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GEOPARKS AND GEOTOURISM - A SUSTAINABLE SOLUTION

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Abstract

A global geopark is a unified area with geological heritage of international significance. Geoparks use that heritage to promote awareness of key issues facing society in the context of the dynamic planet we all share. Many geoparks promote awareness of geological hazards, including volcanoes, earthquakes and tsunamis and many help prepare disaster mitigation strategies among local communities. Geoparks hold records of past climate change and offer lessons on current climate change as well as adopting a best practise approach to utilising renewable energy and employing the best standards of 'green tourism'. Geotourism as a segment of the tourism that has been developed worldwide in recent years. While tourists have long been sought out 'geological wonders', like mountains, caves, volcanoes, fossil remains and canyons, in recent times there has been a greater emphasis on developing tourism around the idea of geological heritage and incorporating learning into the tourist experience. Within the field of tourism, few studies have investigated the issue of geotourism development and geotourists in the Mekong Subregion. Geotourism development in the Mekong Subregion can bring many benefits for different stakeholders involved in related activities, such as public and private sector actors, local communities and NGOs. The potential benefits of developing geotourism include enhancing the local economy; raising geological awareness and improving the wellbeing of the local communities.

Keywords: Geological Hazards, Geoparks, Geotourism.

Introduction

The story of the Earth is a dynamic tale of geological history and diversity that spans millennia. The planet we know today was forged by the powerful shifting of Earth's tectonic plates, the forces beneath us whose activities result in earthquakes and volcanic activities. Mountain ranges have formed and eroded, their remnants being recycled in an abiotic process that has operated continuously on a macro and micro scale for more than four billion years.

Rock formations have developed in many different as continents have migrated across the surface of the globe and through unique climactic zones. The fossil record contained in these formations tells of this remarkable journey and as such it also gives a remarkable account of the history of the Earth. And additions to that record continue to this day – long- term global climate change has influenced surface processes, leading to periodic hot and cold conditions. All of these processes and events have left a legacy in our rock formations and in the diversity of landscapes and landforms evident across the globe.

Global geoparks represent our diverse geological heritage and they tell the story of this planet – a narrative that spans time and is preserved in its rocks, landforms, fossils, minerals and soils. Geoconservation is about protecting that legacy and ensuring that the rich story the Earth has to tell humanity is preserved for many generations to come.

Sustainable Development

The most commonly accepted definition of sustainable development comes from *Our Common Future*, also known as the Brundtland Report, from the United Nations World Commission on Environment and Development in 1987:

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:

- the concept of needs, in particular the essential needs of the world's poor, to which overriding priority should be given; and
- the idea of limitations imposed by the state of technology and social organisation on the environment's ability to meet present and future needs."

Geoparks

More and more countries have started to develop schemes for recognising important geological and geomorphological sites or landscapes within their national boundaries. Such geoheritage sites are important for educating the general public in environmental matters. They also serve as tools for demonstrating sustainable development and for illustrating methods of site conservation whereby recalling that rocks, minerals, fossils, soils, landforms and landscapes are both the products and records of the evolution of our planet Earth and, as such, form an integral part of the natural world.

Through the International Convention adopted by UNESCO in 1972 'Concerning the Protection of the World Cultural and Natural Heritage', the World Heritage Committee identifies and monitors properties of outstanding universal value and decides which properties are to be included on the World Heritage List. As of July 2015, a total of 1031 sites have been inscribed on the World Heritage List, of which 802 are cultural properties, 197 are natural and 32 mixed. Only 20 are inscribed primarily for geological interest.

With respect to sustainable development, there are numerous sites globally that have potential for immediate substantial economic development because of the diverse range of geological phenomena they offer including, among many others, structures, minerals and fossils. Geological heritage sites, properly managed, can generate employment and new economic activities, especially in regions in need of new or additional sources of income.

A fundamental value of the United Nations' Millennium Declaration was a 'Respect for Nature' in the management of all living species and natural resources. In that spirit, we are glad to note that there is growing public awareness throughout the world that environmental conservation is a necessity and that more and more people recognise that geological features play an essential part in managing our environment in a sustainable way.

A global geopark is a unified area with geological heritage of international significance. Geoparks use that heritage to promote awareness of key issues facing society in the context of the dynamic planet we all share. Many geoparks promote awareness of geological hazards, including volcanoes, earthquakes and tsunamis and many help prepare disaster mitigation strategies among local communities. Geoparks hold records of past climate change and offer lessons on current climate change as well as adopting a best practise approach to utilising renewable energy and employing the best standards of 'green tourism'.

Geoparks also inform about the sustainable use of and need for natural resources, whether they are mined, quarried or harnessed from the surrounding environment, while at the same time promoting respect for the environment and the integrity of the landscape. Geoparks are not a legislative designation, though the key heritage sites within a geopark should be protected under local, regional or national legislation as appropriate.

As a model of sustainable development, Geoparks are associated with values such as education, science, culture and socio-economic development, mainly through geotourism (UNESCO, 2014). To realise this potential, geoparks try to benefit from local knowledge and workforce in the area.

Networks are also playing an increasingly important role. The UNESCO Global Geoparks Network (GGN), the European Geoparks Network (EGN), and the Asia Pacific Geopark Network (APGN) are three formal networks that have introduced the network concept to geosciences and geotourism. The establishment of these geopark networks enables the exchange of ideas, experiences and best practices toward common goals: the conservation of natural, geological and cultural heritage; education; and the development of the local economy through geotourism.

Apart from the GGN, EGN and APGN network activities, some countries such as Japan, France, Germany, Italy, Ireland, Greece and China have developed national and local Geopark networks to foster close collaboration between geoparks and the tourism sector, schools, universities and businesses.

Geotourism

The first published definition of geotourism from the perspective of geology-based tourism defined it as 'the provision of interpretive and service facilities to enable tourists to acquire knowledge and understanding of the geology and geomorphology of a site (including its contribution to the development of the Earth sciences) beyond the level of mere aesthetic appreciation' (Hose, 1995). This type of geotourism, with a focus on rural localities has burgeoned since the turn of the century, especially with the emergence of geoparks (Kavecic and Peljhan 2010). However, its growth and impact on geoconservation, and associated concerns over the risks of exploiting natural resources (Hose 2008a), are difficult to accurately quantify due to limited appropriate research and evaluation. Further refinements were made by Hose (2000, 2008 and 2012). Inherent in these definitions is the understanding that geotourism is a vehicle to foster geoconservation, understand geological heritage (geoheritage), and appreciate geological diversity (geodiversity). In this light, geotourism as a form of tourism is underpinned by the concept of sustainability.

An issue central to the development and growth of geotourism globally is the meaning ascribed to the word geotourism. Generally, it is understood to be 'geological' tourism but the US magazine *National Geographic* continues to use the word to mean 'geographic' tourism.

Geotourism, in addition to its primary role in promoting tourism to geosites, raises public awareness of and appreciation for geodiversity. It fosters geoheritage conservation through appropriate sustainability measures and advances sound geological understanding through interpretation.

Geotourism as a segment of the tourism that has been developed worldwide in recent years. While tourists have long been sought out 'geological wonders', like mountains, caves, volcanoes, fossil remains and canyons, in recent times there has been a greater emphasis on developing tourism around the idea of geological heritage and incorporating learning into the tourist experience

Characteristics of Geotourism

Geology is the study of the Earth and its systems, the materials that comprise it, the structure of those materials, and the morphological processes acting upon them. An important part of geology is the study of how the Earth's materials, structures, processes and organisms have changed over time.

Tourism, in a geological sense, encompasses visiting, learning from and appreciating geosites, which comprise natural resources including landforms, rock outcrops, rocky types, sediments, soils and crystals. Overall, geotourism comprises the geological elements of form and process combined with tourism components such as attractions, accommodation, tours, activities, interpretation as well as planning and management.

Tourists who participate in geotours are generally interested in interacting with local communities as well as viewing landforms and other geological features. This occurs when they interact with local people through viewing geo-attractions or participating in related activities. Local guides are often especially highly valued by geotourists as they can provide an enhanced understanding of the surrounding abiotic, biotic and cultural environment (Mao, Robinson, & Dowling, 2009).

The goal of geotourism is to foster tourism development opportunities while at the same time ensuring the conservation and/or protection of the attributes that make a site remarkable for its geoheritage (Newsome, Dowling, & Leung, 2012). Stakeholders become important here because they are the ones with either real or perceived ownership of the geological features.

Geotourism may be further defined by five key principles that comprise a number of interrelated components, all of which should be in place to enable authentic geotourism. The five key principles are: that be geologically-based (that is, based on the Earth's geoheritage); sustainable (ie, economically viable, community enhancing and fosters geoconservation); educative (achieved through geointerpretation); locally beneficial; and that it generate tourist satisfaction. The first three characteristics are considered essential to geotourism, while the last two are viewed as desirable for all forms of tourism (Dowling, 2011).

1. *Geologically Based:* Geotourism is based on the Earth's heritage focusing on its geological forms (features) and/or processes. The focus on the Earth and its geological features (at a range of scales from rock outcrops to entire landscape panoramas), is essential to the planning, development and management of geotourism.
2. *Sustainable:* Geotourism bolsters local socio-economic conditions and in doing so enhances the wider community as well as nurtures geoconservation efforts. The key challenge for any region or country is to develop its tourism capacity without adversely affecting the geo-environment that maintains and nurtures it. This involves ensuring that the type, location and level of geotourism does not cause harm to geological features or geological specimens,, especially in natural settings.
3. *Geologically Informative:* Geosciences education and geo-interpretation are keyto creating an enjoyable and meaningful geotourism experience. Geotourism attracts people who wish to learn and interact with the natural environment in order to develop their knowledge and awareness. Geotourism should ideally lead to sustainable actions by fostering enhanced conservation awareness.
4. *Locally Beneficial:* Residents in the immediate area will experience the impacts of development, whether tourism-related or not and regardless of whether they choose to be active participants in it. Likewise, it has long been established that close cooperation with local communities is key to sustaining biodiversity conservation; the same is true of geodiversity conservation. The involvement of local communities not only improves their socio-economic conditions of and the environment, but also enriches the visitors' experience. Geotourism can also generate income for resource conservation management in addition to the social and cultural benefits it offers. As the economic benefits of tourism increase, residents' attitudes towards it become more favourable.

5. *Tourist Satisfaction:* Visitors' satisfaction is essential to the long-term viability of the geotourism industry. The experience should match or exceed the realistic expectations of the visitor. The importance of visitor safety related to geo-hazards during site visits is part of this concept.

Grant (2010) said that there geotourists should be categorised across a spectrum, from general visitors who either have no or limited awareness of geological knowledge to geologists. Geotourism needs to cater to all categories to be sustainable over the long term.

Geoparks Grouping

Geoparks need to be classified to devise suitable geotourism plans/trails as well as any special activities. We propose this generic classification:

1. Geological Sections-/-Stratigraphic-based Geoparks: Clear identification of stratigraphic successions or unconformities with clear boundary conditions;
2. Palaeontological/palaeo-anthropology based:
    a. Fossil-based sites Palaeoanthropology (relics and fossils of ancient human being-Peking Men sites);
    b. Palaeoanimals dinosaur;
    c. Mixed palaeofauna;
    d. Palaeobotoany (petrified wood);
3. Structural Geology/features based:
    a. Traces of tectonic and metamorphic process and related structural aspects. Examples include structures of metamorphic core complexes, plate collisional high-pressure belts, stylolite structures.
4. Geomorphic features and landscape-based (rock landscapes, for example)
    a. Landform-based granites, clastic, karst, aeolian, loess;
    b. Volcanic landforms: volcanic cones; trachytic rocks, lava tunnels, volcanic craters; volcanic-sedimentary sections;
    c. Glacial landforms: glacial relics and ice caves; periglacial landforms, fluvial, marine and landforms;
    d. Fluvial landforms: river canyons; gorges; lane valleys; Quaternary glaciers; anthropogenic engineering;
    e. Marine erosion landforms: sedimentary structures; ductile shear zones.
5. Water landscapes-based:
    a. Springs: geothermal landscapes;
    b. Lakes and swamps: Tectonic lakes; lake levees; wetlands; lacustrine landforms;
    c. Rivers: Meandering rivers; loess canyon landscapes;
    d. Waterfalls: Narrow and deep canyons; headward erosion;
6. Environmental/Geo-hazard-based:
    a. Earthquake-induced collapses of mountains, earthquake relics.
7. Minerals and ore deposits
    a. Relics of mining.

Geotourism Activities in Geoparks

Activities need to be decided based on the above grouping of Geoparks, as every site will require different infrastructure depending on its geological environment. There should also be geo-museums and information centres created to enhance visitors' understanding of the Geoparks. These are some recommendations regarding geoparks and activities involving them.

- Geoparks cover a huge terrain so park authorities need to organise mobile exhibition units to visit nearby locales.
- Develop digital data bases and update them on a regular basis, providing descriptions of tourism activities offered by the Geoparks (museums and info-centres, trails, events etc.), and exchange them with sister Geoparks around the world.
- During holiday seasons and weekends organise geotourism-activities in Geoparks, such as customised tours to explore the geological history of the Geopark, nature observation, bird-watching, fossil conservation, mountain biking, trekking and rafting.
- Promote Geoparks as an alternative tourism experience through geotourism packages and organised events.
- Exchange knowhow on geosite assessment, conservation and interpretation (by, for example, publishing books and visitors' guides, creating information panels, producing multimedia presentations and DVDs, etc) in order for visitors to explore the fascinating story preserved in the rocks and the landscape of the Geoparks.

Geotourism Development

Geotourism is about creating places where both locals and tourists are free to enjoy geological landscapes (Dowling and Newsome 2008). It generates an experience which brings together the local landscape, the community and its visitors, all of whom have different interests in the Earth's formations. Local businesses and community groups work together to promote and provide a distinctive, authentic visitor experience. Geotourism places a major focus on informing tourists and local communities about the Earth through geological interpretation and education. Geotourism-related businesses are usually operated by local communities and may include interpretation services, tours, accommodation and food outlets. These in turn generate business for the local residents, creating a larger workforce and giving a boost to the economy. The goals of sustainable geotourism development are:

- To develop greater awareness and understanding of the significant contributions that geotourism can make to the environment, local communities and the economy;
- To promote equity in geo-development;
- To improve the quality of life in the host community;
- To provide a positive geological experience for the visitor; and
- To maintain the quality of the geoheritage site, upon which all else depends.

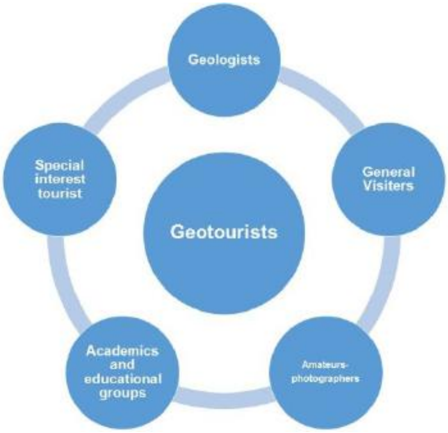

Fig. 1. Geotourism's Potential Participants

Geology of Greater Mekong Sub-region

The evolving geology of the Greater Mekong Sub-region (GMS) is best understood by looking at the development of the Mekong River. About 40 million years ago, its precursor drained into the sea roughly where the Red River now flows. Over time, the rise of the Himalayas with uplifting, folding and faults, turned much of the mountains' drainage southward through steep gorges that appeared perhaps 13 million years ago and by 8 million years ago, formed the present course of three rivers Thanlwin (Salween), Mekong, and Yangtze running down parallel sutures.

The Mekong followed a line of faults through south-western Yunnan, an area still high in seismic activity, indicating that movements of the blocks are continuing. Below this area, the Mekong crosses the Indosinia block, which has been stable since the Jurassic period. There was a wide inland sea during the Upper Mesozoic period. It is probable that the Mekong at this time was flowing directly south and to the west of the Khorat Plateau, joining what was to become the Chao Phraya River. However, during the late Cretaceous and early Tertiary periods, uplift in northern Vietnam formed the Red River rift and Indosinia became warped, with north-eastern Thailand, including the Khorat plateau area, and adjoining parts of the Lao PDR remaining low; the inland sea left salt deposits 250 metres thick in this region.

Much of what is now Cambodia was lifted and has weathered to expose basement granite. The uplifting caused block faulting in northern Thailand resulting in flat basins and steep mountain ranges. Subsequently, in the Cenozoic period, there was much volcanism as well as block movement, accompanied by climate changes and sea level change, particularly affecting southern Cambodia and southern Vietnam. It was only about 600,000 years ago that basaltic areas of the Annamites between Vietnam and the Lao PDR, and in northeastern Thailand and Cambodia were formed and dictated the present structure of the Mekong River in the area, including the Khone Falls. The lower part of the Mekong River has also been influenced by tectonics in the Cenozoic period and some stretches can be seen to follow these recent fault lines. It is believed that subsidence in the Tonle Sap basin in Cambodia, perhaps within the last 12,000 years, drew the Mekong River eastward away from its former Chao Phraya connection and into the Tonle Sap basin. Tonle Sap itself is only about 5,000 years old. Finally, the Mekong Delta began to form only 6,000–7,000 years ago when sea level rose to its present level after a rise of some 130 metres over the preceding 12,000 years, since the last glacial maximum period.

These areas carry significant geological records, which need to be preserved and studied carefully. The concept of Geoparks will bring greater regional and international attention to the need to preserve these natural records.

Potential Benefits of Geotourism Development in the Mekong Sub-region

The Mekong Sub-region has abundant geological and geomorphic features that offer tourism operators the opportunity to improve upon their existing offerings by including geological tourism products or to attract a new segment of tourists. There are several karst, structural, geomorphic, and palaeontological sites in the Mekong Sub-region that can be promoted as potential geological tourism sites.

A growth in geotourism could bring outstanding benefits to the overall tourism industry of the Mekong Sub-region (Figure 2), enhancing what is already on offer in the tourism market and bringing financial and social benefits to the communities adjacent to the geosites.

Other potential benefits of geotourism in the Mekong Sub-region include:

- It can maximise the economic benefits for the local tourism industry and drive the economic development of the geosites.

Geotourism development can enhance the local economy, particularly in the case of geological tourism sites in remote areas. For example, there are more than 5000 show caves around the world that bring more than US $2 billion yearly and provide more than 200,000 direct job opportunities (Forti, 2011). Such economic opportunities could greatly benefit to the Mekong Sub-region and contribute to the sustainable development of these geosites. According to UNESCO (2014), geotourism development is an amalgam of geological conservation, economical activities and supporting financial resources of the local community. Thus, 'geotourism is an economic, success-oriented and fast-moving discipline, a new tourist business sector involving strong multidisciplinary cooperation'.

- Enhancing the wellbeing of communities adjacent to the geological tourism sites.

Generally speaking, geotourism applies the notions of sustainability and supports the local features of the sites by encouraging the use of local products and activities (Komoo and Patzak, 2008). Thus, it can enhance the local economy by providing and increasing employment opportunities for the local community; develop different types of production of local groups, and support the economic development of areas adjacent to the geosites. Geotourism can also strengthen the relationship between the local communities and their land.

- It can promote education and raise awareness about geological issues.

Knowledge is one of the most influential outcomes of a geotourism experience. Thus, Dowling and Newsome (2006) emphasize the educational purpose of geotourism, which includes a 'sense of wonder, appreciation and learning'. Furthermore, Robinson (2008) describes the role of geotourism in learning as extra information 'doubling the value of a tour'. This view is supported by Farsani et al., (2010) who wrote: "At present, geotourism is a new movement helping travellers to increase their knowledge about natural resources, the cultural identity of hosts and ways of preserving them." Thus, geotourism activities can empower tourists to attain knowledge and understanding of the geology, geomorphology, natural resources, and the local communities of different geosites in the Mekong Sub-region. Such knowledge can help in enhancing efforts to preserve and sustain the natural resources and raise awareness about their values.

- Protecting and sustaining the geoheritage in Mekong Sub-region

According to Dowling and Newsome (2010), "Geotourism promotes tourism to geosites and the conservation of geo-diversity and an understanding of earth sciences through appreciation and learning." Thus, geotourism is an essential tool to protect a site's special geological features. It also raises awareness about the intrinsic value of the geological features which leads to greater appreciation of this heritage. As a result, geotourism is concerned about generating a geotourism product that protects geoheritage (Dowling, 2011).

- Geotourism can add value and diversity to tourism offerings in the Mekong Sub-region.

The classification of tourism attractions in the Mekong Sub-region is restricted to different kinds of historical and heritage tourism beach tourism and MICE (meetings, incentives, conferences, and exhibitions) tourism. The Mekong Sub-region has established a cultural resource base to attract both leisure and business travellers with a growing number of international fairs and exhibitions as well as various creative industries, as if it were not already endowed with ample natural resources. To date, there has been little attention paid to the geological and geomorphic resources in Mekong Sub-region tourism. However, many countries have increased their focus on geotourism, and in some cases rely on their geotourism attractions. Australia, for example, has paid full attention to geotourism and introduced its geotourism attractions as the primary tourism attractions in the country. As a result, Australia has protected and promoted many iconic geological sites, such as Uluru and Kata Tjuta (Dowling and Newsome, 2010). Tourism has made significant contributions to the national economies of countries in the Greater Mekong Sub-region (GMS), where tourism's share of Gross Domestic Product (GDP) averaged 12 % in 2006.

The average collective share of international tourism and international fare receipts was 10 % of the GMS countries' tourism exports. Meanwhile, jobs generated by the sector accounted for approximately 9% of total employment in each country.

Fig. 2. Potential Benefits of Geotourism Development

Table 1. Tourism as Percentage of Gross Domestic Product, Exports and Total Employment, 2006

Item	Cambodia	Lao PDR	Myanmar	Thailand	Vietnam	GMS Average
Tourism GDP (% of national GDP)	19.6	9.3	4.3	14.3	10.9	12.0
Tourism (% of total exports)	19.5	20.6	3.3	10.6	3.5	10.2
Tourism Jobs (% of total employment)	15.4	7.3	4.0	10.7	8.7	9.4

Source: Consumer Unity and Trust Society. 2007. Community-Based Ecotourism for Sustainable Tourism Development in Mekong Region. Hanoi Resource Centre Policy Brief, January 2007.

The GMS countries possess a wide range of highly attractive natural, cultural, and historical heritage tourism resources, including ethnic diversity, and geosites could contribute greatly to this richness. . These unique treasures, the so-called "Jewels of the Mekong", include some of the world's interesting archaeological sites, such as Bagan in Myanmar; UNESCO World Heritage sites (Angkor in Cambodia, Hue in Vietnam, Luang Prabangin Lao PDR, Sukhothai in Thailand, and natural wonders (Halong Bay in Vietnam); as well as Buddhist monuments (Shwedagon Pagoda in Myanmar, the Temple of the Emerald Buddha in Thailand, and Wat Pho in Lao PDR).

Sources: Kingdom of Cambodia, Ministry of Tourism. 2007. *Tourism Statistics Annual Report.* Phnom Penh; Lao National Tourism Administration. 2007. *2006 Statistical Report on Tourism in Laos.* Vientiane; Thailand National Statistics Office. 2007. *Statistical*

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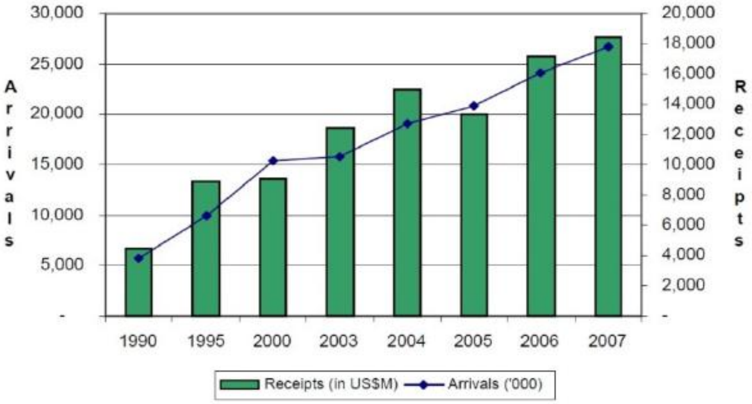

Fig. 3. Tourist Arrivals and Receipts in the GMS 1990-2007

Conclusions

Within the field of tourism, few studies have investigated the issue of geotourism development and geotourists in the Mekong Sub-region. There is a need for further studies to determine the nature and scope of geotourism in the Mekong Sub-region to better understand this phenomenon. Thus, this paper indicates the potential of geotourism development in the Mekong Sub-region. Subsequently, this paper may extend the understanding of geotourism and its participants in the Mekong sub-region. Geotourism development in the Mekong Sub-region can bring many benefits for different stakeholders involved in related activities, such as public and private sector actors, local communities and NGOs. The potential benefits of developing geotourism include enhancing the local economy; raising geological awareness and improving the wellbeing of the local communities. Tourism management in the Mekong Sub-region would benefit greatly from offering geological tourism products to attract a new segment of tourists called geotourists.

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THE EFFECT OF MONSOON RAINFALL SHORTAGE ON FARMER SUICIDES IN INDIA - A PANEL DATA ECONOMETRIC ANALYSIS

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Abstract

Farmer suicides in India is the single most manifestation of the distressed and pathetic situation of the agricultural sector and indicates the vulnerability of the rural economy to the vagaries of nature. Frequent failure of monsoon, inadequate rainfall, crop failure, overburden of loan, harassment of moneylenders and lack of accessibility to government support are the prime causes for a farmer ending his life on his own. This paper attempts to estimate the effects of annual rainfall and its shortage, along with gross irrigated area and GSDP, on farmer suicides in India using state-wise panel data for 10 states and for 10 years, 2001-2010. Panel data regression methods of fixed and random effects models are used for analysis. The estimated empirical results show that with increase in annual rainfall farmer suicides decline. This result is strengthened with the findings that monsoon rainfall is associated with reduced farmer suicides, whereas the shortage in monsoon rainfall increases farmer suicides. Also, female farmer suicides are more responsive to rainfall related factors than the male farmer suicides. Though the Indian growth performance is described as spectacular and even frequently celebrated as a shining example, the life of the Indian farmer still reels under the mercy of nature, and the mere fact that a farmer commits suicide is a dent on face of the surging Indian economy.

Keywords: Farmer suicides, Rainfall, Monsoon shortage, Panel data, Fixed and random effects estimates, Hausman specification test.

Introduction

Farmers around the world have high suicide rates, relative to other professions (Judd et al. 2006). Though farmer suicides may be treated as relatively few and even isolated events compared to all causes of deaths in a large and densely populated India, the sheer phenomenon of suicide by a farmer, who is the backbone for feeding the millions, can not be equated with other forms of suicides and taken so lightly. In fact, it is an indicator of the distressed and ill-fated scenario of development and income distribution. It is an essential facet in a comprehensive assessment of economic development and rural welfare for two reasons. First, the relative frequency of suicides is an objective quantitative measure of the prevalence of extreme individual distress. Second, unlike a transitory shock to household income, a suicide is irreversible. The farmer suicide, that too at a young and prime age, repercussions has not only to the income and debt problems, but also has devastating, pervasive and cascading effects for the entire family, including education and health of children, dependency on others, social neglect, and stigma. Hence, is important to understand the vulnerability of India's rural populations different from the much popular poverty angle and identify whether there is a need for reorienting rural development policies that are necessary to provide protection and mitigation against various sources of risk rather than just aggregate economic or income growth.

In order to understand the magnitude of the issue of farmer suicides, just look at the data on the causes of reported deaths in India available in the national crime records. For example, the actual demographic breakdown by NCRB report shows that out of 134,599 suicides reported in India in 2005, 15,964 belonged to the farming community. Figure 1 shows the trends in farmer suicides by gender in Indian states between 2001 and 2010. It can be observed that in Andhra Pradesh and Karnataka farmer suicides are much higher, despite better irrigation facilities and favourable political and government scenario, relative to poor states like Jharkhand and Rajasthan. It can also be noted that almost in every state the male farmer suicide rate is higher than female farmer suicide rate. In Karnataka, male suicide rate is much higher compared to the female farmer suicide rates, showing the glaring dependency on male in rural areas.

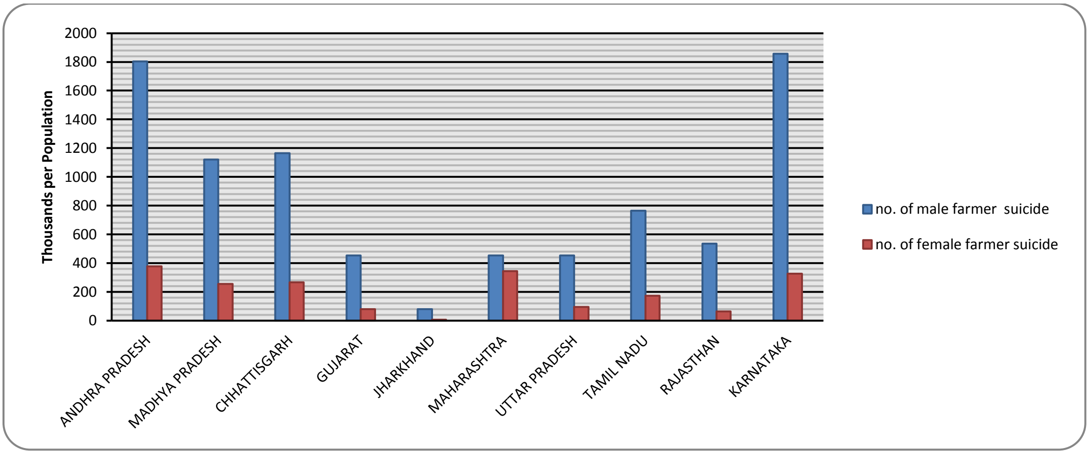

Fig. 1. Farmer Suicides in India

Source: NCRB data (2001-2010)

Traditionally, lack of sufficient and timely rainfall and irrigation facilities, frequent crop failure, poor capital investments and credit facilities, high costs of fertilisers and pesticides, inadequate and inappropriate technology, near non-existence of storage and marketing facilities, and total neglect of agricultural sector in the wake of economic reforms have been cited as the main causes for the phenomenon of farmer suicides. The absence of coping any mechanism, land fragmentation, poor organisational structure, high indebtedness, exploitation by local moneylenders, lack of education, large family size, land being the only asset, poor crop diversification, etc. further aggravate the woes of the farmers. The high levels of economic stress due to severe risks in agriculture and the rapid pace of structural change rub the salt to the wound, thus aggravate the pathetic situation faced by the farmers (World Bank, 2007). The rising farmer suicides have often been cited as the manifestation of the destitute situation of poor farmers in the wake of globalisation and crony capitalism. The post reform drive for economic growth emphasising manufacturing and service sector growth and urban development, relative to agricultural sector growth and rural development have been the cause of concern in many developing countries. The plight of farmers and the increasing farmer suicides have been the bone of contention for political controversy and broad media focus around the globe, especially in India. In fact, increasing farmer suicides reflects the distress, destitute and desperate situation of poor farmers in the midst of growing affluence elsewhere. Despite much acclaimed success in rural poverty reduction, increasing education and improving awareness, suicides by farmers in India in rural areas continues to be a sad reflection of poor state of agrarian structure and its performance.

In fact, it is paradox that much of the farmer suicides have happened in an era of increasing income and impressive growth performance in India. Again, most of farmer suicides are in the relatively developed states like Maharashtra and Andhra Pradesh is perturbing. Further, these states are better placed in terms of irrigation, credit, and rural development, compared to other dry land states like Chhattisgarh, Jharkhand or Rajasthan. This poses a paradoxical situation as if the development activities have no impact on farming and on improving farmer income. Thus, the rural scenario still points to the near no hope for farmers and the poor farmers continue to reel under the vagaries of nature expecting good monsoon every season and hoping that rain will tilt their fortunes. Out of the total geographical area of 328.7 million hectares in India, the net sown area is 141 million hectares, out of which the irrigated area is only 48 million hectares and the majority 92.6 million hectares are dependent on natural rainfall (Tyagi, 1984). This shows that the dry land farming by the Indian farmer is inevitable. The crops that are grown in the dry land farming, jowar, pulses, oilseeds, cotton, etc. often yield poor returns. These crops often depend on timely monsoon rainfall, and the monsoon often fails in India and the feeders of the nation have to stare at crop failure. As the rainfall in India is highly unpredictable, Indian agriculture is termed as the gamble of monsoon. Thus, the farmer is forced to turn to their conventional and the only reliable saviours, the moneylenders and other informal sources, in order to cope with nature's onslaught and to survive in the Indian economy.

As so many Indian farmers take out their life so sadly, without even taking the everlasting consequences his suicide will to impose on the rest of the family, the causes that lead him to such a desperate situation need to be probed seriously. Of all the causes for farmer suicides, insufficient rainfall, that too erratic monsoon and crop failure are the frequently cited primary causes that push the farmers to commit suicide. Hence, this paper investigates the farmer suicides in India by examining the effects of income, irrigated area, and rainfall on farmer suicides using a panel data from 10 major states for 10 years covering the period 2001-2010. To capture the effects of unobservable heterogeneity and individual effects, panel data regression methods of fixed effects and random effects models are used in the empirical analysis.

In the literature on suicides, econometric studies on farmer suicide are scanty. In most studies, suicides generally view suicide as an expression of extreme self-perceived misery. Often farmer suicide is considered to the sign of distress and failure of coping mechanism. The literature that examines farmer suicides in India has focused mostly on listing socioeconomic causes and state-level policy recommendations (Parthasarathy and Shameem, 1998; Revathi, 1998). Among the causes mentioned are inadequate rainfalls, low yield, falling commodity price, lack of institutional credit, poor quality of inputs, and increased reliance on informal moneylenders. All of which, incidentally, are also sources of problems in Indian agriculture at large. Of these, moneylenders are widely vilified as being the primary stressor pushing already over-burdened farmers to take their own lives. Contributing to farmer suicides, Bose (2000) highlights that seed quality and lack of pesticides as primary causes.

In a time-series study for the period from 1995-2011, Basu, Das and Misra (2016) examines the Suicide Mortality Rate (SMR) of farmers and non-farmers in India for 19 major states, that account for more than 97 percent of farmer suicides in India. The study observes that the SMR for male farmers has been consistently and significantly higher than for female farmers. The SMR ratio, i.e. the ratio of farmer SMR and non-farmer SMR, has been less than one, implying that the suicide rate of farmers has been lower than the suicide rate of non-farmers. Further, the SMR ratio for India has increased between 1995 and 2004 and has declined since then.

Hebous and Klonner (2014) analyses the vulnerability of India's rural populations from the usual consumption or income-based poverty angle. The study, examining district-wise data on suicides in farm households in two major Indian states Karnataka and Maharashtra during 1998-2004, observes marked differences across the two states. In Karnataka, where rainfall and rural poverty varies significantly, suicides among male farmers rise sharply with transitory poverty shocks caused by lack of rainfall. For females, an intriguing opposite effect, though quantitatively smaller, has been observed. In Maharashtra, no such effect has been observed because of the effective rural social protection policies. The results underscore the need for rural development policies that are geared towards protection against various sources of risk rather than just aggregate growth.

Rashmi Bhat (2016) examines the predictive power of monsoon and annual rainfall, which is assessed by a comparison of how agricultural suicide rates differ from non-agricultural suicide rates in the way that they respond to fluctuations in rainfall. Using a panel of suicide data for 25 Indian states, the pathways by which rainfall could affect an individual's decision to commit suicide is analysed. The results show that while both monsoon and annual rainfall are significantly associated with suicides rates, the other factors like real GDSP per capita, real agriculture output per worker and percent of the population employed in agriculture have no impact on farmer suicide.

Database and Methodology

The data used in this paper is a 10 years state-wise panel data covering the period 2001-2010. The states are Andhra Pradesh, Madhya Pradesh, Chhattisgarh, Gujarat, Jharkhand, Maharashtra, Uttar Pradesh, Tamil Nadu, Karnataka and Rajasthan. The panel unit is state and time variable is year. The period or number of years is 10 years starting from 2001 to 2010. The dependent variable of the study is the number of farmer suicides. Independent variables are annual rainfall, GSDP (gross state domestic product), GIA (gross irrigated area). The data on farmer suicides are collected from the Accidental Deaths and Suicides in India (ADSI) database of the National Crime Record Bureau NCRB, annual rainfall data from India Meteorological Department (IMD), gross state domestic product (GSDP) data from Planning Commission, Government of India, and gross irrigated area data from CSO (Central Statistical Organisation), and the irrigated area data from Ministry of Statistics and Programme Implementation.

The Figure 2 presents the pattern of average annual rainfall in India, showing the low level of rainfall in most Indian states. The Figure 3 presents the average GSDP of the states in India. The Figure 4 presents the average gross cropped area in the 10 Indian states together.

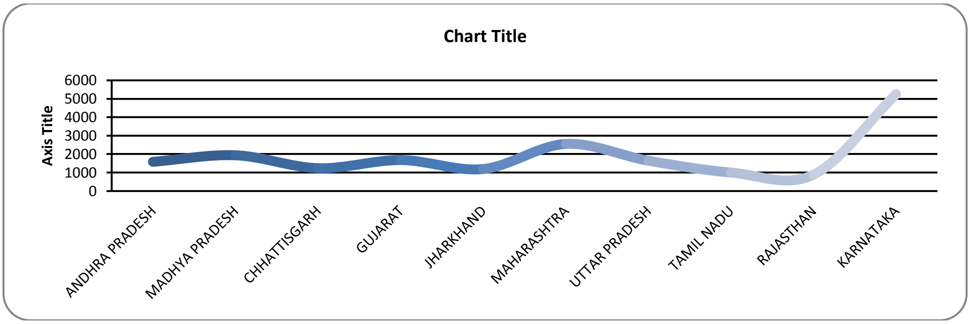

Fig. 2. Annual Rainfall in India

Source: Indian Institute for Tropical Meteorology (2001-2010)

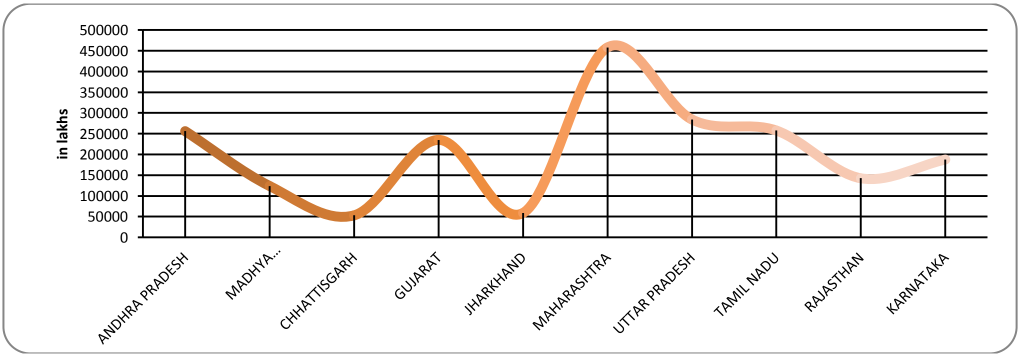

Fig. 3. Gross State Domestic Product (GSDP)

Source: Central Statistical Organization (CSO) (2001-2010)

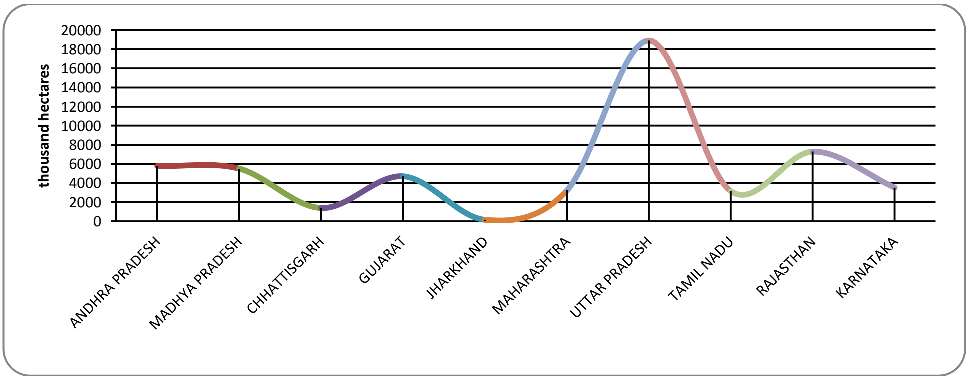

Fig. 4. Gross Irrigated Area (GIA)

Source: Ministry of Statistics and Programme (2001-2010)

Panel Data Methods

The fundamental advantage of panel data compared to cross section data is that it allows greater flexibility in modeling differences in behaviours across states. The panel methods control for both time invariant observed and unobserved individual heterogeneity between the states. The panel model is given by,

$$Y_{it} = X_{it}\beta + Z_i\alpha + \lambda_i + u_{it} \quad (1)$$

$$Y_{it} = X_{it}\beta + c_i + u_{it} \quad (2)$$

where, Y_{it} is the number of farmer suicides in state i during time t, X_{it} is a set of explanatory variables, Z_i is the observed and λ_i is the unobserved individual effects, i.e. heterogeneity. As it stands, this model is a classical regression model. If Z_i is observed for all individuals, then the entire model can be treated as an ordinary linear model and can be estimated by least squares method. The complications arise when Z_i is unobserved, which will be the case in most applications. When Z_i is unobserved but correlated with X_{it} then the least squares estimator of β is biased and inconsistent as a consequence of the omitted variable bias.

However, if the observed heterogeneity is time invariant, i.e. Z_i is constant over time, then Z_i can be conveniently added with the constant term of the model as,

$$Y_{it} = \alpha_i + X_{it}\beta + u_{it} \quad (3)$$

where, α_i specifies an estimable conditional mean. This form of fixed effects estimation approach takes α_i to be a group-specific constant term in the regression model. The fixed effects model allows the unobserved individual effects to be correlated with the included variables. We then modeled the differences between units strictly as parametric shifts of the regression function. If the individual effects are strictly uncorrelated with the regressors, then it might be appropriate to model the individual specific constant terms as randomly distributed across cross-sectional units. The payoff to this form is that it greatly reduces the number of parameters to be estimated. It should be noted that the term 'fixed' as used here signifies the correlation of c_i and X_{it} not that c_i is not-stochastic. If the unobserved individual heterogeneity λ_i is, however formulated, assumed to be uncorrelated with X_{it} then the model may be formulated as,

$$Y_{it} = X_{it}\beta + \varepsilon_{it} \qquad \varepsilon_{it} = \lambda_i + u_{it} \tag{4}$$

That is, a linear regression model with a compound disturbance that may be consistently, albeit inefficiently, estimated by least squares. The random effects estimation approach specifies that λ_i is a group specific random element, similar to u_{it}. Again, the crucial distinction between fixed and random effects is whether the unobserved individual effect embodies elements that are correlated with the regressors in the model, not whether these effects are stochastic or not.

From the standpoint of causal analysis, a question is which model, fixed effects or random effects, is appropriate for empirical analysis. From a purely practical standpoint, the fixed effects model which uses dummy variables for individual effects has the disadvantage of losing as many degrees of freedom as the number of cross-section units, However, it has an advantage over the random effects; in that there is little justification for treating the individual effects as uncorrelated with the other regressors as is assumed in the random effects model. The random effects modeling suffers from the inconsistency due to this correlation between the explanatory variables and the individual effects. To overcome this specification issue, Hausman's (1978) devised a specification test, using the orthogonality property of the common effects and the regressors, based on the idea that under the hypothesis of no correlation, OLS, fixed effects and random effects estimators are consistent, but OLS is inefficient, whereas under the alternative, fixed effect is consistent but the random effect is not. Therefore, under the null hypothesis, the two estimates should not differ systematically. Thus, the Hausman specification test is based on the difference in the variances of the two estimators, i.e. test the covariance matrix of the difference vector $[\hat{\beta}_{FE} - \hat{\beta}_{RE}]$,

$$\text{var}[\hat{\beta}_{FE} - \hat{\beta}_{RE}] = \text{var}[\hat{\beta}_{FE}] + \text{var}[\hat{\beta}_{RE}] - \text{cov}[\hat{\beta}_{FE} - \hat{\beta}_{RE}] - \text{cov}[\hat{\beta}_{RE} - \hat{\beta}_{FE}] \tag{5}$$

Note that, the covariance of an efficient estimator with its difference from an inefficient estimator is zero, implying that,

$$\text{cov}[(\hat{\beta}_{FE} - \hat{\beta}_{RE}) - \hat{\beta}_{RE}] = \text{cov}[\hat{\beta}_{FE} - \hat{\beta}_{RE}] - \text{var}[\hat{\beta}_{RE}] = 0 \tag{6}$$

or $\text{cov}[\hat{\beta}_{FE} - \hat{\beta}_{RE}] = \text{var}[\hat{\beta}_{RE}]$ (7)

Then, the covariance matrix is,

$$\text{var}[\hat{\beta}_{FE} - \hat{\beta}_{RE}] = \text{var}[\hat{\beta}_{FE}] + \text{var}[\hat{\beta}_{RE}] = \Omega \qquad (8)$$

on which the Wald chi-squared test can be performed,

$$W = \chi^2_{K-1} = [\hat{\beta}_{FE} - \hat{\beta}_{RE}]'\Omega^{-1}[\hat{\beta}_{FE} - \hat{\beta}_{RE}] \qquad (9)$$

If the computed value of the test statistics is greater than the critical value, the null hypothesis of the random effects is rejected, and the fixed effects model is specified.

Empirical Analysis

The definition and descriptive statistics of the variables used in the empirical analysis are presented in Table 1. In 2010 alone, 1,34,599 suicides have been reported, which amounts to a suicide rate of 11.4. According to the NCRB, between 2000-2010, the number of suicides has increased by 23.9 percent, compared to the population increase of 18.3 percent during that decade. Out of all the suicides, on average, 1391 farmers per 1 lakh population committed suicide in India during the decade 2000-2010. During this time period, the mean annual rainfall is 1898 millimeters, and the shortfall in monsoon rainfall is 3,512 millimeters. The average gross irrigational area is 5,369 thousand hectares. The average GSDP at constant prices is Rs. 38,91,551 and the mean NSDP per capita is Rs. 26,652.

Table 1. Descriptive Statistics of Variables in the Analysis of Farmer Suicides in India

Variable	Description	Mean	Standard Deviation
FS	No. of farmer suicides (per 1,00,000 population)	1391.18	1060.643
AR	Annual rainfall (millimeter per annum)	1898.012	1276.057
GSDP	Gross state domestic product (Rs. lakhs in constant price)	3891551	6432563
GIA	Gross irrigated area (thousand hectares)	5368.6	5018.541
MRS	Monsoon rainfall shortage (millimeter)	-512.593	4148.579

The empirical specification for panel estimation is,
FSit = β0 + β1 ARit + β2 GIAit + β3 GSDPit + ǀ i + uit (10)
i = 1, 2,…………. 10
t = 2001, 2002, 2010

The heterogeneity or individual effect term ǀ i is treated as a random variable with a specified probability distribution in the random effects model, whereas as a set of fixed parameters in fixed effects model. The term uit is the usual stochastic disturbance term that follows normal distribution with mean 0 and variance ǀ 2.

The Table 2 presents the panel regression results for fixed and random effects models. The variables are taken in the linear form. The coefficient of the main variable annual rainfall is negative and significant at 1 percent level in both models. This result shows that for an increase in rainfall, the farmer suicide rate declines.

An increase of one unit in rainfall will reduce the number of suicides by 5.6 percent in India. Irrigation is a major factor in farmer suicide. An increase one unit in irrigated area will significantly reduce farmer suicides by 2.0 percent. Better irrigation facilities will improve the agricultural production and hence prevent farmer suicides. Aggregate income GSDP has significant positive effect on farmer suicides, though the effect is only modest. As the fixed effects model also produces close estimates similar to the random effects model, the fit of the appropriate model need to be tested further. For the null hypothesis that there is a random effect, the Hausman specification test accepts the null, as the chi-square value for Hausman test is insignificant. Hence, the fixed effects model is rejected and the random effects model is the better one.

Table 2. Fixed and Random Effects Estimates of Farmer Suicides in India

Dependent Variable: Number of Farmer Suicides

Variable	Fixed Effects	Random Effects
Annual Rainfall	-.0881* (-3.09)	-.0565* (-2.72)
Gross Irrigated Area	-.0102* (-3.27)	-.0205* (-3.62)
GSDP	.00002*** (1.70)	.00002*** (1.82)
Constant	155.58* (6.87)	154.07* (3.85)
R-squared (within)	0.209	0.185
R-squared (between)	0.461	0.541
R-squared (overall)	0.337	0.406
Rho	0.9437	0.9418
Hausman's Specification Test Chi-square Value	3.00 Prob > chi2 = 0.3920	

Note: Figures in parentheses are z-values for random effects and t-values for fixed effects models (*significant at 1% level, ***significant at 10 % level).

Table 3.Random Effects Estimates of Monsoon Rainfall Shortage on Farmer Suicides

Dependent Variable: Number of Farmer Suicides

Variable	Specification 1	Specification 2	Specification 3
Annual Rainfall	-.0030* (-3.08)	-	-
Monsoon Rainfall	-	-.0502* (3.37)	-
Shortage In Monsoon Rainfall	-	-	.0357* (3.08)
Gross Irrigated Area	-.0253*** (-1.83)	-.0236*** (-1.73)	-.0243*** (-1.73)
Gsdp	-.0026* (2.81)	-.00009 (-0.27)	-.00009 (-0.26)
Constant	147.707* (4.96)	146.973* (4.63)	166.955* (4.68)
R-squared (between)	0.491	0.452	0.383
R-squared (within)	0.103	0.214	0.197
R-squared (overall)	0.520	0.426	0.432
Rho	0.8954	0.9019	0.9031

Note: Figures in parentheses are z-values for random effects model (*significant at 1% level ***significant at 10% level).

The Table 3 estimates the effects of monsoon rainfall and the shortage of monsoon rainfall on farmer suicides in India. In specification 1, annual rainfall has a negative impact in farmer suicide and significant at the 1 percent level, showing adequate rainfall improves crop prospects and the tendency for suicide by farmers declines.

In specification 2, timely monsoon rainfall also significantly reduces farmer suicides. But, inadequate or a shortage of monsoon rainfall has a statistically significant positive impact on farmer suicides. In all specifications, the effect of gross irrigated area is negative and significant at 10 percent level, showing irrigation facilities reduce farmer suicides. In specification 1, GSDP has a significant positive coefficient, but in other specifications GSDP effect on suicide by farmers is insignificantly negative.

Table 4. Fixed and Random Effect Estimates of Farmer Suicides by Gender

Dependent Variable: Number of farmer suicides

Variable	Males		Females	
	Fixed Effects	Random Effects	Fixed Effects	Random Effects
Annual Rainfall	-.0301* (3.42)	-.0622* (2.91)	-.0561* (2.93)	-.0819*** (-1.70)
Gross Irrigated Area	-.0053*** (2.14)	-.0109*** (-2.35)	-.0071* (2.71)	-.0119*** (-2.28)
GSDP Constant	.0012*** (-1.86)	.0007*** (1.83)	.0012*** (-1.68)	.0015*** (-1.70)
Constant	111.115* (5.38)	112.903* (3.35)	297.089* (5.28)	290.923* (4.66)
R-squared (within)	0.391	0.285	0.337	0.312
R-squared (between)	0.201	0.236	0.302	0.267
R-squared (overall)	0.384	0.246	0.637	0.414
Rho	0.936	0.920	0.887	0.776
Hausman's specification test Chi-square value (with p-value)		2.07 (0.558)		10.15 (0.017)

Note: Figures in parentheses are z-values for random effects and t-value for fixed effects models (* significant at 1% level, *** significant at 10 % level).

In Table 4, the estimated results for male and female farmer suicides are presented separately. An increase in annual rainfall reduces both male suicides, as its sign is significantly positive. Female suicide rates are more responsive to rainfall than male farmer suicides. Further, irrigated area also reduces farmer suicides. The GSDP has got less positive effect on farmer suicides. The Hausman specification test shows insignificance for fixed effects and high significance for random effects leading to the acceptance of the null hypothesis that there is random effect.

Conclusions

It is no wonder that the Indian farmer's life and death revolves around the nature. Among all the ill factors that are responsible to a farmer's suicide, rainfall failure that too shortage of monsoon rainfall is the single most effective factor. A crop failure due to monsoon failure causes a farmer to default the crop loan, and his own life. This paper has attempted to estimate the effects of annual rainfall and its shortage, along with gross irrigated area and GSDP, on farmer suicides in India using state-wise panel data for 10 states and for 10 years. Panel data regression methods of fixed and random effects models are used for analysis.

The estimated empirical results show that there is a direct relationship between annual rainfall and farmer suicide. With increase in annual rainfall, farmer suicide declines in India. This result is strengthened with the findings that monsoon rainfall is associated with reduced farmer suicides, whereas the insufficient monsoon rainfall increases farmer suicides. It seems that female farmer suicides are more responsive to rainfall related factors than the male farmer suicides. Thus, despite India's enviable growth rates, booming economy, and shinning urban sector, Indian farmers are still at the mercy of the 'rain God' and are 'born in debt, live in debt and die in debt', not because of ageing or natural causes, but by cutting short in his own hands his hopeless life, the sin being carrying out his family's professed occupation of agriculture.

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CONVERSION AND DECLINE OF PADDY LANDS: A STUDY ON PALAKKAD DISTRICT, KERALA

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Abstract

Paddy field of Kerala is a typical ecosystem, this wet land ecosystem is under severe threat since the mid-seventies and as a consequence there is a decline in the area under paddy cultivation, severely affect the giving rise to several negative effecting the environmental and social functions. The paddy fields is been converted into plantation crops and for non-agriculture uses. If necessary steps are not to taken to curtail the conversion, the coming generation will not witness any practices of paddy cultivation. Palakkad District, the rice bowl of Kerala which is typical ecosystem been taken for the investigation. The present investigation aims to examine the rate of decline and conversion of paddy lands in Palakkad District into different landuse system.

Keywords: Paddy cultivation, Wetland ecosystems, Conversion, Cropping pattern, Rice bowl.

Introduction

Agriculture is the foundation of Kerala's economic growth. During the last two decades, particularly in the 1970s' this sector witnessed a transformation in favour of commercial crops. One of the dynamic factors contributing to structural changes is due to the changes in the state domestic product and employment and the changes in the cropping pattern triggered by market opportunities and demand factors (Mohandas, 2005). The most important structural change is the relative decline in the area under food crops. Food crops like rice, tapioca and pulses have become less remunerative when compared to the more patronised commercial crops, this could be justified because of the increase in agriculture income from commercial land such a change is inevitable as a consequences of having to compromise with welfare angle which cannot be lost sight of with ever-increasing population the pressure on land is fast increasing (Thoman, 1999). Land being a limited resource, efficient and judicious use of the same has to be made. The decision of the farmers to allocate more resources would depend on the price-expectation and profitability of substitute crops. If the conversion of paddy land is allowed to go ahead, there may be irreparable damage to the environment (Kannan, 2011). Sustainable use of land and making it available for all the use is the present need of the hour, even though unabated huge conversion still continues and that may result in a total abandonment of rice cultivation in the near future.

Study Area

Palakkad district has a total geographical area of 4,480 km^2, represents 11.55 % of the state total geographical area. It extends between 10^0 $24^{'}$ N to 11^0 $14^{'}$ N latitudes and 76^0 $20^{'}$ E to 76^0 $54^{'}$ E longitudes. 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). Palakkad, is one of the interior districts of Kerala and is unique in many respects. The majestic Western Ghats, which stretch over a 1,000 km, break their continuity at 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 played 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).

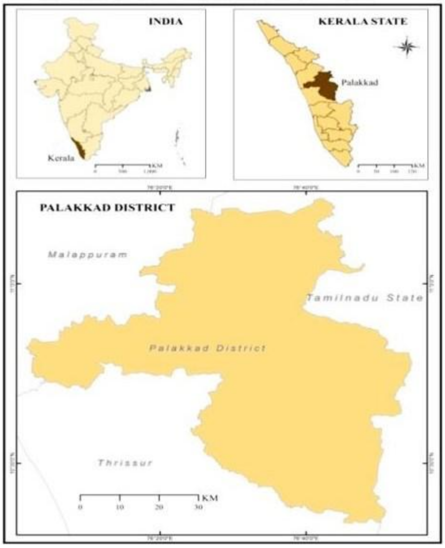

Fig. 1. Location of Palakkad District

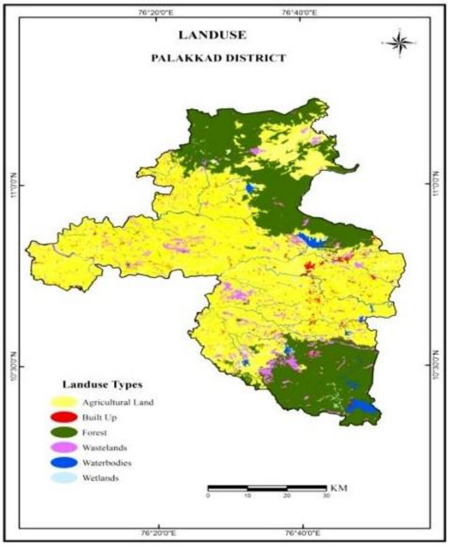

Fig. 2. Landuse of Palakkad District

Database and Methodology

The paddy land has been delineated using the survey of India Topographic map series (58A/8, 58A/12, 58B/1, 58B/2 58B/3, 58B/4, 58B/5, 58B/6, 58B/7, 58B/8, 58B/9, 58B/10, 58B/11, 58B/12, 58B/13) of scale (1:50,000). The agricultural landuse details of (1973) in respect of cropping pattern of paddy fields were also identified from the above topographic sheets. Multi-temporal satellite dataset observed by Landsat 5, Thematic Mapper (TM), Landsat 4 and Multi Spectral Scanner (MSS) were used for the analysing present (2013) agricultural scenario. The satellite digital data was rectified using Survey of India topographic maps, a reconnaissance survey was carried out to collect the ground information. The GIS database generated from the topographic sheets was further updated with the latest changes in the study area. Digital landuse / land cover classification through supervised classification method based on the field knowledge is employed to perform the classification. The image elements were correlated with ground truth verification and the interpretation key was developed. ArcGIS 9.2, ERDAS 8.6 and ArcMap are used in the estimation and preparation of the paddy land conversion map. The secondary data were collected from Agricultural, Economics and Statistical Department of Kerala.

Results and Discussion

The conversion and decline of paddy lands at present is viewed as a choice decision by the land owners. Though the government is against conversion of land under paddy, the farmers have opted for conversion of the paddy fields with a sole purpose of increasing their incomes. In their effort to maximise income, farmers have to sacrifice the ecological and environmental goods and services of paddy wetlands provide, to the farming communities (Mahesh, 1999). If one looks at the issue of an economic point of view, the cost and benefits of paddy cultivation, is no longer considered as being economically viable, as it does not provide as adequate 'returns'. Moreover, land, at present, is seen only as a real estate commodity, that is needed for building residences, for the ever increasing population. This is also considered as the safest and best investment for the new investors on land (George and Chattopadhayay, 2001). Therefore, the economic rationale of the owners of paddy lands suggests that the conversion to non-agricultural lands is a better option to generate higher income. It seems that a majority of the farmers are not fully aware of the real long-term implications of the ecological and environmental imbalances that may emerge from the conversion of the wetland agro-ecosystems (Thomas, 1999).

The analysis also reveals (Table 1 and Figure 3) that there is a considerable transformation of paddy lands that has happened in the last 40 years. Field study reveals that the net sown area under paddy has declined from 1,44,926 ha to 60,198 ha; that is, 84,728 ha of paddy lands has been lost and transferred to different landuses (Figures 4 and 5). Cash crops such as coconut, rubber and arecanut have been the main competitors for paddy due to their high economic returns. As much as 58.41 % of the paddy lands lost in conversion have now been brought under the use of agricultural plantations like coconut, rubber and arecanut. Such transformation has been found mainly in the blocks of Chittur, Kuzhalmannam, Thrithala, Alathur, Mannarkkad, Ottapalam and Sreekrishnapuram. In response to changing ethos of paddy cultivation, non-perennial crops like the banana, plantain, ginger and vegetables are also cultivated in 20.67 % of the lands lost from the paddy area. It is most commonly visible in the areas of Nenmara, Eastern Panchayaths of Chittur, northern Panchayaths of Alathur and Kollengode blocks.

Homesteads and mixed crops have accommodated 18.84 % of the total lands lost from the paddy area. In many homesteads of Palakkad district, coconut is the base crop and other crops like pepper, plantain, arecanut, tapioca and tubers are grown as intercrops.

In, one acre of coconut plantation in the study area 30 cents of tubers, 10 cents for plantains, 5 cents for vegetables, 5 cents for mixed crops and tapioca (Rajalakshmy, 2006). This mixed cropping system has been destroyed when the land has been transferred to use in rubber cultivation since no other crops could grow under rubber trees. Non-agricultural landuses cover 7.08 % of the total area of paddy lost to other uses (Figure 5).

Table 1. Decline and Conversion of Paddy Fields into Other Landuses

Name of Blocks	1973-74, Net Sown Paddy Area ha	2013-14, Net Sown Paddy Area in ha	Total Decline of Paddy Lands	Conversion of Paddy Lands into Other Land Uses			
				Agriculture and Plantations	Non-Perennial Crops	Non-Agricultural Land Use	Homesteads and Mixed Crops
Alathur	9,314	6,230	8,002	4,401	1,600	480	1,520
Nenmara	8,335	2,173	3,084	1,634	678	93	678
Thrithala	14,617	6,615	6,162	2,773	1,541	431	1,417
Chittur	18,195	8,763	9,432	5,659	1,886	377	1,509
Kollengode	10,216	7,542	2,674	1,444	669	80	481
Ottappalam	14,533	3,765	10,768	6,138	2,154	969	1,508
Kuzhalmannam	15,256	7,638	7,618	4,494	1,524	152	1,448
Pattambi	9,442	2,692	6,750	3,578	1,350	540	1,283
Mannarkkad	9,751	1,380	8,371	3,935	1,674	837	1,925
Palakkad	11,727	4,222	7,505	3,527	1,501	751	1,726
Sreekrishnapuram	11,336	2,460	8,876	5,059	1,775	533	1,509
Malampuzha	7,922	4,564	3,358	1,981	672	236	470
Attappady	470	50	420	168	153	2	97
Municipalities	3812	2,104	1,708	461	342	512	393
Total area (ha)	144,926	60,198	84,728	45,252	17,519	5,993	15,964
Total (%)			100	53.41	20.67	7.08	18.84

Source: KSLUB 2012 and Computed by the Author

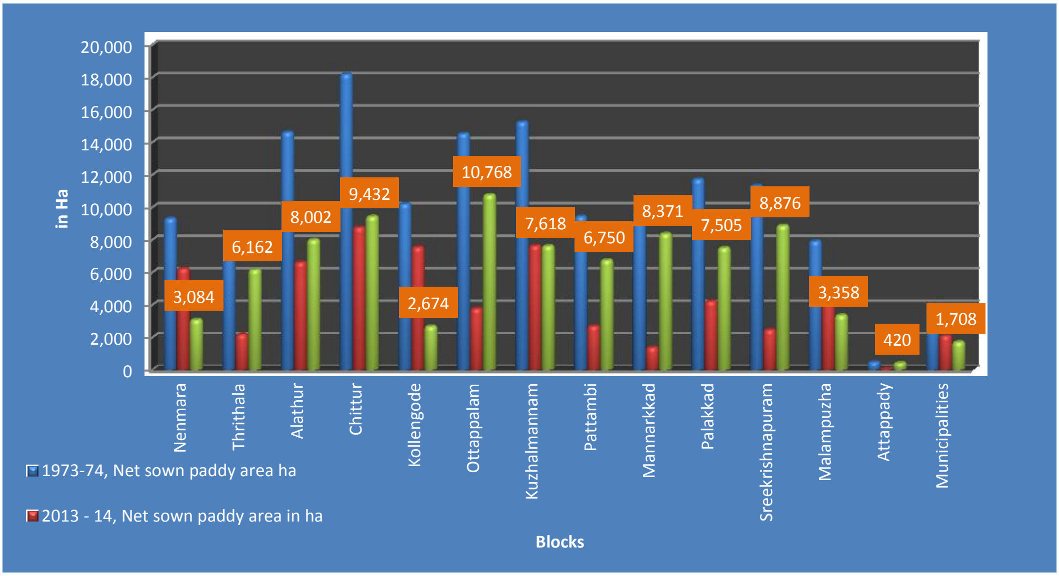

Fig. 3. Decline of Paddy Lands in Palakkad District in 1973 to 2013

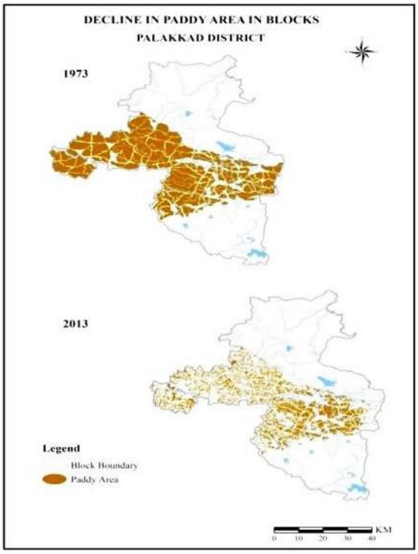

Fig. 4. Decline of Paddy Lands

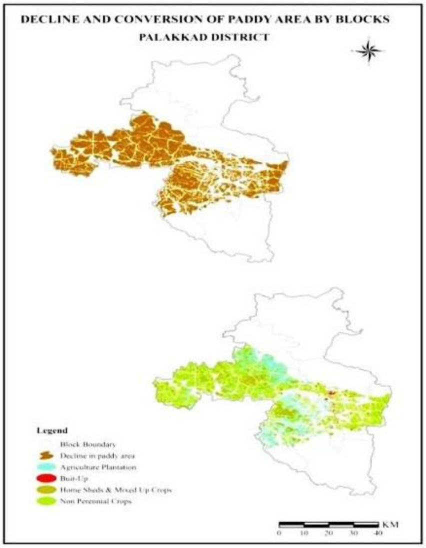

Fig. 5. Conversion of Paddy Lands

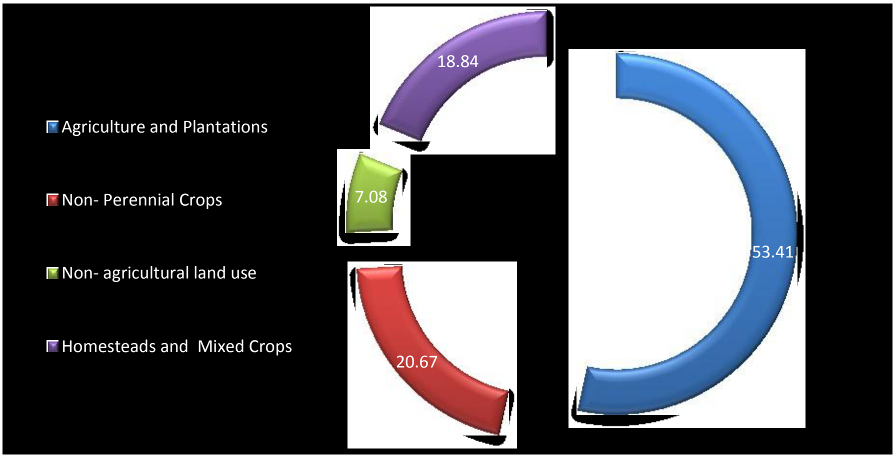

Fig. 6. Conversion of Paddy Fields into Other Landuses in Palakkad District

Conclusions

Rice cultivation is one of the most important agricultural operations in the country, not only in terms of food security but also in terms of livelihood. It plays a major part in the diet, economy, employment, culture and history of India. In Kerala also the situation is the same, majority of people in Kerala depend on agriculture and related activities for their living. Paddy cultivation was part of the culture of Kerala State. But now paddy farms are fast disappearing from Kerala and created a threat to food security of the state. Paddy fields are being converted and residential and commercial buildings. If necessary actions are not taken immediately by the authorities concerned, there will be no land for paddy cultivation for the nothing to hand over to the coming generations. Though no rules exist for the conservation of wet lands, these illegal conversions are done by misinterpreting the rules or by overcoming the clauses with artificial means under this condition everybody must be aware of the impact and refrain from converting paddy fields for other purposes. Unabated massive conversion still continues and that may result in a total abandonment of rice cultivation in the near future in Kerala State.

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ANALYSIS OF SPATIAL INEQUALITIES IN SCHOOL FACILITY AND STUDENTS' ENROLMENT IN SIVAGANGA DISTRICT, TAMIL NADU, INDIA

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Abstract

Equal access to education is among the basic human rights to which everyone is entitled. Education develops human skills for providing the needed services to the community. Regional variations exist in literacy rate, level of education, school enrolment, etc. Inequalities in education are considered to be another source of social and economic inequalities. The spatial inequalities in school facilities and students' enrolment are analysed using the statistical techniques - location quotient analysis and Lorenz curve method of Gini coefficient analysis. The results derived from location quotient analysis shows the share of schools facilities based on population standard. Finally, it is concluded that school facilities are to be initiated and upgraded in Manamadurai, Kalaiyarkoil, Thiruppathur and Sivaganga blocks. The results derived from Lorenz curve method of Gini coefficient analysis shows that high disparity of enrolment is observed in Kannankudi, S.Pudur and Ilayankudi blocks in 2009-2010. In 2010-2011, the high disparity of enrolment is identified in S.Pudur and Kannankudi. But in the year 2011-2012, there was no disparity found in the school's enrolment among the blocks of the study area.

Keywords: Locational quotient, Gini coefficient, Inequality, Spatial gaps.

Introduction

Equal access to education is among the basic human rights to which everyone is entitled. Yet, the educational gaps between various groups in many countries are shocking, as shown by many studies (Thomas et al., 2000). Accessibility to basic education has been identified as a major indicator of human capital formation of a country or region, which is an important determinant of its future rate of growth and as a measure of development (Hanmer, 1998). Education develops human skills for providing the needed services to the community. Therefore, education is considered as human capital. Regional variations exist in literacy rate, level of education, school enrolment, etc. (Khan and Islam, 2010).

Spatial inequality is an important feature of many developing countries that seems to increase with economic growth and development (Sukkoo, 2008). Inequalities in education are considered to be another source of social and economic inequalities (O'Neil, 1995; Park, 1996; Holsinger, 2005). The level of education and its distribution present different social consequences as children's education, birth rate, fertility rate, delinquency and also distribution of income (Barro and Lee, 2000; Frankema and Bolt, 2006; Lloyd and Hewett, 2004; Qian and Smyth, 2008). Locational quotient is a technique used to measure the unevenness in the distribution of schools. Also it is possible to identify the spatial inequality of schools in a particular region. If the result of location quotient is 2.0, that indicates the area has twice the fair share of school facilities based on population standard and a locational quotient of 0.5 indicates that areas share of school facilities based on population standard is half of its normal requirements. Education Gini, which are similar to the Gini coefficients widely used to measure distributions of income, wealth, and land, ranges from 0, which represents perfect equality, to 1, which represents perfect inequality. Actually, the wide use of the Gini index as measure of educational inequality can also be assigned to the improvement of databases that have become more available for a large sample of countries over time and give more various indicators of education (Thomas et al., 2002). Initially, the Gini index was calculated by means of different data related to school enrolment and education expenditure (Ter Weele, 1975; Maas and Criel, 1982; Sheret, 1982; Sheret, 1988). In this paper, locational quotient and Gini coefficient analyses are carried out to find the spatial inequality of schools and inequality in enrolment in each block of Sivaganga district. Further, these results are mapped with the aid of ArcGIS software to visualise the spatial patterns.

Study Area

Sivaganga District extends latitudinally from $9^0 43'$ N to $10^0 20'$ N and longitudinally from $77^0 47'$ E to $78^0 49'$ E. It is bounded by Pudukkottai district on the northeast, Tiruchirappalli district on the north, Ramanathapuram District on southeast, Virudhunagar District on southwest and Madurai District on the west. Sivaganga is the district headquarters. The district has 2 revenue divisions, 6 taluks, 12 blocks and 521 villages. Total area of the district is 4,189 sq.km (Figure 1).

Database and Methodology

The Survey of India toposheets, both in digital and analogue formats were used to prepare base map. The enrolment data of schools is collected from annual report from Directorate of School Education, Government of Tamil Nadu and Sarva Shiksha Abhiyan (SSA reports. Educational information is also collected from the Chief Educational and District Educational offices in Sivaganga district. The statistical techniques locational quotient and Gini coefficient are applied and the results are mapped with the help of software ArcGIS version 9 to identify the inequalities in school facilities and school enrolment.

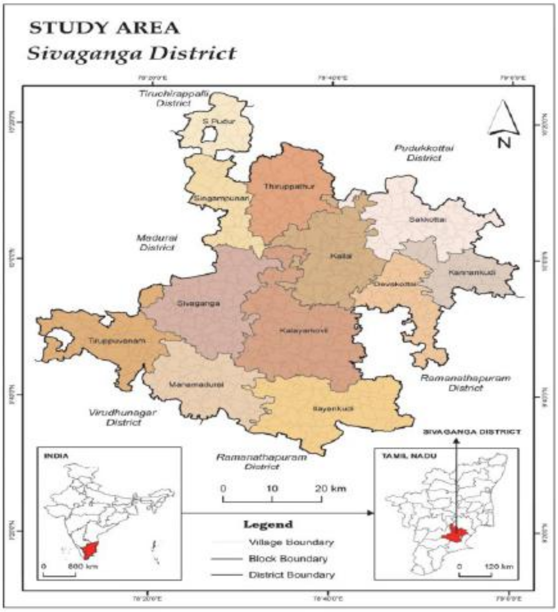


Fig. 1. Study Area

Results and Discussion

Locational Quotient Analysis and Spatial Inequality of Schools in Sivaganga District

Locational quotient was computed by dividing the ratio of number of primary, middle, high and higher secondary schools in each block to total in all blocks (entire district) by the ratio of the population of each block to the total population of all the blocks (entire district). It also ranges from much less than fair share (<0.5) to much more than fair share (>1.5) and the fair share is 1. This connotes that higher the locational quotients, the higher the fair share of the educational facilities based on population standard. The following equation is used in the analysis:

Total Number of all Schools in Each Block

$$\text{Locational Quotient} = \frac{\dfrac{\text{Total Number of all Schools in Each Block}}{\text{Total no. of all School in a district}}}{\dfrac{\text{Population of each block}}{\text{Population of a district}}}$$

The results of field survey and spatial outputs of the distribution of primary, middle, high and higher secondary schools in Sivaganga district reveal that 69 % of the schools are primary schools followed by 17 % of middle schools, 7 % of high schools and 7 % of higher secondary schools during 2011-2012. Among the total schools, the 80 % of primary schools, 71 % of middle schools, 55 % of high schools and 41 % of higher secondary schools are government schools. This implies that majority of schools are owned by government (Table 1).

Location Quotient of Primary Schools in Sivaganga District during 2011-2012

Locational Quotient (LQ) analysis of primary schools shows that Devakottai block is identified with high LQ of 2.4 and Manamadurai block is found with low LQ of 0.6, which indicates the much more than and much less than fair share of primary school facilities based on population standard. The LQ of primary school facilities with much more than fair share is identified in three blocks, they are Devakkotai (2.4), Sakkottai (1.6) and Ilayankudi (1.6) blocks; whereas the more than fair share of LQ is found in five blocks. These blocks are Kallal (1.4), Singampunari (1.3), Kannankudi (1.2), Thiruppuvanam (1.2) and S.Pudur (1.2). The less than fair share of primary school facilities are seen in four blocks, these blocks are Manamadurai (0.6), Kalaiyarkoil (0.7), Thiruppathur (0.7) and Sivaganga (0.8) blocks (Table 1 and Figure 2).

Location Quotient of Middle Schools in Sivaganga District during 2011-2012

The LQ analysis of middle schools ranges between 0.4 (Manamadurai block) and 3.7 (Devakkottai block). The middle school facilities based on population standard have been seen with much more than and more than fair share in Devakkotai (3.7), Thiruppuvanam (2.0), Sakkaottai (1.9), Ilayankudi (1.6), Kannankudi (1.6), S.Pudur (1.2) and Kallal (1.2) blocks. The much less than and less than fair share of middle schools facilities are identified in five blocks, they are Manamadurai (0.4), Thiruppathur (0.5), Kalaiyarkovil (0.6), Singampunari (0.7) and Sivaganga (0.8) blocks (Table 1 and Figure 3).

Location Quotient of High Schools in Sivaganga District during 2011-2012

Locational quotient analysis of high schools ranges from 0.4 (Kalaiyarkoil block) and 2.7 (Sakkottai block). Out of twelve blocks, six blocks are categorized as blocks with much more than and more than fair share of high school facilities. These blocks are Sakkotai (2.7), Kallal (2.3), Devakkottai (1.6), Ilayankudi (1.4), Singampunari (1.2) and Thiruppuvanam (1.1). The remaining six blocks have classified in the categories of much less than and less than fair share of high school facilities. These blocks are Kalaiyarkoil (0.4), Kannankudi (0.4), Thiruppuvanam (0.6), Manamadurai (0.7), S.Pudur (0.7) and Sivaganga (0.9) (Table 1 and Figure 4).

Location Quotient of Higher Secondary Schools in Sivaganga District during 2011-2012

As per the results of LQ analysis carried out for higher secondary schools, the share of higher secondary school facilities ranges from 0.5 (Thiruppathur, S.Pudur and Kallal blocks) to 3.9 (Sakkotai block). The fair share of higher secondary school facilities is identified in only block Ilayankudi (1.0). The much more than and more than fair share are identified in Sakkotai (3.9), Devakkottai (2.9), Singampunari (1.7) and Thiruppuvanam (1.3). Following this, the much less than and less than fair share is found in Thiruppathur (0.5), S.Pudur (0.5), Kallal (0.5), Kalaiyarkoil (0.6), Manamadurai (0.6), Sivaganga (0.8) and Kannankudi (0.8) blocks (Table 1 and Figure 5).

Gini Coefficient Analysis and Enrolment Inequality in Sivaganga District

Education Gini coefficients can be calculated using enrollment, financing, or attainment data (Thomas et al., 2000; Maas and Criel, 1982). Here the education Gini coefficient is calculated based on enrolment. The education Gini coefficient could be calculated in two ways, direct and indirect methods. The direct method measures the ratio to the mean (average years of schooling) of half of the average schooling deviations between all possible pairs of people. In the indirect method, the education Lorenz curve is constructed with the cumulative percentage of the schooling years on the vertical axis, and the cumulative percentage of the enrolment population on the horizontal axis. The forty-five degree line is the education egalitarian line for it represents a completely equality of schooling. The Gini coefficient is defined as the ratio of the area formed by the Lorenz curve and the egalitarian line to the area of the entire egalitarian triangle.

$$GINI = \frac{\text{Area of } A\,(\text{between Egalitarian and Lorenz})}{\text{Area of } OWQ \text{ Egalitarian Triangle}}$$

The spatial outputs of Gini coefficient have classified into five categories as perfect equality (<0.2), relatively equality (0.2–0.3), relatively reasonable (0.3–0.4), high disparity (0.4–0.5) and great disparity (>0.5), where Gini coefficient of 0 represents perfect equality and 1 represents perfect inequality.

Gini Coefficient of Enrolment Inequality in Schools during 2009-2010

The inequality in school enrolments in 2009-2010 is calculated using Lorenz curve method of Gini coefficient. The results shows that inequality in enrolment is found high in Kannankudi block (0.45) and low in Devakkottai block (0.25). The high disparity (0.4–0.5) in enrolment is identified among blocks are Kannankudi (0.45), S.Pudur (0.44) and Ilayankudi (0.40). The blocks with relatively reasonable enrolment is seen in Kallal (0.39), Kalaiyarkoil (0.34), Thiruppathur (0.33), Manamadurai (0.32), Thiruppuvanam (0.30) and Sakkottai (0.30). The remaining blocks fall under relatively equality category of enrolment (Devakottai - 0.25, Sivaganga - 0.28 and Singampunari - 0.29) (Table 2 and Figure 6).

Gini Coefficient of Enrolment Inequality in Schools during 2010-2011

The inequality in school enrolment during 2010-2011 is calculated using Lorenz curve method of Gini coefficient. As per results attained, the high enrolment inequality is found in S.Pudur block (0.43) and low in Sivaganga block (0.17). Sivaganga is the only block found in the category of perfect equality of enrolment. The high disparity (0.4-0.5) in enrolment is identified in S.Pudur (0.43) and Kannankudi (0.42) blocks. The blocks with relatively reasonable enrolment is seen in Ilayankudi (0.38), Kallal (0.38), Kalayarkoil (0.32), Manamadurai (0.31) and Thiruppathur (0.31). The relatively equality category of enrolment is identified in Thiruppuvanam (0.28), Sakkottai (0.28), Singampunari (0.27) and Devakottai (0.24) blocks (Table 3 and Figure 7).

Gini Coefficient of Enrolment Inequality in Schools during 2011-2012

The inequality in school enrolment during 2011-2012 is drastically decreased comparing to the results of previous years. As per results attained, the high enrolment inequality is found in S.Pudur block (0.40) and low in Devakkotai block (0.22). During this academic year, the entire district fall under two categories: relatively equality (0.2-0.3) and relatively reasonable (0.3-0.4). The blocks that fall under relatively reasonable are Thiruppathur (0.30), Manamadurai (0.29), Kalaiyarkoil (0.28), Thiruppuvanam (0.26), Sakkottai (0.26), Singampunari (0.25), Sivaganga (0.24) and Devakkotai (0.22). The remaining blocks found in relatively equality enrolment category, these blocks are S.Pudur (0.40), Kannankudi (0.37), Ilayankudi (0.36), Kallal (0.35) and Thiruppathur (0.30) (Table 4 and Figure 8).

Table 1. Locational Quotient of Primary, Middle, High and Higher Secondary Schools in Sivaganga District

Sl. No.	Name of the Block	Projected Population in 2011-2012	No. of Primary Schools	Locational Quotient of Primary Schools	No. of Middle Schools	Locational Quotient of Middle Schools	No. of High Schools	Locational Quotient of High Schools	No. of Higher Secondary Schools	Locational Quotient of High Sec. Schools
1.	Sivaganga	2,20,253	136	0.8	31	0.8	16	0.9	12	0.8
2.	Kalaiyarkoil	2,29,072	126	0.7	24	0.6	7	0.4	10	0.6
3.	Manamadurai	1,89,784	83	0.6	14	0.4	11	0.7	8	0.6
4.	Thiruppuvanam	84,596	76	1.2	30	2.0	7	1.1	8	1.3
5.	Ilayankudi	84,758	100	1.6	24	1.6	9	1.4	6	1.0
6.	Devakottai	39,199	70	2.4	26	3.7	5	1.6	8	2.9
7.	Kannankudi	34,349	30	1.2	10	1.6	1	0.4	2	0.8
8.	Sakkottai	77,817	94	1.6	27	1.9	16	2.7	22	3.9
9.	Thiruppathur	1,85,549	92	0.7	18	0.5	9	0.6	7	0.5
10.	Singampunari	66,572	65	1.3	8	0.7	6	1.2	8	1.7
11.	S.Pudur	51,605	47	1.2	11	1.2	3	0.7	2	0.5
12.	Kallal	77,697	83	1.4	17	1.2	14	2.3	3	0.5
Total		13,41,252	1,002	-	240	-	104	-	96	-

Table 2. Gini Coefficient of School Enrolment in Sivaganga District during 2009-2010

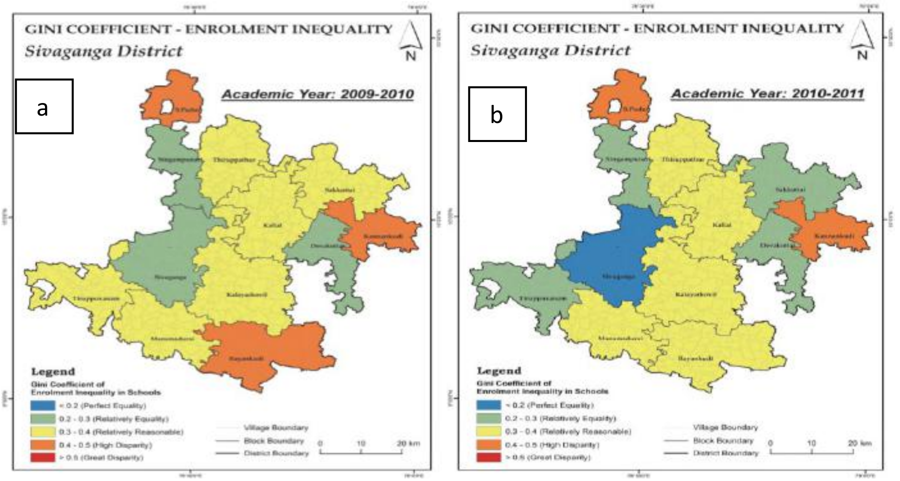
Sl. No.	Name of the Block	School Enrolment					Area	Gini Coefficient
		Primary	Middle	High	Higher Secondary	Total		
1.	Sivaganga	14,940	9,049	5,924	3,552	33,465	0.14	0.28
2.	Kalaiyarkoil	9,892	6,243	2,983	1,696	20,814	0.17	0.34
3.	Manamadurai	10,054	6,040	3,407	1,906	21,407	0.16	0.32
4.	Thiruppuvanam	10,861	6,280	4,381	2,106	23,628	0.15	0.30
5.	Ilayankudi	10,085	5,706	2,147	1,165	19,103	0.20	0.40
6.	Devakottai	9,025	6,679	3,861	2,622	22,187	0.13	0.25
7.	Kannankudi	2,190	1,279	329	170	3,968	0.22	0.45
8.	Sakkottai	21,835	13,696	9,408	3,966	48,905	0.15	0.30
9.	Thiruppathur	9,155	5,431	2,786	1,819	19,191	0.16	0.33
10.	Singampunari	7,413	4,345	2,414	1,880	16,052	0.14	0.29
11.	S.Pudur	4,223	2,731	897	136	7,987	0.22	0.44
12.	Kallal	6,867	4,638	2,088	352	13,945	0.20	0.39
Total		1,16,540	72,117	40,625	21,370	2,50,652	0.17	0.34

Table 3. Gini Coefficient of School Enrolment in Sivaganga District during 2010-2011

Sl. No.	Name of the Block	School Enrolment					Area	Gini Coefficient
		Primary	Middle	High	Higher Secondary	Total		
1.	Sivaganga	14,823	8,936	6,269	9,871	39,899	0.08	0.17
2.	Kalaiyarkoil	9,770	6,133	3,179	1,800	20,882	0.16	0.32
3.	Manamadurai	9,914	5,878	3,497	2,001	21,290	0.16	0.31
4.	Thiruppuvanam	10,741	6,160	4,678	2,424	24,003	0.14	0.28
5.	Ilayankudi	9,939	5,590	2,413	1,280	19,222	0.19	0.38
6.	Devakottai	8,888	6,551	4,082	2,708	22,229	0.12	0.24
7.	Kannankudi	2,038	1,147	370	193	3,748	0.21	0.42
8.	Sakkottai	21,671	13,570	9,904	4,510	49,655	0.14	0.28
9.	Thiruppathur	9,028	5,310	2,979	1,999	19,316	0.15	0.31
10.	Singampunari	7,261	4,229	2,483	2,089	16,062	0.14	0.27
11.	S.Pudur	4,086	2,616	970	154	7,826	0.22	0.43
12.	Kallal	6,708	4,532	2,243	397	13,880	0.19	0.38
	Total	1,14,867	70,652	43,067	23,426	2,58,010	0.16	0.31

Table 4. Gini Coefficient of School Enrolments in Sivaganga District during 2011-2012

Sl. No.	Name of the Block	School Enrolments					Area	Gini Coefficient
		Primary	Middle	High	Higher Secondary	Total		
1.	Sivaganga	14,281	9,352	7,285	4,093	35,011	0.12	0.24
2.	Kalaiyarkoil	8,729	6,041	3,298	2,181	20,249	0.14	0.28
3.	Manamadurai	9,410	6,221	3,769	2,145	21,545	0.14	0.29
4.	Thiruppuvanam	10,900	6,843	4,842	2,725	25,310	0.13	0.26
5.	Ilayankudi	9,806	5,620	2,741	1,409	19,576	0.18	0.36
6.	Devakottai	8,559	6,246	4,354	2,935	22,094	0.11	0.22
7.	Kannankudi	1,742	1,147	475	224	3,588	0.19	0.37
8.	Sakkottai	21,455	13,889	10,224	5,050	50,618	0.13	0.26
9.	Thiruppathur	9,197	5,472	3,297	2,094	20,060	0.15	0.30
10.	Singampunari	6,970	4,369	2,622	2,232	16,193	0.12	0.25
11.	S.Pudur	3,726	2,629	1,136	188	7,679	0.20	0.40
12.	Kallal	6,225	4,354	2,519	478	13,576	0.18	0.35
	Total	1,11,000	72,183	46,562	25,754	2,55,499	0.15	0.30



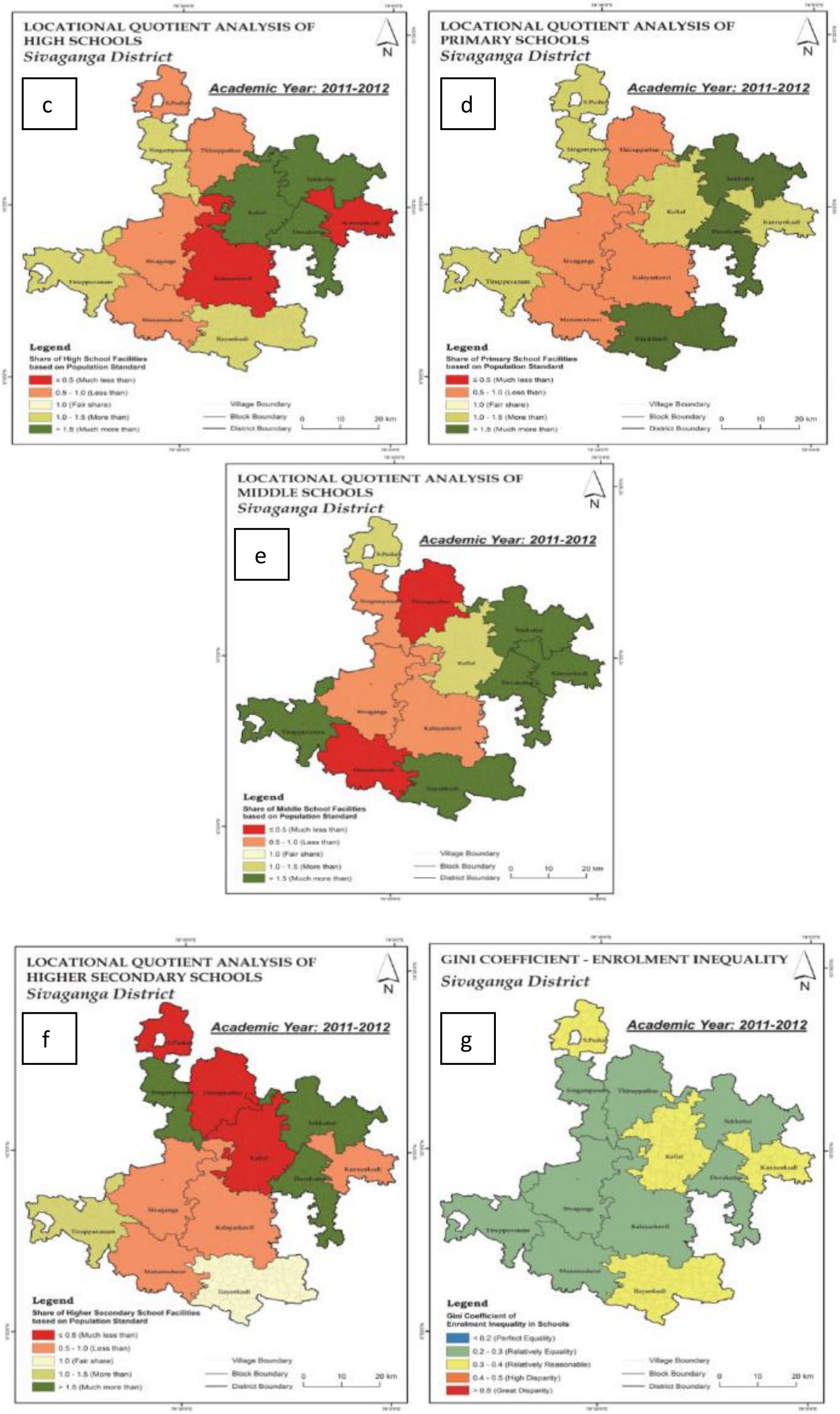


Fig. 3. (a,b,c,d,e,f,g) Gini Coefficent Analysis of Enrolment Inequality

Conclusions

The spatial inequalities in school facilities and students' enrolment are analysed using the statistical techniques such as location quotient analysis and Lorenz curve method of Gini coefficient analysis. The results derived from location quotient analysis shows the share of schools facilities based on population standard. Based on this, the primary school facilities are found less in Manamadurai, Kalaiyarkoil, Thiruppathur and Sivaganga blocks. The less category of middle school facilities are found in Manamadurai, Thiruppathur, Kalaiyarkoil, Singampunari and Sivaganga blocks. During the same time, less high school facilities are identified in Kalaiyarkoil, Kannankudi, Thiruppuvanam, Manamudurai, S.Pudur and Sivaganga blocks. While looking at the higher secondary school facilities, less facility are found in Thiruppathur, S.Pudur, Kallal, Kalaiyarkoil, Manamadurai, Sivaganga and Kannankudi blocks. Finally, it is concluded that the school facilities are to be initiated and upgraded in Manamadurai, Kalaiyarkoil, Thiruppathur and Sivaganga blocks. The results derived from Lorenz curve method of Gini coefficient analysis shows that high disparity of enrolment is observed in Kannankudi, S.Pudur and Ilayankudi blocks in 2009-2010. In 2010-2011, the high disparity of enrolment is identified in S.Pudur and Kannankudi in 2010-2011. But in the year 2011-2012, there was no disparity found in the school's enrolment among the blocks of the study area.

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HEALTH MAPPING - A SPATIAL ANALYSIS OF CUDDALORE AND ITS ENVIRONS, TAMIL NADU

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Abstract

Health implies the quality of life. The quality of life of a person in a particular region can be assessed by the indirect measurements, using demographic variables, socio-economic variables and the distance factors from the hospitals and other health care units. This research paper is an attempt to derive Health Hazard Zones (HHZ) using the indirect indicators and delimit the areas which are highly prone to ill-health and diseases. For this purpose, villages located within the radius of 20 km from Cuddalore urban centre which is the coastal town of Tamil Nadu had been taken to obtain the data of the villages and small towns. Data pertaining to the demographic variables, socio-economic variables and distance factors had been taken for the analysis. Methodology adopted in this analysis was simple method of obtaining a Health Hazard Index (HHI), by assigning positive and negative weightages for the indicators. The resultant health hazard map shows that the villages located near to the rivers were prone to high health hazards and highly prone to diseases. The areas of high literacy rate and short distance to hospitals show low health hazard index and are less prone to diseases.

Keywords: Health, Health Hazard Index (HHI), Socio-economic variables, Demographic variables, Principle component scores, Disease prone region.

Introduction

Health implies the condition of body and mind, especially free from the physical diseases and mental distress; it is an important aspect to be considered for the assessment of development of a nation. Quantitative analysis of health aspects and mapping of such average, therefore needed to enlist the locations and areas, which are highly prone to degradation of quality of health and health hazards. World Health Organisation (WHO) (1968) has reportedly emphasised that health, which is a complete physical, mental and social wellbeing and not merely the absence of diseases or infirmity is a fundamental human right. Several scientific research findings show that human health is largely affected by the physical environment, cultural environment and social environment. Man's relationship to his environment necessarily must be regarded into two complementary aspects viz., (a) the elements of the environment that are hazardous to his health and safety, (b) man's activities within his environment that threatens his own health. The physical, social and ecological aspects of environment are all relevant to human health and wellbeing (Wiesner, 1995).

Assessment of health is one of the important factors to be measured for the human resource management. Mapping of factors which affect the human health is an important area of study for planning. This paper deals with the spatial analysis of health factor, mapping of health issues and a technique of measuring of health hazard pattern. There are direct measures and indirect measures available to estimate such factors which affect the human health. Diseases, disease ecology, climatic conditions, death rates, birth rates, infant mortality rates are some of the direct measurements which are readily available from the Public Health Departments and Department of Statistics of every State of India. Likewise, health related information can be collected from health visitors, health inspectors, health management departments, public health departments, block health supervisors, chief medical officers and community health nurses. Data on communicable diseases and chronic diseases would help to detect some of the major diseases like cholera, tuberculosis, malaria, polio and acute diarrheal diseases etc., which are recorded in government hospitals, primary health care centres, sub-centres, maternity and child welfare centres. These institutions also record data regarding in-patients and out-patients, origin of patients and the nature of diseases. Point data thus obtained are usually used for areal inferences and the preparation of maps. However, these kinds of information reveal the pattern of health or health hazards that had occurred. Without doubt, based on these maps, zones of problematic areas can be classified and preventive measures can be planned.

It is an established fact that health is an outcome of socio-economic conditions of the people. Large proportion of illiterate population implies the lack of understanding and awareness of health prospects among the majority of population. In such situations, the occurrence of diseases and outbreak of periodic ailments are common. In circumstances like this, not only a wide spread of health problems exists but also higher infant mortality, lower life expectancy and malnutrition are prevalent. Access to hospitals and primary health care units at the time of common illness is also a factor determining the health. Therefore, the conditions, especially the socio-economic factors, of the community can be regarded as factors of health and vice-versa (ill-health or health hazard). Health hazard refers to various factors that are hazardous to human health. For example, lower the female literates higher the health hazard; higher the farm workers (especially women), higher the health hazard and; poor access to health facilities higher the health hazard. These indirect measures could readily calculate at any point of time and health planning be exercised accordingly.

Therefore, health of the people is mainly designed by the socio-economic conditions and the prevailing environmental parameters. Mapping of the factors of socio-economic conditions like house hold size, monthly income of the family, major occupations, slum population and environmental parameters like the location of hospitals, nearness to the water bodies and other climatic aspects are an important area of health investigation. This technique of mapping and the health parameters paves the way for the future planning and the better provision of the budgetary allocation. By health survey, it was revealed that women are eager to use basic health facilities, provided if it is accessible. Thus, people who live near the urban centres may take preventive measures and devoid of many communicable and chronic diseases. Nearness to river, irrigated areas, water-logged areas cause hazardous situations like waterborne and vector borne diseases.

Another indirect factor, which influences the health of the people, is literacy rate. For example, the percentage of female illiteracy is a factor of ill health. Owing to illiteracy or poor literacy, such women may not be aware of health and hygiene practices and child welfare measures. Therefore, an appreciable amount of risk is involved in terms of health as far as these groups of illiterate women are concerned. It is apparent that the probability of falling sick is more for the people working in the mines and industries. So, occupational structure of the people has its own implications on the human health. Occupational structure also shows the standard of living of the people, which indirectly affects the human health.

Health hazard maps can be prepared with these indicators and that can be of great values for spatial knowledge. Mukherjee (1976) had suggested that the calculation of health hazard index by aggregating various health related indicators in his article, “a simple method of obtaining a health hazard index and its application in micro-regional health planning”. The present paper is also an attempt to map the health hazard pattern but using indirect indicators.

Study Area

For this study, villages located within the radius of 20 km from Cuddalore, a northern coastal town of Tamil Nadu had been taken into consideration. The study area (Figure 1) has one major urban centre and three medium urban centres viz., Cuddalore, Nellikuppam, Panruti and Cuddalore Port Nova and 124 villages. Rivers such as Gadilam, Ponnaiyaru, Uppanaru, Malgattaru and Pambiyaru flow parallel to each other except Uppanaru. Western part of the area is dry comparing to the middle part, which has more irrigated areas and marshy lands. Eastern part of the region has a number of industries, which are polluting the surrounding area, and brings major health problems to the people living in and around the Cuddalore urban centre. Regarding the location of Health Care Facilities, there are three Government Hospitals (G.H.), ten Primary Health Centres (P.H.C.) and fifteen Maternity and Child Welfare (M.C.W.) found within the study area.

Database and Methodology

To map the health hazards, the following methods are adopted:

1. Weightage technique was followed to prepare health hazard index map. Health hazard index was calculated for all 128 villages by aggregating various health related indirect indicators. Three sets of readily available variables were taken into consideration for calculating the health hazard.
2. Factor analysis were carried out for the given set of variables as an alternative to weightage technique and the principle component scores were thus extracted and used for the mapping of health hazard prone areas.

Variables Used in the Health Hazard Index Construction

Based on the general assumptions, from the population data of 2011 Census, the following first two sets of variables were identified for each village and used in the study.

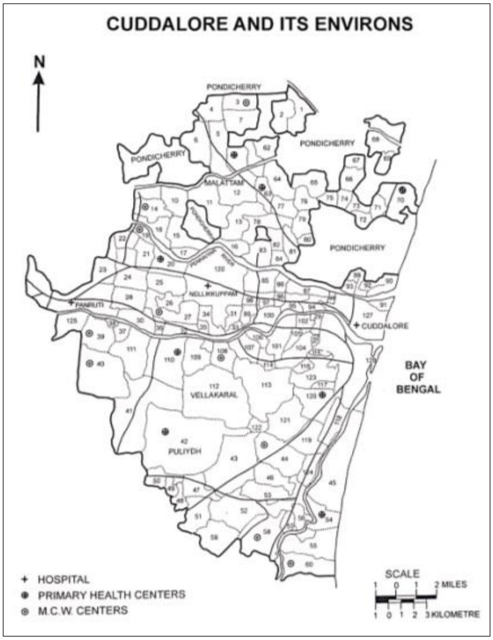

Fig. 1. Cuddalore and its Environs

1. *Demographic Variables*: (Note-1)
   a) Total Population
   b) Density of Population
   c) Average Size of House hold
2. *Socio Economic Variables:* (Note-2)
   a) Total Literates
   b) Percentage of Female Literates to the Total Female Population
   c) Total Main Workers
   d) Total Non-Workers
   e) Ratio of Female Primary Workers to the Male Primary Workers
   f) Ratio of Female Secondary Workers to the Male Secondary Workers
   g) Ratio of Female Tertiary Workers to the Male Tertiary Workers
3. *Distance Factors:* (Note-3)
   a) Distance to the P.H.C
   b) Distance to the Hospitals
   c) Distance to the M.C.W
   d) Distance to the largest Urban Centre
   e) Distance to the nearest Urban Centre
   f) Distance to the nearest river
   g) Distance to the major roads

Note-1: It is assumed that the demographic variables are positively related with the health hazard of a particular village. As the limited resources are shared by many people, villages which have high density are prone to more health problems. Therefore, the population parameters are very important factors to be considered for assessing the health hazard pattern of villages.

Note-2: Socio economic variables are considered to be the second most important variable, since health of the people is mainly designed by the socio economic conditions and the prevailing environmental parameters.

Note-3: Distance factors are also important indicator in analysing the health hazard patterns of the villages. By a health survey, it was revealed that women were eager to use basic health facilities, provided it was accessible. Thus, people living near the urban centres may take preventive measures and devoid of many communicable and chronicle diseases. Nearness to river, irrigated areas, due to the water logged situation, and forms the hazardous situation by bringing water borne diseases and vector borne diseases. Infrastructural facilities may affect the health pattern. People living near the major roads may devoid of many diseases by utilising the transportation facilities to reach the health centres.

Health Hazard Index by Weightage and Mapping

As a first step, weightage were assumed to the variables according to the importance of the variables in contributing to the health hazard. The variables which play an important role in increasing the health hazard were given positive weightages, which reduces the health hazard were given negative weightages. For example, total population was given a weightage of +2, higher the population, higher the exploitation of the basic resources, thus aggravating the health problems more, hence it was given the value of +2. On the other hand, general literates as well as female literates contributed more towards the improvement of health status. Therefore, it was given -5 as weightage. Likewise, all the variables were given weightage according to their importance.

Second step, includes the calculation of an index so as to arrange all villages with the characteristics (or variables) into raw data matrix where in the values were arranged in descending order to assign the decile score. As the name implies, the total number of observations (villages) were divided by 10. The first K number of observations will have the decile rank of 1; next K number of observations would have a decile score of 2 and so on.

In the third step, the decile score of each village were multiplied by the weight corresponding to those variables and then the products were added to obtain the total health hazard score, for the i'th village,

Hi = wj*Dij (i=1,2,3……..N villages; and j= 1,2,3………p variables);

where,

'Wj' was the weight assigned to the jth variable in accordance with values.

'Dij' is a decile score of ith village on the jth variable.

'Hi' index represents each village's degree of health hazard.

After obtaining health hazard values for all the villagers, the hazard values were ranked in ascending order, i.e. highest value receives rank one and so on. Thus, the health map can be prepared by taking the class interval according to these distributions.

Five class intervals were obtained by dividing the ranks into five divisions and health hazard zones were identified such as very high health hazard area, moderate health hazard areas, low health hazard areas and very low health hazard areas, thus the health map were prepared and the spatial pattern be brought out.

The Principle Component Scores and Health Mapping

As an alternative, principle component analysis is applied to define health hazard indices. In general, essential purpose of factor analysis is to describe, if possible, the covariance relationships among many variable in terms of a few underlying, but unobservable random quantities called factors (Johnson and Wichern, 1996). It is used for the reduction of data and easy interpretation. The raw data matrix was first subjected to the circulation of correlation matrix. The correlation matrix of the variable was tested at 0.01 and 0.05 significance levels with required degrees of freedom. Most of the variables were significantly correlated with other variables thus indicating the strong inter-correlation between the variables.

As the Eigen values are more than one of the first five factors, these were taken in to consideration for the extraction of principle component scores. Among these five factors, factor one and factor two alone contribute 50 percent of all variation. Factor one highlight the literates and workers mix and factor two highlights the distance factors. So principle component scores are extracted only for these two factors to prepare health hazard map. In order to prepare the map, the principle component scores are arranged in ascending order or descending order according to their relationship with health hazard. Based on the rankings, the class intervals are assigned and the Health Hazard Index (HHI) maps are drawn for the easy comparison.

Results and Discussion

Health Hazard Index

The Figure 2 clearly shows that the villages located around the rivers have very high health hazard. Villages such as Sirunangaivadi, Velisemandalam, Subauppalavadi, Kondur, Chittarasur, Vilangalpattu, Marudadu, Tirumanikuli, Kilalinjipattu, and Kotlambakam have very high health hazard index in Cuddalore taluk. High density of population, low total literacy, low female literacy, very high percentage of non-workers, poor accessibility to health care units and nearness to water bodies are the major causes for high health related problems in these villages.

Literates and Workers Mix

The Figure 3 shows that the villages located along the major rivers are highly prone to more health related problems. The low health hazard is defined by high scores. To some extent, this map correlates with the health hazard index map. Villages such as Perichchambakkam, Chinnakanganankuppam, Karaikaddu, Kondur, Subauppalavadi, Thiruppanambakkam, Chinnakanganankuppam Agragaram, Kambalilmedu, Puliyur, Vellakarai, Naduvirapattu and Tondamanatham have very high percentage of literates and workers mix, so these villages have very low health hazard.

Therefore, it can be concluded that nearness to rivers has its own implications on the health of the people. Health hazard of a particular village can be purely calculated through the factors of literates and workers mix group alone. This factor is negatively related to the health related problems. More the scores, lower the health hazard.

As the villages located along the rivers Ponnaiyar and Gadilam are highly prone to health related problems, the first principle component score map and the health related problems, coincides with each other. The rho-correlation is tested between the health hazard and the principle component score rank to find out the relationship between the two ranks. It shows that both have positive relationship. Therefore, it is very clear that the factor of low literacy and less number of workers may bring more health related issues. Preventive measures should be taken to avoid inconvenient situations for the village people by undertaking literacy campaign, health campaign and to bring more employment opportunities for the people deserved.

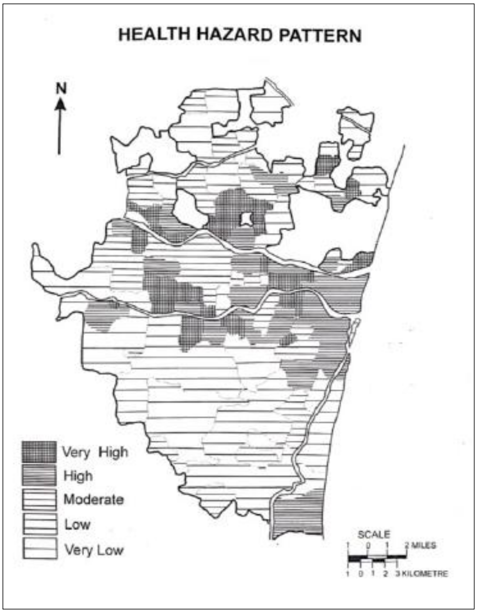

Fig. 2. Health Hazard Pattern

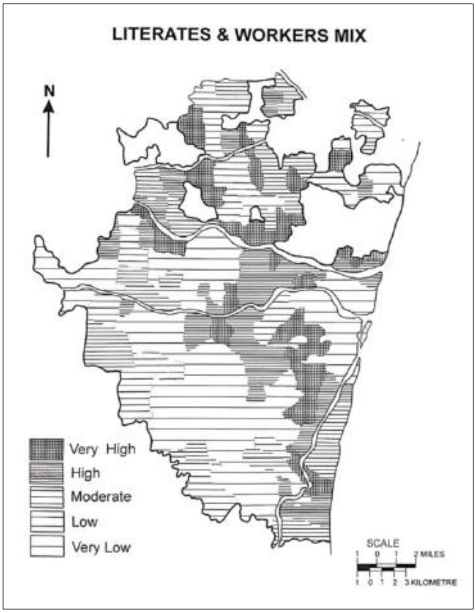

Fig. 3. Literates and Workers

Distance Factor

Distance to the largest urban centre and government hospital were taken as the second most important factor, which determines the health condition of the people of villages. Therefore, the second principle component scores highlight the distance factors. The villages such as Kandamangalam, Ayikuppam, Idankondambattu, Aliyur, Kayalpattu, Singirikudi, Navammalmarudhur are away from the largest urban centres and government hospitals and so they have very high health hazard compared to other villages.

As the villages such as Sathipattu Ponnaiyan Kuppam, Sedapalayam, Pachchyankuppam, Kotlambakkam, Vellapakam, Edyanur, Karamanikuppam, Padirikuppam, Karaikkadu, Kilakuppam, Arisipperiyankuppam and urban centres like

Cuddalore, Cuddalore Port Nova has very less health hazard as they are located very near to the basic health care facilities. As the distance increases, the people run by more health risk.

Variation exists between the Figure 4 of health hazard and the second principle component scores. Thus, the rho-correlation between these two ranks turned out to be -0.3512, indicating that there is a negative association. This contrasting map shows that the distance wise, there are some villages, which may prone to more health problems. Therefore, more infrastructure facilities should be provided to those villages in order to minimize the health problems occur due to the distance factor.

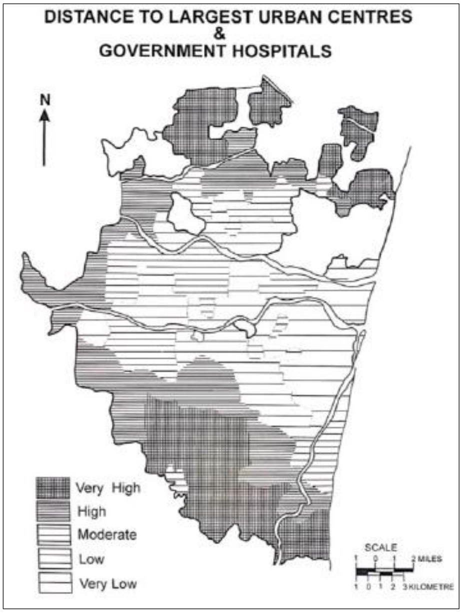

Fig. 4. Distance to Largest Urban Centres and Government Hospitals

Conclusions

This analysis concludes with various results and the procedures for mapping the health hazard prone areas. By this, we could prepare various health maps using the readily available secondary data. All these maps show the villages which are prone to diseases and this needs the attention of the government. Thus, assisting to form guidelines to the planners to take preventive measures. This method is most relevant as it is quicken and least exposure, rather than going for the direct variables for measuring health hazard zones as it only helps to take remedial measures and not preventive measures. This analysis can also be made more appropriate by taking some more indirect variables such as source of drinking water, water contamination, water logged areas, air and land pollutions etc. Thus, the simple method used here to obtain health hazard index could also be adopted to find out the relative level of the health hazard of a particular area. The health hazard demarcates various levels of health hazard zones.

Such identification of hazardous regions suggest the need for new health care facilities, infrastructural facilities and additional health care activities to improve the health status of the corresponding villages or community at large. It also paves the way for the future planning and the better allocation of the budgetary provisions. Thus, we can bring the high health hazard zone to hazard free zones. This method can also be used to calculate women health index, childcare index etc. by taking more gender related variables and child related variables. Thus, we can identify the villages or blocks, which give more or less status to women and children by looking through gender biased values and child biased values.

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GEOSPATIAL ASSESSMENT OF GROUND WATER RESOURCE OF KUNDU NALA, GOMTI BASIN (U.P.) USING WIO TECHNIQUES

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Abstract

The present study has been carried out in Kundu Nala sub unit of Gomti basin. Remote sensing and Geographical Information System (GIS) techniques have been used for delineating the fluvial and other natural elements. In the present study Landsat 8 OLI and ASTER (30 m) data have been used to prepare various thematic maps such as geomorphology, slope, drainage and landuse / land cover map has been generated and integrated. Geomorphology, slope, drainage and landuse maps helped in identification of the water potential for the development and planning. On the basis of relative contribution of each of these maps towards groundwater potential, the weight of each thematic map has been selected and ranking has been made for each of the features. All the thematic maps have been integrated step by step using the Weighted Index Overlay (WIO) analyses method in GIS. On the basis of the final output, the study area is classified in five categories viz., very good, good, moderate, poor and very poor groundwater potential zone. The study shows that the overlay of all maps provides more accurate information for geo-environmental and water resource planning.

Keywords: Groundwater potential zone, Geomorphology, Geospatial, Geographical Information System.

Introduction

Groundwater exploration means to identify and to locate the zone of occurrence and recharge of groundwater in a particular basin or a catchment (Pareta, 2011). Groundwater is most essential natural resource for the human being in both rural and urban environment. Hence, it plays a fundamental role in human well-being in all regions of developed and developing countries. So, an assessment of this resource is extremely significant for the sustainable management of groundwater. It is an in depth study of the relations between man and his geologic, geomorphic, physical and cultural environments. Geomorphology and geology of any area have an important control on the water ability and landuse. High relief and steep slope cause high runoff where topographical depressions increase infiltration. An area of high drainage density also increases surface runoff compared to a low drainage density area. Surface water bodies like rivers, ponds, etc. can act as recharge zones (Murugesan et al., 2012).

Remote sensing (RS) technology, with its advantages of spatial, spectral and temporal availability of data covering large and remote areas within a short time, has emerged as a very valuable tool for the assessment, monitoring and management of groundwater resources (Chowdhary et al., 2009; Engman and Tand Gurney, 2009; Yeh et al., 2009; Jha et al., 2007). As remote sensors directly cannot detect groundwater, the presence of groundwater is indirect from different surface features derived from satellite imagery such as geology, geomorphology, landforms, slope, landuse/ land cover, drainage, and surface water bodies, etc. which act as indicators of groundwater existence (Todd, 1980).

In the past, several researchers have used RS and GIS techniques for the study of groundwater potential zone with successful results (Shahid et al., 2000; Khan and Moharana, 2002; Jaiswal et al., 2003; Rao and Jugran, 2003; Sikdar et al., 2004; Sener et al., 2005; Ravi Shankar and Mohan, 2006; Solomon and Quiel, 2006; Cheng-Haw Lee et al.2008; Deepesh Machiwal et al., 2010; Prabir Mukherjee et al., 2011; and Murugesan Bagyarajet al., 2012). Remote sensing not only provides wide-range of information, but also saves time and money (Murthy, 2000; Leblanc et al.,2003; Tweed et al., 2007). In addition, it is widely used to characterise the earth surface (such as lineaments, drainage patterns and lithology) as well as to examine the groundwater recharge zones (Sener et al., 2005). Integration of RS with GIS for preparing various thematic layers, such as geomorphology, drainage density, slope, and landuse with assigned weight and rank in a spatial domain will support the identification of potential groundwater zones. Therefore, the present study focuses on the identification of groundwater potential zones in Kundu Nala basin, using the advanced technology of remote sensing and GIS for the planning, utilisation and management of groundwater resources.

Study Area

Gomti basin is one of the major tributaries of river Ganga. It originates from Gomat Taal near Madho Tanda, Pilibhit district of Uttar Pradesh. The characteristic of river is perennial and sluggish flow throughout the year, except in monsoon season when heavy rainfall increases the flow. The basin is an elongate basin, trending NW-SE direction. In the present study, a small but important sub-unit of Gomati River *i.e.* Kundu Nala drainage system has been investigated for its groundwater assessment. Kundu Nala originates from a pond near Nerthuwa village in Maharajganj tehsil of Raibareli District, Uttar Pradesh (Figure 1).

Database and Methodology

In order to demarcate the groundwater potential zone of the Kundu Nala basin, GIS and remote sensing technology are applied to prepare various thematic maps like drainage density, contour, and stream length. The drainage characteristics were delineated using Arc GIS software from survey of India topographic maps on 1:50,000 scale and ASTER data 30 m resolution.

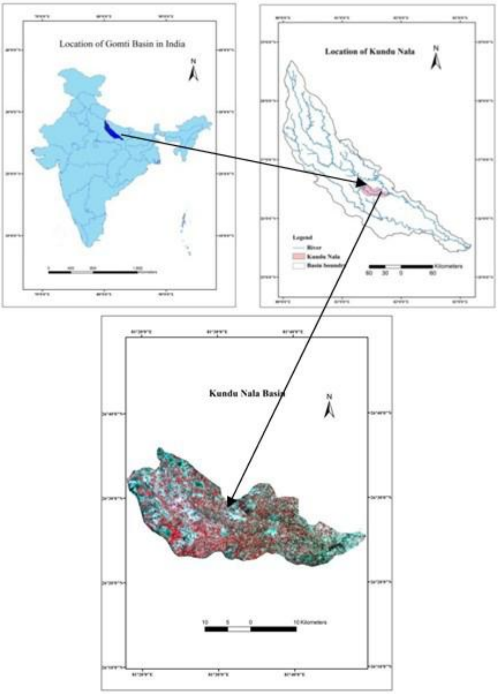


Fig. 1. Location of Kundu Nala Basin

The second stage involved preparation of Digital Elevation Model (DEM). DEM is used to prepare slope, flow direction, flow accumulation and drainage density. The drainage network was analysed according to Horton's laws (Horton, 1945) and stream orders were defined according to Strahler (1964). In the third stage, digital image processing of the satellite data is done in ERDAS Imagine 13 for geometric correction. This is followed by preparing of different thematic maps. In the fourth stage all above the thematic maps are assigned weight and rank according to their characteristics interrelation with groundwater. All the thematic layers were overlaid by using spatial analysis tool in ArcGIS 10.2 to find the final integrated output of groundwater potential zone of the present study.

Results and Discussion

Integration of thematic layers was done based on their influence on the groundwater potential.

Drainage and Drainage Density

Drainage density and type of drainage gives information related to runoff and infiltration. Drainage pattern reflects surface characteristics as well as subsurface formation (Horton, 1945).Drainage network analysis is more important for geo-environmental and groundwater studies of any area. Drainage network of a region depends on the climatic factor, landforms, slope and stage of geomorphic cycle. A drainage map of the study area has been prepared with the help of Google Earth, SOI Toposheet and ASTER DEM data. Kundu Nala is the fourth order stream (Figure 2).

Drainage density is a measure of the total stream length in a given basin to the total area of the basin (Strahler, 1964). Drainage density indicates the closeness of spacing of channels (Horton, 1932) and it is the ratio of the total length of the stream segment of all orders per unit area (Singh et al., 2014). The drainage density characterises the runoff in an area or in other words, the relative rainwater that could have infiltrated. Hence, the lesser the drainage density higher is the probability of recharge or good groundwater potential zone. So, drainage density is important factor to water study. The drainage patterns of the area are dendritic. The drainage density of the area is 1 to 5km / km^2.The entire drainage map is divided into five categories as given in Table 1 and Figure 3.

Table 1. Drainage Density

Class	Drainage Density (km/km^2)	Category
1	1.0-1.8	Very Low
2	1.8-2.6	Low
3	2.6-3.4	Moderate
4	3.4-4.2	High
5	4.2-5.0	Very High

Table 2.Slope gradient and category

Class	Degree	Slope Category
1	< 1	Level
2	1-3	Very Gently sloping
3	3-5	Gently sloping
4	5-10	Moderately sloping
5	10 <	Steep sloping

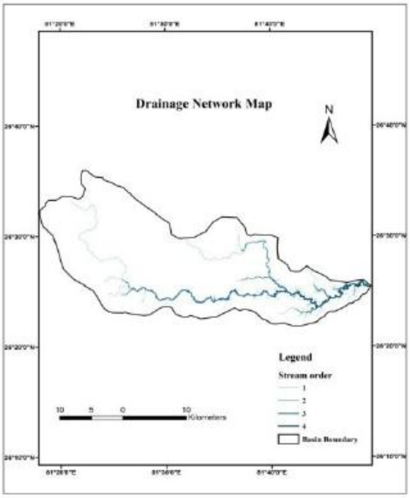


Fig. 2. Drainage Network

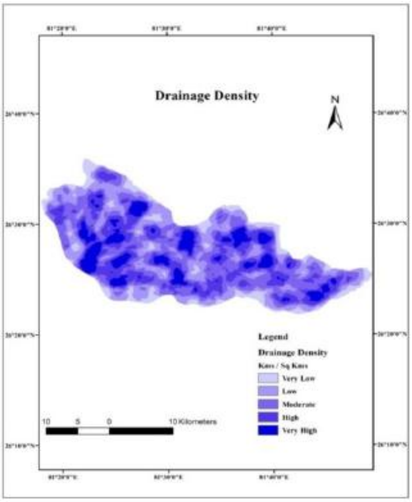


Fig. 3. Drainage Density of the Basin

Slope

Slope is one of the important terrain characteristics and plays a major role in runoff processes, soil erosion, landuse and groundwater planning for basin development. Slope grid is identified as “the maximum rate of change in value from each cell to its neighbours” (Burroug, 1986). It is measured either in percent or in degree. In the level slope area, the surface runoff is slow and allowing more time to percolate the rainwater and consider as good groundwater potential zone where as steep slope area has high runoff and less time to infiltration of rain water so poor ground water potential zone. The slope of the area is categorised in five classes viz., level slope, very gentle slope, gentle slope, moderate slope and steep slope as shown in Table 2 and Figure 4.

Geomorphology

Geomorphology is the study of the form of the earth (landform), its description and genesis (Gupta, 2003). Geomorphology of an area depends upon the structural evolution of geological formation. Geomorphic features area favourable for the occurrence of groundwater potentiality. Kundu Nala, the tributary of Gomti River is a groundwater fed river and represents unique fluvial deposition. The study area fall under fluvial plain, the geomorphology of the study area has been classified into alluvial plain, flood plain and meander scarp. The geomorphology of the study area has been classified into five categories with their areal extend as shown in Table 3 and Figure 5.

Alluvial Plain: An alluvial plain is a relatively flat landform and created by the deposition of eroded material in study area. It comprises sand, silt and clay sequences of late cycle of fluvial deposits. The alluvial plains are represented by river terraces than the flood plains. A district slope break, bordering younger alluvial plain separates at from both flood plain (at lower level) and older alluvial plain (at higher level). It is identified on the imagery dark reddish moderate to fine texture due to agricultural activities. It covers 608.80 sq.km area of study area. It is very fertile land and good for cultivation.

Flood Plain: A flood plain is an area of land adjacent to stream or river that stretches from the bank of the enclosing valley walls and experiences flooding during period of high discharge. It is found along the river bank and occupies an area of 37.88 sq.km.

Meander Scarp: As the outer banks of a meander continue to be eroded through processes such as hydraulic action the neck of the meander becomes narrower. Due to the narrowing of the neck, the two outer bends meet and the river cuts through the neck of the meander usually during a flood event when the energy in the river is at its highest. Deposition gradually seals off the old meander bend forming a new straighter river channel. Due to deposition the old meander bend is left isolated from the main channel as an ox-bow lake. Over time, this feature may fill up with sediment and may gradually dry up. When the water dries up, the feature left behind is known as meander scarp. It covers a small part of 0.89 sq.km area of the study area.

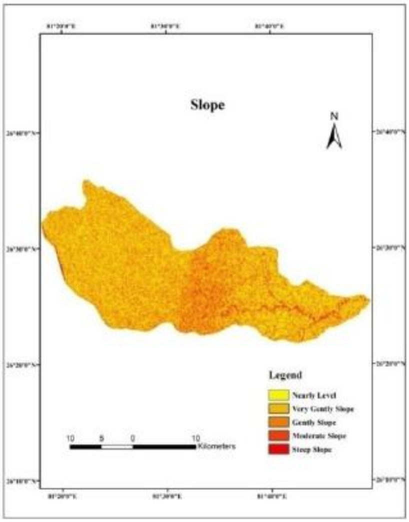


Fig. 4. Slope of the Basin

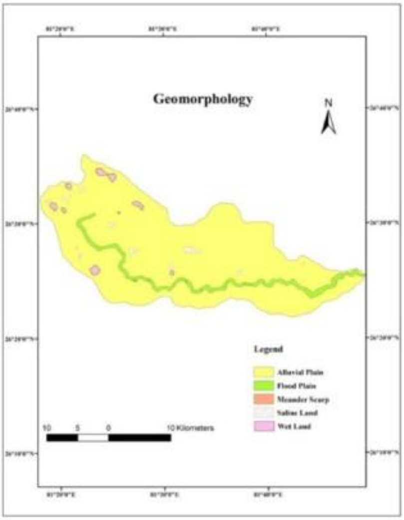


Fig. 5. Geomorphology of the Basin

Saline Land: Soil salinity is the amount of dissolved salts in the soil solution (the aqueous phase in the soil). The process of accumulating soluble salts in the soil is known as salinization. It is identified on the imagery white moderate to fine texture due to the presence of salt in surface. It covers about 6.52 sq.km area of the study area.

Wetland: Wetlands are areas where water covers the soil, or is present either at or near the surface of the soil all year or for varying periods of time during the year, including during the growing season. It found in upper part of the study area and cover 9.74 sq.km area.

Table 3. Geomorphology Category and Area

Sl.No.	Description	Area (km^2)
1	Alluvial plain	608.80
2	Flood plain	37.88
3	Meander scarp	0.89
4	Saline land	6.52
5	Wetland	9.74

Table 4.Landuse / Land Cover Classification and Area

Sl.No.	Type of Land	Area (km^2)
1.	Agriculture land	406.67
2.	Waterbody	29.02
3.	Fellow land	150.52
4.	Forest	37.17
5.	Settlement	22.18
6.	Wasteland	2.16
7.	Wetland	9.56
8.	Saline land	6.56

Landuse/ Land Cover

Land is the most important natural resource, which embodies soil, water and total ecosystem (Pareta, 2011). The landuse pattern of any terrain is a reflection of the complex physical processes acting upon the earth surface. These processes include the impact of climate, geologic and topographic conditions on the surface of the earth. Information about the spatial distribution of landuse / land cover and the pattern of their changes is must for utilisation, management and planning for the development of the land resources of the study area. Landuse plays a significant role in the development of groundwater resources. It controls many hydrogeological processes in the water cycle viz., infiltration, evapo-transpiration, surface runoff etc. In the forest areas, infiltration will be more and runoff will be less whereas in urban areas rate of infiltration may decrease.The landuse of the Kundu sub-watershed shows that it is predominantly agricultural area. In the present study landuse / land cover are mainly classified into eight categories namely agriculture land, fellow land, forest land, salt effected land, wet land, settlement, waste land and water bodies. The agricultural fields are developed all over the area which clearly points out that the soil of area is very fertile in nature. Agricultural land covers 406.67 sq.km areas, fallow land covering 150.52 sq.km area. Forest area are noticed along the river covering area 37.17 sq.km, saline land covering area 6.56 sq.km, tanks, streams and canal grouped under waterbodies covering 29.02 sq.km and settlement covering area 22.18 sq. km. as depicted in Table 4 and Figure 6.

Digital Elevation Model

A Digital Elevation Model (DEM) is a numerical representation of the Earth's surface that contains the terrain height (Felicísimo, 1994). The elevation profile of the DEM ranges between 60 to 142 m in the sub-watershed (Fig.7). The colour variations of the DEM shows the various topographical signatures that accumulate the information regarding the slope. The low elevation and relief was observed from DEM data. The change in elevation from west to east can be easily visualised.

Assigning Weight and Rank

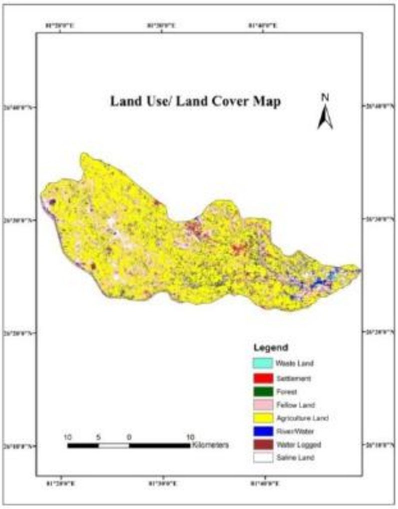
The groundwater potential zones are obtained by overlaying all the thematic maps in terms of weighted overlay method using the spatial analysis tool in ArcGIS 10.2. During the weighted overlay analysis, the ranks have been given for each individual parameter of each thematic map and the weight is assigned according to the influence of the different parameters. In the present study, an index overlay method has been adopted for combining the multiple thematic maps. In this, the map classes occurring in each input map are assigned some different scores, in addition to the maps themselves receiving weights. The average score is then defined by:

$$Swm = \sum wi*ri$$

Where, S is the score for an area object, Wi is the weight for the i^{th} input map, and ri is the rating score for the i^{th} map. The groundwater prospects map is prepared on GIS based analysis which is shown in Figure 8. All the thematic maps are converted into raster format and superimposed by weighted overlay method (rank and weight wise thematic maps and integrated with one another through GIS.

For assigning the weight, the slope and geomorphology were assigned higher weight, whereas the landuse was assigned lower weight. After assigning weights to different parameters, individual ranks are given for sub variable. In this process, the GIS layer on geomorphology, slope and drainage density were analysed carefully and ranks are assigned to their sub variable.

The maximum value is given to the feature with highest groundwater potentiality and the minimum given to the lowest potential features. The landforms such as moderately dissected plateau are given highest rank and lower value is assigned for pediplain. As far as slope is concerned, the highest rank value is assigned for level, gentle slope and low rank value is assigned to higher slope. Among the various drainage density category the higher ranks are assigned to low drainage density because the low drainage density factor favours more infiltration, less surface runoff and lower value assigned to higher drainage density. In landuse / land cover high rank is assigned to agricultural land and low value is assigned to saline land. The overall analysis is tabulated in Table 5.



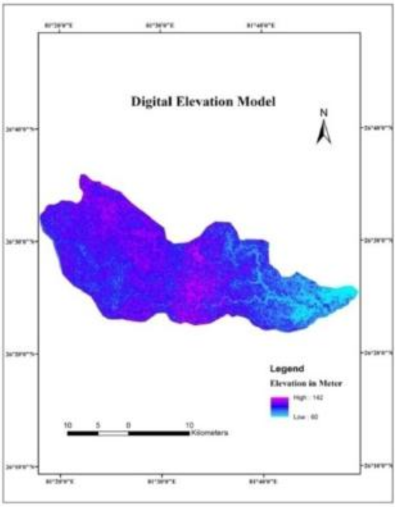


Fig. 6 Landuse / Land Cover of the Basin Fig. 7 DEM of Kundu Nala Basin

Groundwater Potential Zone

Groundwater potential zone of the study area has been analysed by using spatial analysis tool in ArcGIS 10.2 with the drainage density, landuse, geomorphology and slope. On the basis of integration of these maps groundwater favourable zones of the study area were identified. The groundwater favourable zones are shown in Table 6 and Figure 8. On the basis above classification the study area have been classified into five categories of groundwater potential namely, very good, good, moderate, poor and very poor.

The geomorphologic units such as alluvial plain, flood plain and agricultural land, settlement, forest, level slope area are the most favourable zones for the groundwater potential. Hence, these areas are marked as good to very good groundwater potential zones. These zones are mostly found in northern and middle area. Whereas, moderate to poor groundwater potential zone found in the area having moderate slope with drainage density 2 to 3, flood plain, land under the waste. Very poor potential zone found mainly in area having steep slope, high drainage density, land under the saline and wetland area.

Table 5. Weight and Rank for Different Parameter of Groundwater Potential Zone

Parameter	Classes	Groundwater prospect	Weight (%)	Rank
Geomorphology	Alluvial Plain	Very Good	35	5
	Flood Plain	Good		4
	Meander Scarp	Moderate		3
	Wetland	Poor		2
	Saline Land	Very Poor		1
Slope	Nearly Level	Very Good	30	5
	Very Gently Slope	Good		4
	Gently Slope	Moderate		3
	Moderate Slope	Poor		2
	Steep Slope	Very Poor		1
Drainage Density	Very Low	Very Good	20	5
	Low	Good		4
	Moderate	Moderate		3
	High	Poor		2
	Very High	Very Poor		1
Landuse / Land Cover	Agriculture Land	Very Good	15	8
	Waterbody	Very Good		7
	Fallow Land	Good		6
	Forest	Good		5
	Settlement	Good-Moderate		4
	Wetland	Poor		3
	Wasteland	Poor		2
	Saline Land	Very Poor		1

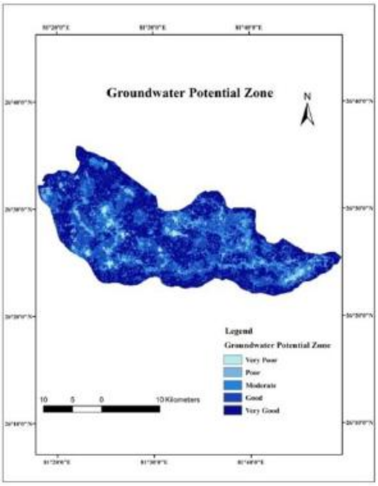


Fig. 8. Groundwater Potential Zone of Kundu Nala

Table 6. Groundwater Potential Zone

Sl. No.	Potential Zone	Area (km^2)
1	Very Good	261.00
2	Good	218.81
3	Moderate	113.79
4	Poor	59.46
5	Very Poor	19.77

Conclusions

The result of this study shows that the RS and GIS technology is a powerful tool with an emphasis on geomorphology, landuse / land cover; slope and drainage density helps for the demarcation of the groundwater potential zones in Kundu basin, UP. With the help of various thematic maps and proper assignment of weight and rank are the key for GIS technique to identify the ground water potential zone. Remote sensing and GIS is also reducing the cost of well drilling by the failure of suitable well site. This information is very useful for the future to development of sustainable groundwater of the study area. The study area is classified in to very good, good, moderate, poor and very poor groundwater potential zones and indicated in Figure 8 The area statistics of different ground water prospect zones are given in Table 6.

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NDVI AND SPI BASED DROUGHT ASSESSMENT OF KARUR DISTRICT, TAMIL NADU, INDIA

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Abstract

Drought is a multi-dimensional disaster that plays a deterministic approach on many climatic zones throughout the world. The drought restricts the growth of a region in many ways viz. physically, culturally and economically. The paper discusses about the use of geoinformatics in disaster risk management planning, which exists as a very powerful tool in identifying the drought occurrences and in processing the spatial information for better predictions for drought. The drought condition of Karur District, Tamil Nadu, has been considered in this study based on the decreasing trend of rainfall. The data has been compiled from various data repositories such as Open Series Map (OSM) sheets, NRSC Bhuvan portal, and Indian Meteorological Department (IMD). The drought assessment is drawn from two indices, first using Normalized Difference Vegetation Index (NDVI) for the years 2011 to 2015 and second, with rainfall to generate Standard Precipitation Index (SPI) for the span of 30 years from 1984 to 2013. The drought condition shows a continuous increase from 2012 to 2015 in January months. The drought vulnerability in the study area shows the highest record of very high vulnerability in the villages Paramathi and Tennilai of Aravakurichi Taluk. The map has been classed into four categories viz. very high, high, moderate, and low vulnerable levels. The SPI values, extreme dryness occurred in the years of 2000 and 2013. The result also shows that the drought condition prevails over Aravakurichi taluk with dryness with no rainfall for a pronged period. This type of versatile study provides a detailed knowledge about climatic based drought assessment, which is helpful to the administrators for making proper plans against disaster like drought.

Keywords: Normalised difference vegetation index, Standardised precipitation index, Drought

Introduction

Northeast monsoon season is the major source of rain over Tamil Nadu, which contributes more than 70 percent of the annual mean rainfall. Rainfall is the primary driver of meteorological drought. Meteorological drought is the earliest explicit event in the process of occurrence and progression of drought. There are numerous indicators based on rainfall that are being used for drought monitoring (Smakhtin and Hughes, 2007). The drought condition of Karur District, Tamil Nadu, has been considered in this study based on the decreasing trend of rainfall. Many drought indices such as the Palmer Drought Severity Index (PDSI) (Dai, 2004), the Deciles Index (DI) (Gibbs and Maher, 1967), Bhalme–Mooley

Index (BMI) (Bhalme and Mooley, 1980), the Surface Water Supply Index (SWSI) (Shafer and Dezman, 1982), the China-Z index (CZI) (Wu et al., 2001) are widely used while the Standardised Precipitation Index (SPI) (McKee et al., 1993) has achieved world popularity.

According to its impacts, following categories of drought are considered: meteorological, agricultural, hydrological and socio-economic drought (Wilhite and Glantz, 1985). The drought restricts the growth of a region in many way: physically, culturally and economically, viz. reduced water supply, crop failure, deteriorating quality of water resources, diminishing power generation, economic crisis, migration, etc. Drought must be considered as a relative, rather than absolute, condition (WMO, 2012). Drought is a multi-dimensional disaster that plays a deterministic approach on many climatic zones throughout the world. Drought is the most complex and least understood of all natural hazards, affecting more people than any other hazard (Wilhite, 2000).

The drought regionally affects through spiral effect downward. Geoinformatics with geo-spatial data from various satellites, Geographic Information System (GIS) and integrative tools provide immense opportunities to evolve a variety of drought indicators and integrate the same with ground based indicators for objective assessment of drought at different spatial scales (Murthy and Sesha Sai, 2010). Geoinformatics is the key tool to extract potential information from an extensive region or inaccessible location. In the recent years, satellite remote sensing technology has successfully proven itself as a valuable information generator for various river engineering studies. The potential of remote sensing data is that it is highly reliable, accurate, and cost effective (Bhanumurthy et.al., 2010).

Remote Sensing, the latest advancement in space and technology has the capability to overcome the shortcomings of the conventional methods. It makes a major technological breakthrough in the method of acquiring information on land resources, agriculture, forestry, ocean resources, and other studies (Rao et.al., 1991; Kumaraswamy et.al., 2011). Karur District has only about 2.38 percent of its land under forest cover. The total geographical area of the District is mostly covered by cropland and fallow land. The digital land use / land cover database of National Remote Sensing Centre (NRSC) reveals that about 57 and 22 percent area of total geographical area of the District falls under cropland and fallow land respectively in 2015. The objectives of the study has been prepared with a notion that the use of geoinformatics in disaster risk management planning, serves as a very powerful tool in identifying the drought occurrences. Thus, the objective of the study is to find the trend of using SPI and NDVI indices and to suggest the location specific drought planning using geoinformatics as a convenient technique. The scope of this versatile study provides a detailed knowledge about climatic based drought assessment in Karur District, which is helpful to the administrators and rulers for making proper developmental plans against the natural disaster like drought in a regional scale.

Study Area

A case study of Karur District in Tamil Nadu has been taken as the study area for this paper. The total geographical area of the District is 2,895 km^2 and it is located between

10°56'45" and 11°04'35" N latitude and 77°49'50" and 78°00'13" E longitude. Karur is 29th most populous District out of total 32 Districts in Tamil Nadu. The population of the District is 1,076,588 and the population density is 371 persons/km^2. The District is bounded by Tiruchirappalli District on the east, Namakkal and Tiruchirappalli Districts on the north, Dindigul District on the south and Erode District on the west.

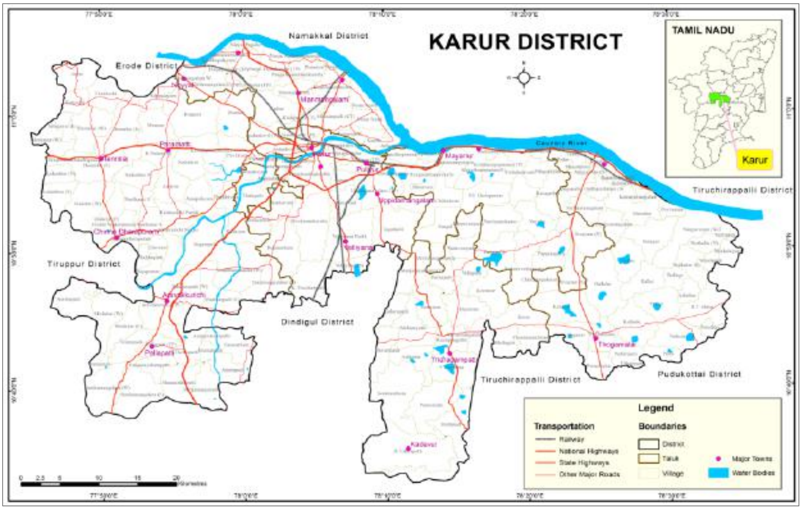

Fig. 1. Study Area - Karur District

The average elevation of the District ranges between 100 m and 200 m above mean sea level. The rivers are seasonal and carry substantial flows during monsoon period The river Cauvery forms the northern boundary of the District along with the Amaravathi and Kodavanar rivers which are other important rivers draining on the western part of the District. The day time heat is oppressive and the temperature is as high as 43.9°C. The following table gives the mean maximum and minimum temperature that recorded in K.Paramathi weather station.

The southwest monsoon rainfall is highly erratic and summer rains are negligible. The average annual rainfall of Karur District is 655 mm. The Table 2 gives the normal and actual rainfall in the District during the southwest monsoon, northeast monsoon, winter season and hot weather season in 2010-2015 (in mm). Figure 5 shows the deviation of actual rainfall from the normal during 2005-2015 depicting the picture of vagaries of rainfall.

Table 1. Mean Maximum and Minimum Temperatures (in Degree Celsius)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max.	30.5	33.4	36.2	37.2	36.3	33.5	32.5	32.5	33.1	31.3	29.6	29.4
Min.	18.7	20.3	22.6	25	25.2	24.7	24.0	23.7	23.7	23	21.5	19.7

Source: Collateral data

Database and Methodology

The methodology adopted in this study is of both qualitative and quantitative basis.

The data has been compiled from various data repositories such as Open Series Map (OSM) sheets (1:50,000), Open Street Map, Google Earth Imagery, NRSC Bhuvan portal, and Indian Meteorological Department (IMD). The drought assessment is drawn from two indices, first using Normalised Difference Vegetation Index (NDVI) for the years 2011 to 2015 and second, with rainfall to generate Standard Precipitation Index (SPI) for the span of 30 years from 1984 to 2013.

The drought condition shows a continuous increase from 2012 to 2015 in January months. The methodology explicitly describes the derivative and functional process that could handle spatial information of disaster through geoinformatics, for any region using mostly freely available data to formulate a spatial disaster plan. The methodology scours through the possibilities of mapping each disaster the District is prone, to evaluate the overall vulnerability, to visualise the multi-facet disaster at the village level, for effective planning. The overall vulnerability of each disaster is ranked according to the highest to lowest categories of hazards affecting every village, based on maximum likelihood and more than one type of disaster concentration. As a result, combining the ranks of each disaster prone villages, deduce the ranks from the former vulnerability for multi-hazard cum overall vulnerability of the villages.

Normalised Difference Vegetation Index (NDVI)

The NDVI is calculated with the reflectance radiated in the near-infrared waveband and the reflectance radiated in the visible red waveband of the satellite radiometer. Higher NDVI indicates a greater level of photosynthetic activity (Peters et. al., 2002; Sellers, 1985; Tucker et. al., 1991).

NDVI when written mathematically, the formula is:

$$NDVI = (NIR - VIS) / (NIR + VIS)$$

Calculations of NDVI for a given pixel always result in a number that ranges from minus one (-1) to plus one (+1); however, no green leaves gives a value close to zero. A zero means no vegetation and close to +1 (0.8 - 0.9) indicates the highest possible density of green leaves.

Standardised Precipitation Index (SPI)

McKee et al. (1993) developed the Standardised Precipitation Index (SPI) for the purpose of defining and monitoring drought. It allows an analyst to determine the rarity of a drought at a given time scale (temporal resolution) of interest for any rainfall station with historic data. It can also be used to determine periods of anomalously wet events. The SPI is not a drought prediction tool. The computation of SPI requires long term data on precipitation to determine the probability distribution function which is then transformed to a normal distribution with mean zero and standard deviation of one.

Thus, the values of SPI are expressed in standard deviations, positive SPI indicating greater than median precipitation and negative values indicating less than median precipitation (Edwards and McKee, 1997). The SPI is equivalent to the Z-score often used in statistics. However, for a series of rainfall measurements with a time scale of 12 months or less, the distribution of the data is usually considered skewed. Thom (1966) found that the gamma distribution fits the rainfall data more appropriately. The gamma distribution is defined by its frequency or probability density function:

$$g(x) = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} x^{\alpha-1} e^{\frac{-x}{\beta}}$$

where, α > 0 is shape parameter, β > 0 is scale parameter, and x is rainfall measurement. The gamma function $\Gamma(\alpha)$ in the above equation is defined as

$$\Gamma(\alpha) = \int_0^{\infty} y^{\alpha-1} e^{-y}\, dy$$

Fitting the gamma distribution to the rainfall data requires estimating α and β. Edwards and McKee (1997) suggested estimating these parameters by using the approximation of Thom (1996) for maximum likelihood to obtain

$$\alpha = \frac{1}{4U}\left(1 + \sqrt{1 + \frac{4U}{3}}\right)$$

$$\beta = \frac{\mu}{\alpha}$$

where,

$$U = \ln(\mu) - \frac{\sum \ln(x)}{n}$$

n is number of rainfall measurements, and μ is the mean of x. The precipitation data is converted to lognormal values and U, shape and scale parameters of gamma distribution are computed. These parameters are used to fit gamma distribution for precipitation data. Integrating g(x) with respect to x and inserting the estimates of α and β yield the expression for the cumulative distribution $G(x)$ for a given month and time scale:

$$G(x) = \int_0^x g(x)dx$$

$$G(x) = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} \int_0^x x^{\alpha-1} e^{\frac{-x}{\beta}}\, dx$$

Assuming that $t = x/\beta$, this cumulative distribution becomes

$$G(x) = \frac{1}{\Gamma(\alpha)} \int_{0}^{x} t^{\alpha-1} e^{-t}\, dt$$

Since, the gamma function is undefined for $x = 0$ and the rainfall data may contain zero measurements, the cumulative distribution may be conveniently expressed as

$$H(x) = q - (1 - q)G(x)$$

where, q is the probability of a zero. If m is the number of zeros in a precipitation time series, Thom (1966) states that q can be estimated by m/n. The cumulative probability, H(x), is then transformed to the standard normal random variable Z with mean zero and variance of one, which is the value of the SPI following Edwards and Mc Kee, 1997.

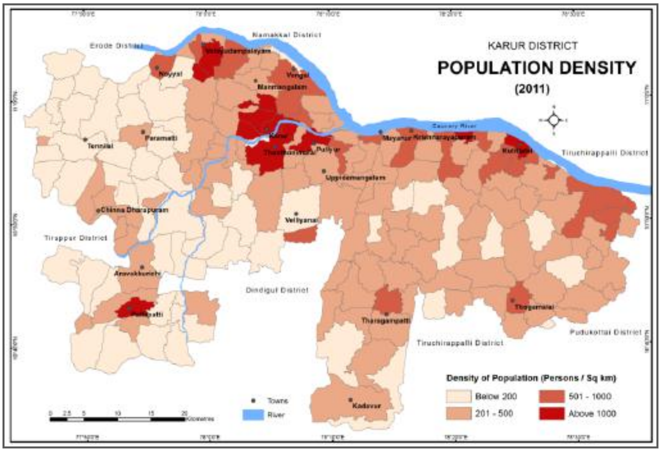

Fig. 2. Population Density of Karur District (2011)

Table 2. Normal and Actual Rainfall in the District during 2005-2015

Season	Month	Normal	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Winter	January	9.7	0	5.17	0.95	4.18	1.56	1.52	0	2.06	0.08	0.25
	February	7.8	0	0	0	1.53	0	0	2.49	0.59	27.06	0
	Total	17.5	0	5.17	0.95	5.71	1.56	1.52	2.49	2.65	27.14	0.25
Summer	March	10.4	33.98	30.76	0	118.6	2.98	0	4.3	0.17	4.01	0
	April	38.0	112.2	47.83	37.3	6.38	19.37	4.73	105.3	83.17	19.21	0.29
	May	60.8	88.01	37.25	57.24	79.64	49.95	131.25	35.71	88.7	47	112.73
	Total	109.2	234.2	115.8	94.54	204.6	72.3	135.98	145.3	172.04	70.22	113.02
Southwest Monsoon	June	19.8	13.34	30.87	36.01	14.59	1.75	32.39	11.18	7.44	3.44	23.79
	July	35.7	44.47	0	45.67	37.73	0.22	65.6	3.56	3.88	0.33	2.73
	August	51.8	84.49	63.03	98.04	130.9	64.96	32.52	90.09	41.08	73.45	74.68
	September	106.3	48.9	87.73	32.52	57.76	107.5	90.96	52.14	40.36	99.39	65.48
	Total	213.6	191.2	181.6	212.2	241	174.4	221.47	157	92.76	176.61	166.68
Northeast Monsoon	October	144.6	239.2	156.7	164.1	271.8	43.36	100.08	202.9	192	102.03	219.93
	November	119.1	370.9	135	81.05	201.1	272	328	196.4	67.4	72.76	51.14
	December	51.0	107.1	5.32	214.7	38.29	47.87	0	23.27	1.16	40.33	21.87
	Total	314.7	717.2	297	459.8	511.2	363.2	428.08	422.5	260.56	215.12	292.94
Annual	Total	**655.0**	**1143**	**599.5**	**767.4**	**962.4**	**611.4**	**787.1**	**727.3**	**528.0**	**489.1**	**572.8**

Source: Collateral data

Table 3. The Gauge Stations of Karur District with Rainfall Values from 1984 - 2013

Year	Rain Gauge Stations			
	Karur	K.Paramathi	Kulithalai	Mayanur
1984	-0.21	0.36	0.25	-0.47
1985	-0.25	0.44	0.06	-0.43
1986	-0.25	0.31	-0.61	-0.47
1987	0.41	0.58	0.50	-0.42
1988	0.08	0.48	0.26	-0.38
1989	-0.06	0.52	0.13	-0.40
1990	0.31	0.35	-1.13	-0.45
1991	0.27	0.53	-0.56	-0.44
1992	-0.25	0.54	0.02	-0.48
1993	0.93	0.41	0.48	-0.44
1994	-0.90	0.36	0.26	-0.36
1995	-1.75	0.31	0.54	-0.48
1996	0.04	0.40	1.33	-0.38
1997	0.09	0.45	0.16	-0.36
1998	0.49	0.45	0.66	-0.40
1999	1.05	0.67	1.58	-0.34
2000	-2.61	0.18	-0.11	-0.41
2001	-0.28	0.56	0.63	-0.38
2002	0.23	0.28	0.58	-0.44
2003	0.29	0.31	0.49	-0.44
2004	0.17	0.56	0.94	-0.38
2005	1.86	0.74	1.18	-0.30
2006	0.02	0.52	-0.25	-0.47
2007	0.81	0.41	-0.37	-0.33
2008	0.86	0.70	0.20	-0.32
2009	-0.11	0.62	-0.87	-0.44
2010	1.26	0.74	-0.26	-0.41
2011	0.73	0.60	-0.48	-0.43
2012	0.02	0.04	-1.05	-0.50
2013	-3.06	-0.73	-4.24	-0.70

Source: Department of Economics and Statistics Tamil Nadu and Indian Meteorological Department

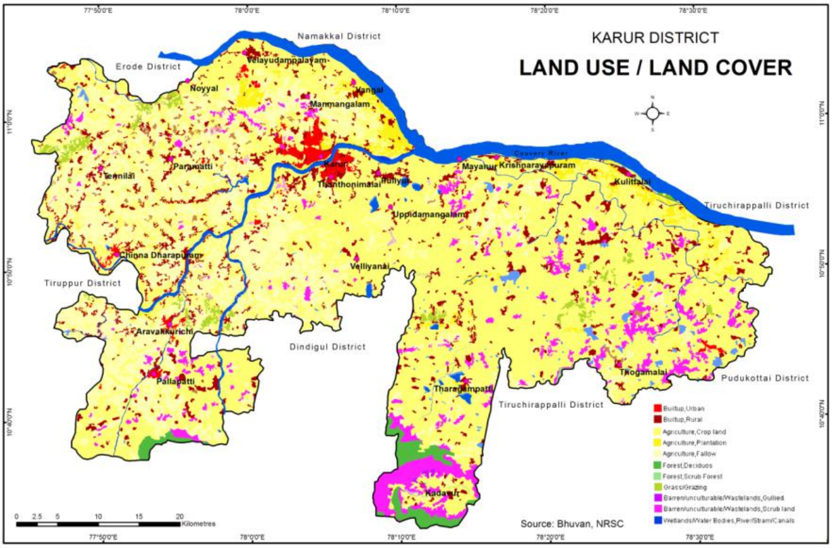

Fig. 3. Land use/ Land Cover Changes in Karur District for the year 2015

Results and Discussion

Drought Hazard and Vulnerability

The drought assessment (Figure 4) enables us to visualise the severity of District drought condition through satellite-based NDVI. The drought assessment map shows a continuous increase in drought condition from 2012 to 2015 in January months. The highest drought condition prevails continuously over the south and eastern parts of Aravakurichi Taluk. The drought vulnerability in the study area shows the highest record of very high vulnerability in the major towns Paramathi and Tennilai (Figure 7). The map has been classed into four categories viz. very high, high, moderate, and low vulnerable levels. The very high vulnerability falls in Paramathi and surrounding 13 villages of Aravakurichi and Manamangalm Taluk. The high vulnerability class falls all over the Karur District except the river terraces of river Cauvery. The moderate and low vulnerability presence is found in the very few places distributed in the fringes of the Kadavur and along the river Cauvery. The SPI generated through rainfall data monitors the meteorological drought severity of 30 years from 1984 to 2013. SPI was calculated in 12 month time scale, and then SPI was categorised based on their range values.

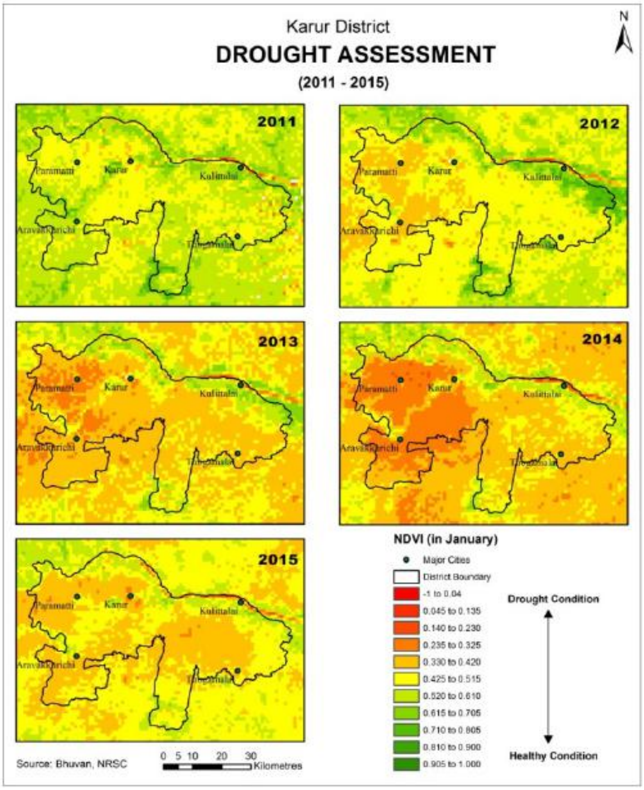

Fig. 4. Normalised Difference Vegetation Index (NDVI) for Drought Assessment in Karur District from 2011 to 2015 (January)

Based on the SPI range values (Table 4), there are two extremes between which all values fall viz. dryness and wetness. The Extreme Dryness occurred in the years of 2000 and 2013 (Figure 6). Severe Dryness occurred in the year of 1995. Moderate Dryness occurred in the year of 1990 and 2012. Severe wetness occurred in the years of 1999 and 2005. Moderate wetness occurred in the years of 1996, 1999, 2005 and 2010. Remaining years are near normal. This observation also shows that the drought condition prevails over Aravakurichi Taluk with dryness with no rainfall for a pronged period.

Table 4. Category of Standardised Precipitation Index (SPI) based on Range Values

SPI Range	Category
-2.00 or Less	Extremely Dry
-1.50 to -1.99	Severe Dry
-1.00 to -1.49	Moderate Dry
-0.99 to 0.99	Near Normal
1.00 to 1.49	Moderate Wet
1.50 to 1.99	Severe Wet
2.00 or More	Extreme Wet

Source: Compiled by the Author

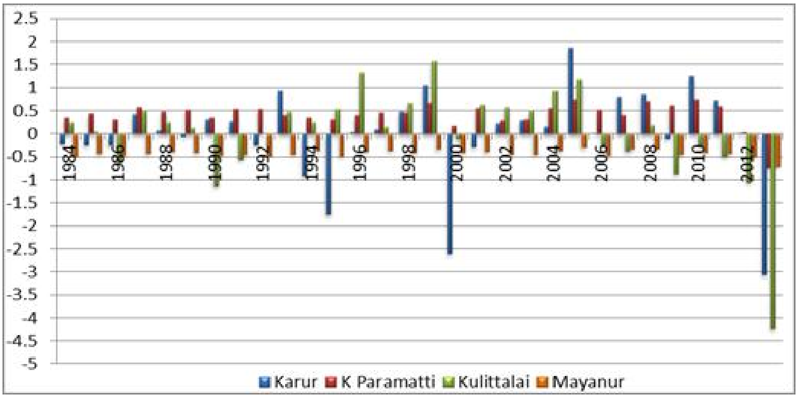

Fig. 4. Rainfall Trend in each Rain Gauge in Karur District from 1984 to 2013

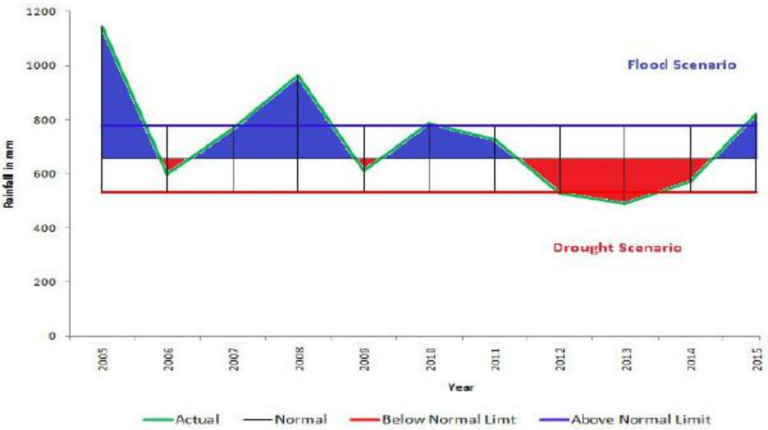

Fig. 5. Deviation of Actual Rainfall from Normal

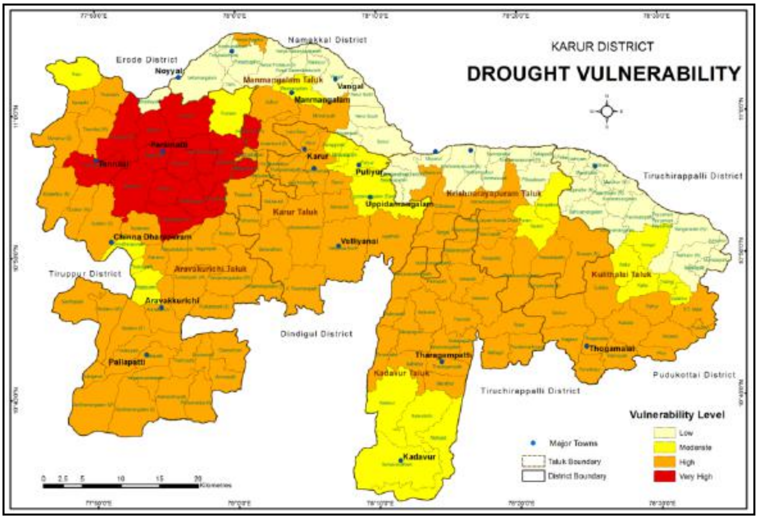

Fig. 7. Village-wise Drought Vulnerability Level 2014 - 2015 (January)
Source: Compiled by the Author

The proper distribution of rainfall in the spatial and temporal period marks the situation of drought, rather than the amount of rainfall. Though drought does not cause any physical damage, its effect seriously affects the region in due course of time. Drought impacts are non-structural and spread over a larger geographical area than are damages that result from other natural hazards such as floods, tropical storms, and earthquakes (Balasubramani, 2014). Since it is a slow-onset disaster, it is very difficult to demarcate the time of its onset and the end. However, regions along the river Cauvery tend to continue normal life to a certain extent even when drought condition severely affects other parts of the District. The impacts slowly spread into social fabric as the availability of drinking water diminishes, reduction in energy production, ground water depletion, food shortage, health reduction and loss of life, increased poverty, reduced quality of life and social unrest leading to migration (Smith, 1992; Hewitt, 1997). Drought is a phenomenon that is either absence or deficiency of rainfall from its normal pattern in a region for an extended period of time leading to general suffering in the society. It is the relationship between demand that people place on natural supply of water and natural event that provides the water in the District (NDMA, 2010).

As normal rainfall fails to downpour for consecutive years, the metrological phenomenon turns into hydrological drought, the impacts start appearing first in agriculture which is most depends on the soil moisture. Irrigated areas are affected much later than the rain-fed areas (PNG-Operational Logistic Contingency Plan, 2011). The failure of the north-east monsoon in 2012, 2013, 2014 and 2015 led to the droughts like conditions (Figure 4 and 5).

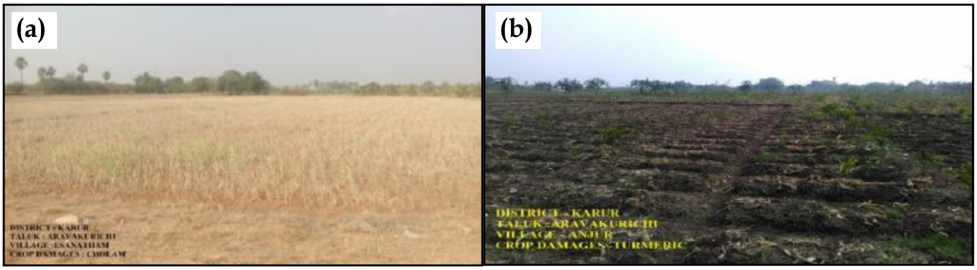

Fig. 8. Photographs of Drought Affected Villages in Aravankurichi Taluk (a) Esanatham Village and (b) Anjur Village

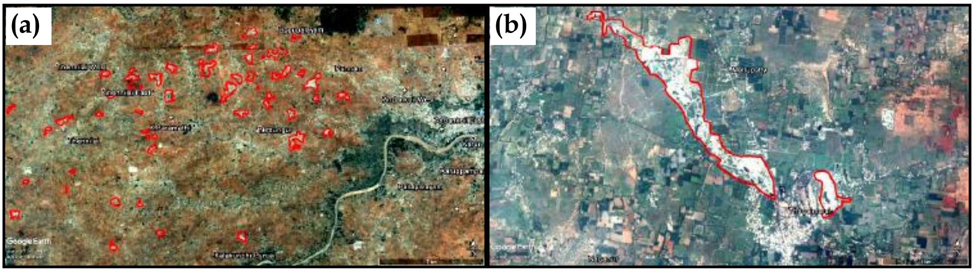

Fig. 9. Coverage of Mines Sites at Karur District (a) Aravakurichi Taluk - Mine Sites and (b) Thogaimalai Taluk - Mine Sites

This further leads to poor agricultural productivity, rural distress, acute shortage of drinking water and fodder and has been reeling under drought conditions for five consecutive years (2012 -2014). The state has declared as drought-hit District owing to more than 50 percent of failure of the northeast monsoon in 2014 (Rajendran, 2014). Thus, the current result supports the fact that, the higher vulnerability classes are distributed entirely over the Karur District from 2012 to 2015.

Conclusions

The use of geoinformatics in disaster plan for a District becomes a formidable tool in identifying, analysing, evaluating and formulating a better spatial disaster management plan for any District. The drought vulnerability in the study area shows the highest record of very high vulnerability in the villages Paramathi and Tennilai of Aravakurichi taluk. The map has been classed into four categories viz. very high, high, moderate, and low vulnerable levels. The SPI values, extreme dryness occurred in the years of 2000 and 2013. The result also shows that the drought condition prevails over Aravakurichi Taluk with dryness with no rainfall for a pronged period. The results highlight the droughts increasing pattern spreading from Aravakurichi Taluk due to the large concentration of mining activities.

The disaster risk plan should explicitly exhibit the short and long term planning and measures such as: standardised mechanism to respond to disaster situation, enhance disaster resilience of the people, assess and strengthen critical infrastructures, hazard-resilient designs in housing in hazard-prone areas, promoting programs of contingency crop planning and crop diversification in agriculture, amend land use and zoning regulations for managing risk of population, revising flood plain zoning for planning and awareness, integrate disaster risk management approaches throughout the tourism industry, access to multi-hazard early warning systems. Further, to adopt disaster resilient construction mechanism in the District by the way of using information, Education and Communication for making the community aware of the need of disaster resilient future development and to develop, periodically update and disseminate, as appropriate, location-based disaster risk information, including risk maps, to decision makers, the general public and communities at risk of exposure to disaster in an appropriate format by using, as applicable, geospatial information technology.

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Archives - 1

TRAVEL AND EDUCATION

Formerly Known as The Journal of The Madras Geographical Association
(Volume XV, 1940, pp.184-186)

By

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

(*Summary of a lecture delivered on the 28th of May 1940 at the 31st Provincial Educational Conference at Ambasamudram*)

The words "travel" and "travail" are derived from the same root. The reason why travel was associated with travail was that in the old days travel was done with a great deal of difficulty. In talking of Travel and Education, we must derive and relate the two words.

* * * * * *

Having spoken something of travel I wish to remind you what education connotes. Education, as we all know, consists in "drawing out" the best qualities of the person.

Advantages of Travel: The chief value of travel lies in the opportunities, which it affords for the attainment of real knowledge and understanding of things. It supplements book knowledge. Through it we understand things clearly and in their natural setting. Further, travel benefits students in their study of particular subjects such as history, geography and geology.

On the emotional side, we find that the appetite for travel "grows with the eating thereof"; for, the joy of travel is great indeed. But, more important than this is the human sympathy we learn to have for those in whose land we travel. There grows along with it a feeling of tolerance towards the customs and habits of people, which are different from our own. "Ours are not the ways of doing things" is what we realize. Mental liberation is one of the right aims of education is achieved by travel.

On the conative side also, travel is highly beneficial. Learning is best done by doing. It is not by mere study but by experience that we have real education. In travel, there are challenging situations, which call forth the best efforts of the individual. Travel makes a person self-reliant and resourceful.

Travel should be a concomitant of education if not also completion of it. In western countries boys and girls go on tours and excursions during weekends and vacations, from return transformed into new beings. People sometimes talk of risks and dangers in travel; but are we free from them nearer me in this age of automobiles? Such mistaken notions should not stand in the way of travel becoming more common in these days of cheap and quick transport. Finally, travel is often a solace bereaved persons.

Opportunities for Travel: There are many opportunities for travel open to us in the educational world. There are inter-school debates and matches and inter-University tournaments, and these are excellent opportunities for travel, though in the nature of things they are confined to a few of the prize boys. For all pupils benefit by travel, there must be a system of conducted tours. As for us teachers, we have our educational conferences-District, Provincial and All-India, with their annual shifting venues.

We should realise the value of the personal and social contacts brought about during these conferences and the advantage to us individually as well as to the profession as a whole. Some fifteen years ago excursions were almost unknown in South Indian schools, but now they have become popular, though they require to be properly planned and conducted in order that the best educational values may accrue from them. Teachers of all subjects should take active part in the conduct of such tours.

Modes of Travel: Man is a highly locomotive animal. Half his height is due to the legs, and he should make a good use of them. Hiking or walking is a form of travel, which makes detailed study of localities possible. This intensive study offers a corrective to the general impressions formed by modern modes of quick travel. Next comes cycling. It is a quicker method by which a larger distance can be covered for local study. Then there is the bus, which has brought the road back into common use , making the most distant corners of the country easily accessible. The railway has its undoubted advantages for travel, far and near, and with its varieties of concessions for educational institutions and educational purposes, it offers an unlimited scope for travel which teachers and students should not fail to take advantage of.

Technique of Travel: In order to get the best out of travel, it must be planned with care and forethought. The leader of the party must plan several days ahead; the time of arrival, the programme and the time of departure must all be settled in their details. The places of lodging, the kind of food, the places to visit, must all be thought out previously. In fact the skill and responsibility demanded of the leader is very great. He will find it advantageous to consult the District Gazetteers and guide book as well as the quarter inch map and the one inch map. The latter must be taken for reference during the journey.

Abroad, the tourist industry is a major industry, which has developed considerably even in small places. With its wide ramifications, it supports a large number of educated people in western countries. Its organisation is a nation-wide one in which are linked up several parties such as photographers, bus companies, railway companies, tourist agencies, hotel-keepers and industrial concerns besides governmental authorities-national and local. A similar development in our country with its wonderful beauty-spots, holy shrines and historic monuments is sure to absorb a considerable proportion of the educated unemployed.

Archives - 2

CADASTRAL SURVEYS

Formerly Known as The Journal of The Madras Geographical Association
(Volume XV, 1940, pp. 368-370)

By

RAO BAHADUR K. N. NARASIMHACHARYA
Deputy Director of Survey, Madras

It is a well-known fact that the bulk of the revenue derived by the Government is from land. The data on which this revenue is fixed are: - Area, nature of soil, source of irrigation, facility for marketing the produce, etc. Area is arrived at by a survey of the lands owned by various individuals. This survey is called "Cadastral-(field-war) Survey" or "Revenue Survey."

The object of the Revenue Survey is briefly stated by Clements R. Markham, C.B., F.R.S., as follows:-

"The Revenue Surveys of India are one of the bases on which the whole fiscal administration of the country rests. By their means the wealth of the various provinces is ascertained, as well as their food-producing capabilities and their power to bear taxation. The surveys furnish the information comprised in the agricultural statistics without which the statesman is deprived of the knowledge enabling him to improve the condition of the people, to increase their means of subsistence, to avert famine, to add to the wealth of the country and to adjust taxation."

After a consideration of over 10 years, the local Government decided in 1855 that a Revenue Survey is necessary for proper administration of the province and recommended the same to the Court of Directors and to the Government of India. After sanction, a department was organised in 1857 for the purpose. Before the revenue survey, revenue demand was based on unchecked statements of the Karnams who were all-in-all in the villages and the ryots were completely under their mercy.

For purposes of survey, revenue holdings, i.e., lands possessed by various individuals are grouped together to form a survey field which is the unit for survey and the several revenue holdings which lie within it are called sub-divisions.

The unit for the preparation of maps in the revenue survey is a village. For facility of mapping, a village is divided into small bits called "khandams", each khandam comprising an area of 100 to 200 acres. At important bends on the village, boundary stones of size 3 feet X 3 inches X 3 inches are planted with one foot above the ground. These stones bear marks △ at the village tri-junctions and H at other points. Angles at these points are observed. Khandam boundaries also are similarly dealt with. This is called 'Traverse Survey', and it serves the purpose of triangulation in topographical surveys, i.e., traverse survey furnishes a skeleton for the preparation of village maps. After the traverse survey is over, fields in the village are surveyed by dividing each field into triangles. The fields are then plotted in the traverse skeleton of the village with all ‘topo’ details, which cross the fields. Then the village map is prepared on scale 16 inches = 1 mile.

From the village maps which show all the ‘topo’ details, taluk maps on scale 1 inch = 1 mile are prepared and from these maps, district maps on scale 1 inch = 4 miles are compiled.

The first operation in the Revenue Survey is the identification of the Trigonometrical Survey Stations. From one of these, the revenue survey traverse work-theodolite survey-commences and runs along village or taluk boundaries until it reaches a point wherefrom another trigonometrical station is connected. The revenue survey traverse distances are then compared with sides of the triangles of trigonometrical survey and the differences between the two are adjusted in the revenue survey distances to agree with the trigonometrical survey. Thus the work of the Madras Revenue Survey adapts itself exactly to the Trigonometrical Survey of India.

HOW A TALUK MAP IS COMPILED IS DESCRIBED BELOW:

A skeleton is prepared on scale 1" = 1 mile by projecting all village trijunction points and all trigonometrical stations in that area; graticules or latitudes and longitudes referred to Greenwich Meridian are also drawn on it. The 16" maps of all the villages comprised in the taluk are reduced to 1" = 1 mile by paragraph showing the village boundary and all topographical features in the village. These reductions are then superimposed on the skeleton in such a manner that the village trijunction points in paragraph reductions exactly fall on the corresponding points already projected on the skeleton; then the "topo" details are traced on to the skeleton and the contours of the hills are traced and inserted into the skeleton from the 1 inch standard sheets of the Survey of India. Thus the rough original of the taluk map is prepared.

This rough original is enlarged by photography to twice the scale and a light blue print is obtained. In this copy all the topographical details are neatly inked in black and all the names neatly printed. This is the fair original. This is reduced to half the scale in 1" = 1 mile by photography and the plate from which final copies are printed is prepared by the process called Zincography. From this plate copies are printed in Rotary offset machine where the impressions are first transferred to a rubber blanket and thence to the paper. By a similar process district maps on scale 1" = 4 miles are published.

It will be remembered in this connection that all the topographical features shown in the taluk maps were fixed by measurements during the revenue survey unlike in the topographical surveys conducted by the Survey of India where they are fixed by plane-table rays, sketching, etc. Thus, the physical features are shown more accurately in the taluk maps published by the Madras Survey Department.

It may be mentioned in this connection that since the Madras Revenue Survey was conducted in such details and in so accurate a manner as to be useful for the compilation of general maps, it was considered that the materials of this survey might be made use of by the Survey of India without unnecessarily doing a fresh elaborate topographical survey but by doing such supplemental surveys by way of bringing the details up-to-date. This was suggested and by agreement, maps are being supplied to the Survey of India by the Madras Survey Department since 1911. Thus the standard sheets now issued by the Survey of India have to a large extent the Madras Survey Maps as the basis.

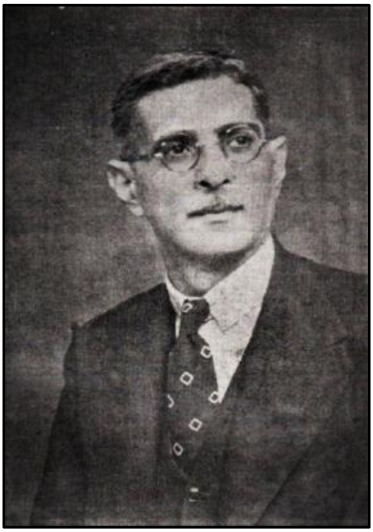
I conclude this lecture by quoting the opinion of an eminent authority on survey.

"It (The Madras Revenue Survey) is designed to show all principal variations in the surface of the soil such as hills, jungles, woods, channels, tanks, topes, houses, cultivated and cultivable lands and the area of each field. The ideal survey while furnishing complete information for Settlement purposes should be executed throughout on accurate principles and supply materials for compiling maps for general use. In the Madras Presidency alone has any approach to a compliance with all the demands been effected. The Madras Revenue Survey must therefore be considered as, on the whole, the best in India."

Archives - 3

RECIPIENT OF DOCTOR OF SCIENCE IN GEOGRAPHY FROM UNIVERSITY OF BOMBAY

Formerly Known as The Journal of The Madras Geographical Association
(Volume XV, 1940, p.186)



Prof. Maneck B. Pithawalla,

upon whom the University of Bombay has conferred the degree of Doctor of Science for his pioneer geographical research on the Lower Indus Basin (Sind). He is the first D. Sc. From Sind and the first Indian to secure this highest distinction in the science of Geography in India.

PROPOSED SYLLABUS OF GEOGRAPHY FOR M.A. AND M.Sc.

Formerly Known as The Journal of The Madras Geographical Association
(Volume XV, 1940, pp.380-384)

By

PROFESSOR M. B. PITHAWALLA, D.Sc. (GEOGRAPHY) , B.A:L.C.P., & F.G.S.,
Recorder, Geography Section, Indian Science Congress

Introduction

While some of our Indian Universities, notably Bombay , have treated Geography as a step-daughter and have neglected its study all these years, (the Senators having refused to recognise its value even as a branch of Science owing to their own ignorance of it), it is a very happy sign of the academic times that some other advanced Universities in India, e.g., Calcutta, Madras and Aligarh, adopting a more liberal and enlightened policy , have encouraged its studies right up to the degree courses. All credit is due to the Oversea Delegation of foreign geographers to the Jubilee Session of the Indian Science Congress held at Calcutta in 1938 and also to the Professors and Teachers of Geography in these centres of learning, who followed up their resolution adopted at the Session to give it a separate Section and a good scope in India for its development. At the above University centres, the progress is so good that it is now necessary to indicate the lines along which post-graduate studies in Geography (in both the Faculties, Arts and Science) should be directed for the benefit of all students. It is with a view to co-ordinate such studies in our Universities , to prevent any overlapping of activities and also with the object of helping our advanced students to make small but useful scientific contributions in their own special line of research that I give below my scheme of a syllabus for the M.A. and M.Sc. examinations.

Position of Geography in the Near Future

Geography is bound to be recognised as a very important subject of study by all, after the present War is over. In fact, we are finding the conduct and results of this 'Geography War' to have been based on a sound knowledge of the geography of the countries involved. I therefore earnestly appeal, through the medium of this Journal, to the Vice-Chancellors and Academic Councils of all Universities in India (no less than 19 in number now) to give Geography its proper place in the curricula of all examinations, Arts and Science. If the proposed syllabus is approved and accepted by the learned bodies, it will be easy for us Indian geographers to lay down certain lines of geographical research for the higher (Doctorate) degrees, so that in a few year it would be possible for us to collect all the data necessary from the various natural regions in India and to produce a comprehensive, authentic and authoritative geography of our dear country, for which the whole civilised world will be grateful to us.

Developing a Spirit of Research

Provision has been made in the Scheme for stimulating a spirit of research among our Indian students for this comparatively young science of Geography, so that at least 200 out of the possible 800 marks (100 for a Paper and 100 for one Practical examination) are substituted for a piece of investigation or enquiry of the students' own choice, during the course of their study at the University for the Master's degree, in order that our science could be put on a par with the other branches of science already developed . I would like to give, if possible, a still greater scope for independent or guided research at this stage of training in the line, so that even more than 200 marks could be assigned to the thesis part at the discretion of the examiners and with the previous sanction of the Board of Studies in Geography.

The Proposed Syllabus

Theory 600 marks. *Practical Examination* 200 marks. There shall be 6 Papers, each carrying 100 marks each as follows:

Theory

Paper I. *Physiography*: This should include the latest theories of geological formations, geological history, history of erosion, evolution of land forms etc., taking typical examples from important countries of the world. An elementary knowledge of geomorphology is expected here. This paper should be compulsory for both Arts and Science students, as physical basis should be the foundation of all geographical studies.

Paper II. *Regional Geography of India and Neighbouring Lands*: India should be given prominence at the post-graduate stage. The study should include physiographic divisions of India and of the countries which influence her, the problem of frontiers and boundaries, economic resources, the problems of water supply, climatic conditions and regions, vegetation zones, types of soil, land forms, animal life, land utilisation and human occupations and settlements. Emphasis should be laid on the influence of physical conditions on human life, especially with reference to the historical geography of India and conditions, physical and others, of the lands in her neighbourhood, e.g., the Iran plateau, Tibetan plateau, Burma, China and Japan.

Paper III. *Study of One of the Major Zones of the Earth*: Candidates may choose one of the following belts and the countries falling within it:

1. Arctic and Antarctic zones
2. Temperate zones
3. Tropical zones
4. Equatorial zones
5. Mediterranean zones

The idea is to make a regional study of the countries involved in each earthly zone with reference to their economic and commercial geography, lines of communication, exports and imports, and races of mankind inhabiting them. It is to be remembered that a thorough regional study can be made without the trammels of political boundaries, which are fast disappearing in Europe and Africa, and therefore the countries, as they are, are not prescribed as they are made by the whims and caprices of political leaders but the divisions are left to the natural conditions and the abilities of students to recognise natural, scientific boundaries only.

Papers IV and V. *Two of the following optional subjects*

Group A (*for M. A. students*)

1. Historical Geography
2. History of Geographical knowledge
3. Survey of Geographical researches
4. Town planning and Military Geography
5. Anthropology and Archaeology
6. Economic and Commercial geography

Group B (*for M. Sc. students*)

1. Geomorphology including study of landscape.
2. Geology and Mineralogy
3. Meteorology and Climatology
4. Ecology
5. Oceanography
6. River geography

The study to include the chief outlines and principles of the subjects chosen. Minor details and technicalities of the different branches of science are not required. A very wide and sufficient choice is given to the students without burdening the Universities and the Colleges affiliated to them with the necessity of engaging specialists on their staffs to teach them.

Though there are two different groups made of the optional subjects, it should not be quite obligatory to the students to stick to one or the other group. Either or both the optional subjects may be taken from them.

Paper VI. *Intensive Study of One of the Principal Physiographic Regions of India Noted Below:*

1. Western Highlands
2. Greater Himalayas
3. Middle Himalayas
4. Sub-Himalayan Region
5. Eastern Highlands
6. Lower Indus Valley
7. Upper Indus Valley
8. Upper Ganges Valley
9. Middle Ganges Valley
10. Lower Ganges Valley
11. Desert Province
12. Rajputana Highlands
13. Deccan Trap Region
14. North-eastern Foreland
15. Southern Plateau

These 15 regions, marked as Provinces in the Physiographic Map drawn by me (*vide* My "Physiographic Divisions of India" (Jour. *Madras Geog. Assoc.,* Vol. XIV No. 4) are generally approved by experts, as they are scientifically made without any local prejudices or misgivings. Over these divisions all matters relating to climate, natural vegetation and even human problems drape themselves completely. The actual boundary lines are left to be drawn by the geographers belonging to the provinces concerned.

OR *A Piece of Geographical Research Based on Field or / and Laboratory Work*

In place of this paper No.VI, candidates may be allowed to present a thesis or investigation of some geographical problem falling within their personal knowledge e.g., geomorphology, water supply, population, food crops, money crops, forest products, ports, communications and industries, of particular localities chosen by the candidates.

N.B.- The problem selected should be first approved by the Board of Studies in Geography.

Practical Examination

Practical I. *Cartography*

1. Map reading. Reading of maps - geological, historical, soils, ordnance, weather and population maps.
2. Map making. Preparation of maps and sections from given data, and map projections. Enlargement and reduction of maps.
3. Cartographical and diagrammatic expression of data, climatic, economic, etc. Diagrams, graphs, sketch maps etc., to be prepared from given data. Students to be allowed the use of blue books, meteorological records, census reports and other government, military and State publications.
4. *Viva voce* on journals and laboratory work of the candidates.

OR

Viva voce on the thesis submitted by the Candidate

Practical II. *Field work, Surveying and Identification of Specimens*

1. Field work, surveying, use of instruments, such as chain, plane table, prismatic compass, theodolite, sextant, aneroid and mercurial barometer, B.P. thermometer, anemometer, rain gauge, planimeter and mariner's compass.
   Surveying, triangulation, plane surveying, trigonometrical surveying, astronomical surveying, nautical surveying and town planning.
2. Identification of typical rocks, minerals, soils, plants, animals and agricultural products. (25 typical specimens of each to be prescribed and to be identified by physical and chemical tests.)

Let us hope that Geography may become a very popular subject among our Indian students and the time may soon come when the whole of the M.A. or M.Sc. may be taken by thesis only as a training degree.

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THE INDIAN GEOGRAPHICAL SOCIETY

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

UG & PG Results of 5th Talent Test - 2015

THE IGS FOUNDER PROF. N. SUBRAHMANYAM AWARD

With the Cash Prize of Rs. 10,000/-

(First Prize: Rs. 5,000/-, Second Prize: Rs. 3,000/- & Third Prize: Rs.2,000/-)

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Register Number	**Name**	**Institute**	**Rank**
121GE004	Amritha Shri Varshini S.	Department of Geography, Nirmala College For Women (Autonomous), Coimbatore - 641 018.	**1**
127GY148	Vignesh B.M.	Department of Geography, Tourism and Travel Management, Madras Christian College (Autonomous), Tambaram, Chennai - 600 059.	**2**
U12GE026	Rama M.	Department of Geography, Government Arts College for Women (Autonomous), Kumbakonam - 612 002.	**3**

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Register Number	**Name**	**Institute**	**Rank**
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33213410	Rajmita Kar	Department of Geography, University of Madras, Chennai - 600 005.	**2**
13PGE04	Gopinath S.	Department of Geography, Periyar E. V. R. Govt. Arts College (Autonomous), Tiruchirappalli - 620 023.	**3**

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 *National Seminar* on Geospatial Technology for Land Use Analysis organised at Department of Geography, Bharathidasan University, Tiruchirappalli on 2 March, 2018 at 2:00 p.m.
3) For any queries, kindly contact the Coordinator Dr. K. Kumaraswamy (94421 57347) / Co-coordinators Dr. G. Bhaskaran (94444 14688) or Mr. K. Balasubramani (99440 60319).

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MORPHOMETRIC EVALUATION OF THATIPUDI WATERSHED, PART OF EASTERN GHATS TERRAIN, ANDHRA PRADESH, INDIA - A GEOSPATIAL TECHNOLOGICAL APPROACH

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Abstract

Watersheds are hydrologic units that are considered to be efficient and appropriate for assessment of available resources and subsequent planning and implementation of various developmental programmes. Watershed development is necessary for harnessing surface and groundwater resources particularly in arid and semi-arid regions. The related information of topography, drainage pattern and erosional status of the area is essential to understand for planning and management of any watershed. The morphometric analysis was carried out to describe the topography and drainage characteristics of Thatipudi watershed. The catchment area of the watershed is 321.1 sq km and the drainage pattern mainly of dendritic to sub-dendritic. Analysis and assessment tools like GIS along with high resolution remote sensing data have proved to be very efficient and effective and hence very useful. Various morphometric parameters such as linear and aerial aspects of nineteen sub-watersheds have been computed. Maximum number of sub-watersheds are elongated in shape. The elongated basin with low form factor (R_f=0.17) indicates that the basin have a flatter peak of flow for longer duration. The rock types that occur in the study area are predominantly khondalite group of rocks and thin capping of alluvium particularly in the valleys are also recorded.

***Keywords**:* Morphometry, Thatipudi Watershed, Eastern Ghats, Geospatial Technologies

Introduction

Basin geometry is generally influenced by various factors such as climate, topography, bedrock, soil type and vegetation cover over a period of time. The study of basin morphometry plays a significant role in understanding the configuration of earth's surface, shape and dimensions of landforms, and erosion characteristics. Analysis of various morphometric parameters using geospatial techniques viz. remote sensing and GIS have emerged as powerful tools in recent years. Remote sensing has the ability of obtaining synoptic view of the large area at a particular time and also in different intervals. The morphometric characteristics of various basins and sub-basins have been studied using conventional methods (Horton, 1945; Strahler, 1952; Agarwal, 1998). Watershed is further classified into sub-watersheds according to IMSD technical guidelines (IMSD, 1995).

Various studies have been carried out across the world on drainage morphometry and its significance, prioritisation of watersheds and modelling by applying remote sensing and GIS techniques (Ribeiro and Rodrigues, 2004; Narendra and Nageswara Rao, 2006; Mesa, 2006; Yanina and Angillieri, 2008; Nageswara Rao et al. 2010; Javed et al., 2011; Hajam et al. 2013).

The present paper describes the drainage characteristics of Thatipudi watershed in Eastern Ghats terrain to understand their hydrological behaviour through geospatial information techniques coupled with field work analysis.

Study Area

The present study area, Thatipudi watershed, is a part of Gosthani river basin. The river Gosthani is a medium sized east flowing river which originates in Anantagiri hills of Eastern Ghats and flows down the hills mostly covered in Visakhapatnam and Vizianagaram districts of Andhra Pradesh state, India. Thatipudi watershed is located at 70 km north-west from Visakhapatnam city in the Eastern Ghats terrain and covers an area of about 321.1sq km lies between 18° 08' 30" N to 18° 20' 54" N latitudes and 82° 56' 10" E to 83° 13' 33" E longitudes falling in Survey of India toposheets (65 N/3, N/4, J/15, and J/16) on 1:50,000 scale (Figure 1). The maximum and minimum elevations encountered in the study area are 80 and 1402 m above mean sea level, respectively. Geologically, the area is underlain by khondalite group of rocks of Early Precambrian and alluvium of recent age. The area is well represented by structural hills, denudational hills, burried pediments, valley fills and alluvial plains forming soil covers of red sandy, red loamy and alluvium. The sparsely distributed population is mainly of the Bagata, Konda Dora and Kondh tribe settled in interior forests and valleys where water source and arable land are available for cultivation. Podu type of cultivation is the most common in tribal hamlets of the study area. Paddy is the predominant crop which is being cultivated by using terrace method in the valleys. The other crops include ragi, maize, jowar, grams, and also cultivating coffee plantation. The area enjoys tropical humid climate of semi-arid in nature and the temperature ranges from 10 to 24ºC in January and 22 to 35ºC in May. The average annual rainfall in the basin is 1400 mm with maximum contribution from south-west monsoon. The Thatipudi reservoir project was constructed across Gosthani River in 1968 and the project is located near Thatipudi village, Gantyadamandal, Vizianagaram district of AP state. The aim of this project is to irrigate a total ayacut of 15,378 acres in Vizianagaram district and to provide drinking water (9 mgd) to the needs of Visakhapatnam population.

Database and Methodology

Survey of India topographic sheets (1:50,000 scale) were used as a base for the delineation of Thatipudi watershed (TW) and sub-watersheds designated as SW-I to SW-XIX. The drainage was initially derived from the base map and later updated using the satellite data coupled with field checks through GPS survey (Figure 1). The morphometric analysis was carried out based on high resolution IRS Resourcesat data on the same scale. Materials used for the analysis in the study area are presented in Table 1. ArcGIS and

ERDAS Imagine softwares were used for statistical spatial analysis and image processing studies respectively. The toposheets and digital satellite data were geometrically rectified and assigned with UTM projection, WGS-84 datum using digital image processing software. Edge detection and linear enhancement techniques were applied to extract the drainage layer from the satellite imageries for better interpretation of the stream order. The order was given to each stream by following Strahler (1964) stream ordering technique. The attributes were assigned to create the digital database for drainage layer of the watershed. Various morphometric parameters such as linear aspects of the drainage network: stream order (N_u), bifurcation ratio (R_b), stream length (L_u) and areal aspects of the drainage basin: drainage density (D_d), stream frequency (F_s), elongation ratio (R_e), circularity ratio (R_c), form factorratio (R_f) were evaluated with established mathematical equations (Table 2).

Fig. 1. Drainage Network of Thatipudi Sub-watersheds

Table 1. Details of the Resourcesat Satellite Data Procured from NRSC, Hyderabad used in the Study

Satellite Sensor	Spectral Bands	Resolution (in mts)	Path/ Row	Date of acquisition
IRS-R2 L4FX	B2: 0.52-0.59 µm(Green) B3: 0.62-0.68 µm(Red) B4: 0.77-0.86 µm(Near-infrared)	5.8	104/060	15-May-2012
				17-Dec-2012
				10-May-2013
				12-Dec-2013

Results and Discussion

Linear Aspects

The linear aspects of the drainage network such as stream order (N_u), bifurcation ratio (R_b), stream length (L_u) are determined for each sub-watershed and the results are presented in Table 3.

Table 2. Morphometric Parameters of Drainage Network and their Mathematical Expressions

Parameter	Symbol	Formula	Reference
Bifurcation Ratio	R_b	N_u / N_{u+1} N_u = Total no. of streams of order 'u' N_{u+1} = Total no. of streams of the next higher order	Horton (1945)
Drainage Density	D_d	L_u/A L_u = Total stream length of all order A = Area of the basin (sq km)	Horton (1945)
Stream Frequency	F_s	N_u/A N_u = Total no. of streams of all order A = Area of the basin (sq km)	Horton (1945)
Elongation Ratio	R_e	$\frac{2\sqrt{A/\Pi}}{L_b}$ A = Area of the basin (sq km) Π = 3.14 (constant value) L_b = Basin length	Schumm (1956)
Circulatory Ratio	R_c	$\frac{4\Pi A}{P^2}$ Π = 3.14 (constant value) A = Area of the basin (sq km) P = Perimeter (km)	Miller (1953)
Form Factor Ratio	R_f	$\frac{A}{L_b^2}$ A = Area of the basin (sq km) L_b= Basin length	Horton (1945)

Stream Order (N_u)

The first step of drainage analysis is assigning the order to each stream. Strahler (1964) stream order technique has been adopted for assigning orders to each stream. Thatipudi watershed is designated as a sixth order watershed. Out of 19 sub-watersheds, SW-XVI is of 6th order, whereas SW-III, V, VIII, IX, XI and XII are of 5th order and SW-I, II, VI, VII, XIII, XIV, XV, XVIII and XIX are of 4th order and SW-IV, X and XVII are of 3rd order. Six sub-watersheds namely SW-III, V, VIII, IX, XI and XVI are not showing the proper sequence of stream order due to the absence of immediate order of streams. Drainage pattern in the watershed mostly are dendritic to sub-dendritic in nature indicating that the area is lack of structural control whereas some parts of the watershed exhibiting patterns like radial and parallel which explains that the topographical features are dipping, folded and highly jointed in the hilly terrains. From Table 3, it is observed that the maximum frequency is in case of first order streams and also there is a decrease in stream frequency as the stream order increases. The logarithm values of number of streams and their lengths are given in Table 3. The plotting of logarithm of number of streams against stream order (Figure 2) gives nearly a straight line explaining that the number of streams usually decreases in geometric progression as the stream order increases (Horton, 1945).

Bifurcation ratio (R_b)

According to Horton (1945), the bifurcation ratio is the ratio of the number of streams of any given order to the number in the next lower order. The mean R_b values varies from 3.0 (SW-XVIII) to 7.15 (SW-IV). It is observed from the results that the mean bifurcation ratio is not same for all sub-watersheds (Table 3). These irregularities are dependent upon the geological and lithological development of the particular watershed. The mean R_b value is 4.18 of the entire Thatipudi watershed indicate that almost the geological structures are not disturbing the drainage pattern (Strahler, 1964).

Stream Length (L_u)

The stream length is calculated based on Horton's law (1945) for all sub-watersheds thus suggesting homogenous lithology in the study area. The number of streams of various orders in the sub-watershed has been counted and their lengths are measured. The total length of stream segments is high in case of first order streams and decreases as the stream order increases. Plots of the logarithm of stream lengths versus stream order are showing the curvilinear to linear pattern (Figure 3). Most of the drainage networks show a linear relationship with a small deviation from a straight line which indicates the lithological and topographical variations in the region (Chow, 1964).

Table 3. Linear Aspects of the Drainage Network of Thatipudi Sub-watersheds

Sub-watershed/ Watershed	u	N_u	L_u kms	Log N_u	Log L_u	R_b	R_b (Mean)
SW-I	1	73	41.37	1.863	1.617	3.65	4.22
	2	20	10.66	1.301	1.028	4.00	
	3	5	9.30	0.699	0.968	5.00	
	4	1	4.00	0.000	0.602		
SW-II	1	46	22.94	1.663	1.361	5.75	3.92
	2	8	6.80	0.903	0.833	4.00	
	3	2	4.60	0.301	0.663	2.00	
	4	1	1.00	0.000	0.000		
SW-III	1	57	29.00	1.756	1.462	5.18	4.23
	2	11	12.60	1.041	1.100	5.50	
	3	2	3.00	0.301	0.477	2.00	
	5	1	6.90	0.000	0.839		
SW-IV	1	43	25.70	1.633	1.410	4.30	7.15
	2	10	7.26	1.000	0.861	10.00	
	3	1	7.60	0.000	0.881		
SW-V	1	19	13.00	1.279	1.114	9.50	5.75
	2	2	2.60	0.301	0.415	2.00	
	5	1	3.50	0.000	0.544		
SW-VI	1	35	18.57	1.544	1.269	3.89	3.46
	2	9	6.30	0.954	0.799	4.50	
	3	2	5.10	0.301	0.708	2.00	
	4	1	2.22	0.000	0.346		
SW-VII	1	36	19.12	1.556	1.281	4.00	3.33
	2	9	7.13	0.954	0.853	3.00	
	3	3	1.95	0.477	0.290	3.00	
	4	1	8.88	0.000	0.948		
SW-VIII	1	53	31.7	1.724	1.501	4.82	4.11
	2	11	4.91	1.041	0.691	5.50	
	3	2	2.46	0.301	0.391	2.00	
	5	1	5.51	0.000	0.741		

SW-IX	1	79	41.8	1.898	1.621	4.16	4.30
	2	19	18.58	1.279	1.269	4.75	
	3	4	7.51	0.602	0.876	4.00	
	5	1	9.00	0.000	0.954		
SW-X	1	36	23.18	1.556	1.365	3.60	6.80
	2	10	10.13	1.000	1.006	10.00	
	3	1	4.06	0.000	0.609		
SW-XI	1	70	30.40	1.845	1.483	5.00	4.22
	2	14	12.97	1.146	1.113	4.67	
	3	3	5.30	0.477	0.724	3.00	
	5	1	3.67	0.000	0.565		
SW-XII	1	98	55.18	1.991	1.742	4.26	3.77
	2	23	18.01	1.362	1.256	3.83	
	3	6	12.15	0.778	1.085	6.00	
	4	1	1.00	0.000	0.000	1.00	
	5	1	6.16	0.000	0.790		
SW-XIII	1	25	15.36	1.398	1.186	3.57	3.02
	2	7	2.60	0.845	0.415	3.50	
	3	2	1.62	0.301	0.210	2.00	
	4	1	2.95	0.000	0.470		
SW-XIV	1	64	34.66	1.806	1.540	4.92	4.09
	2	13	8.99	1.114	0.954	4.33	
	3	3	5.65	0.477	0.752	3.00	
	4	1	3.66	0.000	0.563		
SW-XV	1	85	49.01	1.929	1.690	4.47	4.55
	2	19	14.70	1.279	1.167	3.17	
	3	6	8.77	0.778	0.943	6.00	
	4	1	8.00	0.000	0.903		
SW-XVI	1	41	22.90	1.613	1.360	5.86	3.79
	2	7	8.30	0.845	0.919	3.50	
	3	2	1.80	0.301	0.255	2.00	
	6	1	6.20	0.000	0.792		
SW-XVII	1	46	28.50	1.663	1.455	4.60	3.97
	2	10	11.26	1.000	1.052	3.33	
	3	3	3.62	0.477	0.559		
SW-XVIII	1	20	11.50	1.301	1.061	5.00	3.00
	2	4	4.14	0.602	0.617	2.00	
	3	2	2.70	0.301	0.431	2.00	
	4	1	2.58	0.000	0.412		
SW-XIX	1	47	32.15	1.672	1.507	5.22	3.91
	2	9	8.50	0.954	0.929	4.50	
	3	2	1.85	0.301	0.267	2.00	
	4	1	1.00	0.000	0.000		
TW	1	973	546.20	2.988	2.737	4.50	4.18
	2	216	176.60	2.334	2.247	4.08	
	3	53	89.20	1.724	1.950	5.30	
	4	10	34.10	1.000	1.533	5.00	
	5	2	34.80	0.301	1.542	2.00	
	6	1	6.25	0.000	0.796		

Aerial Aspects

Aerial aspects include different morphometric parameters like drainage density (D_d), stream frequency (F_s), elongation ratio (R_e), circularity ratio (R_c), form factor ratio (R_f) are calculated and the results are presented in Table 4.

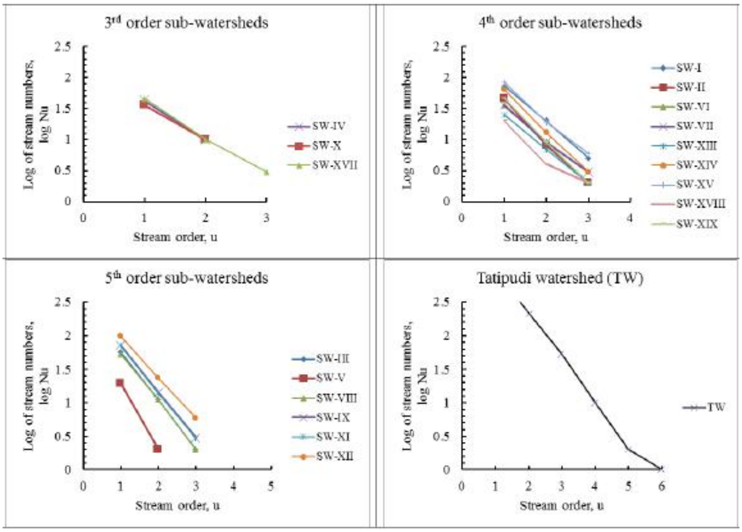

Fig. 2. Plots of Logarithm of Number of Streams versus Stream Order

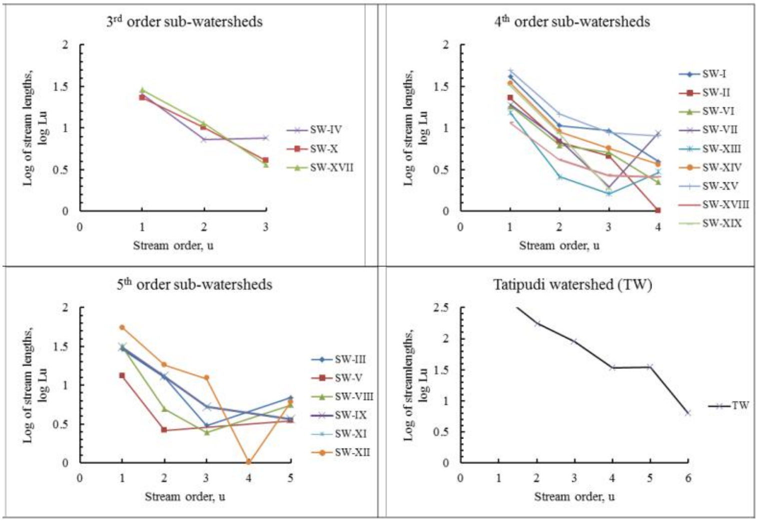

Fig. 3. Plots of Logarithm of Stream Length versus Stream Order

Drainage Density (D_d)

Drainage density (D_d) indicates the closeness of spacing of channels, thus providing a quantitative measure of the average length of stream channel for the whole basin (Horton, 1945). The D_d of the sub-watersheds ranges between 1.84 (SW-VII) and4.10 (SW-XI) km/sq.km. The D_d of whole Thatipudi watershed is 2.76 km/sq km indicating low drainage density. Low drainage density generally results in the areas of highly resistant or permeable sub-soil material, dense vegetation and low relief. High drainage density is the result of weak or impermeable sub-surface material, sparse vegetation and mountainous relief. The type of rock also affects the drainage density. Generally, lower values of D_d tend to occur on granite, gneiss and schist regions. The major type of rock in the study area is khondalite, which falls under the gneissic group of rocks. This corroborates the low drainage density observed in the watershed area.

Table 4. Areal Aspects of the Drainage Basin of Thatipudi Sub-watersheds

Sub-watershed/ Watershed	A	P	D_d	F_s	L_b	R_e	R_c	R_f
SW-I	23.38	22.97	2.79	4.23	8.25	0.66	0.56	0.34
SW-II	10.52	15.49	3.30	5.42	4.95	0.74	0.55	0.43
SW-III	19.75	23.72	2.61	3.59	8.91	0.56	0.44	0.25
SW-IV	16.68	20.77	2.43	3.24	8.95	0.52	0.49	0.21
SW-V	7.71	12.41	2.48	2.85	4.86	0.65	0.63	0.33
SW-VI	15.78	19.24	2.04	2.98	8.14	0.55	0.54	0.24
SW-VII	20.18	23.03	1.84	2.43	11.92	0.43	0.48	0.14
SW-VIII	15.99	19.26	2.79	4.19	6.70	0.67	0.54	0.36
SW-IX	26.1	23.72	2.95	3.95	9.04	0.64	0.58	0.32
SW-X	12.42	15.4	3.01	3.78	5.68	0.70	0.66	0.39
SW-XI	12.78	16.25	4.10	6.89	6.20	0.65	0.61	0.33
SW-XII	23.46	25.27	3.94	5.50	10.44	0.52	0.46	0.22
SW-XIII	6.49	12.89	3.47	5.39	5.12	0.56	0.49	0.25
SW-XIV	16.11	18.49	3.29	5.03	8.29	0.55	0.59	0.23
SW-XV	28.57	28.63	2.82	3.89	14.15	0.43	0.44	0.14
SW-XVI	13.72	20.08	2.86	3.72	8.98	0.47	0.43	0.17
SW-XVII	18.19	40.53	2.38	3.24	4.63	1.04	0.14	0.85
SW-XVIII	8.02	16.1	2.61	3.37	6.46	0.49	0.39	0.19
SW-XIX	16.33	30.94	2.63	3.61	3.39	1.34	0.21	1.42
TW	321.10	116.00	2.76	3.91	43.70	0.46	0.30	0.17

Stream Frequency (F_s)

The F_s values of the sub-watersheds vary from 2.43 (SW-VII) to 6.89 (SW-XI) and 3.91 for total watershed area. The values of stream frequency for all sub-watersheds exhibit almost positive correlation with the drainage density values of the area, which reveals that the stream population increases with drainage density.

Elongation Ratio (R_e)

Elongation ratio (R_e) is the ratio of diameter of a circle of the same area as the basin to the maximum basin length (Schumm, 1956). The R_e of the whole watershed is 0.46, which reveals the fact that the basin is elongated in shape (Table 4). The R_e values of the sub-watersheds vary from 0.43 (SW-VII and SW-XV) to 1.34 (SW-XIX) suggest that the maximum relief and moderate to steep slopes of the terrain in the region. According to Schumm (1956), R_e values close to 1.0 are typical of regions of low relief, whereas those in the range of 0.6–0.8 are generally associated with high relief and steep ground slopes. A circular basin is more efficient in the discharge of runoff than an elongated basin (Singh and Singh, 1997).

Circularity Ratio (R_c)

Circularity ratio is the ratio of the area of a basin to the area of circle having the same circumference as the perimeter of the basin. Low, medium and high values of R_c give an indication of the young, mature and old stages of the tributaries in the basins, respectively. If the R_c value is 1.0, the basin is a perfect circle in shape and the discharge quantity would be high (Miller, 1953). In the study area, the R_c values vary from 0.14 (SW-XVII) to 0.66 (SW-X) and 0.3 for the whole watershed. The sub-watersheds SW-III, SW-IV, SW-VII, SW-XII, SW-XIII, and SW-XV to XIX values of R_c have less than 0.5 indicating that elongated, whereas the remaining sub-watersheds have greater than 0.5 values suggesting that they are more or less circular in shape and are characterised by the high to moderate relief and structurally controlled.

Form Factor Ratio (R_f)

Form factor is the ratio of the basin area to the square of the basin. The R_f varies from 0 (in highly elongated shape) to 1 (in perfect circular shape). Smaller the value of form factor, more elongated will be the basin length (Horton, 1945). The R_f value of the Thatipudi watershed is 0.17 indicating that the whole basin is elongated in form. The R_f varies from 0.14 (SW-VII and SW-XV) to 1.42 (SW-XIX) suggesting that all sub-watersheds elongated in shape resulting lower peak flows for longer duration except SW- XVII (0.85) and SW-XIX (1.42) which shows circular in shape.

Conclusions

Geospatial techniques i.e. remote sensing and GIS have proved to be efficient tools in watershed studies in order to identifying the drainage channels through its delineation and updation. The morphometric analysis was carried out through measurement of linear and areal aspects of the Thatipudi watershed. The watershed is 6^{th} order drainage basin. The mean R_b (4.18) indicates that the drainage pattern is not much influenced by geological structures. Elongation ratio (R_e=0.46) suggesting that the low relief of the terrain and elongated in shape (Schumm, 1956). Circularity ratio (R_c=0.3) indicates that the basin is strongly elongated and covering with highly permeable soils (Miller, 1953). The elongated basin with low form factor (R_f=0.17) of the area is characterised by flatter peak of flow for longer duration. Flood flows of such elongated basins are easier to manage than of the circular basin (Horton, 1945).

Watershed development programmes are meant for either direct or indirect support to the rural community through development and utilisation of economic resources for the inhabitants in order to encourage savings and other income-generation activities. Optimum utilisation of the watershed's natural resources will immensely help in preventing the adverse effects of drought and other ecological disturbances. The morphometric parameters are evaluated using GIS and RS techniques which will help us to understand the various terrain parameters such as nature of the bedrock, infiltration capacity, runoff, etc. and also watershed prioritisation for soil and water conservation at micro level.

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GEOGRAPHY OF RURAL DEVELOPMENT IN THE KONKAN DIVISION OF MAHARASHTRA

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Abstract

About 70 percent of the population in India is rural in character; assessment of rural indicators will give a clear picture of development. Rural development is intimately linked with social development and vice-versa. It is in this context that the present study is conducted to analyse the tehsil-wise rural development of Maharashtra's Konkan division, based on published data obtained from the Census of India, 2011. Sharp disparities are seen across the region and tehsils and also between Mumbai and the rest of the division in education, health, transport and communication and other indicators. The northern and central industrialised tehsils like Kalyan, Thane, Uran and Ambarnath are most backward among all the tehsils and score low on the composite rural development index.

Keywords: Rural development, Infrastructure, Composite index.

Introduction

'Development', a qualitative concept, can be operationalised and determined through the use of social, economic, political, infrastructure, and demographic indicators. These are essential to reveal the stage of development in a region. The level of development is general and rural in particular will give a clear picture of development in the State. As we have entered into the 21st century, it is important to see as to how much the state / division has achieved improvement in the stage of rural development. Development of a section in the society is intimately linked with overall social development and vice-versa. Research on development came to the forefront with the publication of the first human development report of the world in 1990. Since then, various themes have been adopted to analyse regional development. Based on characteristics, region is divided into rural and urban. Since about 70 percent of the population in India is rural, it is essential to understand the echelons of rural development.

Indices of Rural Development

In order to formulate the composite rural development index, many broad indicators can be used like demographic, social, economic, political, health and infrastructure which include availability of educational facilities; sources of drinking water and sanitation facilities; community and primary health centres, maternity and child welfare centres, Tuberculosis (TB) clinics, hospitals and dispensaries, family welfare centres, government and non-government medical facilities and medical practitioners; transport and communication facilities and others.

Indicators of Rural Development

The theme of rural development is multi-dimensional in character and it cannot be recorded by a single indicator. A multi-dimensional index of rural development is preferred. The indicators selected for the present study are listed in Table 1. The broad objective of the present research is to find the levels of development in the coastal tehsils of Maharashtra.

Database and Methodology

Census of India, 2011 provides relevant village-level information regarding presence of various aspects of population and development indicators, which have been used here at tehsil-level in order to study the various indices independently, showing development. Also, information about various indicators has been collected from published reports of the State and Central Government, District Census Handbook, Maharashtra State and District Gazetteer of Ratnagiri, Colaba, Thane, Bombay, Ratnagiri and Savantwadi Districts, socio-economic review, District Statistical Abstracts and other Government Reports of 2011 to evaluate rural development in the Konkan division of Maharashtra. The specific objectives are: to compute the composite rural development index by analysing the spatial variability of individuals indicators like education, health, availability of drinking water sources and drainage facilities, transport and communication indicators and others per 10,000 rural population for the 2011 Census.

Methodology

The data obtained from the above mentioned sources has been converted into usable form by using relevant statistical techniques like ratio, quartiles, standard deviation and correlation. In order to have a meaningful exposition of each development indicator, it is related to the rural population of the tehsil. Population-indicator index is obtained by the maximum-minimum method of normalisation, which is one of the most frequently used methods in composite index (OECD, 2005, 2008). Minimum-maximum normalises indicators in order to have an identical range (0,100). Indices of education, sources of drinking water and sanitation facilities; community and primary health centres, maternity and child welfare centres, TB clinics, hospitals and dispensaries, family welfare centres, government and non-government medical facilities and medical practitioners; transport and communication facilities and others represent the positive elements of development. These single indicators have been analysed and those representing a dimension considered not in the same dimension of the phenomena are inverted. After defining the minimum and maximum values, each indicators has been evaluated tehsil-wise, by the following method:

$$\text{PHCIt} = 100 - \frac{(\text{PHCRt(act)} - PHCRt(min)}{(\text{PHCRt(max)} - PHCRt(min)} X\,100$$

where,

PHCIt = primary health centre index of tehsil
PHCRt (act) = actual primary health centre ratio of tehsil
PHCRt (min) = minimum primary health centre ratio of the region
PHCRt (max) = maximum primary health centre ratio of region

Thus, each single indicator of education, sources of drinking water and drainage facilities, health, transport and communication facilities and others has been analysed. Finally, the indexes of each health indicator are linearly aggregated as all individual indicators have the same measurement unit and the compatibility of indicators per dimension is considered acceptable for each tehsil, by the average method of linear aggregation.

Composite rural development index for Konkan region has been calculated by the following formula:

$$\text{CRDI} = \frac{EDI+HDI+DWSI+{}_{DFI}+TCI+OI}{6}$$

where,

CRDI = Composite Rural Development Index
EDI=Education Development Index
HDI = Health Development Index
DWSI = Drinking Water Sources Index
DFI = Drainage Facility Index
TCI = Transport and Communication Index
OI = Other Index

The indices thus obtained were classified into high, moderate and low regions of rural development. The results are shown with the help of choropleth maps to understand the spatial variation of rural development levels in the Konkan division of Maharashtra State.

Study Area

Konkan division of Maharashtra state lies between 15^0 5' - 20^0 2' N latitudes and 72^0 8' - 74^0 2' E longitudes (Figure 1). It extends over an area of 30,746 sq.km and has 720 km coastline along the Arabian Sea. Its shape being elongated, no point is more than 100 kms away from the sea. Administratively, the region comprises of six districts (2011) like Thane, Mumbai sub-urban, Mumbai, Raigarh, Ratnagiri and Sindhudurg districts, consisting of 46 tehsils. According to the 2011 Census of India, the population of the Konkan division is about 28,60,14,411 people, i.e., 25 percent of Maharashtra's population; the average crude density is 82,976 persons per sq.km in the entire region; Ulhasnagar, Thane and Kalyan Tehsils have the highest concentration of total population. About 22.03 percent and 77.96 percent of population are rural and urban respectively. The region has 52.80 percent males and 47.19 percent female population. The average crude literacy rate is about 69.36 percent. The male literacy is about 55.39 percent, higher than female literacy, which is about 44.60 percent in the entire coastal region.

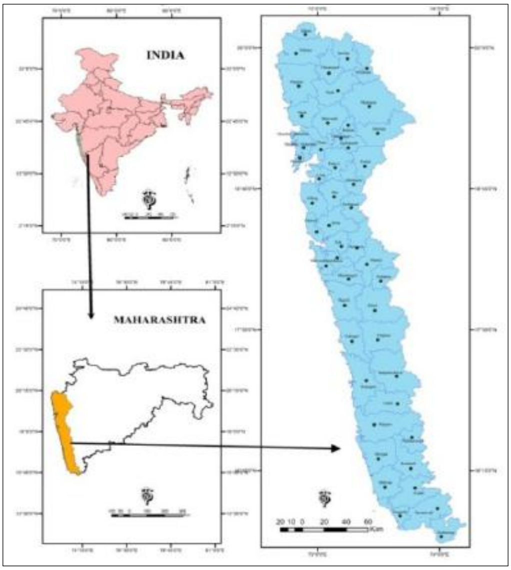

Fig. 1. Location of Konkan Region, Maharashtra

Analysis of the Indicators

Education Development Index (EDI)

The study region's overall education development index ranges from a high of 71 to a low of 96. It is clear from Figure 2A, that the overall educational index is high in Mandangad, Malwan, Kalyan and Kudal Tehsils; while it is very low in Dahanu, Vikramgad, Thane and Jawhar Tehsils. Kudal Tehsil has maximum ratio of government middle, secondary, primary and senior secondary schools; vocational training schools or it is and government school for the disabled. The educational index is also high in Kalyan due to high index of private primary, middle, secondary and senior secondary schools along with government and private arts and science degree colleges. Government pre-primary, primary, secondary and senior schools; middle schools ratio helped to increase overall education index of Malwan Tehsil; while Mandangad Tehsil enjoys the presence of private pre-primary schools and vocational training schools or it is of government in large numbers. At the lower end lie the tehsils of Dahanu, Vikramgad, Thane and Jawhar Tehsils. Dahanu has comparatively lower ratio of both the government and private non-formal training centres, private school for the disabled, arts and science degree, engineering, medicine colleges, management and polytechnic; private pre-primary schools and others. Same condition is recorded in Vikramgad, Thane and Jawhar Tehsils.

Table 1. Rural Development Indicators – List

Sl. No.	Categories	Indicators
	(Ratio per 10,000 of total rural population)	
1	**Education Development Index** (EDI): 15 indicators (Ratio per 10,000 of total rural population above 7 years)	Government and Private: Pre-Primary School, Primary School, Middle School, Secondary School, Senior Secondary School, Senior Secondary School, Arts and Science Degree College, Engineering College, Medicine College, Management Institute, Govt. Polytechnic, Government Vocational Training School / ITI, Non Formal Training Centre, School for Disabled and Others.
2	**Sources of Drinking Water (DWSI):** 8 indicators	Treated, Untreated, Covered, Functioning All year round: Tap Water; Covered, Uncovered, Functioning All year round: Wells, Hand Pump, Tube Wells / Borehole, Spring, River / Canal, Tank / Pond / Lake and Others.
3	**Drainage Facility Index(DFI)**: 9 indicators	Drainage: Closed and Open; Pucca, Kuccha; Area covered under Total Sanitation Campaign (TSC), Community Toilet Complex (including, excluding Bath) for General Public, Rural Production Centres and marts or Sanitary hardware outlet availability near the village, Community Waste Disposal System after house to house collection, Community Bio-Gas or Recycle of Waste for Production use, No System (Garbage on road / street).
4	**Health Development Index (HDI)**: 11 indicators (excluding veterinary facilities)	Community Health Centres, Primary Health Centres and Primary Health Sub Centres, Maternity and Child Welfare Centres, TB Clinics, Hospitals: Allopathic, Alternative Medicine, Dispensaries, Mobile Health Clinics, Family Welfare Centres, Non-Government and Medical Facilities.
5	**Transport & Communication Indicators Index (TCI)**: 24 indicators	Post Office, Sub Post Office, Post and Telegraph Office, Telephone (landlines), Public Call Office / Mobile (PCO), Mobile Phone Coverage, Internet Cafes / Common Service Centre (CSC), Private Courier Facility, Bus Service (Public and Private), Railway Station, Auto / Modified Autos, Taxi, Vans, Tractors, Cycle-pulled Rickshaws (manual and/or machine driven), Carts Driven by Animals, Sea / River / Ferry Service, Roads (National, State Highways, Major, Other District Roads), Black Topped (pucca), Gravel (kuchha) Road, Water Bounded Macadam, All Weather Road, Navigable Waterways (River / Canal), Foothpath and ATM.
6	**Others Index (OI)**: 19 indicators	Bank (Commercial and Cooperative), Agricultural Credit Societies, Self - Help Group (SHG), Public Distribution System (PDS), Shop, Mandis / Regular Market , Weekly Haat, Agricultural Marketing Society, Nutritional Centres - ICDS, Anganwadi, Others, ASHA, Community Centre with / without TV, Sports Field, Sports Club / Recreation Centre, Cinema / Video Hall, Public Library, Public Reading Room, Daily Newspaper Supply, Assembly Polling Station, Birth and Death Registration Office, Power Supply for Domestic, Agriculture, Commercial Use and All Users.

Source: Compiled by the Author

Sources of Drinking water Availability (DWSI)

The region recorded an average drinking water source of 70.00 indices. It is high in Sudhagad, Rajapur, Mandangad, and Vaibhavvadi; it is lowest in Talasari, Kalyan, Dahanu and Uran Tehsils (Figure 2B). The covered wells, hand pumps, tubewells or boreholes, river / canal index all increased the drinking water index of Sudhagad Tehsil. This index is also high in Rajapur because of the covered wells, spring and river / canal ratio. Mandangad is rich in tap water and spring ratio; while Vaibhavvadi has tube wells / boreholes, spring, river / canal index ratio.

Low drinking water index is found in Talasari, Mokhada, Kalyan and Dahanu. Covered wells, springs, tank / ponds / lakes and other drinking water sources index is very low in Talasari Tehsil, while in Mokada Tehsil, treated tap water, covered wells, hand pumps, tube wells / bore wells and others index is very low. Kalyan has deficiency of covered wells, tube wells / boreholes, spring and others index.

Drainage Facilities Index (DFI)

It is clear from Figure 2C, that the overall rural drainage index is high in Kalyan, Vasai, Ambarnath, Talasari and Devgad Tehsils, ranging from 49 (high) to about 98 (low) indices. Villages in Kalyan Tehsil have closed drainage, community toilet complex for general public including baths, rural production centres and marts or sanitary household outlet near the village, community waste disposal system after house to house collection and bio-gas or recycle of waste for production use, bringing up the drainage index in the Tehsil. Presence of closed drainage, community toilet complex including bath for general public, rural production centres and marts or sanitary hardware outlet near the village and community waste disposal system after house to house collection in Vasai increased the drainage index in this tehsil. Absence of many drainage indicators in Jawhar, Vikramgad, Sawantwadi, Vada and Karjat besides many other tehsils have recorded low drainage index in these tehsils.

Health Development Index (HDI)

The Konkan region recorded an average heath development index of about 68.00 units. The greatest proportion of overall health indicator was found to occur in Mandangad, Dodamarg, Mokhada, Lanja and Devgad Tehsils (Figure 2D). The high in Mandangad can be attributed to the favourable ratio of community health centres, different parameters of the primary health sub-centres, maternity and child welfare centres, TB clinics, family welfare centres; while Dodamarg Tehsil has primary health centres, maternity and child welfare centres, TB clinics, dispensaries, mobile health clinics, family welfare centres, and non-government medical practitioners with MBBS degree. Para-medical staff of the primary health centres, maternity and child welfare centres, TB clinics, allopathic hospitals, family welfare centres and non-government medical practitioners with MBBS degree raised the health index in Mokhada Tehsil. At the other end of the spectrum lie the tehsils of Thane, followed by Uran, Shrivardhan and Roha Tehsils, where majority of health indicators ratio are low in quantity.

Transport and Communication Indicators (TCI)

The overall rural transport and communication index is high in Lanja, Rajapur, Malwan, Mhasla and Tala tehsils (Figure 2E); it is low in Kalyan, Karjat, Mokada, Jawhar and Ambarnath Tehsils. In Lanja, ratio of sub-post office, public bus service, railway station, gravel roads, water bounded macadam and landline telephone helped increase the transportation and communication index.

Gravel roads, public bus services and water bounded macadam rose this index in Rajapur Tehsil. Malwan is favoured by major district roads, sub-post office, public bus service and state highway ratios. The low in Kalyan can be attributed to the very poor index ratio of sub-post office, telephone lines, mobile phone coverage, public bus service, tractors, cycle-pulled rickshaws (manual and machine driven), carts driven by animals, major and other district roads, gravel roads and navigable waterways.

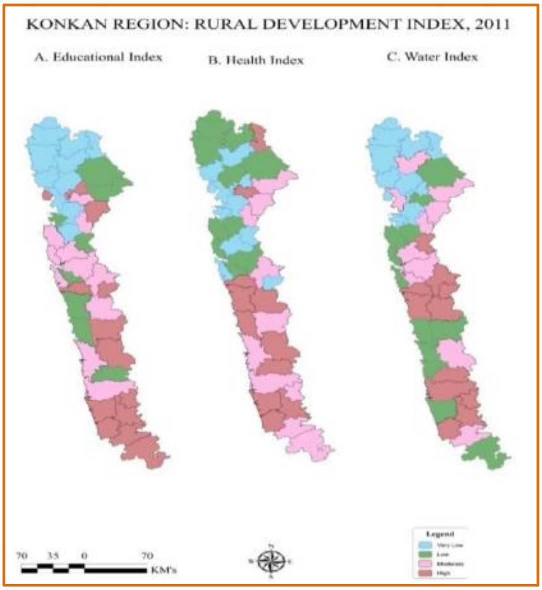

Fig. 2. Development Indices: A. Education B. Health C. Water Development

Other Index (OI)

Agricultural credit societies, self-help groups, ASHA, daily newspaper supply, assembly polling station, birth and death registration office, power supply for commercial and all users index has increased the other index in Kudal Tehsil from Figure 2F. Devgad is rich in commercial and cooperative bank, ASHA, daily newspaper supply, assembly polling station and the birth and death registration office; while Kankavli has bountiful index of cooperative banks, agricultural credit societies, ASHA, daily newspaper supply, assembly polling station and birth and death registration office. The low OI in rural Kalyan, Poladpur, Tala, Sudhagad and Shrivardhan can be attributed to the low index of majority other indicators.

Composite Rural Development Index (CRDI)

High rural development has positive association with the indicators of sources of drinking water, health, transport and communication and others, '*r*' value being 0.76, 0.75, 0.56 and 0.54 respectively. The composite rural development index of the study region ranges from 61.28 units (high) to a 79.72 units (low); it is high, i.e., above the study region's average of 65.30 in Mandangad, Lanja, Malwan, Kudal and Vaibhavvadi Tehsils (Figure 4). The high in the centrally located Mandangad can be attributed to the high levels of educational and health indicators; Lanja recorded more of the health, transport and communication and other indices. Malwan is well off with transport and communication indicators, while Kudal has favourable other indicators along with the educational indicators, thus bringing it on the fourth position of rural development.

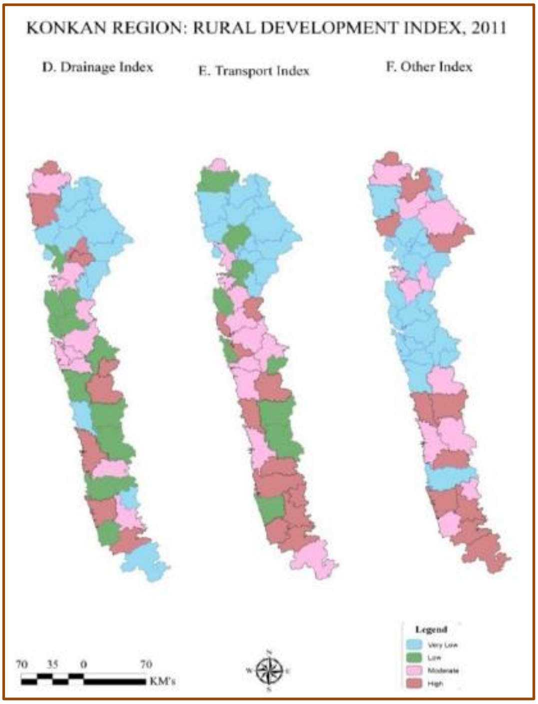

Fig. 3 Development Indices: D. Drainage E. Transportation F. Others

Health, drinking water sources, transport and communication and others indicators are intensively available in Vaibhavvadi Tehsil; while various health indicators concentration is seen more in Dodamarg Tehsil. Rajapur, Khed, Kankavli, Devgad, Sangameshwar and Dapoli Tehsils are located in the high rural development zone. On the bottom side lies, Uran, Talasari, Dahanu, Panvel and Kalyan Tehsils, the index values being well above 79. This may be attributed to the low indices of health and education in Uran Tehsil; the northernmost located Talasari, the adjoining Dahanu and Panvel Tehsils are well equipped with indices of transport and communication and others. Low rural population in the highly urbanised Kalyan Tehsil along with least health and transport communication indicators has placed Kalyan in the fifth position of rural development from the bottom in the Konkan region. Vikramgad, Thane, Bhiwandi, Shrivardhan, Palghar, Vasai, Jawhar, Ambarnath, Murud, Alibagh, Pen, Shahapur, Mokhada, Vada, Roha, Ratnagiri, Sawantwadi and Poladpur are also located in the very low to low zones of rural development. The remaining 11 tehsils lies in the moderate zone.

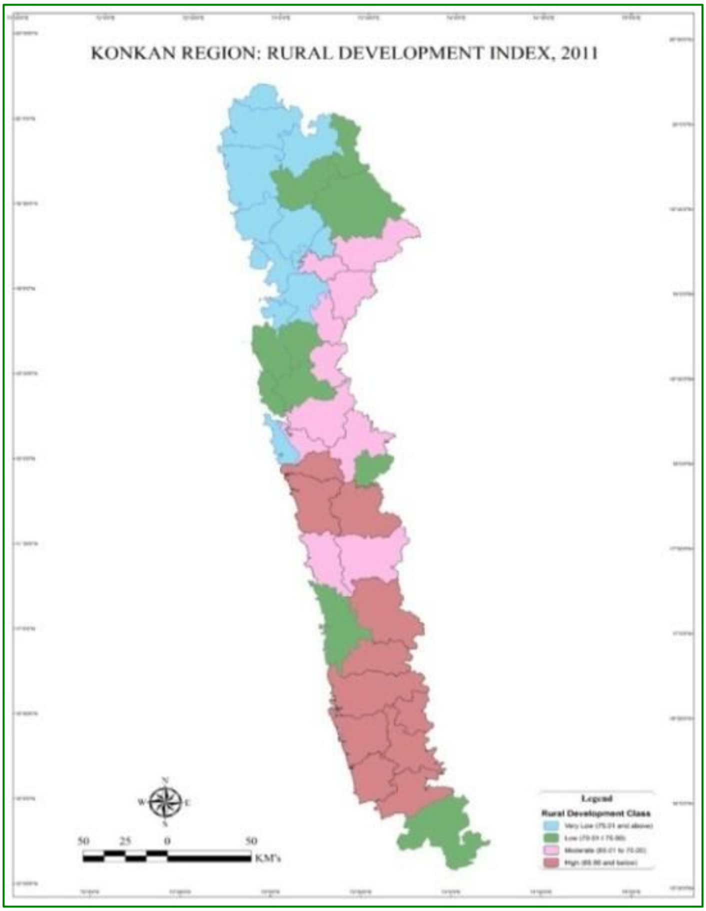

Fig. 4. Konkan Region: Composite Rural Development Index, 2011

Conclusions

From the foregoing analysis it is clear that there are sharp disparities across regions and Tehsils in respect of rural development in the study region. High rural development has positive association with the indicators of sources of drinking water, health, transport and communication and others; it is concentrated in the southern Tehsils, while the northern Tehsils are backward in connection to the rural development. The analysis reveals that though the northern Tehsils have high concentration of rural population, development in these Tehsil is not sufficient or ranges from low to very low, caused by lack of educational, sources of drinking water, drainage facilities and transport and communication facilities. This region is covered by coarse shallow soil, mostly enclosed by foot paths and has deficiency in modern communication components.

On the contrary, the southern tehsils, lying in close proximity to the Kolhapur district, which is a centre of education, are the highly developed ones with the largest concentration of educational, drinking water sources, transportation and other indicators. Some extreme outliers of backward regions exists in the longitudinally central Tehsil of Uran, though lying in close proximity to the Arabian Sea, it is the least developed tehsil. Proximity to the sea, physiological situation and natural resources are not the only factors responsible for the development of a region, but availability and proper utilisation of the existing facilities also affect the overall levels of rural development. Developmental plans in the backward regions can and will help improve the tehsils, through rural transformation and functioning at the village level.

Multi-dimensional strategies are essential to provide rural employment and thus reduce outmigration from the villages. This will improve the per capita income and thus increase the implementation and utilisation of socio-economic, educational, health and other facilities and plans among and within the villages. More than half of the tehsils lie in the backward or the less developed zones of rural development in 2011 and for them availability of the selected indicators is still a crucial factor of development. Thus, there is scope for progress to be made in the region. Regional inequalities can be narrowed down by focusing on rural development in the lagging regions, for which educational, health, provision of drinking water, drainage, transportation, communication and other facilities will play a leading role. Economic activities should be supervised, organised and disseminated so that the indicators are decongested and dispersed. This should form the core of rural development throughout India.

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MORPHOMETRIC ANALYSIS OF BARA TEHSIL OF ALLAHABAD DISTRICT THROUGH CARTOSAT-1 DEM DATA

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Abstract

Morphometric analysis of Bara tehsil of Allahabad district is carried out to understand the hydrological behaviour for assessing groundwater potential, water resource management, hazard reduction, flood control etc. CARTOSAT-1 DEM data is the major data source for extracting drainage network and for delineating Yamuna basin and Tons basin (all the 8 watershed belonging to both the basins). ArcHydro tool of ArcGIS software version 10.2.2 has been used for generating different thematic layers and attribute tables. Raster calculator and excel sheet is used for calculating linear, areal and relief parameters of drainage basin. The obtained result indicates that Yamuna and Tons river basin have 6^{th} and 5^{th} order stream respectively, both have dendritc drainage pattern with moderate to good infiltration due to low slope terrain.

Keywords: CARTOSAT-1 DEM, ArcHydro tool, Morphometric analysis.

Introduction

Morphometric analysis is the measurement and mathematical analysis of the configuration, shape, form and structure of the drainage basins along with their associated networks described by their morphometric parameters (Clark, 1966). Morphometric parameters comprises linear, areal and relief parameter which incorporates quantitative measurement of stream segment like; stream length, stream order, bifurcation ratio, drainage density, stream frequency, texture ratio, elongation ratio etc (Horton, 1945). These morphometric parameters are not only indicators of structural influence on drainage development but also used to assess surface and ground water potentiality of the basins through surface runoff and infiltration ratio of the basins and to locate suitable sites for construction of artificial recharge structures (Avinash et al., 2011). Morphometric parameters are very useful for identification of deficit and surplus groundwater zones (Yadav et al., 2014). Geospatial technology is increasingly being used for deriving morphometric parameters of drainage basins throughout the world (Lyewayee et al., 2007). Hence, in the present study all important morphometric parameters are derived from thematic layers and calculated accurately to infer the hydrological behaviour of study area in ArcGIS.

Study Area

Bara Tehsil comprises of Jasra and Shankargarh development block, which represents transition zone between the plain of Yamuna and uplands of the Vindhyan region. It is situated in the southwestern part of Allahabad District, Uttar Pradesh, India (Figure 1). It lies between $25^0$2' - $25^0$22' N latitude and $81^0$31'- $81^0$50' E longitude with total extent of 729.45 km^2. The plains of Yamuna and Tons river has low elevation (-7 to 33 m) than the northwestern part of Bara Tehsil. The above said plain is occupied by rocks of Kaimur group and have highest elevation ranges from 46 m to 129 m. The study area has tropical monsoon type of climate which is characterised by cool, dry, invigorating winter and scorching and dusty summer. Annual temperature range of the study area is 8.93^0 C to 41.48^0 C and maximum rainfall occurs during monsoon period i.e. 240.82 mm. It is a backward region endowed by low agricultural productivity, stone quarrying and ceramic industry due to presence of red sand stone, glass sand and quartz minerals which belongs to the Vindhyan super group (GSI, 2001). Population statistics of study area discloses that 51.22 % population is supported by Jasra block with only 34.05 % area of Bara Tehsil whereas 48.72 % population is supported by Shankargarh block with 65.95 % area of Bara Tehsil. Both blocks of the study area are facing water scarcity problem, hence study of morphometric analysis is important for water resource management.

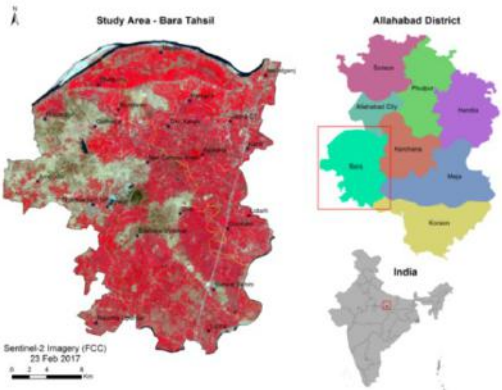

Fig. 1. Location of Study Area

Database and Methodology

Drainage network is extracted from the CARTOSAT-1 DEM data having 2.5 m spatial resolution acquired in 2013. It is downloaded from the website of USGS earth explorer. The delineation of Yamuna and Tons river basin, with its 8 watersheds along with drainage network, is based on thematic layers such as fill, flow direction, flow accumulation, stream to feature etc. (Figure 2). These thematic layers are generated from CARTOSAT-1 DEM data and processed through ArcHydro tool of ArcGIS 10.2.2. Further, attribute table, containing stream length, basin area, basin perimeter, basin relief etc. has been generated and other morphometric parameters has been computed at watershed level through raster calculator and excelsheet using the morphometric formulas listed in Table 1.

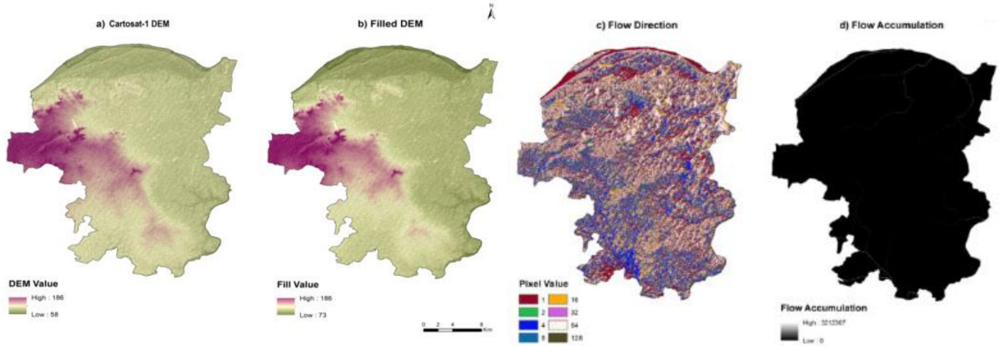

Fig. 2 (a-d). Extraction of Drainage Network from CARTOSAT-1 DEM

Results and Discussion

Yamuna and Tons river delineating north and southeast border of the study area with the length of 31.50 km and 29.62 km respectively. These rivers are the main outlet for all major tributaries in the study area. A total 8 watershed (WS) having minimum 3 order streams are identified from CARTOSAT-1 DEM data (in which WS 1, WS 2, WS 3 and WS 4 belongs to Yamuna basin whereas, WS 5, WS 6, WS 7 and WS 8 belongs to Tons basin). Both Yamuna and Tons river basin are separated by moderately dissected plateau having elevation of 114-180 m. It is endowed by rocks enriched with sandstone and quartzite belongs to Kaimur group of rock of Vindyhan super-group and this plateau is extended in northwest to southeast direction with broader to narrower shape respectively. Linear, areal and relief parameters are discussed in detail with regard to 8 WS of study area in the following sections.

Drainage Network

Drainage network is analysed in reference with stream order, stream length, stream length ratio and bifurcation ratio which is as follows:

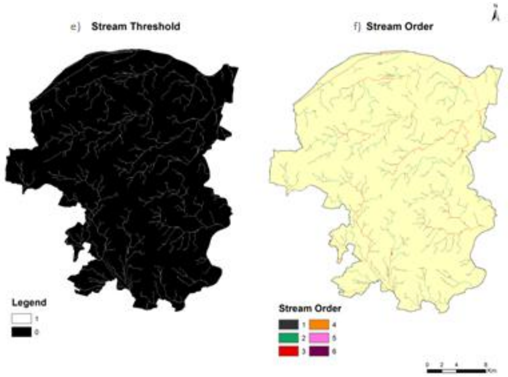

Fig. 2 (e) and (f). Extraction of Drainage Network from CARTOSAT-1 DEM

Table 1. Morphometric Parameters and their Formulas Computed for Yamuna and Tons Basin

Sl. No.	Morphometric Parameters	Formulae	Reference
Drainage Network			
1	Stream Order (S_u)	Hierarchical Rank	Strahler, 1952
2	Stream Number (N_u)	$N_u = N_1 + N_2 + ...+ N_n$	Hortorn, 1945
3	Stream Length (L_u)	$L_u = L_1 + L_2 + ...+ L_n$	Strahler, 1964
4	Stream Length Ratio (L_{ur})	$L_{ur} = L_u / L_{u-1}$	Strahler, 1964
5	Mean Stream Length Ratio (L_{urm})	$\sum L_{ur}$	Hortorn, 1945
6	Bifurcation Ratio (R_b)	$R_b = N_u / N_{u+1}$	Strahler, 1964
Basin Geometry			
7	Basin Length (L_b)	-	Schumn, 1956
8	Basin Area (A)	-	Schumn, 1956
9	Basin Perimeter (P)	-	Schumn, 1956
10	Form Ratio (F_f)	$F_f = A/ L_b^2$	Hortorn, 1932
11	Elongation Ratio (R_e)	$R_e = 2 / L_b*(A/\pi)^{0.5}$	Schumn, 1956
12	Circularity Ratio (R_c)	$R_c = 4 \pi A / P^2$	Miller, 1953
Drainage Texture Analysis			
13	Stream Frequency(F_s)	$F_s = N_u / A$	Hortorn, 1932
14	Drainage Density (D_d)	$D_d = L_u / A$	Hortorn, 1932
15	Drainage Texture(D_t)	$D_t = N_u / P$	Hortorn, 1945
16	Constant of Channel Maintenance(C)	$C = 1 / D_d$	Schumn, 1956
17	Length of Overland Flow (L_g)	$L_g = 1/2*A / \sum L_u$	Hortorn, 1945
18	Infiltration Number (I_f)	$I_f = F_s * D_d$	Faniran, 1968
Relief Parameter			
19	Height of Basin Mouth (z)	-	-
20	Maximum Height of the Basin (Z)	-	-
21	Total Basin Relief (H) (Relative Relief)	H = Z-z	Strahler, 1954
22	Relief Ratio (R_h)	$R_h = H / L_b$	Schumn, 1956
23	Absolute Relief (R_a)	-	-
24	Ruggedness Number (R_n)	$R_N = D_d * (H/1000)$	Strahler, 1964
25	Dissection Index (D_{is})	$D_{is} = H/R_a$	-

Stream Order (S_u)

Stream order shows the hierarchy of streams within an area. Strahler's method (1952) is used for assigning order to stream, where order 1st is assigned to all those streams having no tributaries, convergence of 1st order stream makes 2nd order stream. Thus, same order stream makes higher order when they intersect. Study area has 6th order drainage basins. In study area, total 415 number of streams are identified by providing 1,000 pixels as threshold limit for making a stream using ArcHydro tool. Out of 415 streams, 204 streams are delineated in Yamuna basin (139 are of 1st order, 42 are of 2nd order, 15 are of 3rd order, 5 are of 4th order, 2 are of 5th order and 1 is 6th order), whereas, 211 streams belong to Tons basin (147 are of 1st order, 46 are of 2nd order, 10 are of 3rd order and 7 are of 4th order) (Table 2). Yamuna and Tons river belongs to the 6th and 5th order stream respectively. All the streams of the study area are making dendritic drainage pattern which indicate geological structural control over drainage system in form of in homogenity of drainage pattern.

Bifurcation Ratio (R_b)

Bifurcation ratio denotes the ratio of number of streams of lower order to number of streams of next higher order which ranges from 3 to 5 in plain region. The mean bifurcation ratio calculated as arithmetic mean of bifurcation ratio which is close to 3 and 5 for all 8 WS (Table 2). The value of mean bifurcation ratio is low for Yamuna basin than Tons basin since Yamuna basin have alluvial origin. The bifurcation ratio of 2nd, 5th and 2nd order of WS 6, WS 7 and WS 8 respectively shows higher values which reflect high dissection in the moderately dissected plateau near Shankargarh region. The other lower order stream segments have low bifurcation value showing conformity with alluvial region and slope.

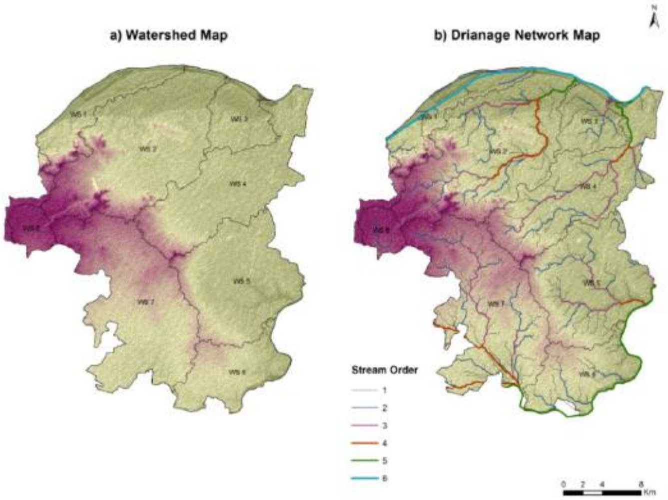

Fig. 3 (a) and (b). Drainage Network of Study Area at Watershed Level

Stream Length (L_u)

Total stream length of study area is 715.76 km, in which Yamuna basin constitutes 366.95 km (Table 2). In general successive stream order has direct relationship with mean stream length but it has inverse relationship with total stream length. This is also seen in study area for Yamuna and Tons basin. However, higher order stream have more stream length in comparison to lower order in both basin because of the following two reasons (i) elongated shape of the basin and (ii) Yamuna and Tons rivers are flowing along with the periphery of the basin. So, in study area, only right and left dendritic branches of Yamuna and Tons rivers distributed respectively.

Stream Length Ratio (L_{ur}) and Mean Stream Length (L_{urm})

The stream length ratio is the ratio of mean length of a given stream order to mean length of next lower stream order which is calculated for each pair of orders for both basins. Stream length ratio for 4th - 5th order of Yamuna and Tons basin are higher than 1st - 2nd order of the same basin. This variation in the length ratio is attributed to variation in slope of topography (Vittala et al., 2004). It also indicates youth and mature stage of geomorphic development of 1st - 2nd order and 4th - 5th order stream respectively.

Table 2. Result of Drainage Network Analysis at Watershed (WS) and Basin Level of Study Area

WS	Su	Nu	Lu	Lum	Lur	Rb
WS 1	1	14	13.663	0.976		
	2	8	18.207	2.276	1.333	1.75
	3	1	2.436	2.436	0.134	8
	4	1	19.001	19.001	7.801	1
	Total	24	53.307	24.688	9.267	10.75
	Average			6.172	3.089	3.583
WS 2	1	66	79.448	1.204		
	2	19	40.899	2.153	0.515	3.474
	3	5	16.133	3.227	0.394	3.8
	4	3	15.455	5.152	0.958	1.667
	5	1	5.243	5.243	0.339	3
	6	1	4.243	4.243	0.809	1
	Total	94	64.777	21.221	3.016	12.94
	Average			3.537	0.603	2.588
WS 3	1	11	15.815	1.438		
	2	4	10.136	2.534	0.641	2.75
	3	3	3.759	1.253	0.371	1.333
	4	1	4.5	4.5	1.197	3
	Total	19	34.209	9.724	2.209	7.083
	Average			4.862	1.104	2.361
WS 4	1	48	50.164	1.045		
	2	11	26.093	2.372	0.52	4.364
	3	6	27.725	4.621	1.063	1.833
	4	2	3.482	1.741	0.126	3
	5	1	6.788	6.788	1.949	2
	6	1	3.764	3.764	0.554	1
	Total	69	118.015	20.33	4.212	12.197
	Average			3.388	0.842	2.439
Yamuna Basin	1	139	159.09	1.145		
	2	42	95.334	2.27	0.599	3.31
	3	14	49.374	3.292	0.518	2.8
	4	5	19.615	3.923	0.397	3
	5	2	12.031	6.015	0.613	2.5
	6	1	31.505	31.505	2.619	2
	Total	204	366.949	48.149	4.746	13.61
	Average			3.329	0.949	2.722

WS	Su	Nu	Lu	Lum	Lur	Rb
WS 5	1	44	55.542	1.262		
	2	16	22.492	1.406	0.405	2.75
	3	4	16.71	4.177	0.743	4
	4	1	3.219	3.219	0.193	4
	5	1	6.835	6.835	2.123	1
	Total	66	104.798	16.9	3.464	11.75
	Average			3.38	0.866	2.938
WS 6	1	22	31.021	1.41		
	2	6	13.937	2.323	0.449	3.667
	3	1	19.819	19.819	1.422	6
	Total	29	64.777	23.552	1.871	9.667
	Average			7.851	0.936	4.833
WS 7	1	69	84.286	1.222		
	2	22	42.279	1.922	0.502	3.136
	3	6	20.852	3.475	0.493	3.667
	4	5	15.825	3.165	0.759	1.2
	5	1	2.969	2.969	0.188	5
	Total	103	166.211	12.752	1.941	13.003
	Average			2.55	0.485	3.251
WS 8	1	11	6.686	0.608		
	2	2	5.014	2.507	0.75	5.5
	3	1	1.492	1.492	0.297	2
	Total	14	13.192	4.607	1.047	7.5
	Average			1.536	0.524	3.75
Tons Basin	1	147	177.365	1.207		
	2	46	83.722	1.82	0.472	3.196
	3	10	39.053	3.905	0.466	4.6
	4	7	19.045	2.721	0.488	1.429
	5	1	29.622	29.622	1.555	7
	Total	210	348.807	39.275	2.982	16.224
	Average			7.855	0.745	4.056

Abbreviations: S_u; Stream Order, N_u; No. of Stream, L_u; Stream Length in km, L_{um}; Mean Stream Length in km, L_{ur} Stream Length Ratio, R_b; Bifurcation Ratio

Basin Geometry

The geological structure, lithology, relief and precipitation pattern of study area controls shape of the basin which varies from narrower elongated form to circular form (Biswas et al., 2014). Three parameters viz. form factor ratio, elongation ratio and circulatory ratio are used for the quantitative expression of shape of the basin:

Form Factor Ratio (F_f)

Form factor ratio is the numerical index used for representation of shape of a basin through ratio of basin area to the square of the basin length (Horton, 1932). It ranges from 0.1 to 0.8 which indicates elongated to circular shape of a basin. Circular shape of basin characterised with high peak flow in short duration can be inferred from high value of form factor ratio of WS 3 and WS 6, whereas WS 1 and WS 4 have low value of form factor which indicate elongated shape of basin with low surface runoff in long duration. Tons basin have high form factor ratio (0.655) compared to Yamuna basin (0.421). High value of F_f is due to hard and consolidated rocky structure coincides along with the upper part of Tilghana, Patpari, Biharia, Gahera tributaries of Tons basin.

Elongation Ratio (R_e)

Elongation ratio is the ratio between diameter of the circle having the same area as the basin and maximum length of the basin (Schumn, 1956). It ranges from 0 to 1 representing three different shape of basin; circular (> 0.9), oval (0.9 – 0.8), less elongated (0.8 – 0.7) and elongated (< 0.7). In study area, WS 3, WS 5 and WS 8 are having circular shape whereas others have elongated shape. Yamuna basin is characterised with more elongated shape whereas Tons basin have more circular shape (Table 3).

Table 3. Basin Geometry, Areal Parameters and Relief Parameters of the Study Area

	WS	WS 1	WS 2	WS 3	WS 4	WS 5	WS 6	WS 7	WS 8	Yamuna Basin	Tons Basin
Basin Geometry	B_l	16.246	20.906	6.193	20.159	12.962	7.335	20.724	5.1	30.075	23.204
	A	48.733	170.987	38.649	122.61	118.073	58.53	158.117	17.79	380.979	352.51
	P	58.242	83.049	36.5	86.217	61.795	50.728	103.273	21.0233	114.228	166.495
	F_f	0.185	0.391	1.007	0.302	0.703	1.088	0.368	0.684	0.421	0.655
	R_e	0.485	0.706	1.132	0.619	0.946	1.177	0.684	0.933	0.785	0.909
	R_c	0.181	0.312	0.365	0.207	0.389	0.286	0.186	0.506	0.367	0.159
Areal Parameters	F_s	0.492	0.549	0.492	0.563	0.559	0.495	0.651	0.788	0.535	0.599
	D_d	1.094	0.944	0.885	0.963	0.887	1.107	1.051	0.742	0.963	0.989
	D_t	0.412	1.132	0.521	0.8	1.068	0.572	0.997	0.666	1.786	1.267
	C	0.914	1.059	1.129	1.039	1.127	0.904	0.951	1.349	1.042	1.011
	Lg	0.457	0.529	0.565	0.519	0.563	0.452	0.476	0.674	0.519	0.505
	If	0.539	0.519	0.435	0.542	0.496	0.548	0.685	0.584	0.516	0.592
Relief Parameters	z	128	178	100	134	154	120	179	179	162	179
	Z	75	74	80	73	77	90	95	135	73	77
	H	53	104	20	61	77	30	84	44	89	102
	R_h	3.262	4.974	3.229	3.026	5.94	4.09	4.053	8.627	2.959	4.396
	R_n	0.024	0.061	0.011	0.036	0.048	0.013	0.052	0.066	0.049	0.063
	D_{is}	0.414	0.584	0.2	0.455	0.5	0.25	0.469	0.246	0.549	0.569

Abbreviations: B_l ; Basin Length (km), **A**; Area (km^2), **P**; Perimeter (km), F_f ; Form Factor Ratio, R_e ; Elongation Ratio, R_c ; Circularity Ratio, F_s ; Stream Frequency, D_d; Drainage Density, D_t; Drainage Texture, **C**; Constant of Channel Maintenance, L_g ; Length of Overland Flow, I_f ; Infiltration Number, **z**; Height of Basin Mouth, **Z**; Maximum Height of the Basin, **H**; Total Basin Relief, R_h; Relief Ratio, R_n ; Ruggedness Number

Circulatory Ratio (R_c)

Shape of watershed is validated through circulatory ratio, which is the ratio of area of the basin to the area of the circle having same circumference as the basin perimeter (Miller, 1953). Its ranges between 0 to 1 representing elongated to circular shape of the basin. In study area, value of R_c for all WS is varies from 0.18 to 0.50 and the R_c value for Yamuna and Tons basin are0.367 and 0.159 respectively.

Drainage Texture Analysis

Drainage texture indicates the amount of dissection in the geomorphic structure and also gives idea about surface runoff and infiltration capacity of the region. It includes calculation of stream frequency, drainage density, texture ratio, constant of channel maintenance, length of overland flow and infiltration number.

Stream Frequency (F_s)

Stream frequency is the total number of stream segments of all orders in per unit area (Horton, 1932). Stream frequency has proportional relationship with increasing elevation. Stream frequency of entire watershed ranges from 0.49km^{-2} to 0.78 km^{-2}. Low stream frequency in study area is attributed to the development of WS in low elevation area and its large extension found in the alluvial and pediplain zone whereas WS 8 have higher stream frequency due to its alignment and development in the plateau region having elevation range 72-128 m.

Drainage Density (D_d)

Drainage density is a numerical index used to express closeness of spacing between streams and is a measure of the total length of stream segment of all orders in per unit area. It is affected by weathering resistance capacity of rocks, rocks permeability, climatic conditions, vegetative cover, relief etc. (Javed Akram et al., 2009). The D_d value for all the watershed ranges from 0.74 km^{-2} to 1.10 km^{-2}. It is higher for WS 6 and WS 7, which indicates that this region underlain by weak and impermeable rock, sparse vegetation and upland slope area, whereas D_d value is low for WS 2 and WS 3, which shows region having more permeable rock with low relief and vegetative cover compared to WS 8.

Drainage Texture (D_t)

Drainage texture is the total number of streams segments of all orders in a river basin to the perimeter of the basin (Horton, 1945). Smith (1950) classified D_t into five classes i.e., very coarse (< 2), coarse (2-4), moderate (4-6), fine (6-8) and very fine (>8). In study area, all the watersheds are categorised in very coarse texture. In general, alluvial basin has very coarse to coarse texture, whereas slope area has fine texture.

Constant of Channel Maintenance (C)

This parameter is inverse of drainage density having dimension of length as a property, which indicates the requirement of unit of channel length (Schumn, 1956). WS 2 has high value of C and low D_d compared to WS 7. Higher value of C indicates high permeability of the area if the WS belongs to alluvial deposit.

Length of Overland flow (L_g)

Length of overland flow is an independent variable used to show length of water over the ground before it gets concentrated into definite stream channels (Horton, 1945). Its value ranges from 0.452 to 0.674. It determines sheet erosion if its quantity exceed to certain threshold of erosion.

Infiltration Number (I_f)

Infiltration number is the product of drainage density and stream frequency. High value of I_f shows low infiltration and more surface runoff i.e. higher D_d. The WS 7 developed in the moderately dissected plateau and pediplain zone have high I_f compared to others.

Relief Parameters

Relief parameters include measurement of relief ratio, ruggedness number and dissection index. These relief parameters reveal the erosion potential of the fluvial processes operating within a drainage basin (Biswas et al., 2014).

Relief Ratio (R_h)

Relief ratio is the ratio between the total relief of a basin i.e. elevation differences of a lowest and highest points of a basin and the longest dimension of the basin parallel to the principal drainage line (Schumn, 1956).Thus, relief ratio measures steepness of drainage basin and indicates intensity of erosion operating on the slope of the basin. The relief ratio of the study area lies from 3.02 to 8.62 (Table 3). The WS 8 has more R_h compared to WS 4 because of following two reasons (i) WS 8 has less basin area compared to WS 4 and (ii) presence of hard quartzite and sandstone rocks in WS 8 facilitates more surface runoff in steeper basin, compared to flat topography and gentle slope surface of WS 4.

Ruggedness Number (R_n)

Ruggedness number is derived by multiplying basin relief (H) to drainage density (D_d) (Strahler, 1968). Its value will be higher if slopes of the basin have high steepness with more length. Value of R_n is low in the region which implies that the area is less or moderately prone to soil erosion (Pareta and Pareta, 2011). In the study area, R_n value ranges between 0.011 for WS 3 with low slope area to 0.066 for WS 8 with higher basin relief.

Dissection Index (D_{is})

Dissection index is a ratio calculated by dividing the basin relief (H) by absolute relief of the basin. D_{is} shows vertical dissection in the region and it reveals the stage of landscape development of the basin (Singh and Dubey, 1994). The D_{is} for study area ranges from 0.20 to 0.58 which shows moderate dissection. High value of D_{is} indicates high dissection in the region and vice versa. The WS 2, WS 5 and WS 7 have more dissection than WS 3, WS 6 and WS 8.

Conclusions

The significance of analysing the morphometric properties of study area lies in the fact that it will be helpful in watershed development, water resource management, hazard reduction, flood control etc. The extended area of Vindhyan ranges in the form of plateau surface is not a very hilly and slope nature except in the inselberg, mesa, butte, isolated hill tops etc. Thus, morphometric parameters have little differences in both Yamuna and Tons river basin in spite of having different origin and sedimentation. So, it can be concluded that plateau area of Tons and Yamuna basin is not severely affected by flash flood as having low topographic surface which facilitates good to moderate infiltration thus having good ground water potential. Morphometric analysis is significant for surface and ground water resource management when a large area (i.e. Bara Tehsil) requires water for irrigation (i.e. Jasra and Shankargarh) and settlement expansion (i.e Shankargarh).

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GEOSPATIAL TECHNOLOGY BASED LAND SUITABILITY CLASSIFICATION FOR SUGARCANE CULTIVATION IN KORAIYAR WATERSHED, COIMBATORE DISTRICT, TAMIL NADU

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Abstract

The Koraiyar watershed is in the mid-portion of the Coimbatore District. It is located between 10°36' - 10° 57' N and 76°48' - 77° 09' E with an area of about 660 km^2. It lies in the south western part of Coimbatore near Chetipalayam at an elevation of 420 metre above Mean Sea Level. The parameters considered for coconut crop are geomorphology, soil, slope, landuse, soil depth, texture, Exchangeable Sodium Percentage (ESP), Electrical Conductivity (EC), pH and rainfall. The parameters are calculated to provide the different suitability classes for sugarcane crop in each land unit. The sugarcane crop suitability map is classified into five categories, like highly suitable (S1), moderately suitable (S2), Marginally Suitable (S3), Currently Not Suitable (N1) and Permanently Not Suitable (N2). The highly suitable area class comes about 12,045 ha or 18.3 percent of the total area of the agricultural land. Moderately suitable land class covers 11,767 ha of area or 17.8%. Marginally suitable land is mainly found in the north and north western part of the Koraiyar watershed, It covers almost 22,413 ha (33.9 %).

Keywords: Land suitability, Landuse/Land cover, Geospatial technology.

Introduction

Sugarcane is an important commercial crop that farmers have taken to, quickly in the 1970s when modern inputs became available and there was an increase in the commercialisation of agriculture. The agricultural scenario changed with a number of agro-industries, most important sugar mills got stabilised in and around the study area. Udumalapeetai Amaravathi sugar mill and Coimbatore sugarcane research centre are located in the study area. Sugarcane is basically a tropical plant thriving well in hot and sunny areas. The ideal climate for sugarcane is long warm summer with adequate rainfall, a fairly dry sunny and cool frost free ripening and harvesting season, it is an irrigated and an annual crop, requiring good water for almost three seasons in any agricultural year. When farmers found surface water scarce, but at the same time possibilities for using groundwater looking bright both by the known groundwater potential and technology for extracting the groundwater (borewells and pump sets), they quickly and increasingly took to the cultivation of sugarcane.

Moderately heavy loams are better suited than heavy and light soils. The optimum pH value reported for good growth is between 6 and 8. Too acidic or too saline soils do not support normal sugarcane yield. The best rooting medium for sugarcane should at least have more than 100 cm soil depth, stable, well-structured loam to clay loam soils. Inadequate aeration decreases the intake of water and indirectly reduces root growth which leads to reduced sugarcane growth.

Hopkins (1977) reported a comparative evaluation of alternative methods of assessing land use suitability. There is significant amount of literature dealing with land suitability assessments. Collins et al., 2001 define Landuse suitability analysis is a multicriteria evaluation, which aims at identifying the most appropriate spatial pattern for future land uses according to specify requirements, preferences, or predictors of some activity. Dent and Young (1981) define land evaluation as the process of estimating the potential of land for alternative kind of use. These include productive uses, such as arable farming, livestock production and forestry. The fundamental purpose of land evaluation is to predict the consequences of change. In determining the potential for alternative uses, the primary purpose is defining land suitability. The concept of land suitability, for example a particular crop or cropping system, is complex, because suitability has to be assessed for sustained production in a rational cropping system (FAO, 1976).

Anderson (1987) surveyed different methods of land capability/suitability analysis ranging in degrees of computational and analytical sophistication. Land evaluation is a procedure that involves a lot of information which is distinguished by its geographic and multivariate character (FAO, 1996). Masilamani et.al (2015) identified crop suitability analysis for groundnut through Geoinformatics for sustainable agriculture in Koraiyar watershed, Coimbatore District, Tamil Nadu; the suitable areas for agricultural use are determined by an evaluation of the climate, soil, topographical, environmental components and the understanding of local biophysical restraints. There are many variables involved and each one should be weighted according to their relative importance on the optimal growth conditions for crops through weighted overlay process in GIS. The main aim of the study is to analyse the land suitability for sugarcane. It can be achieved based on the following objectives such as to study about the crop suitability analyse through identifying various parameters; to refine collected data and estimate the various parameters; and to classify the study area according to physical and climatic requirements of the crop in Koraiyar watershed.

Study Area

The Koraiyar watershed is in the mid-portion of the Coimbatore District. It is located between 10°36’ N - 10° 57 ’N and 76°48’ E - 77° 09’ E with an area of about 660 sq.km. It lies in the south western part of Coimbatore near Chetipalayam at an elevation of 420 metres above MSL. It covers four taluks and five blocks. The climate is hot and humid. The area receives rainfall mainly from southwest and northeast monsoon seasons. The watershed lies between the Noyyal river basin in the north and Palar river basin in the south, the Valayar reserved forest of the Western Ghats forms the northern limits and Parambikulam canal set the eastern limit. The minimum width of the watershed is 26 km, runs along the eastern margin and maximum of 37 km runs along the western margin, over the Tamil Nadu-Kerala state boundary.

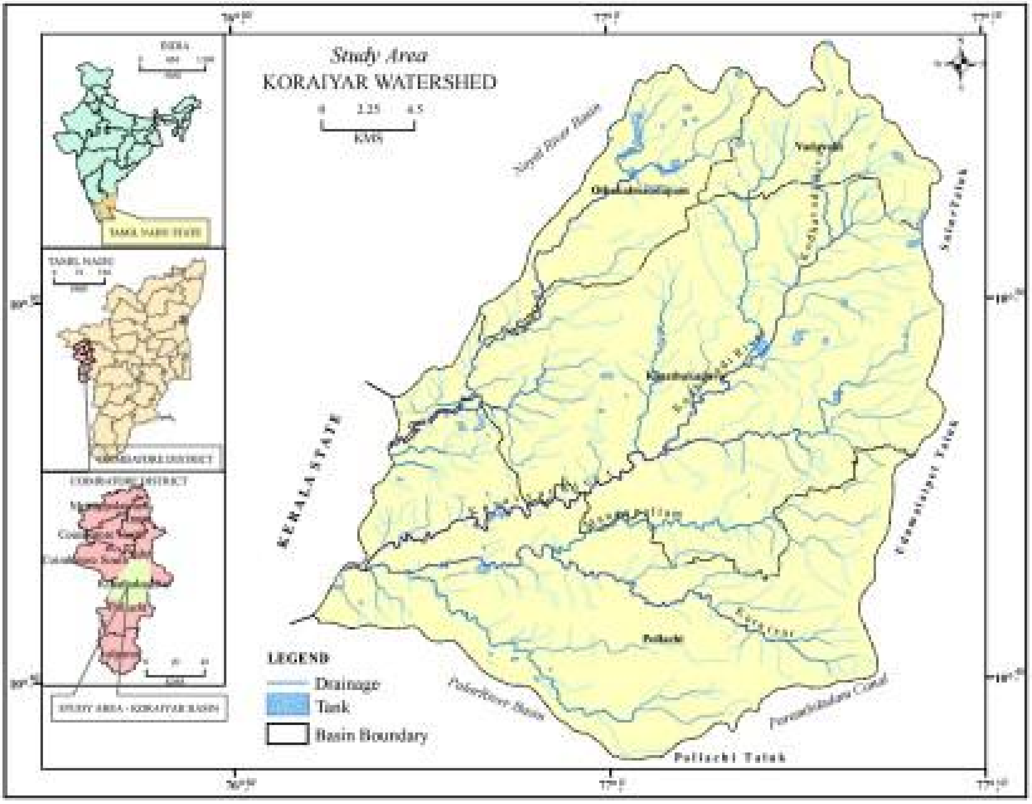

Fig. 1. Study Area - Koraiyar Watershed

Database and Methodology

The present analysis is based on the primary and secondary data. The study area map prepared based on Survey of India toposheet 58B/13,14 and F/1,F/2. Landuse map was prepared from LISS-IV satellite data. Rainfall data for 32 years (1980-2011) were collected from Indian Meteorological Department IMD Department Chennai. Geomorphology map collected from Institute of Remote Sensing, Anna University, Chennai. Various geomorphic zones are identified with the help of images using false colour composites.

Slope map was prepared based on ASTER data. The soils of the Koraiyar watershed have been classified into twenty two soil series, the thematic layers such as soil map, Soil texture, Soil pH, Soil EC, Land capability and Land Irrigability map prepared by the Soil Survey and Land use Organization. (Source Compiled by Author based on Department of Remote sensing and GIS, Tamil Nadu, Agricultural University, Coimbatore). Criteria and Weightage of Land Characteristics for Coconut Plantation have been prepared.

Results and Discussion

Rainfall

The mean annual rainfall of the watershed is about 1,187 mm, of which the winter rainfall in the month of January and February receive only 1.7 percent. The summer season from March to May contributes 13.9 percent. The summer rainfall is associated with the thunderstorms. Hence, summer has a slightly higher amount of rainfall than winter. However, in the watershed during the month of June, the southwest monsoon rainfall starts and continues till September. This monsoon brings 41.7 percent of the rainfall (4,952.5mm) which is comparatively very high when it is compared with other seasons due to its location on wind ward side. The northeast monsoon from October to December contributes 42.7 percent (5,071.4mm) (Figure 2).

Geomorphology

The various geomorphic zones are identified with the help of images using false colour composites. There are five geomorphic classes in the Koraiyar watershed. They are inselberg, pediment, shallow buried pediplain, moderately buried pediplain and deep buried pediplain (command area). The highly suitable sugarcane areas are observed in pediment and shallow buried pediplains regions. The moderately suitable areas for sugarcane cultivation are found in the buried pedeplain of the study area. The deep pediplain is marginally suitable for sugarcane cultivation.

Table 1. Geomorphology and their Areal Extent of Koraiyar Watershed

Sl.No	Landforms		Area	
	Features	Code	Square Kilometre	Percentage
1	Inselbergs	I	0.1	0.0
2	Pediment	Pt	7.4	1.1
3	Shallow Buried Pediplains	SBP	374.7	56.8
4	Moderately Buried Pediplain	MBP	136.5	20.7
5	Deep Pediplain	P	141.3	21.4
	Total Area		660	100

Source: Compiled by the Author based on the map produced by Institute of Remote Sensing, Anna University, Chennai.

Soil Texture

Soil texture represents the relative proportion of the various sizes of soil particles viz. sand (> 0.05 mm), silt loam (0.002 mm to 0.05 mm) and clay (< 0.002 mm). It determines the drainability, permeability and Water Holding Capacity (WHC) of the soils, which are the deciding factors for arriving any land suitability classification. In the Koraiyar watershed sandy clay loam has occupied 274.9 Sq.km (41.7 %), it is observed in north eastern part of the watershed like Avalappampatti, Kondakavundampalayam, Mullupadi, Devanampalauyam and Kakadavu. Clayloam shares 24.5 % (161.6 sq.km) of the study area. It is found along north eastern part of watershed like Vadachittur, Kondampatti, Bogampatti, Othakalmandapam and Malumachampatti. study area like Edaiyapalayam and Kallapalayam. It shares an area of about 46.7 sq.km i.e. 7.1 %.The most suitable soil textures are suited for crop cultivation are loamy sand and sandy clay .It occupies 54.67 sq.km (8.2%) of the total study area. It is shown in Figure 3.

Landuse and Land Cover

Built-up land includes Industrial areas, rural and town settlements. It occupies an area of 6.5 % (4,2581ha). The most dominant land use type is agricultural land. There are four urban centres in the study area viz. Pollachi, Kinathukadavu, Malumachampatti and Chettipalayam. Agricultural land use comprises farming and associated activities like fibre, commercial and horticultural crops.

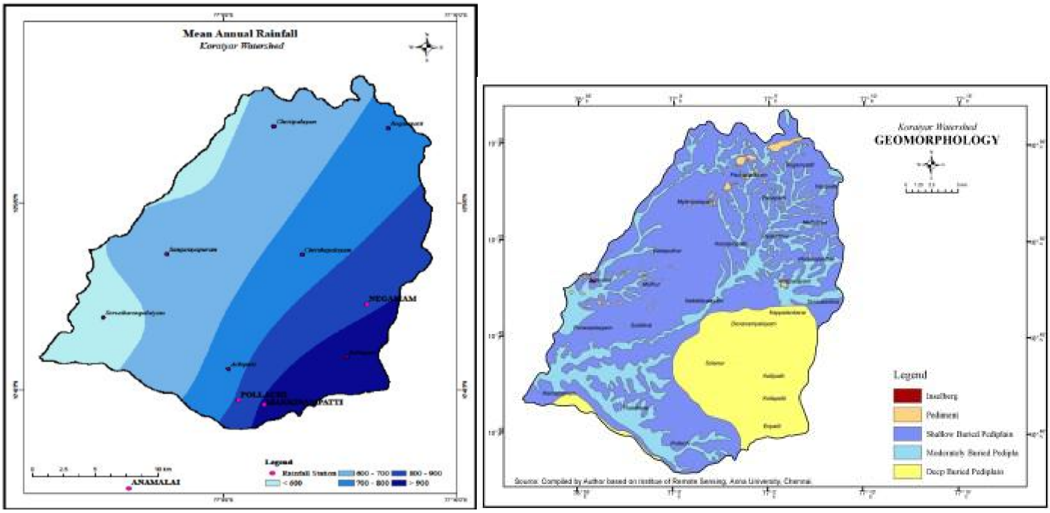

Fig. 2. Rainfall and Geomorphology

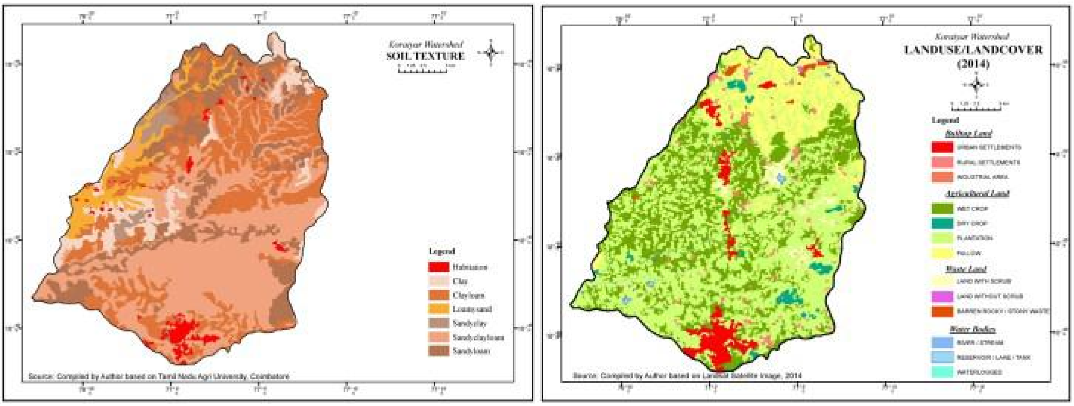

Fig. 3. Soil Texture and Landuse and Land Cover

It includes dry crop, wet crop, fallow land and the area under plantation crops. It concentrates 91 % (60,041.3 ha). It covers almost all the areas of the entire watershed. Waste land includes barren land, land with scrub and others. It is distributed almost 2.1 % (1,380.4 ha). Barren rocky is observed on north, north east and north western part of the watershed. Water bodies comprises of reservoir/ tanks, rivers and water logged areas which occupies 0.5 % (317.3 ha). The spatial distribution of landuse and land cover shown in Figure 3.

Land Capability Classification (LCC)

Land capability classification is an interpretative grouping of soil mapping units mainly based on inherent soil characteristics, external land features and environmental factors that limit the use of land for agriculture, pasture, or other uses on a sustained basis (IARI, 1971). According to soil characteristics in the present study area, Koraiyar watershed is grouped into seven capability classes. They are IIs, IIIs, IVes, IVs, IVws and Vs (Fig 4). About 24.1% (159.8 Sq.km) of the land in the study area is good cultivable land (Class II) with soil limitations, mostly associated with plains. Moderately good cultivable lands (Class III) have erosion, wetness and soil problems, which occupies 1,51.5 sq.km (22.9 %) of the total watershed area. The land under these two classes is suitable for agricultural practices (47 %) with less limitation.

pH

The optimum pH for irrigation water depends upon the type of crops to be grown and on the physical and chemical properties of the soil. The pH has no direct effect on human health. Generally, pH of water is influenced by geology of catchment area and buffering capacity of water. In the study area, pH value is ranging from < 5.2 to above 8.4 in the pre monsoon period. They are perceived in Thalakkarai, Avalappampatti, Papampatti and Chandhrapuram. Below 5.2 is distributed in part of Suleswarampatti, Makkinampatti and Solapalayam. In the post monsoon period, above 8.4 perceived in Papampatti, Kallapalayam and part of Chettipalayam. The pH value of groundwater required for sugarcane cultivation is 6-8 which comes under highly suitable and 7.5 to 8.5 are moderately suitable categories. The marginally suitable class falls under 4.4 to 4.0 and 5 to greater than 8.5 under marginally suitable.

Land Suitablity for Sugarcane

Moderately heavy loams are better suited than heavy and light soils. The optimum pH reported for good growth is between 6 to 8 .Too acidic or too saline soils do not support normal sugarcane yield. The best rooting medium for sugarcane should at least have more than 100 cm soil depth, stable, well-structured loam to clay loam soils. Inadequate aeration decreases the intake of water and indirectly reduces root growth which leads to reduced sugarcane growth.

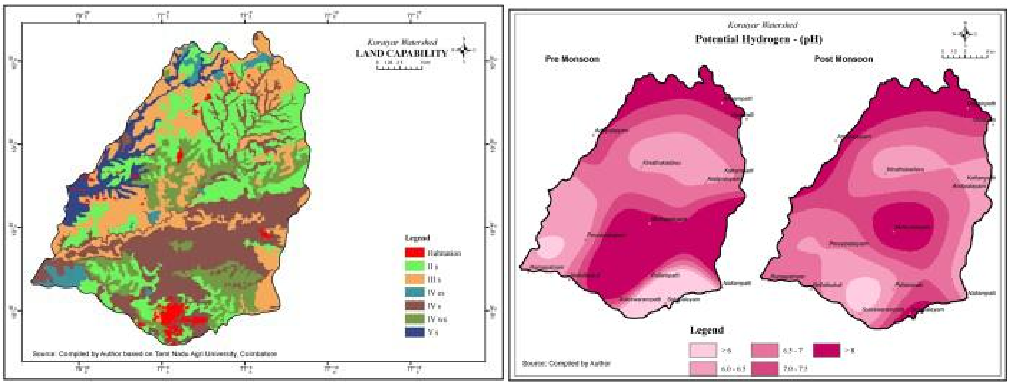

Fig. 4. Land Capability and Potential Hydrogen (pH)

Highly Suitable Land for Sugarcane (S1): The soil requirements for sugarcane cultivation are clayey loam and sandyclayloam with moderately well-drained soils. Irrigation must be provided once in every 10 or 12 days where the sandy loam soils is observed and once in every 8 days for dry and porous areas. In deep clayey loamy soil, irrigation interval is 2 to 3 weeks. The soils distributed over the shallow buried pediplain and buried pediplain, like Ettinayampatti, Annur, Attipalayam, and Irugur, have the depth exceeds with pH ranges of 6-8 are the favourable determiners of S1 class in the study area. All these conditions are fulfilled in Bogampatti, Kattampatti, Devarayapuram, Kappalankarai, Thoppampatti, Sulakkal and Suleswarampatti. S1 class land under sugarcane is 12,045 ha or 18.3 %.

Moderately Suitable Land for Sugarcane (S2): A total of 11,767 ha (17.8 %) of land falls under moderately suitable. These are mainly found in southeastern part of the study area notably Sirukalandhai, Kappalankarai, Servakarampalayam, Andipalayam, Periyakalandhai, Solanur, Kullakapalayam and Kurumbapalayam. However, though these areas have the positive features like pediplain, pediment and buried pediment nature, good groundwater potential, pH of the soil is 7.5 - 8.5, the area come down from S1 to S2 class due to soil limitation like less depth (75 - 100 cm) sand and clay textured soils of Anamalai, Attipalayam, Ettinayakampatti, Kottayam and Sengalam.

Marginally Suitable Land for Sugarcane (S3): These are spreading in several ecosystems like moderately buried pediplain, pediplain and part of command area. However, the less soil depth is 50 to 75 cm, the pH value of less than 5 to greater than 8.5 are setting the area under marginally suitable. It is mainly found in the centre and northeastern part of the Koraiyar watershed, which covers the villages Sirukandhai, Eripati, Makkinampatti, Achipatti, Ramapatnam and Mannur. Further, Kottayam, Mettupalayam and Ettinayakampatti soils are associated with river course and there by poor drainability which brought these areas under marginally suitable (S3) class for sugarcane cultivation. About 33.9 % (22,413 ha) of land belongs to this category (Figure 5).

Table 2. Criteria and Weightage of Land Characteristics for Sugarcane Plantation in Koraiyar Watershed

Parameters	Suitable Class	Weight	Sugarcane	Parameters	Suitable Class	Weight	Sugarcane
Geomorphology	S1	4	Pp,sbp	Soil Texture	S1	4	C, cl, sc
	S2	3	Mbp		S2	3	Sandy clay soil
	S3	2	pd		S3	2	Sandy
	N	1	Mbp, sbp, lb		N	1	
Slop	S1	4	0-5	Soil Depth	S1	4	>75
	S2	3	5-10		S2	3	51-75
	S3	2	10-30		S3	2	25-50
	N	1	>30		N	1	<25
Rainfall	S1	4	1,500-2,500	Soil pH	S1	4	5.5-7.5
	S2	3	1,000-1,500		S2	3	7.6-8.5; 5.0-5.4
	S3	2	500-1,000		S3	2	8.6-9.5; 4.0-4.4
	N	1	<500		N	1	<4.0
Landuse	S1	4	wc	Soil EC	S1	4	<1
	S2	3	Dc		S2	3	1.0-2.0
	S3	2	Pt, Fl		S3	2	2.0- 4
	N	1	La, T, Lws, Br, S		N	1	>4
LCC	S1	4	lis	Land Irrigability	S1	4	e0
	S2	3	IIIE,IIIS,IIIW		S2	3	e1
	S3	2	Lvs, Ivws		S3	2	e2
	N	1	Lves, Ves, Vs, Vies		N	1	e3

Note : Abbreviations

Geomorphology	Landuse	Texture	Soil Erosion
Pp - Pediplain Sbp - Shallow buried pediment Mbp - Moderately buried pediment Pd - Pediment	Wc - Wet crop Dc - Dry crop Pt - Plantation Fl - Fallow land Ia - Industrial area T - Tank Lws - Land with scrub Br - Barren rock S - Settlement	C - Clay Cl - Clayloam Ls - Loamysand S - Sand Sc - Sandyclay Scl - Sandyclayloam Sl - Sandyloam	e0 - No Erosion e1 - Slight Erosion e2 - Moderately Erosion e3 - Severe Erosion

Source: Compiled by the Author

Table 3. Land Suitability for Sugarcane Cultivation

Land Suitability Classes			
Suitability Class	**Area in sq.km**	**Areas of Occurrences**	**Constraints and Remarks**
S1	12,045 Or 18.3	Bogampatti, Kattampatti, Devarayapuram, Kappalankarai, Thoppampatti, Sulakkal and Suleswarampatti	Clayey loam and sandy clay loam with moderately well- drained soils. In deep clayey loamy soil, irrigation interval is 2 to 3 weeks. The soils distributed over the shallow buried pediplain and buried pediplain, like Ettinayampatti, Annur, Attipalayam and Irugur, have the depth exceeds with pH ranges of 6 - 8, slope < 3 %.
S2	11,767 Or 17.8	Sirukalandhai, Kappalankarai, Servakarampalayam, Andipalayam, Periyakalandhai, Solanur, Kullakapalayam and Kurumbapalayam.	Pediment and buried pediment nature, good ground water potential, pH of the soil is 7.5- 8.5, less depth (75-100 cm) sand and clay texture, slope 3-5 %.
S3	22,413 Or 33.9	Sirukandhai, Eripati, Makkinampatti, Achipatti, Ramapatnam and Mannur.	Moderately buried pediplain, pediplain, less soil depth 50 - to 75 cm, the pH value of less than 5to greater than 8.5, slope 5-8 %.
N1	18,256 Or 27.7		Temperature < 20 and > 400 °C temperature, very poorly drained, loamy sandy and sandy texture. pH > 9.5 and below 4, slope > 8%. Soil depth below. 50 cm.
N2	1,519 Or 2.3		Rural and urban settlement, industrial site, tank, waterbodies.

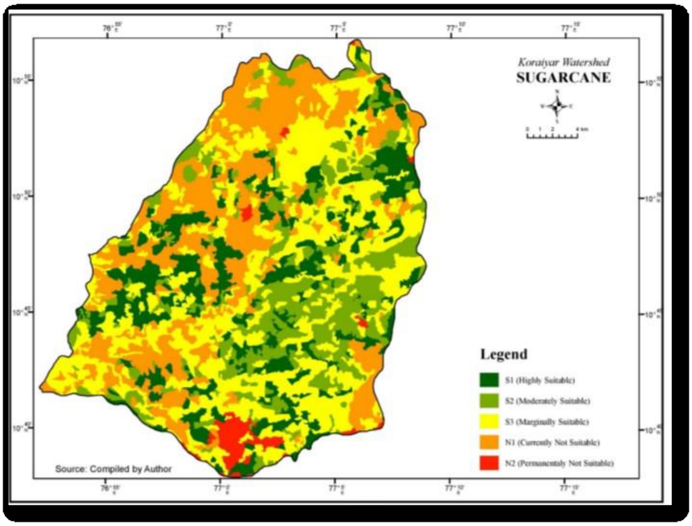

Fig. 5. Suitablity for Sugarcane Cultivation

Conclusions

From the above analysis, degree of suitability for sugarcane plantation and the land potential is understood. By overlaying the thematic layers like geomorphology, soil, slope, landuse, soil texture, rainfall, and land capability the land suitability for sugarcane cultivation is obtained. Highly suitable area under this class is about 12,045 ha or 18.3 %. Moderately suitable and marginally suitable altogether holds 11,767 (ha), 17.8 % of study area. However, it should be noted that is greater while comparing not suitable and permanently not suitable. Hence, it could be concluded that the Koraiyar watershed is agriculturally developed by sugarcane plantation. This kind of plantation is economically valuable all-over India. As the study area is located in the windward side of the Palghat gap the area receives rainfall from both monsoon seasons like south west and northeast monsoon which benefits the watershed for sugarcane cultivation.

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SPATIAL VARIATION OF BODY MASS INDEX (BMI) AMONG SCHOOL CHILDREN (7-14 YEARS) IN GUJAR COMMUNITY OF GREATER KASHMIR HIMALAYAS

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Abstract

As physical dimensions of body are influenced by nutrition particularly during the rapidly growing period of early childhood and thus provide information regarding malnutrition. Weight for age, height for age and body mass index are the best parameters. The present study was carried out on spatial variation of Body Mass Index (BMI) among school children (7-14 years) in Gujar community of Greater Kashmir Himalayas. The weight and height of sample children was measured and BMI was calculated from weight and height for all sample children for all altitudinal zones of Kashmir Himalayas. The WHO Classification of 2007 was employed for classifying children in grades of malnutrition on the basis of BMI. Study reveals that average weight, average height and average BMI were less than ICMR standards with good contrast among male and female children with a declining trend with altitude. The main findings depict mean height, weight, and BMI were 123.3 cm, 22.105kg, and 15.96 kg/m^2 for male and 119.6 cm, 21.270 kg, and 14.53 kg/m^2 for female respectively. Nearly about 16.40 % male and 16.96 % female were having BMI <18.5 kg/m^2 while as 10.63 % of male and 11.55 % of female were having severe to moderate malnutrition. The study shall be of great help for future health planning in this mountainous region.

Keywords: Malnutrition, Under nutrition, ICMR Standards, Gujar community, Great Kashmir Himalayas.

Introduction

The Body Mass Index (BMI), calculated as weight in kilograms divided by the square of height in metres (kg/m^2). It is a standard measure of weight-for-height that is commonly used to classify malnutrition of people and correlate with future health risks of morbidity and death. Globally, one-fifth of the world's population accounting about 1.2 billion adolescents are under the grip of under nutrition with the number ever increasing mostly in developing countries, on the other hand USA, a developed country revealed that if obesity continues to increase at current rate nearly 90 % of adults and two thirds of children by 2050 will be overweight or obese (21). India with inter-state variation in the levels of malnutrition shows a dismal picture among adults with 15.8 percent men and 12.6 percent women suffering from underweight while 4.5 percent men and 9 percent women as as overweight (22) as compared to children that accounts 43 percent as underweight (20). The state of Jammu and Kashmir where the present study was carried out also revealed dual burden of malnutrition in adults as well as children with 25 percent of women and 28 percent of men are too thin; and 17 percent of women and 6 percent of men are overweight or obese as compared to children, where 35 percent are stunted, 15 percent are wasted and 26 percent are underweight (12). The BMI of an individual is often the result of many inter-related factors which can be classified as immediate, underlying and basic, (18) complex, ranging from biological and social to environmental factors, political instability and slow economic growth, to highly specific ones such as the frequency of infectious diseases and the lack of education. Moreover, suitable aspects of natural environment, or example, mineral traces in water, the geological nature of bed rock material and specific biologic complexes also affect human health and may lead to long term chronic ailments (2).

Impact of nutrition on health of children is not a recent approach in medical geography but has attracted the attention of experts for the last more than half a century and plenty of literature is available at national, international level but very less is available at regional level. Stamp (1960) worked on the consumption of calories in terms of energy of 2460 K.Cal. for Western Europe (17) and Shafi did same in Uttar Pradesh by introducing the concept of Standard Nutrition Unit (SNU) equal to 1,000,000 K.Cal (15). National Institute of Nutrition formerly named as Nutrition Research Lab did nation-wide nutritional survey based on food consumption and the results were published in the form of Nutrition and Diet Atlas of India (4). Zargar found 46.39 percent of the Population in Pulwama and 52.32 percent in Anantnag affected by goiter (23) while Khuroo have identified hepatitis D as an etiologic cause of an outbreak of 'hepatitis' within a mean age of 28.2 ±10.5 years (range 10–56 years) thus became leading cause of malnutrition (8). Rather identified twenty nine percent children suffering from various deficiencies because of low birth weight as compared to ICMR (13).

Khanday related the malnutrition with conflict situation (7). Mayer identified diverse agricultural activities responsible for highest prevalence of anemia in Kashmir valley (11). Dewan attributed it to poor socio-economic status as the root causes of malnutrition with 25.2 % women as compared to male's 20.2 % in Punjab (3) while Villar analysed the relationship between income and Body mass Index found the negative relationship between household income and women (19) and Shukla revealed the encouraging association between literacy and malnutrition (16). Akhtar and Koundal in J&K (1,9) while Krishnan in Tamil Nadu found out the regional disparity in health care patterns and planning process of the state mainly responsible for malnutrition in J&K (10) and Khan et al. (2012), found feeding practices sub-standard before the recommended standards leading to parallel increase in the malnutrition with 14.1 %, 17.2 % and 16.8 % of the children in Jammu, Kashmir and Ladakh attributed (6). Gull (2014) assessing the women health aspects of Gujar and Bakerwal Community of J&K found the health of Gujar and Bakerwal women's very deteriorating the reasons being high family pressure as all the work is being done by women folk besides rearing of animals, illiteracy, lack of awareness about the schemes and facilities are meagrely provided by the government agencies and lack of health services (5). The present research paper was an attempt to analyse Body Mass Index of school children in the age group of 7-14 years and variation of same with altitude. The study reveals the health status of sample children and shall be of great help for future health planning in this mountainous region.

Study Area

Great Kashmir Himalayan range is one of the most important physiographic divisions of Jammu and Kashmir State and extends uninterruptedly for a length of 150 km from Sundran drainage basin of Anantnag in the south to Kazinag ridge of Baramulla in the north (Figure 1). Great Kashmir Himalayan range is a massive topographical feature enclosing Kashmir Valley on the east-northeast and north-northwest. The range lies between 33^0 22' 32″ N - 34^0 47 '42″ N latitude and 73^0 48 '10″ E - 75^0 34' 22″ E longitude. The mountainous range has an average altitude of 3,442 metres and stretches over an area of 8,948.84 sq.km.

Of the various mountain ranges girdling the valley of Kashmir, Great Himalayan range is by far the most important range because of the altitude of its peaks, Kolahi (5,425 metres), Sheshnag (5,096 metres), Saribal (4,882 metres), Harmukh (4,876 metres), Shutiyan (4,371 metres) Rang top (3,487 metres). The base contour of the range is around 1,800 meters in the south and gradually decreases to around 1,600 towards north. Below the base contour of the mountain range, the Valley of Kashmir has homogeneity in level. The region has a slope from $10\text{-}30^0$ in the foothills and above 40^0 in the hilly areas. The present slope characteristics have evolved through a sequence of events including spectacular changes in base level through faulting, folding and the consequent rejuvenation of drainage channels with pronounced effects on land forms in general and slope in particular (14). The region is inhabited by Gujar community with very low socio-economic development.

Database and Methodology

The present research work was based on both primary and secondary data. Large data both primary and secondary was collected and generated from different sources. A comprehensive methodology used for the present study and described under the following headings.

Delineation of Study Area and Demarcation of Altitudinal Zones (Unit of Study)

Base map of the study area was delineated from 19 Survey of India toposheets and processed digitally in GIS environment. Great Kashmir Himalayan range was divided into the following seven altitudinal zones with the help of softwares like ERADAS Imagine 9.0 and ArcView GIS 3.2a (Table 1).

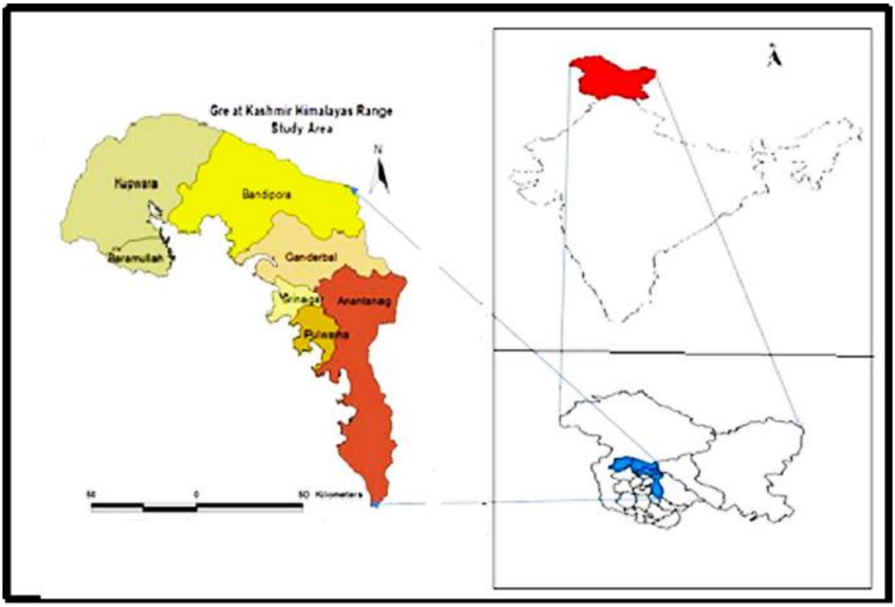

Fig. 1. Location of Great Kashmir Himalayan Range

Table 1. Altitudinal Zones by Area

Altitudinal Zone	Alt. in metres amsl	Area in sq.km	Area in % to Total Area
A	1,600-1,750	499.18	5.59
B	1,750-1,900	510.22	5.70
C	1,900-2,050	490.19	5.47
D	2,050-2,200	516.45	5.70
E	2,200-2,350	515.38	5.75
F	2,350-2,500	530.12	5.96
G	2,500-6,000	5,887.30	65.83
	Total	8,948.84	100

Source: Compiled by the Author

Table 2. Sample Frame of the Study

Alt. Zone	Alt.In mts. (AMSL)	Total Area (Km ^{2})	Revenue villages			Number of households			Number of children (7-14 years) for MICRO STUDY		
			Total In Area	Sample	Percentage of sample	Total in Sample villages	Sample	Percentage of sample	Male	Female	Total
A	1600-1750	499.18	9	2	22.22	460	92	20.00	45	46	91
B	1750- 1900	510.22	31	6	19.35	1000	200	20.00	103	103	206
C	1900- 2050	490.19	71	14	19.71	2380	476	20.00	242	241	483
D	2050- 2200	516.45	72	14	19.44	2290	458	20.00	228	228	456
E	2200- 2350	515.38	81	16	19.75	2790	558	20.00	275	275	550
F	2350- 2500	530.12	40	8	20.00	1480	296	20.00	153	154	307
	Total	**8948.84**	**304**	**60**	**19.73**	**10,400**	**2080**	**20.00**	**1046**	**1047**	**2093**

Source: Computed from SOI Toposheets and Census of India, 2011

Selection of Sample Villages, Sample Households and Sample Children (7-14 years):

Stratified random sampling technique was used for selection of around 20 % of sample villages (60) and 20 % of sample households (2,080) in proportion to total number of villages and households from each altitudinal zone. A sample of 2,093 children, one male and one female, falling in 7-14 years were selected for micro study (Table 2). The reason behind selection of this age group was because of most suitable for BMI study. Geo-coordinates and altitude of each sample village was measured with the help of GPS during field survey (Table 3).

Table 3. Sample Villages with Altitude and Geo-Coordinates

S. No	Village Name	Lat./Long	Altitude (mamsl)	S.No	Village Name	Lat./Long	Altitude (mamsl)
1	Grand	33^{0}40'43'N 75^{0}15'20' E	1830	31	DardporaGugerpati	34^0 25'43' N 74^0 42'16.' E	2250
2	Hard kichloo	33^{0}50'45' N 75^{0}16'40' E	2390	32	AragamNagbal	34^{0}22'31' N 74^0 40'58' E	2060
3	GujranBatkot	33^{0}56'34' N 75^{0}18'07' E	2186	33	ChithiBandechaliwan	34^{0}22'46' N 74^0 41'13.' E	2290
4	Ishnad	33^{0}52'08' N 75^{0}18'04' E	2268	34	ArgamHalwadi	34^{0}22'30' N 74^0 40'57.' E	2055
5	Hapatnar	33^{0}48' 17' N 75 ^{0} 21'15'E	2520	35	SumlarGujarpati	34^{0}22'30' N 74^0 43'41' E	1885
6	Salia	33^{0}55'28' N 75^{0}17'26' E	2210	36	Chuntimulagujarpati	34^{0}24'23' N 74^0 44'05.' E	1980
7	Gous	33^{0}52'09' N 75^{0}18'32' E	2190	37	ChatibandhiGorhajan	34^{0}23'40' N 74^0 42'25' E	1835
8	Shojan	33^{0}51'14' N 75^{0}18'25' E	1890	38	Malangamgujarpati	34^{0}26'12' N 74^0 33'26. E	1950
9	Grandwan	33^{0}52'43' N 75^{0}17'54' E	2020	39	Mulkalamagujarpati	34^{0}24'03' N 74^0 43'34' E	2375
10	Lidu	33^{0}57'31' N 75^{0}18'52' E	2049	40	GujarpatiMuqam	34^{0}26'58' N 74^0 34'36' E	2250
11	Rishkobal	33^{0}08'03' N 75^0 17'51' E	2350	41	Kudara	34^{0}25'03' N 74^0 47'01' E	2410
12	Nagbal	33^{0}52'32' N 75^{0}20'25' E	2260	42	DachnaGujarpati	34^{0}26'02 ' N 74^0 30'56' E	1680
13	Dragund	34^{0}25'51' N 75^{0}04'55' E	2120	43	Manobal	34^{0}30'15' N 74^0 30'15' E	2055
14	Narasthan	34^{0}13'27' N 75^{0}05'25' E	2250	44	Londa	34^{0}18'24' N 74^0 10'20' E	2010
15	Guturu	34^{0}30'27' N 75^{0}25'20' E	2160	45	Nilzab	34^{0}30'25' N 74^0 12'42' E	2290
16	Hajannar	34^0 04'31' N 75^{0}03'37' E	1893	46	Potwari	34^{0}19'45' N 74^0 12'20' E	2065
17	Nogh	33^{0}55'46' N 75^{0}11'10' E	2142	47	Khaitan	34^{0}30'50' N 74^0 30'35' E	1935
18	Bangidar	33^{0}54'40' N 75^{0}14'09' E	2354	48	Nowgam	34^{0}28'19' N 74^0 14'25' E	1980
19	Basmia	33^{0}55'44' N 75^{0}11'06' E	2262	49	Lahkoot	34^{0}21'45' N 74^0 20'52' E	1955
20	FaqirGujri	34^{0}24'16' N 74^{0}38'50' E	2089	50	Rashiwari	34^{0}40'55' N 74^0 48'45' E	2410
21	Shalkhud	34^{0}10'59' N 74^{0}54'58' E	2215	51	Shiltra	34^0 19'14' N 74^0 12'08' E	1835
22	Nagbalgujarpati	34^{0}15'22' N 74^{0}34'25' E	1967	52	Inderdaji	34^{0}20'12' N 74^0 08'54' E	1950
23	Khanan	34^{0}18'47' N 74^0 51'59' E	2030	53	Khuripayeen	34^{0}39'55' N 74^0 45'30' E	2250
24	Poshkar	34^{0}14'26' N 74^0 58'05' E	2080	54	KhuriBala	34^{0}42'15' N 74^0 45'40' E	2315
25	Pahalnar	34^{0}20'49' N 75^0 51'59' E	2142	55	Wadurbala	34^0 18'26' N 74^0 11'06' E	2058
26	Wangat	34^{0}19'33' N 75^0 06'50' E	2195	56	Turkkpora	34^{0}32'52' N 74^0 26'35' E	2386
27	Astanmohla	34^{0}15'29' N 74^0 54'44' E	2048	57	Wanpur	34^{0}28' 12' N 74^0 16'30' E	2036
28	Yarmukam	34^{0}17'44' N 74^0 47'11' E	2360	58	Wahalutar	34^{0}46' 22' N 74^0 14'32' E	2253
29	TsuntWali war	34^{0}47'14' N 74^0 54'28' E	2370	59	Potus	34^{0}4 5' 20' N 74^0 12'28' E	2 146
30	Waniarm	34^{0}17'44' N 74^0 48'30' E	2295	60	Naidhu	34^{0}2 5' 23' N 74^0 16'55' E	1684

Source: Based on GPS readings during Sample Survey, 2013

Anthropometric Measurements

Anthropometric measurement of 2,093 sample children, comprising of one male and one female from each household of sample villages were carried out to obtain data regarding weight and height. The BMI was calculated from weight and height for both male and female children of all altitudinal zones. As physical dimensions of body are influenced by nutrition particularly during the rapidly growing period of early adulthood thus body measurement can also provide information regarding malnutrition. So, height, weight and BMI were measured. The weight and height of all individual sample children was measured by using digital weight measuring machine and non-stretchable tape. The method was repeated more than once and the mean was of the reading was taken as final.

BMI of all the sampled children was calculated by employing the formula:

$$BMI = \frac{Weight\ in\ Kg.}{Height\ in\ m2}$$

The WHO classification of 2007 (Table 4) was used to classify the sample children into different grades of malnutrition based on BMI.

Table 4. WHO Classification of Malnutrition Grades based on BMI

Classification	Principal cut-off points	BMI (kg/m) Additional cut-off points
Underweight	<18.50	<18.50
Severe Thinness	<16.00	<16.00
Moderate Thinness	16.00 - 16.99	16.00 - 16.99
Mild Thinness	17.00 - 18.49	17.00 - 18.49
Normal Range	18.50 - 24.99	18.50 - 22.99
		23.00 - 24.99
Overweight	≥25.00	≥25.00
Pre-Obese	25.00 - 29.99	25.00 - 27.49
		27.50 - 29.99
Obese	≥30.00	≥30.00

Source: WHO, 2007

Results and Discussion

Weight for Age

Analysis of the Table 5 reveals that average weight in the age group 7 to 14 years was 22.105 kg for males and only 21.270 kg for females. It was very interesting to note that the average weight of both male and female children was very less than the ICMR recommended weight for children of different age groups. Weight of children varies from one sample village to another. There was a decline in the weight of both male and female children with the increase in the altitude (Figure 2).

Largest differences in the calculated weight than the ICMR recommended weight was noted and the reason could be large nutrition need for the fast growth on one side and very less attention of parent's towards child because of being engaged in primary activity of collection of fire wood from the forest and herding of animals, getting of water from large distances etc.

Height for Age

Analysis of the Table 5 reveals that average height in the age group 7 to 14 years was 123.3 cm for males and only 119.6 cm for females. It was very interesting to note that the average height of both male and female children was very less than the ICMR recommended height for children of different age groups. Height of children varies from one sample village to another. There was a decline in the height of both male and female children with the increase in the altitude (Figure 3).

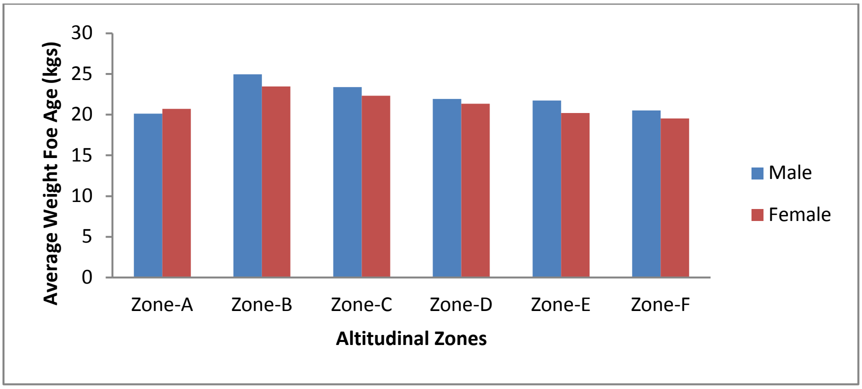

Fig. 2. Average Weight for Age Among Sample Children (7-14 years)

Source: Based on Sample Survey 2013-2014

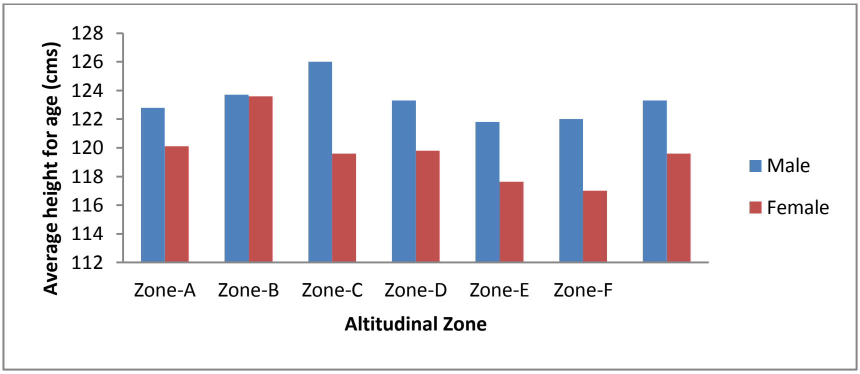

Fig. 3. Average Height for Age Among Sample Children (7-14 Years)

Source: Based on Sample Survey 2013-2014

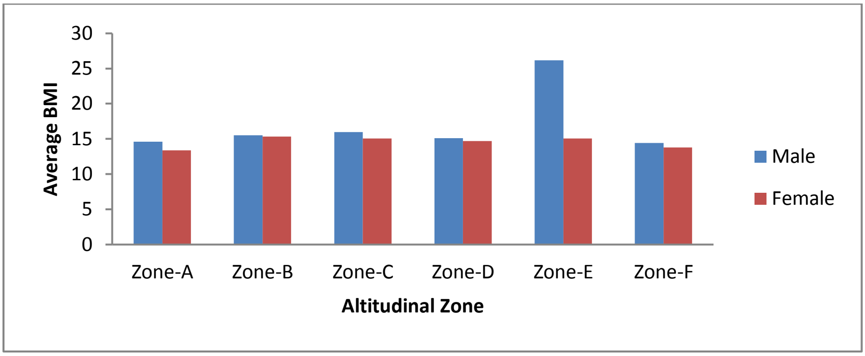

Fig. 4. Average BMI Among Sample Children (7-14 years)

Source: Based on Sample Survey 2013-2014

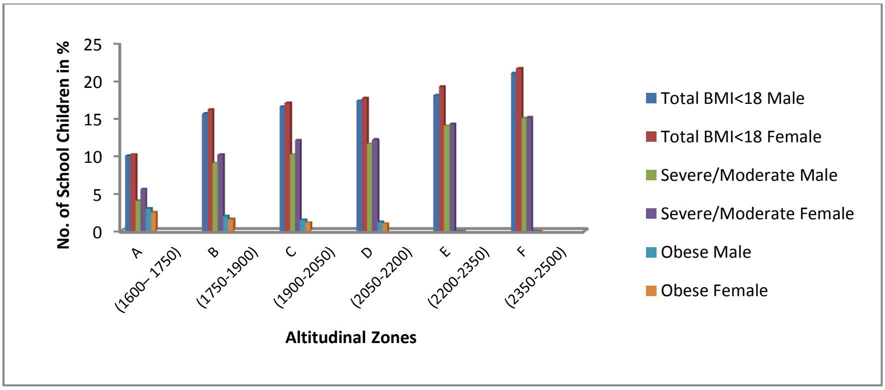

Fig. 5. Malnutrition Grades Based on BMI

Body Mass Index (BMI)

Analysis of the Table 5 reveals that average body mass index in the age group 7 to 14 years was 14.53 for males and only 16.96 for females. It was very interesting to note that the average body mass index of both male and female children was very less than the ICMR recommended weight for children of different age groups. Body mass index of children varies with altitude (Figure 4).

Grades of Malnutrition among Sample Children (7-14 years) Based on BMI

Analysis of the Table 6 reveals that very good variation of malnutrition grades with altitude. Percentage of male sample children with BMI >18 was 10 percent in altitudinal zone A and increased with altitude to 21 percent in altitude zone F. Severe / moderate grades of malnutrition among male children increased from 4 percent in altitudinal zone A to 15 percent in altitudinal zone F and grade of obese was only 3 percent in altitudinal zone A and no obese in altitudinal zone E and F. While as in case of female sample children percentage was lower than males in each grade of malnutrition with altitudinal zone (Figure 5).

Table 5. Average Weight for Age, Average Height for Age and Average Body Mass Index Among Sample Children (7-14 Years) by Sex in Kashmir Himalayas

Altitudinal Zone with Alt. in metres (amsl)	No. of Male Sample Children (Male & Female –same ratio)	Average Anthropometric values for Parameters Among Sample Children by Sex					
		Average Weight for Age (Kg)		Average Height (cms)		Average Body Mass Index	
		Male (ICMR Standard : 33.10 Kg)	Female (ICMR Standard: 34.00 Kg.)	Male (ICMR Standard: 140cms)	Female (ICMR Standard: 139cms.)	Male (ICMR Standard: 18.5)	Female (ICMR Standard: 18.5)
A (1600-1750)	91	20.130	20.730	122.8	120.1	14.58	13.35
B (1750-1900)	206	24.962	23.467	123.7	123.6	15.52	15.31
C (1900-2050)	483	23.380	22.340	126.0	119.6	15.97	15.04
D (2050-2200)	456	21.930	21.350	123.3	119.8	15.08	14.68
E (2200-2350)	550	21.720	20.190	121.8	117.6	16.15	15.04
F (2350-2500)	307	20.510	19.540	122.0	117.0	14.44	13.77
Total	2,093	22.105	21.270	123.3	119.6	15.96	14.53

Table 6. Variation in Malnutrition Grades (Percentage) Among School Children Using BMI

Zone	Total BMI <18		Severe / Moderate		Obese	
	Male	Female	Male	Female	Male	Female
A (1600– 1750)	10.00	10.20	4.00	5.63	3.00	2.51
B (1750-1900)	15.60	16.14	9.03	10.15	2.00	1.60
C (1900-2050)	16.52	17.00	10.18	12.10	1.50	1.15
D (2050-2200)	17.34	17.65	11.58	12.14	1.20	1.00
E (2200-2350)	18.06	19.18	14.00	14.20	0.01	0.00
F (2350-2500)	21.00	21.60	15.00	15.10	0.00	0.00
Average	**16.42**	**16.96**	**10.63**	**11.55**	**2.57**	**1.04**

Source: Based on Sample Survey, 2013-2014

Conclusions

The study leads to the conclusion that mean height, weight and BMI were 123.3 cm, 22.105 kg, and 15.96 kg/m^2 for male and 119.6 cm, 21.270 kg, and 14.53 kg/m^2 for female respectively and were less than ICMR standards. Near about 16.40 % male and 16.96 % female were having BMI <18.5 kg/m^2 while as 10.63 % of male and 11.55 % of female were having severe to moderate malnutrition analyses reveal decrease of BMI with increase in altitude. It may be attributed to traditional cropping practices and harsh agro climatic conditions, which prevail there, besides non-availability crop essentials in the vicinity. The sample population face extended period of illness because of poverty and non-ability of medicare and if present that too is of low standard thus affects the BMI. Some suggestions are recommended as below:

1. The present study shows a dismal picture of malnutrition by analysing the BMI. So, awareness programmes / counselling, regarding balanced diet, health, and physical activity are needed badly. These programmes should be encouraged through ICDS centres and government schools.
2. Implementation of various schemes of NRHM at gross root level as only AHSA component of JSA scheme is found visible in J&K. Availability / appointment of dietitian in every government and semi government institutions.

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The author is highly thankful to ICSSR for providing funding assistance to our project on Assessment of Malnutrition among Children - A Micro level study of Gujars of Great Kashmir Himalayan Range. The present research paper is a part of this project.

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ASSESSMENT OF SEASONAL RAINFALL PATTERN AND OCCURRENCES OF DROUGHT IN TAMIL NADU

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Abstract

Rainfall and drought are intertwined parameters that needs careful investigation. There are various study indicating the pattern to prediction the rainfall for monitoring drought, however the rainfall analysed on a regional scale to examine the past rainfall pattern to determine accurate drought scenario.The patterns of rainfall at different seasons have been examined for the 208 rain gauge stations collected from Tropical Rainfall Measuring Mission (TRMM) data. The present study studies the seasonal wise rainfall pattern of entire Tamil Nadu to analyse the occurrence of the drought. Rainfall data for the three deficit (drought) years (1987, 2004 and 2014) have been analysed on seasonal basis to assess the occurrences of drought. The analysis indicated that there is gradual decrease in northeast monsoon that prolongs the drought condition over Tamil Nadu for 27 years. The season wise rainfall pattern reveals that southwest monsoon, summer season and winter season shows an increase in rainfall pattern especially in 2004. The analysis revealed that 2004 was the wettest year and 1987 was the driest year in the drought years. The expected rainfall of northeast monsoon, southwest monsoon, summer season and winter season recurrence interval was 90.2 mm, 97.2 mm, 47 mm, and 26.1 mm respectively. Drought occurrences are observed from mild to extreme drought conditions. The deficit rainfall pattern during northeast monsoon helps in predicting the drought years and to provide feasible plan for agricultural to cope up for deficit periods.

Keywords: Rainfall pattern, Drought, Tropical rainfall measuring mission data, Deficit year.

Introduction

Hydrological parameters especially rainfall aids in analysing most of the hydrological based disasters namely, flood, landslide, drought and extreme temperatures. The climate of Tamil Nadu is generally tropical and features fairly hot temperatures over the year except during the monsoon seasons. Meteorological droughts were studied for predicting the expected rainfall at different probability levels for planning a suitable cropping pattern (Kumar, 2009; Singh et al., 2007). Under the Koppen climate classification the greater part of Tamil Nadu falls under tropical savanna climate and a smaller portions of the State falls under humid subtropical climate; the climate of the coastal districts ranges from dry sub-humid to semi-arid. Tamil Nadu is heavily dependent on monsoon rains, and thereby is prone to droughts when the monsoons fail.

The hot weather of summer sets in and lasts until the middle of June. The highest temperature is often registered in May, which is the hottest month in the state. The hot winds of the plains blow during April and May with an average velocity of 8-16 km/hour. These hot winds greatly affect human comfort during this season. The cold weather of winter commences early in November and comes to an end in the middle of March. The climate in the cold weather is pleasant. The days are bright and warm and the sun is not too hot. As soon as the sun sets, the temperature falls and the heat of the day yields place to a sharp bracing cold.

The normal annual rainfall of the state is about 945 mm of which 48 % is through the northeast monsoon and 32 % through the southwest monsoon. Since, the state is entirely dependent on rains for recharging its water resources, monsoon failures lead to acute water scarcity and severe drought. The State has three distinct periods of rainfall especially in monsoon: advance rainfall; the southwest monsoon from June to September, with strong southwest winds; and the northeast monsoon from October to December, with dominant northeast winds. The dry season is from January to May. The normal annual rainfall of the state is about 945 mm of which 48 % is through the northeast monsoon and 32 % through the Southwest monsoon. Since, Tamil Nadu is entirely dependent on rains for recharging its water resources, monsoon failures lead to acute water scarcity and severe drought. Tamil Nadu has rain during the monsoon season due to the southwest trade winds which blow towards the northern hemisphere. Tamil Nadu receives rainfall in the winter season due to northwest trade winds.

During the period, 1871-2015 there were 26 major drought years, defined as years with All-India Summer Monsoon Rainfall (AISMR) (June-September) less than one standard deviation below the mean: 1873, 1877, 1899, 1901, 1904, 1905, 1911, 1918, 1920, 1941, 1951, 1965, 1966, 1968, 1972, 1974, 1979, 1982, 1985, 1986, 1987, 2002, 2004, 2009, 2014, 2015. It is interesting to note that there have been alternating periods extending to 3-4 decades with less and more frequent weak monsoons over India. During the periods of 1965-1987, which had as many as 10 drought years out of 23, the monsoon was found to be strongly linked to the ENSO (Parthasarathy et al., 1991).

The State of Tamil Nadu is bounded by Karnataka and Andhra Pradesh on the north, the Bay of Bengal on the east, Kerala on the west and the Indian Ocean on the south. The State comprises of 32 Districts (Figure 1) in the present study area. Rivers flowing from the west to east in Tamil Nadu viz. Palar, Ponnaiyar, Vellar, Cauvey, Vaigai, Vaippar, Thamrabarani rivers drains themselves at coast into the Bay of Bengal. The roadway of the State is one of the highest economic generators and also have dense network, covering nearly one fifth of road networks along the coastal taluks. Rainfall is abundant in nature, owing much of its shower to the northeastern monsoon. Drought incidences; regardless its severity, have become more common in recent years in parallel to global climate changes. Droughts have adverse socio-economic, agricultural and environmental impacts that can be reduced by assessing and forecasting drought behaviour (Manikandan and Tamilmani, 2011).

Database and Methodology

The patterns of rainfall at different seasons have been examined for the 208 rain gauge stations (Figure 2) collected from Tropical Rainfall Measuring Mission (TRMM) data. The present study studies the seasonal wise rainfall pattern of entire Tamil Nadu to analyse the occurrences of the drought. Rainfall data for the three deficit (drought) years (1987, 2004 and 2014) have been analysed on seasonal basis to assess the occurrences of drought. Based on the following criteria given by Sharma et al. (1987) seasonal rainfall events were classified as drought, normal and wet. A season receiving rainfall less than or equal to average seasonal rainfall minus standard deviation is called a drought season (deficit year); a season receiving rainfall more than or equal to average seasonal rainfall plus standard deviation is called a wet season (surplus year); and a season receiving rainfall between the limits of seasonal rainfall corresponding to drought and wet seasons is called a normal season.

Intensity of Drought

The intensity of drought was determined using the criteria suggested by Indian Meteorological Department (1971) which is based on the percentage of deviation of rainfall from its long term mean. If the percentage deviation of rainfall from annual mean is zero or above zero, it is termed as no drought; if the percentage deviation is between 0 to -25, it is called as mild drought; if the deviation varies from -25 to -50, it is called as moderate drought; if the departure ranges between -50 and -75 per cent, it is called severe drought and if the departure exceeds -75 per cent of normal value, it is termed as extreme drought.

Results and Discussion

The analysis indicated that there is gradual decrease in northeast monsoon that prolongs the drought condition over Tamil Nadu for 27 years. The season wise rainfall pattern reveals that southwest monsoon, summer season and winter season shows an increase in rainfall pattern especially in 2004. The analysis revealed that 2004 was the wettest year and 1987 was the driest year in the drought years. The expected rainfall of northeast monsoon, southwest monsoon, summer season and winter season recurrence interval was 90.2 mm, 97.2 mm, 47 mm and 26.1 mm, respectively. Drought occurrences observed from mild to extreme drought conditions. The deficit rainfall pattern during northeast monsoon helps in predicting the drought years and to provide feasible plan for agriculture to cope up for deficit periods.

The rainfall distribution ranges in 5 classifications below 50 to above 900 cm. The highest rainfall in centimetres resides in fewer places than other ranges. The following decades shows anomaly in decreasing trend from 1987 to 2014. The State, as a whole, received 16.64 cm rainfall against the normal of 16 cm, a deviation of four percent, which is considered normal. Tamil Nadu's rainfall was close to deficit with a deviation of minus 18 or 19 percent. But, the monsoon picked up rapidly.

Table 1. Rain Gauge Stations of Tamil Nadu

Id	Rain Gauge Stations	Id	Rain Gauge Stations	Id	Rain Gauge Stations	Id	Rain Gauge Stations
1	Agasthiswaram	53	Kamudi	105	Palayankottai	157	Thiruvarur
2	Alanguam	54	Kanchipuram	106	Palladam	158	ThiruvidaiMarudur
3	Alangudi	55	Kangayam	107	Pallipattu	159	Tindivanam
4	Ambasamudram	56	Karaikkudi	108	Pandalur	160	Tiruchendur
5	Ambattur	57	Kariyapatti	109	Panruti	161	Tiruchengodu
6	Andipatti	58	Karur	110	Papanasam	162	Tiruchirappalli
7	Arakkonam	59	Katpadi	111	Papireddipatti	163	Tirukkalukkunram
8	Arani	60	Kattumannarkoil	112	Paramakkudi	164	Tirukovilur
9	Arantangi	61	Kilvelur	113	Paramathivelur	165	Tirumangalam
10	Aravakurichi	62	Kodaikkanal	114	Pattukkottai	166	Tirumayam
11	Arcot	63	Kotagiri	115	Pennagaram	167	Tirunelveli
12	Ariyalur	64	Kovilpatti	116	Peraiyur	168	Tirupathur
13	Aruppukkottai	65	Krishnagiri	117	Perambalur	169	Tiruppattur
14	Attur	66	Krishnarayapuram	118	PeramburPurasavakkam	170	Tiruppur
15	Avadiyarkovil	67	Kudavasal	119	Peravurani	171	Tiruttani
16	Avanashi	68	Kulattur	120	Periyakulam	172	Tirutturaipundi
17	Bhavani	69	Kulithalai	121	Perundurai	173	Tiruvadanai
18	Bodinayakkanur	70	Kumbakonam	122	Pochampalli	174	Tiruvaiyaru
19	Chengalpattu	71	Kunda	123	Pollachi	175	Tiruvallur
20	Chengam	72	Kunnam	124	Polur	176	Tiruvannamalai
21	Cheyyar	73	Lalgudi	125	Ponneri	177	Tittakudi
22	Cheyyur	74	Madattukulam	126	Poonamallee	178	Tottiyam
23	Chidambaram	75	Madurai North	127	Pudukkottai	179	Tovala
24	Coimbatore North	76	Madurai South	128	Radhapuram	180	Turaiyur
25	Coimbatore South	77	Madurantakam	129	Rajapalaiyam	181	Tuticorin
26	Coonoor	78	MambalamGuindy	130	Ramanathapuram	182	Udaiyarpalaiyam
27	Cuddalore	79	Manachanallur	131	Rameswaram	183	Udumalaippettai
28	Denkanikota	80	Manamadurai	132	Rasipuram	184	Ulundurpettai
29	Devakkottai	81	Manamelkudi	133	Salem	185	Usilampatti
30	Dharapuram	82	Manapparai	134	Sankarankovil	186	Uthukottai
31	Dharmapuri	83	Mannar Gudi	135	Sankarapuram	187	Uttamapalaiyam
32	Dindigul	84	Mayiladuturai	136	Sankari	188	Uttangarai
33	Edappadi	85	Melur	137	Sattankulam	189	Uttiramerur
34	EgmoreNungambakkam	86	Mettuppalaiyam	138	Sattur	190	Vadipatti
35	Erode	87	Mettur	139	Satyamangalam	191	Valangiman
36	Ettaiyapuram	88	Mudukulattur	140	Sendurai	192	Valappadi
37	Fort Tondiarpet	89	Musiri	141	Sengottai	193	Valparai
38	Gandarvakottai	90	MylaporeTiruvallikkeni	142	Sirivilliputtur	194	Vandavasi
39	Gangavalli	91	Nagapattinam	143	Sirkazhi	195	Vaniyambadi
40	Gingee	92	Namakkal	144	Sivaganga	196	Vanur
41	Gopichettipalaiyam	93	Nanguneri	145	Sivagiri	197	Vedaranyam
42	Gudalur	94	Nannilam	146	Sivakasi	198	Vedasandur
43	Gudiyattam	95	Nattam	147	Sriperumbudur	199	Vellore
44	Gummidipundi	96	Nidamangalam	148	Srirangam	200	Veppanthattai
45	Harur	97	Nilakottai	149	Srivaikuntam	201	Vilattikulam
46	Hosur	98	Oddanchattram	150	Tambaram	202	Vilavancode
47	Ilayankudi	99	Omalur	151	Tarangambadi	203	Villupuram
48	Iluppur	100	Ootacamund	152	Teni	204	Virakeralampudur
49	Kadaladi	101	Orattanad	153	Tenkasi	205	Virudhunagar
50	Kadavur	102	Ottapidaram	154	Thanjavur	206	Vriddhachalam
51	Kalkulam	103	Palakodu	155	Thiruchuli	207	Walajapet
52	Kallakurichchi	104	Palani	156	Thirukkuvalai	208	Yercaud

The season wise rainfall distribution of each year 1987, 2004 and 2014 of Tamil Nadu is plotted in line graph that helps us understand the scenario of rainfall pattern within same year. The season wise scenario for the period 1987 observation shows that the rainfall pattern higher in northeastern monsoon and gradually decreases from southwest monsoon, summer and winter. The pattern in 2004 observes a higher rainfall in the entire monsoon except winter season. The rainfall pattern in 2014 observes similar to the pattern of 1987; however there is a significant decrease in rainfall than rainfall observed in 1987.

Fig. 1. Location of Tamil Nadu

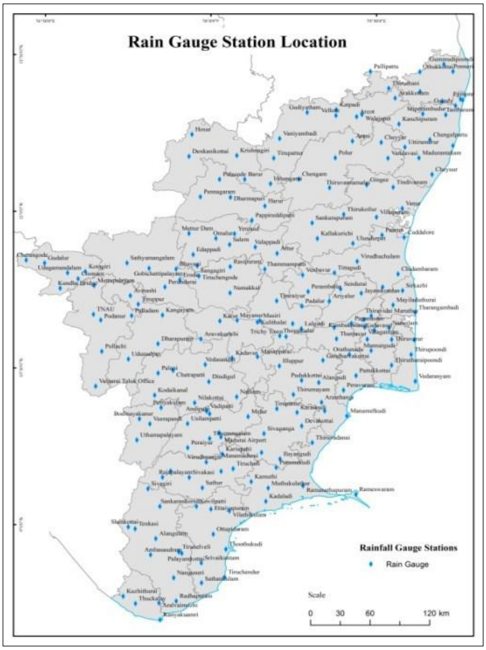


Fig. 2. Location of Rain Gauge Stations

The analysis of seasonal rainfall for assessing the dry, normal and wet periods and probability chances of expecting rainfall at different return periods in presented in 6 (a-d). The individual season wise pattern of rainfall in Tamil Nadu for the period of 1987, 2004 and 2014 is shown in each graph. The Figure 6a shows the 208 rainfall stations (Table 1), comparison between the years 1987, 2004 and 2014. The graph depicts the intense pattern of rainfall in southwest monsoon where the rainfall is highest in the year 2004 and a declining pattern in 2014. The Figure 6b graph depicts the intense pattern of rainfall in northeast monsoon where the rainfall is highest in the year 1987 and a declining pattern is seen towards 2014.

The Figure 6c graph depicts the intense pattern of rainfall in summer monsoon where the rainfall is highest in the year 2004, however a decrease in pattern in 2014. The Figure 6d graph depicts the intense pattern of rainfall in winter monsoon where the rainfall is lowest all the seasons, however there is a significant increase in 2014.

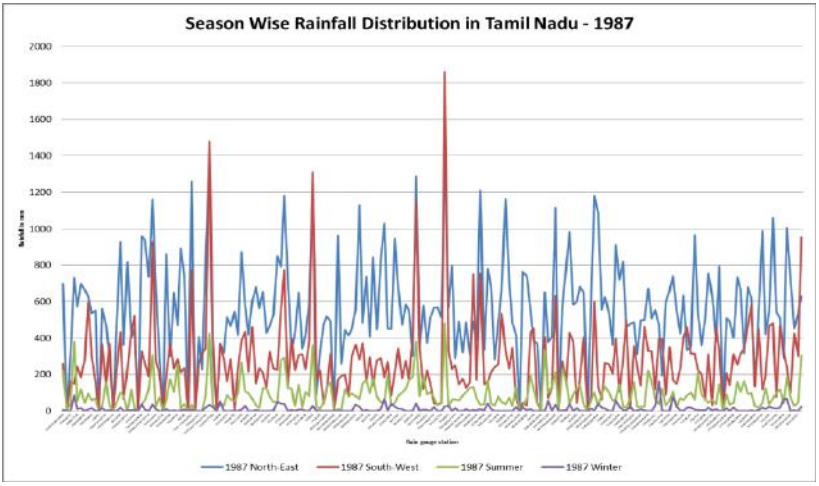


Fig. 3. Season wise of Rainfall Distribution in Tamil Nadu in 1987

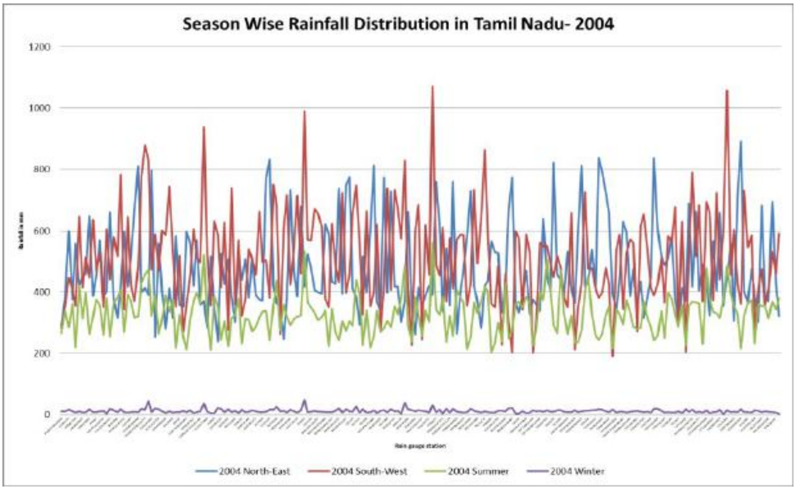


Fig. 4. Season wise of Rainfall Distribution in Tamil Nadu in 2004

The 27 years (1981-2007) annual rainfall is presented. The maximum annual rainfall was received during the year 2005 (973.5 mm) and the minimum rainfall was received during the year 1995 (477.3 mm). The mean value of annual rainfall was 708.08 mm and standard deviation was found to be 162.03 mm. Therefore, any year receiving less or equal to 546.06 mm will be the drought year. Any year receiving rainfall equal to or more than 870.11 mm will be wet year and between 546.06 mm and 870.11 mm will be normal year. During the study period of 27 years were found to be drought, wet and normal years, respectively. The Figure 2 shows the rainfall distribution during different months of the drought years.

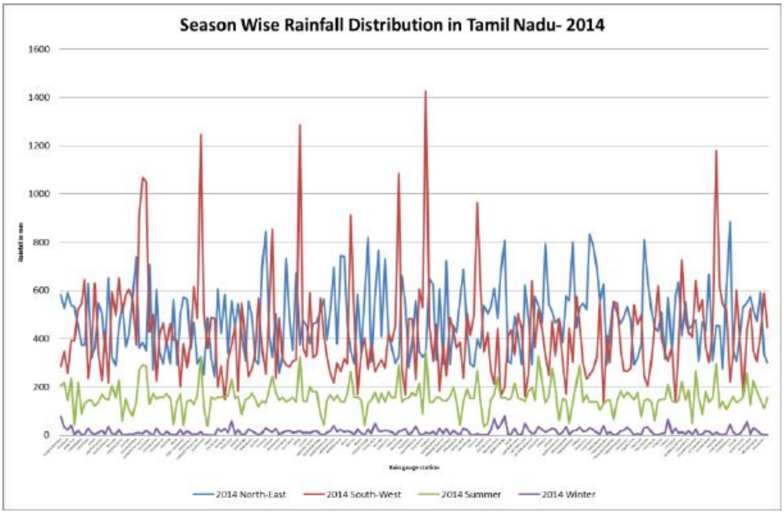
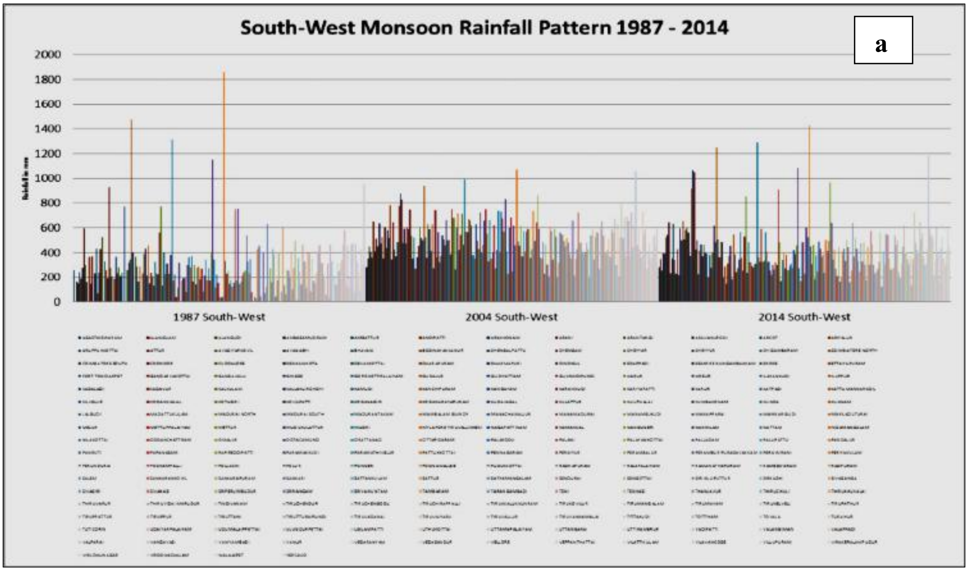
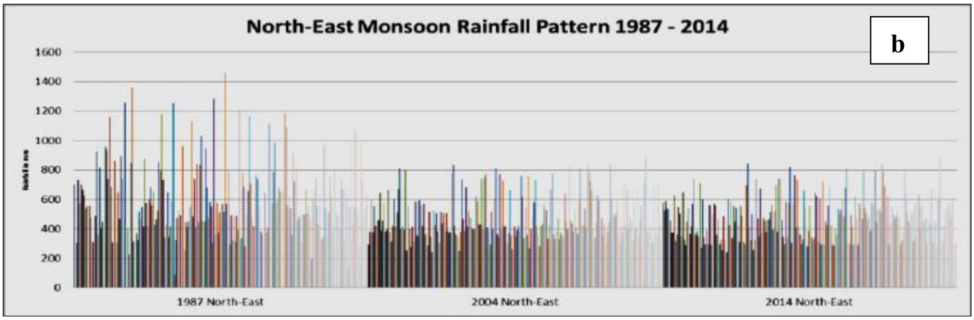


Fig. 5. Season wise of Rainfall Distribution in Tamil Nadu in 2014





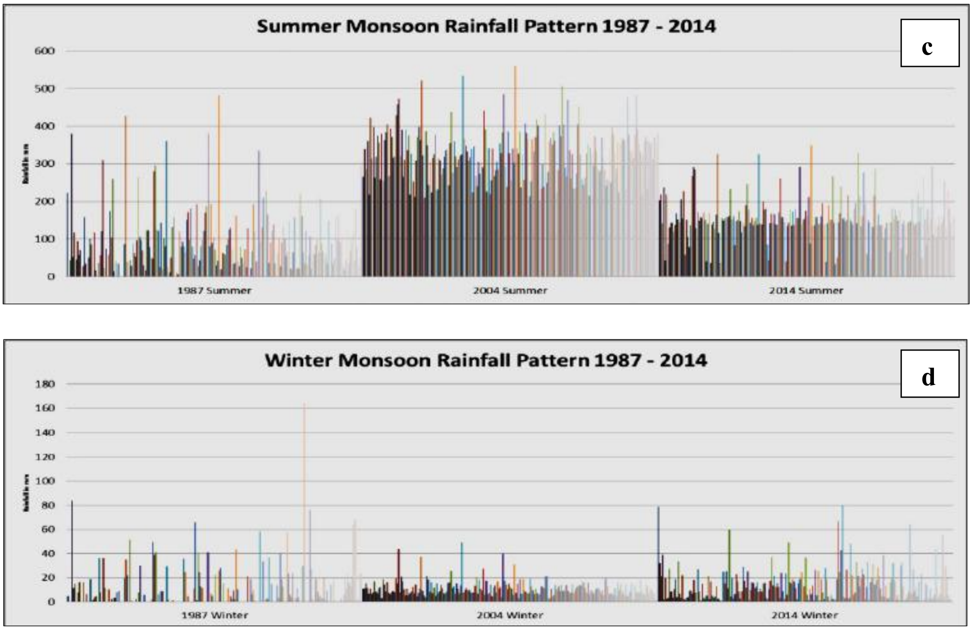


Fig. 6 (a-d). Season wise Pattern of Rainfall in Tamil Nadu for the Period of 1987, 2004 and 2014

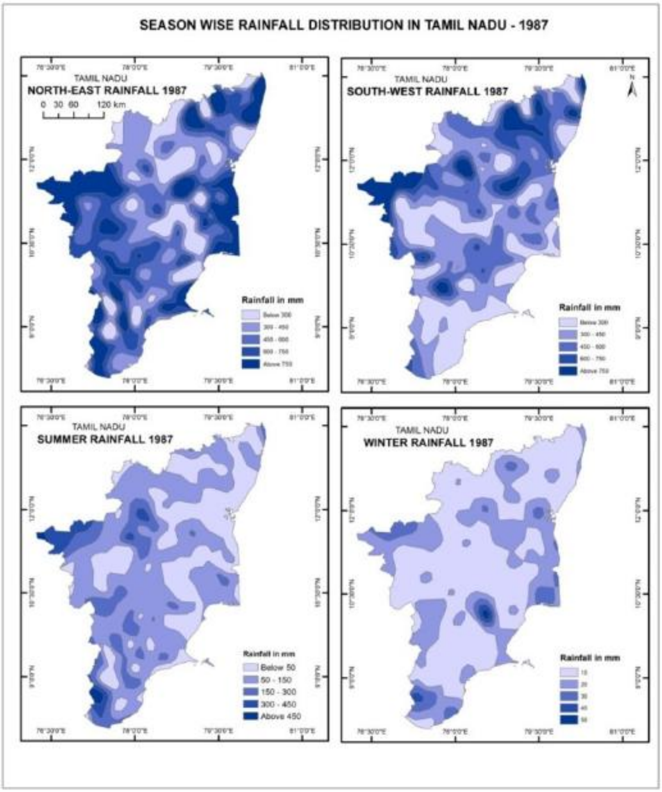


Fig. 7. Season wise Rainfall Distribution Pattern in Tamil Nadu of 1987

The Figures 7, 8 and 9 shows the season wise rainfall pattern in the districts of Tamil Nadu from the year 1987, 2004 and 2014. The maps show a variability of rainfall in the year 2004.

The worst drought was experienced in 1995 with annual rainfall below 67.41 percent of its mean value. The wettest year was observed during 2005 which was 35 percent more than mean annual rainfall. It can also be observed that at one year return period only 477.3 mm of rainfall can be expected to occur and this value remains below the drought definition level. A rainfall of 867.9 mm which is equal to wet definition level may be expected once in 4 years. There is no systematic interval between two successive droughts but, on an average, one drought year can be expected over a period of 3 years. The time interval between drought years has a variation of 1 to 6 years.

The yearly intensity of drought is determined using the approach recommended by IMD and it reveals that the total number of years having no drought, mild drought and moderate drought were found to be 12, 11 and 4 years, respectively. There was no occurrence of severe or extreme drought in Tamil Nadu.

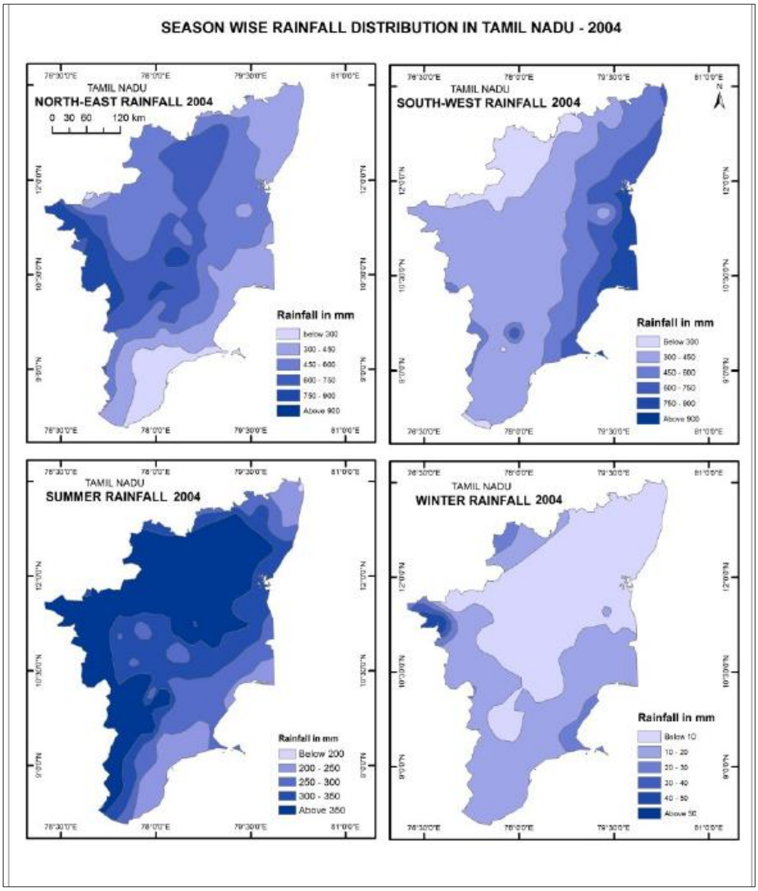


Fig. 8. Season Wise Rainfall Distribution Pattern in Tamil Nadu of 2004

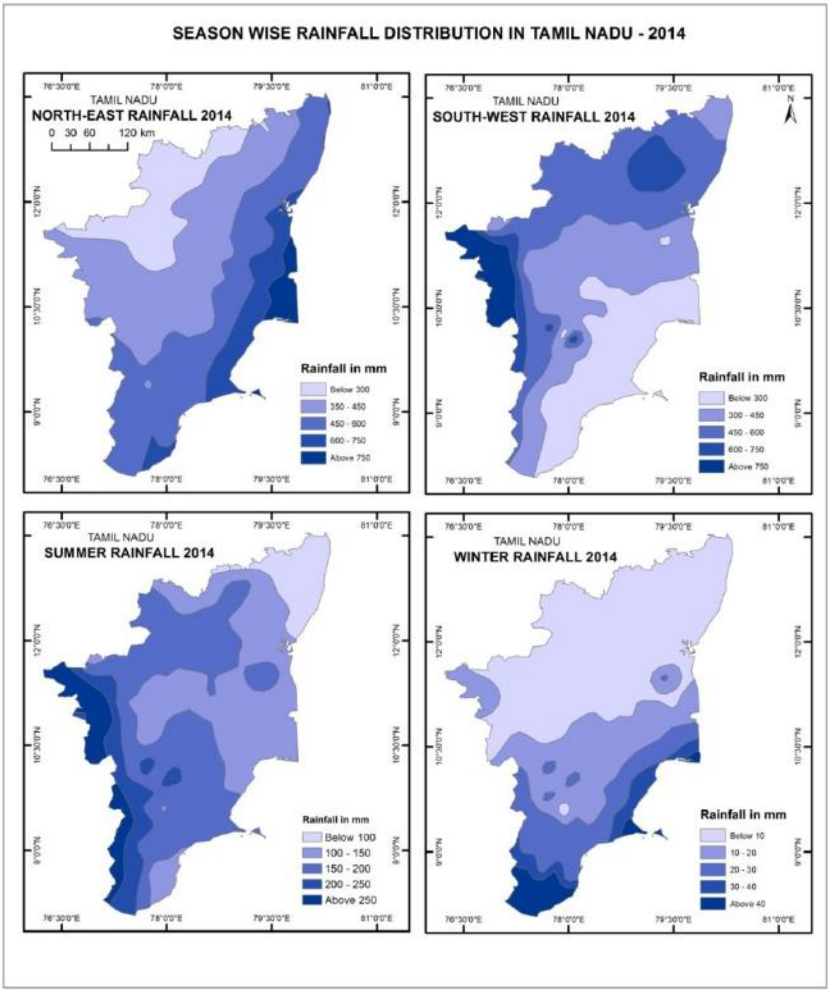


Fig. 9. Season Wise Rainfall Distribution Pattern in Tamil Nadu of 2014

Conclusions

A significant aspect of the rainfall pattern this time is that of the composite Thanjavur District, Nagapattinam has registered excess rainfall and Thanjauvur and Thiruvarur Districts have recorded normal rainfall. With the Mettur dam's water level remaining more or less at full level, a fairly good amount of rainfall in the Cauvery delta during the southwest monsoon brightens the prospects of a bumper samba crop. As both Kancheepuram and Thiruvallur Districts along with Chennai have seen surplus rainfall, people in the three Districts, one among the populous belts of the State, may not have much problem with regard to drinking water supply at least for the next few months. Though it is during the northeast monsoon (October-December) that the State gets benefitted hugely, the current season - southwest monsoon (June-September) - does play a role in ensuring a relatively comfortable level of groundwater table, before the onset of the northeast monsoon.

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IS PULICAT LAGOON SHRINKING? – AN ASSESSMENT THROUGH GEOSPATIAL APPROACH

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Abstract

Pulicat lagoon, highly intricate transitional environment located in the eastern sea board of India. The lagoon has under gone change in size for over thousands of years as a result of natural as well as anthropogenic causes. In this work, long term lagoon water spread area change analysis was done by using geospatial information available since 1988. Satellite imageries from 1988, 2000, 2008 and 2014 have been interpreted. During 1988 - 2000, the lagoon water spread area shrunk by 5.65 km^2 (from 340.28 km^2 to 334.63 km^2) with the dynamic degree of 0.14 %; between 2000 and 2008, the lagoon water spread area is augmented by 1.93 km^2 i.e. 336.56 km^2 with the dynamic degree of - 0.07 %; from 2008 to 2014, the lagoon area is contracted by 5.56 km^2 and reached 331.00 km^2 with the dynamic degree of 0.11 %. The results confirm that the Pulicat lagoon has undergone major geomorphological changes with a reduction in its areal extent, which could have resulted in pessimistic ecological brunt on the environment and individual life and assets.

Keywords: Geographical information system, Pulicat lagoon, Remote sensing, Transitional Environment, Water spread area.

Introduction

Coastal lagoons are essential and dynamic inland transitional ecosystems, which are highly susceptible to environmental factors and anthropogenic influences [4]. The lagoon water spread area mainly altered by precipitation, surface outflow and groundwater inputs and other factors such as evaporation, surface outflow and groundwater outputs and so on [3]. In addition, the amount of water enters and leave is mainly pivot on anthropogenic influences. Anthropogenic escalations such as change in land use patterns in the upstream areas and industrialisation with urbanisation activities play vital threat in altering the morphological setup of these fragile ecosystems. As a result of climate variability (rising temperature as well as altered precipitation), local geology and local oceanic processes coalesces with anthropogenic causes induce remarkable change in lagoon water spread area leads these vulnerable transitional environment into terminal state.

The increased access to geospatial platforms with sufficient spatial and temporal resolutions, near large-scale coverage and low expenditure afford the potential of monitoring lagoon water environments at greater spatial level and extended timescales.

Initial footstep towards planning the protection and sustainable management of this fragile ecosystem is to have precise and updated records. Geospatial technology plays a constantly better task in monitoring and protection, they are suitable to offer the capacity to monitor changes in waterbody area [14].

Study Area

Pulicat lagoon is the second largest brackish water body next to Chilika lake in Orissa, located on the northern part of Chennai (13°25' - 13°55' N, 80°03' - 80°19' E), formed out of backwaters of the Bay of Bengal (Figure 1). Pulicat lagoon, also called 'Lagoon of Palar Basin' [6] got its origin during Holocene geological period [9]. The lagoon has a length of approximately 60 km and a breadth varying from 0.2 to 17.5 km. The lagoon is drained by three major rivers namely Swarnamukhi, Arani and Kalangi and many minor inflows. It is connected with an estuary mouth with a width of 200 m. In the wake of its immediacy to the sea, it has turned into a salt-water lagoon. It also act as a biodiversity hotspot in southeast coast of India with many threatened, vulnerable, endangered and critically endangered species listed by International Union for Conservation of Nature (IUCN). Two colonised islands (Irukkam and Venaadu) and several unoccupied tiny mud flats are located in the northern side of the lagoon. The Buckingham canal surpasses through north to south direction next to the eastern edge of the lagoon. Siltation from Swarnamukhi, Kalangi rivers and sandbar formation at the mouth regions are the two major threats which cause danger to the complete ecological balance of this fragile ecosystem.

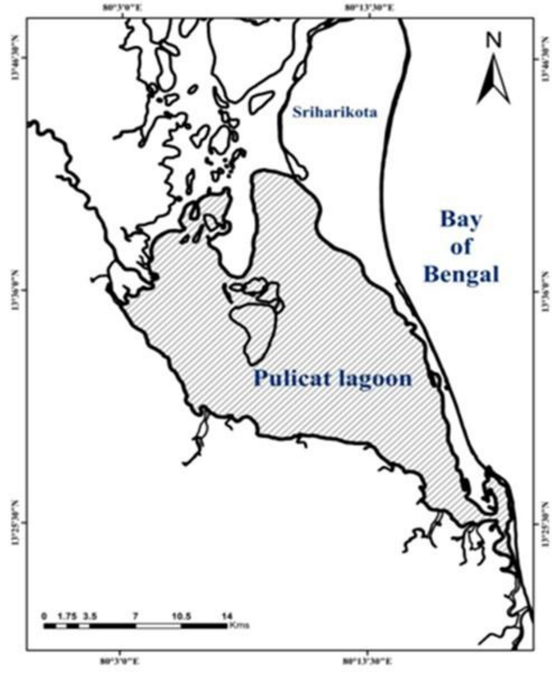

Fig. 1. Study Area

Database and Methodology

In order to assess long term lagoon water spread area, the satellite data from the same season have been collected between 1988 and 2014 as shown in Table 1.

Table 1. Details of Satellite Data Used

Period	Satellite Sensor	Spatial Resolution (m)
11-05-1988	Landsat TM	30
05-05-2000	Landsat TM	30
27-05-2008	Landsat ETM+	30
28-05-2014	Landsat ETM+	30

Methodology

The cloud free Landsat data was collected from USGS EARTH EXPLORER (*earthexplorer.usgs.gov/*), and data preprocessing was progressed with ENVI 4.7. The lagoon – land boundary was digitized with the aid of ArcGIS 10.1. The vector representations of the boundary of Pulicat lagoon for 1988, 2000, 2008 and 2014 were overlaid in GIS. Figure 2 discusses the methodology followed in this study. The locations under shrinkage or expansion were demarcated by making use of Analysis tools of ArcGIS 10.1.

To identify the change of morphology of the lagoon during various time periods and trend, the single lagoon area dynamic degree was espoused. An indicator developed by Zhao et al. (2013) was utilized to examine the alteration in the lagoon area in a particular time period

$$k=\left(\frac{Ua\text{-}Ub}{Ua}\right)*\left(\frac{1}{T}\right)*100$$

where,

k - Dynamic indicator for the lagoon area

U_a - Lagoon area at the start date

U_b - Lagoon area at the end date

T - Timescale under consideration

Morphological Variations of Pulicat Lagoon

Variations in Water Spread Area

Digitised lagoon water spread area in 1988, 2000, 2008 and 2014 were compared with each other (Figure 3). An alternate shrinkage (in 2000 and 2014) and expansion (in 2008) in the water spread area is very much coinciding with the rainfall, resulting in net shrinkage of 9.28 km^2 between 1988 and 2014 (Table 2).

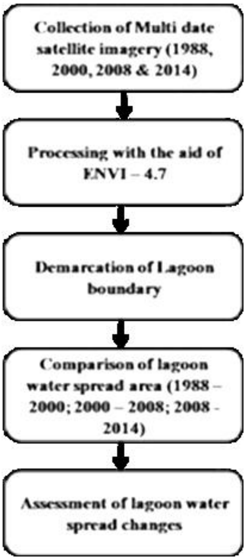

Fig. 2. Methodology

Table 2. Pulicat Lagoon Water Spread Area and Rainfall

Period	Lagoon Water Spread Area (km^2)	Rainfall (in mm) *
1988	340.28	979.02
2000	334.63	899.33
2008	336.56	1491.7
2014	331.00	1051.4
Net reduction in the water spread area between 1988 and 2014 is 9.28 km^2		

** Amount of rainfall calculated from June of the preceding year to April of the subsequent year*

During 1988 - 2000, the lagoon water spread area decreased by 5.65 km^2 with the dynamic degree of 0.14 %; between 2000 and 2008, the lagoon water spread area increased by 1.93 km^2 with the dynamic degree of -0.07 %; during 2008 - 2014, the lagoon boundary subsequently decreased by 2.58 km^2 with the dynamic degree of 0.13 % (Table 3). As stated above, the precipitation followed by surface runoff particularly from Kalangi, Swarnamukhi and other streams contribute a major role in modifying the lagoon water spread area. Figure 3 portrays the nature of lagoon morphology and its environment. A lucid change in lagoon water spread area is noticed at the confluence point of river Kalangi revealing the dynamic processes happened over the past decades. In line with that, southern part of the lagoon also sustains its dynamic nature with Bay of Bengal recognised by its footsteps. On the other hand, not much change is noticed along northeastern part near Sriharikota which discloses the absence of natural or anthropogenic influences.

Marginal changes are observed near north western part (Sunnambukkulam) as a result of confluences of minor streams.

Table 3. Variation in Lagoon Water Spread Area (1988-2014)

Period	Area of Change (km^2)	Ua - Ub/Ua	Time Factor	Dynamic Degree	Lagoon Status
1988 - 2000	5.65	0.017	0.083	0.14	Shrinking
2000 - 2008	-1.93	-0.006	0.125	-0.07	Expansion
2008 - 2014	2.58	0.008	0.17	0.13	Shrinking
1988 - 2014	9.28	0.027	0.038	0.10	Shrinking

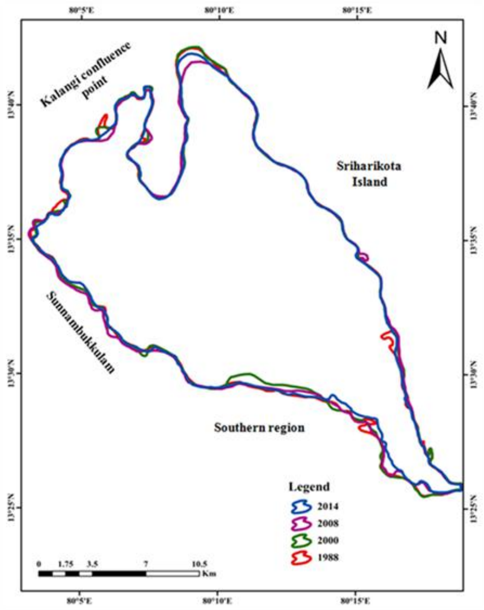

Fig. 3. Variations in Lagoon Water Spread Area (1988-2014)

Change in lagoon water spread area is influenced by a range of causative factors. Both human as well as nature play vital role in altering water spread area. Human role starts with modifying landscape configuration or altering land use and land cover pattern for their expedient. Apart from anthropogenic influences, nature also acting crucial role in altering lagoon water spread area. Figure 4 enlightens various natural causative factors responsible for the changes in lagoon water spread area.

Causes

Exchange of water and materials between Pulicat lagoon and sea mainly depends upon coastal processes, tidal conditions and cyclonic storms of Bay of Bengal. Pulicat lagoon is mainly subjected to a limited tidal influence, the average variation between high and low tides being not often more than 30 cm [8]. The lagoon is also distinguished by fairly calm waters, because the barrier spit keeps off larger waves from the open sea [13]. Depression occurred during September 1981, severe cyclonic storm during May and October 1982, November 1984 [2], October 1985 [5] , Tsunami during 26th December 2004, are all some events that cause appreciable changes along coastal stretch of Pulicat lagoon.

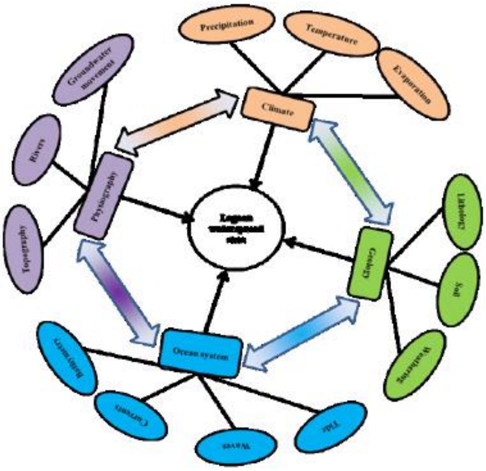

Fig. 4. Various Factors that Influence the Lagoon Water Spread Area

Gradually increasing temperature and shifting precipitation trends between 1901 and 2014 (Figure 5) cause considerable stress on water storage of the Pulicat lagoon. Variation in lagoon water spread area on timescales that are extended than a century is controlled chiefly by temperature and precipitation trends. Climatic data demonstrate a steady increment in the annual precipitation and mean temperature during 1901 - 2010. Even though, the annual temperature amplified steadily between 1988 and 2014, the annual precipitation increased slightly that leads to a significant change in the lagoon area as shown in Figure 6. This specifies that, the lagoon surface area changes have a direct association with precipitation during the study period, which appears to be the most significant factor for recent lagoon shrinkage in the Pulicat lagoon.

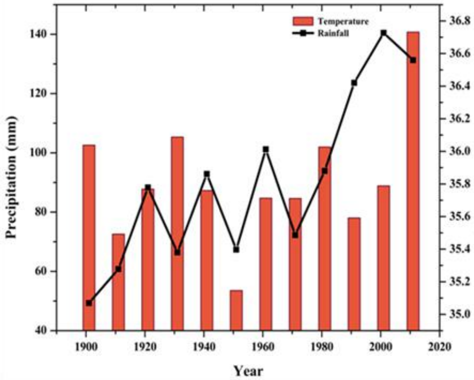

Fig. 5. Temperature and Rainfall Variations from 1901 to 2011

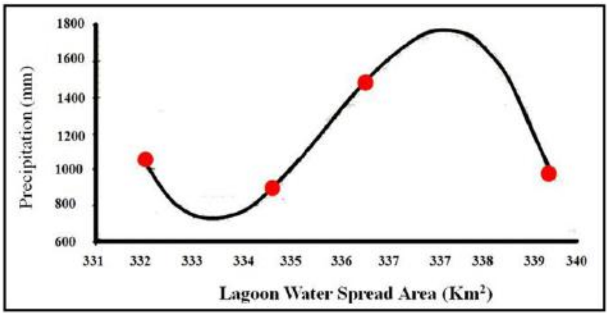

Fig. 6. Precipitation vs Lagoon Water Spread Area

More sedimentation is inferred from the bathymetry data of 2014 collected from Integrated Coastal and Marine Area Management (ICMAM), Chennai. The maximum water depth reduced from 6 m (1970) to 2 m (Present study) (Figure 7). Maximum water depth is observed in the mid of lagoon and nearer to the Venadu Island. Most of the lagoon area is shallow in nature. Gentle increment in bed slope noticed nearer to Kalangi confluence point indicating higher sedimentation rate compared to the rest of the lagoon. Topography also contributes significantly to the movement of water and sediments in to the lagoon. For example, in areas with high topographic relief (PP 2-9) (Figure 8), the runoff will be more and vice-versa.

On the other hand, a gentle slope is noticed on the southern side of the Pulicat lagoon (PP 1 & 10) (Figure 8). Augmented water flow may change site level hydrology as well as sedimentation rate. A drastic change in landscape configuration in the upstream areas can lead to intense sediment load in natural and artificial water ways. Pulicat lagoon receives discharges from the Buckingham canal and two other rivers, the Arani and Kalangi, with sedimentation rates of 14.3 mm/yr, 13.7 mm/yr and 15.75 mm/yr respectively [12]. The sedimentation rates at these discharge points are much higher as compared to the rest of the lagoon [11]. Because of sedimentation, northern part of the lagoon is nearly dried up and has bowed the lagoon into extensive mudflats. Due to this, a large part of the lagoon becomes sterile for fisheries and is available for shorter periods for the water bird's usage.

Lithological units in the upstream areas may also important indirect structure in determining the type and amount of material got deposited in coastal lagoon. Soft rock such as sedimentary rocks may easily undergo weathering and gets simply washed away from the source rock. Hard rock such as crystalline rocks may not easily undergo weathering. The trail of the Kalangi and other streams mainly formed by shale and feldspathic sandstone, which are easily washed away from the source rock and got eroded. Pulicat lagoon supports a huge and incessantly growing human population; however, many areas have been reclaimed for various purposes. As a result, the regional environment has been greatly altered over the past three decades. The effects of human activity on lagoon in a specified area always have diverse features and depend on many issues, for instance geomorphic uniqueness, hydrological cycling and the types of local human actions including water conservancy project, excavation near mouth region, construction of breakwater, aquaculture and domestic and industrial water usage. Evaluating both the regional lagoon changes and the impacts caused by human activities in recent years is a very important factor for water resource management and decision-making of the local government [5].

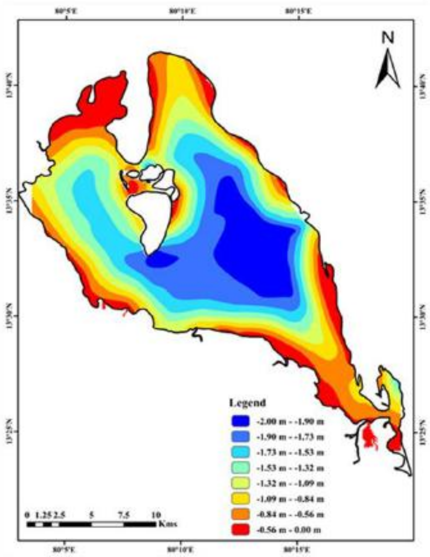

Fig. 7. Bathymetry of Pulicat Lagoon

Fig. 8. Path Profile (PP) Status in the Vicinity of Pulicat Lagoon

Conclusions

Pulicat lagoon has undergone gradual shrinkage and expansion in the water spread area since 1988. This is mainly narrated to natural (climate, local geology, physiography and oceanic system) and anthropogenic influences (aquaculture and changing landscape configuration). From the authors' point of view, the lagoon inundation resulted from increased freshwater discharge to the lagoon from Kalangi and other tributaries. A bathymetry study reveals that the maximum water depth reduced from 6 m to 2 m demonstrating more sedimentation occurred during past decades.

Linear trend analysis of mean temperature enlightens the average rate annual temperature had increased by 0.14 ^{0}C. Even though, the annual temperature amplified steadily between 1988 and 2014, the annual precipitation increased slightly that leads to a significant change in the lagoon area. Pulicat lagoon water spread area has decreased considerably in the 2000 - 2008 and 2008 - 2014 periods. Over these 14 years (2000 - 2014), the lagoon water spread area declined by 5.65 km^2. Net reductions in the water spread area between 1988 and 2014 is 9.28 km^2.These changes are mainly attributable to reduced wet periods and also more withdrawal of water for aquaculture purposes in recent decades.

Shrinking in lagoon area has a pessimistic ecological brunt on the environment and individual life and assets. The lagoon area is the main significant issue to ensure the environment of the lagoons' basin and the key indicator to measure the environmental balance. This vulnerable ecosystem needs proper management measures for protection. This is very important because sustainable utilisation only is the best option for maintaining the resources without deterioration.

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News and Notes

THE INDIAN GEOGRAPHICAL SOCIETY

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

Conduct of 6th Talent Test - 2016 for Geography students on 22nd January, 2016

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The Indian Geographical Society is organising the state wide **Sixth Talent Test - 2016** for final year UG and PG students of the Geography Departments in Tamil Nadu on **22nd January, 2016**. 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*

The Heads of the Geography Departments to contact the coordinator/regional coordinators and conduct the Talent Test successfully.

General Information

1. Talent Test **will be conducted in English language only for PG and UG students** for 1.30 hours consisting of 100 questions without any choice.
2. Syllabi for UG and PG talent tests are UGC NET Paper II & III respectively.
3. Final year UG and PG students of Geography are eligible for Talent Test.
4. The students should enroll their names with the concerned Head of the Geography Department on or before 14th January, 2016.
5. The co-ordinators would contact the Heads of nearby Geography Departments and send the representatives for conducting Talent Test.
6. The Head of the Geography Departments would collect the registration fee from the students of their Department and inform the coordinators accordingly.
7. Talent Test is scheduled on 22nd January, 2016 (Friday) between 11.00 a.m. and 12.30 p.m.
8. Registration fee for UG Students is Rs.50/- and for PG Students it is Rs.75/-. Only Cash should be collected from the interested candidates.

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 ***International Conference*** on Future Earth Perspectives in South Asia being organised between 05th and 07th Feb. 2016 at Department of Geography Bharathidasan University, Tiruchirappalli. 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: 14-01-2016 (Thursday)

Date of the Talent Test: 22-01-2016 (Friday)

Fellowship and Award

Dr. K. Kumaraswamy, Professor and Head, Department of Geography, Bharathidasan University, Tiruchirappalli and the present Editor of The Indian Geographical Journal is awarded with the following Fellowship and Award:

UGC BSR Faculty Fellowship (UGC-BFF)

The UGC Fellowship is meant for successful and active senior faculty member with proven academic track record. It enables continuance of research career and mentorship role in Universities for three years (2016-2019).

UGIT Excellency Award 2016

The international award has been given for his achievement and contribution in Geography and Geospatial Technologies at 4th Union of Geographic Information Technologists (UGIT) International Meet to be held at Mangalore University on 16th February 2016.

Statement about ownership and other particulars about

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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