Original Paper

Recommended Optimal Land Utilization and Farming Techniques (ROLUFS) in Pendurthi Mandal, A Geospatial Approach, Vishakhapatnam District, Andhra Pradesh, INDIA

Usha Chirala<sup>1</sup> & Bhavana Pedada<sup>1</sup>

<sup>1</sup> Department of Geo-Engineering, Andhra University, Vishakhapatnam, AP, INDIA

Received: September 22, 2020   Accepted: October 8, 2020   Online Published: November 30, 2020
doi:10.22158/ees.v3n2p139  URL: http://dx.doi.org/10.22158/ees.v3n2p139

Abstract

Integrating land and water resources is a major key in sustainable development. Managing agricultural land is a concerning task keeping the ever increasing population in mind as agriculture utilizes largest amount of water in the world. A case study of Pendurthi mandal, Vishakhapatnam district, Andhra Pradesh, India has been taken up for resource appraisal. Basic integration of land and water resources (BILWRUS), generation of thematic maps using remote sensing in conjunction with Geographical Information System, and ground laboratory techniques has been the major task. The proposed landuse has been assigned to all the 23 villages of the study area, using recommended optimal land utilization and farming techniques (ROLUFS) as per the norms set by National water Development Program for Rainfed areas (NWDPRA).

Keywords

bilwrus, rolufs, mandal

1. Introduction

Indian civilization was rich and prosperous in the ancient past. However with the ever increasing population and the changing philosophy of the governments, the traditional methods of rural lifestyle and practices have become anachronistic. This has necessitated a change in the outlook and practices in so far as rural living, agriculture, arts, crafts and administrations are concerned. In the light of this application, modern and scientific methods has become necessary and mandatory too. Inappropriate and uncontrolled use of natural resources can downgrade their quality and destroy them. Sustainable
development and optimized use of natural resources involves effective utilization of the existing resources without damaging the assets and preserves these valuable resources for the future generations. At Present, scientific and optimized management of agriculture and natural resources are considered to be important items in sustainable development. In order to achieve sustainability and optimized land allocation we can use linear programming, multi objective linear programming and Geographical Information System (GIS) approaches. Watershed Planning and management (2018).

Land use is a crucial link between human activities and the natural environment. Large parts of the terrestrial land surface are used for agriculture, forestry, settlements and infrastructure. This has vast effects on the natural environment. Land use is the most important factor influencing biodiversity at the global scale. TijanaVulević et al. (2018), freshwater availability Rosegrant et al. (2002), Sala et al. (2000). Global biogeochemical cycles, McGuire et al. (2001), and climate Brovkin et al. (1999).

Keeping the above objective in mind, the study area Pendurthi Mandal of Vishakhapatnam district with a total area of 120sqkms consisting of 23 villages, has been taken up for resource appraisal and utilization of its natural resources using modern techniques of remote sensing and GIS. With critical study, and analysis of a wealth of information related to the people of the mandal coupled with survey of India toposheets, geological maps, satellite imageries, thematic maps, Basic Integration of land and water resources (BILWRUS) has been generated, and integrated with landuse/landcover. Finally proposed landuse for all the 23mandals have been derived from Recommended optimal land utilization and farming system (ROLUFS) as per the norms set by National Water development Program for Rainfed areas (NWDPRA).

2. Review of Literature

Few studies have been carried out in and around Pendurthi mandal and Meghadrigedda, the major river that flows through the mandal. Among them are Identification of soil erosion zones with special reference to silt deposition in Meghadrigedda reservoir, Usha Chirala, Ph.D Thesis (2013), Correlation of geometric parameters for the hydrological characterization of the Meghadrigedda watershed, Vishakhapatnam, A GIS approach, Usha Chirala et.al. (2012), Nageswara Rao and Narendra, (2009 & 2006), Mapping and evaluating the urban sprawl, Nageswara Rao et al. (2008), on the ground water quality of the Meghadrigedda Watershed, Narendra and Nageswara Rao (2006), Mapping of Hydrogeomorphic features in the Pendurthi mandal using IRS data Usha Chirala (2003).

3. Study Area

The study area, Pendurthi mandal falls in Vishakhapatnam mandal in between $17^049'30''$ north latitudes and $82^012'13''$ east longitudes under SOI toposheet 650/1 and 0/2&3 on 1:50000 scale (Table 1). The total area is 120sqkm, 40m above MSL. The mandal headquarters is located 25km north-west of Vishakhapatnam and extends for a maximum distance of 20km in the north-south direction and 12km in east-west direction. The vegetation type is deciduous comprising mostly of deciduous dry and deciduous
scrub. Red soils predominates the area. Agriculture is the main economic activity of the people. Paddy is the main crop and other crops include sugarcane, groundnut, macrotyloma uniflorum (horsegram), finger millet (ragi) and sesame. There is no irrigation system; the entire activity is under dug wells, bore well and tanks. The number of tanks found after delineation are 108 covering an area of 5.22 sqkm. as per 2020 Sentinel-2 satellite data.

The location map of the study area is shown in Figure 1(a) and the sentinel data of the study area in 1(b).

Table 1. Division of Mandals (Blocks)

| Division of Mandals          | Number |
|------------------------------|--------|
| Narsipatnam division        | 13     |
| Paderu agency division      | 11     |
| Vishakhapatnam division     | 19     |
| **Total**                   | **43** |

Figure 1(a). Location Map of the Study Area
4. Physiography

The study area forms part of Vishakhapatnam fold belt, and the foliation generally strikes NE-SW. In the central part of the EGGB there are four main tectono thermal events dated at 2600, 2200-1900, 1180-950, 625-500 Ma Fonarev et al. (1998). Majority of the area is plain and under agriculture, with hills in the eastern, northern and southern parts of the mandal. The predominant rock type is khondalite, followed by charnockites, kallonized clay and quartzite. The charnockites occur as outcrops in small patches. Some of the big rock (khondalite quarries) are at Juttada and Chinamushiwada. Laterite with iron oxide concretions is exposed near Pendurthi. All the hills inside the study area are khondalites. Workable deposits of graphite are reported near Narava (Figure 2a).
The study area enjoys sub-tropical climatic conditions and the temperature ranges between min 14°-20°C during the month of December and maximum 33°-42°C during May. The area receives rainfall during June to December from both south-west and north-east monsoon and the average rainfall is 1110mm per annum (Source: Zilla Praja Parishad, Vishakhapatnam, Andhra Pradesh).

5. Hydrology of Meghadrigedda Reservoir

The study area has numerous ephemeral streams, and depicts dendritic type of drainage which is found in regions where rocks offer uniform resistance in a horizontal direction. The highest order obtained is 6th, most part of this particular subbasin comes under the jurisdiction of the study area. Meghadrigedda is an east flowing river taking its rise from the Eastern Ghats from the Nandikonda hill. It flows south upto karupavani village and thereafter in south eastern direction until it joins the sea near Dolphin’s nose, Vishakhapatnam town (Figure 2b). Meghadrigedda reservoir drains an area of 220.77 sqkm.

The Meghadrigedda reservoir occupies 6.6 sqkm in the study area, hence deserves a mention separately. The geographical dam site is East Longitude 83°11’27” and North Latitude 17°45’54”. Meghadrigedda reservoir was formed near the confluence of Meghadrigedda and Narava rivers to supply 8MGD drinking water to the people of the Vishakhapatnam city. The flood bank was formed on the left side of the reservoir to protect the Howarh-Vizianagaram railway line. The FRL of the reservoir is fixed at 61.00m. The gross capacity of the reservoir at FRL is estimated to be 1169 mcf. The dead storage is 1043 mcf.

The catchment area is under the influence of S.Kota, Vishakhapatnam, Chodavaram and Anakapalli rain gauge stations. The catchment is studded with numerous tanks above the full reservoir level. Below the reservoir there exists wetland of 510 acres on the right sided which is stabilized under the reservoir scheme. Lower riparian rights have been considered while working out the proposals for the reservoir scheme. The catchment area is influenced by both south west and north east monsoons form June to September, and flash floods occur mostly in October and November due to the influence of cyclones in the Bay of Bengal (Source: Zilla Praja Parishad, Vishakhapatnam, Andhra Pradesh). The drinking water facilities are met by 385 bore wells, 15 open wells and 1 piped water supply. The minor irrigation sources are 115, along with 15 sprinklers and 4 drips covering an ayacut of 1835 hectares (18.35 sqkm) where tanks cover 1.24 sqkm, tube wells 6.55 sqkm dug wells 4.55 sqkm, sprinklers 0.12 sqkm and drip irrigation covering 0.03 sqkm as per the year 2018-2019 (source: Chief Planning Officer, Vishakhapatnam, Andhra Pradesh).

6. Methodology

Sentinel data 2 has been georeferenced using Survey of India (SOI) topographical maps 65O/1 and 65O/2&3 on 1:50000 which cover the study area. The drainage network has been demarcated as a vector layer in *.shp format. Individual maps as well as thematic maps have been studied in combination. Generation of basic resources and thematic maps using remote sensing in conjunction with ground laboratory technique has been the major task for integration. Geology, geomorphology and structural
maps have been combined to achieve at ground water potential zones. Basic Integration of land and water resources (BILWRUS) was generated using slope, soil, hydrogeomorphology and landuse/landcover (Table 6). Schematic chart showing methodology adopted for integrated resource analysis for the study area is shown in (Figure 8). Various intersecting polygons have been classified according to combinations, and the two composite maps have been integrated to arrive at Recommended optimal land utilization and farming techniques (ROLUFS). Finally present landuse and proposed landuse of the study area has been displayed in Table 7.

![Figure 3(a). Slope and 3(b) Hydrogeomorphology](image)

7. Thematic Maps

7.1 Slope

Slope, aspect and altitude are the important terrain parameters which influence micro climatic temperature regime and runoff which play a significant role in soil development, vegetation and crop productivity. Slope plays a very important role in the utilization of the prevailing land surface. A higher slope contributes very high erosion as compared to lower slope to less erosion. The first paper in which observed slope form is applied to the elucidation of the origin of landforms was studied by Sorby (1850) of the origin of the striking steep sided valleys. Significant contributions have been made in calculation of slope by Wentworth (1930), Raisz and Henry (1937), Robinson (1948), Miller (1953), and Strahler (1957).

Highest slopes of more than 15 degrees to 35 degrees are confined to south-western, eastern and norther parts. Major part of the area is under less than 1 degree (Figure 3(a) and Table 2).
Table 2. Contour Spacing Related to Percentage Slope

|   | Slope   | Lower and upper limits of contour spacing |
|---|---------|------------------------------------------|
| 2 | 0-1     | >4cm                                      |
| 3 | 1-3     | 1.33-4                                   |
| 4 | 3-5     | 0.8-1.33                                  |
| 5 | 5-10    | 0.4-0.8                                  |
| 6 | 10-15   | 0.26-0.4                                  |
| 7 | 15-35   | 0.11-0.26                                 |
| 8 | >35     | 0.11 and less                             |

7.2 Hydrogeomorphic Units

According to Jean Bhunes, “there is no house or human habitation in the building of which man has not had to take into account the proximity of water” in the archaeological excavations of the Saraswati and Indus Valley civilizations well developed water works came to light. Vishnu Kautilya (4th century B.C) in his book “Artha Shastra” mentioned about the importance of water resources in the economy of the state. Varahamira (3rd Century B.C) in his book “Brihat Samhita” discussed about the ground water exploration and quality.

Extraction of hydrological parameters from remotely sensed data were done as early as by Jackson and Mcuen (1979) Kelly et al. (1977), Peck et al. (1981), Johnson et al. (1982), Peck et al. (1983).

Hydrogeomorphology deals with the ground water occurrence, its distribution and has the interrelationships with rock types, geological structures, landforms and surface recharge conditions. Groundwater potential of any area is mainly dependent on geology (various rock types), geomorphology (different landforms) and structures (Lineaments, fractures etc.). The related hydrogeological characters have been considered, evaluated and presented together as hydrogeomorphological units. The occurrence of ground water plays an important role in sustainable agricultural operations.

Twelve hydrogeomorphic units have been categorized in the study area viz, Pediplain moderate, Pediplain shallow, structural hills, Inselbergs, residual hills, pediment zone and pediment. The three geomorphic units made up of pediplain moderate, pediplain shallow, pediplain and pediment zones dominate the study area, followed by small patches of residual hills and inselbergs (Figure 3b and Table 3). Ground water prospects map of the study area shows a plenty of scope to increase ground water sources. There is no irrigation system; the entire activity is under dug wells, bore well and tanks. The total number of tanks are 108 tanks and tank area is 5.22sqkm, the smallest tank is in Juttada covering 0.01sqkm and the largest tank is in Pinagadi covering an area of 0.87sqkm (Sentinel data 2020, Figure 3(b) and Table 3).
7.2.1 Pediplain moderate (PPM)
There are plain table lands with very gentle to nil slopes (flat table lands) with ground water potential being moderate to good. It has moderately thick 5-20m over burden of weathered material of varying lithology. This unit covers the western and northern parts of the mandal lying in the contour interval of 10-30m. The pediment is overlaid with moderate layer of overburden (cobble to clay). Ground water prospects are moderate to good because the unit is adjacent to rivers Meghadrigedda and Naravagedda.

7.2.2 Pediplain shallow (PPM)
These are flat and smooth surface of buried pediment with shallow 0-5m of overburden of weathered material of varying lithology. Ground water prospects are poor to moderate. This unit mostly covers the eastern part of the mandal, and lies to some extent in western and southern parts, and is between the contours 20-30m. In this layer the pediment is laid with a thin layer of overburden and is exposed to shallow depths.

7.2.3 Pediment Zone (PZ)
It is a transitory zone between the debris slope and the next important hill slope element the Pediment. Nookaraju and Vaidyanaadhan (1971). This zone lies in the contour interval of 50-100m. It’s noticeable on the foot hills near the villages Porlapalem, Cheemalapalli, Vepagunta, Sowbhagyapuram and Mudapaka.
Being at the foot of the hills they are composed of loose and rocky outcrops with a thin a veneer of detritus. The pediments in this unit have developed on charnockites and khondalites. Ground water potential depends on the thickness of the debris. Wide pediments have been observed on the eastern and southern sides of the mandal. Moderate ground water aquifers are identified in this zone.

7.2.4 Pediment (P)
Pediment as stated by Twidale (1976) is a complex phenomenon and single explanation applies to all pediments; several different processes could apparently produce similar landforms.
Pediment is noticeable in Chintagatla, Mudapaka and Vepagunta villages. It lies in the contour interval of 30-50m. It has a gentle slope and rocky surface. The joints in the khondalites will be the channels of recharge to groundwater.

7.2.5 Inselbergs (I)
Expansion of the pediment or series of pediments may continue until all the remains of the original mountain mass are scattered knolls which rise above its surface. Such hills are analogue to Mouad rocks on a peneplain surface and were originally and to some extent are still, called Inselbergs. Thornbury (1999). These inselbergs are noticed at four places lying in the contour interval of 100 to 200m near Sowbhagyapuram (281 and 211m), Mudapaka (169m) and in Chintagatla (211m) made of charnockites. The slope of these inselbergs is between 6 to 18 degrees.
7.2.6 Residual Hills (RH)
These residual forms are relic features lift out during scrap retrieval and pediplanation. These boulder maps owe their origin to mineralogical resistance (Twidale, 1976) and to primary parting/pacing Schumm and Chorley (1966) Garner (1974). These isolated hills are noticed at two places lying in the contour interval of (80-100m) Jerripotulpalem village (96m) and Pulagalipalem (98m) and are also made of charnockites. The slope of the hills varies from 12 to 18 degrees. The slope and sparse vegetation accounts to high runoff, hence ground water prospects are very poor. Mass wasting is prevalent in the form of soil creep.

7.2.7 Structural Hills (SH)
There are five structural hills, Yerrakonda (370m), Narava (375m), Vepgunta (263m), Porlupalem (324m), and near Mudapaka (321m). These are made up of well jointed Khondalites. The slope of the hills is in between 12 to 13 degrees. The Yerrakona hill range in the reserve forest is named after the forest. The Narava hill and the reserved forest are named after the Narava village.

| S.No | Hydrogeomorphic unit    | Area in sqkm | Percentage of the study area |
|------|-------------------------|--------------|------------------------------|
| 1    | Structural hills        | 17.70        | 14.75                        |
| 2    | Residual hills          | 0.50         | 0.41                         |
| 3    | Inselberg               | 0.52         | 0.43                         |
| 4    | Pediment zone           | 12.03        | 10.02                        |
| 5    | Pediment                | 3.10         | 2.58                         |
| 6    | Pediment shallow        | 39.22        | 32.68                        |
| 7    | Pediment moderate       | 46.02        | 38.35                        |
| 8    | Total                   | 120          | 100.00                       |

7.3 Ground Water Prospects and Water Quality
Ground water hydrology may be defined as the science of the occurrence of the distribution and movement of water below the surface of the Earth Todd (1980). Ground water prospects map is prepared for the study area (Figure 4).

92 samples were collected from the 23 villages of the study area (Table 4). The hydrochemical data includes the samples from both bore and open wells for certain parameters like pH, TDS, chlorides, flourides, hardness, alakalinity etc. These are determined by using the standard procedures (US salinity Laboratory, 1954; USGS, 1996; Hem, 1970; APHA, 1971) in the laboratory.
pH is determined electronically with a direct reading called public health meter. Chloride is estimated by trititating the water sample against shear nitrate solution (0.005N) using potassium chromate indicator. Total alkalinity of water sample is estimated by trititating against standard sulphuric acid using methyl orange as indicator and represented as cacosin mg/l. Hardness of the water sample is determined by trititating against EDTA solution (0.02N) and expressed as mg/l. Flouroide is determined by the Zirinium alizarine method and is expressed as mg/l (Figure 5(a), (b) and (c)).
7.4 Soils and Soil Erodability

Barring the hills and the water bodies the rest of the area is covered with alluvial soils and red loams and clays. The gravelly loams are confined to the peripheral areas of the hills in the eastern and northern part of the study. On the basis of the soil map prepared, the soils of the Pendurthi mandal have been categorized into alluvial, red loams and clays, gravelly loams and shallow skeletal sandy soils which are confined to the mountains. Figure 6(a). The soils of Pendurthi are free from salinity hazard, but the study area is subject to varying degrees of erosion hazard depending upon the topographic location. The soil fertility is low to medium, necessitating the application of both organic and chemical fertilizers for obtaining good yields. Soil samples were collected for estimation of physical and chemical characteristics in the Laboratory (Anakapalli soil Laboratory, Ankapalli, Vishakhapatnam district). Based on the soil analysis, it can be stated that the soil reaction (pH) is tending to be alkaline. The soluble salt content is normal (less than 0.1 mhos/cm). The fertility status in respect of organic carbon is low, available P is low to medium attaining good crop yields. The spatial distribution of the soils is shown in (Table 5).

Table 4. Chemical Analysis of the Water Samples of the Study Area

| No | Name of the Village | Type of Source | pH | T.D.S | Total Alkalinity as CaCO₃ | Total Hardness as CaCO₃ | Fluoride as F⁻ | Chloride as Cl⁻ | Nitrate | Magnesium as Mg²⁺ | Iron as Fe²⁺ | Calcium as Ca²⁺ | Carbonate as CaCO₃ | Remarks |
|----|---------------------|----------------|-----|-------|--------------------------|------------------------|---------------|----------------|---------|-------------------|-------------|-----------------|-------------------|---------|
| 1  | Pendurthi (W.A)     | B. W           | 7.4 | 570   | 135                      | 524                    | 0.2           | 72             | Nil     | 33                | Nil          | 116             | 389               | Potable |
| 2  | Pendurthi near Vet Hos | B. W         | 6.8 | 1500  | 220                      | 324                    | 0.2           | 256           | Nil     | 28                | Nil          | 208             | 104               | Potable |
| 3  | Jerripotulapalem    | B. W           | 8.2 | 480   | 200                      | 180                    | 0.6           | 60            | Nil     | 22                | Nil          | 90              | Nil                | Potable |
| 4  | MPWS Mudapaka colony | B. W        | 8.2 | 570   | 240                      | 180                    | 0.4           | 60            | Nil     | 20                | Nil          | 100             | Nil                | Potable |
| 5  | MPWS at Gurrampalem | O. W          | 8.2 | 1680  | 310                      | 320                    | 0.4           | 300           | Nil     | 50                | Nil          | 110             | 10                | Excess in TDS |
| 6  | MPWS SR Puram       | B. W           | 8.2 | 1630  | 340                      | 460                    | 0.4           | 340           | Nil     | 36                | Nil          | 310             | 120               | Excess in TDS & Calcium |
| 7  | Juttada Purushotam puram | O. W     | 8.2 | 1390  | 340                      | 420                    | 0.2           | 230           | Nil     | 44                | 40           | 240             | 80                | Potable |
| 8  | Pulagalipalem       | B. W           | 7.3 | 1200  | 450                      | 380                    | 0.1           | 160           | Nil     | 60                | Nil          | 120             | Nil                | Potable |
| 9  | Chinnamushidwada (MPWS) | O. W     | 7.5 | 660   | 260                      | 220                    | 0.4           | 60            | Nil     | 24                | 40           | 120             | Nil                | Potable |
| No. | Location            | O. W | O. W | Total | TDS | TH | Ca | Mg | CH | Nil | Nil | Nil | Nil | Potable | Excess in TDS | TDS, TH, CL, Mg, Ca | TDS & Ca | Excess in Ca hardness | TDS, TH, Mg&CH | TDS, TH, CH | TDS, TH, THk&CH |
|-----|---------------------|------|------|-------|-----|----|----|----|----|-----|-----|-----|-----|---------|---------------|-------------------|----------|----------------------|----------------|-------------|-------------------|
| 11  | MPWS at Chimalapaluni | 8.5  | 960  | 370   | 240 | 0.2| 100| Nil| 65 | Nil | 130 | 150 | Potable |                     |                   |                       |          |                     |                |             |                   |
| 12  | Porlupalem          | 8.5  | 2580 | 430   | 610 | 0.4| 520| Nil| 112| Nil | 150 | 180 | Excess in TDS |               |                   |                       |          |                     |                |             |                   |
| 13  | Vepagunta           | 7.5  | 920  | 280   | 270 | 0.2| 100| Nil| 30 | Nil | 160 | Nil | Potable |                     |                   |                       |          |                     |                |             |                   |
| 14  | MPWS at Peddagadi  | 7.5  | 1480 | 230   | 280 | 0.4| 270| Nil| 60 | Nil | 30  | 50  | Potable |                     |                   |                       |          |                     |                |             |                   |
| 15  | MPWS at Pinagadi   | 7.5  | 730  | 180   | 220 | 0.4| 60 | Nil| 43 | Nil | 50  | 60  | Potable |                     |                   |                       |          |                     |                |             |                   |
| 16  | Rampuram            | 7.5  | 1090 | 160   | 190 | 0.1| 180| Nil| 34 | Nil | 50  | 30  | Potable |                     |                   |                       |          |                     |                |             |                   |
| 17  | Gorapalli           | 7    | 1500 | 160   | 320 | 0.4| 340| Nil| 60 | Nil | 70  | 160 | Potable |                     |                   |                       |          |                     |                |             |                   |
| 18  | MPWS at Saripalli  | 8    | 1630 | 230   | 300 | 0.6| 320| Nil| 46 | Nil | 110 | 70  | Potable | Excess in TDS |               |                       |          |                     |                |             |                   |
| 19  | Rayyayapeta at Peddagadi | 8    | 900  | 240   | 260 | 1  | 70 | Nil| 46 | Nil | 70  | 20  | Potable | Excess in TDS |               |                       |          |                     |                |             |                   |
| 20  | Gorapalli Elementary School | 7.5  | 5240 | Nil   | 1860| 0.2| 1880| Nil| 136| Nil | 1300| Nil | Potable | Excess in TDS, TH, CL, Mg, Ca |                   |                       |          |                     |                |             |                   |
| 21  | Saripalli SC colony | 8.5  | 2900 | 380   | 480 | 0.6| 660| Nil| 48 | Nil | 280 | 100 | Excess in TDS & Ca |               |                       |          |                     |                |             |                   |
| 22  | Pinagadi NH roadside | 8    | 1010 | 340   | 280 | 0.4| 260| Nil| 49 | Nil | 72  | Nil | Potable | Excess in Ca hardness |               |                       |          |                     |                |             |                   |
| 23  | Pinagadi            | 8.2  | 1040 | 220   | 480 | 0.2| 860| Nil| 82 | Nil | 143 | 260 | Potable | Excess in TDS, TH, Mg&CH |                   |                       |          |                     |                |             |                   |
| 24  | Pinagadi            | 8.2  | 3060 | 348   | 1240| 0.2| 240| Nil| 288| Nil | 80  | 890 | Potable | Excess in TDS, TH, CH |                   |                       |          |                     |                |             |                   |
| 25  | Laxmipuram          | 8.4  | 1500 | 296   | 610 | 0.2| 280| Nil| 130| Nil | 64  | 310 | Excess in TDS, TH, THk&CH |                  |                       |          |                     |                |             |                   |
| 26  | Laxmipuram          | 8.2  | 1720 | 292   | 630 | 2  | 1360| Nil| 110| Nil | 170 | 340 | Excess in TDH, THk&CH |                  |                       |          |                     |                |             |                   |
| 27  | Laxmipuram          | 8.4  | 3120 | 468   | 1080| 0.3| 430| Nil| 243| Nil | 56  | 610 | Excess in TDH, THk&CH |                  |                       |          |                     |                |             |                   |
|   | Location | Type | Zone | TDH | TH | CH | Fl | Mg | Excess in |
|---|----------|------|------|-----|----|----|----|----|-----------|
| 28 | Laxmipuram | B.W | 8.2  | 1770 | 260 | 690 | 0.2 | 1540 | Nil | 150 | Nil | 68 | 430 | TDH, TH & CH |
| 29 | Laxmipuram | B.W | 8.2  | 1060 | 380 | 680 | 0.3 | 560  | Nil | 132 | Nil | 142 | 300 | TH & CH |
| 30 | Laxmipuram | B.W | 8.4  | 1011 | 820 | 664 | 3   | 456  | Nil | 153 | Nil | 36  | Nil | TH, Fluoride & Mg |
| 31 | Laxmipuram | B.W | 8.6  | 1040 | 600 | 749 | 1.8 | 400  | Nil | 151 | Nil | 130 | 140 | TH, Fluoride & Mg |
| 32 | Laxmipuram | B.W | 8.5  | 840  | 580 | 372 | 0.3 | 200  | Nil | 74  | Nil | 66  | Nil | Potable |
| 33 | Laxmipuram | O.W | 8.9  | 890  | 540 | 428 | 1   | 190  | Nil | 94  | Nil | 40  | Nil | Potable |
| 34 | Pinagadi  | O.W | 8    | 5610 | 272 | 3040| 0.2 | 1300 | Nil | 527 | Nil | 870 | 2760 | Excess in TDH, TH, CL, Mg, Ca & CH |
| 35 | Pinagadi  | O.W | 7.8  | 1900 | 332 | 1300| 0.3 | 2280 | Nil | 277 | Nil | 160 | 970 | Potable |
| 36 | Pinagadi  | B.W | 8.2  | 1880 | 590 | 524 | 0.3 | 260  | Nil | 110 | Nil | 42  | Nil | Potable |
| 37 | Pinagadi  | B.W | 8.2  | 1040 | 480 | 240 | 0.3 | 140  | Nil | 50  | Nil | 26  | Nil | Excess in TDS & Fluoride |
| 38 | Porlupalem| B.W | 8.8  | 700  | 440 | 340 | 0.8 | 200  | Nil | 76  | Nil | 26  | Nil | Excess in TDS & Fluoride |
| 39 | Porlupalem| O.W | 8.7  | 1120 | 450 | 344 | 2.8 | 190  | Nil | 68  | Nil | 64  | Nil | Excess in TDS & Fluoride |
| 40 | Porlupalem| B.W | 8.8  | 1700 | 454 | 280 | 2   | 100  | Nil | 41  | Nil | 110 | Nil | Potable |
| 41 | Porlupalem| O.W | 8.6  | 3560 | 510 | 436 | 2   | 260  | Nil | 147 | Nil | 32  | 126 | Potable |
| 42 | Pinagadi  | B.W | 8.4  | 1210 | 488 | 932 | 0.4 | 336  | Nil | 82  | Nil | 48  | Nil | Potable |
| No. | Location | Type | TDS | TH | CH | Excess in TDS, TH, CH |
|-----|----------|------|-----|----|----|---------------------|
| 43  | Pinagadi | O.W  | 8.4 | 1840 | 362 | 656 | 0.2 | 488 | Nil | 135 | Nil | 96 | 304 |
| 44  | Pinagadi | B.W  | 9   | 1030 | 490 | 472 | 2.2 | 280 | Nil | 79  | Nil | 148 | Nil |
| 45  | Pinagadi | O.W  | 8.8 | 790  | 548 | 380 | 2   | 190 | Nil | 60  | Nil | 110 | Nil |
| 46  | Pinagadi | B.W  | 8.4 | 1050 | 410 | 368 | 2   | 360 | Nil | 77  | Nil | 52  | Nil |
| 47  | Pinagadi | B.W  | 8.5 | 710  | 510 | 280 | 1.8 | 140 | Nil | 60  | Nil | 32  | Nil |
| 48  | Cheemalapalli | B.W | 8.4 | 700  | 350 | 320 | 2   | 144 | Nil | 34  | Nil | 180 | Nil |
| 49  | Cheemalapalli | B.W | 8.5 | 630  | 430 | 268 | 1.8 | 80  | Nil | 56  | Nil | 37  | Nil |
| 50  | Cheemalapalli | B.W | 8.4 | 650  | 490 | 290 | 1.8 | 20  | Nil | 63  | Nil | 32  | Nil |
| 51  | Cheemalapalli | B.W | 8.4 | 740  | 580 | 360 | 1.8 | 100 | Nil | 66  | Nil | 92  | Nil |
| 52  | Saripalli | B.W  | 8.4 | 1830 | 480 | 660 | 0.8 | 752 | Nil | 138 | Nil | 92  | 180 |
| 53  | Saripalli | B.W  | 8.6 | 1510 | 420 | 652 | 0.4 | 508 | Nil | 148 | Nil | 92  | 280 |
| 54  | Saripalli | B.W  | 8.6 | 1680 | 440 | 790 | 0.8 | 404 | Nil | 178 | Nil | 40  | 350 |
| 55  | Saripalli | B.W  | 8.5 | 1190 | 440 | 408 | 0.4 | 1180 | Nil | 75  | Nil | 90  | Nil |
| 56  | Saripalli | O.W  | 9   | 1320 | 400 | 500 | 0.4 | 220 | Nil | 114 | Nil | 26  | 100 |
| 57  | Saripalli | B.W  | 9   | 960  | 320 | 220 | 2.2 | 160 | Nil | 39  | Nil | 58  | 100 |
| 58  | Saripalli | B.W  | 8.8 | 780  | 490 | 200 | 2.1 | 260 | Nil | 34  | Nil | 56  | 100 |
| 59  | Rajayapeta | B.W | 8.6 | 640  | 460 | 52  | 0.8 | 68  | Nil | 1   | Nil | 28  | 100 |
| 60  | Rajayapeta | B.W | 8.7 | 400  | 280 | 44  | 0.4 | 64  | Nil | 1   | Nil | 28  | 100 |
| 61  | Rajayapeta | O.W | 8.7 | 400  | 280 | 260 | 0.8 | 52  | Nil | 56  | Nil | 32  | 100 |

Published by SCHOLINK INC.
| 62 | Rajayapeta | B.W | 8.6 | 620 | 320 | 306 | 0.2 | 116 | Nil | 58 | Nil | 66 | 100 | Potable |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 63 | Gurrampalem | O.W | 9 | 960 | 460 | 370 | 0.3 | 462 | Nil | 80 | Nil | 42 | 100 | Potable |
| 64 | Gurrampalem | B.W | 8.8 | 1000 | 400 | 440 | 0.6 | 240 | Nil | 92 | Nil | 60 | 40 | Potable |
| 65 | Gurrampalem | O.W | 8.8 | 600 | 320 | 330 | 0.2 | 88 | Nil | 58 | Nil | 90 | 10 | Potable |
| 66 | Gurrampalem | B.W | 8.4 | 840 | 370 | 640 | 1 | 160 | Nil | 140 | Nil | 52 | 270 | Excess in TH&CH |
| 67 | Gurrampalem | B.W | 8.6 | 1400 | 600 | 210 | 2.6 | 360 | Nil | 44 | Nil | 26 | Nil | Excess in Fluoride |
| 68 | Gurrampalem | B.W | 8.2 | 1300 | 670 | 456 | 1 | 352 | Nil | 100 | Nil | 40 | Nil | Potable |
| 69 | Mudapaka | O.W | 8.2 | 1090 | 320 | 260 | 0.2 | 310 | Nil | 44 | Nil | 34 | Nil | Potable |
| 70 | Mudapaka | B.W | 8.6 | 440 | 260 | 220 | 0.2 | 100 | Nil | 32 | Nil | 86 | Nil | Potable |
| 71 | Mudapaka | O.W | 8.7 | 410 | 320 | 200 | 2.4 | 40 | Nil | 36 | Nil | 48 | Nil | Excess in Fluoride |
| 72 | Mudapaka | B.W | 8.3 | 1840 | 320 | 836 | 0.4 | 740 | Nil | 143 | Nil | 50 | 560 | TDS, CH,C |
| 73 | Mudapaka | B.W | 8.8 | 520 | 380 | 272 | 0.6 | 410 | Nil | 41 | Nil | 100 | Nil | Potable |
| 74 | S.R. Puram | B.W | 8.4 | 1000 | 590 | 644 | 0.2 | 316 | Nil | 151 | Nil | 20 | 54 | Excess in TH & MG |
| 75 | S.R. Puram | B.W | 8.5 | 820 | 260 | 600 | 0.2 | 128 | Nil | 126 | Nil | 78 | 384 | Excess in TH & CH |
| 76 | S.R. Puram | O.W | 8.1 | 960 | 440 | 310 | 0.4 | 252 | Nil | 60 | Nil | 52 | 384 | Potable |
| 77 | Saripalli MPWS | B.W | 8.4 | 1400 | 330 | 460 | 0.6 | 490 | Nil | 92 | Nil | 22 | 130 | Potable |
| 78 | Chinamushivada PWGS | B.W | 8.6 | 880 | 260 | 460 | 0.6 | 138 | Nil | 94 | Nil | 74 | 200 | Excess in TH, MG, CH ETC |
| 79 | Purushotam Puram PWS | B.W | 8.6 | 540 | 270 | 280 | 0.6 | 50 | Nil | 50 | Nil | 62 | 10 | Potable |
| 80 | Purushotam Puram PWS | B.W | 8.5 | 940 | 560 | 440 | 0.4 | 150 | Nil | 80 | Nil | 84 | Nil | Potable |
| 81 | Pendurti OW | B.W | 8.4 | 730 | 280 | 220 | 0.3 | 90 | Nil | 40 | Nil | 53 | Nil | Potable |
| 82 | Mudapaka | B.W | 8.5 | 660 | 210 | 200 | 0.4 | 110 | Nil | 40 | Nil | 32 | Nil | Potable |
| 83 | Gurrampalem | O.W | 8.4 | 1900 | 240 | 420 | 0.4 | 84 | Nil | 94 | Nil | 28 | 180 | Potable |
| 84 | Rampuram | B.W | 7.8 | 1600 | 200 | 624 | 0.6 | 420 | Nil | 115 | Nil | 48 | 420 | Excess in TH, MG, |

*Published by SCHOLINK INC.*
|   | Location   | Type | TH | TDS | CL | MG | CH | Excess in | Potable | Excess in | TDS | CL | MG |
|---|------------|------|----|-----|----|----|----|-----------|---------|-----------|-----|----|----|
| 85 | Rampuram   | O.W  | 8.7| 1720| 270| 490| 0.4| 500       | Nil     | 92        | Nil  | 110| 270|
| 86 | Rampuram   | O.W  | 8  | 1010| 260| 490| 0.4| 80        | Nil     | 80        | Nil  | 84 | 160|
| 87 | Rampuram   | B.W  | 8  | 2400| 300| 1200| 0.3| 1020      | Nil     | 243       | Nil  | 200| 460|
| 88 | Rampuram   | O.W  | 8  | 2400| 300| 1140| 0.2| 1060      | Nil     | 219       | Nil  | 84 | 160|
| 89 | Rampuram   | B.W  | 8.2| 200 | 260| 1080| 0.3| 910       | Nil     | 210       | Nil  | 220| 420|
| 90 | S.R. Puram | B.W  | 8.7| 1240| 300| 380 | 0.8| 246       | Nil     | 78        | Nil  | 55 | 80 |
| 91 | Rampuram   | B.W  | 8.8| 980 | 220| 180 | 0.3| 142       | Nil     | 37        | Nil  | 28 | Nil|
| 92 | Juttada    | O.W  | 8.4| 1120| 385| 0.5 | 200| Nil       | 77      | Nil       | 77   | -  | -  |

*Note:* *B.W( Bore well), O.W(Open Well).*

**Figure 6(a). Soil and Figure 6(b). Soil Erodibility**
Soil erodibility map has also been prepared and has been categorized into three categories. Figure 6(b). Slight erosion (e1) these areas are flat having none to slight degradation in the form of sheet wash resulting in the loss of 0.5 cm top soil.

Moderate erosion (e2). In moderate erosion soil profile loses about 50-75 percent of the soil erosion.

Severe erosion (e3) when the soil profile has lost the entire surface horizon, and also a part of subsurface erosion, it is said to be severely eroded.

| S.No | Category                  | Area in sqkm | Percentage of the study area |
|------|---------------------------|--------------|------------------------------|
| 1    | Alluvial soil             | 39.22        | 32.68                        |
| 2    | Red loams and clays       | 41.56        | 34.63                        |
| 3    | Gravelly loams            | 15.20        | 12.66                        |
| 4    | Shallow skeletal sandy soils | 16.45      | 13.70                        |
| 5    | Reservoir                 | 6.60         | 5.50                         |
|      | Total                     | 120          | 100                          |

7.5 Landuse Landcover

Landuse refers to “mans” activities and the various uses which are carried out on the land. Landcover refers to natural vegetation, water bodies, rock/soil besides any artificial cover that may result due to land transformation. The terms landuse and landcover are apparently very closely related and are mutually dependent. According to Vink (1975), the use to which land in a certain region at a certain time is put to use is known as landuse. Based on the 1920 census data (USA) Weaver 1954 published a land use map of that country. Based on Stamps (1950) land utilization system numerous studies were carried out in the Eastern European countries. Landuse maps were prepared by Avery (1965) for the USA and Bruyin (1974) for Netherlands. The world Atlas of Agriculture (1973) was based on the landuse survey map of Vink (1975).

It is estimated that the human footprint has affected 83 percent of the global terrestrial land surface and has degraded about percent of the ecosystems services in the past 50 years alone. Land Use and land cover (LUCC) change has been the most visible indicator of the human footprint and the most important driver of loss of biodiversity and other forms of land degradation (SD21, 2012).

The landuse/landcover information mapped have been arranged and grouped into a framework of landuse/landcover classification system primarily developed for interpretation with remotely sensed data. The landuse/landcover has been classified into level I and level II classes, National Remote
Sensing Center (NRSA) Here, the “level” indicates the degree of information content. Higher the level, greater will be the information. Variations in multispectral responses of the different landcover categories enable detection, identification and categorization of different landuse classes commensurate with the scale of mapping. Temporal variability of landuse/landcover evidenced by seasonal changes in water bodies and agricultural crops as well as confusion arising from similar spectral response from the different landuse/landcover classes categories are resolved by resource to multi season remote sensing data and group verification. Systematic image interpretation involving detection, identification, classification and codification of the landuse/landcover with reference to image interpretation keys in conjunction with corresponding SOI topographical sheets and other ancillary maps were utilized (Figure 7 and Table 6).

7.5.1 Built Up Land
It is defined as an area of human habitation developed due to no agricultural use where the land is covered with residential, transportation, institutional industrial recreational in association. The built up land in this mandal accounts for 15.01sqkm, 8.45 percent of the land area.

7.5.2 Agricultural Land
It is defined as the land primarily used for the cultivation of agricultural crops. The agriculture in the study area is irrigated by tanks and is rainfed. The major crops that are grown in the study area include

7.5.2.1 Double Crop
Double Crop refers to the standing crop during both kharif and rabi season. It constitutes to 29.86sqkm, i.e., 24.88 percent of the of the study area.
7.5.2.2 Kharif Unirrigated
It is associated with rainfed crops under dryland farming covering 32.85sqkm of the mandal and accounting for 27.37 percent of the landuse.

7.5.3 Plantations
Plantations are clearly identified in the crop lands during rabi season by their relatively low response particularly red and infrared regions related to their internal structure of their foliage and sizable open area of the soil exposed between the trees. Major plantations in the region are Cashew, Casuraina and Mango, covering 4.50sqkm and constitute 3.75 percent of the study area.

7.5.4 Forests
It’s an area within the notified forest boundary having an association of trees and other vegetation types. The total forest area is 10.15sqkm covering 8.45 percent of the study area which is associated with trees and other vegetation cover. The scrub forest is an area of degraded forest mainly due to excessive biotic interference and natural causes which contain mainly bushes and scrubs. The degradation is mainly seen on steep slopes of the hills of the Pedurthi and Vepagunta area subject to severe erosion.

Table 6. Landuse/Landcover

| Landuse Category                     | Area in Hectares | Area in percentage |
|-------------------------------------|------------------|--------------------|
| Forest                              | 10.15            | 8.45               |
| Settlements                         | 15.01            | 12.50              |
| Industrial                          | 2.10             | 1.75               |
| Tanks                               | 5.22             | 4.35               |
| Reservoir                           | 6.60             | 5.50               |
| Upland with dense scrub             | 4.51             | 3.75               |
| Upland with sparse scrub            | 4.00             | 3.33               |
| Public Institution                  | 1.30             | 1.08               |
| Plantations                         | 4.50             | 3.75               |
| Stone quarry                        | 0.07             | 0.05               |
| Mud quarry                          | 1.09             | 0.90               |
| Steep sloping hilly area            | 2.50             | 2.08               |
| Double crop                         | 29.86            | 24.88              |
| Kharif unirrigated                  | 32.85            | 27.37              |
| Total                               | 120              | 100                |
7.5.5 Water Bodies
This class encompasses surface water bodies either impounded in the form of lakes ponds rivers, etc.

7.5.6 River/Stream
It is a natural course of water flowing on the land surface along a defined channel. It may be seasonal or perennial.

7.5.7 Reservoir/Tanks
A lake is a large body of surface impounded water natural or artificial within the landmass. Tanks are small lakes of impounded water. The reservoir constitutes 6.60sqkm, 5.50 percent of the study area and tanks 5.22sqkm comprising 4.35 percent of the study area.

7.5.8 Others
Industrial and mining are has been combined in the landuse/landcover map. It covers 2.10sqkm comprising 1.75 percent of the study area.

![Schematic Chart Showing Methodology Adopted for Integrated Resource Analysis in the Study Area](image-url)
| S.No | Category                  | Lithology  | Geomorphology       | Slope % | Soil Type                     | Land capability | Landuse         | Groundwater prospects |
|------|--------------------------|------------|---------------------|---------|------------------------------|-----------------|------------------|-----------------------|
| 1    | Dryland agriculture      | Khondalite | Pediplain shallow   | 0-3     | Redloams and clays           | II              | Kharif unirrigated| Moderate              |
| 2    | Intensive agriculture 1  | Khondalite | Pediplain moderate  | 0-3     | Alluvial                      | II              | Double crop      | Good                  |
| 3    | Intensive agriculture-2  | Khondalite | Pediplain moderate  | 0-3     | Redloams and clays           | III             | Kharif unirrigated| Good                  |
| 4    | Intensive agriculture-2  | Khondalite | Pediplain moderate  | 0-3     | Alluvial                      | II              | Kharif unirrigated| Good                  |
| 5    | Intensive agriculture-4  | Khondalite | Pediplain shallow   | 0-3     | Redloams and clays           | III             | Double crop      | Moderate              |
| 6    | Intensive agriculture-5  | Khondalite | Pediment            | 3-15    | Alluvial                      | II              | Double crop      | Poor                  |
| 7    | Agrohorticulture-1       | Khondalite | Pediplain shallow   | 0-3     | Red loams and clays          | III             | Plantation       | Moderate              |
| 8    | Agrohorticulture-1       | Khondalite | Pediplain shallow   | 0-3     | Alluvial                      | II              | Kharif unirrigated| Poor                  |
| 9    | Agrohorticulture-1       | Khondalite | Pediment            | 0-3     | Gravelly loams               | IV              | Kharif unirrigated| Poor                  |
| 10   | Agrohorticulture-2       | Khondalite | Pediplain shallow   | 0-3     | Alluvial                      | II              | Plantation       | Moderate              |
| 11   | Agrohorticulture-2       | Khondalite | Pediplain shallow   | >15     | Redloams and clays           | III             | Plantation       | Moderate              |
| 12   | Agrohorticulture-3       | Khondalite | Pediplain moderate  | 0-3     | Alluvial                      | III             | Plantation       | Good                  |
| 13   | Agrohorticulture-4       | Khondalite | Pediment zone       | 0-3     | Gravelly loams               | IV              | Plantation       | Poor                  |
| 14   | Agrohorticulture-5       | Khondalite | Pediment            | 0-3     | Gravelly loams               | IV              | Plantation       | Poor                  |
| 15   | Horticulture-2           | Khondalite | Pediplain moderate  | 0-3     | Alluvial                      | II              | Plantation       | Moderate              |
| No. | Afforestation | Khondalite Subtype | Elev. | Soil Type | Landform | Plantation Type | Result |
|-----|---------------|--------------------|-------|-----------|-----------|-----------------|--------|
| 16  | Horticulture-2| Khondalite Pediplain| 3-5   | Alluvial   | II        | Plantation      | Good   |
| 17  | Horticulture-3| Khondalite Pediplain| 3-5   | Red loams and clays | III     | Plantation      | Poor   |
| 18  | Afforestation | Khondalite Inselberg| >15   | Alluvial   | VII       | Upland with dense scrub | Poor   |
| 19  | Afforestation | Khondalite Pediment zone| 0-3   | Gravelly loams | IV       | Dense scrub | Poor   |
| 20  | Afforestation | Khondalite Structural hill| >15   | Alluvial   | VII       | Upland with dense scrub | Poor   |
| 21  | Afforestation | Khondalite Structural hill| >15   | Shallow skeletal sandy soils | VII     | DO/DS | Poor   |
| 22  | Afforestation | Khondalite Structural hill| >15   | Shallow skeletal sandy soils | VII     | Dense scrub | Poor   |
| 23  | Afforestation | Khondalite Structural hill| >15   | Shallow skeletal sandy soils | VII     | Dense deciduous | Poor   |
| 24  | Afforestation | Khondalite Structural hill| >15   | Shallow skeletal sandy soils | VII     | Deciduous open/Deciduous scrub | Poor   |
| 25  | Afforestation | Khondalite Structural hill| 3-5   | Shallow skeletal sandy soils | VII     | Deciduous open/Deciduous scrub | Poor   |
| 26  | Afforestation | Khondalite Structural hill| 5-15  | Shallow skeletal sandy soils | VII     | Dense scrub | Poor   |
| 27  | Afforestation | Khondalite Structural hill| >15   | Shallow skeletal sandy soils | VII     | Dense deciduous | Poor   |
| 28  | Afforestation | Khondalite Structural hill| >15   | Shallow skeletal sandy soils | VII     | Upland with sparse scrub | Poor   |
| 29 | Afforestation | Khondalite | Structural hill | >15 | Red loams and clays | VII | Deciduous scrub | Poor |
| 30 | Afforestation | Khondalite | Structural hill | 5-15 | Shallow skeletal sandy soils | VII | Dense deciduous scrub | Poor |
| 31 | Afforestation | Khondalite | Structural hill | >15 | Red loams and clays | VII | Dense deciduous scrub | Poor |
| 32 | Afforestation | Khondalite | Structural hill | 5-15 | Shallow skeletal sandy soils | VII | Upland | Poor |
| 33 | Afforestation | Khondalite | Structural hill | 5-15 | Red loams and clays | VII | Upland with dense scrub | Poor |
| 34 | Afforestation | Khondalite | Structural hill | 5-15 | Red loams and clays | VII | Upland with sparse scrub | Poor |
| 35 | Afforestation | Khondalite | Structural hill | 5-15 | Red loams and clays | VII | Deciduous open/deciduous scrub | Poor |
| 36 | Afforestation | Khondalite | Structural hill | >15 | Shallow skeletal sandy soils | VII | Deciduous open/deciduous scrub | Poor |
| 37 | Social forestry-2 | Khondalite | Residual hill | >15 | Alluvial | VII | Sparse scrub | Poor |
| 38 | Social forestry-5 | Khondalite | Pediment zone | 0-3 | Gravelly loams | IV | Steep sloping hill area | Poor |
| 39 | Social forestry-5 | Khondalite | Pediment zone | 5-15 | Gravelly loams | IV | Steep sloping hill area | Poor |
| 40 | Social forestry-6 | Khondalite | Structural hill | 5-15 | Gravelly loams | IV | Pediment | Poor |
| 41 | Social forestry-6 | Khondalite | Pediment zone | 5-15 | Gravelly loams | IV | Kharif unirrigated | Poor |
| 42 | Social forestry-7 | Khondalite | Structural hill | >15 | Shallow skeletal sandy soils | VII | Upland with sparse scrub | Poor |
| No. | Type                  | Soil Type                  | Horizon | Slope | Vegetation Type                  | Soils            | pH | Land Use         |
|-----|-----------------------|----------------------------|---------|-------|----------------------------------|------------------|----|------------------|
| 43  | Social forestry-7     | Khondalite Inselberg       | 0-3     |       | Upland with dense scrub           | Shallow skeletal sandy soils |    | Poor             |
| 44  | Social forestry-7     | Khondalite Structural hill | >15     |       | Upland with dense scrub           | Shallow skeletal sandy soils |    | Poor             |
| 45  | Silvi pasture-2       | Khondalite Pediment zone   | 0-3     |       | Upland with sparse scrub          | Gravelly loams   |    | Poor             |
| 46  | Silvi pasture-3       | Khondalite Pediplain shallow | 5-15    |       | Upland with sparse scrub moderate | Red loams and clays |    | Poor             |
| 47  | Silvi pasture-3       | Khondalite Pediplain shallow | 0-3     |       | Upland with sparse scrub          | Red loams and clays |    | Poor             |
| 48  | Silvi pasture-4       | Khondalite Residual hill   | >15     |       | Upland with sparse scrub          | Red loams and clays |    | Poor             |
| 49  | Barren stone area     | Khondalite Pediplain shallow | 0-3     |       | Upland                           | Gravelly loams   |    | Poor             |
| 50  | Barren stone area     | Khondalite Pediment zone   | 3-5     |       | Upland                           | Gravelly loams   |    | Poor             |
| 51  | Barren stone area     | Khondalite Pediment zone   | 3-5     |       | Upland                           | Gravelly loams   |    | Poor             |
| 52  | Barren stone area     | Khondalite Structural hill | >15     |       | Upland                           | Gravelly loams   |    | Poor             |
| 53  | Barren stone area     | Khondalite Pediment zone   | 3-15    |       | Upland                           | Red loams and clays |    | Poor             |
| S.No | Categories                  | Conservation measures                                      |
|------|-----------------------------|-----------------------------------------------------------|
| I    | Dryland Agriculture         | KU-PPS- II Vegetation barriers and contour bunding       |
| II   | Intensive Agriculture       |                                                           |
| 1)   | DC-PPS, PPM-II              |                                                           |
| 2)   | F, KU-PPM, VF-II, III       | Irrigation and water Management                           |
| 3)   | DC-PPS, PPM-II(Sodic)       | Field bund maintenance                                    |
| 4)   | DC-PPS, III                 |                                                           |
| 5)   | P, DC II                    |                                                           |
| III  | Horticulture                |                                                           |
| 1)   | P, PPS, PPM                 | Contour trenches                                          |
| 2)   | PPM, P, II                  |                                                           |
| 3)   | PPS-II                      |                                                           |
| IV   | Agrohorticulture            |                                                           |
| 1)   | F, KU, PPS,P, IV, V II, III |                                                           |
| 2)   | LS, PPS,P, II, III, IV      |                                                           |
| 3)   | LS, PPM, II                 |                                                           |
| 4)   | P-PZ-IV                     |                                                           |
| 5)   | P-P-IV                      |                                                           |
| 6)   | KU-PZ, IV                   |                                                           |
| V    | Silvipasture                |                                                           |
| 1)   | LS-P-V,VI                   | Soil and moisture conservation                            |
| 2)   | LS-PZ,IV                    |                                                           |
| 3)   | PPS-LS, III                 |                                                           |
| 4)   | RH-LS,III                   |                                                           |
| VI   | Social Forestry             |                                                           |
| 1)   | LS-P,V,VI, VII              |                                                           |
| 2)   | RH, LS, VIII                |                                                           |
| 3)   | PPS                         | Gully plugging, contour trenches with vegetation hedges  |
| 4)   | KU, hills-VI                |                                                           |
| 5)   | PZ,IV                       |                                                           |
| 6)   | Hills, P, VII               |                                                           |
| 7)   | Hills-LS, VII               |                                                           |
| VII  | Afforestation               |                                                           |
SF-Hills
Quarrying

1) BSA-Hill
Contour trenches with vegetation hedges.

2) BSA-P

The expanded form of the abbreviated words listed in the above table can be seen in Table 7.

8. Development and Management Plans

Inappropriate and uncontrolled use of natural resources can downgrade their quality and destroy them. Sustainable development and optimized use of natural resources involves effective utilization of the existing resources without damaging the assets and preserve these valuable resources for the future generations. At Present, scientific and optimized management of agriculture and natural resources are considered to be important items in sustainable development. In order to achieve sustainability and optimized land allocation we can use linear programming, multi objective linear programming and Geographical Information Systems (GIS) approaches (Watershed Planning and management 2018).

The development of the landuse optimization tool called for a detailed understanding of the variation in productivity and physical characteristics on the field parcel scale, as these conditions are important drivers for land allocation and landuse changes. PirjoPeltonen-Sainio'et al. (2019). One of the most basic requirements for planning is the availability of timely accurate landuse data at the shortest possible time which was achieved here with the satellite data in the area of land use and more so in the agriculture land use. Following activities have been suggested pertaining to the hydrogeomorphology, slope, soil, and ground water prospects on the existing landuse/land cover for all the 23 villages to augment the income of the farmers as agrarian economy prevails in the study area.

8.1 Intensive Agriculture

Intensified agriculture which aims at higher yields per unit area. This particular type of cropping involves high amount of labor and money. If it’s practiced in the allocated villages, it will increase the incomes of the families.

8.2 Agrohorticulture

Alongside agricultural crops, horticulture sector has been suggested in the villages with a holistic growth of spices, fruits, vegetables, aromatic plants, coconut, cashew, etc. as nearness to Vishakhapatnam city makes a good business for supply of fresh flowers as well.

8.3 Horticulture

By switching on to species like local berries (ber), cluster beans, gooseberry (aonla) wood apple (custard apple) and pomegranate, the green cover can be increased to eight times. By adopting to drip irrigation the coverage increases to 32 times. The other moisture stress species are guava, cashew, pineapple and manilkarazapota, commonly known as sapodilla (Sapota). Flowers and aromatic plants can also be encouraged.
8.4 Silvipasture
Nourishment of cattle improves their working capacity, milk and meat production. Jowar, maize, bajra and horsegram are good fodder crops followed by cowpea, glycine, digitaria, pospalum, and tubers like casava, sweet potato, and arrowroot are some of the crops which can improve the health of the cattle.

8.5 Afforestation
It grows maximum foliage next to forestry; an activity chiefly looked after the government. Wood industries are the chief consumers of plantations and forests, next only to fuel needs. Of them housing and paper industry takes the lions share. Wood dust boards must be used instead of main trunk branches, and for paper, mesta based factories must be increased. NAP (National Afforestation Programme) NAP Scheme aims to support and accelerate the ongoing process of devolving forest protection, management and development functions to decentralized institutions of Joint Forest Management Committee (JFMC) at the village level, and Forest Development Agency (FDA) at the forest division level. (http://naeb.nic.in/NAP_glance.htm). NAP scheme could be taken as an aid by the mandal revenue office, and forward the proposed afforestation for the covered villages.

Hibiscus Sabdarifa species yields 12-15 tonnes per hectare, while Cannabinus 10 to 17 tonnes/hectare. There are several species which spur out long branches in no time and they must be encouraged. EryhtinalIndica (local name, Dadap), ficusInfectoria (bunyan) and Firligosia (Pipa) are all very good to support afforestation, by implanting such ideas biomass growth can be increased.

8.6 Social Forestry
Social forestry is an activity of utmost importance to the common man, hence must be practiced anywhere from high moisture zones like tank bunds, water harvesting structures, etc. Even broad casting of seeds in rock beds also will yield excellent results. The stress should be laid on local needs, growing a variety of plants and social fencing. Neglect of the organic matter of the trees by training at growing stage not only wastes biomass, but also stunts growth and economy. Close density hastens vertical growth, trimming girth, growth, and biomass. Social fencing is a must for survival of greenery.

8.7 Barren Stone Area
The quarrying is mostly done in the villages on the sides of the barren mountainous area. In the first place heavy quarrying must be stopped by the local government, however if the activity is being carried on with the support of the local or state government, then it must be encouraged in making large plunge holes in the center, in such a way that they become reservoirs of water in the monsoon season, especially near Vepagunta village.
Table 9. Current Landuse and Proposed Land Use of the Study Area

| S.No. | Name of the Village | Present Landuse | Proposed Landuse |
|-------|---------------------|-----------------|------------------|
| 1     | Gorrapalle          | Rabi unirrigated, plantation, Double crop | Dryland Agriculture, Agrohorticulture-2, 4, Intensive agriculture-1, 4 |
| 2     | Saripalle           | Double crop, Rabi unirrigated, Plantation | Intensive agriculture-1, Social forestry |
| 3     | Mudapaka            | Upland with dense scrub, Upland with sparse scrub, plantation, Rabi unirrigated | Afforestation, Silvipasture, Agro horticulture-4,6, Dryland agriculture |
| 4     | Gurrampalem         | Upland with dense scrub, Upland with sparse scrub, plantation | Afforestation, Horticulture-2, Silvipasture, Agro horticulture |
| 5     | Rajayyapeta         | Double crop, Rabi unirrigated, Plantation | Social Forestry, Dryland agriculture, Silvipasture |
| 6     | S.R. Puram          | Rabi unirrigated | Dryland agriculture, Horticulture-2 |
| 7     | Valimeraka          | Plantation, forest, Rabi unirrigated, Upland with sparse scrub | Agro horticulture-2, Horticulture-2, Intensive Agriculture-1, 2, Dryland Agriculture, Afforestation |
| 8     | Pulagalipalem       | Rabi unirrigated, Plantation | Dryland Agriculture, Social Forestry-2 |
|   | Location        | Description                          | Agriculture/Forestry & Land Use                          |
|---|----------------|--------------------------------------|---------------------------------------------------------|
| 9 | Juttada        | Plantation, Double crop              | Agro horticulture-2, Horticulture-2, Silvipasture       |
| 10| Chinnamushiwada| Rabi unirrigated, Plantation, Settlements | Dryland Agriculture, Agro horticulture-1, 2, 4, Intensive agriculture-1, Social forestry-2, 5, Silvipasture-2, Afforestation |
| 11| Ramapuram      | Plantation, Double crop, Rabi unirrigated | Agro horticulture-1,2, Horticulture-3                     |
| 12| Pinagadi       | Plantation, Double crop, Rabi unirrigated, Industrial and mining area | Intensive Agriculture-1, Agro horticulture-2, Dryland Agriculture |
| 13| Pedagadi       | Double crop, Rabi unirrigated, mining area | Agro horticulture-2, Dryland Agriculture, Horticulture, Intensive Agriculture-2 |
| 14| Chintagatla    | Double crop, Rabi unirrigated, Upland with sparse scrub, Plantation | Agro horticulture-1, Silvipasture, Social Forestry |
| 15| J.R. Palem     | Forest, Upland with dense scrub, Upland with sparse scrub, plantation | Agro horticulture-4, Silvipasture-3, 4                       |
| 16| Narava         | Forest, Upland with dense scrub, Double crop, Rabi unirrigated | Silvipasture, Dryland Agriculture, Agro horticulture-1, 2, Horticulture-3 |
| 17| Porlupalem     | Upland with dense scrub, Upland with sparse scrub, Stone quarrying | Afforestation, Silvipasture, Intensive agriculture-2        |
| 18| Chemalapalli   | Upland with dense scrub, Upland with sparse scrub, Rabi unirrigated, Stone quarrying | Silvipasture-2, Dryland agriculture, Social Forestry, Afforestation |
| 19| Lakshimipuram  | Double crop, Plantation              | Agro horticulture-1, 2                                   |
| 20| Krishnarayapuram| Plantation, Rabi unirrigated, Industrial area, Settlements | Social Forestry-2, Intensive agriculture-1, Agro horticulture-2 |
| 21| Purushotampuram| Rabi unirrigated, Settlements, Plantation | Dryland agriculture, Intensive agriculture-1, Agro horticulture-2 |
| 22| Vepagunta      | Double crop, Upland with sparse scrub, Rabi unirrigated, Plantation, Industrial area, Settlements | Social forestry-2, 5, 7, Afforestation, Dryland agriculture, Agro horticulture-1, 2, 3, 4, Silvipasture-2, 3, Intensive agriculture-1 |
| 23| Pendurti       | Double crop, Plantation Rabi unirrigated, Mining and Industrial area | Social forestry, Silvipasture-2, Dryland agriculture, Horticulture |
9. Discussions

National Water Development Program for rainfed areas (NWDPR) norms have been followed in achieving at (BILWRUS) Basic Integration of land and water resources by integrating Drainage, Slope, Soil, and Hydromorphology, which has been overlayed with Landuse and cover to arrive at Recommended Optimal Landutilization and Farming Techniques (ROLUFS). The Prepared BILWRUS (Table 7) has been set as a guideline to match with the ROLUFS (Table 8) to arrive at conclusion for a proposed landuse for each and every village (Table 9). In Table 7, 55 categories of land utilization have been covered as against geology, geomorphology, slope, soil, land capability, ground water prospects, and as per the pertaining landuse, the proposed land use has been suggested for all the 23 villages with suitable conservation methods as well (Figure 9, Table 9).

It is essential to develop rural technologies system with a proper setup of delivery modes in growing greens. The covered aspects are silviculture, horticulture, social forestry afforestation and organic fertilization. Rain water strategy could be developed so that water is stored in underground channels during the rainy season when in plenty, and consumed during the dry season, when water is scarce. This strategy will also complement the bore well technique which is much more expensive and sometimes non-functional. The construction of rural roads must be backed with adequate transportation system so that the rural dweller should be able to transport their agriculture produce to the district headquarters. The farmers could organize marketing of their products to obtain better returns. Facilities must be extended to lease out machinery as most of the villagers lack the machinery, and have to expend most of their energy for physical work, their productivity is also very low, and their cycle of poverty becomes a viscous one. In order to allow and maintain continuity in the rural development programs, the Government must enshrine rural development programs into Law, so that subsequent administration will continue to follow and maintain the program, as it is common practice when one administration leaves power, the subsequent administrations tend to jettison or underplay the previous government programs. Proposed land use pattern helps in improving the environmental conditions and rural economic growth, equally helping in sustainable development.

Acknowledgements

The authors wish to thank USGS for the sentinel data, 2020, Junior Irrigation Officer for the base map, the Chief Planning Officer and Zilla Praja Parishad for the source data.
References
Avery, G. (1965). Measuring landuse changes on USDA photographs. *Photo Engg, 31*, 62-64.

Brovkin, V., Ganopolski, A., Claussen, M., Kubatzki, C., & Petoukhov, V. (1999). Modelling climate response to historical land cover change. *Global Ecol. Biogeogr, 8*, 509-517. https://doi.org/10.1046/j.1365-2699.1999.00169.x

Fonarev, V. I., Konilov, A. N., & Rao, A. T. P. (1998). The condition of Polymetamorphism in the central parts of the Eastern ghats mobile belt. *Petrology, 6*(1), 70-85.

Garner, H. F. (1974). *Origin of Landscape, A synthesis of Geomorphology* (p. 734). Oxford University Press.

*Handbook of Statistics*. (2019). Vishakhapatnam.

Jackson,. & McCuen. (1979). Accuracy of impervious area values estimated using remotely sensed data. *Journal of the American Water Resources Association, 15*(2). https://doi.org/10.1111/j.1752-1688.1979.tb00346.x

McGuire, A., Sitch, S., Clein, J., Dargaville, R., Esser, G., Foley, J., & Wittenberg, U. (2001). Carbon balance of the terrestrial biosphere in the twentieth century: Analyses of CO2, climate and land use effects with four process-based ecosystem models. *Global Biogeochem, 15*, 183-206. https://doi.org/10.1029/2000GB001298

Miller, V. C. (1953). *A quantitative geomorphic study of drainage basin characteristics in Clinch mountain area, Virginia and Tennessee Technical report*. 3 Office of the Naval Research, Dept. of Geology, Columbia University, New York.

Nageswararaao, K., & Narendra, K. (2006). Mapping and evaluation of urban sprawling in the Meghadrigedda watershed in Vishakhapatnam metropolitan region using remote sensing and GIS. *Current Science, 91*(11).

Narendra, K., & Nagewara, R. K. (2006). Morphometry of Meghadrigedda watershed, Vishakhapatnam district, Andhra Pradesh, India using GIS and Resource data. *Journal of Indian Society of Remote Sensing, 34*(2), 101-110. https://doi.org/10.1007/BF02991815

Nookaraju, D., & Vaidhyanadhan, R. (1971). Hill slope elements and surficial deposits near Vishakhapatnam, Andhra Pradesh. *Journal of Indian Science Association, 13*, 45-51.

Raisz, & Henry. (1937). An average slope map of Southern New England. *Geographical Review, 27*, 412-467. https://doi.org/10.2307/210331

Robinson, A. H. (1948). A method for producing shaded relief from areal slope data. *Surveying and Mapping.*

Rosegrant, M. W., Cai, X., & Cline, S. A. (2002b). *World Water and Food: Dealing with Scarcity*. International Food Policy Research Institute, Washington, DC, USA.

Sala, O., Chapin, F., Armesto, J., Berlow, E., Bloomfield, J., Dirzo, R., & Wall, D. (2000). Biodiversity—Global biodiversity scenarios for the year 2100. *Science, 287*, 1770-1774. https://doi.org/10.1126/science.287.5459.1770
Schumm, S. A., & Chorley, R. J. (1966). Talus weathering and scarp recession in the Colorado Plateaus. *Zeitschrift für Geomorphologie N.F.*, 10(1966), 11-36.

Stamp, L. D. (1950). *The land of Britain: Its use and misuse 2ed London Longman Greens* (p. 507).

Strahler, A. N. (1957). Quantitative analysis of watershed geomorphology. *Geophys union, 38*, 913-920. https://doi.org/10.1029/TR038i006p00913

Tijana, V. A., Mirjana, T., Nada, D., & Miodrag, Z. (n.d.). Land use optimization for sustainable development of mountain regions of western Serbia. *Journal of Mountain Science, 15*, 1471-1480. https://doi.org/10.1007/s11629-017-4777-1

Tiwadale, C. R. (1976). *Analysis of Landforms* (p. 572). John Wiley and Sons Pvt. Ltd., Australia.

Usha, C. (2003). *Geographical review of India* (Vol. 65, No. 2).

Usha, C. (2013). Identification of soil erosion zones with special reference to silt deposition in Meghadrigedda reservoir, Vishakhapatnam, India, A Geospatial approach (PhD Thesis). Andhra University Department of Geo Engineering, INDIA.

Usha, C. et al. (2012). Correlation of geometric parameters for the hydrological characterization of the Meghadrigedda watershed, Vishakhapatnam, A GIS approach. *International Journal of Engineering science and Technology, 4*(7), 91-104.

Vink, A. P. A. (1975). *Landuse in Advancing Agriculture*. https://doi.org/10.1007/978-3-642-66049-8

Weaver, J. C. (n.d.). Crop combination regions in the Middle West. *Geographical Review, 175*-200. https://doi.org/10.2307/212355

Wentworth, C. K. (1930). A simplified method of determining the average slope of land surface. *Amer. Jour. Sci.*, 5(20), 184-194. https://doi.org/10.2475/ajs.s5-20.117.184

William, W. T. (1999). *Principles of Geomorphology*.

World Atlas of Agriculture. (1973). Novara. Instituto Geografico de Agostini. *Phtonirvacak, 2*(1), 19-27.