACHEM SOFTWARE

Santhiya Mahalingam, Selvakumar Muniraj and Vasanthy Muthunarayanan

Department of Environmental Biotechnology, Bharathidasan University,
Tiruchirappalli - 620 024
E-mail: drvasanthy02@gmail.com, vasanthy@bdu.ac.in

Abstracts

The objectives of this study are to analyse the undergroundwater quality of Ariyalur and Perambalur region by water quality index. Physico-chemical parameters such as pH, Electrical conductivity, Total Solids, Total Dissolved Solids, Total Suspended Solids, Total Alkalinity, Total Acidity, Total Hardness, Calcium, Magnesium, Chloride, Dissolved Oxygen, Biological Oxygen Demand, Chemical Oxygen Demand, Phosphate, Sulphate, Silicate, Nitrate, Sodium and Potassium collected from 48 different locations since a period of 2012-2013 were analysed. The type of water that predominates in the study area is Ca-HCO3 type during year, based on hydro-chemical facies. In this study, 80 percent water samples were found of good quality and only 20 percent water samples fall under moderately poor category. Therefore, there is a need of some treatment before usage and also it is necessary to protect that area from contamination.

Keywords: Hardness, Piper diagram, Groundwater, Chemical characters, BOD

Introduction

Water is one of the nature's most important gifts to mankind. Pure water is an odourless, tasteless, clear liquid. Water is one of the most essential elements needed for good health and it is also necessary for livelihood of people. Water is also reported to be a precious asset. Water is needed for domestic purposes and energy production. Above all, water is the most critical limiting factor for many aspects of life such as economic growth, environmental stability, biodiversity conservation, food security and health care. Health officials emphasize the importance of drinking water by suggesting to drink at least eight glasses of clean water each and every day to maintain good health (Venkatesharaju et al., 2010). The existence of a wide range of contaminants in drinking water makes it essential to limit their concentration levels in order to safeguard human health. The primary pathways for exposure to chemical substances are ingestion, inhalation and dermal sorption. The relative impact of each of the exposure pathways depends upon the physical and the chemical nature of the contaminant.

Potable water can be defined as "Water free from disease-causing organisms, and free from minerals and organic substances that may produce adverse physiological effects and aesthetically pleasing with respect to turbidity, color, taste and odor" (AWWA, 1990). Although, biological contaminants have traditionally received more attention from a public health standpoint, in recent years, there has been growing concern for chemical contaminants present in drinking water that might be hazardous to human health. Exposure to contaminants in water is thought to lead to human health problems ranging from minor effects such as fatigue to more serious effects such as cancer (Wilkes et al., 1992).

Most public water supplies depend on a chlorine disinfection process, which may produce water containing chloroform and other tri halo methane (Lindstrom and Pleil, 1996). In addition, a wide variety of volatile and synthetic organic chemicals, pesticides, inorganic chemicals and radio nuclides have been detected in water supplies (AWWA, 1990). Groundwater represents the largest available source of fresh water as more than 97 percent of the total freshwater on the earth is undergroundwater (Rai and Sharma, 1991). Groundwater is naturally replenished by surface water from precipitation, streams and rivers when this recharge reaches the water table. Groundwater recharge is the process by which water percolates down the soil and reaches the water table. The recharge from rainfall is significant where rainfall coincide with increased humidity; otherwise the recharge is reduced partially or totally by evaporation and transpiration. In India rainfall is the most important source of groundwater recharge (Mall et al., 2006; Mohd Saleem et al, 2016).

Groundwater is a readily available source of water for irrigation, domestic and industrial uses. However, with increase in water demand due to population pressure this resource is over exploited in many parts of the world resulting in permanent depletion of the aquifer system and associated environmental consequences such as water quality deterioration. With the change in land use and increase in quantities and type of agricultural, domestic and industrial effluents entering the hydrological cycle a gradual decline in water quality due to surface and subsurface pollution also takes place (Sharma et al., 2004; Karanth, 1989). The objective of the present work is to discuss the major ion chemistry of groundwater of Ariyalur and Perambalur Districts. This was done in terms of piper trilinear diagram.

Study Area

Ariyalur District has a geographical area of 1,949 sq. km. It lies between the latitude 10o 54' and 11.30' of north longitude 780 40' and 10o 30' of East. The district has an average rainfall of 951.1 mm. The maximum temperature is 38°C and the minimum temperature is 24°C. Land of Limestone Ferruginous red loam occurs in Ariyalur district. The soils are of medium depth with good drainage, free from accumulation of salt and calcium carbonate, pH ranges from 6.5 to 8.0 and contain low amounts of organic matter, nitrogen and phosphorus but with generally adequate amounts of potash and lime.

Perambalur District is centrally located in Tamil Nadu and is 267kms away in southern direction from Chennai. The Perambalur district is located between the East longitudes 79o 15’ to 79o 30’E and North latitudes 11o 22’ to 11o 30’N. Total Area is reported to be 691 sq.km. The district has an average Rainfall of 951.1 mm (Annual). The district for administrative purpose has been divided into three taluks namely, Perambalur, Kunnam, Veppanthattai which is further sub-divided into four blocks such as

Perambalur, Veppanthattai, Veppur, Alathur. The district is fairly rich in mineral deposits. Celeste, Lime Stone, Shale, Sand Stone, Canker and Phosphate nodules occur at various places in the district. A good deal of building stone is quarried in Perambalur, Kunnam, and Veppanthattai taluks. It is an inland district without any coastal line. The District has Vellar River in the North and Kollidam River in the South and it has no well-marked natural divisions. The Pachamalai hill situated on the North of Perambalur is the most important hill in the district.

Database and Methodology

The collected samples were analyzed for different physicochemical parameters such as pH, Electrical conductivity, Total Solids, Total Dissolved Solids, Total Suspended Solids, Total Alkalinity, Total Acidity, Total Hardness, Calcium, Magnesium, Chloride, Dissolved Oxygen, Biological Oxygen Demand, Chemical Oxygen Demand, Phosphate, Sulphate, Silicate, Nitrate, Sodium and Potassium (APHA, 2005). The analytical data can be used for the classification of water for utilitarian purposes and for ascertaining various factors on which the chemical characteristics of water depend.

Results and Discussion

The drinking water sampled from different stations of Ariyalur and Perambalur districts has been characterized in terms of pH, Electrical conductivity, Total Solids, Total Dissolved Solids, Total Suspended Solids, Total Alkalinity, Total Acidity, Total Hardness, Calcium, Magnesium, Chloride, Dissolved Oxygen, Biological Oxygen Demand, Chemical Oxygen Demand, Phosphate, Sulphate, Silicate, Nitrate, Sodium and Potassium. Maximum and minimum concentration of major ions present in the groundwater from the study areas is presented in Table 1 and 2. The values were plotted using piper tri-linear diagram. (Aqua chem software version- 5.1) and were represented in Figure 1. The Piper-Hill diagram is used to infer hydro-geochemical facies. These plots include two triangles, one for plotting cations and the other for plotting anions. The cations and anions fields are combined to show a single point in a diamond-shaped field, from which inference is drawn on the basis of hydro-geochemical facies concept (Sadashivaiah et al, 2008). These tri-linear diagrams are useful in bringing out chemical relationships among groundwater samples in more definite terms rather than with other possible plotting methods.

The evolution of hydro chemical parameters of groundwater samples in Ariyalur district distribution is displayed by plotting the concentration of major cations and anions in Piper diagram shows that most of the groundwater samples analyzed fall in the field of mixed Ca-HCO3 type, Ca-Mg-Cl type and Na-Cl type. The dominant anion of the groundwater ranges from bicarbonate to chloride with a corresponding increase in the total suspended solids. From the plot, it is observed that alkalis ($Na^+ + K^+$) dominate, which is quality of the deeper groundwater. The ion concentrations are characterized by comparatively uniform typical deeper thermo mineral groundwater composition with Na–Cl–HCO3- dominance.

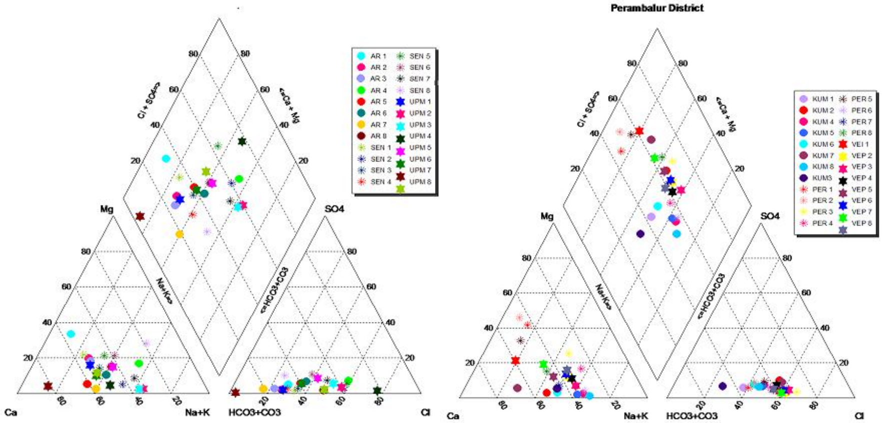

Fig. 1. Groundwater Samples from Ariyalur (on left) and Perambalur (on right) Districts Plotted Piper-Trilinear Diagram

The groundwater characteristics of Perambalur district plotted in Piper diagram represented that the Ca and Na+K were dominant among the cations, HCO3- and Cl- were present among the anions, resulting in three types of groundwater such as Ca-HCO3 type, Ca- Mg-Cl type and Na-Cl type respectively. Romani, (1981) reported that the Uruli-Devachi area is conspicuous by the presence of (Na+K) type of water and such water has temporary hardness and residual sodium carbonate. The excess alkali ions present in the water is compensated by these anions. The majority of the samples are concentrated with Ca-HCO3 present in the fields (Perambalur and Kunnam taluk) representing the dominance of fresh water recharge into the aquifer.

Table 1. Physico-chemical Characterisation of Drinking Water Samples from Ariyalur District

Sampling Station	Sample ID	pH	TDS	Alkalinity	Hardness	Calcium	Magnesium	Chloride	DO	BOD	COD	Sulphate	Silicate	Nitrate	Phosphate
Kallankurichi	AR 1	8.21	2,000	150	356	142	52	89.15	4.85	1.27	88	20.93	26.38	27.6	0.075
Tirumanur	AR 2	7	1,000	200	464	256	57.83	100.28	4.08	0.96	230	10.85	20.57	22.95	0.052
Kilapulur	AR 3	7	1,000	160	402	216	45.19	70.35	7.85	3.26	110	11.25	28.19	14.76	0.025
Periatirukkonam	AR 4	7.12	2,000	180	250	94	34.02	250.13	2.75	0.08	108	40.63	10.65	2.06	0.055
Vilangudi	AR 5	7.28	1,500	200	344	284	14.58	115.89	4.45	1.29	225	25.53	20.05	6.93	0.015
Valajanagaram	AR 6	7.15	1,000	170	314	204	26.73	120.19	4.38	1.83	330	29.65	18.15	9.3	0.035
Venganur	AR 7	9	1,500	145	376	340	8.26	45.84	6.43	2.87	138	8.99	19.29	17.83	0.018
Punganguli	AR 8	8.4	2,000	138	354	190	39.85	200.15	6.08	3.65	90	9.58	15.6	7.75	0.057
Sendurai	SEN 1	7.4	4,000	520	400	200	48.6	120.35	6.07	4.38	102	8.34	20.37	22.25	0.017
Kilamaligai	SEN 2	7.2	1,000	100	257	198	14.33	220.45	3.38	2.22	155	12.45	15.58	11.32	0.035
Sirukadambur	SEN 3	7.8	5,500	310	300	175	30.37	96.38	4.43	1.25	100	10.55	19.57	12.32	0.019
Periakurichi	SEN 4	8	1,500	235	408	220	45.68	100.57	3.87	2.85	220	12.24	15.28	23.24	0.076
Vanjinapuram	SEN 5	7.11	1,000	300	265	120	35.23	250.02	3.25	2.29	167	32.48	29.67	9.24	0.078
Anandavadi	SEN 6	7.23	4,800	400	238	100	33.53	102.45	3.64	3.05	80	39.35	14.32	5.64	0.006
Tular	SEN 7	7.45	500	500	156	95	14.82	95.37	6.06	2.64	127	20.15	10.99	9.31	0.015
Pilakurichi	SEN 8	8.22	3,600	250	368	78	70.47	78.32	3.33	2.37	139	44.38	12.04	5.47	0.018
Aiyur	UPM 1	7.27	2,000	600	400	231	41.06	89.15	3.32	1.02	120	9.25	12.38	9.5	0.075
Olayur	UPM 2	7.84	2,000	210	120	100	4.86	100.28	6.32	2.28	95	8.36	10.29	12.24	0.052
Devamangalam	UPM 3	7.34	1,500	200	100	85	3.64	70.35	6.08	2.62	100	10.28	33.85	17.58	0.025
Thandalai	UPM 4	7.57	2,000	359	124	100	5.82	250.13	3.25	1.24	220	6.59	22.34	7.36	0.055
Sripuranthan	UPM 5	8.11	2,000	400	234	125	26.48	115.89	4.05	1.26	115	32.25	10.89	8.34	0.015
Kadambur	UPM 6	7.11	1,000	450	350	238	27.21	120.19	4.33	3.54	100	25.64	15.68	6.48	0.035
Andimadam	UPM 7	9	4,500	526	349	310	9.47	45.84	6.02	2.25	85	10.59	20.29	2.24	0.018
Udayarpalayam	UPM 8	8.2	2,000	294	350	225	30.37	200.15	6.08	2.92	78	12.24	22.76	21.95	0.057

*All values are expressed in mg/L except pH

Table 2. Physico-chemical Characterisation of Drinking Water Samples from Perambalur District

Sampling Station	Sample ID	pH	TDS	Alkalinity	Hardness	Calcium	Magnesium	Chloride	DO	BOD	COD	Sulphate	Silicate	Nitrate	Phosphate
Perambalur	PER 1	7.71	500	100	150	120	7029	66.96	6.48	3.15	140	12.65	6.88	9.85	0.01
Siruvachur	PER 2	7.97	1,600	150	144	114	7029	72.16	6.89	4.05	100	20.15	5.8	35.89	0.075
Tiraimangalam	PER 3	7.42	500	200	118	96	5035	58.88	5.27	2.75	85	10.65	3.5	16.25	0.028
Kurumbalur	PER 4	7.31	4,500	175	130	110	4086	93.67	5.67	3.8	120	13.95	2.25	12.85	0.011
Melapuliyur	PER 5	7.42	2,550	150	122	104	4037	77.61	6.08	2.28	135	20.75	4.44	5.26	0.077
Aranarai	PER 6	7.68	1,000	120	135	102	8.02	99.02	5.67	3.18	109	9.88	4.6	6.65	0.035
Velur	PER 7	7.6	3,100	135	150	105	10.93	93.67	6.28	1.05	115	15.75	3.25	5.35	0.01
Kalpadi	PER 8	9	2,500	115	170	95	18.95	77.61	6.48	2.73	137	16.83	2.35	15.7	0.019
Adanur	KUM 1	7.64	400	120	130	100	7.29	50.95	7.25	1.08	150	10.58	2.38	2.06	0.085
Paravai	KUM 2	7.52	600	155	108	95	3.16	99.08	5.38	1.28	120	23.72	6.8	18.93	0.093
Perali	KUM 3	7.41	2,500	100	264	128	8.76	60.92	6.29	3.28	230	20.53	4.4	13.95	0.073
Kulappadi	KUM 4	7.68	1,000	160	120	102	4.37	75.25	6.45	3.75	110	15.8	4.82	2.15	0.015
Kilappliyur	KUM 5	7.78	2,000	130	110	98	2.97	66.95	5.93	3.25	125	12.35	4.37	8.7	0.018
Tungapuram	KUM 6	8.04	900	105	143	124	4.62	70.93	6.05	1.33	100	16.95	3.5	6.08	0.078
Chettikulam	KUM 7	7.4	1,000	140	99	82	4.13	95.78	6.65	2.8	225	20.2	2.87	21.85	0.028
Allinagaram	KUM 8	7.04	1,500	118	105	97	1.94	58.93	6.32	1.89	130	10.95	2.98	0.68	0.019
Veppantattai	VEP 1	9.2	1,500	96	178	85	18.47	157.91	5.67	3.15	120	13.85	7.2	22.15	0.089
Nuttappur	VEP 2	7.05	1,000	145	160	87	17.74	163.26	6.48	1.05	180	10.15	5.55	4.87	0.015
Vengalam	VEP 3	7.77	2,200	130	150	100	12.15	165.94	6.08	2.85	230	15.95	3.25	17.85	0.088
Pimbalur	VEP 4	8.02	500	152	172	96	18.47	144.52	6.48	2.38	100	25.85	2.3	6.05	0.075
Pulambadi	VEP 5	7	2,000	128	150	95	15.79	141.85	5.55	4.03	110	14.78	7.01	8.82	0.045
Dandapappadi	VEP 6	7.24	2,000	120	168	87	19.68	165.94	5.27	1.89	130	15.59	4.65	2.54	0.015
Valikandapuram	VEP 7	7.44	1,000	100	184	90	22.84	168.6	6.08	2.68	90	10.9	6.15	14.73	0.085
Tondamandurai	VEP 8	7.71	1,000	115	197	92	25.51	152.25	6.28	3.3	150	18.55	2.67	6.95	0.072

*All values are expressed in mg/L except pH

Most of the drinking water sampled in different taluks of two districts had the parameters such as pH, EC, COD, BOD, DO well within the permissible levels. Few water samples of the study areas ranged from soft to moderately hard categories but are suitable for drinking purposes. Groundwater quality in drinking water sources in Ariyalur and Perambalur district is also safe and the values were well below the water quality standards.

Conclusions

Water quality analysis of the different taluks of two different districts namely Ariyalur, and Perambalur of Tamilnadu state, India was performed. The predominant cations and anions were reported to be Na+, Ca+, Mg+, HCO3- and Cl- in most of the drinking water samples. However, the water samples of many of the taluks of all the two districts were found to be suitable for drinking as the physico-chemical parameters were well within the permissible limit. Thorough analysis has shown the presence of Hardness and Nitrate more than the USEPA permissible limits in some of the taluks namely Ariyalur, Sendurai, Perambalur, Veppantattai etc., most of the water sample were of Ca-HCO3 type, which may be mainly due to the geology of the area which comprises igneous rocks of crystalline nature.

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GEOMATICS AND STATISTICAL MODELS TO DETERMINE THE STATUS OF SEA WATER QUALITY ALONG THE INDIAN COAST

Radha Y., Bhaskaran G., Narmada K. and Dhanusree M.

Department of Geography, University of Madras, Chennai - 600 005
E-mail: grbhaskaran@gmail.com, narmadakm@yahoo.com

Abstract

Marine water quality has become a matter of serious concern because of its effects on human health and aquatic ecosystems, including a rich array of marine life, with the growth of population and commercial industries, marine water has received large amounts of pollution from municipal and industrial sources, as also from surface runoff. In this research, an attempt was made to present the complex datasets in a more comprehensive approach, in a single indicator of Coastal Water Quality Index (CWQI). For the study mainly eight water quality parameters (DO, pH, Water Temperature, BOD, Nitrate, Phosphate, Suspended Sediments), were chosen for four seasons (Summer, Pre-monsoon, Monsoon, Post monsoon) from 1990 to 2010 and coastal water quality index was calculated along the Indian coast for 15 COMAPS locations. The GIS techniques add simplification and visualisation to the dataset by integrating multiple layers like discharge points, sampling stations and water quality variables that help in easy understanding. From this study it has been proved that geoinformatics is a vital tool for decision makers to identify the sources and polluted areas. It was found out that Kochi was the only location having bad WQI - average value (47.82) and Ennore, Kakinada, Hazira, Mumbai, Pondicherry location are at the verge of getting into bad WQI but they are in medium water quality range according to NSFWQI.

***Keywords**:* Water Quality Index, Geomatics, Coastal Areas, GIS

Introduction

Good quality coastal water is an important part of keeping our coasts healthy for the future. Natural marine systems, including plant, animal and fish life need clean coastal water to survive. The coastal regions are believed to hold better biodiversity than open ocean regions. However, it has been altered over time due to the consequences of human activities. Decline in water quality is mainly due to the increased concentration of various pollutants such as oils, heavy metals, nutrient and organic compounds causing turbidity and a significant drop in dissolved oxygen levels (Chang-An Yan, 2015). Coastal water quality variables such as pH, dissolved oxygen, biochemical oxygen demand, total suspended solids, ammonia, nitrate, total phosphorous, chlorophyll-a and fecal coliform are the health indicators of coastal environment. Thus, this is an attempt to present the complex datasets in a more comprehensive approach, a single indicator of Coastal Water Quality Index (CWQI). The CWQI is a dimensionless number that combines multiple water quality variables into a single number by normalising values to subjective rating curves.

The CWQI takes complex scientific information of measured parameters and synthesises into a single number (0 to 100 scale) based on the recommended level to derive significant information that are easily understandable by the coastal policy managers and administrator. Coastal regions played a significant role in the history of human settlement as it provides natural resources as well as route for the trade. The human dependence on the bays and channels for livelihood has given rise to urbanisation that led to decline of water quality. The concern on coastal water quality is being raised in the past two decades due to excessive settlements near the coastal areas and over exploitation.

The Integrated Coastal Marine Area Management Centre of Earth System Science Organisation (ESSOICMAM) has been implementing a program called 'Coastal Ocean Monitoring and Prediction System (COMAPS)' with the objectives to monitor water quality parameters periodically in selected locations in the coastal waters of India and to develop possible prediction of sea water quality.

Study Area

Coastal India spans from the south west Indian coastline along the Arabian sea from the coastline of the Gulf of Kutch in its western most corner and stretches across the Gulf of Khambhat and through the Salsette Island of Mumbai along the Konkan and southwards across the Raigad region and through Kanara and further down through Mangalapuram or Mangalore and along the Malabar through Cape Comorin in the southernmost region of South India with coastline along the Indian Ocean and through the Coromandal Coast or Cholamandalam Coastline on the South Eastern Coastline of the Indian Subcontinent along the Bay of Bengal through the Utkala Kalinga region until the easternmost corner of shoreline near the Sunderbans in Coastal East India.

Database and Methodology

The coastal water quality measurements, erstwhile in operation under the name COMAPS for the last two decades have been reviewed annually and the data generated by different participating institutions are deposited with INCOIS of MoES. The data generated are made available through web site of the Ministry for Public dissemination as well as through user agencies such as Pollution Control Boards, Department of Fisheries, and Department of Environment (Coastal Water Quality Measurements Protocol for COMAPS Programme, 2012).

Eight water quality parameters (DO, PH, Water Temperature, BOD, Nitrate, Phosphate and Suspended Sediments), were chosen for four seasons (summer, premonsoon, monsoon, post monsoon) from 1990-2010 and coastal water quality index was calculated along the Indian coast for 15 COMAPS locations Vadinar, Hazira, Thane

Mumbai, Ratnagiri, Mandovi, Kochi, Kavaratti, Sandheads, Hooghly, Paradip, Kakinada, Ennore (Chennai), Pondicherry, Port Blair for 1 km from shore.

Fig. 1. Study Area

Arc GIS 10.3, was used for interpolation of different water quality index parameters and for deriving thematic maps. Finally, it was used as a decision support system to easily interpret the calculated results. Origin Pro 3.4, as statistics software was used for plotting the trend line graphs of all water quality parameters for all seasons. It was also used for analysing the relationship between different parameters by giving double-y coordinate graphs.

After the data collection, managing the data and creation of database is important. In this study both the spatial dataset (i.e. latitude, longitude) for each COMAPS location and accurate attribute data for physic-chemical parameters is of significance. In order to study the variations of the different parameters the interpolation (Krigging) method was done. Finally, the water quality index was calculated.

This study proposes an innovative approach by combing CWQI and Geographical Information System (GIS) in a comprehensive manner to visually demarcate the healthy and polluted areas for sustainable coastal resources management.

Results and Discussions

Water Quality Index

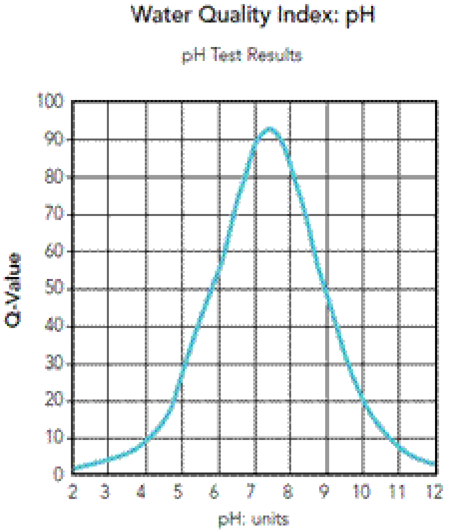
Monitoring programs of aquatic systems play a significant role in water quality management. However, the water quality is difficult to be evaluated from a large number of samples, each containing concentrations of many water quality variables. A Water Quality Index (WQI) summarises large amounts of water quality data into simple terms (e.g., excellent, good and poor.). The WQI can be used as a tool in comparing the water quality of different sources and it gives the public a general idea of the possible problems with water in a particular region (Srinivasan, 2013). The indices are among the most effective ways to communicate the information on water quality trends for the water quality management. Available water quality indices have some limitations such as incorporating a limited number of water quality variables and providing deterministic outputs.

Water quality index is a performance measurement that aggregates information into a usable form, which reflects the composite influence of significant physical, chemical and biological parameters of water quality conditions. The use of a WQI allows 'good' and 'poor water quality to be quantified by reducing a large quantity of data on a range of physico-chemical and biological variables to be a single number in a simple, objective and reproducible manner. The use of a numerical index as a management tool in water quality assessment is a rather recent innovation. An index is a number, usually dimensionless, which expresses the relative magnitude of some complex phenomenon or condition.Water quality index is a 100 point scale that summarises results from a total of eight different measurements such as temperature, pH, Dissolved Oxygen, Turbidity, Nitrates, Total Phosphates, Total Suspended Solids and Biochemical Oxygen.

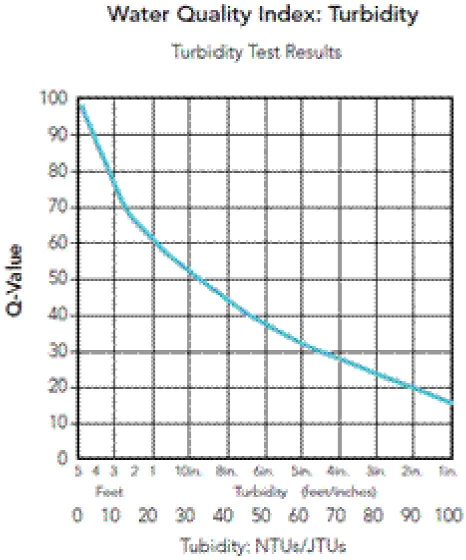
The Multiplicative Water Quality Index (WQIM) is defined as follows that each parameter may be of different weight based on the importance of water quality situation. Individual index (qi) and weighing factors (Wi) for six parameters (DO, pH, BOD, Temperature, Nitrate and Phosphate) has been carried out.

WQI formula

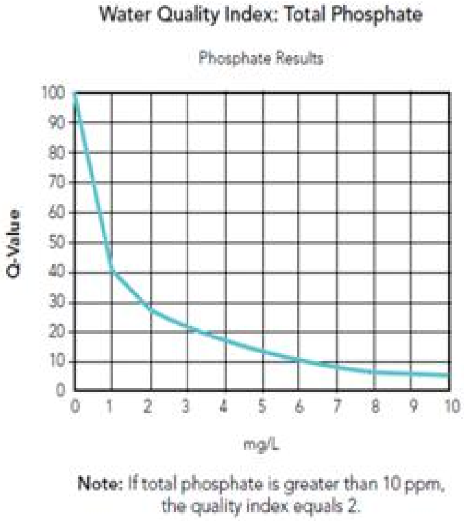
$$WQI_M = \sum_{i=1}^{n} q_i w_i$$

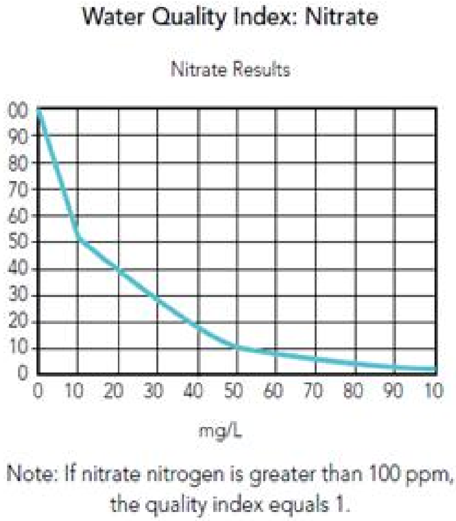


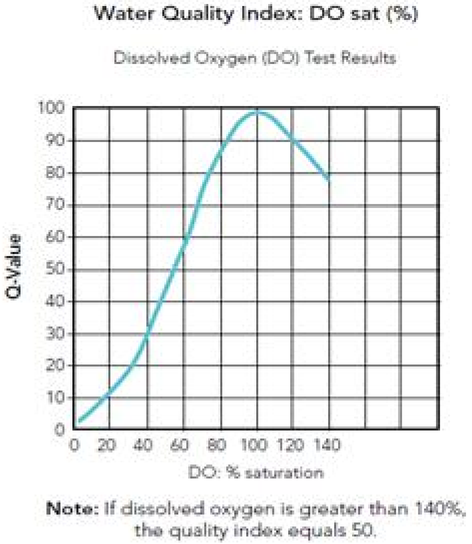
Note: If pH is less than 2.0 or greater than 12.0, the quality index equals 0.



Note: If turbidity is greater than 100 ntu, the quality index equals 5.







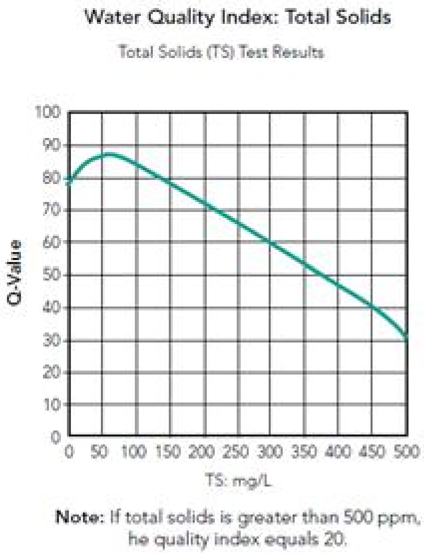


Table 1. WQI Weightage

Parameter	Weightage
Dissolved oxygen (mg/L)	0.18
pH	0.16
Biochemical oxygen demand (mg/L)	0.14
Temperature (°C)	0.13
Suspended particulate matter (mg/L)	0.11
Turbidity (NTU)	0.11
Nitrate (µmol)	0.09
Phosphate (µmol)	0.09

Finally, the numbers shown in the total column were added to determine the overall Water Quality Index (WQI) for the sample point.

Table 2. NSFWQI Standards for WQI

National Sanitation Foundation Water Quality Index (NSFWQI)	
WQI Value	**Rating of Water Quality**
91-100	Excellent water quality
71-90	Good water quality
51-70	Medium water quality
26-50	Poor water quality
0-25	Very poor water quality

The Water Quality Index uses a scale from 0 to 100 to rate the quality of the water, with 100 being the highest possible score. Once the overall WQI score is known, it can be compared against the following scale to determine how healthy the water is.

Water supplies with ratings falling in the good or excellent range would able to support a high diversity of aquatic life. In addition, the water would also be suitable for all forms of recreation, including those involving direct contact with the water. Water supplies achieving only an average rating generally have less diversity of aquatic organisms and frequently have increased algae growth.

Water supplies falling into the fair range are only able to support a low diversity of aquatic life and are probably experiencing problems with pollution. Water supplies that fall into the poor category may only be able to support a limited number of aquatic life forms, and it is expected that these waters have abundant quality problems. A water supply with a poor quality rating would not normally be considered acceptable for activities involving direct contact with the water, such as swimming.

Water Quality Index Calculation

Table 3. WQI for Mandovi - Summer

Parameter	Actual Value	Q Value	Weightage	WQI
Water temperature (ºC)	29.64	89	0.11	09.8
PH	07.98	90	0.12	10.8
DO(mg/l)	06.02	43	0.18	07.7
BOD(mg/l)	02.26	80	0.12	09.6
NO3(µmol/l)	15.63	43	0.10	04.3
Phosphate(µmol/l)	04.96	12	0.11	01.3
Total			**0.74**	**43.5**

WQI = 43.55/0.74 = 58.85 (51-70 Medium WQI - from table NSFWQI)

Likewise the water quality index is calculated for all the COMAPS locations for all the four seasons from 1990-2010. The coastal water quality index is calculated for summer season from 1990-2010, where Ennore (50.02), Kakinada (48.93), Kochi (48.14) Mumbai (48.93) are having poor water quality in the summer season (26-50 poor WQI - from table NSFWQI). Other locations have medium WQI based on National Sanitation Foundation Water Quality Index (NSFWQI).

Poor water quality is found in Kochi (46.71), Pondicherry (50.28) station in pre-monsoon station. In monsoon season only Kochi (48.01) is having poor water quality. In the post monsoon season Kochi is having poor water quality (48.41).

Table 4. WQI for Kochi - Summer

Parameter	Actual Value	Q Value	Weightage	WQI
Water temperature (^{0} C)	29.49	93	0.11	10.2
PH	08.16	82	0.12	09.8
DO(mg/l)	04.64	20	0.18	03.6
BOD(mg/l)	16.93	16	0.12	01.9
NO3(μmol/l)	02.65	90	0.10	09.0
Phosphate(μmol/l)	03.10	21	0.11	02.3
Total			0.74	36.9

WQI = 36.9/0.74 = 49.86 (26-50 Bad WQI - from table NSFWQI)

Table 5. WQI for Summer

Location Name	Latitude	Longitude	WQI
Andaman Nicobar	11.37965	92.58781	68.74
Ennore	13.22878	80.35219	50.02
Hazira	21.08874	72.60564	54.50
Hooghly	21.52023	88.18544	59.67
Kakinada	16.97986	82.30864	48.93
Kochi	09.96541	76.22532	48.14
Mandovi	15.45448	73.77569	65.98
Mumbai	19.03501	72.80651	48.93
Paradip	21.02117	86.71566	61.06
Pondicherry	11.90239	79.83573	55.13
Ratnagiri	16.97358	73.26016	69.86
Sandheads	21.52023	88.58781	62.66
Vadinar	22.45283	69.66289	52.76

Table 6. WQI for Pre-monsoon

Location Name	Latitude	Longitude	WQI
Andaman Nicobar	11.37965	92.58781	62.98649
Ennore	13.22878	80.35219	53.63514
Hazira	21.08874	72.60564	61.38095
Hooghly	21.52023	88.18544	60.41892
Kakinada	16.97986	82.30864	58.14865
Kavarati	10.61415	72.61231	58.47297
Kochi	09.96541	76.22530	46.71622
Mandovi	15.45448	73.77569	59.63514
Mumbai	19.03501	72.80651	55.78378
Paradip	21.02117	86.71566	57.90541
Pondicherry	11.90239	79.83573	50.28378
Ratnagiri	16.97358	73.26016	60.71622
Sandheads	21.52023	88.58781	63.25676
Thane	19.27659	72.76408	55.68254
Vadinar	22.45283	69.66289	61.20270

Table 7. WQI for Monsoon

Location Name	Latitude	Longitude	WQI
Andaman Nicobar	11.37965	92.58781	65.31081
Ennore	13.22878	80.35219	55.13514
Hazira	21.08874	72.60564	52.16216
Hooghly	21.52023	88.18544	59.89189
Kakinada	16.97986	82.30864	56.58108
Kavarati	10.61415	72.61231	61.59459
Kochi	09.96541	76.22530	48.01351
Mandovi	15.45448	73.77569	65.22973
Mumbai	19.03501	72.80651	53.79730
Paradip	21.02117	86.71566	61.72973
Pondicherry	11.90239	79.83573	55.93243
Sandheads	21.52023	88.58781	58.83784
Thane	19.27659	72.76408	56.31081

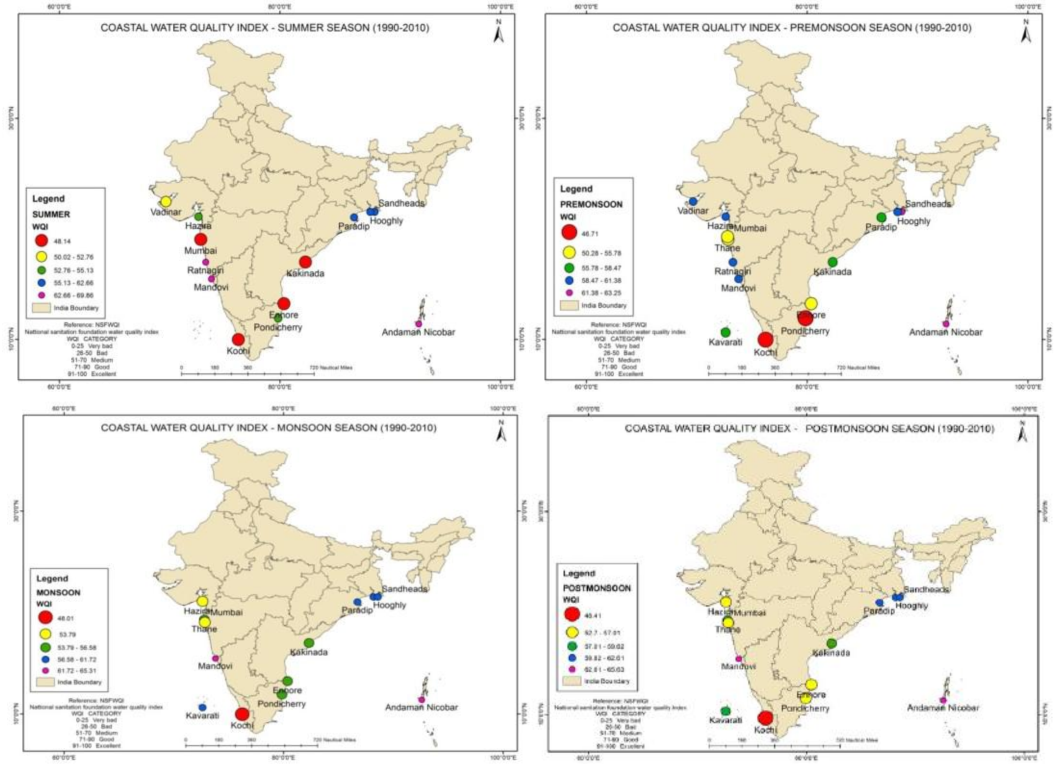


Fig. 2. WQI for Summer, Pre-monsoon, Monsoon and Post-monsoon

Taking the average for all the seasons from 1990-2010, Kochi is the only location having bad WQI, and Ennore, Kakinada, Hazira, Mumbai, Pondicherry location are at the verge of getting into bad WQI.

Table 8. WQI for Post-monsoon

Location Name	Latitude	Longitude	WQI
Andaman Nicobar	11.37965	92.58781	65.63514
Ennore	13.22878	80.35219	54.54054
Hazira	21.08874	72.60564	52.71622
Hooghly	21.52023	88.18544	58.68919
Kakinada	16.97986	82.30864	51.22973
Kavarati	10.61415	72.61231	59.63514
Kochi	09.96541	76.22530	48.41892
Mandovi	15.45448	73.77569	60.93243
Mumbai	19.03501	72.80651	59.82540
Paradip	21.02117	86.71566	61.81081
Pondicherry	11.90239	79.83573	55.13514
Ratnagiri	16.97358	73.26016	65.43243
Sandheads	21.52023	88.58781	57.01351
Thane	19.27659	72.76408	62.61905
Vadinar	22.45283	69.66289	56.67568

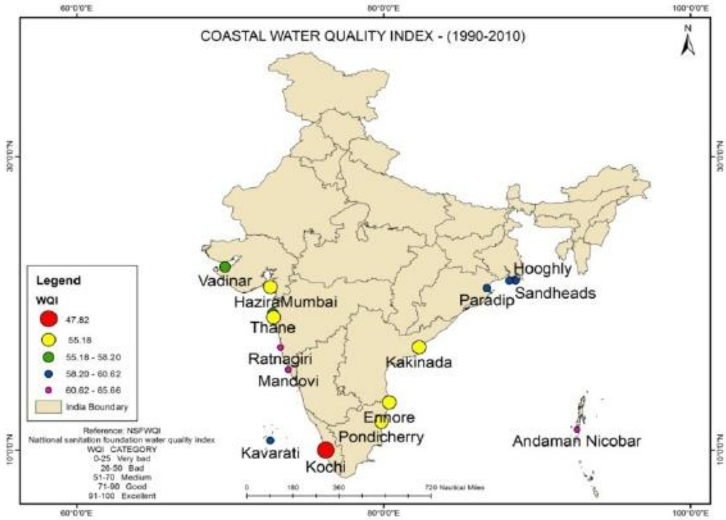


Fig. 6. Average WQI

Table 9. Average WQI

Location Name	Summer	Pre-monsoon	Post-monsoon	Monsoon	Average
Andaman Nicobar	68.74	62.98648649	65.63514	65.31081	65.66811
Ennore	50.02	53.63513514	54.54054	55.13514	53.33270
Hazira	54.5	61.38095238	52.71622	52.16216	55.18983
Hooghly	59.67	60.41891892	58.68919	59.89189	59.66750
Kakinada	48.93	58.14864865	51.22973	56.58108	53.72236
Kavarati	---	58.47297297	59.63514	61.59459	59.90090
Kochi	48.14	46.71621622	48.41892	48.01351	47.82216
Mandovi	65.98	59.63513514	60.93243	65.22973	62.94432
Mumbai	48.93	55.78378378	59.8254	53.7973	54.58412
Paradip	61.06	57.90540541	61.81081	61.72973	60.62649
Pondicherry	55.13	50.28378378	55.13514	55.93243	54.12034
Ratnagiri	69.86	60.71621622	65.43243	---	65.33622
Sandheads	62.66	63.25675676	57.01351	58.83784	60.44203
Thane	---	55.68253968	62.61905	56.31081	58.20413
Vadinar	52.76	61.2027027	56.67568	---	56.87946

Conclusions

Assembling multiple parameters into single unit leads to easy classification and interpretation of index, thus providing an important tool for environmental management purposes. However, it is vital to provide precise information and evidence of specific ecosystem to allow policy makers to decide and implement plans on particular problems. This also helps the policy makers to understand the problem clearly and take necessary mitigation measures for the specific area. On the other hand, GIS techniques add simplification and visualisation to the dataset by integrating multiple layers like discharge points, sampling stations and water quality variables that helps in easy understanding. It has also proved to be a vital tool for decision makers to identify the sources and polluted areas. The data accuracy was checked using trend line graphs and the relationship between various parameters were studied which showed that pH and water temperature are directly proportion, BOD and DO are directly proportional and the Nitrate and DO are inversely proportional. Then the CWQI was calculated. From the calculated data, Kochi was the only location having bad WQI - average value (47.82) and Ennore, Kakinada, Hazira, Mumbai, Pondicherry location are at the verge of getting into poor WQI, but it falls in medium water quality range according to NSFWQI.

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A GIS-BASED MORPHOMETRIC ANALYSIS OF VAIPPAR BASIN, TAMIL NADU

Balasubramani K., Gomathi M. and Kumaraswamy K.

Department of Geography, Bharathidasan University, Tiruchirappalli - 620 024
E-mail: geobalas@gmail.com

Abstract

Geographic Information Systems (GIS) opens up new horizons in spatial planning and simplify the complex mapping as well as planning processes. In this paper, GIS has been used in order to determine the spatial variations in the drainage characteristics of the Vaippar River basin and its sub-basins. The evaluation of morphometric characteristics of the basin helps us to understand the terrain characteristics and hydrological related parameters in a quantitative manner. This paper presents a simplified methodology to generate stream network, delineate sub-basins and extract basin parameters from Digital Elevation Model (DEM) using the Spatial Analyst extension tool in ArcGIS. The conventional quantities such as stream order, stream length, bifurcation ratio, drainage density, drainage texture, stream frequency and circulatory ratio were extracted from the DEM based stream network for each delineated sub-basin. The extracted values were used to characterise the drainage basin systems. The study finds that Charnokite dominated Arjuna Nadi sub-basin has higher values of stream order, stream number, stream length, stream frequency, drainage texture and drainage density; lower values of circulatory ratio indicates that there is a strong geologic control in the landscape development of this basin and susceptible to higher risks of soil erosion and peak flood discharge.

Keywords: GIS, Drainage basin, DEM, Morphometric parameters, Vaippar basin

Introduction

Generally, drainage channels are the arteries on the earth surface. The spatial arrangement of a number of streams gives the formation of the drainage basin and studying its typical arrangement provides insight into the interdependency of geology, climate and fluvial processes. Morphometry is a classic technique which is based on the measurement and mathematical analysis of the geometry of streams, relief features and dimensions of drainage basins. It provides a quantitative description of the basin geometry so as to understand inequalities in the rock hardness, structural controls, recent diastrophism and geomorphic processes of the drainage basin (Strahler, 1964). Morphometric analysis of a basin is an essential first step, toward a basic understanding of landscape dynamics (Thomas et al., 2010). Basin morphometry is a kind of specific morphometric technique which is capable of bringing out size, shape, form and functional variations and their inter-relationships between basins / sub-basins (Kumaraswamy, 1994). Horton (1932, 1945) is the pioneer in basin morphometric analysis and he has established the practical value of this analysis. Later, Miller (1953), Smith (1950), Suchumn (1956), Strahler (1964), Chorley (1969) and several scientists have developed many quantitative techniques for morphometric analysis and applied for different drainage basins throughout the world.

The GIS is a convenient system for morphometric analysis as it provides a various set of tools for delineation of basins, extraction of basin parameters and visualisation of results (Tripathi et al., 2013). It simplifies the extraction of drainage network and provides accurate details for morphometric calculations (Ahmed et al., 2010). It also provides very powerful tools to automatic extraction of stream network and basin parameters from DEM. Unlike the traditional methods, the DEM based automatic extraction of basin parameters are standardised throughout the basin. Further, GIS offers very powerful tools for visualisation of basin landscape using DEM. The present study demonstrates the application of GIS in the morphometric analysis by taking a case study area. The study also tries to find out and visualise the intra-basin variations in the morphometric parameters at the sub-basin level.

Study Area

Vaippar basin in South Tamil Nadu, India has been chosen for the present investigation. The basin is bound between 8o 57' 13" N to 90 46'33" N latitudes and 77o 14' 34" East to 780 14' 34" East longitudes with an area of about 5,200 sq.km (Figure 1). Vaippar is a non-perennial river, collects water from the eastern sides of Western Ghats and drains into the Bay of Bengal. The river Vaippar is 147 km long and has two major branches viz., upper Vaippar in the south and Arjuna Nadi in the north. The basin covers Tirunelveli, Thoothukudi, Virudhunagar, Madurai and Ramanathapuram Districts and shared a boundary with Vaigai basin (West and North West), Gundar basin (North, Northeast), Pampa and Achankovil basins (Southwest) and Thamaraparani basin (South and Southeast). The topography of upper part of Vaippar basin is rugged and marked by ridges eastwest in the south and northeast-southwest in the north. The important hills located in the western part of the basin are Sangumalai, Kurangumalai, Ambarimedumalai, Kottamalai (2016 m - the highest point in the study area) Toppimalai, Ambarimedumalai, Sivavigirimalai and Kodalapparimottai. After a certain distance of eastward travel from these hills, the topography suddenly drops down and gives birth to a number of tanks. All the tanks are rainfed and remain dry except Thenmalaikulam and Puttur tanks. Most of the streams running parallel to each other from the retreating scarp face join the next higher order segments at a height of 120-150 metres above Mean Sea Level (MSL). About 70 percent of the drainage basin, especially the central and eastern parts, is underlined by Genesis and 25 percent by Charnokite (western part). An alluvial track prevails in the lower reaches of the basin (Figure 2). The basin falls under semi-arid tropical monsoon type of climate with the mean temperature of 35o C and an annual average of rainfall of 812 mm.

Database and Methodology

To study the morphometric characteristics of Vaippar basin, DEM of the study area was collected from ASTER (Advanced Spaceborne Thermal Emission and Radiometer) data (30 m pixel resolution). The gaps and spikes in the DEM were corrected with the help of sink and fill tools in ArcGIS (Figure 3). The direction of surface flow from DEM was identified with the help of flow direction tool and accumulation of water flow was estimated. The flow direction layer was used to delineate the basin boundary and the flow accumulation layer was used to generate a stream network by determining the cell value of more than 100 in the raster calculator. The generated stream network later converted into a vector in order to extract parameters for morphometric analysis. The workflow of automatic stream generation is presented graphically in Figure 4.

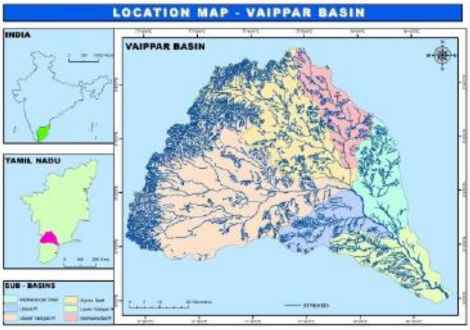

Fig.1. Location of Vaippar Basin

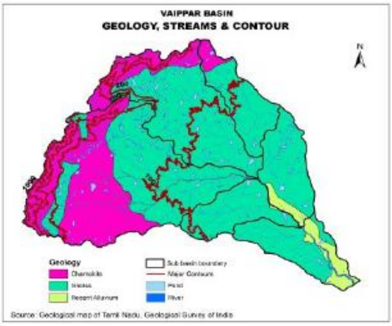

Fig. 2. Geology of the Basin with Major Streams and Contours

Based on topography configuration and major tributaries of the main river, the basin was divided into six major sub-basins viz. Upper Vaippar, Arjuna Nadi, Mannarkkottai, Melkaranai Odai, Uppar and Lower Vaippar by fixing the pour points at appropriate locations. The generated stream network of all sub-basins were cross verified with Survey of India toposheets (1:50,000) and altered wherever blunder appears. The amount of blunders usually high in the lower parts of the basin and almost negligible in the upper reaches. The measurements of shape and length of stream networks were derived from rectified stream networks to calculate conventional morphometric parameters' (stream length, relief ratio, drainage density, stream frequency, elongation ratio and circulatory ratio) adopting methods are presented in Table 1. All the parameters were tabulated (Table 2) and maps were prepared (Figure 5) to bring out the intra-basin variations.

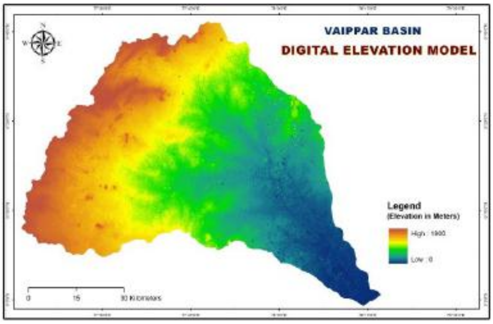

Fig. 3. Asters Derived Digital Elevation Model

Table 1. Method Adopted for Computation of Morphometric Parameters

Parameter	Method	Reference
Stream order	Hierarchical rank (Strahler method)	Strahler (1964)
Stream length (Lu)	Length of the stream (km)	Horton(1945)
Mean stream length (Lsm)	Total stream length in each order divided by total no. of stream segments in that order	Strahler (1964)
Bifurcation ratio (Rb)	The total length of stream segments in each order divided by the number of segments in the next higher order	Suchumn (1956)
Drainage density (D)	Total stream length (km) of all orders divided by area of the basin (sq.km)	Horton (1945)
Stream frequency (Fs)	Total no. of streams of all orders divided by area of the basin (sq.km)	Horton (1932)
Drainage texture (Rt)	Total number of streams of all orders divided by perimeter (km)	Horton (1932)
Circularity ratio (Rc)	$Rc = 4 \times \pi \times A/P^2$ (π = 3.14; A = area of the basin; and P^2 = square of the perimeter)	Miller (1953)

Results and Discussion

Linear Aspects of the Drainage Basins

The total number of streams in the Vaippar basin is 6,651. Strahler's (1964) method of identifying different stream orders is used in the present analysis. Generally, a higher number of orders reflect well resistant underlying rock system which is found in Upper Vaippar (7) and Arjuna Nadi (6) sub-basins. The stream numbers are also counted order wise. As a general rule, the number of segments decreases as the stream order increases for the main river as well as for the sub-basins. All the sub-basins follow the general rule as there is no extremity at any level of stream order, which indicates that Vaippar river basin has matured relief development. The higher number of streams and stream length in Upper Vaippar and Arjuna Nadi sub-basins reflect that the slope in these basins is steep.

Generally, the total length of stream segments decreases with stream order increases. A smaller deviation from this trend is noticed in the higher orders of Arjuna Nadi and Lower Vaippar sub-basins indicating either structural complexity or impermeable bedrock. Since all other basins are indicating this general rule, the evolution of the basin follows erosion laws with homogeneous weathering characteristics.

The bifurcation ratio, indicating the number of lower order streams to a given higher order stream, is 4.7 for the Vaippar basin as a whole. The ratio ranges from 2.33 to as high as 14 between different orders of sub-basins. In a well-developed drainage network, the bifurcation ratio ranges from 2 to 5 (Horton, 1945; Strahier, 1964). Deviations from the normal values indicate the influence of geological formations (parent rock or lineament) and rainfall variations. Melkaranai Odai and Uppar sub-basins deviate from the normal range indicate a strong structural control on drainage development and low permeability of the subsurface strata. The mean bifurcation ratio also suggests that Melkaranai Odai (6.21) and Uppar sub-basins (7.67) have a certain extent of structural complexity. The hilly sub-basins (Upper Vaippar and Arjuna Nadi) have more streams in first and second order segments indicates that the lower order streams are developed due to a larger volume of water at higher altitudes.

Table 2. Linear Aspects of Vaippar and its Sub-Basins

Name of the Sub-Basin	Stream Order	Total No. of streams	Bifurcation Ratio (Bu)	Length of each Stream Order (km)	Mean Stream Length (km)	Total Length (km)
Upper Vaippar	I	2441	4.43	1620.2	0.66	2,983.9
	II	551	4.37	582.02	1.06	
	III	126	4.5	325.43	2.58	
	IV	28	4	173.42	6.19	
	V	7	2.33	191.83	27.4	
	VI	3	3	56.42	18.81	
	VII	1		34.58	34.58	
Arjuna Nadi	I	1599	4.63	1094.39	0.68	1,946.52
	II	345	4.31	463.16	1.34	
	III	80	4.44	215.34	2.69	
	IV	18	3.6	55.47	3.08	
	V	5	5	45.56	9.11	
	VI	1		72.59	72.59	
Mannarkottai	I	261	4.35	250	0.96	440.51
	II	60	3.75	90.22	1.5	
	III	16	4	51.88	3.24	
	IV	4	4	24.14	6.03	
	V	1		24.28	24.28	
Melkaranai Odai	I	291	3.83	283.09	0.97	460.33
	II	76	3.3	101.01	1.33	
	III	23	11.5	63.59	2.76	
	IV	2		12.64	6.32	
Uppar	I	276	3.78	267.94	0.97	486.05
	II	73	5.21	123.22	1.69	
	III	14	14	46.59	3.33	
	IV	1		48.3	48.3	
Lower Vaippar	I	268	4.39	301.75	1.13	534.58
	II	61	4.07	108.46	1.78	
	III	15	5	58.93	3.93	
	IV	3	3	25.53	8.51	
	V	1		39.9	39.9	
Vaippar Basin	VII	6651		6851.89	1.03	6851.89

Areal Aspects of the Drainage Basin

The closeness of drainage channels is affected by factors such as resistance to weathering, permeability of rock, climate, vegetation etc. (Javed et al., 2009). The measurement of closeness of drainage channels i.e. drainage density provides a numerical measurement of landscape dissection and runoff potential (Bagyaraj and Gurugnanam, 2011). As the drainage density controls the speed of runoff following a period of precipitation, the increasing value shows the increasing size of the mean annual flood. The drainage density varies from 0.96 to 1.61 km/sq.km for different sub-basins. Therefore, the basin and its sub-basins are found with low drainage density and low risks of annual floods. However, Arjuna Nadi and Upper Vaippar sub-basins represent comparatively higher drainage density due to its mountainous character. The stream frequency is also higher in Upper Vaippar and Arjuna sub-basins where the first and second order streams are freely developed in larger numbers and affirm the higher probability of surface runoff. Mannarkottai, Melkaranai Odai and Lower Vaippar sub-basins have very low drainage density and stream frequency, indicating a very low potential for water flow and infiltration.

Table 3. Areal Aspects of Vaippar and its Sub-basins

Name of the Sub Basin	Area (Sq.km)	Total no.of Streams	Mean Bifurcation ratio	Drainage Density	Perimeter (km)	Circulatory Ratio	Drainage texture	Stream Frequency
Upper Vaippar	2,183.88	3,157	3.77	1.37	249.14	0.44	12.67	1.45
Arjuna	1,207.01	2,048	4.40	1.61	217.13	0.32	9.43	1.70
Mannarkottai	432.96	342	4.03	1.02	116.20	0.40	2.94	0.79
Melkaranai Odai	480.93	392	6.21	0.96	106.84	0.53	3.67	0.82
Uppar	410.34	364	7.67	1.18	107.99	0.44	3.37	0.89
Lower Vaippar	486.50	348	4.12	1.10	119.00	0.43	2.92	0.72
Vaippar Basin	5,201.63	6651		1.32	376.94	0.46		1.28

By measuring relative channel spacing in a fluvial dissected terrain, Smith (1950) identified five classes of drainage texture viz. very course (<2), coarse (2-4), moderate (4-6), fine (6-8) and very fine (>8). In the present study, the very fine texture is observed in Upper Vaippar (12.67) and Arjuna Nadi (9.43) sub-basins due to the impervious character of charnokite granite as underlying rocks. All other sub-basins have coarse drainage texture due to gentle plains with alluvium and patches of crystalline limestone.

Circularity ratio which is a measure of outline form of the basin varies from 0.32 to 0.53. Since the value 0.0 indicates the highly elongated shape and the value 1.0 a circular shape, the circular ratio of the Vaippar basin (0.47) shows that it is closer to the elongated shape. The lower value of circularity ratio in Arjuna Nadi sub-basin (0.32) indicates that the sub-basin is structurally controlled and characterised by youth stages of landscape development.

Conclusions

The present investigation of drainage characteristics of the Vaippar basin unveiled the importance of morphometric studies in terrain characterisation and the role of GIS in the accurate extraction of drainage parameters. The drainage network of the Vaippar basin has seven levels of stream ordering which reflect a well-developed river system with a large number of first and second order streams. The higher values of drainage density, drainage texture and stream frequency in Upper Vaippar and Arjuna Nadi sub-basins indicates that the topography of these sub-basins provide enough power to sediment transportation through surface runoff and thus increased the rate of erosion. Though both the sub-basins are characterised by youthful stages of landscape development, Arjuna Nadi is structurally controlled and more susceptible to soil erosion as well as surface runoff as indicated by higher values of mean bifurcation ratio, drainage density and stream frequency and lower value of circulatory ratio. The highest value of drainage texture and lowest value of mean bifurcation ratio suggest that Upper Vaippar sub-basin is structurally less disturbed and attained a well-developed drainage network through homogeneous weathering and head-ward erosion.

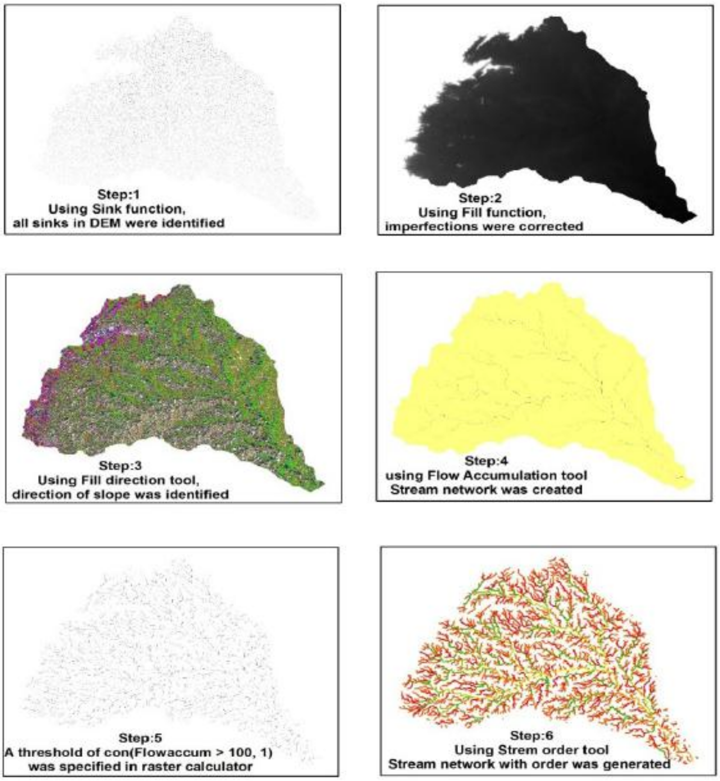

Fig. 4. Step-by-Step Process for Extraction of Stream Network Using Hydrology Tool in ArcGIS

Though the basin hydrology is a very complex phenomenon, the analysis of the morphometric parameters provides reliable measurements about landscape characteristics and hydrological response of the basins. Hence, the application of GIS in basin morphometry would produce a beneficial effect on basin resource conservation and management.

Acknowledgements

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REGIONAL VARIATIONS OF POPULATION DISTRIBUTION IN TAMIL NADU - A SPATIO-TEMPORAL ANALYSIS BASED ON PHYSIOGRAPHIC REGIONS

Lazar A.

Directorate of Census Operations, Chennai - 600 090
E-mail: lazar.gis@gmail.com

Abstract

The ability to adapt to the prevailing environment of human beings is influenced by the physiographic settings. However, the adaptability to the physiographic settings is not uniform in the global distribution of population. It is essential to compile the demographic, socio-economic variables at physiographic regional level to ascertain the distribution pattern, dependencies and to help in regional planning and disaster responses. In this study, the regional variations of population distribution in the physiographic region of Tamil Nadu are discussed. The study compiles and infers Census data published during 1981, 1991, 2001 and 2011 on the basis of physiographic regions which was devised during 1981 Census and revised in 1991, but which were consequently discontinued. Computation and analysis of the variations in population distribution at sub-micro regional level and measure the distribution inequality across the regions using appropriate statistical methods are carried out in this study. The sub-micro regional level cumulative proportion of area (Xi) and cumulative proportion of population (Yi) have been used to compute the Spatial Gini's coefficient. The Census data at physiographic regional level have been compiled using GIS application by utilising the spatial data of physiographic regional boundaries and locations of villages / towns. The results shows that the State of Tamil Nadu have 0.38 Spatial Gini's coefficient which is fairly distributed across the two meso regions within the State but at micro regional level we could see inequality of population distribution. Thus, the study helps to understand the influences on population distributions in a physiographic region.

Keywords: Physiography, Population Distribution, Spatial-GINI's Coefficient

Introduction

The global distribution of population has been influenced by many factors and primarily by the interaction of humans with physiographical settings and their ability to sustain in the prevailing environment. It is observed that the characteristics of continental physiography such as elevation, proximity to nearest coastline or river presumably influence habitation (Small and Cohen, 2004). But over time these dependencies are getting reduced depending upon the level of development attained by the occupied population. But this adaptability to the physiographic settings is not uniform across the globe and depends on various socio-economic variables.

About half of the Earth's habitable land is sparsely populated and accounts for only 2 percent of world's population with density of less than 10 per sq.km. Yet half of Earth's human population lives in less than 3 percent of the potentially habitable land area, which effectively leads to high population densities (Small and Cohen, 2004).

The data sets pertaining to demography, socio-cultural and economic domains are generally collected on the basis of administrative divisions / hierarchies and this leads to lack of information at physiographic regional level. Hence, it is necessary to compile the demographic, socio-economic variables at physiographic regional level to ascertain the distribution pattern, dependencies and to help in regional planning and disaster management.

The objective of this paper is compile Census data published during 1981, 1991, 2001 and 2011 on the basis of physiographic regions (was devised during 1981 Census and revised in 1991 but consequently discontinued) using GIS applications. It is also proposed to compute and analyse the variations in population distribution at sub-micro regional level and measure the distribution inequality across the regions using appropriate statistical methods.

Study Area

The State of Tamil Nadu (Madras), created on 1st November, 1956 by the State reorganisation act, is presently one of the fast developing States of India with vibrant economic growth, high literacy and a young population with well-developed transport connectivity across the State. The State lies between 8^{o} 5' and 13^{o} 35' North latitudes and between 76^{o} 15' and 80^{o} 20' East longitudes. The State consists of 39.6 percent of Plains out of which 8.3 percent are Coastal, 23.5 percent of Uplands, 19 percent of Forested Hills and the remaining 4.9 percent is of valley (ORGI, Primary Census Abstract, 2011). Total population of the State as per 2011 is 7,21,47,030 out of which 48.4 percent live in urban areas. Post-independence, the State witnessed highest growth of population during 1961-1971 (22.3 percent) and the lowest (11.7 percent) in 1981-1991. During the last decade the State witnessed 15.6 percent growth in population (ORGI, Primary Census Abstract, 2011).

Database and Methodology

Analytical frame for the Study

As proposed, the physiographical divisions have been taken as the frame for data compilation which has been devised for the entire country during Census 1981 by the Census of India (CoI). These divisions were made on the basis of topography, geology, soils, climate, natural vegetation etc., the country has been divided in to four macro regions namely, (1) The Northern Mountains, (2) The Great Plains, (3) The Deccan Plateau and (4) The Coastal Plains and Islands. These four macro regions were further divided into 28 meso regions confined within the State boundaries.

For carving out Micro regions from meso regions and Sub-Micro regions from Micro regions, the following criterions were considered by the CoI;

1. Contiguous geographical area,
2. Homogeneous administrative machinery capable of formulating and implementing integrated area plans,
3. Reliable statistical database,
4. Existence of nodal regions and
5. Amenability of the natural boundaries to marginal adjustments so that the former, by and large, conform to administrative boundaries at any given point of time. All these regions were numbered as well.

Hierarchy of Physiographic Regions in India

- Macro regions (1)
    - Meso regions (States) (1.1)
        - Micro regions (Districts) (1.1.1)
            - Sub-Micro regions (constituted by Villages/Towns) (1.1.1.1)

On applying the above mentioned criterions, the meso regions within the State were further divided into *micro* regions using district's as bounding units. Each of these micro regions were split into *sub-micro* regions using the lowest administrative units i.e. villages / towns as bounding units. The State of Tamil Nadu falls in two macro regions of India namely the Deccan Plateau (3) and Coastal Plains and Islands (4) (Figure 1) and areas under these two regions within the State are called meso regions. The area which is part of the Deccan Plateau region in Tamil Nadu is called Tamil Nadu Uplands (3.10) which consists of 47.1 per cent of the State area and the remaining areas of the State (52.9 percent) fall in the region of Coastal Plains and Islands and are called as Eastern Coastal (4.3). These two meso regions were further divided into five micro regions i.e., Tamil Nadu Uplands (3.10.1), Eastern flanks of Sahyadri (3.10.2), Kanniyakumari Coast (4.3.1), Sandy littoral (4.3.2) and Coromandel Coast (4.3.3). Among these five micro regions, Coromandel coast is the largest with a share of 33.1 percent area. Further, these five micro regions of Tamil Nadu have been divided into 83 sub-micro regions (last updated in 1991 as per prevailing jurisdictional boundaries) by considering the districts as limiting factor and village / towns as lowest units.

Data Compilation Using Geographic Information System (GIS)

Census indicators used in this paper were compiled at sub-micro regional basis and then at higher orders of regions i.e. Micro and Meso. Since the geophysical features are generally same within the natural regions (Sub-micro regions which were named as plains, coastal plains, basins, valleys, uplands and forested hills grouped to ascertain the distribution variation within these broad regions) (Figure 3) like, Plains, Uplands etc., these sub-micro regions were also grouped as Coastal Plains, Plains, Basins, Uplands, Valleys and Forested Hills for the analysis purpose. Physiographic region level Census indicators pertaining to the years 1981 and 1991 have already been compiled and are available in published volumes.

Fig. 1. Physiographic Divisions of Tamil Nadu

(*Source: Census of India, 1991, Regional Divisions of India, Vol. XXII)*

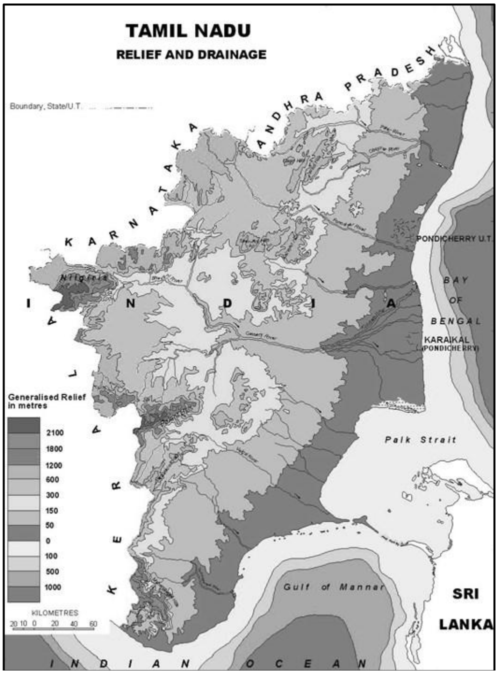

Fig. 2. Relief and Drainage

(Source: Census of India, 1991)

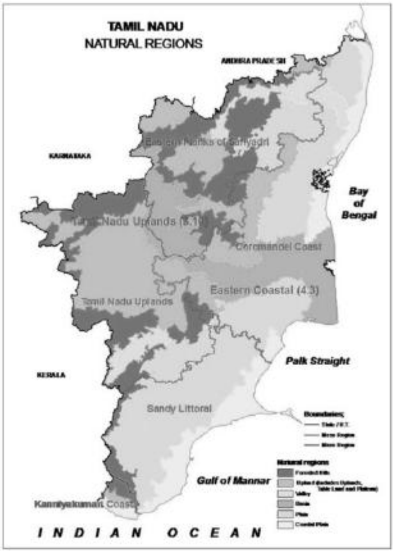

Fig. 3. Natural Regions

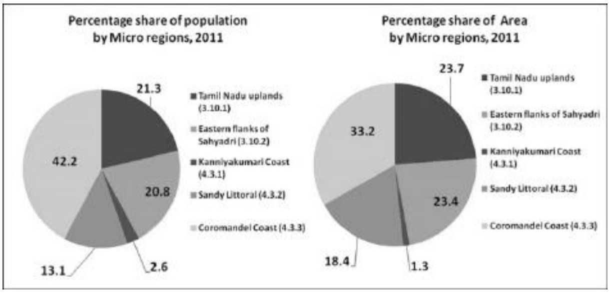

Fig. 4. Percentage Share of Population and Area at Micro Regional Level, 2011

The data for years 2001 and 2011 were generated using GIS application (ArcGIS). The Primary Census Abstract data at village / town level have been compiled for each of the census years i.e. 2001 and 2011. These tables were imported into GIS application and linked with village / town locations (point shapefile). Using the Regional Divisions spatial layer (Polygon Shape file) these village / town locations have been assigned with appropriate region codes using spatial join method and then exported into MS Excel for required tabulation and analysis.

Spatial GINI'S Coefficient

The Gini's Coefficient is a measure of inequality developed by the Italian statistician Corrado Gini and published in his 1912 paper 'Variabilità e mutabilità'. It is defined as a ratio with values between 0 and 1, the numerator is the area between the Lorenz curve of the distribution and the line of equality (line of equal distribution), and the denominator is the area under the line of equality. It has generally been used to measure the income inequality, but social scientists do use it for measuring equality of distributions.

Table 1. Spatial Gini's Coefficient for Physiographic Regions of Tamil Nadu

Macro Regions (Inter State)	Meso Regions *(Confined within State)*	Area	Population	Per. Share of Area	Per. Share of Population	Density *(Persons per Sq. Km.)*	Gini's Coefficient
The Deccan Plateau (3)	Tamil Nadu Uplands (3.10)	61297	30367269	47.1	42.1	495	**0.39**
Coastal Plains &Islands (4)	Eastern Coastal (4.3)	68761	41779761	52.9	57.9	608	**0.37**
Tamil Nadu		**130058**	**72147030**			**555**	**0.38**

**Note: Areas falling in the two of the macro regions namely Deccan Plateau (3) Coastal Plains & Islands (4) within the State are called meso regions i.e., Tamil Nadu Upland (3.10) and Eastern Coastal (4.3) respectively.*

Table 2. Micro Regional Divisions of Tamil Nadu

Micro Regions of Tamil Nadu	Code	Area (in Sq. Km.)	Population				Decadal growth rate		
			1981	1991	2001	2011	1981-91	1991-01	2001-11
Tamil Nadu Uplands (3.10.1)	3.10.1	30869.8	10294712	11749114	13212799	15370754	14.1	12.5	16.3
Eastern flanks of Sahyadri (3.10.2)	3.10.2	30427.6	9853101	11394389	13029550	14996515	15.6	14.4	15.1
Kanniyakumari Coast (4.3.1)	4.3.1	1685.3	1423399	1600349	1676034	1870374	12.4	4.7	11.6
Sandy Littoral (4.3.2)	4.3.2	23968.2	6911160	7747190	8390522	9462243	12.1	8.3	12.8
Coromandel Coast (4.3.3)	4.3.3	43107.4	19925705	23368369	26096774	30447144	17.3	11.7	16.7
Tamil Nadu		**130058**	**48408077**	**55859411**	**62405679**	**72147030**	**15.4**	**11.7**	**15.6**

The ‘Spatial GINI’S Coefficient’ (Sutton) can be derived from two spatially explicit datasets. In this study, instead of Income and Population, sub-micro level Cumulative proportion of Area (Xi) and Cumulative proportion of Population (Yi) have been used to compute the Spatial Gini’s coefficient (Farris, 2010). It varies from 0 (Equal distribution) to 1 (One region has all the population) as does the traditional Gini’s coefficient. It is also expressed in percentage term called Gini’s Index by multiplying the Spatial Gini’s Coefficient value by 100 (Yu Song, 2000). For each of the regional category mentioned above the GINI’S coefficient is being calculated with Brown Formula shown below for the Census years1991, 2001 and 2011 at sub-micro level.

$$G = |1 - \sum_{k=1}^{n} (X_k - X_{k-1})(Y_k + Y_{k-1})|$$

*where, G: Gini’s coefficient, Gini’s Index = G * 100*
Xk: cumulated proportion of the Area variable, for k = 0,...,n, with X0 = 0, Xn = 1
Yk: cumulated proportion of the Population variable, for k = 0,...,n, with Y0 = 0, Yn = 1

Results and Discussion

Population Distribution

Meso regions*

The areas confined to the meso region of Eastern Coastal of Tamil Nadu (Table No.1) are the most populated with 4.18 crore persons, (1981: 58.4 percent, 2011: 57.9 percent) this may be attributed to the long history of human settlements, gentle relief across the region barring few hillocks and presence of many rivers with fertile agricultural lands. The Uplands of Tamil Nadu are also equally populated with 3.04 crore persons (1981:41.6 percent, 2011: 42.1 percent) though there are large tracts of areas under forested hills with sparsely populated regions. The proportion of population among these two meso regions are quite consistent throughout the last four Census years (Table No.2) i.e., 1981, 1991, 2001 and 2011 and each of these regions are maintaining their respective share of population with very little change. The distribution of population in Tamil Nadu at meso regional level (calculated by using sub-micro regions falling in each of these meso regions) gives a Spatial Gini’s Coefficient of 0.39 (Table No.3) for Tamil Nadu Uplands (3.10) and 0.37 for Eastern Coastal (4.3). This is a reflection of fairly distributed population between these two meso regions in the State.

Micro Regions

Among the micro regions (Fig.1), Coromandel Coast (4.3.3) is the most populated (3.04 Crore persons) with the highest share of population and area of the State (42.2 percent and 33.1 percent respectively). Two other micro regions of Eastern Coastal namely Sandy Littoral (13.1 percent) and Kanniyakumari Coast (2.6 percent) accounts for 15.7 per cent of the State population.

The two micro regions within Tamil Nadu Uplands (3.10) share almost equal percentage of population and area with fractional differences. The Tamil Nadu Uplands accounts for 21.3 per cent of State population and the Eastern flanks of Sahyadri consists of 20.8 per cent of population. The Spatial Gini's Coefficient of Sandy Littoral region (0.22) is the least among the five micro regions (Table No.3) in the State which means, in this region population is comparatively well distributed. The Tamil Nadu Uplands have the highest (0.46) Spatial Gini's Coefficient and which shows unequal distribution of population within the region. The reason may be attributed to the presence of large tracts of forested hills. The Kanniyakumari Coast (0.43) also shows a high measure of unequal distribution.

Sub-Micro Regions

As per 2011 Census, more than 75 per cent of persons in the State live in 25 sub-micro regions (in 50 percent of the State area) while the remaining 25 per cent live in 58 sub-micro regions. Among 83 sub-micro regions, 25 have more than 10 lakhs population. Madras coastal plain (46,46,732 persons) is the most populated region constituting 6.4 per cent of State population and the least populated region is Srivilliputtur Forested Hills (251 persons). Within the micro region of Tamil Nadu Uplands, Coimbatore tableland is the most populated with 38.9 lakhs persons and the least is Mudumalai Forested Hills with 2177 persons.

In the micro region of Eastern Flanks of Sahyadri, Cauvery Basin, which extends into other micro regions as well, is the most populated (41.6 lakhs persons) and the lowest is in the Palar valley sub-micro region of Tiruvannamalai Districts (41,906 persons) which also overlaps with more than one micro region. Among the sub-micro regions of Kanniyakumari Coast micro region, Kanniyakumari coastal plain is the most populated and accounts for 69 per cent of population of the micro region. In the Sandy Littoral of Eastern Coastal, the highest population is in Virudhunagar Tiruchuli Black Soil Plain (19.4 Lakhs persons) and the least is in Srivilliputtur Forested Hills (251 Persons).

Spatial Lorenze Curve generated using sub-micro level data for Tamil Nadu shows the cumulative population of each sub-micro region as a function of cumulative land area of the respective region for increasing population density of the area occupied by the corresponding percentage of population. The area between line of equality and Spatial Lorenze Curve calculated using Gini's Coefficient works out to 0.38 for Tamil Nadu. Given that 19 per cent of State area is under the Forested Hills regions, the population distribution across the State by excluding these Forested Hills would be more evenly distributed.

Natural Regions

The physiographic regions have been further grouped as per their broad physical characteristics namely Plains, Coastal Plains, Basins, Valleys, Uplands and Forested Hills. As per Census 2011, the sub-micro regions (Table 4) falling in Plains (Plains 16.1 percent and Coastal Plains 32.1 percent) accommodates the highest share of population (48.2

percent) while the Forested Hills contribute the least percentage (5.4 percent) share of population. The Uplands and Basins of the State consist of 22.7 per cent and 16.7 per cent of population respectively.

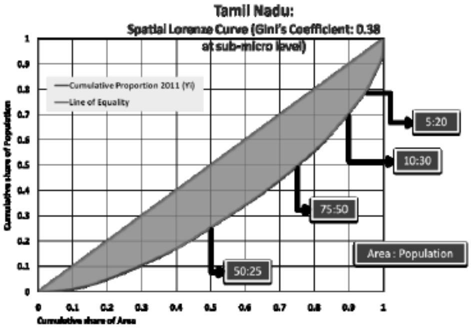

Fig. 5. Spatial Lorenze Curve using Sub-Micro Level Population and Area

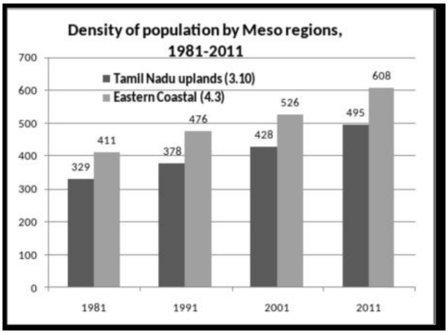

Fig. 6. Density by Meso Regions

Table 3. Physiographic Regions of Tamil Nadu

Macro Regions (Inter State)	Meso Regions *(Confined within State)*	Micro Regions *(Confined within State*	Districts falling within the regions	No. of Sub-Micro Regions *(Confined within Districts)*	Area	Population, 2011	Density (Persons per Sq. Km.)	Gini's Coefficient	Gini's Index (%)
The Deccan Plateau (3)	Tamil Nadu Uplands (3.10)	Tamil Nadu Uplands(3.10.1)	Coimbatore, Tiruppur, Madurai, Nilgiris, Dindigul, Erode and Theni	24	30870	1,53,70,754	498	**0.46**	**46**
		Eastern flanks of Sahyadri(3.10.2)	Tiruvannamalai, Vellore, Dharmapuri, Krishnagiri, Salem and Namakkal	15	30428	1,49,96,515	493	**0.3**	**30**
Coastal Plains &Islands (4)	Eastern Coastal (4.3)	Kanniyakumari Coast (4.3.1)	Kanniyakumari	3	1685	18,70,374	1110	**0.43**	**43**
		Sandy Littoral (4.3.2)	Sivaganga, Ramanathapuram, Virudhunagar, Thoothukkudi and Tirunelveli	15	23968	94,62,243	395	**0.22**	**22**
		Coromandel Coast (4.3.3)	Thiruvallur, Kancheepuram, Chennai, Cuddalore, Viluppuram, Ariyalur, Perambalur, Nagapattinam, Thiruvarur, Thanjavur, Pudukkottai, Tiruchirappalli and Karur.	26	43107	3,04,47,144	706	**0.37**	**37**
Tamil Nadu	**2**	**5**		**83**	**130058**	**7,21,47,030**	**555**	**0.36**	**36**

Table 4. Spatial Gini's Coefficient for Natural Regions of Tamil Nadu (Grouping)

Natural Regions	No. of Sub-Micro Regions	Percentage of area under each natural region	Total Population, 2011	Density in Sq.KM.	Spatial Gini's Coefficient	Gini's Index (%)
Coastal Plains	8	8.3	1,16,04,098	1069	**0.56**	**56**
Plains	23	31.3	2,31,76,060	570	**0.27**	**27**
Basins	7	13	1,20,91,954	717	**0.16**	**16**
Uplands	16	23.5	1,63,72,431	535	**0.24**	**24**
Valleys	5	4.9	50,07,625	787	**0.09**	**9**
Forested Hills	24	19	38,94,862	158	**0.41**	**41**
Tamil Nadu	**83**	**100**	**7,21,47,030**	**555**	**0.22**	**38**

The Spatial Gini's coefficients calculated for each of the natural regions shows greater variation than the physiographical regions. Coastal Plains of Tamil Nadu gives the highest Gini's Coefficient (0.56) which may be attributed to the presence of two highly urbanised micro regions of Coromandel and Kanniyakumari Coast and relatively less urbanised Sandy Littoral region. Also the forested hills have Gini's Coefficient of 0.41 indicating higher measure of unequal distribution of population within this region. The lower Spatial Gini's Coefficients recorded in the regions of valley (0.09), Basin (0.16), Uplands (0.24) and Plains (0.27) which show fairly uniform distribution of population within these natural regions.

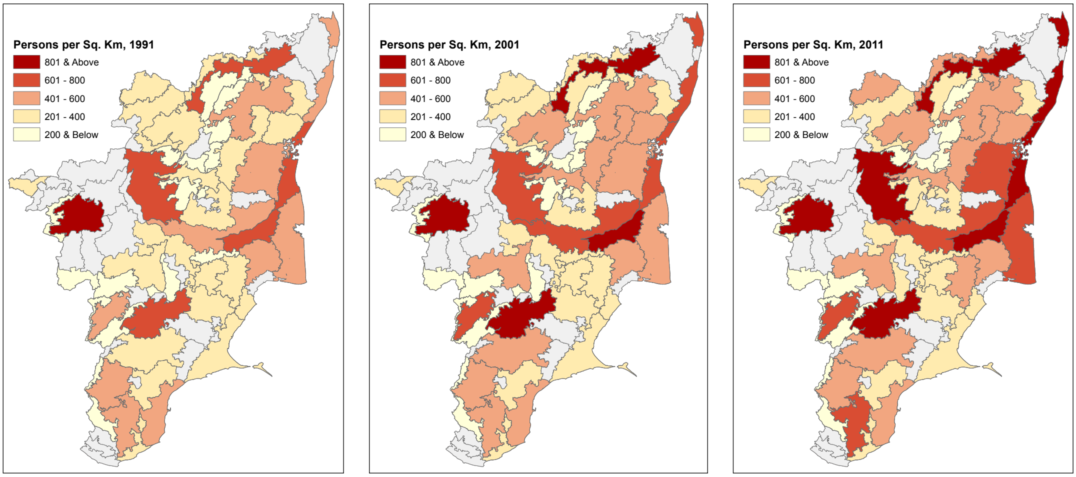

Fig. 6. Density of Population in Tamil Nadu (Sub-Micro Regions)

Density Pattern

As per Census 2011, the density of population in the State is 555 persons per sq.km. (Table 1) and this has increased from 372 in 1981. At meso regional level, Eastern Coastal region had a density of population of 411 in 1981, which has increased to 608 persons per sq. km in 2011. Among the micro regions, the Kanniyakumari Coast is the most densely populated (Other than Chennai, which is 26,777 per sq.km.) with 1,110 persons per sq. km which is higher than the State and is followed by the Coromandel coast (706). The micro region of Sandy Littoral is the least densely populated with 395 persons per sq.km.

The density of population for the years 1991, 2001 and 2011 across the sub-micro regions is shown in (Map. No.4) with 5 ranges (Class Interval of 200 persons per sq.km.). The most densely populated sub-micro regions are located in the Coromandel Coast, Cauvery Basin, Coimbatore Upland, Madurai Plain and Kanniyakumari Coast. The density of population shows an increasing trend in these regions. Highest density of population is in Madras Plain (26,705 persons per sq.km) and lowest is in Srivilliputtur Forested Hills (1). Leaving aside the Madras Plain, among the remaining 82 sub-micro regions, 12 have more than 800 persons per sq.km out of which 5 have more 1000 persons per sq.km.

Conclusions

As proposed, the Census data at physiographic regional level have been compiled using GIS application by utilising the spatial data of Physiographic regional boundaries and locations of Villages / Towns. The compiled census data for each of the regions at different levels have been analysed for exploring the distribution pattern and inequality.

It is found that the State of Tamil Nadu have 0.38 Spatial Gini's Coefficient which is fairly distributed across the two meso regions within the State but at micro regional level we could see inequality of population distribution. The Eastern flanks of Sahyadri have the highest Spatial Gini's Coefficient value of 0.46. The derived Spatial Gini's Coefficient of the six Natural regions gives higher regional variations in population distribution. The most unequal distribution of population could be seen in the coastal Plains (0.56) and the least unequal distribution in valleys (0.09).

For better understanding of the relationships between population distribution and physiographic regions discussed in this paper, a detailed analysis using more number of demographic, socio-cultural and economic variables is needed. Some of the Sub-micro regions along the coast and important transport corridor may offer economic and strategic advantages which could be the driving force for the unequal distribution of population. By extending this type of quantitative analysis to more socio-economic variables we may be able to have a better understanding of the influences on population distributions.

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MGNREGS IN SUSTAINABLE PADDY CULTIVATION AND FOOD SECURITY IN PALAKKAD DISTRICT

Richard Scaria and Vijayan P.K.

Department of Geography, Kannur University, Kannur - 670 327
E-mail: richardscaria0707@gmail.com

Abstract

The fast disappearance of paddy land ecosystems in India is also envisaged in Kerala and is one of the biggest challenges to retain this. Paddy land ecosystems which are essential for are food security but also for Human livelihoods, income and employment, economic growth, ecology and the environment. Until 1970s, Kerala had more than 0.9 million ha of paddy cultivated area, but these area declined to about 0.2 million ha in 2014, which resulted in a serious damage to food security, livelihood, economic growth, ecology and the rural environment in Kerala. Kerala is a food grain deficit state, and as a consequence the deficit has increased steadily in the state from 45 percent to 85 percent between 1957 and 2014. However, enough attention has not been given to mitigate food 'in' security problem in the state in the context there has been a large scale decline in area and production of paddy. The present paper tries to analysis the application of MGNREGS in agricultural sector, especially in Paddy Cultivation. Result of the study shows that the application of the MGNREGS enhances the profit, cost-benefit ratio and Profitability from paddy cultivation.

Keywords: MGNREGS, Paddy cultivation, Wetland ecosystems, Profitability, Cost-benefit ratio, Conversion, Cropping pattern, Rice bowl

Introduction

Kerala is well known for its remarkable achievements in 'social (human) development' however, 'economic performance' is the comparable with the developed countries. Hence, many scholars referred to it as a 'paradox of social development and economic backwardness'. Despite a high level of social development, the disappointing performance of the economy among other things led to a severe 'food grain deficit'. This food grain deficit is the highest in the State of Kerala, where requirement is almost four times higher than the production of food grains (M.S. Swaminathan Research Foundation and World Food Programme 2001). According to Kannan (2011), Kerala's deficit in rice was 50 to 55 percent from the early fifties to the mid-seventies. Since then the deficit has increased steadily and now stands at more than 80 percent. From the national view, Kerala accounts only 1.3 percent of the production of food crops in India till the mid-seventies, given the continuing trend in the decline of the area of paddy cultivation and the continuing increase in the requirement as a result of population increase, although at a slower rate, the deficit is likely to go up to 80-85 percent of the requirement within the next few years. However, enough attention has been given to study and solve the food insecurity in the state. The researcher has suggested the MGNREGS expand intervention in paddy cultivation for reducing the labour costs of production, as labour cost is the main component in the production of paddy and gaining profits from paddy cultivation to synthesis, the present study attempts link to MGNREGS in paddy cultivation the application expand and its impact in the food crop sector for transforming a country into a state of food surplus.

Study Area

Palakkad District has a total geographical area of 4,480 sq. km, which represents 11.55 percent of the state total geographical area. It extends between $10^{0}\ 24^{'}$ North to $11^{0}\ 14^{'}$ North latitudes and $76^{0}\ 20^{'}$ East to $76^{0}\ 54^{'}$ East longitudes and it is surrounded by Malappuram District on the North and Northwest, Thrissur on the South and Coimbatore District on the East. It is situated almost at the centre of the State, spreading over the midland plains and mountainous highlands. Palakkad is one of the four districts that do not have a coast line (Figure 1).

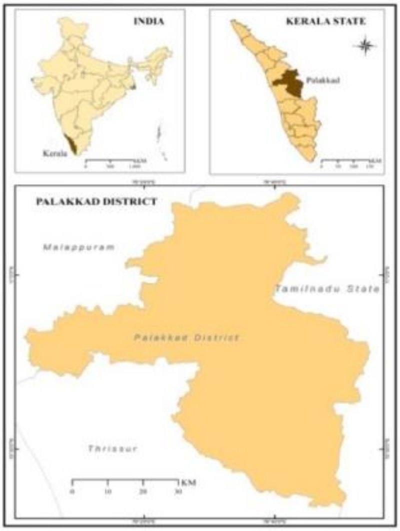

Fig. 1. Location of Palakkad District

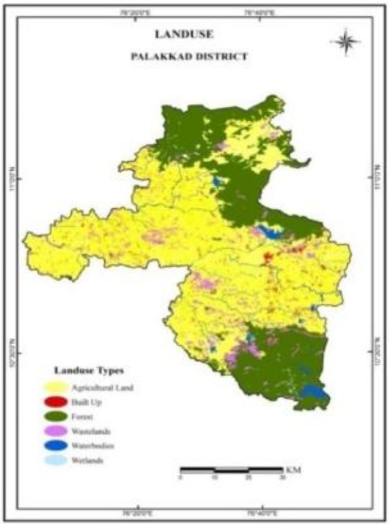

Fig. 2. Landuse

Palakkad, one of the interior districts of Kerala, is unique in many respects. The majestic Western Ghats, which stretches over 1,000 km, break the continuity of the Palakkad Gap with a width of 40 km. On either side of the gap are the giant Nilgiri Hills and Anamalai Hills. The Palakkad Gap acts as a corridor between Kerala and Tamil Nadu which plays a stellar role in trade contacts between the East and West coasts of the Peninsular India. Palakkad District has extensive paddy fields and is suitably known as the *granary of Kerala* and is a vast expanse of luxuriant plains interrupted with hills, rivers, mountains, streams and forests (Figure 2). The key objective of the study is to develop a model of MGNREGS intervention for paddy land sustainability.

Results and Discussion

Kerala has a long history of being a food grain deficit state. Coastal Travancore has passed through a food famine due to unemployment and high prices in 1941 and 1942 and the food shortage gave high prices in the whole State in 1943 and the first quarter of 1944. During these years the quantity of rice consumption was at the rate of 350 grams to 450 grams per day of rice per capita per annum for an adult population of 55 lakhs (treating one fourth of the population as non-adults) which was 6 lakh tonnes. The annual production of rice was estimated to 2.4 lakh tonnes. The net deficit in rice was thus 3.6 lakh tonnes in Travancore. For Cochin, it was 90,000 tonnes during the period 1944-1945 (Sivaswamy et al., 1945). Since then deficit in rice has increased steadily from 45 percent to 85 percent between 1957 and 2007 in Kerala. In 1956 the state of Kerala was an acute food deficit region with 7.59 lakh hectares of land under food crops. However, per capita availability of rice was only 182 grams against the minimum requirement of 330 gms. In fact, the area under food crops increased to 10.8 lakh hectares and per capita rice availability increased to 213 grams between 1956-57 and 1980-81. The production has increased from 8.83 to 12.9 lakh tonnes and productivity increased from 1,164 to 1,638 kgs per ha during this period. Since then, rice production has declined significantly in Kerala (Chib, 1988).

During the past two decades, Kerala has witnessed a decline in food grains production at an annual rate of 1.09 percent. Area under food grains fell from 960,000 hectares in 1970 –1971 to 560,000 hectares in 1990-91. The share of cultivators to total work force declined from 17.8 to 12.24 between 1970-71 and 1990-91. In the country as a whole the area under food grains has declined marginally during the nineties but the output increased by around 15 percent. Kerala experienced a different trend, area under food grains declined 37 percent and the output by 33 percent (GOK, 1990).

Rice deficit in Kerala has increased significantly between 1991-1992 and 2013-2014. Kerala's rice deficit of around 70 percent in 1991-1992 and then it increased significantly upto 85 percent in 2013-2014. This shows that, Kerala has produced just one third of its requirements in 1991-1992 and less than one-fifth in 2013-2014. The availability of rice in Kerala is 10.6 lakh MT in 1991-1992 and then it decreased very sharply up to 3.28 lakh MT in 2013-2014. It gives an insight that the availability of rice in Kerala declined more than 50 percent during this period (GOK, 2013). There is a huge gap between the availability and requirements of rice in Kerala. More importantly, the gap between the availability and requirements of rice has increased for the last five decades in the state of Kerala especially, since 1991. Paradoxically, Kerala has also been experiencing an unprecedented consumption boom, especially in food items and increasing standards of living of the Keralites as a result of the remittances from the gulf countries. Despite its remarkable and somewhat unique development experience, Kerala is said to be passing through a severe food grain crisis, especially in rice. In fact, there are number of reasons behind it. The most important among them are as follows: i) shift in the cropping system from food crops to non-food crops; ii) labour cost in the paddy cultivation is very high in Kerala, as compared to other states in India- among other things led to a severe crisis in the production of food crops in the state.

MGNREGS Intervention for Sustainable Paddy Cultivation

In reviewing the voluminous and controversial literature on the problem of food and hunger, six dominant lines of thought can be identified namely, neo-malthusianism, technological determinism, monetarism, structuralism, over consumption and poverty. A review of the arguments introduced by each of these theses reveals the many interrelated facets that this complex crisis assumes as well as the ideological underpinnings of alternative interpretations. However, all these theories are trying to identify reason of the food crisis. None of these theories are trying to solve the present crisis. In view of this, the research feeds the need to develop a new theoretical model to solve the food crisis in the state. In order to achieve this researcher is the opinion that to apply the MGNREGA in the Paddy cultivation in Palakkad District where food crisis is too severe, as compared other places in India. Hence, the present theoretical attempts is to show the application of the MGNREGA in the food-crop sector and its impact on demand for labour, production of food crops and profitability of farmers in the state of Kerala State as well as Palakkad District.

As the main problem faced by rice cultivators is the availability of labour and the labour cost, which cannot be reduced and the working hours cannot be increased as, paddy cultivation is labour intensive. As mechanisation are not always possible in Kerala because of its undulated topography. A sincere and low cost approach should be made applicable. The survey conducted at the sample locations for the study has revealed that there is need for about 100 to 110 days of labour for paddy cultivation. As there is a labour, the MGNREGS can be wisely turned to the work of the paddy fields based on their knowledge and experience. In this way, the Government interventions can tackle this serious problem judiciously in the following way (Figure 3).

Competitiveness is highly correlated with cost of production. Thus, the competitiveness of farmers will increase, if the total cost of production declines. While analysing the competitiveness of farmers in Kerala, it was observed that their competitiveness was very low due to high cost of production, especially because of the reason that the labour cost was high. This is because of the reason that the wage of the skilled and unskilled agricultural reported for male and female labourers are very high in the state. Hence, labour cost of production accounts to 60 percent to 78 percent of the total cost of paddy cultivation in Kerala. This would have an adverse impact on the production cost. In order to avoid the high labour cost of production in paddy, there is a need for an intervention, which can be accomplished through MGNREGS towards paddy cultivation in the case of marginal and small paddy cultivators in Kerala. Thus, the labour cost of paddy production among rice farmers could be reduced relatively, to a large extent. As a result, the competitiveness can be increased among the paddy farmers. The net return from the marginal and small paddy farmers can be increased, resulting in increased paddy cultivation, net income, biodiversity, employment, and decrease in rural poverty and backwardness.

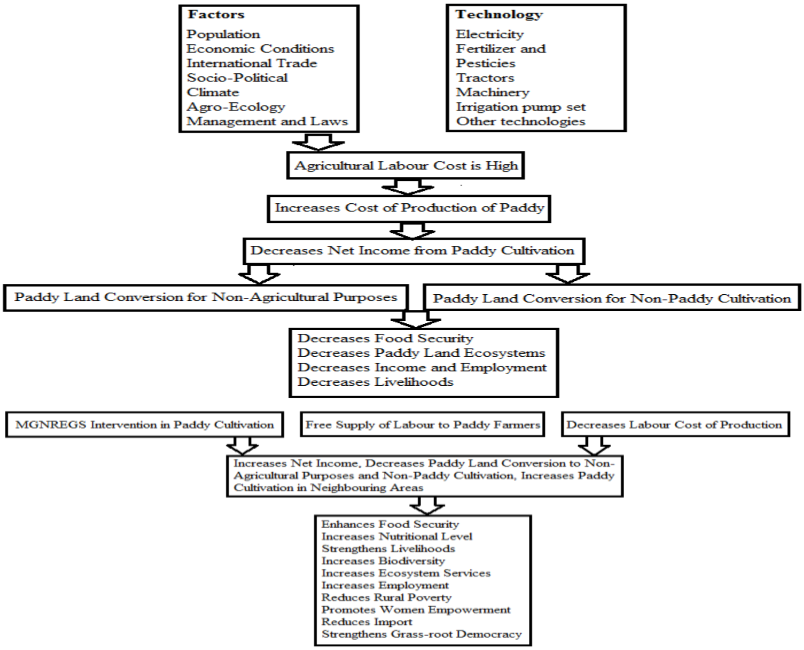

Fig. 3. Framework for MGNREGS Intervention for Sustainable Paddy Cultivation

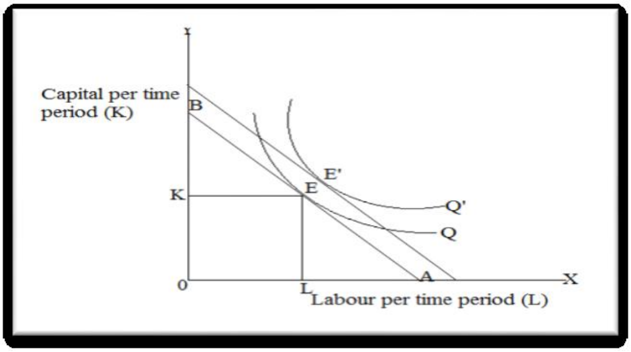

Fig. 4. MGNREGS Intervention Model for Sustainable Paddy Cultivation

Assumptions of MGNREGS Model

1. The intervention of the Mahatma Gandhi NREGS is permissible for the small and marginal farmers and
2. All assumptions of isoquant and isocost lines are applicable.

AB represents isocost line (equal cost line), which refers to the combination of two inputs (labour and capital) and as a result in the same total cost, the Q, Q' are isoquants (equal output curve), which refers to all the combinations of a set of inputs that yield the same level of total output. A farm's objective is to produce a given level of output at least cost, hence a farm is constrained, however, by the prices of the inputs (labour and capital).

Price of labour is wage and price of capital is rent. The 0L and 0K are the amount of labour and capital used for production (Figure 4). In a simple case, in which only two inputs are being used, the farm's total cost (TC) function can be written as:

$$TC = P_L L + P_K K$$
$$P_K K = TC - P_L L$$
$$K = TC/P_K - (P_L/P_K) L$$
$$L = TC/P_L - (P_K/P_L) K$$

where, E represents the least-cost input combination.

It is clear from the economic analysis of paddy cultivation that factor of cost of production is the main cause of paddy lands decline in the study area. Labour cost alone covers nearly 65 percent to 70 percent of total cost of production and it is most expensive input for paddy farmers. So any initiatives from government in managing labour availability, wage rate and efficiency will work effectively on paddy lands conservation and the Government can introduce MGNREGS in paddy cultivation. Then paddy cultivators will get labour free of cost through the implementation of this model. Therefore, the farmers need not spend money for labour, which results in increase in the income of the paddy farmers as they need to spend only on capital for production. The MGNREGS, while providing labour free of cost to the producer, will bring the labour cost of production down to zero for the rice farmers. This situation increases the profit and capital of paddy farmers in Kerala. Capital accumulation makes farmers to choose new mode cultivation in paddy sector. Hence, this model will help to increase paddy production and productivity, paddy lands, employment, food security and biodiversity conservation. Moreover, there is a no need to allocate funds by the Government for the sustainability of paddy lands.

Conclusions

Government has taken a double stand in enacting the act that meant for paddy field conservation. On the one hand, the Government is to initiate paddy field conservation measures and on the other hand, it is to violate the rules and measures of paddy land conservation with its support, directly or indirectly. In fact, the corruption and inefficient policies are the major cause of decline in paddy lands in Kerala. It is in this context that the researcher suggests that MGNREGS can help to put an end to paddy land conservation, which means that the labour cost of paddy cultivation should be taken up by the Government.

The food grain deficit is becoming a central problem of the Kerala economy. The main feature of this problem is the growth rate of the availability of rice is decreasing too faster than the population and food requirement growth rates. The worsening of the availability of rice had several reasons, including worsening marginality for a substantial sector of the rural population, a continual land squeeze, a massive exodus to the cities, a simultaneous reduction in the supply of both hired and family labourers in agriculture due to the rapid expansion of education and occupational diversification of labour, an increasing tendency to convert paddy lands for the cultivation of other crops especially, for cash crops, failure of land reforms among other things led to a severe crisis in the food crop sector (Spalding, 1984; Balakrishnan, 2008; Nair and Menon, 2005).

Despite Kerala has remarkable and unique development experience, although neglected the importance of the production of food crops. There has been justified criticism that since 1960s Kerala concentrated too much on the production of cash crops and they neglected the importance of food crops, especially rice which is the staple diet of the population. It shows the serious failure of the policy makers, planning developers and administrators in understanding Kerala's food situations in the long run. Now, Kerala is facing a severe food crisis in its history. The labour cost of production of paddy is too high in the State, recent studies show that 60 to 70 percent of the total cost of production of paddy is the labour cost. In order to mitigate higher labour cost of production of farmers we argue that the need for the introduction of the MGNREGS in food crop sector, especially in paddy field. Hence, farmers can reduce the cost of labour in the production function considerably. As a result, the demand for labour will increase in the State due to increase in investment in paddy field by small and marginal farmers. More importantly, we can improve food security and net return of the small and marginal farmers in the State.

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SLUM SEX RATIO IN METROPOLITAN CITIES OF INDIA - AN OVERVIEW

Satinder Kaur[1], Gurinder Kaur[2] and Ramandeep Singh[1]

[1]Department of Geography, S.R. Govt. College for Women, Amritsar - 143 001
[2]Department of Geography, Punjabi University, Patiala - 147 002
E-mail: jaismeek1969@gmail.com; gurinder2005@yahoo.co.in

Abstract

Sex ratio is an important demographic parameter, which defines as number of females per 1,000 males. It is also an important index of socio-economic conditions of an area and also a composite indicator of women's status in the society. The objective of the present paper is to study the spatial patterns of slum sex ratio and to find out the reasons behind spatial variation in metropolitan cities of India. It is also an endeavor to compare slum sex ratio with that of urban sex ratio and to study the trends in slum sex ratio during 2001 and 2011. Results reveal that slums and urban areas have identical sex ratio at national level and with little variations at city level. It depicts that the male child 'obsession' is prevalent in both cases.

Keywords: Sex ratio, Sex composition, Slum, Metropolitan city, Female foeticide

Introduction

The sex ratio is one of the important demographic parameters, which indicates the balance between females and males in the society. It is an important index of the socio-economic conditions of an area and also a composite indicator of women's status in the society (Kaur, 2011). The study of proportion of the two sexes is fundamental to the geographic analysis of an area as it manipulates the other demographic elements and provides an additional means for analysing the regional landscape. Sex ratio is used as a tool for cross sectional analysis to measure gender balance. The Census of India defines the sex ratio as number of females per 1,000 males in the population, whereas sex ratio in many western countries such as United States of America is defined as number of males per 100 females (Chandna, 2012). Comparing India's sex ratio with other developing and developed countries of the world, it's observed that India is one of the few countries in the world where there are more males than females as per Census of India 2011. The neighboring countries of Nepal (1,014 females), Pakistan (943 females), Sri Lanka (1,034 females) and Myanmar (1,048 females) are having higher sex ratio than India (Kaur, 2011). One study found that sex-selective abortion is less available and acceptable in Pakistan and Bangladesh (Hesketh and Xing, 2006).

India supports a heterogeneous society consisting of numerous stratifications based on religion, caste and class; however, unfortunately gender discrimination is practiced in all classes and castes. All religious groups in the country preach equality of males and females yet preference for sons is high amongst all religious groups and social classes (Aggarwal, 2005). Historical evidences show that the gender bias, deep-rooted prejudice and discrimination against girl child have been prevailing in the Indian society from the centuries. But the concern for same has grown recently as now even the fetus of a girl child has started facing the peril of pre-birth elimination i.e. female foeticide. As per World Bank estimation, over the last two decades, each year, around 2.5 lakh girls were killed in India (Pal, 2014). In the beginning of 20^{th} century, the average sex ratio in the country was 972 and decreased to 940 in 2011. Female selective abortions in the country rose from 0 to 2.0 million in the 1980s to 1.2 to 4.1 million in the 1990s and further 3.1 to 6.0 in the 2000s (Jha et.al, 2011). Son preference is the foremost reason for female deficit which seems to be a part of Indian culture. The objective of the present paper is to study the spatial patterns of slum sex ratio in metropolitan cities of India.

Study Area

Republic of India is the seventh-largest country of the world by area (32, 87,613 sq. km, 2.4 percent of the total area of the world) and the second-most populous country of the world next to China with over 1.2 billion people. Metropolitan cities of the country act as focal points on the cultural landscape of India. Presently, there are 46 metropolitan cities in the country as per Census of India 2011. Varanasi and Patna in the North and Madurai in the South are the oldest existing cities in India which originated around 500 BC, are symbolic of India's long urban heritage originated during the medieval period (Kumar, 2014). Kolkata Mumbai and Chennai had emerged as major port cities and became metropolitan cities in 1901, 1911 and 1951 respectively. Delhi also emerged as an administrative centre and got metropolitan status in 1951. In the British period, introduction of the railways and modern industry led to the creation of new Industrial township such as Kanpur, Dhanbad, Asansol and Jamshedpur. The post-Independence period saw the influx of refugees in settlements like Faridabad, Amritsar and Ludhiana and consequently population increased in these cities and they emerged as important metropolitan cities of north. The origin of metropolitan cities viz. Dhanbad, Jabalpur, Jamshedpur, Raipur, Durg-Bhilainagar was the outcome of industrialisation.

Database and Methodology

An attempt has also made to compare slum sex ratio with that of urban sex ratio and to study the trends in slum sex ratio during 2001 and 2011. For the present study, secondary data is collected from Census of India, Primary Census Abstract for slums for 2001 and 2011.

Results and Discussion

Indian Status of Slum Sex Ratio

In 2011, average slum sex ratio and urban sex ratio is recorded as 928 and 929 respectively in India. However, it varies from one state / union territory to another. Like general sex ratio, South Indian States are marked with a relatively favorable slum sex ratio in comparison to north and Northwestern States. Kerala in south India has recorded the highest slum sex ratio while union territory of Chandigarh recorded the lowest slum sex ratio among both cases. Average sex ratio of slums and urban India is recorded almost equal at national level (Census of India, 2011).

Slum Sex Ratio in Major Metropolitan Cities of India

Unlike western countries, there is paucity of females in urban India (Krishan and Chandna, 1973). The Table 1 shows that an average slum sex ratio in the country is recorded as 928. However, it varies from one metropolitan city to another. Among metropolitan cities, Chennai and Coimbatore recorded the highest slum sex ratio (1,003) while Surat city recorded the lowest slum sex ratio (698). It further shows that number of females exceeded the number of males in four metropolitan cities namely Chennai, Coimbatore, Madurai and Vijayawada. Out of 46 metropolitan cities, 15 cities are having slum sex ratio above national average and rest of the cities recorded slum sex ratio below national average (928).

Furthermore, Table 1 and Chart 1 represents comparison between urban sex ratio and slum sex ratio. Average urban sex ratio is (929) marginally higher than slum sex ratio (928). The highest urban sex ratio (999) is recorded in Madurai metropolitan in Tamil Nadu State while the highest slum sex ratio (1,003) is shared by 2 metropolitan cities i.e. Chennai and Coimbatore also located in Tamil Nadu. The lowest slum sex ratio (698) is recorded in the city of Surat (Gujarat) which is 56 points lesser than it's urban sex ratio (754). Hyderabad and Ahmadabad have identical sex ratio of 955 and 898 respectively in both cases. In Bhopal and Dhanbad, urban sex ratio is recorded only one point higher than their slum sex ratio.

There are four metropolitan cities i.e. Coimbatore, Chennai, Madurai and Vijayawada where slum sex ratio is in favour of females i.e. more than 1,000. On the other hand, urban sex ratio is found low in all the metropolitan cities of the country. In 21 cities, slum sex ratio is found adverse i.e. less than 900 while in urban areas, there are 20 such cities with adverse sex ratio. Among 46 metropolitan cities, 23 cities recoded relatively higher slum sex ratio in comparison to urban sex ratio while 21 metropolitan cities recorded higher urban sex ratio than that of slum sex ratio. Thus, there is not found huge difference between slum sex ratio and urban sex ratio.

Spatial pattern of Slum Sex Ratio in Metropolitan Cities of the Country

The Figure 1 shows the spatial pattern of slum sex ratio in metropolitan cities of the country. Three categories are represented on the map:

(a) Metropolitan cities with relatively high slum sex ratio (950 and above)
(b) Metropolitan cities with moderate slum sex ratio (900 to 949)
(c) Metropolitan cities with Relatively Low Slum Sex Ratio (900 and below)

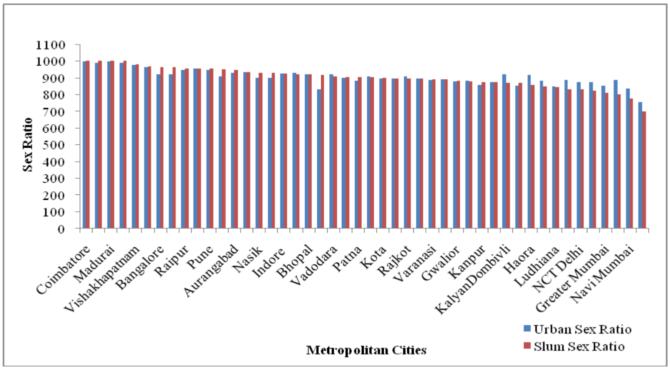

Chart 1. Urban and Slum Sex Ratio in Metropolitan Cities of India, 2011

(a) Metropolitan Cities with Relatively High Slum Sex Ratio (950 and above)

The Figure 1 and Table 2 shows that among 46 metropolitan cities of the country, 12 cities are recorded relatively high slum sex ratio. All the metropolitan cities with relatively high slum sex ratio are found in South India with the exception of Srinagar, Ranchi and Raipur. All the metropolises falling in the States of Andhra Pradesh and Tamil Nadu viz. Vijayawada, Vishakhapatnam, Hyderabad, Coimbatore, Chennai and Madurai are recorded relatively high slum sex ratio. Other metropolitan cities with high slum sex ratio include Bengaluru in Karnataka, Nagpur, Pune in Maharashtra, Raipur in Chhattisgarh, Srinagar in Jammu and Kashmir and Ranchi in Jharkhand.

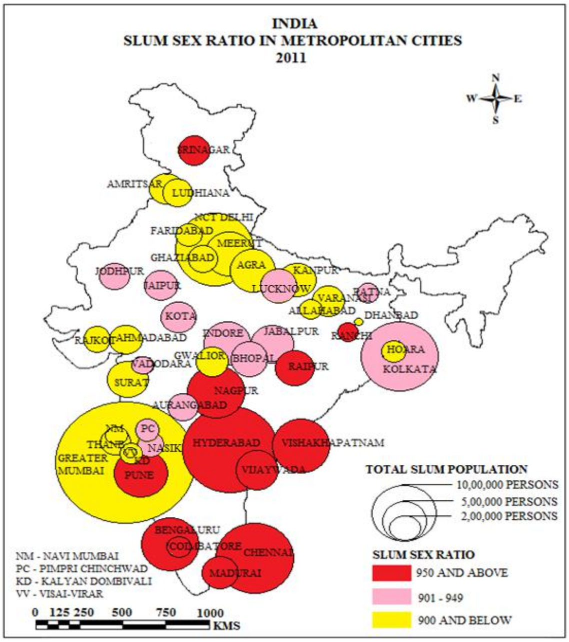

Figure 1. Slum Sex Ratio in Metropolitan Cities (2011)
(Source: Primary Census Abstract for Slums, Census of India, 2011)

High slum sex ratio in all of these cities is positively associated to their high female work participation rate (except Srinagar and Vishakhapatnam), high female literacy rate (Census of India, 2011) and sizable proportion of scheduled caste and schedule tribe population (as in the case of Ranchi, Raipur and Vishakhapatnam) (Kumar, 2014). Furthermore, family migration to cities also positively impact sex ratio. Woodruff (1960) observed that postwar industrial boom in Bangalore has attracted in-migration from different States of the country in search of employment. Migration stream arrived in the form of family-migration instead of male-selective migration (Krishna, 2013). Thus, high status of women in the society and high female education in slum areas of Coimbatore and Chennai can be attributed to high slum sex ratio as an educated woman is likely to be less dependent on their sons as a source of social status and old-age security and this reduces preference of boy and resists male pressure to discriminate in favour of boys (Murthi et.al., 1995).

(b) Metropolitan Cities with Moderate Slum Sex Ratio (901-949)

Out of 46 metropolitan cities, 13 cities of the country namely Aurangabad, Jabalpur, Nasik, Jodhpur, Indore, Lucknow, Bhopal, Pimpri-Chinchwad, Vadodara, Jaipur, Patna, Kolkata, Kota are recorded moderate slum sex ratio (Table 2). The major reasons of moderate slum sex ratio in these cities are preference for son over daughter, neglect of girl child and dowry demand, raising crime rate against girls, male-selective migration (Srivastava et.al. 2005 and Datta, 2011).

(c) Metropolitan Cities with Relatively Low Sex Ratio (900 and below)

Rest of 23 metropolitan cities of the country recorded relatively low slum sex ratio. Most of the metropolitan cities with low slum sex ratio are located in North and Northwestern parts of the country and forms the part of Gangetic plains and are hubs of economic and industrial activities in their respective states and predominance of male selective migration therein which adversely impact the slum sex ratio (Das and Murmu, 2010). In-migration is the main components of the growth of urban population of Delhi (Singh, 2009). The lower sex ratio in NCT Delhi may be attributed to large scale male selective in-migration. Delhi received 1.7 million migrants in 2001, mainly from Uttar Pradesh, Bihar and Haryana.

Slums are the most convenient places for their settlement. Sex ratio of net migrants in Delhi was only 673 in 2001 (Census of India, 2001). Similarly, large scale male selective migration resulted in skewed sex ratio in favour of males in metropolitan cities which traditionally attract migrant as workers such as Mumbai, Thane and Pune (Barakade, 2012). The volume of male and female migrants is highest for Mumbai urban agglomeration in comparison to other mega cities. But the percent of female migrants for Mumbai urban agglomeration decreased in 2001 that may result in lowering of slum sex ratio in the city (Census of India, 2001 and Das and Murmu, 2010).

Table 1. Urban and Slum Sex Ratio in Metropolitan Cities of India, 2011

Country/ Metropolitan City	Urban Sex Ratio	Slum Sex Ratio
India	929	928
Coimbatore	997	1,003
Chennai	989	1,003
Madurai	999	1,001
Vijayawada	989	1,001
Vishakhapatnam	978	983
Nagpur	963	970
Bangalore	922	963
Ranchi	921	963
Raipur	948	956
Hyderabad	955	955
Pune	948	955
Srinagar	909	950
Aurangabad	929	945
Jabalpur	934	936
Nasik	899	930
Jodhpur	902	928
Indore	925	924
Lucknow	928	922
Bhopal	921	920
Pimpri-Chinchwad	833	919
Vadodara	920	909
Jaipur	900	905
Patna	885	905
Kolkata	908	903
Kota	895	902
Ahmadabad	898	898
Rajkot	908	897
Meerut	897	896
Varanasi	887	892
Dhanbad	891	890
Gwalior	879	881
Amritsar	884	879
Kanpur	857	876
Agra	875	874
Kalyan-Dombivli	920	872
Allahabad	853	869
Haora	919	858
Ghaziabad	885	850
Ludhiana	850	844
Thane	888	833
NCT Delhi	873	832
Faridabad	874	824
Greater Mumbai	853	810
Vasai-Virar	886	804
Navi Mumbai	837	776
Surat	754	698

Source: Primary Census Abstract for Slums, Census of India, 2011

Table 2. Patterns of Slum Sex Ratio in Metropolitan Cities, 2011

Slum sex ratio	State / Union Territory
(a) Areas with Relatively High Slum Sex ratio (above 950)	Coimbatore, Chennai, Madurai, Vijayawada, Vishakhapatnam, Nagpur, Bangalore, Ranchi, Raipur, Hyderabad, Pune, Srinagar,
(b) Areas with Moderate Slum Sex Ratio (901-949)	Aurangabad, Jabalpur, Nasik, Jodhpur, Indore, Lucknow, Bhopal, Pimpri-Chinchwad, Vadodara, Jaipur, Patna, Kolkata, Kota*
(c) Areas with Relatively Slum Low Sex ratio (below 900)	Ahmadabad, Rajkot, Meerut, Varanasi, Dhanbad, Gwalior, Amritsar, Kanpur, Agra, Kalyan-Dombivli Allahabad, Haora Ghaziabad, Ludhiana, Thane, NCT Delhi, Faridabad, Greater Mumbai, Visai-Virar, Navi Mumbai, Surat

Source: Primary Census Abstract for Slums, Census of India, 2011,

The Decadal Change in Slum Sex Ratio

Furthermore, many studies reveals that high cost of living in major metropolitans such as Delhi, Mumbai etc. also compelled people to practice sex selective abortions (Iyer, 2013). This legacy of the past is still having its impact felt on the present sex ratio of these cities. The Table 3 shows the decadal change in slum sex ratio among metropolitan cities of the country. It shows that slum sex ratio grew tremendously by 108 points during 2001-11. The change of increase varies from 148 points in Allahabad to 9 points in Vishakhapatnam. However, during the corresponding period, sex ratio has declined in 2 metropolitan cities i.e. Srinagar (-8) and Surat (-3). The Table 4 further reveals that out of 46 metropolitan cities, in 6 cities, decadal change in slum sex ratio was more than 51 points viz. Allahabad, Kolkata, Ludhiana, Haora, Visai-Virar and NCT Delhi.

Table 3. Metropolitan Cities Decadal change in Slum Sex Ratio (2001-2011)

Change	Metropolitan Cities
51 and above	Allahabad, Kolkata, Ludhiana, Haora, Visai-Virar, NCT Delhi
26-50	Ahmadabad, Greater Mumbai, Jodhpur, Ranchi, Navi-Mumbai, Aurangabad, Coimbatore, Dhanbad, Patna, Pimpri-Chinchwad, Chennai, Faridabad, Jabalpur, Vadodara, Lucknow, Kalyan-Dombivli, Pune
25 and Below	Vishakhapatnam, Rajkot, Varanasi, Nasik, Agra, Indore, Raipur, Amritsar, Nagpur, Meerut, Madurai, Hyderabad, Vijayawada, Bangalore, Bhopal, Jaipur, Thane, Ghaziabad, Gwalior, Kota, Kanpur, Srinagar and Surat

Source: Primary Census Abstract for Slums, Census of India, 2001 and 2011

Decadal change in slum sex ratio in 17 cities ranges from 26 to 50 viz. Ahmadabad, Greater Mumbai, Jodhpur, Ranchi, Navi Mumbai, Aurangabad, Coimbatore, Dhanbad, Patna, Pimpri Chinchwad, Chennai, Faridabad, Jabalpur, Vadodara, Lucknow, Kalyan-Dombivli and Pune while rest of the cities recorded decadal change in slum sex ratio is below 25 during 2001-11. Furthermore, map 2 and 3 reveals that the cities with high slum sex ratio witnessed low decadal change. However, the cities with low slum sex ratio witnessed the high decadal change. It shows that pattern of slum sex ratio and decadal change in slum sex ratio is inversely correlated.

Conclusions

Sex ratio is an important social indicator to measure the extent of prevailing equity between males and females in a society. The cultural differences also manifest themselves in the form of lower or higher sex ratios in different cities. Women are valued more in South and Northeastern parts of the country where they enjoy greater autonomy and higher social status. In contrast, women are undervalued in Northern and Western regions of the country that is evident in the sex ratio of their respective populations in different metropolitan cities of the country. Economically better off north Indian metropolitan cities in the states of Punjab, Haryana, Chandigarh, Delhi and Gujarat are declared the worst offenders. Despite economic prosperity and the advances made in education, literacy, health care and income in northern region, gender inequality still prevails and attitude towards women is alarmingly 'biased'. A comparative picture of sex ratio in slums and urban areas reveals that slums and urban areas have identical sex ratio at national level and with little variations at city level. It depicts that the male child 'obsession' is similar in both cases.

Better economic status of North Indian metropolitan cites has adversely affected sex ratio in this region while high literacy rate and better status of women has positively affected sex ratio in the metropolitan cities located in southern part of the country. Furthermore, the cities with high slum sex ratio witnessed low decadal change and vice versa. Recently, government has taken several measures and is also making endeavors to elevate the status of women in the society by promoting equality of men and women. To reduce excessive son preference, North India needs to accept bilateral kinship systems. More recently different schemes (such as cradle Scheme, Ladli and Balika Samridhi Yojna, Apni Beti Apna Dhan, Shagan scheme and the newly proposed national scheme scheme Beti Bachao Beti Padhao) are launched in the country to spread awareness among people regarding female foeticide, women education and empowerment. The negative impact of son preference has already started showing its impact in form of high proportions of unmarried men in most affected areas. The lawmakers of the country, law enforcement agencies, educators and administrators can play an important role to alter the old crumbling value system through awareness campaigns and laws.

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Archives - 1

IMPRESSIONS OF LAHORE SCIENCE CONGRESS, 1939

Formerly Known as The Journal of The Madras Geographical Association
(Volume XIV, 1939, pp. 59-64)

By

N. SUBRAHMANYAM
Editor, The Journal of The Madras Geographical Association

On January 2, 1939, the Science Week of the Indian Science Congress Association was inaugurated at the University Buildings of Lahore by H. E. Sir Henry Craik, the Governor of the Punjab. Dr. J. C. Ghosh of Dacca, the President of the year, delivered the General Address, reviewing Science Progress in India. From the following day, the eleven sectional presidents gave their addresses to their several sections.

Geography has been made into a separate section permanently from this year; and Mr. N. Subrahmanyam, M.A., L.T., F.R .G .S., of Madras, this year's president, delivered his address to a throng of delegates from all sections and from various Provinces. The subject chosen was, “The Geographical Personality of India." The address met with warm approbation all round, for matter, form, and style. ‘It is a comprehensive survey of India,' said some, ‘It makes a new synthetic approach’; ‘it is eloquent, brimming all over with sympathy,’ said some high authorities. ‘I never thought Geography can be so full of life and interest,' said many a delegate, upon hearing it read.

This new section of Geography was able to attract as many as twenty papers on various topics. Dr. Chatterjee of Calcutta led off with his Lecture on Ranchi, giving it, he said, in the true French manner as a series of slides with explanations in between. His next paper on Puri was similarly done. Mr. A. C. Bannerjee, also of Calcutta, read a paper on ‘some of the markets of Calcutta.’

Mr. B. M. Tirunaranan of Madras presented two papers; one was on certain methods of anticipating Tank Breaches; the other, on the Boundaries of Tamil Nadu. He made helpful contributions to the discussions, accompanying them often with drawings on the blackboard drawn with remarkable ease and accuracy. He has a working belief in the maxim, ‘no Maps, no Geography.’ It may be stated, by the way, that from his study of Lahore Map, he made himself, on the very first day, as familiar with the streets and lanes and buildings as a long-time resident. And he has done so for other towns he visited on his way to Lahore up and down.

The summaries of several papers of absentee-members were read; and others were taken as read. These are a few titles of such papers: - The Sources of the Brahmaputra; Sugar-cane cultivation in India; The growth of a modern city (Coimbatore);

The Fisheries of Cochin; Cole Cultivation in Cochin; Results of irrigational changes in Tanjore; Potential Spas of Sind; Greater Karachi; Tanning in South India; the Cheyyar Basin; etc.

Besides the papers of the Section, there were joint discussions with other Sections.

Dr. Arthur Geddes of Edinburgh, who had been on a Geographical Tour in India stayed on expressly to attend the Geography Section at Lahore before sailing home. He read his suggestive paper on “Some Problems of Geographical Reconnaissance in India”, which is valuable equally for the methods indicated and for the new angles of approach in geographical studies. In his quiet but illuminating way, he made valuable contributions to the several discussions. With ever-ready pencil, note-book and camera, he sets an example to field-geographers in India, taking notes and sketches, observing keenly, and vivifying and verifying facts, wherever he can.

Prof. Pithawalla of Karachi made a plea for a Regional Division of India, so as to make such division the basis of scientific records. Admittedly, the present Political Divisions of India are not helpful from a scientific stand-point, being more divisions of administrative convenience or bare results of historical accidents. A division by natural regions is a want generally felt but there is no consensus as to the criteria or their practical application.

The particular map drawn by Prof. Pithawalla turns largely on geological data; but, observed Mr. Tirunaranan, it did not adequately provide for climatic differences: the same relief sets up two different regimes of life, one on the front and the other on the lee side. Prof. Agharkar of Calcutta presented the Botanist's objection. The Botanist is not impressed by geological limits, he said, and would have his divisions follow ecology; every science should make such divisions as suit it best; and the time for finding elements common to all is not yet.

The Discussion on the Dynamic Role of the Modern Geographer was opened by Mr. N. Subrahmanyam in a lucid and convincing speech summing up the arguments from all points of view. Followed by Mr. Bannerjee, Dr. Chatterjee reverted to the teaching side; and incidentally threw it out that he intended making a soil survey of Bengal, by sampling, with his band of 150 scholars, in the Long Vacation. Dr. Geddes pointed out how inadequate it must be and he and others thought that Government alone could do it well, and suggested better utilisation of Government records and machinery.

The next discussion was also opened by the President and it was on The Agricultural Cycle in relation to the Rhythm of Life in India. Dr. Ramakrishna Ayyar of Coimbatore, the Entomologist, dwelt on the necessity of co-ordinating efforts and putting the valuable results obtained into a calendar provided with maps and charts. He pointed out also the attendant difficulties. Mr. Ramdas of Poona gave the Meteorologist's view. For this very purpose, he said, phenological studies of 3,000 plants have been taken up in England; not one plant has been so observed in India; it will be a long, long time before any success can be attained. All were agreed, however, that each department should make its own start, even now, making fullest use of Geographical Methods of Distribution, Correlation and Expression.

Mr. Mackenzie Taylor of The Irrigation Research Department opened the discussion on Erosion, touching on all its Indian aspects. The piece de resistance was the contribution by Mr. Gorrie, who, with well-planned slides, convinced all present of the havoc wrought in the Punjab by the unrestricted grazing by goat (to which should be added the camel). Such places were contrasted with the careful husbandry in Hissar; the Punjab sides with the U. P. sides of the same mountains. His remarks explain the denuded landscape that greets the traveller in the Punjab; the denudations are so extensive that he, too, that runs by rail or bus, cannot help reading them.

It was acknowledged on all hands that in the discharge of his several duties as President, Mr. N. Subrahmanyam was admirably tactful and business-like.

The last, but by no means the least of his work, lay in his infecting with his own enthusiasm the Geographers of Lahore so as to bring them together into a common association, reconciling certain conflicts of view that showed themselves. There has been a Punjab Geographical Association under the guidance of Rai Bahadur Sohan Lal who has done yeoman's service for Geography in schools. As a result of the appeal, it has since opened a Research Section. There are keen Geographers in the Punjab. To mention but a few names, there are Messrs. Dean of the Forman Christian College and Syed Gauhar Ali of Gujrat; the Misses C. L. H. Geary of Women's College and Grace W.Mason of Kinnaird College. The University has Degree Courses already. One may therefore confidently hope that Punjab will stride into its rightful place in Geographical Research before long.

Mr. Dean as Local Secretary made the arrangements, excellent; Prof. Bhatnagar was all attention; the Local Secretary, Diwan Anand was very obliging. The General Secretary, Mr.J.N.Mukherji, has brought scientific method to bear on the working of the Science Week and has raised it to a Fine Art. The working, accordingly, went off efficiently; smoothly and grandly.

The foregoing description is a brief account of the transactions at one section only, the Geography section, the youngest section and a small segment of the whole. At the Physics section, discussion on one paper alone went on from day to day; the number of papers in Chemistry Section fairly beat the time and would last beyond Sunday but for closure.

There were side-dishes also: every evening there was a general lecture and one morning, Sir Shah Sulaiman, the Federal Judge threw on the screen his formulae combining Newton and Einstein, the verification of which he expects in the Solar Eclipse of 1940.

At the Science Week, the output of intellectual work is great; and much of it is available, too, later on, in cold print. But greater than that by far is the coming together into close contact of kindred spirits from far and near. To meet, discuss and ‘change views is a rich and freshening experience inexpressible in words but none the less invaluable. Of such, all have had their fill.

And then, the Social opportunities, how great they are! The Science Congress was provided with sumptuous entertainments. H. E. The Goyernor was At Home at Government House in the open lawn amid pleasant greenery. The Reception Committee gave an open air Tea in the cool January evening. It gave also a Variety Entertainment of which Miss Zutshi on the sithar is an outstanding memory. The Farewell Dinner, setting before guests a truly Punjabi hospitality, was given in the University Hall where His Excellency gave the toast of the Science Congress. The Madras Community at Lahore entertained Madras visitors at Tea. Such rounds of social meeting brought folks closer together than ever.

And then, the Excursions! The first was in the City itself. One cannot behold without emotion the ruins of former Moghul splendour visible in Shalimar gardens, the Shadhdara Mausoleums of Jehangir and Nur Jehan, the Badshahi Mosque and the Fort; nor the former Sikh Power writ large in the small Ranjit Singh's urns and the Baradari, where he held his court. The Lahore Museum exhibits the History of Punjab displaying the vestiges and Art of Hindus, Buddhists, Greeks, Moslems, Sikhs etc., from early times. It is an impressive sight to see the little finger of the Punjab Policeman, expressive of British authority, keeping order at the Mall or the Railway Station among the unruly and burly crowds.

To the Geographer, the special points of interest are the luscious grass, the hardy tonga-horse, the hardier men; the rich bazaars and the profusion of fruits and nuts and vegetables which are very cheap and widely consumed the Park-like environs; and the Old Ravi and the New Ravi breaking through old-time pleasure-gardens of the Moghul.

The excursion to Amritsar traversed the Trunk Road which is flanked every now and then by villages looking like little fortresses or their ruins. The Khalsa College gave Tea in a delightful shamiana on the college grounds. Amritsar is one of the biggest of Trades-capitals of North India as well as the Sikhs' Holy Place. It is most densely peopled, narrow gullies being the rule, two-car roads the exception. The Jallianwala Bagh is maintained as a solemn garden. The Golden Temple with pavements of marble and cupolas glittering with gold; the Tank with marble paths and marble steps; the Temples round about in memory of former Gurus are living testimony to Sikh fervour and Sikh inspirations. Other Gurudwaras, seen at Arjun Singh Saheb, Shahidganj or Panja Saheb near Taxila, leave upon one the same impression. A simple, solemn air pervades those places of worship, where Bhajan to the Grandh Saheb is maintained perpetually amid throngs of religious men and women.

The excursion to Taxila, which is eight hours by rail, was splendidly arranged. A special train took the delegates by night and the whole day was spent amid the hills and the museum, and the several ruins. The weathered Buddhist stupas, the exposed site of the Greek Town with a Greek temple on the opposite hill, the wide circuit of the ancient city, and the collections in the Museum thereof specimens of ancient art testifying to former excellence and glory are ineffaceable impressions. At the beginning of the Christian era, it flourished as a University Town and Religious Centre. Its hills and its situation on the Road to India from the West, only about a hundred miles from the Khyber Pass account both for its rise and for its fall. It had a life of 800 years at least when it fell to the fury of invading hosts about Vth century A.D. and was buried in its own debris. The ruin, once begun, weathering and the dust of centuries completed it. The River Hari is in active erosion; and there is much to interest the geographer, as could be seen in Dr. Geddes' being busy taking notes of the entirely different types of men and place, settlements and country.

Taxila is a lesson in Historical Geography; Lahore and Amritsar, in Modern; but Lyllapur bears the seeds of Future Geography of the Punjab.

The Agricultural College at Lyllapur is not surpassed by any other in India. Experiments are carried on in all matters of interest to the Ryot; and the Ryot, with his simple but strong faith and strong will, has taken kindly to the knowledge the college provides him. Such co-operation is found nowhere else in India. Ryots, by thousands, BUY BACTERIA to infect their lucernes with, for feeding their cattle. The cultivation of rape-seed and of rye has been introduced by the College. Sugar-canes, bred at Coimbatore, are tried in the college first and then the Ryots take them: some successful ones are only a six-months' crop. The Fruits Experimental Garden is the best in India, what with vines, dates, oranges, plums, palash, etc. Experiments are in progress in fishery, in implements, in cattle food and breed, dairying and manures; in cotton and wheat, two of the principal sources of Punjab Ryots' wealth. The tried and tested successes pass on to the Ryot readily.

. Near-by are Oil-mills with Hydrogenation plants; and there is a cloth-mill to which move long strings of asses and camels laden with cotton.

The roads raising clouds and whirlwinds of dust under motor wheels; the ashen grey soil; the straight canals spreading fertility wherever its waters can reach; the plains beyond, denuded by goat and camel which leave not a shrub behind; the ramparted villages verdant with growing wheat and oil-seeds-all provide the geographer with ample food for thought.

Back to Lahore in the nipping cold, and then to the train to Madras, the ticket-dates being up. Geography and History together force themselves upon one across the Railway carriage windows. To mention one or two: the bad lands of the Chambal are among the best of their kind in India, and among the most extensive. Geography makes it plain why the conquerors found it so easy to spread along the Indo-Gangetic plain from West to East (as the Moguls did) or from East to West (as the British did) but not from North to South or vice versa. It explains why the loyalty of Dinkar Rao and Sir Salar Jung was invaluable in the Sepoy Mutiny . Even through the windows of an Express Train one can read the importance of Gwalior, Jhansi or Bhopal.

Altogether, it was a great experience to have attended the Science Week at Lahore.

REPORT OF THE SUMMER SCHOOL OF GEOGRAPHY

Formerly Known as The Journal of The Madras Geographical Association
(Volume XIV, 1939, pp. 195-196)

The Secretary of the Association has the honour to present the following Report of the Summer School of Geography, held at the Teachers' College, Saidapet in April-May 1939:-

At its meeting held on 17-2-1939, the Executive Committee decided to hold a Summer School of Geography in April-May 1939, and authorised the Secretary to organise and conduct the course as in previous years. 31 teachers joined the School (Appendix I) , some of them coming from distant places such as Janjira, Poona, Hyderabad , and Kottayam.

The classes were formally opened by Miss J. M. Gerrard at 10.30 A.M. on Monday the 17th April 1939 with an Address (Appendix II). The work of the Summer School went on steadily for five weeks at 5 to 6 hours a day; and the following scheme of work was gone through:-

(a) Pedagogy of Geography by Mr. N. Subrahmanyam;
(b) Elementary Surveying by Mr. K. Srinivasaraghavan;
(c) Map Work by Mr. N. Subrahmanyam;
(d) Mathematical Geography by Mr. M. Subramaniam;
(e) Diagrammatic Methods by Mr. S. Balakrishna Ayyar;
(f) Land Forms by Mr. V. D. Krishnaswami;
(g) Climate & Weather by Miss E. D. Birdseye;
(h) Oceanography by Mr. K. Ramamurthy; and
(i) Economic Geography by Mr. V. Thyagarajan.

The following general lectures were also delivered to the teachers attending the course: -

(1) Some Aspects of Plant Geography by Mr. M.S. Sabhesan;
(2) Earth as the Abode of Man by Mr. George Kuriyan;
(3) Identification of Rocks by Mr. P. G. Dowie.

Miss H. T. Scudder gave a show of Geographical Films.

Besides short excursions to St.Thomas Mount, Pallavaram Hill, Madras Harbour and Ennore Backwaters, two whole-day major excursions were conducted by bus under the joint auspices of the Summer School, the Geographical Conference and the Provincial Educational Conference. The first of them which included a party of 45 persons in 3 buses was a circular tour, conducted on 6th May to Poonamallee, Sriperumbudoor, Trivellore, Tripasore, Pundi, Uthukottai, Manjakaranai, Red Hills Tank and Kilpak

Waterworks. The second major excursion was on 7th May to Thirukalukuntram and Mahabalipuram.

On the afternoon of 20th May, the last day of the course, a tea party was held, after which Mr. M. Subrahmaniam presented the certificates to the teachers who attended the Summer School, and delivered the valedictory address to them.

The total collection of fees amounted to Rs.465, out of which a sum of Rs.115 was expended on conveyance allowance of lecturers, clerical and other services and miscellaneous expenses, leaving a net balance of Rs.350.

The thanks of the Association are due to the Lecturers for their honorary work in the Summer School as well as to the Director of Public Instruction, Madras and the Principal, Teachers' College, Saidapet, for permitting the Officers of the Educational Department to work in the Summer School and for allowing the classes to be held in the Geography Department of the Teachers' College.

INAUGURAL ADDRESS

(Volume XIV, 1939, pp. 198-201)

By

MISS J.M. GERRARD

Principal, Lady Willingdon Training College, Madras

It is a great pleasure to me to be here to-day to open this Summer Course in Geography; for I consider the establishment of this course year after year a notable achievement of the Madras Geographical Association. It is over 10 years since the course was first started; and when you consider how comparatively small is the Association (i.e., how few in the number of trained geographers) and what little support it gets, this continuity is little short of marvellous. This Summer Course in Geography has become an established tradition; and without advertisement, applications for attendance come steadily in year after year.

Teachers' College may be called the first home of Geography in India; and as many of you know, its Lecturer in Geography, Mr. N. Subrahmanyam is the doyen of geographical studies. The spirit of the place must have been seriously ruffled last year - when the summer course was held at Bangalore at the invitation of the Vice-Chancellor of Mysore University. I feel glad that the College is once again the venue of a band of enthusiastic teachers from the four corners of the peninsula .

The directing force, as I have said, has been the Madras Geographical Association, and for a long time Mr. N. Subrahmanyam has been the life force of that Association. The way it has successfully nursed the tiny seed of geographical research through these difficult years is, I think, a magnificent achievement; and side by side with that has been its influence upon the teaching of Geography in the schools through these vacation courses.

To-day we have a situation in which the schools and the teachers are crying out for training in Geography. From Hyderabad from Bombay, from Travancore they are here to-day, besides from all the districts of our own Presidency! But the Colleges stand aloof, refusing to give the instruction for which there is so great a demand. Thus the future Geography teacher is penalised by having to put in a fifth year, if he wants to be fair to his pupils, and he takes the Diploma Course of the Madras University. That there are some who do take this extra year says a great deal both for them and for the interest the subject gives. Such men and women are the fortunate few who can afford it, and they are limited to a large extent to those who live in the metropolis. But for the greater number of Geography teachers- in the schools of this Presidency alone-no opportunity for geographical study is provided.

This is where the Madras Geographical Association steps in with its introductory course.

Geography is one of the most difficult subjects to teach. Partly it is due to the fact that the subject as a science is developing so rapidly. To look back 25 years as I can, is to realize what, strides have been made, and how the emphasis has changed. For the school teacher there is first the problem of selection - what regions to teach and how much detail to be demanded at each stage. Local geography, the homeland, the world-all three have to be kept going simultaneously.There is no subject in the school curriculum, which needs so much adjustment to the conditions of the local environment; and every Geography teacher must be capable of re-arranging his teaching syllabus accordingly. Then there is the need for training in geographic method and in the tools of learning. You cannot take a course in map-reading and finish it off in any one year-this involves a progression of training to be accomplished in the whole school scheme. (And what are we going to do about teaching the one-inch map when the medium of instruction is Tamil or Kannada etc.?).

The teaching syllabus has to plan for this progression. The teaching of climate similarly has to provide for training in the recording of local observations, in the reading of maps showing the distribution of temperature, pressure and rainfall, and the study of climatic regions-each with its regime of temperature and pressure through the year, where both a spatial and a time factor have to be taken into account. In each year of the school scheme something of this has to be provided for, each stage a little more difficult than the last. Thus all the three aspects have to be provided for, simultaneously in teaching Geography in school-acquisition of skills in the use of geographic tools, the development of geographic ideas, and the acquisition of geographical facts. Such is the nature of the subject, which is to be taught, apparently, without any previous training-by the light of nature alone.

Now this course has been admirably planned to help the teacher. This year it has been extended to a period of five weeks, giving 180 hours of work; thus it is more intensive than the training given to the Geography teacher in the L. T. course. The emphasis is to be placed on practical work; and this is most wise, for not only is practical work becoming of increasing importance in the school curriculum, but it is just that part of Geography which is most difficult for the learner to acquire without a guidance and help. The middle school course should be two-thirds practical. We have tried out this experiment in our school for the last two years; and the good results most noticeable are-the children get a grasp of the fundamentals of Geographic method, the use of maps of all kinds, the value and use of statistics, training in direct observation and some elementary training in deduction and induction, which helps them to understand the work in the upper forms. Unless time is given to this kind of training in the middle school, the later work can be nothing but unintelligible cram.

This course has been planned to give something of that practical foundation. Surveying, you will find, will give you a fresh outlook altogether and a new sense of power over your environment, besides a deeper understanding of maps. Every school should have a map of its building and lay-out of its grounds, and it is the business of the Geography teacher to produce this. I believe the middle school Mathematics and Geography teaching would benefit by the introduction of a little map-making. This was tried out last year in Form I of the Wesley School, and I believe the interest and enthusiasm shown by the boys was astonishing. The course on map-reading will also be particularly valuable to you, and especially that on the one-inch map, since there is no treatise published to guide you in the intricacies of the geographical interpretation of Indian maps.

In fact, the whole course has been admirably planned to help you; it is being taught by a body of experts; and your teaching of the subject will be enormously enriched by this introduction to it. Not only that, but it will also open a vista to an entrancing subject; and some of you I hope will want to follow it up the whole way. You can do that by taking the Geography Diploma to be followed up later by an Honours course at some Indian University, if you are lucky enough to get a windfall in cash!

Fellow-teacher -let me congratulate you on your enterprise and your sense of duty to your profession, evidence of which is your attendance here; let me prophesy for you five weeks of intense activity-considerable exercise of brain and limb-and at the end a feeling of satisfaction at a piece of work well done!

NEWS AND NOTES

(Volume XIV, 1939, p. 208)

The 27th session of the Indian Science Congress will be held at Madras from January 2 to 8, 1940. Dr. S.P. Chatterjee of Calcutta University has been elected President, Mr. George Kuriyan the Recorder, and Mr. B.M. Thirunaranan the Local Secretary of the Geography and Geodesy section for this session. It is hoped that several good papers will be contributed to this section, which was confirmed as a separate one only last year.

Archives - 3

THE DIRECT STUDY OF GEOGRAPHY

Hints and Suggestions with Special Reference to Saidapet

Formerly Known as The Journal of The Madras Geographical Association

(Volume XIV, 1939, pp. 435-438)

By

N. SUBRAHMANYAM,

Editor, The Journal of The Madras Geographical Association

Under the above caption goes an important section of the new L.T. Syllabus in Geography, which reads as follows: "The .observation and expression of the facts of Local Geography: the possibilities and uses of different environments. (This should be done through a practical study either of the student's home region or of the home region of the Training College)." As the home regions of the students under training will necessarily be different, it is proposed to offer some hints and comments regarding some of the main topics relating to Saidapet in a suggestive rather than a comprehensive way. It is expected that the students will be able to apply and follow them up for their own respective places also, when they return to them. Probably it is unnecessary to state that it is not a full regional survey that is intended, as that term is applied for what is a good deal more than Geography. But in so far as the geographical part of it (which is its core) is concerned, its aims and methods may be adopted especially by way of personal investigation, recording the data, mapping the distributions and expressing the data diagrammatically.

The start may be made by getting a bird's-eye view of the whole locality from what may be called, an "outlook tower" - an eminence in the neighbourhood such as the top of St. Thomas Mount, and fixing the features and landmarks with the help of the one-inch topographical map of the Survey of India. With the same map or better still with one on a bigger scale, preliminary rambles may be made to different parts of the town, noting facts and features not to be found in the map owing to changes having taken place since the map was prepared at first, either by removal or by addition and growth. For example, on the latest one-inch map the present Teachers' College is still shown as Agricultural College, in spite of the fact that it is over 30 years since the latter was removed to Coimbatore. Conversely, Todhunternagar, Y. M. C. A. College of Physical Education, the Golf Links, the Richards Park, Panagal Buildings, Water storage tank, etc., do not find a place in it. It is a good exercise for groups of students to go round the different parts of the locality and note such changes in an outline map. Surveying the college compound, contouring levels near the Adyar bank or Little Mount, and sketching the different areas visited and noting the features observed and the routes are other important items of practical work, connected with map-making. The times and exact directions of sunrise and sunset and midday altitudes of the sun should be noted periodically in the course of the year, expressed diagrammatically and correlated with the seasons. The method of finding and drawing the meridian line should be learnt and applied. Simple methods of finding the midday altitude of the sun will be learnt incidentally.

The surface levels and features and the courses of the Adyar and the Cooum, especially the curves and the bed of the latter, should be observed and noted in rambles and visits, gathering evidences of erosion and deposition. Specimens of rocks and soils in the neighbourhood should be collected, examined and classified. Peeps at bed-rock may be obtained in railway cuttings and in diggings made for underground drainage, wells or foundations for buildings. The changing water-table in the wells of the different parts of the locality should be noted in the different seasons. Visits to the countryside and to the rivers in flood are particularly useful in illuminating much that is otherwise purely theoretical in the study of physical geography. Weather recording offers a specially rich field for observational work. Wind direction, maximum and minimum temperature and rainfall are some of the chief items to be observed, recorded and expressed in appropriate diagrams such as the wind-rose and the climograph. The results of observational work may be compared with published normals and actual figures available in the meteorological reports.

Preparation of land utilisation maps affords scope for another valuable kind of direct study of environment. Important public buildings, groups of residential areas, cultivable lands, open spaces, parks, etc., may be noted in special outline maps and studied side by side with the topographical map as already suggested. The straggling nature of the municipality of Saidapet, extending from Chengamedu on the right bank of the Cooum through Puliyur, Kodambakkam, Saligramam, West Mambalam, Mettupalaiyam, and Saidapet proper to Guindy and Little Mount beyond the Adyar river, with large stretches of cultivated and barren land and brick pits intervening, the water-works, the bazaar, the temples, mosques and churches, and the groupings of the people in communities, occupational or otherwise should all find their places in the map. The difficulties of natural drainage (said to be due to the bunding up of the Adyar bank for the construction of the Marmalong bridge) , the methods of disposal of sullage water and their relation to public health are worthy of note.

On the economic side, there are important items to observe and collect data about. In the adjoining cultivable lands, agriculture is precarious owing to poor fertility of the soil and want of irrigation facilities; but, market gardening, especially of vegetables and flowers, is more important, owing to the proximity of the town. The brick industry is a flourishing one; the location of the kilns, the soil and other conditions, transport and market are to be studied. The weaving industry of Thopet is another local industry to be investigated. The locality, the community engaged in it, the kinds of stuff woven, the market and the present condition of the industry should be inquired into. Dhobying is another well-known occupation in Saidapet, the bed of the Adyar being a dhobykhana of Madras. The easy transport and the fresh water in the river above the tidal limit as well as the presence of the washer class in connection with the bleaching work of the weaving industry should be noted as favouring causes. Jutka-making and jutka-repairing were well-known in Saidapet; but this industry seems to have fallen on evil days with the growth of the motor transport and the running of the electric train. Regarding the population: besides noting its distribution in the several wards, it will be interesting to find out the extent to which Saidapet is suburban in character, that is, what proportion of its inhabitants are working for their livelihood in Madras and not at Saidapet. The relative popularity of the train and the bus is an interesting piece of investigation to make. Taking the road transport: the southern trunk road-or the Mount Road as it is called here, as leading to St. Thomas Mount-with its width, tarring, etc., and the colleges, and open spaces on either side of it-is what gives the best impression of Saidapet to the casual passer-by. But the other roads, especially those linking Saidapet with West Mambalam, Saligramam and Chengamedu should be visited, and the causes for their bad condition should be investigated: e.g., the effect of brick carts, bad finances of the municipality or the unremunerative nature of some of these roads, having to link up distant residential areas. The traffic in the trunk road should be observed and noted at different times in the day and in the different seasons, as to the kinds of goods taken and as to how far it is local and how far 'through'. Some of the commonest in evidence are brick, straw, hay, grain, curds and vegetables in head loads, fish in Ford cars from Sadras, hides and skins, tanning materials. Note the extra hard cementing of the sides of the road for heavy laden carts to pass. Note also the diversion of the slow traffic on race days through Alandur road, when the congested motor traffic has to pass through the bottle-neck of the Marmalong bridge. The seasonal fruits, flowers and vegetables in the market and in the field should also receive attention.

One of the most interesting topics is the study of the formation and growth of the different types of settlements in the locality itself: for example, Guindy and Fanepet as roadside settlements; Little Mount as a Christian settlement round the place of martyrdom of a Saint; the weaving ward of Thopet with its broad open streets for pitching the looms; the old type of settlement round a temple as in Perumal Koil St., Karaneeswarar Koil St., and southern part of West Mambalam; the bungalow type near the Guindy Railway Overbridge. The location of particular trades and occupations in particular places is to be noted; as the dhoby near the river, the potter just on the outskirts, the jutka-repairer near the main road and the binder near the college.

Further, as Saidapet is a suburb of Madras, lying on the trunk road and the electric railway (four stations on which serve the municipality) possibilities of planning new extensions on the lines of Theagarayanagar may be examined and explored, taking into account the lie and structure of the land and facilities of water- supply, drainage, open space, etc. Geography has as much to do with man's play and leisure as with his work: and sports competitions and physical demonstrations in the colleges, the races at Guindy, the festivities in the Little Mount and of the Karaneeswara temple that draw large crowds from the city and its environs are noteworthy-the times and seasons when they take place, the incidental increase of trade and transport in particular directions at the time of the festivities, and how far they disturb the normal even life of the residents and their other reactions. Possibilities of improvement are not outside the scope of local study. It is unnecessary to repeat that personal observation, collection of data, mapping and diagrammatic expression, and interpretation should all go hand in hand in such a study, Most of this can be co-operative work.

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THE INDIAN GEOGRAPHICAL SOCIETY

Department of Geography, University of Madras, Chennai - 600 005

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Please Note:

1) The Winners are requested to send their passport size photograph, postal address and contact phone number by email (kkumargeo@gmail.com / geobalas@gmail.com)
2) The Winners are requested to make arrangements to attend the award ceremony function being arranged in the *89th IGS Annual Conference* to be held at Bharathidasan University, Tiruchirappalli on Saturday, the 25th January, 2014 at 2:00 p.m.
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THE URBAN CHALLENGE - PROVISIONING OF BASIC SERVICES IN NOTIFIED AND NON-NOTIFIED SLUMS OF INDIA

Anuradha Banerjee[1], Joydeep Saha[2] and Dinabandhu Mondal[1]

[1] School of Social Sciences, Jawaharlal Nehru University, New Delhi - 110 067
[2]Department of Geography, Bijoy Krishna Girls' College, Howrah - 711 101
E-mail: anuradha@mail.jnu.ac.in, banerjee.anb@gmail.com

Abstract

This paper attempts to explore whether the gap between 'notified' and 'non-notified' slums have reduced or not, across nine selected states over a decade of decentralised governance regime and also to relate the issue of provisioning water and sanitation services within the slum development planning and policy domain. Using the secondary data provided by NSSO from 2002 to 2012, across three different rounds, this paper focuses on the condition of basic amenities, its temporal changes and the role played by various stakeholders in the improvement of slums. It finds that while 'notified' slums continue to receive services and remain in more or less better conditions, whereas 'non-notified' slums still have a long way to go.

Keywords: Slum, Services, ULB, Sanitation, Planning

Introduction

In an academic sense, the notion of 'slums' in India is complex and added to that the 'definition' followed by Census of India and National Sample Survey Organisation (NSSO) and a substantial number of legal documents, create a taxonomy of 'notified' and 'non-notified' slums. National Sample Survey Organisation (NSSO), since 2002 to 2012, has been categorising 'notified' and 'non-notified' slums and then 'defines' the respective categories of slums as the "areas notified as slums by the concerned municipalities, corporations, local bodies or development authorities were termed *notified* slums', and 'any compact settlement with a collection of poorly built tenements, mostly of temporary nature, crowded together, usually with inadequate sanitary and drinking water facilities in unhygienic conditions, was considered a slum by the survey, provided at least 20 households lived there. Such a settlement, if not a *notified* slum, was called a *non-notified* slum". Census of India also agrees largely with this 'definition', as it denotes own one as: "A slum, for the purpose of Census, has been defined as a residential area where dwellings are unfit for human habitation by reasons of dilapidation, overcrowding, faulty arrangements and design of such buildings, narrowness or faulty arrangement of street, lack of ventilation, light or sanitation facilities or any combination of these factors which are detrimental to the safety and health". Census of India, in 2011, categorises slums into three categories - *'notified', 'recognised'* and *'identified'*. The first category is *'notified'* by state / local administration through legal acts; second one is also *'recognised but not formally notified'* by these bodies; and the last category is defined as "A compact area of at least 300 population or about 60-70 households of poorly built congested tenements, in unhygienic environment usually with inadequate infrastructure and lacking in proper sanitary and drinking water facilities". Two things appear very clearly from these definitions – one, recognition and notification of slums are done by Urban Local Bodies / Parastatal Agencies and second, non-notified slums are hardly availing basic amenities like drinking water and sanitation system. The only visible difference in these two definitions is the minimum cut-off in the number of households and it has been argued that with increasing events of slum eviction cycles and breakdown of large slums into smaller clusters in Indian cities today, present Census definition lacks inclusive nature (Bhan and Jana, 2013).

The paucity of basic services in residential areas lived by poor people, according to Mitlin (2005), is one of the basic reasons behind chronic urban poverty. It is also generally portrayed in the literature that urban poor mainly lives in slums. While the notified slums usually receive some basic services provided by Urban Local Bodies or Parastatal Agencies, non-notified slums remain less served in India. Even if policy-makers often suggest amelioration of the living condition of those places where urban poor live, in practice, demolition and dislocation of large-sized slums is not uncommon. In addition to that, continuous inflow of new migrants into large cities lead to the formation of small-sized slum clusters over a period of time. As the entire process of 'recognition' and 'notification' of slums takes time, these clusters mushroom haphazardly and that too without basic provisions of water and sanitations. Against such a backdrop, this paper attempts to explore whether the gap between 'notified' and 'non-notified' slums have reduced or not. This paper also attempts to focus on the condition of basic amenities, its temporal changes and the role played by various stakeholders in the improvement of slums while relating the issues of basic service provisioning within India's slum development planning and policy domain.

Database and Methodology

After looking at the variables of slum database in both Census of India and NSSO files, few issues need to be discussed before moving onto the main paper. Firstly, in both the datasets, the *availability* of amenities like drinking water and latrines is captured, not *adequacy*. Secondly, Census captures *household level* information on availability and accessibility of such amenities, whereas NSSO takes into account *slum level* information, gathered from knowledgeable persons living in the slum. Thirdly, 'It is for the first time in Census that datasets on Housing stock, Amenities, and Assets based on the Houselisting and Housing Census are being released. In Census 2001, information on Slums was released only on demographic characteristics based on the Population Enumeration. For this purpose, Slum Blocks were identified in Statutory Towns having a population of 20,000 by the local authorities at the time of Population Enumeration phase. In Census 2011, Slum Blocks have been delineated in all statutory towns irrespective of population size' (Census of India website). Fourthly, NSSO provides an additional information, i.e. change in the 'conditions' of these amenities and 'sources of improvement'. Fifthly, as already mentioned, NSSO data is more inclusive in nature as compared to Census dataset. Given all such advantages and disadvantages of both datasets at the outset, it would be more judicious to use NSSO dataset on slums, across three different Rounds, i.e. 58th Round- 'Condition of Urban Slums' (2002), 65th Round- 'Some Characteristics of Urban Slums' (2008-09) and 69th Round- 'Key Indicators of Urban Slums in India' (2012).

For all three Rounds, nine common states, for which data is available, have been taken into account: Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Odisha, Tamil Nadu, Uttar Pradesh and West Bengal. This paper largely focuses on the qualitative aspects of the living environment in slums. In terms of living environment, some of the basic urban amenities related to water and sanitation have been taken into consideration. These are: drinking water, latrine, drainage, sewerage, and garbage disposal. Another point is that these indicators have direct linkages with health, hygiene, and well-being of slum dwellers (WHO). Conspicuously, a majority of existing research works on slum environment are based on the primary survey in particular cities/towns. These papers are helpful to assess the ground situation of slums. But, macro-level discussion of slums' living environment, where a composite and analytical picture is depicted, could draw the attention of policymakers for prioritizing issues and directing slum improvement schemes. Undoubtedly, Census 2011 provides important information on slums for each statutory towns, but the decadal data is not sufficient. In case of NSSO data, unequal and inadequate distribution of sample slums in different geographical regions, to a considerable extent, limits the scope of a detailed analysis in this paper.

Results and Discussion

Changing Number of Slums

In absolute figures, the number of slums has consistently declined over three Rounds. This is truer in case of 'notified' slums, whereas 'non-notified' slums, in between 58th and 65th Round, do not show much change. If one looks at the percentage figures, the proportion of 'notified' slums have declined, whereas the proportion of 'non-notified slums' has increased. This reestablishes concerns of "exclusionary urbanisation" raised by urban experts (for example, see Kundu and Roy Saraswati, 2012), which assert that cities have become so hostile these days, that poor migrants are unable to find a space to live and work. The figures in Table 1, absolute and percentage, also show the proliferation of non-notified slums as compared to notified slums, thereby leading one to presume that poor migrants, if able to settle in cities for livelihood, stay in very small clusters, and might need strong political roots and temporal stability to get 'recognition' and 'notification' from concerned ULBs / Parastatal Agencies. This decline is sharper in Maharashtra, and less in Andhra Pradesh. States like Uttar Pradesh, West Bengal, and Gujarat shows a substantial increase in the number of 'notified slums' in between 58th and 65th Round, and then again a certain drop in the 69th Round. Karnataka, in the last two Rounds, does not show much change. Maharashtra and Andhra Pradesh exhibit consistent increase in the proportion of 'non-notified' slums over three Round. Odisha's scenario is beyond any possible explanation, and one of the plausible reasons is the very small number of sample slums in

58th and 69th Round. 65th Round data for Odisha shows a higher proportion of non-notified slums as compared to notified slums.

Table 1. Estimated Number of Notified and Non-notified Slums, 2002-2012

	58th Round (2002)			65th Round (2008-09)			69th Round (2012)		
State	**Notified**	**Non notified**	**Total**	**Notified**	**Non-notified**	**Total**	**Notified**	**Non-notified**	**Total**
Uttar Pradesh	775 (29.3)	1,868 (70.7)	2643 (100.0)	1,334 (55.7)	1,060 (44.3)	2,394 (100.0)	836 (46.1)	978 (53.9)	1814 (100.0)
West Bengal	2871 (35.3)	5253 (64.7)	8125 (100.0)	2,475 (49.1)	2,570 (50.9)	5,045 (100.0)	1274 (32.2)	2684 (67.8)	3958 (100.0)
Odisha	11* (2.7)	390 (97.3)	401 (100.0)	630 (32.3)	1,323 (67.7)	1,953 (100.0)	12* (1.6)	744 (98.4)	756 (100.0)
Madhya Pradesh	1530 (68.9)	691 (31.1)	2221 (100.0)	759 (34.3)	1,456 (65.7)	2,215 (100.0)	1327 (81.2)	308 (18.8)	1635 (100.0)
Gujarat	413 (26.9)	1120 (73.1)	1533 (100.0)	1,342 (39.9)	2,017 (60.1)	3,359 (100.0)	865 (29.6)	2058 (70.4)	2923 (100.0)
Maharashtra	10189 (61.2)	6472 (38.8)	16661 (100.0)	9,282 (54.5)	7,736 (45.5)	17,018 (100.0)	1954 (25.3)	5769 (74.7)	7723 (100.0)
Andhra Pradesh	6384 (82.7)	1340 (17.3)	7724 (100.0)	3,964 (75.5)	1,285 (24.5)	5,249 (100.0)	3224 (71.0)	1315 (29.0)	4539 (100.0)
Karnataka	1178 (59.4)	805 (40.6)	1983 (100.0)	1,118 (49.7)	1,132 (50.3)	2,250 (100.0)	716 (50.3)	708 (49.7)	1424 (100.0)
Tamil Nadu	930 (29.4)	2234 (70.6)	3164 (100.0)	1,711 (52.8)	1,663 (47.2)	3,374 (100.0)	1208 (51.1)	1156 (48.9)	2364 (100.0)
Total	**24282 (54.6)**	**20174 (45.4)**	**44456 (100.0)**	**22616 (52.8)**	**20243 (47.2)**	**42859 (100.0)**	**11414 (42.1)**	**15721 (57.9)**	**27135 (100.0)**

Note: Figures in parentheses refer to percentage; * Small size of sample slums
Source: Calculated from NSSO Data, 58th Round, 65th Round and 69th Round

Drinking Water Supply

In 'notified slums', the tap is the main source of water supply, followed by tube wells. Over three Rounds, use of wells has gradually declined. In West Bengal and Tamil Nadu, slums reporting the use of taps have declined in between 58th and 65th Round, and then picked up in 69th Round. In many slums of Uttar Pradesh and Madhya Pradesh, during 58th and 65th Round, tube well is the major source of water supply. In 'non-notified' slums also, the tap is the major source of water supply. But its coverage, although gradually picked up in between 58th and 65th Round, but again declined in 69th Round. Wells have consistently declined, and other sources of water supply have consistently gone up in non-notified slums. Maharashtra and Madhya Pradesh report a consistent decline in coverage of tap water in non-notified slums, whereas the exactly opposite situation is observed in Andhra Pradesh and Karnataka. Maharashtra also reports a consistent increase in slums with tube well as the main source of water. In Andhra Pradesh, there is a consistent decline in the percentage of slums dependent mainly on tube well. Gujarat and Madhya Pradesh exhibit higher proportion of slums where water comes from other sources.

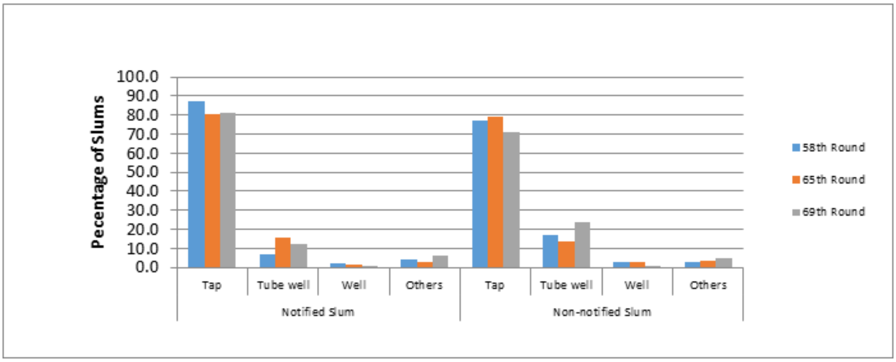

Fig. 1. Sources of Water Supply in Slums, 2002-2012
Source: Calculated from NSSO data, 58th Round, 65th Round and 69th Round

It should be noted that the percentage of 'notified' slums having 'tap' as a major source of drinking water is somewhat unchanged in between 65th and 69th Round. It might point towards sluggish role played by ULBs / Parastatal Agencies. Parallely, the percentage of 'notified' slums with other sources of drinking water is increasing, leading one to presume that small-scale private water providers are supplying treated drinking water in large-sized containers. Those slum dwellers who can afford it, and are concerned about spreading of water-borne diseases in slums might be opting this source of drinking water.

Latrine Facilities

So far as 'notified slums' are concerned, proportion of slums with 'shared' latrines has consistently declined across three Rounds. However, slums having 'public / community' latrine, after increasing in between 58th and 65th round, saw a decline in the 69th round. Exactly opposite situation prevails in case of slums with 'own' latrines. Uttar Pradesh and Madhya Pradesh report a consistent decline in the percentage of slums with 'public / community' latrines over the three Rounds. But, West Bengal and Tamil Nadu exhibit consistent increase in slums having such type of latrines. Gujarat's case, in terms of slums having 'own' latrines, is beyond any possible explanation (84.9, 10.3 and 94.5, respectively in the three rounds). Only Madhya Pradesh, and to some extent Karnataka, report some improvement in terms of slums with 'own' latrines.

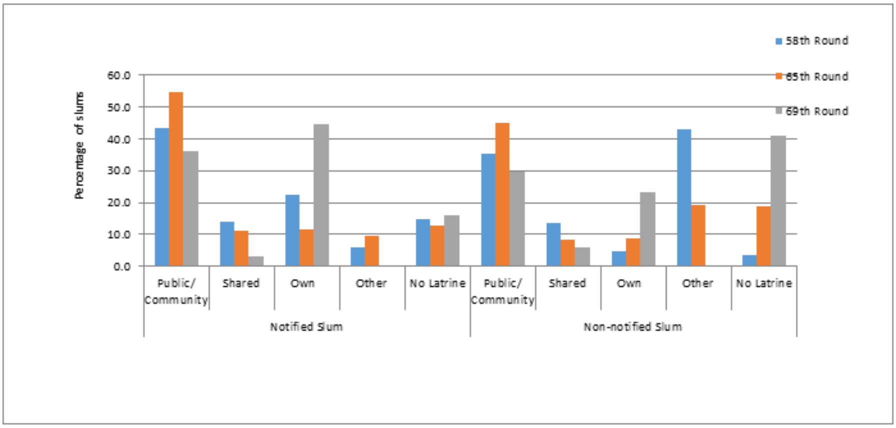

Fig.2. Types of Latrines in Slums, 2002-2012

Source: Calculated from NSSO data, 58th Round, 65th Round and 69th Round

In non-notified category also, slums with 'shared' latrines have consistently declined in percentage terms and corresponding shares of 'own' latrines have gone up. It is shocking to note that percentage of slums without latrines have consistently gone up - from 3.5, 18.9 and 41.1, respectively in the three Rounds. Madhya Pradesh and Karnataka report a consistent decline in the percentage of slums with 'public / community' latrines, whereas Tamil Nadu shows exactly the opposite trend. Maharashtra exhibits consistently increasing shares of slums with 'own' latrines. The 69th Round provides an additional data on 'public latrines' where user charges are applicable. In states like Madhya Pradesh, Tamil Nadu, Uttar Pradesh and Maharashtra, a large chunk of notified slums has such type of latrines. In states like Gujarat, Uttar Pradesh, Karnataka, Maharashtra and Tamil Nadu, one can find a higher proportion of such slums. As per NSSO estimates, West Bengal and Odisha do not have such latrines.

Drainage System

In notified slums, across three Rounds, one can see gradual improvement in terms of 'underground' drainage system, although 'covered drains' show an increase in between 58th and 65th Round, and then a certain decline in the 69th round. The same trend is applicable to 'open pucca' type of drainage system. It is heartening to observe that slums without drainage system have declined from 14 to 7.8 percent. Otherwise, it is difficult to interpret the trends. Gujarat, for instance, reports 84.9 percent slums with 'underground' drainage system in 58th round, declining to 14.3 percent in 65th and then surprisingly again, this Figure stands at 93.5 percent in the 69th round. West Bengal reports a consistent increase in slums with 'covered' drainage, whereas Andhra Pradesh reports a consistent increase in slums having 'open pucca' drainage system.

Table 2. Absence of Drainage System - Changing Profile, 2002-2012

State	58th Round (2002)		65th Round (2008-09)		69th Round (2012)	
	Notified Slums	Non-notified Slums	Notified Slums	Non-notified Slums	Notified Slums	Non-notified Slums
Uttar Pradesh	0.9	71.2	8.7	54.1	2.0	71.8
West Bengal	0.1	38.8	9.4	19.5	0.3	45.6
Odisha*	0.0	90.0	48.8	49.4	100.0	55.3
Madhya Pradesh	31.4	38.4	0.0*	13.0	15.1	27.8
Gujarat	2.1	73.4	62.1	39.9	2.5	59.6
Maharashtra	9.6	22.6	0.0*	9.0	5.8	26.3
Andhra Pradesh	21.4	65.7	7.2	37.4	8.8	43.7
Karnataka	35.6	25.3	0.0*	14.5	0.0*	12.8
Tamil Nadu	16.1	43.9	23.7	33.2	20.2	36.8
Total	**14.0**	**41.3**	**9.7**	**22.8**	**7.8**	**39.8**

Note: * Absence / Negligible Presence of Sample Slums;
Source: Calculated from NSSO data, 58th Round, 65th Round and 69th Round

In non-notified slums, certain positive changes have occurred in terms of 'underground' drainage system. In case of 'open pucca' drainage, there is not much change. It is difficult to assess the trends of the absence of drainage system in non-notified slums. Although in between 58th and 65th rounds, the percentage of slums without drainage system has declined substantially, 69th Round data reflects the almost same situation as of 58th Round. Drainage type of 'open katcha' category reports increase in between 58th and 65th Rounds, and then a sudden drop in the 69th round. At the state-level, almost double percentage of non-notified slums report 'underground' drainage system in Maharashtra over 58th and 69th rounds. Gujarat also shows almost same results. Maharashtra also exhibits consistent decline of slums having ' open pucca' type of drainage system, and the exact opposite situation prevails in Tamil Nadu. In West Bengal, there is a small decline in the percentage of slums with 'open katcha' drainage system over three Rounds.

Waterlogging

In non-notified slums, there is a consistent decline in the percentage of slums having waterlogged condition over the three rounds. However, one cannot discern any particular pattern in case of notified slums. Uttar Pradesh reports a consistent decrease of such notified slums, whereas Gujarat and Karnataka exhibit consistent increase over the three Rounds. Uttar Pradesh and Maharashtra show a consistent decline in the share of non-notified slums with waterlogging problems.

Sewerage

In between 58th and 65th round, coverage of underground sewerage in notified slums (Ref. Figure 3) has not changed much, although this has certainly increased as observed in the 69th Round. Maharashtra reports a deviation from such trends with certain increment, whereas states like Tamil Nadu, West Bengal and Gujarat exhibit such trends. Karnataka and Andhra Pradesh exhibit certain improvement in between 58th and 65th Rounds, and then not much change up to the 69th Round.

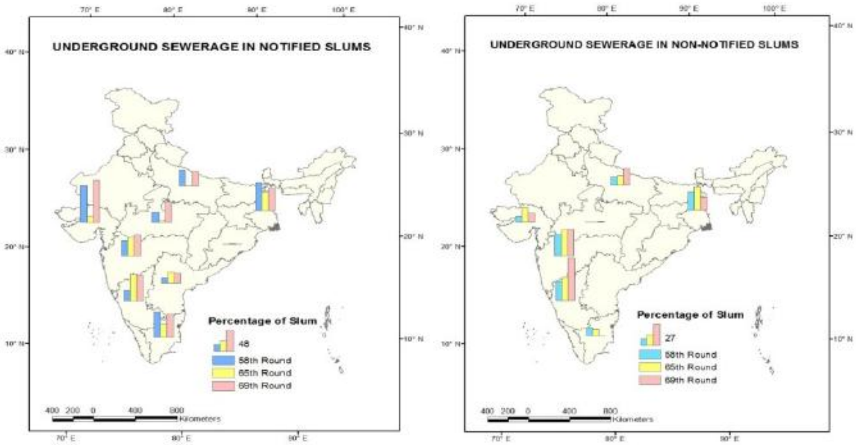

Fig. 3. Underground Sewerage in Notified and Non-notified Slums

Over three rounds, there is a very low increment in the percentage of non-notified slums with underground sewerage system (Ref. Figure 3). Uttar Pradesh and Maharashtra report continuous increment in the percentage of such slums over three Rounds. West Bengal and Gujarat report increment in between first two Rounds, and then again a slump in the latest one. It should be noted that the cities in general and slums in particular, do not have the separate system for draining out sewerage waste and stormwater. The analysis reports that most of the slums, especially non-notified ones, lack proper drainage system as well as underground sewerage, added to the burden of waterlogging in the rainy season. This deplorable living condition often leads to spreading of diseases.

Garbage Disposal

In more than 75 percent of the notified slums, the arrangement of garbage disposal is borne by Urban Local Bodies (ULBs) like Municipality or Municipal Corporation. This is very much prominent in highly urbanized states like Maharashtra and Tamil Nadu. However, for non-notified slums, residents and other agencies also have some contribution. Over three Rounds, ULB service coverage for non-notified slums has gradually improved, from 47.3 to 59.5 percent.

On the other hand, the absence of garbage disposal arrangement is more prominent in non-notified slums as compared to notified slums. In such non-notified slums, over three Rounds, the role of residents has not changed much. However, the role of other agencies has sharply declined to zero in between 65th and 69th Rounds.

Table 3. No Arrangement for Garbage Disposal - Changing Profile, 2002-2012

	58th Round (2002)		65th Round (2008-09)		69th Round (2012)	
	Notified Slums	**Non-notified Slums**	**Notified Slums**	**Non-notified Slums**	**Notified Slums**	**Non-notified Slums**
Uttar Pradesh	1.7	81.5	16.0	54.3	12.0	46.4
West Bengal	4.1	43.2	11.3	22.3	6.0	39.2
Odisha*	100.0*	81.2	32.8	48.1	0.0*	68.5
Madhya Pradesh	41.4	59.1	48.3	23.7	18.0	30.1
Gujarat	4.2	30.1	62.3	32.7	3.0	61.2
Maharashtra	10.5	17.0	2.6	6.3	13.8	18.3
Andhra Pradesh	16.2	62.1	2.6	39.8	7.7	23.4
Karnataka	49.9	55.3	0.2	14.9	3.8	12.6
Tamil Nadu	0.9	46.5	11.5	39.0	26.4	27.0
Total	**14.4**	**41.0**	**10.8**	**22.7**	**11.5**	**32.7**

Note: * Absence/Negligible Presence of Sample Slums

Source: Calculated from NSSO data, 58th Round, 65th Round and 69th Round

Given the fact of gradual pace of ULB service coverage in these slums, the corresponding percentage of slums without any garbage disposal arrangement has suddenly gone up from 22.7 to 32.7 percent. In few states like Uttar Pradesh and Andhra Pradesh, the percentage of such type of slums without such arrangement has consistently declined.

With the introduction of Urban Local Bodies and NGOs' growing contribution in slum amelioration schemes, residents' role sometimes gets minimised to a certain extent, and sometimes it again revives. Perhaps due to the slowdown of NGO's role in one hand and residents' increasing awareness level lead to such revival. Sengupta (1999) has argued that at the end of the day, slum residents experience the real situation of their living environment. Therefore, environmental management at the community level is seriously required. His studies on slums of Howrah in West Bengal show how such community can play a role in amelioration of living environment.

Gaps between Notified and Non-notified Slums

It is sensible to assess the gaps in between notified and non-notified slums. Strictly speaking, notified and non-notified slums are not truly comparable for 58th Round. A criterion of minimum 20 households was attached with non-notified slums in 58th Round. However, this criterion is applicable to both categories of slums in 65th, as well as in 69th Round. Slums are heterogeneous in socio-cultural characteristics, perhaps due to different growth histories. Some of the notified slums are very large and old in cities. It is therefore judicious to examine whether gaps exist between notified slums and non-notified slums, and whether there is any change over three rounds.

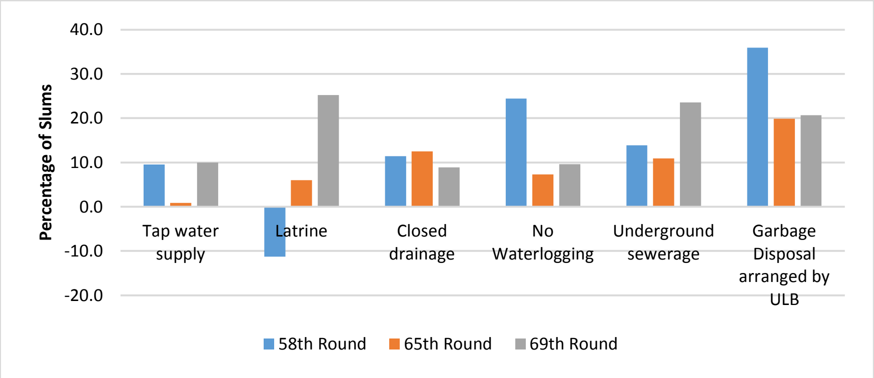

Fig. 4 .Changing Gap between Notified and Non-notified Slums, 2002-12

Source: Calculated from NSSO data, 58th Round, 65th Round and 69th Round

Notified slums supposedly get more attention from policymakers through Government and NGO initiatives. For instance, a study done by Hazra and Goel (2009) on solid waste management system in Kolkata (i.e. capital of West Bengal) has found that 'registered' slums are mainly characterised with door-to-door garbage collection, whereas 'unregistered' slums are still depending on garbage disposal at vacant land and canal with no further pick-up. As evident from Figure 4, the gaps between notified and non-notified slums have continued in terms of latrine availability. In case of four selected indicators, i.e. 'tap water supply', 'no waterlogging', 'underground sewerage' and 'garbage disposal by ULB', the gaps have reduced in between 58thn and 65th Round, and again increased in the 69th Round. Only so far as 'closed drainage' is concerned, the gap has reduced from 58th to 69th Round, after a small increase in 65th Round.

Planning and Policy Perspectives: A Critical Review

Since late 1980s to early 200s, various government-sponsored schemes (e.g. National Slum Development Programme, 1996; Valmiki Ambedkar Awas Yojana i.e. VAMBAY, 2001) have attempted to ameliorate living environment of slums. But, in case of, the inadequacy of funds and diversion of little available funds were some of the challenges that NSDP experienced in reality (India: National Report, 2001). Eleventh 5-year Plan document (2007-12), also, observed that slum dwellers are largely deprived of basic urban facilities like water supply and sanitation. Existing schemes of VAMBAY and discontinued scheme of NSDP were subsumed into Integrated Housing and Slum Development Programme (IHSDP). It also aimed at ameliorating living conditions of slum dwellers as well as holistic slum development in terms of shelter and other physical amenities. An Approach to the Twelfth 5-year Plan (2011) noted that urban poor still 'lack access to basic amenities such as water supply, sanitation, healthcare, education, social security and decent housing' and are going through 'multiple deprivations and vulnerabilities'. A major finding that emerges is that in spite of various Government initiatives, a larger chunk of urban poor is living in the squalor of slums and squatter settlements. One should note that there have only been mere changes in names and funding patterns for all these schemes, but the focus (i.e. amelioration of living environment in slums) and components (physical infrastructure like water supply and drainage system and social infrastructure like health centres and schools) have remained more or less same. Apart from this, the norms and guidelines attached to many of these schemes are itself problematic. For instance, the "basic norms" of Environmental Improvement of Urban Slums, as per Delhi Urban Shelter Improvement Board – the nodal agency maintaining *jhuggi-jhopdi* clusters in Delhi, mandates '1 Tap/hydrant for 50 persons' / '1 WC Seat for 25 persons'. Although it appears sensible to Government, one-hour water supply in summer thereby allows only 3 minutes for a 5-member household in general and long waiting time in the line for toilet use and consequent chaos might lead slum dwellers to defecate openly, especially in the morning. Another thing appears clearly: Government is gradually moving towards slum-free cities to facilitate cities' beauty and economic growth or say to promote urban management. Scholars have argued that urban rich and poor live in a symbiotic socio-economic sphere and share common public space (Patel, 2011). However, urban poor have little to say in political decision making. As evident in Delhi, preparation of Commonwealth Games (2010) as part of 'world-class city' has led to the demolition of several slums. Delhi's slum policy, being biased against poor residents, tends to create mushrooming of squatter settlements (Dupont, 2008).

Although Jawaharlal Nehru Urban Renewal Mission (JNNURM), the major urban programme launched in 2005, had two attached schemes for Non-Mission Small & Medium Towns: (1) Urban Infrastructure Development Scheme for Small And Medium Towns (UIDSSMT) - binding together the existing programmes of Integrated Development Scheme for Small and Medium Towns (IDSMT) and Accelerated Urban Water Supply Programme (AUWSP) and (2) Integrated Housing and Slum Development Programme (IHSDP) – subsuming the existing programmes of Valmiki Ambedkar Awas Yojana (VAMBAY) and discontinued National Slum Development Programme (NSDP). Most of the projects undertaken in JNNURM were concentrated in relatively more developed states like Maharashtra, West Bengal, Tamil Nadu, Uttar Pradesh, Andhra Pradesh and Gujarat. Out of total funding of JNNURM (Approximately Rs.18,462 crore), Basic Service for the Urban Poor (BSUP) component received only 22.7 percent and Urban Infrastructure and Governance (UIG) received 77.3 percent. There was a systematic decline in the percentage of population covered by JNNURM with size-class of urban centres (Kundu and Samanta, 2011). Scholars have critically argued that through advocating neo-liberal urban agenda, this scheme is biased and is against the poor people in a number of ways. Construction of flyovers and roads often relocated them from demolished slums, and some of the prescribed reforms like full cost recovery and user charge policies along with the participation of private agencies hit them hard. Another issue was the limited technical and financial capacity of small and medium towns (Mahadevia, 2006; Mukhopadhay, 2006; Chandran, 2010). Rajiv Awas Yojana (RAY), launched in 2011, also aimed towards providing basic urban amenities to slum dwellers as well as finding suitable vacant land for rehabilitating them in affordable houses, finally to reach a goal of slum-free cities in the long run. The NSSO data provides an opportunity to make some comments on 'changing conditions' - 'improvement', 'no change', 'deterioration' and 'neither existed nor existing' (Table 4 and 5).

In 'notified' category of slums, on an average, almost 50 percent have observed no change in all these parameters during last five years. The condition of notified slums, except latrines to a certain extent, has not deteriorated. In almost 19 percent notified slums, sewerage system neither existed, nor existing now. Only in case of latrines, higher shares of notified slums have seen deterioration as compared to non-notified slums. A significant chunk of non-notified slums, in general, report water and sanitation facilities in the category of 'neither existed earlier nor existing now'. In this category too, the gap between notified and non-notified is larger in parameters like drainage, latrine, and sewerage system. Around 40 percent of the non-notified slums have not seen any changes in conditions of enlisted five parameters in last five years. One should note that whatever improvement is happening on the ground, the responsibility is borne by the Government. Cycles of eviction and absence of tenurial rights amidst vulnerabilities of the informal economy, residents are not very active in making and owning such amenities. NGOs have a conspicuous absence, especially in smaller cities and towns, which needs further exploration.

Table 4. Changing Conditions in Notified Slums, 2002-2012

Parameter	IMP	NOC	DET	NENE
Water Supply	45.0	51.9	2.0	1.1
Latrine	33.6	52.8	6.6	6.9
Drainage	40.2	52.1	1.5	6.3
Sewerage	28.5	51.7	1.0	18.8
Garbage Disposal	36.5	58.3	0.5	4.7

Note: IMP - Improvement; NOC - No Change; DET – Deterioration;
NENE – Neither Existed Earlier Nor Existing Now
Source: Calculated from NSSO data, 69th Round

Recently launched Swachh Bharat Mission (SBM) also attempts to check open defecation, not only by constructing new toilets but also raising awareness and monitoring. It also intends to put a curb on littering through the proper arrangement of solid and liquid waste collection. Another recent initiative, is the Smart City Mission (SMC). While aspiring for 'inclusive cities', it intends to 'drive economic growth and improve the quality of life of people by enabling local area development and harnessing technology. Area-based development will transform existing areas (retrofit and redevelop), including slums, into better-planned ones, thereby improving liveability of the whole City'[1]. It should be pointed out here that unless 'better planning' of slums significantly improve provisioning of drinking water and sanitation services, the stated purpose of SMC, i.e. improving 'quality of life', creating 'employment' and enhancing 'income for all, especially the poor and the disadvantaged' is bound to get hampered or failed. Poor quality of drinking water and inadequate sanitation facilities will lead to deterioration of health and hygiene conditions, and therefore consequent morbidity will reduce the working capacity of slum dwellers. Lack of proper toilet facilities will force women to defecate openly, making them vulnerable to sexual abuse, thereby again defying SMC's one 'core infrastructural element', i.e. 'safety and security of citizens, particularly women"[2]

Table 5. Changing Conditions in Non-notified Slums, 2002-2012

Parameter	IMP	NOC	DET	NENE
Water Supply	42.7	43.3	3.8	10.2
Latrine	34.1	40.0	2.1	23.7
Drainage	31.7	40.4	1.7	26.2
Sewerage	19.7	48.5	2.2	29.5
Garbage Disposal	37.0	43.1	2.2	17.7

Note: IMP – Improvement; NOC - No Change; DET – Deterioration;
NENE – Neither Existed Earlier Nor Existing Now
Source: Calculated from NSSO data, 69th Round

Conclusions

As per NSSO estimates, the proportion of 'notified' slums have declined, whereas the proportion of 'non-notified slums' has increased. While considering water and sanitation-related indicators, no such specific temporal pattern can be discerned across the states. Over the three Rounds, use of 'well' has declined in notified as well as notified slums, and in both the categories of slums, 'tap' is the main source of drinking water. It suggests that government's initiatives of piped water supply through taps have yielded some positive results. In the non-notified category, slums having 'shared' latrines have consistently declined. In the category of notified slums, across three rounds, there is a gradual improvement in terms of 'underground' drainage system, and decline of slums without drainage system has declined from 14 to 7.8 percent. In the category of 'non-notified' slums, there is a consistent decline in the percentage of slums having waterlogged condition over this decade. In between 58th and 65th Rounds, the proportion of notified slums with underground sewerage has not changed much, although it has certainly picked up as observed in the 69th Round. A very low increase in the percentage of non-notified slums with underground sewerage system is also observed. The ULB service coverage for non-notified slums has gradually improved, although the absence of garbage disposal arrangement is more prominent in non-notified slums as compared to notified slums. The

[1] http://smartcities.gov.in/upload/uploadfiles/files/What%20is%20Smart%20City.pdf as viewed on 25th February, 2017
[2] Ibid.

gaps between notified and non-notified slums have continued to increase in terms of latrine availability. Four indicators, however, show inconsistent results (i.e. decline of gaps in between 58th and 65th Round, and increase in 69th Round). The evaluation of plans, policies, and schemes coupled with latest Round observations on changing conditions of water and sanitation related parameters suggest that slums still need better availability of amenities. Non-notified slums are in comparatively poorer condition, because a lion's share of these clusters have not seen the presence of any services earlier and even now in last five years, these services are conspicuously absent. Given the fact of very low shares of expenditure allotted under BSUP in JNNURM, discontinuation of RAY and only limited expansion of Swachh Bharat Mission programme, it is understandable that slums will take much time to even get such basic amenities, and the gap between notified and non-notified slums may continue to remain at large. This also raises broader issues of how to achieve inclusive urban growth and make out cities resilient and smart.

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We are thankful to our peer Research Scholars in CSRD, namely, Sharmistha Singh for providing NSSO raw dataset and, Asha Bauri and Biswajit Kar for helping in data extraction methods. CSRD deserves special mention for making raw NSSO dataset available.

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AGRO-CLIMATIC REGIONALISATION AND WATER BALANCE OF GUNTUR DISTRICT, ANDHRA PRADESH

Srinivasa Gopinath G.S.[1] and Chandrayudu N.[2]

[1]VLITS, Department of BS & H, Vadlamudi - 522 213
[2]Department of Geography, S.V. University, Tirupati - 517 502
E-mail: gopinathgarre@gmail.com, ncrayudu@yahoo.com

Abstract

An 'Agro-climatic zone' is a land unit in terms of major climates, suitable for a certain range of crops. Agro-climatic conditions mainly refer to soil types, rainfall, temperature and water availability (Water balance) which influences the type of vegetations. The study area is one of the few 'Crop intensive districts' in A. P. In Guntur district different Agricultural& Horticultural crops are being raised. By using 'water balance technique' Agro-climatic Regionalisation can be studied. The water balance study has also become important in the field of eco climatology. It also strives to gauge and estimate the water balance of the study area by adopting the method of Thornthwaite and Mather. The water-balance framework thus extracted guides in the understanding the agricultural appropriateness of the region, establishment of drought years by their magnitude and portrayal of drought-prone areas. The study indicated that crop cultivation without dependability on irrigation is not possible in the district especially during Rabi season. Agro-climatic regionalisation revealed the fact that paddy cultivation is not possible without irrigation in most parts of the district. With irrigation, paddy cultivation will be prosperous in coastal regions. However, with little irrigation facilities, millet crops will give good yields. The present study is an attempt on an area which has typical physical and climatic variations, in turn, leads for agro-climatic regionalisation.

Keywords: Indian Economy, Seasonal soil moisture, Agro-climatic region, Coefficient of rainfall variability, Crop suitability.

Introduction

Agricultural development of any region is mainly controlled by climatic and edaphic factors of a region. In addition, proper planning of land use/land cover conditions is quite indispensable for achieving the desired target. Agriculture is the key input for India's economy. About forty-five percent of India's geographical area is availed for agriculture and two-thirds of country's population engaged in agriculture, the success of which almost wholly depends on a sufficient and well-distributed rainfall apart from other climatic and edaphic conditions. Higher crop production can be achieved by proper management of water and soil resources in the light of temperature and rainfall conditions though irrigation projects have coming up in a big way during the last few decades, yet the area under irrigation remains to be less than adequate. Hence, suitable crops should be selected according to the available resources instead of going for the crop which is not suitable for existing climatic conditions. The guiding principle in the selection of crops and cropping systems should be that their growth period should coincide with the duration of moisture availability. The following are the objectives for the present study 1. To find out that temperature is not a constraint factor for the growth of crops in tropical environments like India in general and Andhra Pradesh / Guntur in particular. 2. To assess the variability of rainfall and water balance. 3. To assess the agro -climatic regions (agro climatic regionalisation).

The study proposes following hypotheses namely, 1. An 'Agro-climatic zone' is a land unit in terms of major climates, suitable for a certain range of crops. Agro-climatic conditions mainly refer to soil types, rainfall, temperature and water availability (Water balance) which influences the type of vegetations. 2. The study area is one of the few 'Crop intensive districts' in A. P. 3. In Guntur district different Agricultural& Horticultural crops are being raised. By using 'water balance technique' Agro-climatic Regionalisation can be studied.

Database and Methodology

For the present study two atmospheric elements viz., mean monthly air temperature and mean monthly rainfall are needed to do water balance. Thus, the data of twenty representative Mandals of the Guntur district were collected/gathered from the records of India Meteorological Department for a period of 30 years that is from 1983-2013. Agricultural improvement of any region can be accomplished by an appropriate outlying of land use/land cover, taking into the climatic and soil factors of the region into consideration. The two environmental parameters that are associated with crop production are rainfall and temperature. Temperature is now not a constraint aspect for the increase of crops in the tropical environments like India in typical and Andhra Pradesh / Guntur in particular, while, rainfall which is a principle ecological parameter is accountable for various agricultural patterns in the world. High or low attention of farming is completely established on rainfall intensity. The low and erratic nature of rainfall is responsible for the low seasonal soil moisture availability at the root zone. Thus, the study of the variability of rainfall in specific vicinity is essential. The book-keeping method of Thornthwaite and Mather, which has a multivariate utility in scientific research additionally acts as a device to delineate agro-climatic regions is used for this study. Each of the agro-climatic areas indicates its suitability to specific crops based totally on the soil moisture prominence of that region. In addition, water balance process helps in measuring soil moisture storage which is the principal element to be understood for agricultural planning. GIS technique is also employed for the representation of the results.

Study Area

Guntur district is in Andhra Pradesh, India, on the east coast of Bay of Bengal. It has a coastline of about 100 kilometres. The district is located between $15^0 18' - 16^0 50'$ N latitude and $79^0 19'$-$80^0 55'$ East longitude. The total area of the district is about 11,400 sq.km with a population of 48.9 lakh (2011, Census). The district's population density is 430 per sq.km. 33.81 percent of the District's population is living in urban areas and the remaining in rural areas. The district has 57 revenue mandals. The main agricultural products cultivated in the district are cotton, chilies, paddy and tobacco, It is a major transportation and textile hub in Andhra Pradesh as well as India. Guntur area has a worldwide reputation for its exports of chilies, cotton, and tobacco.

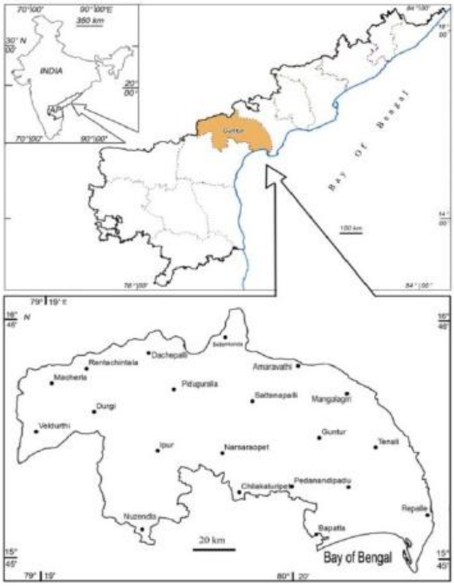

Fig. 1. Location and Administrative Divisions of Guntur District

Results and Discussion

The study indicated that crop cultivation without dependability on irrigation is not possible in the district especially during Rabi season. Agro-climatic regionalisation revealed the fact that paddy cultivation is not possible without irrigation in most parts of the district. With irrigation, paddy cultivation will be prosperous in coastal regions. However, with little irrigation facilities, millet crops will give good yields. While the western and southwestern regions of the district are suitable only to millet crops rather than paddy, which are uneconomical. In view of the above facts, an attempt is made to find out the "Agro climatic Regionalisation and Water Balance of Guntur District, Andhra Pradesh". In this paper, we have taken only 20 mandals out of 57 in the Guntur District, because these mandals represent almost the entire District.

The Coefficient of Rainfall Variability

Variations in total rainfall may be caused by a change in the frequency of rainfall events or in the intensity of rainfall or both. Knowledge of rainfall variations is essential in agro climatic studies. The Coefficient of rainfall Variability (C.V.) is the percentage ratio of the standard deviation of rainfall to the mean rainfall of that area for a given period. It is a measure of rainfall dependability and indicates the agricultural usefulness of any region, which is inversely proportional to dependability. Hence, the low degree dependability is synonymous with high degree of variability and vice-versa (Brij Mohan, 2014). Hema Malini (1988) several investigators used the following method to compute the Coefficient of rainfall variability of a given region.

$$\text{The Coefficient of Rainfall Variability} = \frac{\sigma}{\overline{X}} \times 100$$

where: σ = standard deviation; $\overline{X}$ = mean rainfall

Table 1. Average Annual Coefficient Rainfall variability of Guntur District

Sl. No.	Name of the Mandal	Coefficient of Rainfall Variability (percent)
1	Repalle	28.2
2	Tenali	25.2
3	Mangalagiri	22.1
4	Ponnuru	25.4
5	Bapatla	34.2
6	Guntur	24.2
7	Amaravathi	31.9
8	Pedanandipadu	33.8
9	Chilakaluripet	32.5
10	Piduguralla	27.8
11	Bellamkonda	24.7
12	Sattenapalli	22.7
13	Ipur	29.6
14	Dachepalli	34.3
15	Nuzendla	33.1
16	Narsaraopet	26.6
17	Durgi	28.0
18	Rentachintala	27.5
19	Macherla	38.5
20	Veldurthi	27.5

Mean Annual Rainfall Variability

Rainfall variability may be computed on yearly, seasonal or even on a monthly basis as the case may be. In the present study, average rainfall variability is computed and analyzed on an annual and seasonal basis for twenty mandals of Guntur District of Andhra Pradesh based 31 years of monthly rainfall data. Table 1 shows that the annual average coefficient of rainfall variability of Guntur District. The analysis of Coefficient of rainfall variability indicates that the mean annual rainfall variability of Guntur District range between 22.1 and 38.5 percentage (Figure 1). Of all the mandals, Macherla (38.5 percent) Dachepalli (34.3 percent) and Bapatla (34.2 percent) experiencing high rainfall variability followed by Pedanandipadu (33.8 percent), Nuzendla (33.1 percent) mandals, Chilakaluripet (32.5 percent), Amaravathi (31.9 percent), Ipur (29.6 percent), Repalle (28.2 percent), Durgi (28 percent). Among all the mandals Mangalagiri (22.1 percent) and Sattenapalle (22.7 percent) shows comparatively low rainfall variability. In the remaining mandals are the rainfall variabilities ranges between 24.2 to 27.8 percent.

The inference is the high rainfall variability indicates a low degree of dependability on rainfall and that exists in Macharla and Dachepalle mandals. The dependability on rainfall is comparatively high in Mangalagiri and Sattenapalle, which shows low rainfall variabilities. In the remaining districts, the dependability on rainfall is in between. The analysis indicates that in the higher rainfall variability regions, there is a need for systematic irrigation scheduling and preparation of crop weather calendar to adjust the phenology growth of the crop.

Seasonal Rainfall Variability

Further, knowledge of seasonal variability of rainfall provides better information as it is significant in agriculture point of view. Hence, for better understanding, seasonal rainfall variability of the study area during cropping seasons was worked out. In India, cropping season is from July to June and it is mainly recognized as two seasons namely the Kharif and Rabi. 'Kharif' means autumn in Arabic. Kharif crops are sown with the beginning of first rains in July, during the monsoon season and harvest in autumn (October-November). Kharif crops are totally dependent on the quantity of rainfall as well as on its timing. The main crops grown during kharif season include paddy, jowar, bajra, maize, ragi, pulses, sesamum, castor, sunflower, soya bean, cotton and sugarcane and the crops grown from October to March are known as Rabi crops.

The kharif season starts with the onset of southwest monsoon while the rabi season kicks off after the summer monsoon and continues through the following spring associated with northeast winter monsoon (October-December). The major rabi crops are barley, potato, wheat, grams, mustard, onion. Etc. The precipitation during the term of summer monsoon season contributes soil moisture to *rabi* crops, at the same time kharif crops are precisely influenced by day-to-day fluctuations in summer monsoon precipitation. Hence, the precipitation in summer monsoon season is significant for both the kharif and rabi crops (Gadgil, 1996; Swami, 2001 and Chaudhary, 2010).

Southwest monsoon season which is associated with kharif cropping performs a crucial role in agriculture, economy, quality of life and living status of the population. More than 75 percent of rainfall received by India is during this season. Therefore, the prosperity of Kharif crops completely based on the quantity of rainfall received during this season. An upturn in precipitation generally associated with a boost in the yields of food grain. And the decrease of rainfall reflects in the decrease in the yields and sometimes completes failure of crops. Fluctuations in the monsoon's precipitation dominate the Indian economy drastically as it is mostly based on agriculture (Jameson, 1932).

Studies indicated that Year to year variations strongly related to kharif grain food production, even 10 percent decrease of the long-term average precipitation leads to serious shrinkage in paddy yields (Palmer, 1995; Gadgil, 1996 and Brij Mohan, 2014). According to Gadgil (1996), the deficit of monsoon precipitation during kharif season has a larger negative impact than the positive impact of good rainfall on crops. Drought due to lack of rainfall during this season reduces the yields of the crops and excess rainfall adversely affect the crop growth. Table 2 and Figure 2 (A-C) provides the mandal-wise rainfall variability on a seasonal basis.

Table 2. Mandal wise Coefficient of mean Seasonal Rainfall Variability in Guntur District. The Coefficient of Rainfall Variability (percent)

Sl.No	Name of the Station	Kharif Season (July-October)	Rabi Season (October-March)	Zaid Season (April-June)
1	Repalle	12.3	90.7	63.0
2	Tenali	8.0	117.5	59.0
3	Mangalagiri	16.2	121.0	70.0
4	Ponnuru	23.5	190.0	41.2
5	Bapatla	13.0	104.5	56.2
6	Guntur	8.1	122.6	65.6
7	Amaravathi	14.0	128.0	63.0
8	Pedanandipadu	8.6	129.0	62.6
9	Chilakaluripet	11.4	120.0	100.0
10	Piduguralla	9.5	124.3	70.3
11	Bellamkonda	12.0	136.4	67.4
12	Sattenapalli	18.0	113.0	64.5
13	Ipur	12.5	115.0	54.5
14	Dachepalli	21.4	132.8	66.3
15	Nuzendla	18.0	117.0	49.2
16	Narsaraopet	14.0	106.0	59.2
17	Durgi	17.5	124.4	72.2
18	Rentachintala	19.2	132.2	66.6
19	Macherla	13.0	122.0	59.0
20	Veldurthi	17.3	134.0	51.0

The analysis of the coefficient of rainfall variability for the twenty mandals of Guntur District indicates that the rainfall variability varies between 8.0 percent and 190.0 percent. During kharif season the rainfall variability ranges between 8 percent and 23.5 percent. the high variability of rainfall is associated with the mandals of Ponnur (23.5 percent), Dachepalle (21.4 percent), Rentachintala (19.2 percent) and Sattenapalle, indicates 18.0 percent of the variability in kharif season. While, Tenali (8.0 percent), Guntur (8.1 percent), Pedanandipadu (8.6 percent), and Piduguralla (9.5 percent) mandals show comparatively low rainfall variability in the region. The analysis indicates that in the mandals namely Ponnur, Dachepalle, Sattenapalle and Rentachintala alternative arrangements for irrigation is required because dependability on rainfall is low. While in the remaining Districts the dependability on rainfall is comparatively better.

Rabi Season and Zaid Season

The analysis of the coefficient of rainfall variability for the twenty mandals of Guntur District indicates that the rainfall variability varies between 8.0 percent and 190.0 percent. During kharif season the rainfall variability ranges between 8 percent and 23.5 percent the high variability of rainfall is associated with the mandals of Ponnur (23.5 percent), Dachepalle (21.4 percent), Rentachintala (19.2 percent) and Sattenapalle, indicates 18.0 percent of the variability in kharif season. While, Tenali (8.0 percent), Guntur (8.1 percent), Pedanandipadu (8.6 percent), and Piduguralla (9.5 percent) mandals show comparatively low rainfall variability in the region. The analysis indicates that in the mandals namely Ponnur, Dachepalle, Sattenapalle and Rentachintala alternative arrangements for irrigation is required because dependability on rainfall is low. While in the remaining districts the dependability on rainfall is comparatively better.

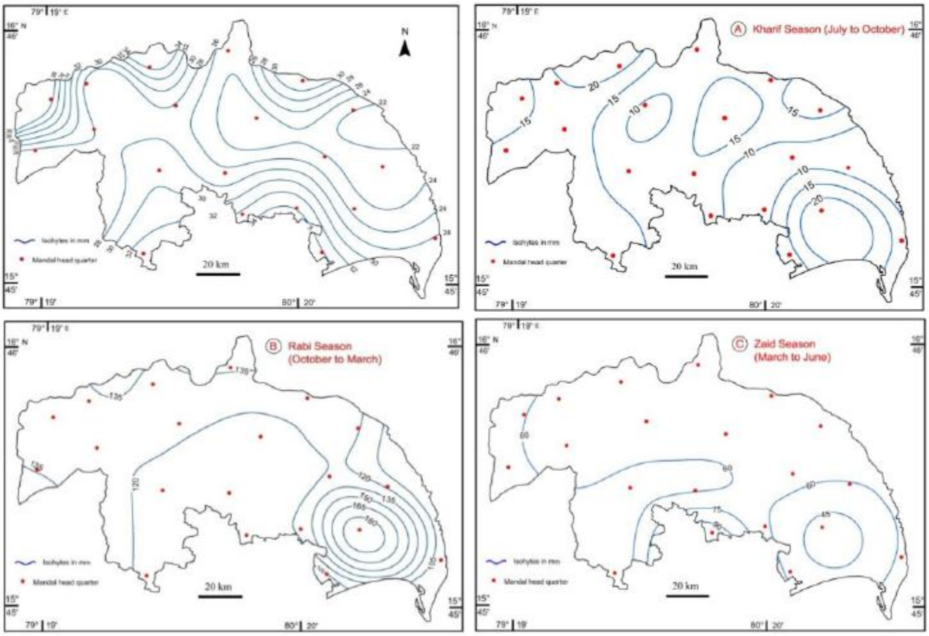

Fig. 2. Coefficient of Mean Annual Rainfall Variability and (A-C) the Coefficient of Mean Seasonal Rainfall Variability of Guntur District

The analysis of rainfall variability of Guntur District ranges from 90.7 percent to 190 percent indicating high rainfall variability during Rabi season. Thus without irrigation facilities cultivation is not encouraging during this season in Guntur District. During the Zaid season, the analysis of rainfall variability of Guntur District ranges from 41.2 percent to 100 percent indicating a higher degree of rainfall variability stressing the need for alternate irrigation facilities. Thus, the knowledge of annual as well as the seasonal coefficient of rainfall variability is useful not only to understand how far the agricultural activities can be dependable on rainfall but also indicate the management practices to be adopted to get agriculture prosperity.

Water Balance Technique in Agro Climatic Studies

The book-keeping procedure of Thornthwaite and Mather, which has a multivariate application in scientific studies also acts as a tool to delineate agro-climatic regions (Hema Malini, 1991). Each of the agro climatic-region indicates its suitability to certain crops based on the soil moisture status of that region. In addition, water balance procedure helps in estimating soil moisture storage which is the major component to be understood for agricultural planning.

The Actual Evapotranspiration (AE), which is one of the derived parameters of water balance, represents the amount of water that actually evaporated and transpired to the atmosphere by deriving from the soil. If the Actual evapotranspiration is expressed as a percentage ratio of PE, the derived index is known as the Index of moisture adequacy (Ima). It varies with the total availability of moisture and therefore is the best index to estimate the agricultural potentiality of the region to grow varied types of crops.

Table 3. The General Scheme of Crop Suitability Based on Index of Moisture Adequacy

Index of Moisture Adequacy (percent)	Crop Suitability
Above 80	Efficiently Suitable to paddy
60 – 80	Suitable to paddy but yields are low; efficiently suitable to millets
40 – 60	Suitable to millets; Paddy is not economical
20 – 40	Suitable to drought resistant crops only
Below 20	Not suitable to crop cultivation

Table 4. Mandal Wise Agro-Climatic Suitability of Crops in Guntur District

S.No.	Mandal	Ima percent	Suitability of Crop
1	Repalle	39.2	Suitable to drought-resistant crops only.
2	Tenali	44.8	Suitable to millets; Paddy is not economical.
3	Mangalagiri	41.3	Suitable to millets; Paddy is not economical.
4	Ponnuru	49.2	Suitable to millets; Paddy is not economical.
5	Bapatla	36.1	Suitable to drought-resistant crops only
6	Guntur	48.4	Suitable to millets; Paddy is not economical.
7	Amaravathi	42.9	Suitable to millets; Paddy is not economical.
8	Pedanandipadu	50.9	Suitable to millets; Paddy is not economical.
9	Chilakaluripet	53.2	Suitable to millets; Paddy is not economical.
10	Piduguralla	55.6	Suitable to millets; Paddy is not economical.
11	Bellamkonda	56.3	Suitable to millets; Paddy is not economical.
12	Sattenapalli	52.4	Suitable to millets; Paddy is not economical.
13	Ipur	59.9	Suitable to millets; Paddy is not economical.
14	Dachepalli	58.4	Suitable to millets; Paddy is not economical.
15	Nuzendla	62.3	Suitable to paddy but yields are low; Efficiently suitable for millets.
16	Narsaraopet	55.3	Suitable to millets; Paddy is not economical.
17	Durgi	59.5	Suitable to millets; Paddy is not economical.
18	Rentachintala	57.9	Suitable to millets; Paddy is not economical.
19	Macherla	61.1	Suitable to paddy but yields are little; Efficiently suitable for millets.
20	Veldurthi	61.5	Suitable to paddy but yields are little; Efficiently suitable for millets.

The higher values of Ima indicate high moisture potentiality of the region for the growth of cereals which require more water for their growth. On the other hand, low values of this parameter indicate low potentiality of the region and restricted for the growth of dry crops. Thus, the Index of moisture adequacy (Ima) is a useful parameter to delineate the agro-climatic zones of any region as it suggests the suitability of particular crops in a particular region. Brij Mohan et al., (1964), based on the concept of moisture adequacy identified agro-climatic zones. Table 1.3. provides the general scheme of crop suitability of areas based on Index of moisture adequacy (Ima).

According to the concept of Moisture Adequacy, when Ima values are between 60 percent and 100 percent, cultivation of paddy can be carried out even in the absence of supplemental irrigation. On the other hand, in areas where 'Ima' values are between 60 and 80 percent, paddy cultivation is uneconomical without supplemental irrigation. However, these areas are efficiently suitable for millet cultivation. In the areas where Ima values are between 40 and 60 percent, only millets can be grown successfully, whereas, in the areas with Ima values between 20 and 40 percent, the choice of crops is highly limited to drought-resistant crops that can withstand water scarcity conditions. Lastly, areas with less than 20 percent of Ima are not at all suitable for any type of crop cultivation. However, livestock rearing can be suggested as an alternative to crop cultivation. Based on this assumption, moisture adequacy indices for all the mandals of Guntur District were computed and presented in Table 4 and Figure 3.

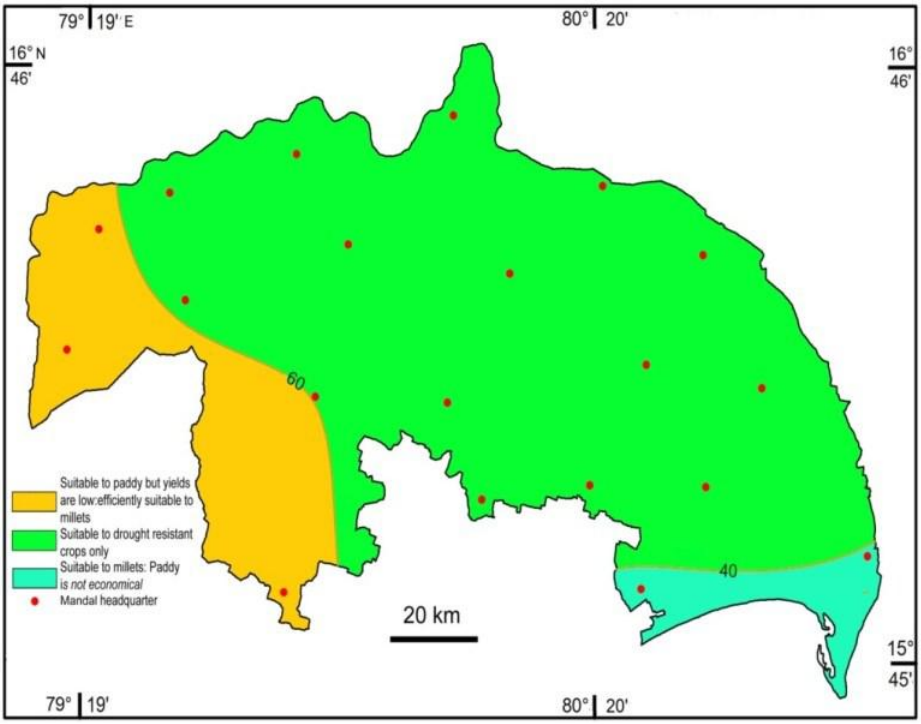

Fig. 3. Agro-climatic Regions of Guntur District

Conclusions

The moisture adequacies of Guntur District as a whole ranging between 36.1 percent and 62.3 percent. The maximum crop potentiality lies along with the coastal areas and it decreases towards western and south-western interior parts. However, the entire district can be recognized into three distinct agro-climatic zones namely; (1) suitable to paddy but efficiently suitable to millets, and (2) suitable to millets, Paddy is not economical, (3) Reasonable to drought-resistant crops only. (Figure 3). Based on moisture status it was found that the mandals of the district namely Nuzandla, Veldurthy and Macherla are suitable to paddy but efficiently suitable to millets. However, with efficient irrigation, Paddy may be prosperous in these mandals. The remaining mandals of the coastal region are suitable to millets only. Though paddy is grown in these regions with the help of irrigation facilities, those efforts will be uneconomical because of low yields of paddy. Instead, if the same irrigation facilities extended to millet crops in these mandals, the yield will be high and economical.

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PHYSICO-CHEMICAL AND PHYTOPLANKTON STUDIES IN COASTAL WATERS OF KANYAKUMARI-INTERMONSOON SCENARIO

Yoganandan V.[1], Nisha Priyadarshini D.[2], and Krishnaveni M.[2]

[1]Department of Marine Science, Bharathidasan University, Tiruchirappalli - 620 024
[2]Department of Marine Science, M.S. University, Rajakkamangalam - 629 502
E-mail: yoganandan1@gmail.com

Abstract

As we know about 60 per cent of the world population live near the coastal area and they depend on the ocean for their survival and it is well-known fact that 80 per cent of the world fish catch comes from the continental shelf region. Hence, monitoring coastal water is essential to maintain the healthy coastal ecosystem. In the present study physico-chemical parameters and phytoplankton studies carried out in the inshore coastal waters of Kanyakumari during the intermonsoon period to know the environmental condition of the marine environment, nutrient level and the link between the oceanographic conditions. The study revealed that distribution and diversity of the phyto and zooplankton community influence the nutrient level of the coastal waters and regional climatic conditions that plays a significant role in the nutrient level of the coastal water, which is proved through this study.

Keywords: Inter-monsoon, Southeastern Arabian Sea, Phytoplankton, Physico-chemical, Coastal waters

Introduction

Oceans cover nearly 70 per cent of the Earth's surface, which not only gives a pleasant blue colour to our planet earth but also drives and regulates the earths' climate system through its physical, chemical and biological processes, which makes existence of life forms. It is also proved that the climate change has control on specie's diversity in the earth. Biological productivity in the Arabian Sea is strongly linked to the intensity of the monsoon, although the lowest biological productivity was noticed during the inter-monsoon period in the Arabian Sea. These strong seasonal contrasts during summer, winter and inter-monsoon periods reflects in water column productivity of the Arabian Sea and therefore, considered as an excellent natural laboratory to study the productivity changes. The complex dynamism in physico-chemical characteristics of coastal waters is related to riverine flows, upwellings, atmospheric depositions, vertical mixing and other anthropogenic sources. Hence, the present study was carried out to know the nutrient status of the coastal waters, off Kanyakumari, especially during the pre-monsoon season of 2011 with an aim to avoid dilution effect by the copious southwest monsoon.

Study Area

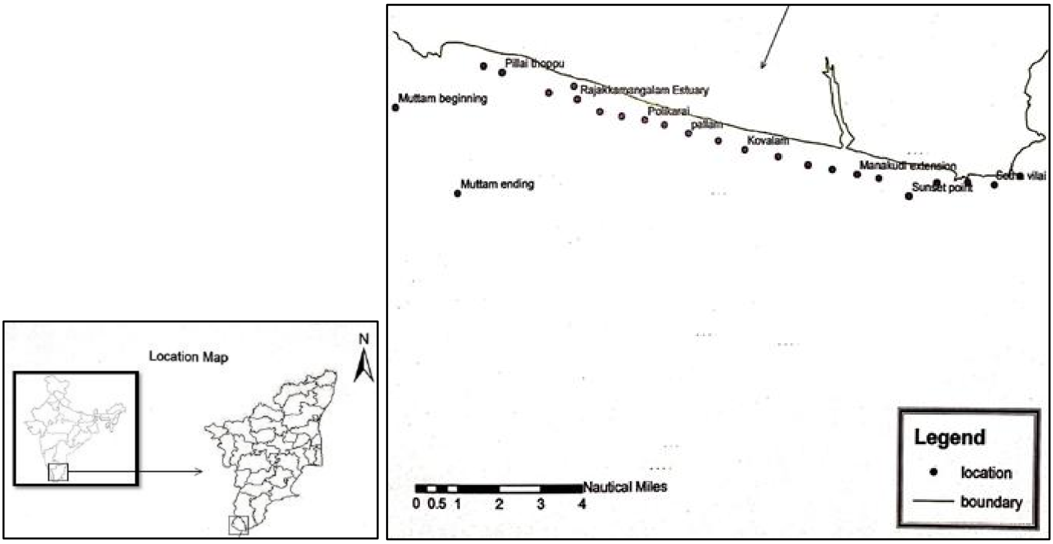

Fig. 1. Study Area with Sampling Locations

Geographical Features

Kanyakumari is the smallest district in Tamil Nadu (Figure 1), with a land spread of 1,684 km² and has almost all ecosystems - forests, wetlands, freshwater resources, marine, etc. There are four important riverine ecosystems, which confluence with the Arabian Sea. They are:

Kadiapattanam Estuary

Kadiapattanam estuary is situated 17 km away from Nagercoil town and is formed by Valliyar River, originating from Pechiparai hills and finally merges with the Arabian Sea. This estuary is a seasonal one and the flow of fresh water is nil during the summer season. The length of the estuary is about 4 km.

Manakudy Estuary

Manakudy estuary is situated nearly 13 km away from Nagercoil in the southeast of Agasteeswaram Taluk. The river Pazhayar originates in the hills of Kalkulam Taluk and flows through the outer area of Nagercoil for a distance of 34.6 km across the district and forms the estuary finally confluence with the Arabian Sea.

Rajakkamangalam Estuary

Pannai Vaikka is one of the river systems that are found in this district. It originates from the Vellimalai hills about 25 km northwest of Nagercoil and traverses 12 km before it joins the Arabian sea at Rajakkamangalam and forms the estuary.

Thengapattinam Estuary

Thengapattinam estuary, formed by the confluence of river Thamirabarani in between Thengapattinam and Erayumanthurai.

Database and Methodology

Physico Chemical Parameters Analysis

The temperature was measured on board by high resolution (0.1) thermometer. Salinity was measured by using salinity refractometer. The pH is a negative logarithm of hydrogen ion concentration it was measured by digital pH meter.

Inorganic phosphate

The 40 ml water sample taken in the conical flask and mixed reagent is added then the sample was diluted with distilled water and OD was taken at 882 nm.

Reactive Silicate

Water sample is mixed with 1 ml of HCl, 2 ml of ammonium molybdate after 10 minutes the oxalic acid solution was added and OD was taken at 410 nm.

Nitrate

The NaCl, H_2S0_4 was added in the water sample and mixed well then 0.1ml brucine sulfanilic acid was added and then placed in a hot water bath for 20 minutes then cooled and OD was taken at 410 nm. Nitrite: Water sample was mixed with 0.2ml of sulfanilamide solution and waited for 2 minutes then 0.2ml naphthyl ethylenediamine solution was added and OD was taken at 543 nm.

Phytoplankton Analysis

For phytoplankton analysis, 500 ml of water sample was preserved in Lugol's iodine and for the analysis, to identify plankton species we used an inverted microscope at 100x – 400x magnification following the standard literature (Subrahmanyan, 1959, 1971).

Results and Discussion

The physicochemical parameters were analysed from the coastal water of Kanyakumari and the data is presented here in Table.1.

Temperature

In the present study surface water temperature recorded a minimum of 29.5°C and a maximum of 30.5° C. Normally tropical water temperature is almost constantly above 25^{o} C.

Table.1. Physicochemical Parameters of the Collected Water Samples

Sl.No	Temperature	Salinity(‰)	Ph	No_2 (µgAt/L)	No_3 (µg)	Sio_4 (µg)	Po_4 (µg)	Nh_4 (µg)	Ca (Mg/Ml)	Mg (Mg/Ml)
26	30°C	30	8.11	0.0201	0.0161	15.60	9.61	0.0056	31	6.4
27	30°C	31	8.07	0.0060	0.0042	9.92	5.12	0.0028	30	6.3
28	30°C	30	8.09	0.0058	0.0041	7.37	3.38	0.0034	31	6.5
29	30°C	31	8.10	0.0057	0.0046	12.48	3.57	0.0027	29	6
30	30°C	33	8.10	0.0065	0.0051	7.94	7.50	0.0031	31	6.4
31	30.5°C	32	8.10	0.0076	0.0043	17.04	4.39	0.0036	31	6.3
32	30.5°C	31	8.11	0.0101	0.0052	14.46	3.84	0.0034	32	6.7
33	30°C	32	8.11	0.0092	0.0040	17.30	6.04	0.0044	31	6.4
34	30°C	30	8.10	0.0086	0.0040	14.46	6.77	0.0052	30	6.2
35	30°C	31	8.12	0.0085	0.0040	13.33	5.12	0.0033	30	6.2
36	29.5°C	32	8.10	0.0088	0.0041	11.63	4.30	0.0052	31	6.4
37	29.5°C	31	8.10	0.0079	0.0050	9.07	4.30	0.0039	32	6.7
38	30°C	31	8.09	0.0074	0.0053	9.36	6.86	0.0047	30	6.3
39	30°C	32	8.10	0.0073	0.0050	16.17	4.85	0.0034	30	6.2
40	30°C	29	8.09	0.0059	0.0044	14.46	5.95	0.0044	30	6.2
41	30°C	32	8.12	0.0098	0.0050	4.53	4.76	0.0050	29	6
42	30°C	33	8.11	0.0062	0.0051	5.67	11.90	0.0047	30	6.3
43	30°C	31	8.10	0.0084	0.0060	4.25	6.13	0.0046	31	6.6
44	30°C	31	8.08	0.0130	0.0057	4.25	16.94	0.0051	30	6.2
45	30°C	32	8.08	0.0096	0.0058	7.65	12.08	0.0051	29	6
46	30°C	32	8.10	0.0100	0.0056	4.53	10.25	0.0046	30	6.2
47	30°C	32	8.10	0.0079	0.0059	3.97	9.52	0.0051	33	6.9
48	30°C	32	8.09	0.0119	0.0059	4.53	10.53	0.0044	28	5.8
49	30°C	32	8.09	0.0114	0.0057	7.94	10.34	0.0049	28	5.7
50	30°C	32	8.08	0.0126	0.0057	7.65	9.70	0.0051	32	6.6

Local restriction of circulation causes a further increase in temperature, sometimes approaching 35^{o} C in restricted lagoons and pools.

Salinity

The salinity ranges we observed in this study area are varied from 29 to 33‰ and the minimum value was observed in Sothavilai and maximum value observed from Azhikkal and Kelamanakudi. Salinity acts as a limiting factor in the distribution of living organisms and its variation caused by dilution and evaporation is most likely to influence the fauna in the coastal ecosystems.

pH

The pH ranges of this study varied from 8.08 to 8.12 and the minimum value was observed in near the Kovalam and Thiruvalluvar Statue. Generally, fluctuations of pH values occur during different seasons of the year is attributed to factors like removal of CO_2 by photosynthesis through bicarbonate degradation, dilution of Seawater through freshwater input, reduced primary productivity, reduced of salinity and temperature apart from decomposition of organic materials.

Nutrients

Nitrite

The concentrations of NO_2-N varied from 0.0057 to 0.0201 µg-at/l and this range was more or less equal to previously recorded nitrite range for Kanyakumari coastal waters during pre-monsoon season. Nitrite is generally present in low concentrations, as an intermediate product of microbial reduction of nitrate, oxidation of ammonia and as an excretory product of plankton. In the marine environment, inorganic nitrogen compounds exist in their oxidising or reducing forms.

Nitrate

The concentrations of NO_3-N varied from 0.0040 to 0.0161 µg-at/l and this range was more or less equal to previously recorded nitrite range for Kanyakumari coastal waters during pre-monsoon season. Nitrogen supplied through rivers mainly exists as dissolved nitrate, which is derived from rock weathering and drainage from agricultural lands. Nitrate is considered as the stable oxidation level of nitrogen in seawater.

Reactive Silicate

The present study shows a minimum of 3.97 and maximum of 17.30 µg Si-at/l. The source of silica to the marine environment is mainly through river discharges (Livingstone, 1963), with submarine hydrothermal emanations and glacial weathering (Warnke, 1970; Wolery and Sleep, 1997) also contributing substantially. Silicon is biologically essential for the growth and the formation of their skeletal materials in marine organisms like diatoms, radiolarians, and sponges.

Phosphate

Present study shows concentrations of phosphate varied from 3.57 to 16.94 µg-at/l and this range was more or less equal to the previously recorded range for Kanyakumari coastal waters. Ecological interest in phosphorus stems from its major role in biological metabolism in spite of its relatively subdued presence in the hydrosphere. Weathering of earth's crust and surface water transport deliver phosphorus to coastal waters through rivers.

Phytoplankton Analysis

We analysed phytoplankton soup under the microscope with the magnification of 100x. Through this analysis, we recorded 20 species and observation also shows phytoplankton abundant species which is given in Table 2. Marine phytoplankton can be described as ‘The Jewel of the Ocean’. It contains a unique combination of life-sustaining nutrients and antioxidants including essential fatty acids, amino acids, protein, vitamins, chlorophyll, minerals, trace elements, and phytonutrients. Zooplankton is the primary consumers of the oceans and grazes on the phytoplankton. They themselves are an important food source for large animals. Basking sharks, whales, fish and some species of rays rely on zooplankton for their food supply.

Results and Discussion

Temperature and Salinity

Analytical data of the present study are shown in Table 1. The surface water temperature recorded a minimum of 29.5° C and a maximum of 30.5° C. This range is considered slightly high when compared to other seasons from earlier studies.

Table. 2. Identified Plankton Species from the Study Area

Sl. No	Name of the Species
1	*Trichodesmium erythraeum*
2	*Rhizosolenia*
3	*Coscinodiscus*
4	*Leptocylindrus*
5	*Nitszchia pungens*
6	*Thalassiothrix longissima*
7	*Thalassionema nitschiodes*
8	*Bacillaria paradoxa*
9	*Chaetoceros affinis*
10	*Chatoceros socialis*
11	*Biddulphia rhombus*
12	*Pleurosigma directum*
13	*Skeletonema costatum*
14	*Triceratium favus*
15	*Navicula membranacea*
16	*Noctiluca miliaris*
17	*Peridinium sp.*
18	*Ceratium sp.*
19	*Ornithocerus magnificus*
20	*Pleurosigma elongatum*

It has been evident from the previous works that the surface water temperature usually increased from October to November in each year along this coast then the water temperature gradually reduced to a minimum during the month of January. Subsequently, the temperature used to increase and reaches its maximum in the month of May. Higher water temperature observed here is consistent with higher sea surface temperature observed in May by (Smitha et al.,2008). Along the West Coast, the period of highest water temperature coincided with the period of greater insolation (Rivonker., et al.,1990,). The salinity ranges from 29 to 33‰ recorded in the present study this range is due to the influence of low saline water from the Bay of Bengal and also this water forms a thin surface layer in the southeastern Arabian Sea during spring inter-monsoon period, which is correlate with several earlier studies (Muraleedharan and Prasanna Kumar et al., 1996).

Nutrients

The observed trace amount of Nitrate and Nitrite, lower value of Phosphate and Silicate in the inshore waters mimic the offshore region. As we know the investigated area was the southeastern Arabian Sea bordered by the west coast of India on the eastern side. This region has a unique oceanographic feature of monsoonal winds, which drive near – surface currents which affect mixed layer development, hence nutrient availability in the upper euphotic zone is less. Along with this following factors limit the nutrient level in the study area 1) Study area receives intense solar heating during the inter-monsoon period, 2) The low saline water from the Bay of Bengal produce a thin surface layer in the southeastern Arabian Sea which intensifies the surface water stratification during the intermonsoon period, and 3).

The very scanty rainfall during this season which drastically reduces the nutrient influx to the study area (Muraleedharan and Prasannakumar, 1996; Qasim, 2003).All the above mentioned earlier studies gave the excellent reason for the low nutrient level at offshore region during the intermonsoon period. If we see the present data set, which mimics the offshore region, which proved that present study area around 30 metre water depth also has the similar oceanographic condition, in addition to this phytoplankton analysis of present study also giving supporting evidence to present argument (which is discussed below).

Response of Phytoplankton

Through phytoplankton analysis, we identified twenty sp, which is distributed in the study area during the intermonsoon period; an interesting observation is we could see the dominance of the following species Trichodesmium erythraeum, Rhizosolenia, Coscinodiscus, and Leptocylindrus.

The earlier studies from this region suggest that chlorophyll-a concentration is high in the offshore region, which is contributed mostly by the dominant sp Trichodesmium erythraeum, the reason for the dominance of this sp is prevailed environmental condition in this region, which is discussed in-detail in the previous paragraph while discussing nutrient limiting factors. This interpretation is supported by following previous studies (Nair et al.,1992; Carpenter, 1993; Capone et al., 1997; Jyothibabu et al., 2003). The present study area also shows a lower value of major nutrients especially traces amount of nitrogen. This condition facilitates the dominance of the above-motioned species.

Conclusions

Physico-chemical parameter and phytoplankton studies carried out in the inshore coastal waters of Kanyakumari during the inter-monsoon period to know the environmental condition, nutrient level and to know the link between the oceanographic condition and physicochemical parameter. A summary of the work carried out and the salient findings of this study are described below. Present study shows that inter-monsoon period has second highest values of temperature and thin low saline surface water in this region and also the field observation shows that sea was calm and low wind speed. Influence of upwelling was not observed during the early stage of the inter-monsoon season. The lower values of all major nutrients in the surface water suggest that the river input contribution play a major role in coastal waters. From the present phytoplankton analysis twenty phytoplankton sp was recorded among this few species were found abundant and they are Trichodesmium erythraeum, rhizosolenia, coscinodiscus, and leptocylindrus. Distribution and diversity of the phyto and zoo-plankton community influence the nutrient level of the coastal waters and regional climatic condition plays a significant role in the nutrient level of the coastal water which is proved by this study.

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ANALYSIS OF RIVERBED SILTATION IN JIADHOL RIVER OF BRAHMAPUTRA VALLEY

Luna Moni Das

Department of Geography, North Eastern Hill University, Shillong - 793 022
E-mail - lunamonidas87@gmail.com

Abstract

Most of the North bank tributaries of the Brahmaputra River brings heavy loads of sediments to the plains and makes siltation a major problem in the region. Jiadhol River is one among those rivers; it is a small yet very dynamic North bank tributary of the Brahmaputra River. The upper catchment of this river is within West Siang District of Arunachal Pradesh and the river flows through Dhemaji and Lakhimpur District of Assam. This paper is an attempt to understand the pattern and rate of riverbed siltation in the Jiadhol River basin. The channel cross-section has been observed over a period of two years to understand the pattern of siltation in different sections of the river. The study of the change in channel cross-section confirms that the heavy river bed siltation has occurred in the river from the foothills and in the centre of the basin but the lower reaches has experienced riverbed erosion during the period of 2013 and 2014. During the period of 2007 to 2014, 2.32 m thick layer of silt deposited under the Jiadhol RCC bridge located in the centre of the basin. A sediment rating curve has also been derived for the river Jiadhol through this paper to establish an empirical relationship between discharge and sediment load of the river.

Keywords: Siltation, Sediment rating curve, Jiadhol River, Width-depth ratio.

Introduction

Riverbed siltation is a process of settling down of the load transported by a river on its own bed due to the loss of transporting capacity. This is a very important and common process in all the fluvial systems. The high rate of siltation has been considered as a major problem in many of the literature (Dendy, 1968; Mahmood, 1987; Walling,1997; Ali, 2007). The problem of siltation becomes more severe when it occurs out of the river channels in the areas of human settlement and cultivation. High sedimentation or siltation is obviously related to high erosional rate in the upper catchment (Robinson, 1977; Mahmood, 1987; Walling, 1997). It has been mentioned that the increase in the sediment flux is due to catchment disturbance by human activities (Meade, 1982). Asselman (2000) in his paper has provided a method of curve fitting and interpretation of sediment rating curve for a better understanding of the relationship between sedimentation and discharge. Field survey is considered as one of the best methods for analysing the pattern and trend of siltation in river (Yin Hongfu, et al., 2004). The Jiadhol or Jiya Dhol River is one of the most notorious rivers in the North bank of the mighty Brahmaputra causing devastating floods almost every year during the peak monsoon season. Heavy siltations are cited as one of the most important causes of the flood in the Jiadhol river. So, it is very important to study the pattern of siltation within the river bed in various cross-sections of the river brings. This paper is a sincere attempt to understand the pattern and rate of siltation of the Jiadhol River with the help of field survey and measurements.

Study Area

The Jiadhol River is one of the North bank sub-tributaries of the Brahmaputra River that empties into Charikoria River. Charikoria is one of the anabranches of the Brahmaputra like Kherkutia Suti. The basin of the Jiadhol River extends from 27˚15′ North to 27˚45′ North latitudes and 94˚15′ Eeast to 94˚40′ East longitudes (Figure 1). It covers an area of 1,094.93 sq. km, of which 38 percent (416.07 sq. km) lies in Arunachal Pradesh and 62 percent (677.86 sq. km) in Assam.

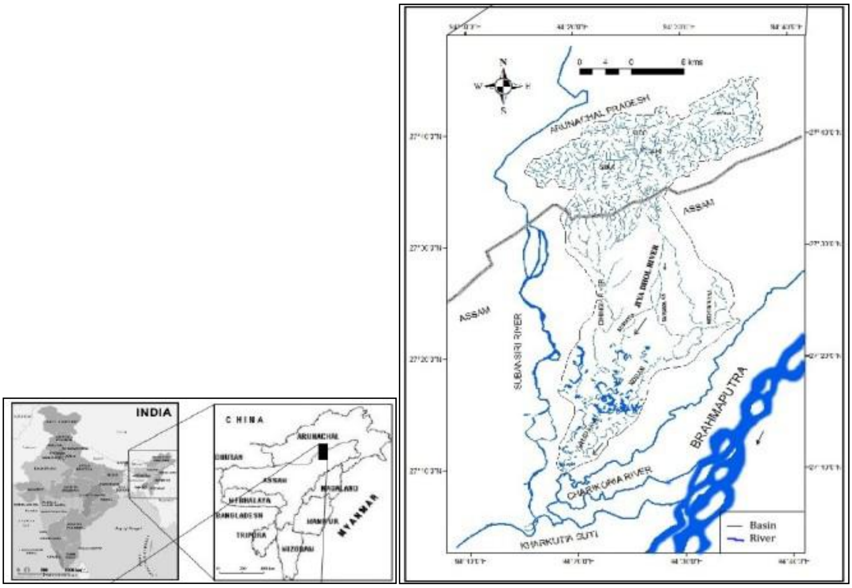


Fig. 1. Jiadhol River Basin

Database and Methodology

Data on total silt load, suspended sediment load and the discharge of Jiadhol River was collected for the station Jiyadholmukh for a period of ten years from 2003 to 2014 from Brahmaputra Board, Lakhimpur District. For analysing, the trends and estimating the relationship between these two parameters are plotted on a graph. Sediment rating curve fitting is done for the river for the year 2014. Detailed field survey is done to understand the pattern and rate of siltation in Jiadhol River. Channel width and depth has been manually measured in 15 sites along with the main channel and the tributaries. The depth is collected in an interval of 1 metre along the smaller cross-section whereas at larger cross-section (more than 40 m), the depth is measured in larger intervals. Out of these 15 sites, only three most suitable sites are selected for observing the change in channel cross-section between 2013 and 2014. The ground clearance of the bridges over the river is measured during field survey to find out the rate of siltation under the bridges since it has been constructed.

Results and Discussion

The time series of the annual total sediment load for past ten years (2005-2014) of the Jiadhol has a cyclic pattern with a gradual increase over the years. The analysis of the relationship between the total silt load and the discharge of the river gives high positive correlation. The comparison of the trend of the annual discharge and total annual silt load is shown in Figure 2. The recent trends in the discharge show constancy whereas the annual silt load has a positive trend. The comparison of these two trends suggests that there is more silt in a particular volume of water in the recent times. Large silt load will subsequently lead to more siltation of river bed.

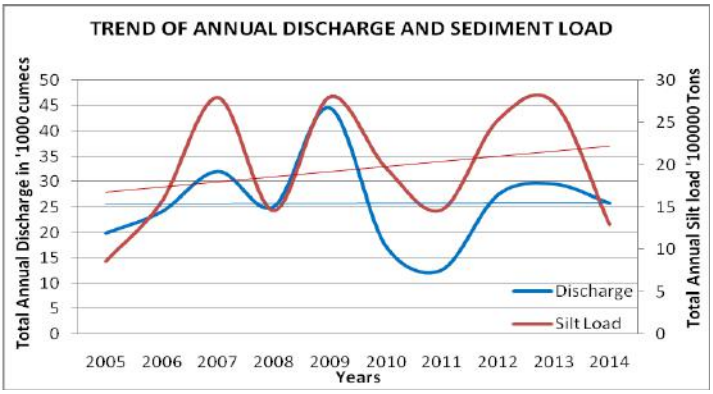


Fig. 2. Trends of Annual Discharge and Sediment Load

Sediment Rating Curve for Jiadhol River

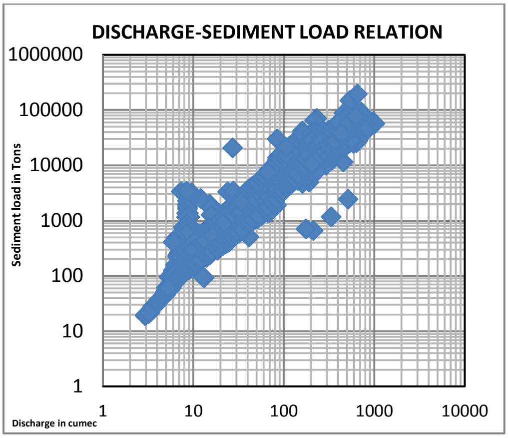
The analysis of the relationship between the total silt load and the discharge of the river gives high positive correlation (Figure 3). Sediment rating curve represents the relationship between suspended sediment concentration and the water discharge at a stream measurement station. The daily average stage and discharge for the year 2014 are plotted in a log-log graph and shown in Figure 4. The co-efficient correlation between sediment load and discharge is approximately equal to unity (0.997). Thus, there is one to one correlation between discharge and corresponding sediment load.

The equation for the line of best fit derived from the Figure is

$$\mathbf{Y = 4.872\ X1.438}$$

where, log S= 4.872 (log Q)1.4 and S = antilog (4.872 (log Q)1.4)

The above equation gives the relation between sediment load and discharge in the studied river for 2014. With the help of the equation, we can estimate the silt load of the river once we had data of discharge. This relationship is significant at 95 percent level of significance.



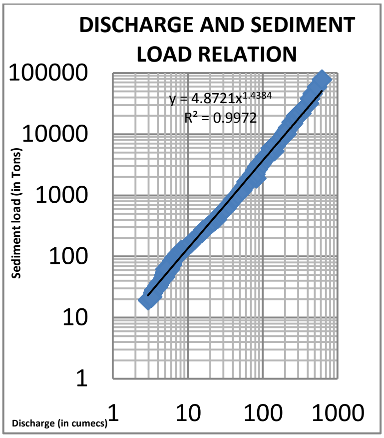


Fig. 3. Relationship between Daily River Discharge and Sediment Loads
Fig. 4. Sediment Rating Curve of Jiadhol River

Change in Channel Cross Section

The study of changes in channel cross sections of Jiadhol River is conducted by comparing the channel cross-section of the river in three sites evenly spread over the river. The first cross-section is drawn for the site D (Figure 5), it is located at the foot hills and here the river debouches to the plains of Assam. The second cross-section is drawn along the site is I (Figure 6), this is located towards the centre of the basin. The third cross-section is along sites O (Figure 7), located along the lower course of the river. The cross-sections at these three sites are measured during two time period to analyses the temporal change. The first field survey was conducted in December 2013 and the second on December 2014. Out of these three cross-sections, the first two sites D and I, shows a rise in the bed level during the studied period, whereas the third site O do not show any significant changes.

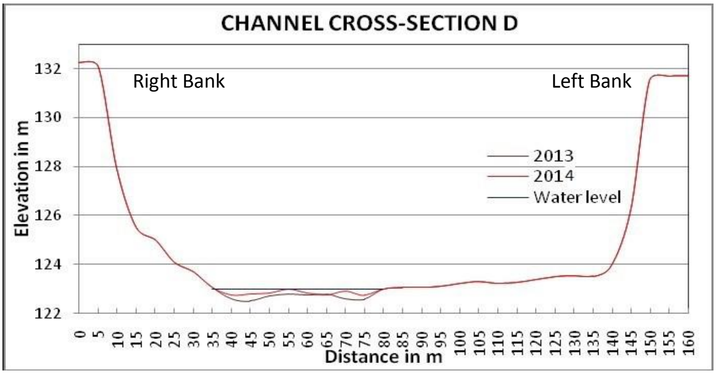


Fig. 5. Channel Cross Section at D

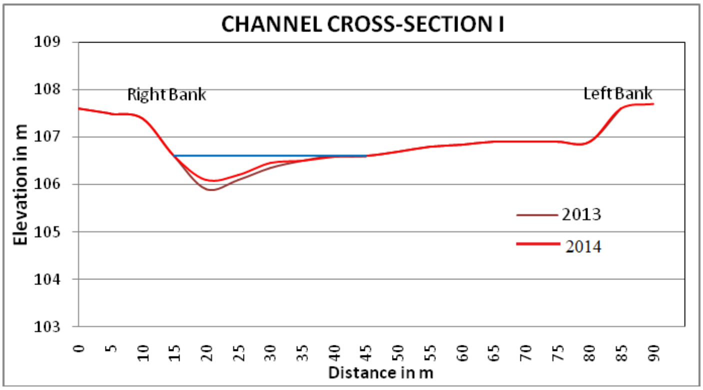


Fig. 6. Channel Cross Section at I

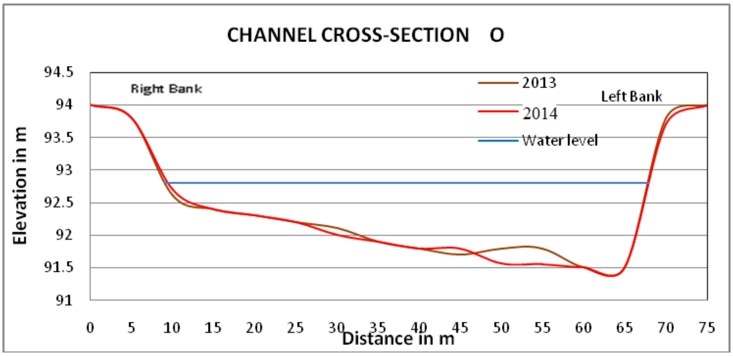


Fig. 7. Channel Cross Section at O

Siltation of Riverbed under Bridge

The Jiadhol RCC bridge on NH 15 was completed in 2007 with a vertical clearance of 3 m. During the field survey in December 2013, the average vertical clearance of the bridge is measured as 0.76 m. Thus, it can be concluded that during the period of 2007 to 2014, 2.24 m thick layer of silt deposited under the Jiadhol RCC bridge and on an average 0.28 m per year siltation of river bed is observed under the Jiadhol bridge.

Conclusions

The Jiadhol River has a positive trend for both the discharge and sediment load for the period between 2003 and 2014. The rate of increase in sediment load is increasing more sharply compared to the discharge of the river. Thus, the river is carrying more volume of sediment at present. The relationship between sediment load (S) and discharge (Q) can be established using the sediment ratio curve, S = antilog (4.872 (log Q) 1.4) river Jiadhol. The study of the change in channel cross-section suggests that the river bed siltation is rapid in the foot hill section of the river throughout the center but it is not distinct in the lower section of the river. Thus, the problem of heavy siltation in Jiadhol River is limited to the foothill section of the river. The field measurement revels that the average rate of siltation under the Jiadhol RCC Bridge is 0.28 m per year.

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GENDER DISPARITY OF LITERACY IN RAJASTHAN

Devendra Singh Chouhan

Department of Geography, M. L. Sukhadia University, Udaipur - 313 001
E-mail: dscgeodsc@gmail.com

Abstract

Gender issues mean the discussion on both men and woman, though woman who suffer from gender inequality. From all gender issues, gender inequality is the most prevalent in Rajasthan. According to the 2011 Census of Rajasthan, the overall rate of literacy is only 66.10 percent. But breaking up the state average reveals that while the rate of literacy for male is 79.20 percent and for females, it is 52.12 percent. This means that more than one-fourth the state's population is still illiterate. Within that figure, nearly one-fifth of male are illiterate compared with more than one-third of the females there. It shows there is a slow rate of improvement in female literacy as compared with male literacy, is a matter of grave concern. Despite the number of efforts made at state and national level, there exist a significant number of illiterate woman in society, a disturbing factor for all development efforts. Literacy plays a significant role in reducing gender inequality. The purpose of the research is to map and analyse gender disparity in literacy across the districts.

Keywords: Census, Education, Female literacy, Male literacy, Gender disparity

Introduction

Human capital is the most important ingredient in the overall development of a society (Dubey, 1981). Education is a key element as it has the potential to increase human capital; it removes inequality from society, impacts the growth of employment and improves a country's Gross National Product (GNP). Literacy is the basic building block and a crucial element in the development of education in society. In the context of Indian society, which is essentially patria renal, it is the women and girls suffer especially due to low accessibility to education (Chattoraj, 2015). In other words, gender becomes an important factor in determining the education level of an individual. Woman constitutes approximately half, which is 48.14 percent of the population in Rajasthan. However, a large gap exists between the male and female population in the levels of literacy. According to the 2011 Census of Rajasthan, there is difference of about 27.85 percent between the two reference groups. The problem of illiteracy, especially among women, is a huge concern not only in Rajasthan but also across India which directly affects the development efforts. This research attempts to analyse levels of literacy across the various districts of Rajasthan. It has been divided into three major sections. The first section analyses literacy trends in Rajasthan with special reference to the period 1951 to 2011. The second section examines patterns of literacy in Rajasthan. The last section provides details of gender disparity (Jhaniya, 2014) with respect to males and females across Rajasthan.

Database and Methodology

The major objectives of the study are to analysis the spatial pattern of gender disparity and identify the factors that are responsible for gender disparity and to provide suggestions to reduce gender disparity. The present study primarily based on the secondary data extracted from the Census of Rajasthan, 2011. Besides, some other reports and government publications have also been used to supplement in the analysis.

Three major statistical tools are used for showing the regional patterns of literacy rate and examining the gender gap between males and females. First, a simple literacy rate was computed for trend analysis and spatial analysis of the study. Second, it has been applied for analysing the regional pattern of gender disparity across Rajasthan. Finally, Geographic Information System (GIS) mapping was followed using choropleth mapping for showing regional disparity in the State.

Study Area

Rajasthan is situated in North-western parts of the India. It lies between 23˚3' to 30˚12' North latitudes and 69˚30' to 78˚17' East longitudes. Rajasthan is bounded by Pakistan in the West and North and by Haryana in the North-east. In East it is surrounded by Uttar Pradesh, by Madhya Pradesh in the South-east and Gujarat in the South-west. It is the largest State in terms of area in India has an area (3,42,239 square kilometres). From East to West it is about 869 km and from North to South it is about 826 km long, the State can be divided into two major divisions along the Aravalli Range which divides the State into East and West Rajasthan. The most notable feature of the State is the Aravalli Range of hills. It is one of the oldest mountain systems in Western sandy plains and the area lying to the East of it is called as Central highlands. On the basis of relief features, the State can be divided into the following physiographic divisions: 1. Western Sandy Plain, 2. Aravalli Range and Hilly Region, 3. Eastern Plain and 4. Hadoti Plateau or South-eastern Rajasthan Plateau.

Gender Disparity

There are disparity index to measure the disparities. According to this method, if X_1 and X_2 represent the respective percentage values of the variable groups 1 and 2, than the disparity index (D) can be calculated by the following formula:

$$D = \text{Log}\ (X_2/X_1) + \text{Log}\ [(Q-X_1) / (Q-X_2)]$$

where, X_2 > or = X_1 and Q = 100

In this method, group 2 is taken for the variable having a comparatively higher value and group 1 is taken for the variable with a relatively lower value. In case there is no disparity (perfect equality), the value of D will be 0. This method reveals that the higher the value of D, the higher the extent of disparity and the lower the value of D, the lower the extent of disparity.

Fig. 1. Study Area - Rajasthan

Results and Discussion

Table 1 reveals that the literacy rate for people, both males and females, have been increasing continuously. The literacy rate has increased 9 times during 1951-2011 (Sawant, 2002). The literacy rate of males has increased 5.59 times during 1951-2011. The literacy rate of females has increased 17.53 times during 1951 and 2011.

These figures also reveals that gender disparity in literacy has increased continuously from 1951-1991 and it became 3.03 times during 1951-1991. During the last 40 years, it got decreased by 2.75 percent points for the first time in 2001. Thereafter, it had been decreasing continuously until 2011. If there is a comparison of gender disparity across different years, it can be observed that gender disparity was the lowest (11.4 percent) in 1951, while it was the highest (34.6 percent) in 1991.

Overall, gender disparity in literacy has increased 3.03 times during 1951-2011 from 11.4 percent to 27.85 percent. The Figure 1 shows that total literacy is continuously increasing during the reference period (1951-2011) and it got increased during 1991 to 2011.

Literacy among males and females has the same rate of pace in the same periods. Gender gap in literacy between males and females was increasing between 1951 and 1981 with few exceptions (Chattoraj, 2015). Afterwards, this gap started declining at relatively faster rate and reached below 20 percent. Thus, the Figure reveals that the literacy is increasing and literacy gap between male and females are declining the reference period.

The Table 2 reveals that more than one-fifth of the population is still illiterate in the State. The gender disparity in literacy is 27.86 percent. In rural areas, it is 31.24 percent, while in urban areas it is 17.63 percent. There is a difference of 13.61 percent in gender disparity in literacy between rural and urban areas.

Table 1. Literacy Rates in Rajasthan (1951-2011)

Year	Total Literacy Rate	Male Literacy Rate	Female Literacy Rate	Gender Disparity (Male/Female Difference in Literacy Rates %)	Net Change in the Gender Disparity
1951	8.9	14.4	3.0	11.4	-
1961	15.2	23.7	5.8	17.9	+6.5
1971	19.1	28.7	8.5	20.2	+2.3
1981	24.4	36.3	11.4	24.9	+4.7
1991	38.6	55.0	20.4	34.6	+9.7
2001	60.04	75.70	43.85	31.85	-2.75
2011	66.10	79.20	52.12	27.08	-4.77

Source: Census of Rajasthan, 1951-2011.

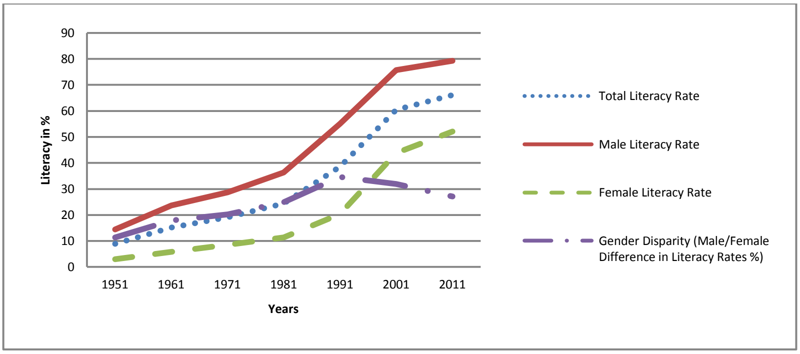

Fig. 2. Trend of Literacy in Rajasthan

Table 2. Literacy Rates in Rajasthan, 2011

Geographical Location	Total Literacy	Male Literacy	Female Literacy	Gender Disparity
Total	66.10	79.20	52.12	27.08
Rural	61.40	76.26	45.80	30.46
Urban	79.70	87.90	70.70	17.20

Source: Census of Rajasthan, 2011

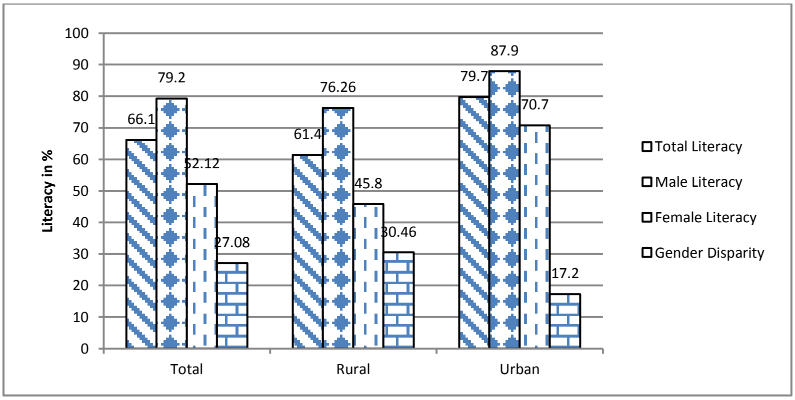

Fig. 3. Literacy Rate in Rajasthan

The Figure 2 shows that the total literacy rate at the State level is 66.10 percent while male literacy is 79.20 percent and female literacy is only 52.12 percent. Thus, there is 27.08 percent difference of gender gap in the literacy rates of males and females are identified. Looking closely, in rural areas, the literacy rate is lower than the national average as well as urban literacy rate (80.73 percent). From Figure 2, three major facts are evident: (i) female rural literacy rate is the lowest when compared with urban female rate, the State average and the literacy rate of males; (ii) The gender gap in the literacy rate is highest in rural areas and (iii) Finally, The most important fact is that literacy among females is unfavourable in all the cases.

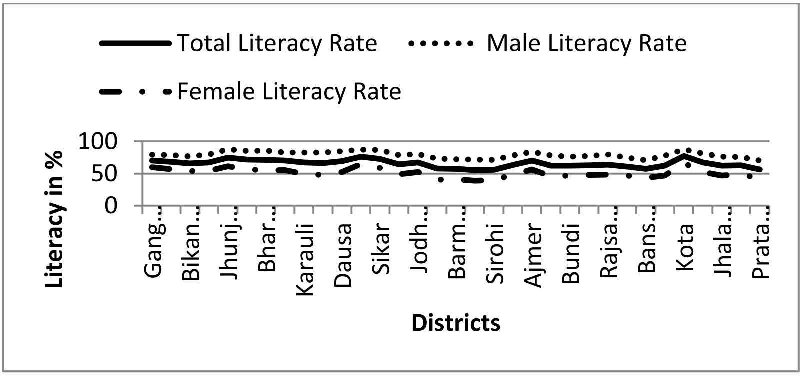

Fig. 4. Regional Pattern of Literacy, 2011

The Figure 3 shows that the district of Jalore stands at the bottom among the districts of Rajasthan, while on the other hand, Kota shows the highest literacy rate in the States. From the Figure, it is clear that, generally, literacy rates indicating females are always lagging behind their male counterparts due to the lack or poor access to the educational institutions.

Urban-Rural Disparity

The Figure 5, shows that the female literacy rate is lower, while males are in an advantageous position in achieving literacy, infact the urban male literacy rate and the rural male literacy rate is almost the same, varying between 70 and 85 percent, while the female literacy rate shows much more variations among the districts as 40-80 percent (Varshney, 2002).

Gender Disparity

As stated earlier, the State average of gender disparity is 27.08 Percent. Twenty-one districts show a gender disparity above the State average. In rural areas, there are twenty-nine districts and in urban areas there is only one district above the State average. Twelve districts have gender disparity below the state average i.e. it is so in rural areas in four districts and in urban areas it is thirty-two districts.

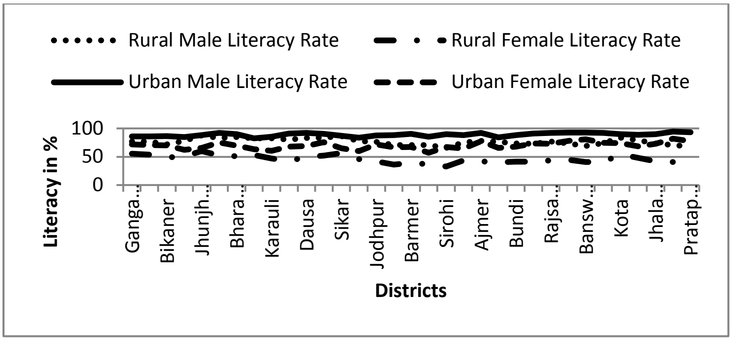

Fig. 5. Regional Pattern of Rural and Urban Literacy in Rajasthan, 2011

Table 4. Disparity Index of Different Years

Year	Disparity Index
1951	5.93
1961	5.31
1971	4.66
1981	4.57
1991	4.46
2001	4.04
2011	3.94

The data on disparity presented in Table 4 reveals that the gender disparity in literacy levels had been continuously decreasing from 1951 to 2011. The rank correlation measurement of Table 5 reveals the in urban areas there exists a high positive correlation between the total literacy rate and the male literacy rate, the total literacy rate. It means that if literacy increases, male and female literacy will also increases. If the male literacy rate increases, the female literacy will also increase. But there is a negative correlation between gender disparity and the total literacy rate, the male literacy rate and the female literacy rate. It means that if the literacy rate increases the gender disparity decrease.

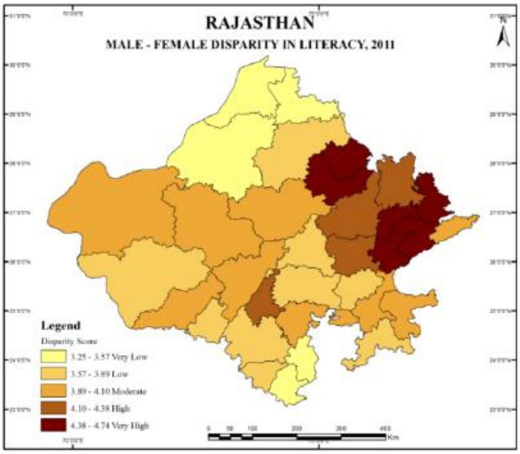

Fig. 6 . Male and Female Disparity in Literacy, 2011

The Figure 6 is showing the pattern of male-female disparity in literacy in Rajasthan in 2011. It shows that Sawai Madhopur and Bharatpur have highest male-female disparity in literacy that is literacy among females is unfavourable in these districts. The Karauli, Jhunjhunu, Sikar, Dausa, Alwar, Tonk, Bharatpur, Rajsamand and Sirohi falls under the second highest level of disparity in male-female literacy.

Table 5. Total Gender Disparity in Rajasthan, 2011

Sl.no.	District	Total Literacy Rate	Rank	Male Literacy Rate	Rank	Female Literacy Rate	Rank	Gender Disparity	Rank
1	Ganganagar	70.25	8	79.33	16	60.07	4	19.26	33
2	Hanumangarh	68.37	11	78.82	18	56.91	6	21.91	31
3	Bikaner	65.92	17	76.90	23	53.77	12	23.13	29
4	Churu	67.46	12	79.95	14	54.25	11	25.7	28
5	Jhunjhunu	74.72	3	87.88	1	61.15	3	26.73	27
6	Alwar	71.68	5	85.08	6	56.78	7	28.30	18
7	Bharatpur	71.16	6	85.70	5	54.63	10	31.07	9
8	Dholpur	70.14	9	82.53	11	55.45	9	27.08	25
9	Karauli	67.34	14	82.96	9	49.18	16	33.78	2
10	Sawai Madhopur	66.19	16	82.72	10	47.80	22	34.92	1
11	Dausa	69.17	10	84.54	7	52.33	15	32.31	6
12	Jaipur	76.44	2	87.27	3	64.63	2	22.64	30
13	Sikar	72.98	4	86.66	4	58.76	5	27.90	19
14	Nagaur	64.08	18	78.90	17	48.63	18	30.27	12
15	Jodhpur	67.09	15	80.46	13	52.57	13	27.89	20
16	Jaisalmer	58.04	28	73.09	28	40.23	31	32.86	4
17	Barmer	57.49	29	72.32	29	41.03	30	31.29	7
18	Jalor	55.58	33	71.83	30	38.73	33	33.10	3
19	Sirohi	56.02	32	71.09	31	40.12	32	30.97	10
20	Pali	63.23	20	78.16	20	48.38	20	29.78	13
21	Ajmer	70.46	7	83.93	8	56.42	8	27.51	23
22	Tonk	62.46	23	78.27	19	46.01	27	32.26	5
23	Bundi	62.31	25	76.52	24	47.00	24	29.52	14
24	Bhilwara	62.71	22	77.16	22	47.93	21	29.23	16
25	Rajsamand	63.93	19	79.52	15	48.44	19	31.08	8
26	Dungarpur	60.78	27	74.66	27	46.98	25	27.68	22
27	Banswara	57.20	30	70.80	32	43.47	28	27.33	24
28	Chittorgarh	62.51	24	77.74	21	46.98	26	30.76	11
29	Kota	77.48	1	87.63	2	66.32	1	21.31	32
30	Baran	67.38	13	81.23	12	52.48	14	28.75	17
31	Jhalawar	62.13	26	76.47	25	47.06	23	29.41	15
32	Udaipur	62.74	21	75.91	26	49.10	17	26.81	26
33	Pratapgarh	56.30	31	70.13	33	42.40	29	27.73	21

Source: Census of Rajasthan, 2011.

Thus, these districts are relatively better than Sawai Madhopur and Bharatpur. Pali, Ajmer, Bundi, Bhilwara, Dungarpur, Chittorgarh, Kota, Baran and some of the North-east districts fall under the moderate rate of male-female disparity in literacy. Male-female disparities in literacy are lowest in Ganganagar, Bikaner and Banswara. Thus, in these districts female is higher than the rest of all the districts. Consequently, it is revealed that literacy among most of the districts are not severable to females except in Ganganagar and Bikaner.

The rank correlation measurement of table 6 also reveals that in rural areas there exists a high positive correlation between the total literacy rate and the male literacy rate, the total literacy rate and the female literacy rate and the male literacy rate and the female literacy rate. It means that if literacy increases, male and female literacy will also increases. But there is a negative correlation between gender disparity and total literacy rate, male literacy rate and female literacy rate. It means that if literacy increases, gender disparity decreases and any increase in literacy will reduce gender disparity.

Table 6. Rural Gender Disparity, 2011

Sl. No.	District	Total Literacy Rate	Rank	Male Literacy Rate	Rank	Female Literacy Rate	Rank	Gender Disparity	Rank
1	Ganganagar	66.76	9	76.70	16	55.65	3	21.05	33
2	Hanumangarh	65.79	11	77.02	14	53.48	5	23.54	31
3	Bikaner	58.95	20	71.72	25	48.81	12	22.91	32
4	Churu	64.98	12	78.06	11	51.13	9	26.93	30
5	Jhunjhunu	73.95	1	87.71	1	59.86	1	27.85	29
6	Alwar	68.83	6	83.46	6	52.69	7	30.77	21
7	Bharatpur	68.87	5	84.68	3	50.85	10	33.83	7
8	Dholpur	69.20	4	82.55	7	53.23	6	29.32	25
9	Karauli	66.15	10	82.50	8	47.05	14	35.45	4
10	Sawai Madhopur	62.68	14	80.62	9	42.65	19	37.97	1
11	Dausa	67.43	8	83.46	6	49.85	11	33.61	9
12	Jaipur	68.43	7	83.63	5	52.07	8	31.56	18
13	Sikar	71.83	2	86.44	2	56.75	2	29.69	23
14	Nagaur	62.16	15	77.78	13	45.92	15	31.86	16
15	Jodhpur	59.79	18	76.32	18	41.99	21	34.33	6
16	Jaisalmer	54.61	29	70.47	29	36.06	32	34.41	5
17	Barmer	55.72	27	70.87	26	38.92	30	31.95	14
18	Jalor	54.05	30	70.52	28	37.03	31	33.49	10
19	Sirohi	49.77	32	65.86	32	33.02	33	32.84	12
20	Pali	59.21	19	75.02	19	43.74	18	31.28	19
21	Ajmer	60.22	17	78.05	12	41.87	22	36.18	3
22	Tonk	58.86	21	76.63	17	40.14	28	36.49	2
23	Bundi	58.13	23	73.47	22	41.56	23	31.91	15
24	Bhilwara	57.17	25	73.12	24	41.08	24	32.04	13
25	Rajsamand	60.23	16	76.98	15	43.77	17	33.21	11
26	Dungarpur	58.95	20	73.28	23	44.75	16	28.53	27
27	Banswara	54.78	28	68.98	30	40.47	27	28.51	28
28	Chittorgarh	57.63	24	74.39	20	40.68	26	33.71	8
29	Kota	69.54	3	83.79	4	54.23	4	29.56	24
30	Baran	64.29	13	79.21	10	48.24	13	30.97	20
31	Jhalawar	58.24	22	73.73	21	42.01	20	31.72	17
32	Udaipur	55.85	26	70.84	27	40.46	25	30.38	22
33	Pratapgarh	53.50	31	67.90	31	39.05	29	28.85	26

Source: Census of Rajasthan, 2011

The Table 8 reveals that the strongest correlation (0.96) exists between the total literacy rate and the female literacy rate in urban areas followed by the second strongest correlation (0.99) exists between the total literacy rate and female literacy rate and the total literacy rate and female literacy rate in all areas and total literacy rate female literacy rate in rural areas. The correlation between the total literacy rate and the male literacy rate, total literacy rate and female literacy rate are all same in the area. There is correlation (0.96) between the total literacy rate and the male literacy rate.

A highly negative correlation (-0.50) exists between the female literacy rate and gender disparity in urban areas followed by 0.60 in the same category. The lowest negative correlation (-0.50) exists in the male literacy rate and gender disparity in rural areas followed by second lowest negative correlation of (-0.80) in the same category. The correlation between the male literacy rate and the female literacy rate is highest (0.84) for all areas and lowest at (0.83) for rural areas. The correlation between the total literacy rate and gender disparity is highest at (-0.89) for urban areas and lowest (-0.17) for rural areas.

The correlation between the female literacy rate and gender disparity is highest (-0.60) in urban areas and lowest in (-0.12) for rural areas.

Table 7. Urban Gender Disparity, 2011

S.no.	District	Total Literacy Rate	Rank	Male Literacy Rate	Rank	Female Literacy Rate	Rank	Gender Disparity	Rank
1	Ganganagar	79.43	18	86.19	26	71.78	14	14.41	30
2	Hanumangarh	78.78	22	86.06	27	70.76	15	15.30	27
3	Bikaner	78.65	24	86.39	25	70.12	16	16.27	23
4	Churu	73.63	31	84.66	30	62.00	29	22.66	9
5	Jhunjhunu	77.33	25	88.46	20	65.54	25	22.92	6
6	Alwar	84.25	6	92.16	6	75.22	7	16.94	22
7	Bharatpur	80.19	15	89.75	17	69.43	17	20.32	15
8	Dholpur	73.64	30	82.42	33	63.51	28	18.91	17
9	Karauli	73.93	29	85.60	28	60.79	30	24.81	2
10	Sawai Madhopur	79.96	16	91.06	11	67.80	21	23.26	5
11	Dausa	81.04	13	91.98	8	69.14	18	22.84	7
12	Jaipur	83.48	8	90.43	12	75.82	6	14.61	29
13	Sikar	76.64	27	87.38	24	65.26	26	22.12	11
14	Nagaur	72.11	32	83.56	32	60.03	31	23.53	4
15	Jodhpur	80.23	14	87.81	23	71.85	13	15.96	24
16	Jaisalmer	78.91	20	88.43	21	66.81	24	21.62	12
17	Barmer	79.52	17	90.28	13	67.45	22	22.83	8
18	Jalor	71.97	33	85.54	29	57.32	32	28.22	1
19	Sirohi	79.24	19	89.91	16	67.41	23	22.50	10
20	Pali	76.78	26	88.30	22	64.55	27	23.75	3
21	Ajmer	85.05	5	92.17	5	77.48	4	14.69	31
22	Tonk	74.78	28	84.03	31	65.54	25	18.49	18
23	Bundi	78.67	23	88.51	19	68.16	20	20.35	14
24	Bhilwara	82.63	10	91.20	10	73.40	10	17.80	19
25	Rajsamand	82.71	9	92.01	7	72.95	11	19.06	16
26	Dungarpur	85.79	3	93.00	3	78.29	3	14.71	28
27	Banswara	86.58	2	92.68	4	80.88	2	12.40	33
28	Chittorgarh	83.60	7	91.96	9	74.80	8	17.16	21
29	Kota	82.61	11	90.06	15	74.28	9	15.78	25
30	Baran	78.86	21	88.74	18	68.25	19	20.49	13
31	Jhalawar	81.82	12	90.23	14	72.84	12	17.39	20
32	Udaipur	88.45	1	94.45	1	82.02	1	12.43	32
33	Pratapgarh	85.46	4	93.10	2	77.61	5	15.49	26

Source: Census of Rajasthan, 2011

Table 8. Matrix of Rank Correlation between Different Variables

Variables	Rank Correlation		
	All areas	Rural areas	Urban areas
Total literacy rate and male literacy rate	0.945	0.96	0.931
Total literacy rate and female literacy rate	0.963	0.93	0.99
Male literacy rate and female literacy rate	0.84	0.83	0.83
Total literacy rate and gender disparity	-0.45	-0.17	-0.89
Male literacy rate and gender disparity	-1.00	-0.50	-0.80
Female literacy rate and gender disparity	-0.6	-0.12	-0.50

Source: Calculated by Authors based on data Census of Rajasthan, 2011

The Table 9 reveals that gender disparity in literacy at the district level is 27.08 percent in all the areas. Breaking up the figure, it is 31.24 percent in rural areas and in urban areas it is 17.63 percent. Thus, evidently there is more gender disparity in literacy in rural areas than in urban areas. If we compare gender disparity among districts, we find that Sawai Madhopur occupies first position in all sectors and rural areas. The top six districts in all urban and rural areas are Karauli Jalor, Jaisalmer, Tonk and Dausa. The least gender disparity are observed in both rural and urban areas is in Ganganagar.

Table 9. Matrix of Gender Disparity in Rajasthan, 2011

Sl. No.	Districts	All Areas		Rural Area		Urban Area	
		Gender Disparity	Rank	Gender Disparity	Rank	Gender Disparity	Rank
1	Ganganagar	19.26	33	21.05	33	14.41	30
2	Hanumangarh	21.91	31	23.54	31	15.30	27
3	Bikaner	23.13	29	22.91	32	16.27	23
4	Churu	25.17	28	26.93	30	22.66	9
5	Jhunjhunu	26.73	27	27.85	29	22.92	6
6	Alwar	28.30	18	30.77	21	16.94	22
7	Bharatpur	31.07	9	33.83	7	20.32	15
8	Dholpur	27.08	25	29.32	25	18.91	17
9	Karauli	33.78	2	35.45	4	27.81	2
10	Sawai Madhopur	34.92	1	37.97	1	23.26	5
11	Dausa	32.21	6	33.61	9	22.84	7
12	Jaipur	22.64	30	31.56	18	14.61	29
13	Sikar	27.90	19	29.69	23	22.12	11
14	Nagaur	30.27	12	31.86	16	23.53	4
15	Jodhpur	27.89	20	34.33	6	15.96	24
16	Jaisalmer	32.86	4	34.41	5	21.62	12
17	Barmer	31.29	7	31.95	14	22.83	8
18	Jalor	33.10	3	33.49	10	28.22	1
19	Sirohi	30.97	10	32.84	12	22.50	10
20	Pali	29.78	13	31.28	19	23.75	3
21	Ajmer	27.51	23	36.18	3	14.69	31
22	Tonk	32.26	5	36.49	2	18.49	18
23	Bundi	29.52	14	31.91	15	20.35	14
24	Bhilwara	29.23	16	32.04	13	17.80	19
25	Rajsamand	31.08	8	33.21	11	19.06	16
26	Dungarpur	27.68	22	28.53	27	14.71	28
27	Banswara	27.33	24	28.51	28	12.40	33
28	Chittorgarh	30.76	11	33.71	8	17.16	21
29	Kota	21.31	32	29.56	24	15.78	25
30	Baran	28.75	17	30.97	20	20.49	13
31	Jhalawar	29.41	15	31.72	17	17.39	20
32	Udaipur	26.81	26	30.38	22	12.43	32
33	Pratapgarh	27.73	21	28.85	26	15.49	26
Rajasthan		27.08		31.24		17.63	

Source: Calculated by Authors based on data Census of Rajasthan, 2011

Conclusions

The article presents empirical analysis of gender disparity in literacy across the districts of Rajasthan. It is observed that gender disparity increased continuously from 1951 to 1991 and for the first time gender disparity decreased by 2.75 percent in 2001. Since then, it has been continuously decreasing based on this study; we found that the district of Sawai Madhopur has the maximum gender disparity in both rural and urban areas. Meanwhile, the district of Ganganagar has the minimum gender disparity in rural areas and Banswara has the lowest disparity in urban areas. The article concludes that there is an inverse relationship between literacy and gender disparity; it reveals that there identifies higher gender disparity in rural areas than in urban areas (Ali, 2009). Major reasons for gender disparity in literacy in Rajasthan are traditional value system and social customs, anti-female attitude or biased mentality, distance from schools / colleges, lack of transport facilities, high dropout ratio among females, crime against females, more household responsibilities and so on. Some other reasons are poverty, family discouragement, lack of self-confidence, lack of awareness, low mobility, non-availability of proper guidance, unemployment, child marriage etc.

There is no district in the state which has better rate of female literacy than that of males. Hence, there is an urgent need to focus on female literacy in all areas, particularly rural areas to address the issue of gender disparity. It should be (Govt., common people and other organizations) demoralised the anti-female attitude and biased mentality among the people for better gender equality.

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TERRAIN MAPPING OF BANGALORE UNIVERSITY CAMPUS AND SURROUNDING AREAS USING GEOINFORMATICS

Lavanya J.[1] and Krishna Das[2]

[1]Department of Geography, Osmania University, Hyderabad - 500 007
[2]Department of Geography, Guwahati University, Guwahati - 781 014
E-mail: lava_gis@yahoo.com, rishnageog@gauhati.ac.in

Abstract

This study is attempted to map and also to study the surface terrain condition of Bangalore University campus with its surrounding areas using geoinformatics. Terrain is used as a general term in physical geography, referring to the lay of the land. This is usually expressed in terms of the elevation, slope and orientation of terrain features. The SRTM 30 metre resolution DEM data is used to extract useful terrain parameters like relief, slope, aspect, TRI and viewshed. The TIN model of the study area has visualised the terrain in three-dimensions. The study has found 790 metre as the base height that ranges to 885 metre as the maximum point. The study has also generated a GIS-based model for check dam site suitability and observed around 15 percent areas are suitable for the check dam. The entire study has focussed the applications of geospatial technology in mapping and analysing surface terrain characteristics of the study area. Terrain mapping and analyses results of this study will provide the base and also help the decision makers to make various infrastructural development planning choices in and around the study area with a scientific framework.

Keywords: Terrain, Development, DEM, TIN, TRI, GIS

Introduction

This study attempts to map and also to study the surface terrain conditions of Bangalore University campus with its surrounding areas using geoinformatics. The study area is located in the southwestern part of Bengaluru city in Karnataka State of India. Terrain analysis employs elevation data, usually in conjunction with other geospatial information, to describe the landscape, for basic visualisation, modelling or to support decision making. This is done under GIS environments using satellite-derived DEM, various terrain parameters like relief, slope, aspect, ruggedness, viewshed etc. The objectives of this study is to extract contours, triangulated irregular network, surface elevation profile of the study area using satellite derived digital elevation model (DEM) data; to map the terrain elements of the study area like relief, slope, aspect, terrain ruggedness index (TRI), viewshed using DEM data and to prepare a check dam site suitability model of the study area using parameters like slope, TRI and normalised difference vegetation index (NDVI).

Study Area

The study is confined to Bangalore University campus and surrounding areas that come within 500 metres within the University campus. The geographical extension of the study area is from 12.921°N to 12.965° N latitudes and 77.490° E to 77.525° E longitudes. The study area covers 12.32 sq. km with a volume of 45, 977,2131.06 cubic metres from 790 metre plane height. The study area includes whole of Gnana Bharathi University campus and some parts of surrounding areas like Nagarbhavi, Suvarna Badavane, Kenchenhalli, Jnana Ganga Nagar (Figure 1). Bangalore University has around 131 buildings in the campus comprising the roof top area of about 97,850 sq. mts. The landscape area of Bangalore University comprises of built-up land, road networks, green vegetation, plantations, waterbodies etc. There are check dams (waterbodies) in campus for water harvesting. Borewells and septic tanks also add up to the landuse of Bangalore University. The vegetation cover of 300 acre bio-park which is a lung space is also present in the campus.

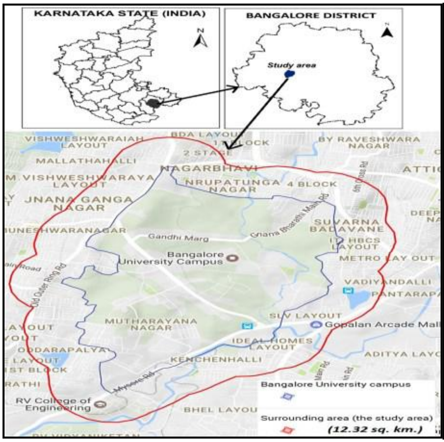


Fig. 1. Study Area

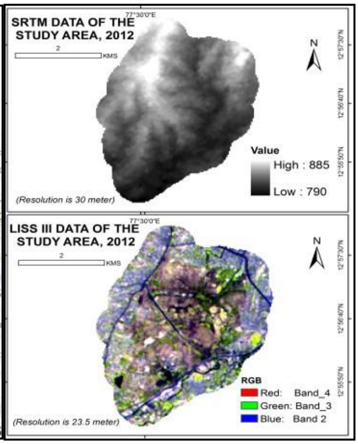


Fig. 2. Satellite Datasets used in the Study

Database and Methodology

Shuttle Radar Topography Mission (SRTM) DEM data is the prime data source of this study. The SRTM data is a satellite derived DEM data with one arc-second, i.e. 30 metre resolution. The SRTM is an international research effort. The elevation models are arranged into tiles, each covering one degree of latitude and one degree of longitude, named according to their south-western corners. It follows that 'n45e006' stretches from 45^0 N and 6^0 East to 46 ^{0} N and 7 ^{0} East and 's45w006' from 45^0 S ad 6^0 West to 44^0 South and 5^0 West. The resolution of the cells of the source data is one arc second. The IRS LISS III data with 23.5 metre resolution is also used in this study. The LISS III data have been collected from the Bhuvan geo-portal of ISRO. These satellite datasets have been projected on WGS84UTM 43 North projection system for further analysis in GIS environments.

Licensed ArcGIS and Open source QGIS software packages have been used in the analyses and map making.

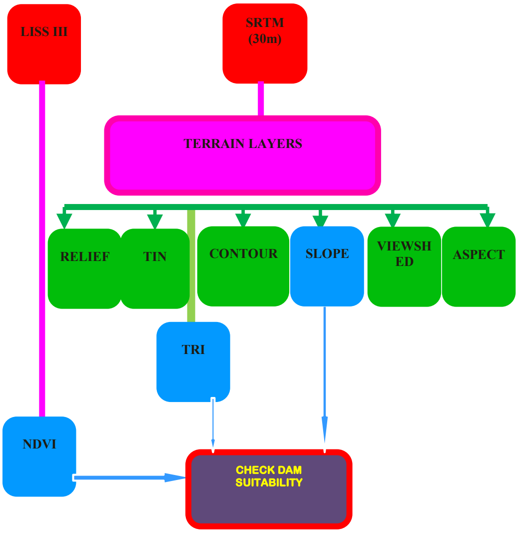


Fig. 3. Flow of the Methodology

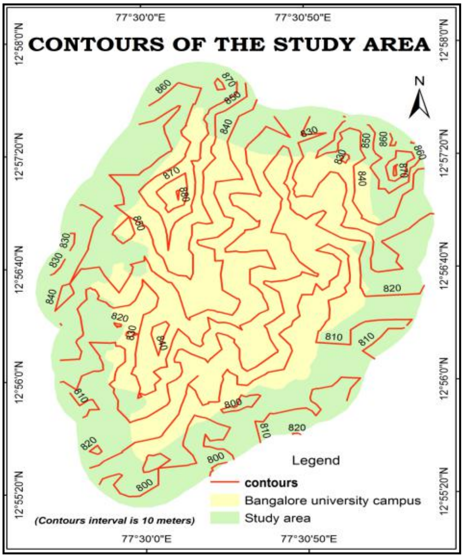


Fig. 4. Contours

Table 1. The IRS LISS III Data Specification

IRS LISS III Tiles; Year: 2012; Season: Post-monsoon; Resolution: 23.5 metre; Projection: WGS84UTM43N.	
Band	**Wavelength (micrometres)**
B2 (green)	0.52-0.59
B3 (red)	0.62-0.68
B4 (near infrared)	0.77-0.86
B5 (mid infrared)	1.55-1.70

Results and Discussion

All outputs of the study are presented in maps and using these maps, statistics and results have been derived. The 3-D analyst, terrain analysis and spatial analysis tools are used to derive the map analyses in this study under GIS environments. Raster-based reclassification and raster-overlay techniques are also used to extract geo-statistics from the analyses.

From the SRTM DEM data of the study area, 790 metre is observed as lowest elevated point, whereas, 885 metre is observed as the highest elevated point in the study area. To calculate the volume of the study area, TIN surface model has been generated with 10 metres interval contours for the study area as a whole. A transect line is drawn to understand the vertical surface profile condition of the study area.

The Figure 4 shows the contours of the study area at 10 metres interval. These contours have been extracted from SRTM DEM of the study area The 800 metre is the base contour of the study area, whereas, 880 meter is observed as the highest contour. The Figure 5 shows the TIN model of the study area that is visualised in three dimensions. The TIN model is used to calculate the volume of the study area above the 790 metre plane height. The volume of the study area has been observed at 45,977,2131.06 cubic metres. The Figure 6 shows the surface elevation profile of the study area on AB transect line. From point A to point B over the transect line, an undulating as well as increasing altitude condition of the terrain has been observed. The Figure 7 shows NDVI of the study area. The NDVI value of the study area ranges from 0.002 to 0.645. High positive decimal of NDVI values show healthy and dense vegetation in the study area.

This NDVI output is taken as an input for check dam site suitably analysis for the study area. The Figure 8 shows the relief map of the study area with four relative relief classes. These classes include four scaled categories of relief of the study area. These are very high (above 859 m), high (836-859 m), moderate (814-836 m) and low (below 814 m). It has been observed that relief of the study area increases from South to the North-Western corner of the study area. The Table 2 shows the relief statistics of the study area. The percentage share of each relief class to the total geographical area of the study area is observed. It is found that the category above 859 m has the least percentage, whereas, 814 to 836 m category has the highest percentage. It has been observed that below 814 m category relief covers an area of 315 hectares.

Table 2. Relief Statistics of the Study Area

Elevation in Metres	Area Hectare	Percentage to Total Area
Below 814	315.00	25.57
814-836	514.00	41.72
836-859	332.00	26.95
Above 859	71.00	5.76
Total	**1,232.00**	**100.00**

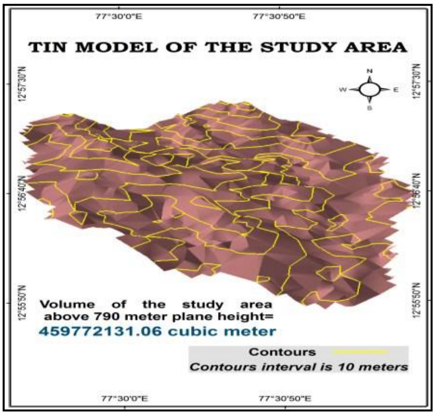


Fig. 5. TIN Model

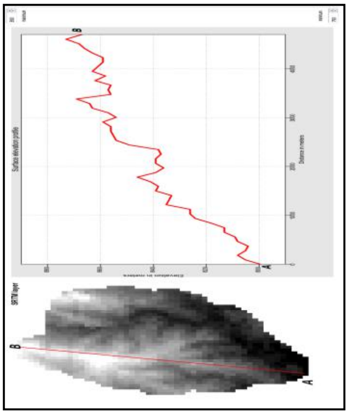
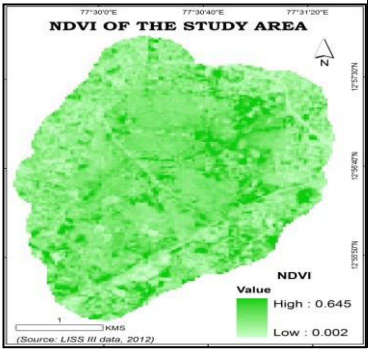


Fig. 6. Elevation Profile on AB Transect Line



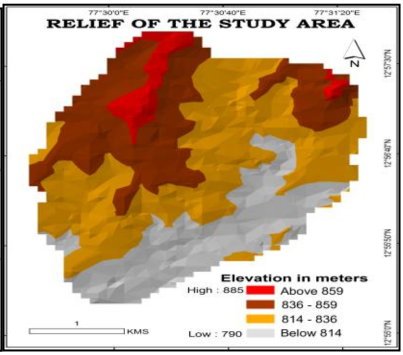


Fig. 7. NDVI - 2012 **Fig. 8. Relief**

The Figure 9 shows slope map of the study area with four slope classes. These classes include four scaled slope categories of the study area. These are nearly gentle slope (below 3 degree), moderately gentle slope (3-5 degree), moderately steep slope (5-7 degree) and highly steep slope (above 7 degree). The Table 3 shows the slope statistics of the study area. The percentage share of each of the slope classes to the total geographical area of the study area is observed. It is found that the category below 3 degree slope category shares the highest percentage, whereas, above 7 degree slope category shares the least percentage to the total. It has been observed that below 3 degree slope category covers an area of 503 hectares.

Table3. Slope Statistics of the Study Area

Slope in Degree	Area Hectare	Percentage to Total Area
BELOW 3	503.00	40.83
3-5	435.00	35.31
5-7	204.00	16.56
Above 7	90.00	7.31
Total	**1,232.00**	**100.00**

The Figure 10 shows the aspect map of the study area. This shows direction of the slope clockwise from 0 to 360 degrees in 0 directional categories. The Table 4 shows the aspect statistics of the study area extracted from Figure 10. Maximum 216 hectares of area is observed under southeast direction of aspect classes and the same shares around 18 percentages to the total area The Figure 11 shows the Terrain Ruggedness Index (TRI) map of the study area. This TRI map categorises the study area into four ruggedness classes. These are nearly level terrain (below 4.35), intermediately rugged terrain (5.35-6.85), moderately rugged terrain (6.85-10.14) and highly rugged terrain (above 10.14). Highly rugged terrain patches are observed more in the northern part of the study area. The Table 5 shows the TRI statistics extracted from Figure 11. It has been observed that intermediately rugged terrain covers an area of 487 hectares. Intermediately rugged terrain has the highest percentage share to the study area, whereas, highly rugged terrain shares the least percentage.

Table 4. Aspect Statistics of the Study Area

Aspect Direction	Area Hectare	Percentage To Total Area
Flat	1.00	0.08
North	55.00	4.46
Northeast	135.00	10.96
East	186.00	15.10
Southeast	216.00	17.53
Southeast	160.00	12.99
Southwest	152.00	12.34
West	168.00	13.64
Northwest	123.00	9.98
North	36.00	2.92
Total	**1,232.00**	**100.00**

Table 5. The TRI Statistics of the Study Area

TRI	Area in Hectares	Percentage to Total Area
Below 4.35	375.00	30.44
4.35-6.85	487.00	39.53
6.85-10.14	286.00	23.21
Above 10.14	84.00	6.82
Total	**1,232.00**	**100.00**

The Figure 12 shows the viewshed condition map of the study area observed from eight random locations. A, B, C, D, E, F, G, and H are the observed random locations from where terrain visibility condition has been observed. From these eight observed locations, the visibility conditione is observed and mapped under two major categories. These two categories are visible and not visible classes. The Table 6 shows the statistics of viewshed analysis. Visible class covers an area of 662 hectares, whereas, non-visible class covers an area of 570 hectares. From the eight observed locations around, 54 percent area is visible to the total study area. The Table 7 shows the co-ordinate's details of the observed random locations in terms of latitude, longitude and altitude from point A to point H.

Table 6. Viewshed Statistics of the Study Area

Viewshed	Area in Hectares	Percentage to Total Area
Not Visible	570.00	46.27
Visible	662.00	53.73
Total	**1,232.00**	**100.00**

Table 7. Location Details of the Random Observed Points for Viewshed Analysis

ID	Code	Longitude (X)	Latitude (Y)	Altitude in Metres
1	A	773462.60618100000	1433710.05303999000	857
2	B	772360.56220100000	1433867.48789000000	824
3	C	772035.85281499900	1431997.94900000000	842
4	D	771150.28176000000	1429803.70072000000	794
5	E	770727.17558899900	1432922.87877000000	837
6	F	770559.90105600000	1431240.29376000000	825
7	G	772439.27962799900	1430640.07338000000	814
8	H	773620.04103500000	1432558.81067000000	825

The Figure 13 shows the GIS-based model for check dam site suitability using three selected parameters. These parameters include slope, terrain ruggedness index and NDVI derived vegetation cover of the study area. For the check dam site suitability analysis, a conditional procedure has been adopted. This condition explains that the check dam sites should be in rugged terrain areas with steep slope and minimum vegetation. To meet this condition under GIS environment, the slope layer, terrain ruggedness index layer and NDVI layer have been reclassified into two distinct classes using raster-based reclassification technique. These two classes include suitable class with code 1 and not-suitable class with code 0. Using these 2 two class codes, each of the three parameters (slope, TRI and NDVI) has been reclassified to generate the final input layers for check dam site suitability model. For slope layer above 5 degree slope area is taken as suitable; for NDVI layer below 0.241 NDVI area is taken as suitable; and for TRI layer above 6.85 rugged terrain area is taken as suitable. These three reclassified input layers of the study area have been overlaid onto one another under The GIS environment using raster overlay technique to generate the final suitability map as the model output. The final check dam suitability map shows two classes, i.e. suitable with code 1 and not suitable class with code 0. It has been observed that the final suitable sites for check dams are distributed over the study area in such a way where the pre-defined condition for all three input layers met. The Table 8 shows the final site suitability statistics of check dam extracted from site suitability model. Around 15 percent of area to the total geographical area is found to be suitable for check dam. It has been observed that 190 hectares of area is generated as suitable and within these areas check dam can be set up anywhere. On the contrary, 1,042 hectares of area is found to be not suitable for check dam in the study area.

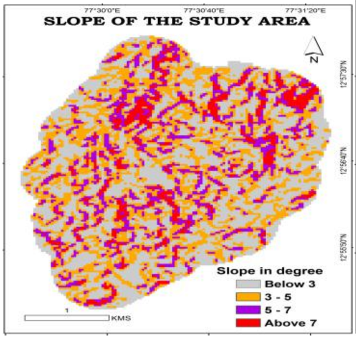


Fig. 9. Slope

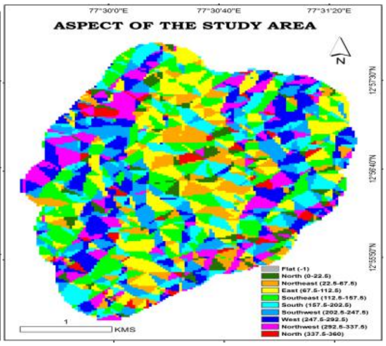
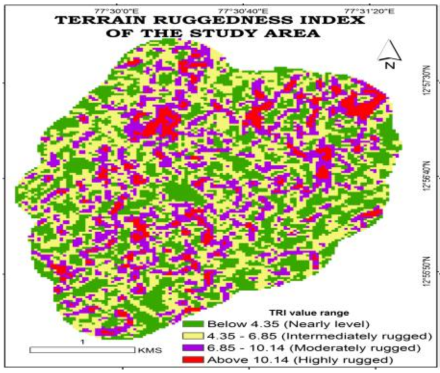


Fig. 10. Aspect

Table 8. The Suitability Statistics of the Study Area

Suitability	**Area in Hectare**	**Percentage to Total Area**
Not Suitable	1,042.00	84.58
Suitable	190.00	15.42
Total	**1,232.00**	**100.00**



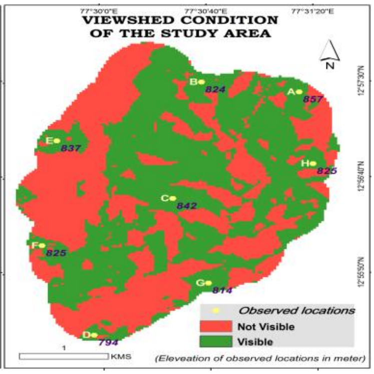


Fig. 11. TRI **Fig. 12. Viewshed**

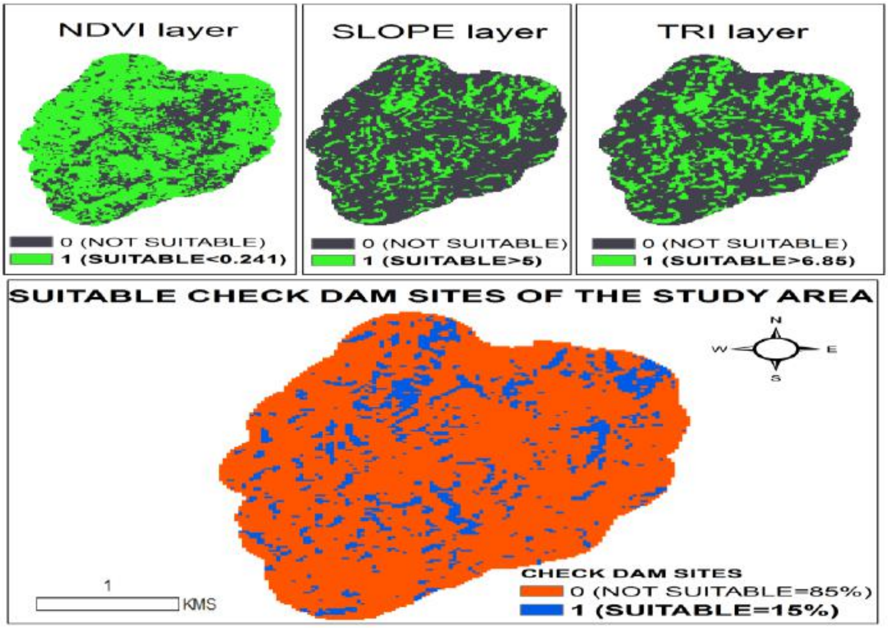


Fig. 13. Site Suitability for Check Dam in the Study Area

Conclusions

The study has observed terrain condition of Bangalore University campus and surrounding areas through the analyses of satellite derived DEM data using geoinformatics. SRTM 30 meter resolution DEM data is used to extract useful terrain parameters like relief, slope, aspect, TRI and viewshed. TIN model of the study area has visualized the terrain in three-dimensions. The study has found 790 meter as the base height that ranges to 885 meter maximum point. The study has also generated a GIS-based model for check dam site suitability and observed around 15 percent areas are suitable for the check dam. The entire study has focussed on the applications of geospatial technology in mapping and analysing surface terrain characteristics of the study area. This study will certainly provide useful knowledge and information to the researcher community for effective application of geoinformatics in various natural resources observational studies. Terrain mapping and analyses results of this study will provide the base and also help the decision makers to plan various infrastructural developments in and around the study area with a scientific framework.

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DINDIGUL PANCHAYAT UNION - IMPACT OF LEATHER TANNING INDUSTRIES ON SOIL QUALITY USING GEOINFORMATICS

Latha S. and Kumaraswamy K.

Department of Geography, Bharathidasan University, Tiruchirappalli - 620 024
E-mail: lathapala@yahoo.co.in, kkumargeo@gmail.com

Abstract

Our standard of living, that predominantly depends on agriculture, is often determined by a combination of the physical, chemical and biological characteristics of the soils and the crops raised on them. Soil is defined as a natural medium, which serves as a reservoir of nutrients and water for crops and provides mechanical anchorage and favourable tilth for crops. Soil quality degradation is a serious problem affecting the agricultural productivity. The industrial waste dumped in the soil, deteriorates the quality of the soil and leads to degradation. The toxic effluents of the 38 leather tanning industries have highly degraded the soil quality of the study area, Dindigul Panchayat Union. The surface soil samples were collected and subjected to chemical analysis for various parameters. The results prove that the soil quality of the study area has lost its importance and it is slowly stepping towards degradation. Hence in the present study, an attempt is made to assess the the impact of leather tanning industries on soil quality in relation to plant growth in Dindigul panchayat union using Geographic information System. The present study will contribute to the methodology of scientific analysis on the one hand and will also help to preserve the quality of the soil on the other hand.

Keywords: Soil quality, Leather tanning industries, Chemical analysis

Introduction

Soil is defined as a natural medium, which serves as a reservoir of nutrients and water for crops and provides mechanical anchorage and favourable tilth for crops. The knowledge of soil is very essential for any kind of planning for development and management of land for agriculture, better land use and cropping pattern and water management practices for better production of crops. Our standard of living that predominantly depends on agriculture is often determined by a combination of the physical, chemical and biological characteristics of the soils and the crops raised on them. Soils provide essential material on which agriculture is based, and therefore, any comprehensive survey of the geography of agriculture should undertake a fairly thorough treatment of soil.

Soil exhaustion results very rapidly from excessive population pressure, unenlightened farming practices and the excessively liberal and therefore, dangerous doctrine of production at the lowest investment of soil-capital. The toxic effluents of the leather tanning industries, located in the study area, have highly degraded the soil quality of the study area. Hence in the present study, an attempt is made to assess the soil quality in relation to plant growth in Dindigul panchayat union.

Bhavani (1995) has assessed the soil quality in North Arcot District, Tamil Nadu, India. In the study, the soil quality is measured through standardized soil testing methods and the alkalinity, acidity and salinity levels were analysed. Carlos et al., (2002), made an analysis on the adverse effects of chromium among the tannery workers. Chandhuri (1984) has attempted to study the soil fertility of Bolpur District of West Bengal. The results of the study proves that the different chemical constituents i.e., nutritive elements like nitrogen, phosphorus and potassium, have an integrated effect on crop yield. Chapman (1963) observed that tannery wastes has altered the entire physical and chemical characteristics of the soil. His results proved that the tannery waste water that was taken in by the plants had influenced their metabolic processes.

During the dry and rainy season, to assess the effect of farming along river banks on the quality of water, where a significant seasonal change is studied by Chimwanza et.al., (2006). Gerald (2001) in his study on arsenic contamination by a tannery site near Compton town house in Wilmington has reported that the arsenic concentration in the soil was higher than the acceptable level. This arsenic concentration has made the soil barren. Vijayakumari (2003), made a study on the impact of textile dyeing effluent on growth of soybean. Vidal et.al., (2004), analysed the combined oxidative and biological treatment of separated streams of tannery wastewater. Krishna et.al., (2007) undertook a study on soil contamination in Surat, Gujarat, to determine the extent and distribution of heavy metals and have delineated the geogenic and anthropogenic sources and correlation of metals in soils.

Study Area

Dindigul panchayat union is situated in Dindigul District, Tamil Nadu (Figure 1). It lies between 10°14’45” and 10°31’00” North latitudes and 77°45’ and 78°4’30” East longitudes covering the Survey of India (SOI) topographic map 58 F/14, F/15, F/16 and 58 J/3 extending over an area of 378.71 sq.km. The area consists of 18 administrative units i.e., village panchayats namely Adiyanuthu, Agaram, Alakkuvarpatti, Ammakulathupatti, Anaipatti, Balakrishnapuram, Chettinaickanpatti, Kovilur, Kurumbapatti, Mullipadi, Pallapatti, Periyakottai, Silapadi, Sirumalai, Thadikombu, Thamaraipadi, Thottanuthu and Vellodu. Among these, Sirumalai village panchayat is a hilly area located in the southern part of the study area (Figure 2).

Out of the 61 leather tanning industries located in Dindigul District, 38 leather tannery units (62.3 percent of the district’s units) are located in Dindigul panchayat union. The 38 leather tannery units that are located in Dindigul panchayat union were captured using GPS (Global Positioning System) survey and mapped. These 38 leather tanning industries are distributed in Pallapatti (19), Adiyanuthu (12) village panchayat, Dindigul

Municipality (4), and Vellodu (3) village panchayat. The 38-leather tanning industries located in the study area are captured using GPS (Global Positioning System) survey, and the zoomed portions of these industries are shown in Figure 3. It is quite obvious that the leather tanning industries are concentrated in the central western part of the study area.

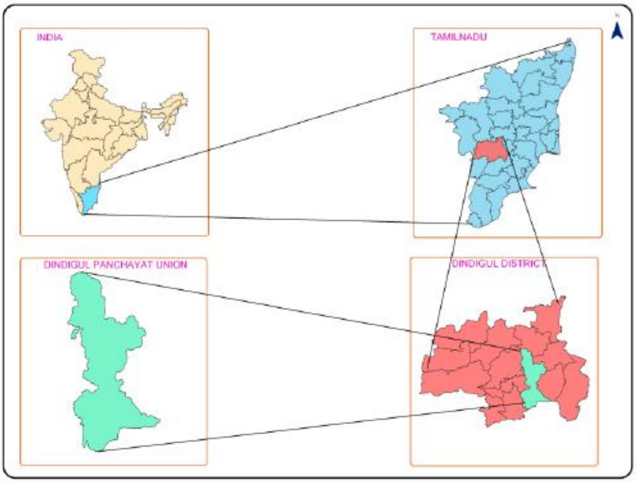

Fig. 1. Location of Dindigul Panchayat Union

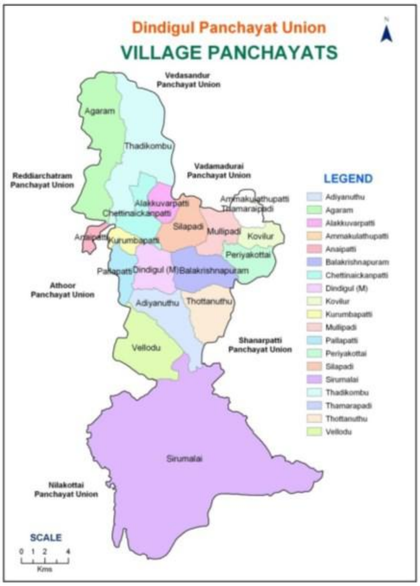

Fig. 2. Dindigul Panchayat Union - Village Panchayats

Location of Leather Tanning Industries

In the study area the leather tannery industries may have an effect on the quality on ground water and soil as they discharge about 6,88,000 litres to 15,48,000 litres per day of waste water with toxic effluents like, Chloride, Chromium, Nitrate, Sodium, Calcium, Magnesium, Copper, Iron etc. The effluents of the leather tanning industries have degraded the soil quality of soil in the study area. In the light of this discussion, it is felt to test and analyze the quality of soil in Dindigul panchayat union. Hence in the present study, an attempt is made to assess the soil quality in relation to plant growth in Dindigul panchayat union.

Database and Methodology

To study the spatial distribution of soil nutrients status during 2014, surface soil samples (0-20 cm) were collected from five to six different sites selected at random in each of the village panchayats and were subjected to chemical analysis for 11 parameters. The methodology followed to assess the soil quality of the study area is shown in Flow Chart1. The objectives are to study the spatial distribution of soil nutrients during 2014 and further to analyse the impact of leather tanning industries on the soil quality of the study area.

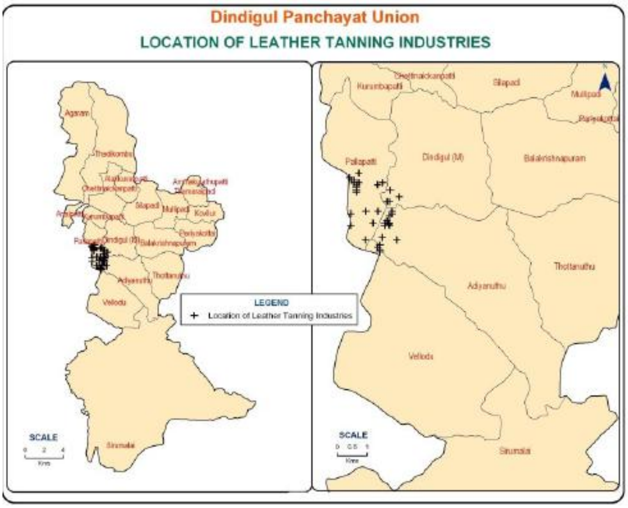

Fig. 3. Location of Leather Tanning Industries

Spatial Distribution of Soil Quality

To study the spatial distribution of soil nutrients status during 2014, surface soil samples (0-20 cm) were collected from five to six different sites selected at random in each of the village panchayats and were subjected to chemical analysis for 11 parameters. These soil samples were analyzed for their Organic Carbon content (OC), Soil Reaction (pH), Electrical Conductivity (EC) and status of major plant nutrients like, Available Nitrogen, Available Phosphorus and Available Potassium and also the micronutrient contents like, Zinc, Iron, Manganese, Copper and Chromium.

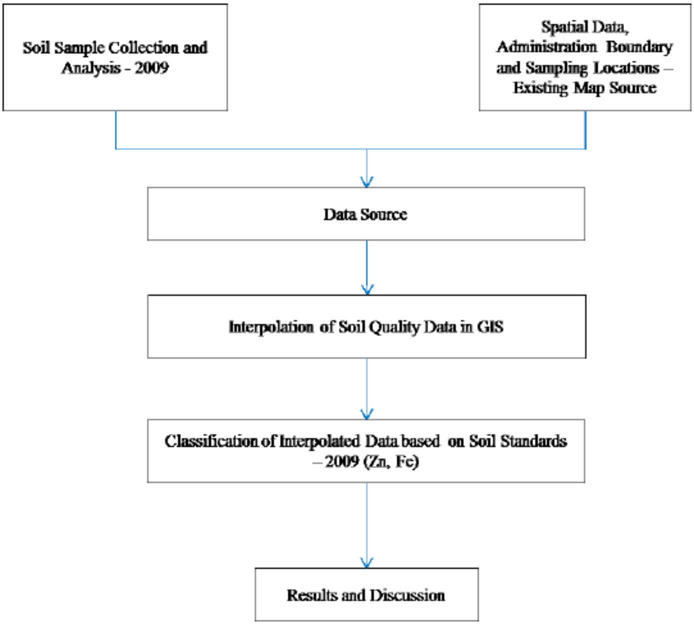

Fig. 4. Methodology of the Study

Average values were calculated for every village panchayat. Inverse distance weighted method is used to create the soil quality maps. No distortion of isoline was interpolated. Table 1 shows the standards for the selected parameters used in the study.Based on the results, contour maps are generated for each parameter using ARC/MAP software to study the spatial distribution of each parameter in the study area.

Soil Reaction (pH)

The study on the spatial distribution of pH in the study area during 2014, shows that the values are noticed between 6.5-8.5, indicating that the soil reaction was neutral in all the village panchayats. This may be due to the soil types prevalent in the study area.

Electrical Conductivity (EC)

The spatial distribution of EC in the study area during 2014, shows that the values are found to be less than 1.0 dsm-1, which means non-saline, in all the village panchayats. This may be due to the soil types existing in the study area.

Available Nitrogen

The plant available nitrogen content of soils in the study area during 2014, shows that the nitrogen content is low (<113 ppm) in all the village panchayats.

Available Phosphorus

The spatial distribution of available phosphorus during 2014 in the study area is shown in Figure 4. From the figure, it could be observed that the phosphorus content is moderate (4.6-9.0 ppm) in parts of Adiyanuthu, Pallapatti, Chettinaickanpatti, Thamaraipadi, Anaipatti and Sirumalai village panchayats.

It is noted to be high (>9.0 ppm) in the rest of the study area.It should be noted that, none of the village panchayats have low (<4.5 ppm) phosphorus content. These changes may be due to the application of different management practices like, types of crops grown, fertilizers applied etc.

Available Potassium

A study on the distribution of plant available soil potassium during 2014 in the study area is shown in Figure 5. From the figure, it could be observed that the potassium content is moderate (49-113 ppm) in some areas of Pallapatti, Adiyanuthu, Kurumbapatti, Kovilur, Ammakulathupatti and Chettinaickanpatti village panchayats.

It is high (>113 ppm) in the rest of the village panchayats. It should be noted that, none of the village panchayats have low (< 48 ppm) potassium content. The changes may be due to the differences in soil characteristics.

Manganese

The spatial distribution of concentration of manganese during 2014, in the study area is shown in Figure 6. From the Figure, it could be observed that the manganese content is deficient for plant growth (<2.0 ppm) in Silapadi and small parts in Periyakottai, Kovilur, Mullipadi, Agaram, Chettinaickanpatti and Thadikombu village panchayats totally covering an area of 12.84 sq.km.

In the remaining areas, the manganese content is sufficient for plant growth (>2.0 ppm) totally covering an area of 396.86 sq.km. The spatial distribution of concentration of manganese, shows that the manganese content is deficient for plant growth in 3.13 percent and it is sufficient for plant growth in about 96.87 percent of the study area.

Zinc

The study on the concentration of zinc during 2014, in the study area is shown in Figure 7. From the figure, it could be observed that the zinc content is deficient for plant growth (<1.2 ppm) in Agaram, Thadikombu, Anaipatti, Chettinaickanpatti, Alakkuvarpatti, Silapadi, Thamaraipadi, Ammakulathupatti, Vellodu and parts of Adiyanuthu and Kovilur village panchayats covering an area of 155.94 sq.km. In the remaining areas, the content of zinc is sufficient for plant growth (>1.2 ppm), occupying an area of 253.76 sq.km. The spatial distribution of concentration of zinc shows that it is deficient for plant growth in about 38.06 percent and is sufficient for plant growth in about 61.94 percent of the study area.

Iron

The spatial distribution of concentration of iron during 2014, in the study area is shown in Figure 8. From the figure, it could be observed that the iron content is deficient for plant growth (<3.5 ppm) in minor areas of Thamaraipadi and Agaram village panchayats covering an area of only 0.99 sq.km. In the rest of the areas, the iron content is sufficient for plant growth (>3.5 ppm) occupying an area of 408.71 sq.km. The spatial distribution of concentration of iron, shows that it is deficient for plant growth in about 0.24 percent and it is sufficient for plant growth in about 99.76 percent of the study area.

Copper

In the study area, the spatial distribution of concentration of copper during 2014, is shown in Figure 9. From the figure, it could be observed that the copper content is deficient for plant growth (<1.2 ppm) only for 0.02 sq.km in Alaguvarpatti village panchayat.

In the remaining areas, the copper content is sufficient for plant growth (>1.2 ppm) covering an area of 409.68 sq.km. The spatial distribution of concentration of copper, shows that it is deficient for plant growth in about 0.01 percent and it is sufficient for plant growth in about 99.99 percent of the study area.

Table 1. Standards for Soil Quality in Relation to Plant Growth

Parameters	Permissible Limits		
Soil Reaction (pH)	Acidic < 6	Neutral 6.5 - 8.5	Alkaline > 8.5
Electrical Conductivity (EC) (dsm-1)	Low < 1.0	Medium 1.0 - 2.0	High > 3.0
Available Nitrogen (in ppm)	Low < 113	Moderate 114 - 183	High > 183
Available Phosphorus (in ppm)	< 4.5	4.6 - 9.0	> 9.0
Available Potassium (in ppm)	< 48	49 - 113	> 113
Manganese (in ppm)	Deficient for Plant Growth < 2.0		Sufficient for Plant Growth > 2.0
Zinc (in ppm)	< 1.2		> 1.2
Iron (in ppm)	< 3.5		> 3.5
Copper (in ppm)	< 1.2		> 1.2
Organic Carbon (in %)	Low < 0.5	Moderate 0.5 - 0.75	High > 0.75
Chromium (in ppm)	Safe < 0.1	-	Unsafe > 0.1

Source: Soil Testing Laboratory, Dindigul

Analysis of the Spatial Distribution of Critical Parameters

Among the above-discussed parameters, the most critical parameters for soil are Organic Carbon and Chromium. These sensitive parameters are found to be affected by the leather tannery effluents that are detrimental to soil quality.

It is already noted that the leather tanning industrial units located in the study area are concentrated in Pallapatti, Adiyanuthu and Vellodu village panchayats and Dindigul Municipality. Hence, an attempt is made to study the spatial distribution of these critical parameters in the village panchayats where the leather tanning industries are located.

Organic Carbon

Being the major indicator for pollution, the distribution of organic carbon during 2014, in the study area is shown in Figure 10. From the figure, it could be observed that the organic carbon content for plant growth is moderate (0.5-0.75 percent) in Kurumbapatti, parts of Agaram, Sirumalai, Chettinaickanpatti, Thadikombu and Kovilur village panchayats totally occupying an area of 11.37 sq.km. In the remaining areas, the content of organic carbon is high (>0.75 percent) occupying about 398.33 sq.km.

The organic carbon content is noted to be ranging between 1.06 to 2.84 percent in the area (Danger Zone) where the leather tanning industries are located. The areas that have very high content of organic carbon may indicate the pollution effects of leather tannery effluents in the soil. The spatial distribution of organic carbon in the study area, shows that it is moderate in about 2.78 percent and it is high in about 97.22 percent of the study area.

Chromium

The spatial distribution of concentration of chromium during 2014, in the study area is shown in Figure 11. From the figure, it could be observed that the chromium content for plant growth is safe (<0.1 ppm) in Ammakulathupatti and minor parts of Thamaraipadi, Kovilur, Silapadi, Mullipadi, Balakrishnapuram and Thottanuthu village panchayats totally covering an area of 5.25 sq.km. The rest of the village panchayats, the content of chromium is unsafe (>0.1 ppm) covering about 404.45 sq.km. The chromium content is found to be very high ie., 0.5 to 0.9 ppm in the areas (Danger Zone) where the leather tanning industries are located. The spatial distribution of concentration of chromium in the study area, shows that it is safe for plant growth in about 1.28 percent and it is unsafe for plant growth in about 98.72 percent of the study area.The above analysis made on the status of critical parameters of leather tannery industries on the soil quality reveal that the concentration of organic carbon is high in the areas where leather tannery industries are found. Also, the content of chromium is unsafe in the village panchayats where the leather tannery industries are located. Hence, it could be safely concluded that the effluents of leather tannery industries in the study area has affected the soil quality. It could also be stated that if this situation continues for years, the soil quality might still be degraded and will result in desertification.

Results and Discussion

Based on the above results, it could be concluded that the soil quality is getting depleted in the study area. The status of plant available nitrogen, phosphorus and potassium were found in sufficient levels in the soil of the study area. The status of micro nutrients like manganese, zinc, iron and copper are not affected by the leather tannery effluents.The discharge of toxic leather tannery effluents has increased the content of organic carbon in the soil of the study area.

The spatial distribution of organic carbon shows that it is moderate only in about 2.78 percent (11.37 sq.km) and it is high in about 97.22 percent (398.33 sq.km) of the study area. But the concentration of the most critical parameter, chromium, is noted to be exceeding the permissible standards in major part of the study area. This indicates the pollution effect of leather tannery effluents in the soil. The content of chromium is noted to be safe only in village panchayats like Ammakulathupatti and parts of Thamaraipadi, Kovilur, Silapadi, Mullipadi, Balakrishnapuram and Thottanuthu covering about only 5.25 sq.km (1.28 percent). But the rest of the areas fall under the poor (unsafe) class totally occupying 404.45 sq.km (98.72 percent).

It is noticed that the concentration of Chromium is unsafe in village panchayats like Pallapatti, Adiyanuthu, Vellodu and Dindigul Municipality, where the leather tanning industries are located. It can thus be concluded that the effluents of leather tanning industries containing toxic elements like chromium has degraded the soil quality in these areas. The soil conditions of the village panchayats, which are located near the leather tanning industries, are also affected by the intrusion of Chromium.

Generally, soil is not affected easily like water due to its buffering (resistance to any change) capacity. The soil pH level is neutral in the study area. In future, if the soil pH is still increased by the addition of toxic leather tannery effluents, naturally the quality of the soil will also slowly deteriorate in the study area. The general slope of Dindigul panchayat union is from south to north. The major river of the study area, Kodaganar, has its origin from the hill tracts located in the southern part of the study area. The toxic effluents from the leather tannery industries, located in the western part of the study area, mixed in the ground water might have been carried through the under-ground water throughout the study area, as the slope is from south to north. Thus, the degraded ground water quality has also affected the soil status of the study area.

It could be concluded that the degraded soil quality in the western part of the study area including Pallapatti, Adiyanuthu and Vellodu village panchayats and Dindigul Municipality may be due to the protrusion of toxic effluents directly to the soil from the leather tanning industries. But in the remaining areas of the study area, the decrease in the quality of soil is due to the intrusion of toxic chemicals mixed in the leather tannery effluents that are carried by the under-ground water. Hence proper soil conservation measures should be undertaken to recover the fertility of the soil in the study area.

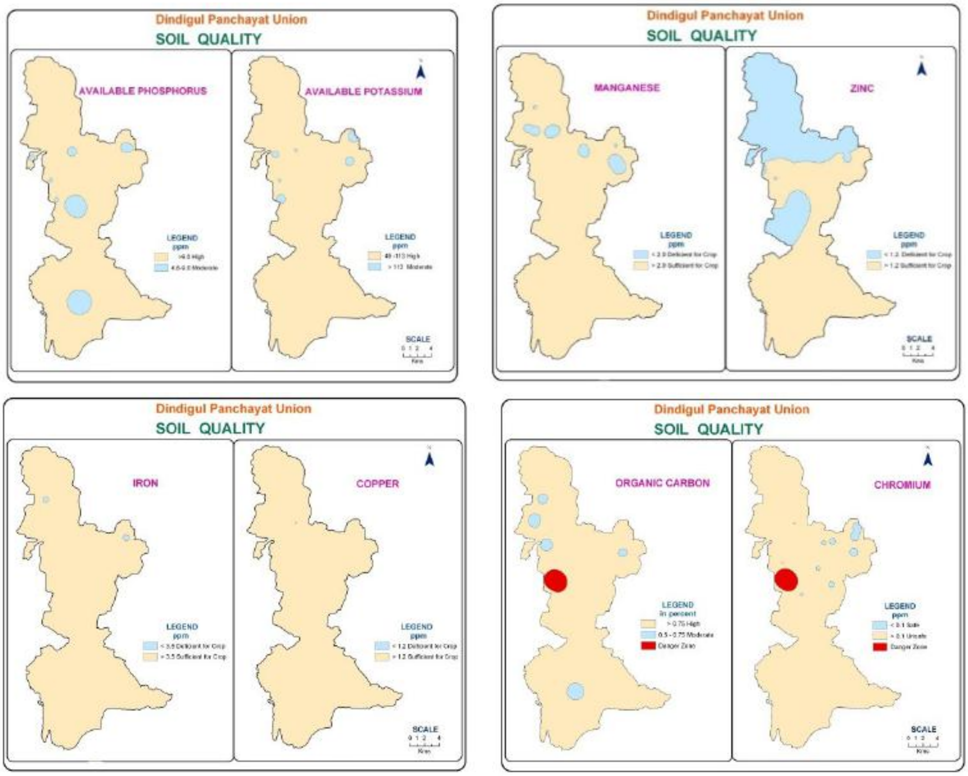

Fig. 4. Soil Quality Parameters of Dindigul Panchayat Union

This study on soil quality of Dindigul panchayat union has proved that the status of soil has been degraded due to the intrusion of the toxic effluents from the leather tannery industries located in the study area. Hence, the following recommendations are suggested for improving the soil quality in the study area.

1. Fertilizer consumption determines the growth of a crop. But recently it is observed that the use of chemical fertilizers may damage the quality of soil. Hence increased use of green manure consumption will enhance the soil quality of a region. Bio fertilizer and compost may stabilize the fertility of the soil.
2. Pesticide consumption at the proper time also helps to increase the productivity of soil. Chemical fertilizers use has to be avoided so as to improve productivity of soil from further degradation. Natural farming using herbal pesticides will protect the microorganisms in soil. Pest attack recommendations suggested by the agricultural department should be followed.
3. Periodical soil testing has to be done. Based on this the crops suitable for cultivation can be selected. Soil testing also help in further plant protection measures. Proper soil management is the dire need for increasing the productivity of soil. Soil enrichment can be made by following effective irrigation systems that includes drip and sprinkler irrigation. Dry farming technologies such as soil conservation measures are also suggested.
4. Policies should be framed in adopting suitable restriction on the use of vulnerable lands. This can be better achieved through national spirit and co-operation with technical experts, planners, administrators and active participation of farmers. Cultural practices like removal of weeds should be done in summer season. Based upon the tests, market requirement and season, the crops which suits the soil quality should be selected for cultivation. Native trees, which need less water, may also be planted on all fallow and waste lands. Neem is the best native tree that can be grown in any type of soil.

Conclusions

By adopting these measures in the right time, the area under low quality soil can also be used successfully to obtain a high produce. By following the necessary recommendations suggested in the study, the further deterioration of the soil quality can be minimised to a certain level in Dindigul panchayat union. The present study on soil quality would help in knowing the real causes for the agricultural backwardness and will provide a sound base for the rural economic progress making agriculture more viable and sustainable. Hence, delineating and improving the quality of the soil is a pre-requisite for future planning and development of agricultural activities in the study area.

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News and Notes

THE INDIAN GEOGRAPHICAL SOCIETY

Department of Geography, University of Madras, Chennai – 600 005

Conduct of 5th Talent Test - 2015 for Geography students on 20th January, 2015

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The Indian Geographical Society is organising the state wide **Fifth Talent Test - 2015** for final year UG and PG students of the Geography Departments in Tamil Nadu on **20th January, 2015**. The Executive Committee of the Society has identified the following coordinators to organise this event successfully with the support of Principals of the respective colleges and Heads of Geography Departments.

Regional Coordinators

1**. Dr. G. Bhaskaran (Chennai Region),**
Assistant Professor, Department of Geography, University of Madras,
Chennai - 600 005, ***Mobile**: 94444 14688, **E-mail**:* *grbhaskaran@gmail.com*

2. **Dr. K. Balasubramani (Rest of Tamil Nadu)**
Assistant Professor, Department of Geography, Bharathidasan University,
Tiruchirappalli - 620 024, ***Mobile**:99440 60319, **E-mail***: *geobalas@gmail.com*

Details of Awards and Prizes

Prize	Award and Prize Amount	
	UG The IGS Founder Prof. N. Subrahmanyam Award	PG Prof. A. Ramesh Award
I	Rs. 5,000/-	Rs. 7,000/-
II	Rs. 3,000/-	Rs. 5,000/-
III	Rs. 2,000/-	Rs. 3,000/-

Prizes will be awarded to the winners of Talent Tests during ***90th IGS Annual Conference / Seminar / General Body Meeting*** to be held at Department of Geography, Mu. Va. Hall, Madurai Kamaraj University on 20.02.2015 (Friday) at 3:00 p.m. All other participants will be given Certificate of Participation. Please visit IGS website for registration forms and further information: http://www.igschennai.org/

Dates to Remember

Last Date for the Enrolment: 09-01-2015 (Friday)

Date of the Talent Test: 20-01-2015 (Tuesday)

Awards and Fellowships

Dr. Swarna Subba Rao, Surveyor General of India, Survey of India, Dehradun has received **Professor B.M. Thirunaranan Life Time Achievement Award** from Dr. Karu. Nagarajan, Member Secretary, Tamil Nadu State Council for Higher Education (TANSCHE) at the 90^{th} Annual Conference of IGS on *Sustainable Resources Management in Cauvery Basin, South India* and National Workshop on *Photogrammetry: Principles and Applications* at Bharathidasan University, Tiruchirappalli on 25.01.2014. Besides them are (from the left) Dr. K. Kumaraswamy, Professor & Head, Department of Geography, BDU and Editor, The Indian Geographical Journal; Dr. E. Ramganesh, Registrar, BDU and Dr. A. Ganesh, Professor, Department of Geography, BDU and Dr. M. Stalin, Director, Survey of India, Raipur.

Dr. K. Kumaraswamy, Professor and Head, Department of Geography, Bharathidasan University, Tiruchirappalli and Editor of The Indian Geographical Journal is awarded with the **UGC-BSR Mid-Career Award / One Time Grant** for the period 2014-2016. The Grant is aimed to augment the research efforts of the faculty member with the research incentive.

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I, K. Kumaraswamy, hereby declare that the particulars given above are true to the best of my knowledge and belief.

Dr. K. Kumaraswamy
Editor, The Indian Geographical Journal