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**K Anitha**
Department of Chemistry, S.K. University, Anantapuramu, Andhra Pradesh, India

**P Chandra Mouli**
School of Earth System Science (Institute of Surface-Earth System Science), Tianjin University, China

**Corresponding Author:**
**K Anitha**
Department of Chemistry, S.K. University, Anantapuramu, Andhra Pradesh, India

# Characterization of land use and land cover over south eastern Indian city Tirupati: Status of the quality of environment

**K Anitha and P Chandra Mouli**

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**Abstract**
Land use/land cover (LULC) study is highly important in selecting, planning, organizing, settling, utilizing natural resources, implementing the schemes for meeting the increasing demands of needs of human population, livestock, aquaculture, forestry, industrial and urban land use. This paper focusses on the demographic details, land use and land cover pattern, climatology and the socioeconomic status of city Tirupathi in the Southern India peninsular region. The study has been evaluated by the analysis and interpretation of two types of data; (1) Basic data (Fused data of IRS-ID PAN and IRS-ID LISS-III satellite data and Toposheets) and Ground data (Meteorological data and other sources). Topography, Geology, drainage, soil, vegetation, agriculture, wind rose pattern, socioeconomic status has been presented.

**Keywords:** Land use/land cover (LULC), demographic details, climatology and socioeconomic status

## 1. Introduction
Industrialization and urbanization are global phenomena. These processes, which lead to congestion and uncontrolled development, are caused by both growth and the ongoing migration of rural populations to urban areas in search of greater economic possibilities. In addition to causing air pollution, the rapid and careless expansion of urban sprawl and growing population pressure is also causing the infrastructure facilities to deteriorate, the productive agricultural lands and green open spaces to disappear, the surface water bodies to be lost due to siltation, the dumping of solid waste, and the depletion of ground water potential zones. Effectively addressing these problems necessitates careful environmental monitoring, especially of atmospheric aerosols (P. Chandramouli *et al*., 2004) [7], as all of these activities have the potential to release more particles into the atmosphere, which could have a negative impact on human health and alter the climate.
An analysis of the study area's profile is necessary in order to create a suitable environmental monitoring program (EMP) for the evaluation of the region's environmental condition. It is anticipated that this would assist in creating a workable EMP in order to reduce negative consequences and produce advantages in terms of an enhanced standard of living for the local populace (Praveen Kumar, 2013) [8]. The first step in identifying consequences is gathering fundamental data for several important environmental segments, such as land use and land cover pattern, climate, and socioeconomic factors, which give a clear picture of the region's environmental conditions.

## 2. Location of the Study Area
The study area, Tirupati region is located in southern peninsular India. India is one of the fastest growing economics in Asia, with an annual average GDP growth of 6.1% (WDR, 2000) [10]. This has resulted in an increase in commercial energy consumption in the last decade (38%) between 1990 and 1998 (CMIE, 1999; TEDDY, 1999) [1, 9]. India is located in southern Asia, bordering the Arabian Sea and the Bay of Bengal, between Burma and Pakistan, having the total area of 3,287,590 km, with a geographic co-ordinates $20.00^0$ N and $77.00^0$ E. It has the population of 1,029,991,145 according to 2001 Census with a growth rate of 1.55%. Generally, India has the textile, chemical, food processing, steel, transportation equipment, cement, petroleum, machinery, software industries with higher production rate augmenting the major sources of pollution along with traffic activities which include Railways (63,693 km),

Highways (3,319,644 km), Waterways (16,180 km) and also Airways. India is divided into 28 states, which are administrated through state governments and 8 territories (as of 2011 census), directly administered by the union government, with four metropolitan cities; Delhi, Kolkata, Mumbai and Chennai (Fig. 1). Southern India is well growing part in India, in all the respects such as industry, transportation, and education as well as business. The geohydrological features of the southern peninsular India is shown by a satellite image (Fig.2), where the study area, Tirupati is situated nearby the metropolitan city, Chennai at a distance of about 145 km. Tirupati, a world famous holy piligrim place for devotees of Lord Sri Venkateswara is situated in Chittor district of Andhra Pradesh (AP) state at an altitude of 182.9 m (13.05$^0$ N latitude and 79.05$^0$ E longitude which represents a semi-arid urban area surrounded by major industrial and agricultural activities along with dense forest.

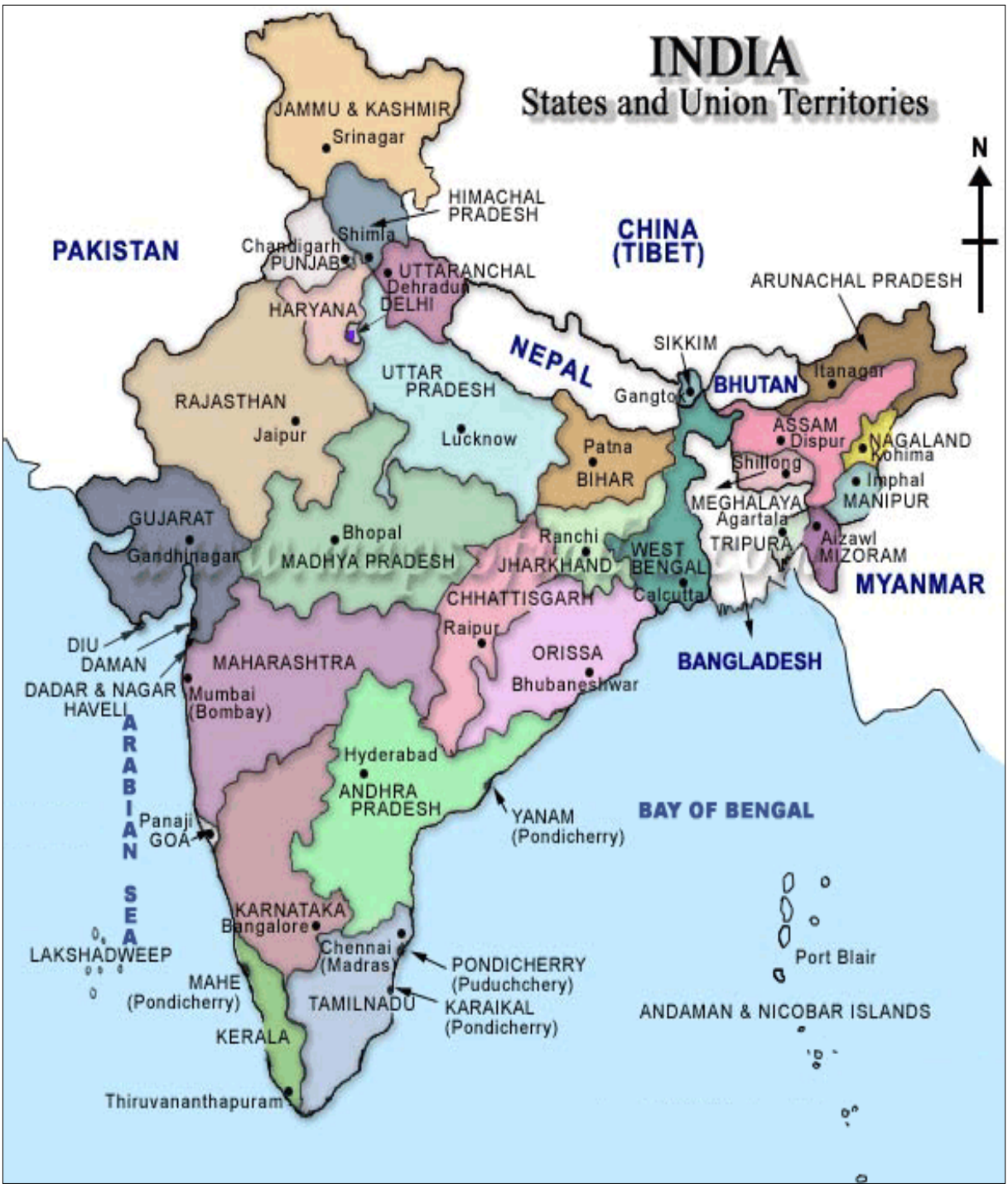


**Fig 1:** Map showing the states and union territories of India (source: web)

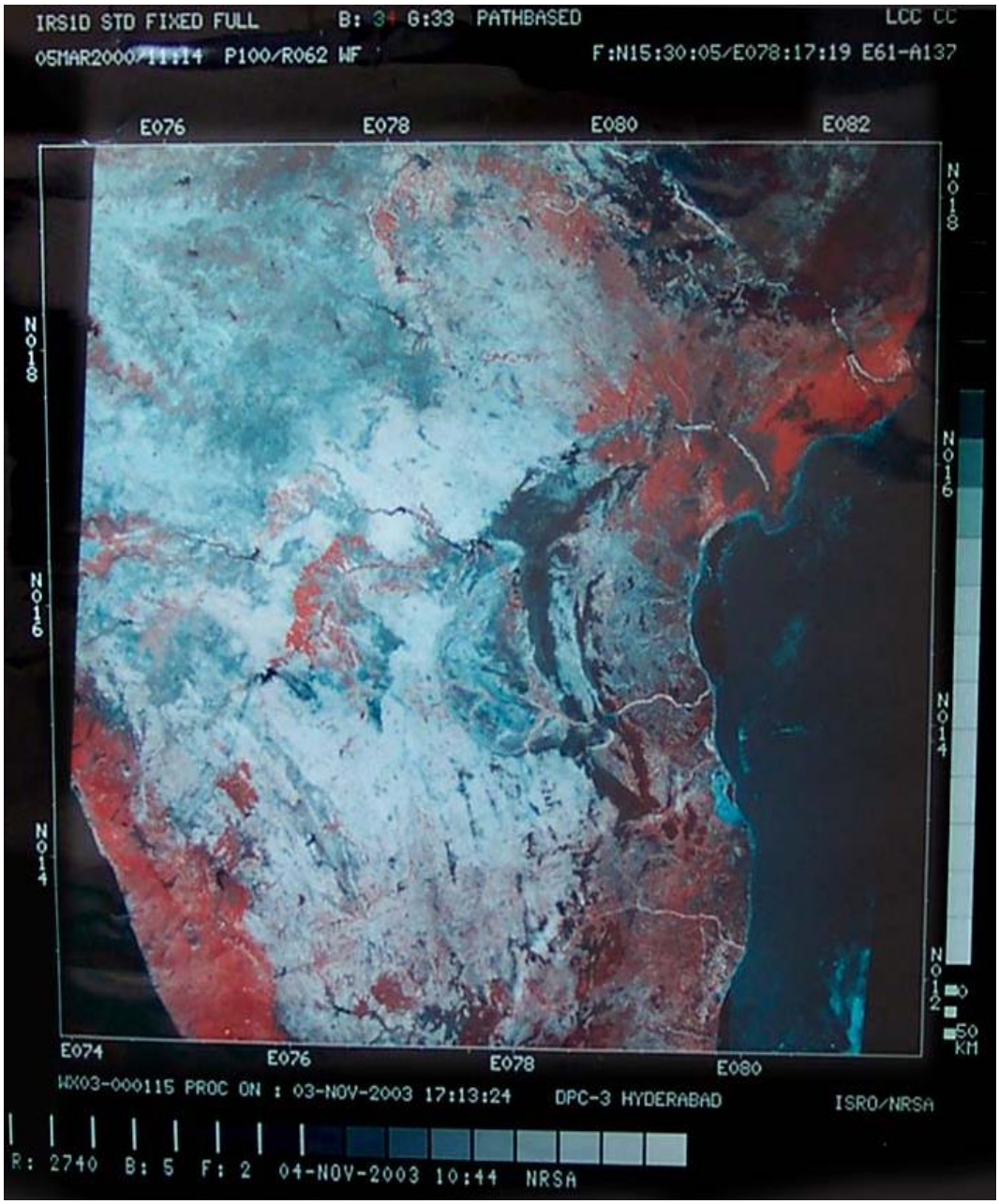


**Fig 2:** Satellite image showing the southern part of India.

## 3. Methodology Adopted

The environmental baseline data was generated by the detailed survey of the region within 10 km radius of the study area. The data generated by various State and Central Government Organizations were utilized (Table 1) for synthesis of the environmental status of the study area. Land use and land cover pattern has been evaluated by the analysis and interpretation of two types of data; (1) Basic data and (2) Ground data. Basic data includes, (i) Fused data of IRS-ID PAN and IRS-ID LISS-III satellite data, (ii) Toposheets, (iii) Local knowledge, (iv) Area map on any scale to transfer details, (v) Reports and other literature of the study area. Also, collecting the additional data from the revenue and forest departments respectively along with reconnaissance whereas the meteorological data was collected from the meteorological centre. Data for occupational status, education, and health in the region have been collected. The information on socioeconomic profile was collected from the records of 2001 census statistics, health and education departments and formal interviews with people.

**Table 1:** Data sources

| S. No. | Data product | Source |
|---|---|---|
| 1 | Satellite data | National Remote Sensing Agency, Balanagar, Hyderabad |
| 2 | Toposheets (1:50,000; 1:25,000) | Survey of India, Hyderabad |
| 3 | Maps showing the existing information of Tirupati (Study area) | Municipality, and APPCB, Tirupati |
| 4 | Topography, Geology and Land use and land cover information | By field survey as well as from Forest and Revenue Departments |
| 5 | Meteorological data | Meteorological centre, Tirupati |
| 6 | Socioeconomic data | Municipality, Tirupati and Field work |

## 4. Land Use and Land Cover Pattern

Land is the most important natural endowment on which all the man's activities are based. Growing population, and increased human activities are exerting pressures on limited land resources. Land use and land cover have a direct relationship with environmental characteristics and processes, including productivity of land, species diversity, biogeochemistry, climate and the hydrological cycle. Hence, it becomes necessary to understand the land use patterns, land cover changes as well as availability of resources. Land use refers to man's activities and various uses, which are carried on land. Several land use/land cover studies in and around Tirupati has been carried out in several time periods (Nagaraju Arveti *et al*., 2016) [5]. Land cover refers to natural vegetation, water bodies, rock/soil, artificial cover and others resulting due to land transformation. Although land use is generally inferred based on the cover, yet both the terms land use and land cover are closely related and interchangeable.

The major aim of land use classification system is to provide a framework as broad as possible and would cover all the possible types of land use within the country that could be mapped within certain limitations. Secondly, to see the applicability of Fused data of IRS-ID PAN and LISS-III satellite data for delineating various land use, land cover categories through computer analysis as well as visual interpretation techniques. Finally, to provide a standardized land use, land cover classification system, which can be used with the satellite imagery available in India, at present.

## 5. Objectives

The main objectives of land use map are:

1) The land use map will be utilized as a basic database.
2) It will incorporate demographic, economic and environmental impact, which have occurred in an area.
3) Land use/ land cover map can make it possible, to determine special areas, such as prime agricultural lands, etc. which may contribute the air pollutants in big way.
4) Land use/ land cover map will serve as a basis for monitoring land use change.
5) The land use map will serve as a base in agricultural and industrial development of the region.

Many diverse types of spatial data are needed to monitor and understand the dynamic process, as well as to develop the environmental simulation models that are needed for scientific assessment of environmental problems. In these efforts, remote sensing techniques comes as a handy tool (Narayan, 1999) [6], which offers an efficient and timely approach to the mapping and collection of basic land use and land cover data over large area. Remote sensing is a multi-disciplinary activity which deals with the inventory, monitoring and assessment of natural resources through the analysis of data obtained by observations from a remote platform. The unique capability of space-based sensors to provide wide range of information available in the electromagnetic spectrum, in a synoptic and more frequent manner, has made this technology an inevitable tool in the sustainable development and utilization of our natural resources (Kasturirangan *et al*., 1996) [2].

## 6. Satellite Data Acquisition

The second generation operational Indian Remote Sensing IRS-ID were launched in the year 1998 by the indigenously developed Polar Satellite Launch Vehicle (PSLV) from Sriharikota, India. This satellite is placed in a near circular, sun-synchronous, near polar orbit with nominal inclination of 98°. 53′ at a mean attitude of 780 Km. There are three sensors, namely (1) Panchromatic Camera (PAN), (2) Linear Imaging and Self Scanning Sensor (LISS III) 3) Wide Field Sensor (WiFS).

In this study, the remote sensing data in the digital mode is used and is obtained by LISS III and PAN of IRS ID (Fig 3). Therefore, it is more appropriate to give the sensor characteristics of LISS III and PAN (Table 2). LISS- III sensor operates in four spectral bands; there are separate optics and detector arrays for each band. Map of 1:50,000 scales obtained from SOI covering the entire study area is used to extract the Ground Control Points (GCPs)
and to demarcate the boundary of study area. This information is then used for image registration of LISS III and PAN digitally using ERDAS software.

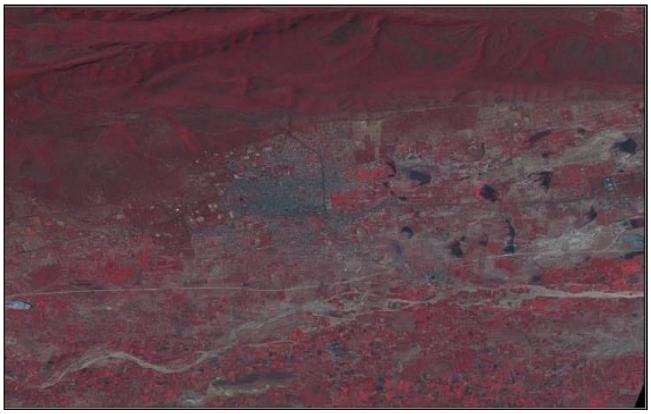

**Fig 3:** Fused data of IRS-ID, PAN and LISS-II satellite imagery

**Table 2:** Sensor characteristics of IRS ID (LISS III and PAN)

| Sensor Characteristics | Sensor | |
|---|---|---|
| | LISS III | PAN |
| Spatial Resolution | 23.5 m | 5.8 m |
| Spectral Resolution | 4 | 1 |
| Radiometric Resolution | 6 | 6 |
| Swath width | 127-141 | 63-70 |

## 7. Satellite Data Processing

i) **Geo-coding and Geo-referencing:** ERDAS (Image Processing Software) has been used for Geo-referencing of LISS III and PAN data covering the study area. 1:50,000 scale toposheets are scanned and raster file for study area is created. These are geo-referenced based on the longitudinal & latitudinal co-ordinates. After geo-referencing all the maps are edge-matched and a digital mosaic is prepared which depicts the continuity of the study area. The LISS III data obtained from NRSA is processed for initial corrections like drop outs, stripping and earth rotations etc. Sufficient number of well distributed ground control points are selected both on the maps and corresponding imagery. Care is taken to satisfy the condition on density of GCPs for image registration. The geo-referenced image is further mosaicked and then feature matching is carried out. At the end of this process the digital data which is free from all distortions is available for digital image enhancement, classification for Land use/land cover map preparation with the help of Visual image analysis techniques

ii) **Digital Image Enhancement of LISS III Data:** Image Enhancement deals with the individual values of the pixels in the image. The goal of spectral enhancement is

to make certain features more visible in an image by bringing out more contrast. Initial display of LISS III data through ERDAS software revealed that the features like minor roads, streams and river are not clear/visible as the contrast of the imageries very dull because of the raw data values fall within a narrow range. Therefore, an attempt is made to apply linear contrast stretch technique in order to improve the contrast of the image, which can be capable of expanding the dynamic range of radiometric resolution of LISS III digital data.

iii) **Visual Image Interpretation:** The procedure consists of a set of image elements or characteristics like color / tone, texture, pattern, size, shape and so on, which help in the recognition or interpretation of various land use /land cover features systematically on the enhanced satellite imagery during the classification of features. The land use/ Land cover classification system used in this project is the system which is pioneered by United States Geological Survey (USGS) and is modified by National Remote Sensing Agency (NRSA) according to Indian conditions. The details of this LU/LC system are beyond this report and can be referred in the NRSA LU/LC book. A preliminary image classification key is prepared for the fussed pictorial data and is used during interpretation process. Using the image interpretation key, preliminary interpretation of satellite imagery is carried by transferring the features from base map on to the transparency. This transparency with base line data features is then overlaid on the satellite imagery. Then the features of LU/LC are extracted and transferred from the satellite pictorial data.

The doubtful areas (due to similar spectral response and spectral signature) identified during the preliminary image classification are listed out before ground verification. After finalizing the ground traverse plan the doubtful areas are physically verified and field observation about terrain condition and land use pattern are noted. Based on the ground information collected, corrections and modifications of miss classified land use/land cover details and doubtful areas are carried out on enhanced imageries for final land use/land cover classification.

## 8. Land use/land cover description

The different land use land cover classes existing in the area over space and time are shown in Fig 4 and briefly discussed here in their dimension.

### i) Topography

The study area, forming a part of the Mysore plateau of the Eastern Ghats, is characterized by a sudden contrast of topography with an abrupt rise of hill ranges with nearly vertical faces to form scarp topography at an elevation ranging from 1100 to 330 m in the northwest and a more or less plain land lying at an elevation ranging from 330 to 110 m in the south and east. The dividing line between the highlands and low lands show a general easterly slope. In the eastern portion of the highlands, a valley sloping due south, dissect the otherwise mountains terrain. The sudden contrast in topography has been described by king (1880) as a step and plain country.

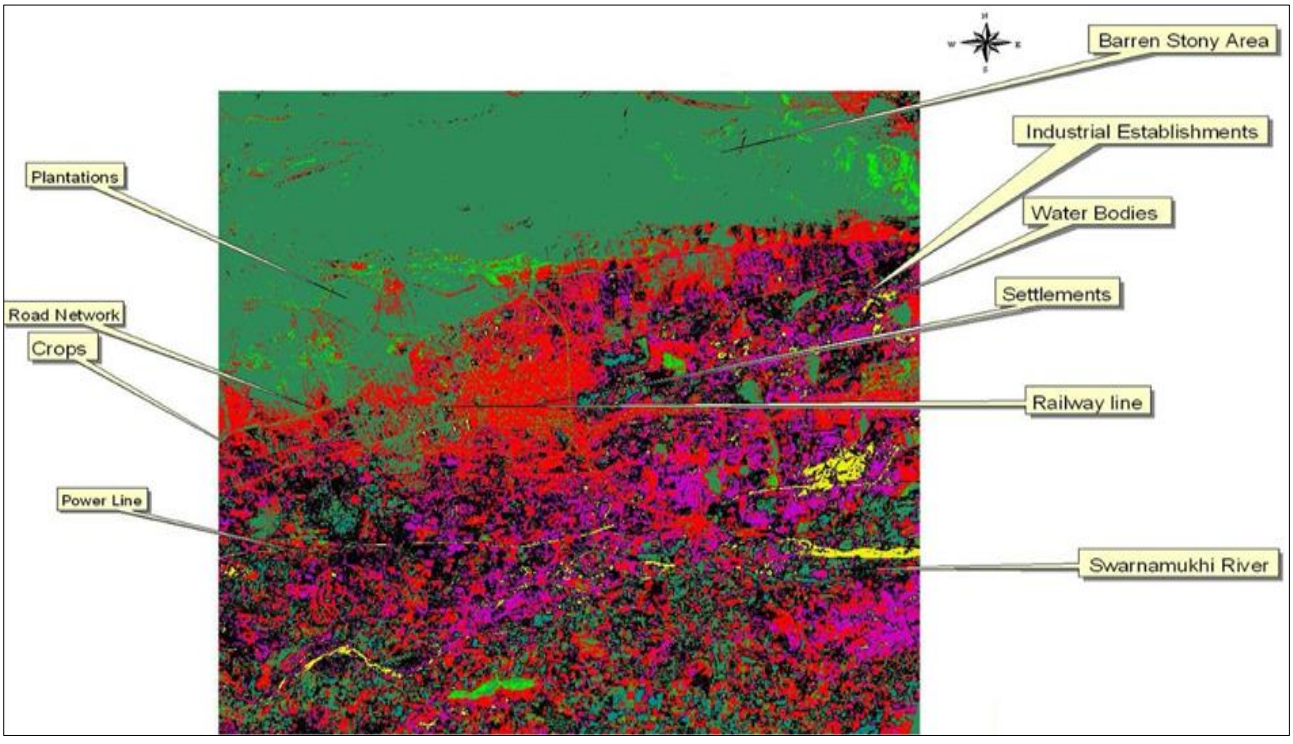


**Fig 4:** Classified imagery of the study area with identifiable land use categories

Tirupati hill ranges include the seven hills between Tirupati and Tirumala temple. Other hill ranges of importance located east of the Tirupati hill ranges include Mamandur, Krishnapuram and Karakambadi. An interesting and rare topographic feature seen at Tirumala is a natural bridge, preserved as a geological monument by the Geological Survey of India.

### ii) Geology

The Geological Survey of India (King, 1872) [3] investigated this area and provided the geological composition of this region. According to this, the geological succession of the rock formations in the area is as follows:

- **Sub-Recent and Recent:** Alluvium and soils
- **Pleistocene and Holocene:** Boulders and older alluvium

- **Lower cuddapahs:** Nagari quartzites with shaley intercalations and dyke rocks
- **Archeans:** Granitic and dyke rocks.

The major portion of this area is covered by granitic rocks, which are intercepted by innumerable dyke rocks of narrow width and considerable linear extent. The granite is a coarse grained equigranular to porphyritic granite, which promote more rapid disintegration (Lahee, 1961) [4]. The phenocrysts of potash feldspars, have random orientation. To the north of Tirupati township, a flat or gently dipping quartzite due north is exposed as vertical cliffs forming escarpment to the south. The quartzite is yellowish brown and is barren of vegetation. The weathering of quartzite leads to the mechanical process of dislodgement of blocks along the joint planes. Shales occur as a band along the Mamandur-Karakambadi valley. They are light grey to dark brown in colour and are sometimes variegated. At places they are represented by soft clay that is mostly white in colour. The shales are generally rich in chert. Alluvium, composed of beds that are containing sand altering with clay is found along Swarnamukhi River and some other places. Basic dykes traversing the granitic rocks trend essentially in an east-west direction and subordinately in a north-south to northwest-south directions. The mineralogical and chemical compositions of the dyke rocks suggest that they are dolerites.

**iii) Drainage**

The study area covers many water streams, majorly the Swarnamukhi River basin. All the streams including the Swarnamukhi River are ephemeral and rise from the Tirupati hill ranges. The streams, while flowing from the upland to lowlands, form steeply dissected valleys often covered with boulders, showing striations. The surface runoff in most of the streams is restricted to a few hours after the rain, while in the Swarnamukhi and Rallakalva Rivers, the flows last for a few days to a few weeks after the rain. For most part of the year, they are dry.

**iv) Soils**

The soils of the study area are red soils, alluvial soils, alkaline soils and calcarious soils. Red soils cover along the foot of Tirupati hill ranges and along the Mamandur-Karakambadi valley and also at some other parts. The upper layer (A-horizon) of this red soil extends about 40 cm depth from the surface and is represented by reddish brown sand and sandy loam. It crumbles easily to simple grains on applying slight pressure. It is generally low in organic matter and is moderately well drained. As these lands support little or no vegetation, these soils are extensively eroded and transported as suspended particles in flash floods. The alluvial soils occur predominantly in the south western and the southern portions of the area. The first layer (A-horizon) of these soils extends up to a depth of 35 cm and is composed of yellowish brown to light brown fine sandy loam. It is loose and moist.

The alkaline soils occur as an east-west trending belt between Tirupati and Renigunta. They are black in colour with encrustation of white sodium carbonate seen conspicuously during summer. They are similar to alluvial soils with the exception that the clay content in different soil horizons is so high that drainage is very poor. The areas covered by alkaline soils support little vegetation. As such, these soils are subjected to severe gully erosion, and at places, the soil alkalinity is so high that the land is covered with white encrustations of sodium carbonate. Also, the calcareous soils occur as patches within the alluvial soils at some places within this region.

**v) Vegetation**

The reserved forest occupies the upland area of the study. Vegetation is quite scarce on the hill ranges facing Tirupati town while it is dense with in the interior valleys in the hilly terrain of the uplands or at the foots of the hills. The forests are not properly managed. There is a large scale falling of trees to serve as a source of firewood. Man-made forest fires intended for the manufacture of charcoal are quite common in every summer. There is no programme to rise plantations in the forests or to prevent the forest fires which can also lead to extensive soil erosion in the uplands.

The plain lands are covered by minor irrigation reservoirs, which are dry or nearly dry for most part of the year and are barren of vegetation or carry weed plants. In the wetlands under the irrigation reservoirs and other dry lands in plain lands, irrigation crops like paddy, sugarcane, groundnut and vegetables are grown. The plain lands occupied by alkaline soils are mostly barren of vegetation or have crops with poor agricultural yields.

Thus, the land use and cover pattern in the study area is broadly classified into forestland, land not available for cultivation and land available for cultivation. According to the records of the Revenue Department of Andhra Pradesh state, it is estimated that the 50 percent of the land in the region is covered with the forests and 28 percent of the land is not available for cultivation. Land not available for cultivation includes rocky terrain, badlands, and land occupied by townships, streams, and burial grounds, whereas land available for cultivation is about 22 percent, which includes the registered wetland, registered dry land and Government land under cultivation. The season between July and December when rainfall is maximum is called Kharif, while the season between January and June when the rainfall is minimum is called Rabi. With available irrigation facilities, only 52 percent of cultivable land is put to irrigation in Kharif, while the corresponding figure in Rabi is only 12 percent.

**9. Climatology**

Continental type of climate with three distinct seasons: winter, summer and monsoon are prevailing in the region. The winter months are from January to February, summer season is from March to May and monsoon months are from June to December (S-W monsoon from June to September and N-E monsoon from October to December). The meteorological data such as temperature, relative humidity, wind speed and direction, and rainfall have been taken from the meteorological center situated in S.V. Agricultural College beside the University Campus (sampling site). The measurements of these parameters were measured at 7.12 AM and 2.12 PM on each day. The monthly average of temperature, humidity, wind speed and rainfall during the study period has been presented in Table 3.

**Table 3:** Monthly mean of meteorological parameters during the study period

| Month | Temperature ($^0$C) | | Relative Humidity (%) | | Wind speed (mile/hr) | Rainfall (mm/d) |
|---|---|---|---|---|---|---|
| | Max | Min | RH I | RH II | | |
| October | 32.31 | 23.06 | 79.39 | 53.23 | 2.78 | 5.63 |
| November | 29.28 | 20.92 | 84.66 | 64.50 | 2.38 | 1.50 |
| December | 27.69 | 17.77 | 83.00 | 50.23 | 3.20 | 3.40 |
| January | 28.76 | 18.59 | 82.52 | 52.74 | 3.00 | 1.00 |
| February | 30.87 | 16.66 | 84.14 | 43.11 | 3.66 | 0.00 |
| March | 35.73 | 20.92 | 73.45 | 28.45 | 3.38 | 0.00 |
| April | 37.88 | 24.93 | 66.80 | 29.77 | 3.51 | 0.00 |
| May | 38.69 | 27.61 | 59.94 | 30.55 | 6.31 | 2.83 |
| June | 35.53 | 26.16 | 70.13 | 44.40 | 5.25 | 5.25 |
| July | 35.77 | 27.37 | 57.26 | 36.03 | 7.21 | 0.44 |
| August | 34.37 | 25.20 | 66.97 | 43.68 | 5.59 | 5.83 |
| September | 34.48 | 24.39 | 61.13 | 46.37 | 3.85 | 5.04 |

**i) Temperature:** The local ambient temperature (Which is affected by solar radiation) starts to increase in February and reaches its maximum in April-May (Approx. 40 $^0$C) after which decreases to a minimum of 11 $^0$C during January. Weekly (Standard week) trend of both minimum and maximum temperatures is depicted in Fig. 5 From the Fig. 5, it is clear that the climate is characterized by high daytime temperature ranging between 16.1 and 41.2 $^0$C during summer, while during the monsoon period the temperature ranges between 13.5 and 37 $^0$C. The winter months are little bit cool with a temperature ranging between 11 and 33 $^0$C. The monthly average day temperature varied from a minimum of 16.66 $^0$C during winter (February) to maximum of 38.69 $^0$C during summer (May) (Table 3).

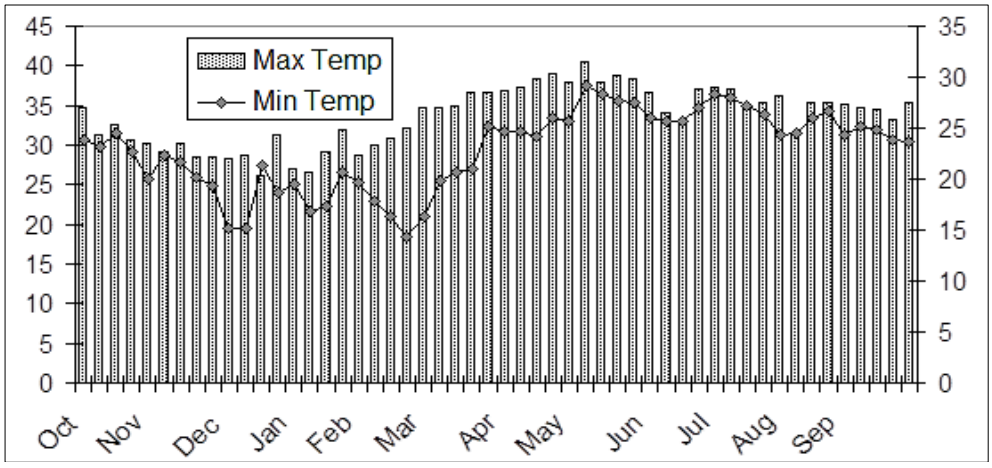


**Fig 5:** Weekly average variations in temperature ($^0$C) at Tirupati during the study period

**ii) Relative humidity**

Fig 6 shows the weekly variation in relative humidity (RH I and II). During summer, the climate becomes dry with low RH ranged between 19 and 72%, while during the monsoon period, it is wet and the RH varied between 27 and 98%. During winter also it is relatively high, ranging between 23 and 95%. The monthly average relative humidity (RH) lowers down to 28.45% during March with a maximum, 84.66% during November, of course, RH I for the months of March, April and May and RH II for November, December, January and February are more/less similar respectively (Table 3). Humidity is generally high from October to February showing the highest percent (98%) during post monsoon (December) whereas the lowest percent (19%) during summer (May).

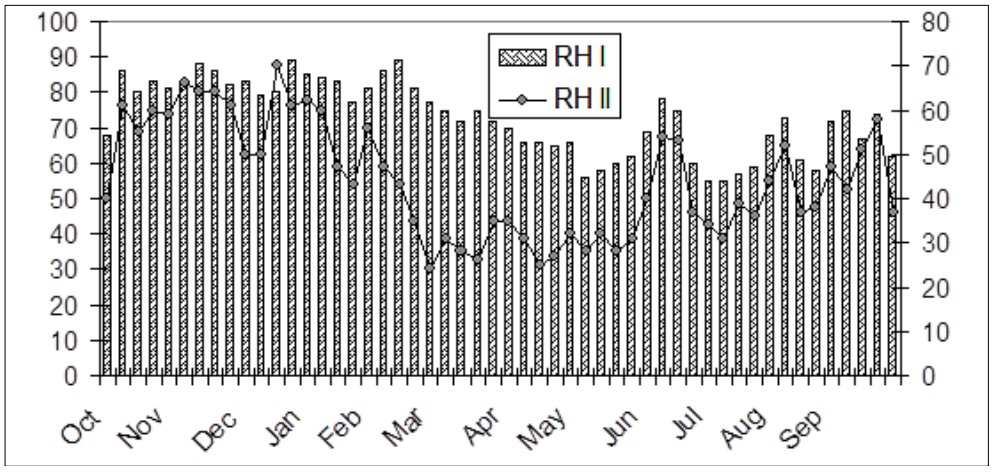


**Fig 6:** Weekly average variations in relative humidity (%) at Tirupati during the study period

**iii) Rainfall**

There is seldom much rain during the early months of the year until April. The southwest monsoon sets in the month of June and brings some rains until the end of September. The northeast monsoon, which breaks in the month of October, brings heavier rains till December. Heavy rains are often associated with the depressions and storms, which generally occur in Bay of Bengal during northeast monsoon. A total number of 66 events (i.e. > 0.5 mm) (Fig. 7) with total amount of 850 mm in volume were occurred during the study period (Oct., 2001 to Sept., 2002), in which the highest rainfall 69.4 mm in June and the lowest, 0.5 mm in January (Fig. 7), and on an average, the higher rate of rainfall 5.83 mm was observed during the month of September followed by 5.63 and 5.25 during October and June respectively, whereas there is no rain for the months of February, March and April (Table 4). Precipitation during wet season (June–December) accounted for 86.36% of the total events and 86% of the total annual rainfall volume. The wet season had a frequency of about 0.27 events per day in contrast to 0.06 events per day in the dry season, and average daily rainfall in the wet and dry seasons are 3.42 and 0.79 mm/day respectively.

The means of monthly variation in atmospheric temperature ($^0$C) and rainfall (mm) for 3-year period (June, 2000-May, 2003), depicted in Fig. 8 reveal that the study area is mostly wet during the monsoon period and dry in the summer months.

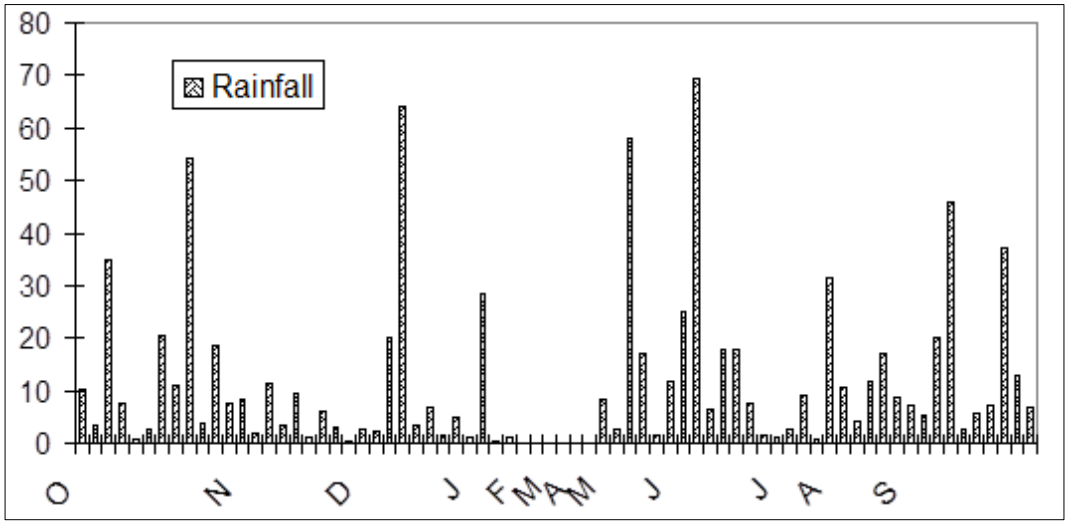


**Fig 7:** Event wise rainfall (mm) occurrence at Tirupati during the study period

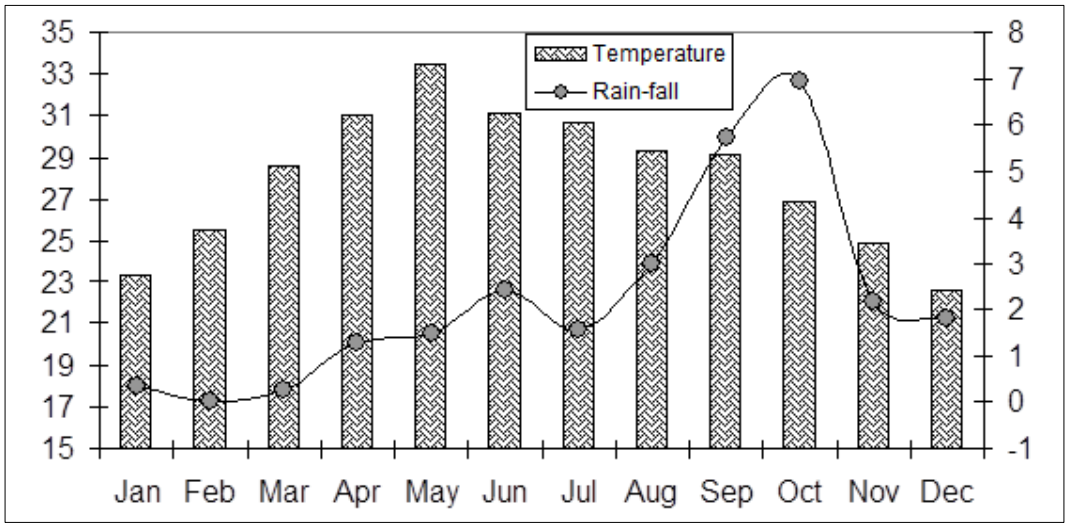


**Fig 8:** Monthly averages of temperature ($^0$C) and rainfall (mm) for 3-year period at Tirupati region

**iv) Windrose pattern**

The monthly average wind speed varied from 2.38 mile/hr (September) to 7.21 mile/hr (July). The frequency of the wind speed and direction has been depicted in Fig. 9. The greater wind speed (14.23 mile/hr) is observed during southwest monsoon (July), and lower (0.75 mile/hr) during northeast monsoon (December) whereas moderate during other parts of the year. The predominant wind direction is due east during southwest monsoon and due west during northeast monsoon. Annual wind frequency is, thus, noted to be highest in northeast followed by southwest northwest directions (Fig. 9).

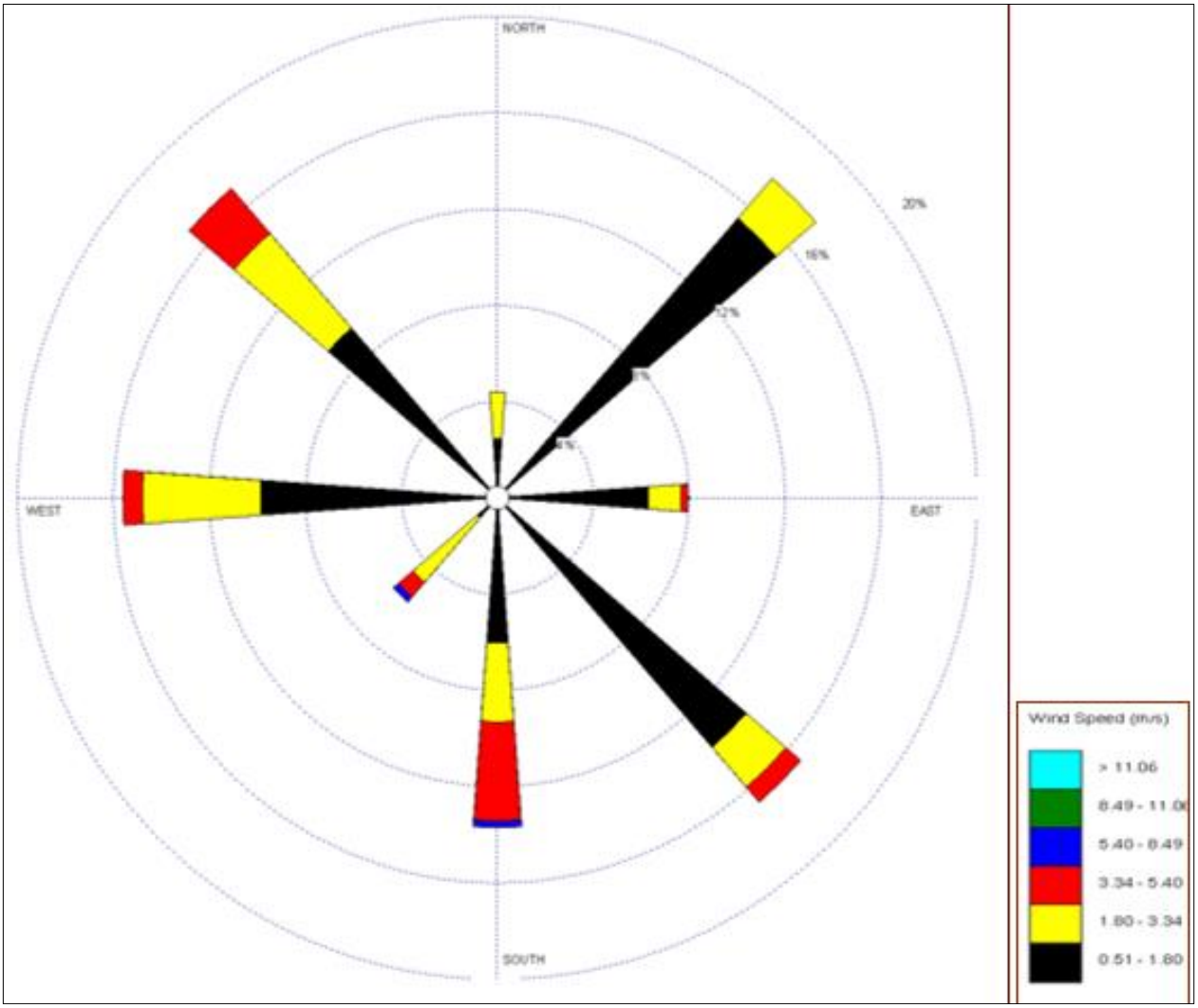


**Fig 9:** Wind rose pattern and predominant wind direction at Tirupati during study period

**10. Socioeconomic status**

Socioeconomic conditions of the area are imperative, which plays an important role in the study of environmental scenario of that area. The information on socioeconomic profile of the Tirupati region was collected from 2001 census statistics at Tirupati urban development authority (TUDA) and Revenue department of AP State Government. The town is high profile centre for business, tourism (Mainly due to pilgrims of Lord Sri Venkataswara), education and industrial activities along with higher agricultural activity in rural.

**i) Populations and their Activity**

The total population of Tirupati region is about 3,09,000 (2001 Census), residing 94.44% in Tirupati urban and 5.56% in Tirupati rural. In this, 1,58,000 are male and 1,51,000 are female with 80.37 and 66.89% literacy respectively. Also, the town is with a floating population of about 70,000 per day in the form of pilgrims of Lord Sri Venkateswara. A good percentage of people live on providing amenities to the pilgrims both at Tirupati and Tirumala apart from the employees in different disciplines but in rural the main occupation of the residents is agriculture and other services. About 31.37% of the population are working and the remaining are non-workers. Among the workers, cultivators are 0.78%, agricultural labours are 1.69% and house industrial workers are 2.81% only and the remaining belongs to other works. All the houses in the study area are electrified. Firewood and LP gas are the chief sources of cooking fuels.

**ii) Education**

The town is a very good centre for education in the region with too many numbers of institutions providing the higher education to the people living in southern region covering five districts (Chittoor, Cuddapah, Anantapur, Kurnool, and Nellore) of AP. There are two Universities namely, Sri Venkateswara University and Sri Padmavathi Mahila Viswa Vidyalayam for higher education along with two more Deemed Universities; Sanskrit Vidyapeeth for Sanskrit and Sri Venkateswara Institute of Medical Sciences (SVIMS) for medical sciences. It also has the Medical, Veterinary, Dental, Agricultural, and Engineering colleges along with much number of other academic colleges and schools for lower education.

**iii) Transportation and Communication**

Tirupati is well connected to other parts of India by air, rail, and road facility. There is flight connectivity to both Chennai and Hyderabad daily. There is a very good train facility directly to almost all cities like Chennai, Hyderabad, Bangalore, Mumbai, Delhi, etc. and the road connectivity is very convenient with a National highway (NH No. --). AP State Road Transport Corporation (APSRTC) operating about 1520 trips per day from Tirupati to other parts in southern India and to Tirumala by Tirupati depots and also about 1260 trips from outstation to Tirupati by outside depots. Also, about 150 heavy vehicles are running on highway and about 150 four wheelers may go through Tirupati in the form of

tourism. About 43,000 two wheelers, 450 three wheelers, 3,200 four wheelers and 70 heavy vehicles are running on the roads of Tirupati by the residents. Similarly, the communication facility is very good. Electronic communication is very well provided through BSNL and private organizations. The telephonic facility is well spreaded over the town with 7000 public telephone booths and about 1,80,000 land/mobile connections.

**iv) Health**

The town is with very good health care facilities such as SVIMS, BIRRDS, RUYA Govt. hospital as well as many other Nursing homes and Super specialty hospitals, providing the treatment for all the health problems with modern technology. Also, the research activity in medicine is going on.

**v) Industry**

Tirupati is with good number of industries. The major industries are located heavily at Tirupati industrial area situated at the east nearby Renigunta. The industries include manufacturing units of transformers and electrical appliances and auto parts as well as mopeds, drug and pharmaceutical industries, chemical industries such as manufacturing of silicon carbide, barium chemical factory, PVC pipes etc., flour mill, food and beverage units and a solvent extraction plant. The south-central railway is also operating a carriage repair workshop beside the industrial estate, to cater the needs of south India. There are also many other industries located in different parts of the region like a biggest manufacturing industry of lead acid batteries located at northeast; Co-operative sugar factory and few more drug and pharmaceutical industries at southeast; and few number of chemical industries, Dairy firms and ceramic manufacturing units at the western part of the Tirupati rural. Some of the small-scale industries include the semi-mechanized brick factories and the country type brick kilns located in most of the dry tanks. The granite quarries are most famous in the area in supplying road metal and dimension stones of granite on a large scale.

## 11. Conclusions

Being a very fast-growing area Tirupati was chosen as a study area to quantify the LU/LC pattern by taking considerations of NRSC. The study area, Tirupati region is located nearby the metropolitan city, Chennai, at a distance of about 145 km in southern peninsular India. The greater wind speed (14.23 mile/hr) is observed during southwest monsoon (July), and lower (0.75 mile/hr) during northeast monsoon (December) whereas moderate during other parts of the year during the time period. Some parts of the soils are loose, dry and some are wet. There is significant expansion of built-up area noticed. On the other hand, there is decrease in agricultural area, water spread area, and forest areas due to increase in industrialization. This study clearly indicates the significant impact of population, transportation, industries and its development activities on LU/LC change. Continuous urbanization and industrialization may continue to decrease the agricultural lands, forests initiating the climate changes.

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