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To cite this article: R Rajkumar *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **1006** 012015

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Agro-Climatic Zonation for Tamil Nadu Using GIS and AHP Techniques

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Abstract. Agro-climatic zonation is a classification technique that uses several meteorological and topographical data of our targeted region for proper zonation with higher priority towards crop suitability factors. This study deals with creating such zonation using 7 major factors for the entire state of Tamil Nadu using GIS and AHP. The Agro-climatic variables include precipitation, evapotranspiration, land surface temperature, land use and land cover data, soil moisture, soil order and ground water level. On incorporating the data in GIS with attribute tables, thematic maps were created through inverse distance weighting interpolation. Such maps were over-laid so that zoning using all the defined factors could be made feasible. Weightage given for each factor was determined based on Analytical Hierarchy Process, with precipitation and soil order with the highest priority. A final map was obtained with Agro-climatic zones defined based on the degree of suitability for agriculture from highest to lowest. This classification can further help to define the suitability of various crops on a region and can help in planning an appropriate crop pattern for that region.

1. Introduction

Productivity of crops in an area mainly depends on some major topographical and meteorological factors. Such factors are to be considered before deciding the crop to be cultivated. So, based on such factors, distinguishing regions of different nature helps in making utmost yield of crops that are more suited to the conditions. Agro-climatic zone classification system enables taking up the desired meteorological factors into account and distinguish the target area into separate regions based on the factors for the main aspect of taking developmental actions accordingly in each of the zones[1,5]. The aim of this zonal classification is to aid in crop suitability issues in a region [2,9]. In this study, the target area is taken as the entire state of Tamil Nadu. The major factors of consideration are precipitation, soil order, land surface temperature, land use and land cover, evapotranspiration groundwater level and soil moisture. Mean values of the data are taken into consideration and incorporated in ArcGIS as separate data maps [3]. Analytical hierarchy process is used for arriving appropriate weightage of each factor over the other based on the desired priority. On taking such weightage into account, weighted overlay could be done quite precisely. Regions



with similar range of data are taken as unique zone and crop suitability analysis is made to grow such crops throughout the zone.

2. Materials and methods

2.1 Study area

The state of Tamil Nadu is one of the 28 states of India. Its capital and largest city is Chennai. It is located in the south-eastern part of Indian peninsula between $8^{\circ} 5'$ and $13^{\circ} 35'$ North latitude and $76^{\circ} 15'$ and $80^{\circ} 20'$ East longitude and is bordered by the union territory of Puducherry and the South Indian states of Kerala, Karnataka, and Andhra Pradesh. The total population of the study area as per 2011 census is 72,147,030. The state covers $1,30,058 \text{ km}^2$ and is the 10th largest state in India. The state is significantly known for its agriculture and is the second largest producer of rice in the country [4]. The study area is depicted in figure 1.

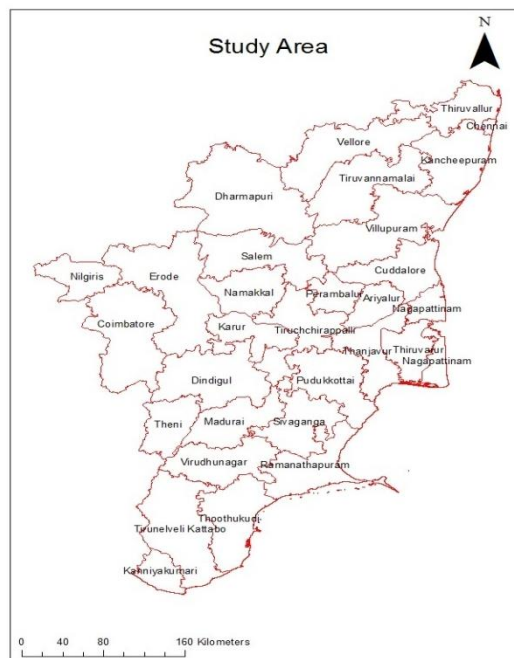


Figure 1. Study area map

2.2 Meteorological and topographical data

Meteorological data obtained for a period were averaged and the mean value was considered for further analysis [5]. The meteorological and topographical data taken for analysis are listed below.

2.2.1. Precipitation

Moist air floats up higher into the sky which is colder than the land surface and condenses into tiny liquid droplets of water forming clouds. Several cloud droplets fuse to form heavier clouds which makes it unable to float and in turn it starts to precipitate in any form such as rain, snow, hail etc. The most predominant form of precipitation in our study area is rainfall. We have collected rainfall data across Tamil Nadu over the last five years for the analysis from India-WRIS [6]. The rainfall data are integrated into Arc map Software and the layout for the precipitation is prepared and shown in Figure2.

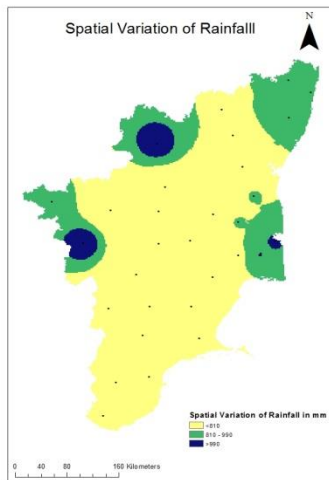


Figure 2: Spatial Variation of rainfall

2.2.2. Soil order

Soil order or soil taxonomy is a soil classification system based on one or two dominant physical, chemical, and biological properties. It is generally classified into 12 categories or orders with each of them having distinct characteristics and ecological significance. In our study area, 7 orders are predominant namely Alfisols, Entisols, Inceptisols, Mollisols, Ultisols, Vertisols and other miscellaneous. These 7 orders are considered for our analysis and it is shown in figure 3. We have acquired a soil order map of Tamil Nadu from the Department of Remote Sensing and GIS, Tamil Nadu Agricultural University.

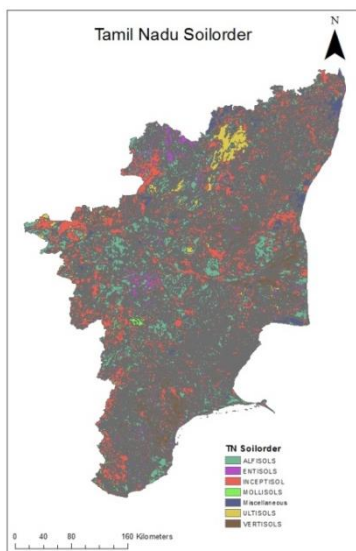


Figure 3: Soil order of Tamil Nadu

2.2.3. Land surface temperature

Land surface temperature (LST) is the radiative temperature of the Earth’s surface due to solar radiation. In general, it varies from place to place depending upon the climate and weather, the type

of surface and its properties. We have acquired the average LST over the last 5 years through LANDSAT-8. It is the satellite that is predominantly used to determine LST across the world [7].

2.2.4. Land use and land cover

Land use and land cover (LULC) denotes the physical land type of a region and the type of usage of the land cover by people. It is displayed with help of maps over a topographical area. LULC maps are created using of satellite or aerial imagery with the help of remote sensing and geographical information system. We have used the current LULC map of Tamil Nadu for our analysis shown in figure 4.

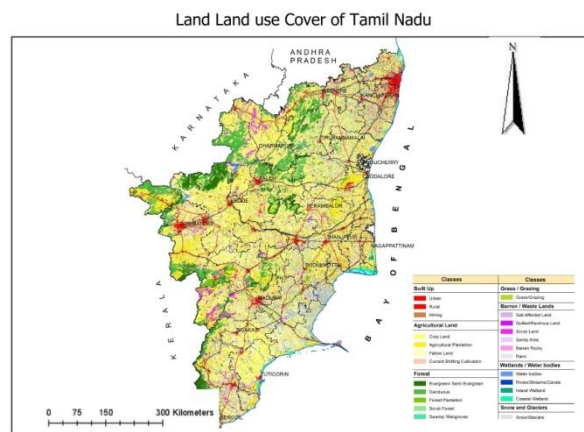


Figure 4: LULC Pattern of Tamil Nadu

2.2.5. Evapotranspiration

Evapotranspiration is the loss of water from the surface of the Earth to the atmosphere through evaporation and plant transpiration combined. The amount of evapotranspiration loss depends on the temperature and pressure at the point on the surface. It also accounts for the movement of water through air from variable sources. We have collected evapotranspiration data across Tamil Nadu over the last five years for the analysis from India-WRIS.

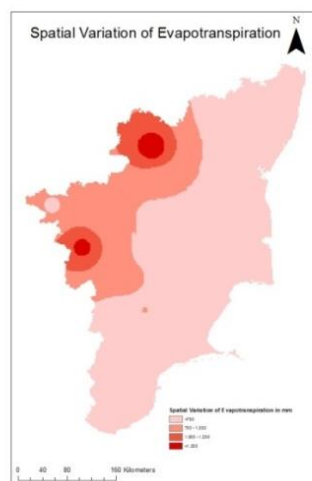


Figure 5: Layout of Evapotranspiration

2.2.6. Ground water level

Ground water level is an important parameter that defines the property and the applications of a particular cover of land. We have collected ground water level data across Tamil Nadu over the last five years for the analysis from India-WRIS. The layout of groundwater level is shown in figure 6.

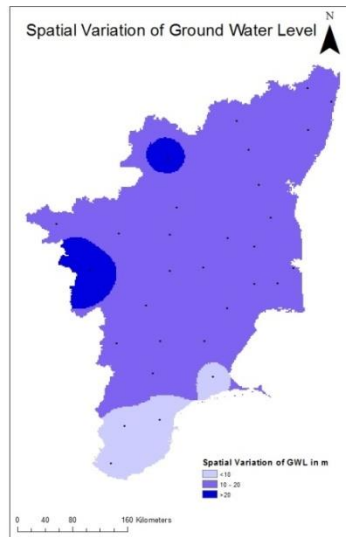


Figure 6: Variation of groundwater level

2.2.7. Soil moisture

Soil moisture is the amount of water (in all forms) held between the soil particles on the land surface. Soil moisture affects the crop growth and sustainability on a piece of land. We have collected soil moisture data across Tamil Nadu over the last five years for the analysis from India-WRIS shown in figure 7.

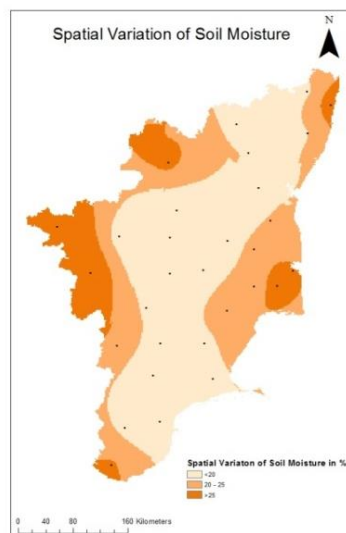


Figure 7: Variation of Soil moisture

2.3 AHP analysis

Analytical Hierarchy Process (AHP) is a structured technique used for organising and analysing complex decisions. It is powerful tool in Multi Criteria Decision Making (MCDM) technique. The parameters considered are compared pair wise with the help of a matrix in Table 1 in which each of them is given a relative importance over another (shown using numbers 1 to 9) based on priorities and their weights are determined by the evaluation scale developed by Saaty [8]. The parameters that are considered here include precipitation, soil order, land use and land cover, surface temperature, groundwater level, evapotranspiration, and soil moisture. Precipitation and soil order are given with higher priorities while soil moisture with the least. And finally, a consistency checks in done to ensure whether the original preference ratings were consistent or not. The Consistency ratio for this process is about 0.036 which is lesser than the maximum acceptable value of 0.1.

Table 1. Criteria AHP pair-wise comparison matrix

Criteria	Prep	Soil Order	LST	LULC	EVP	GWL	Soil Moisture	AHP Weights
Prep	1	1	3	5	7	7	9	0.32
Soil Order	1	1	3	5	7	7	9	0.32
LST	1/3	1/3	1	3	5	5	7	0.17
LULC	1/5	1/5	1/3	1	3	3	5	0.09
EVP	1/7	1/7	1/5	1/3	1	1	3	0.04
GWL	1/7	1/7	1/5	1/3	1	1	3	0.04
Soil Moisture	1/9	1/9	1/7	1/5	1/3	1/3	1	0.02
Total Weight								1.00

2.4 GIS analysis

GIS analysis was carried out in ArcGIS. The point shape file, integrated with the study area shape file, for each parameter across the study area was created by using the spatial data consisting of the latitude and longitude of each district and the attribute data consisting of the corresponding mean value calculated and individual thematic maps for the parameters were developed using the Inverse Distance Weighted (IDW) interpolation method [5]. Based on the criteria weights determined by AHP analysis, raster weighted overlay analysis technique was used to prepare the final agro-climatic zonation map.

3. Results and discussion

The weight of criteria resulting from AHP is presented in Table 1. The results indicate that the value of the consistency ratio (Cr) is 0.1. This indicates that the results are valid in accordance with the threshold recommended by Saaty (2008). The weighting results showed that the soil criterion has the highest weight. This result indicates that soil order is very crucial in the successful cultivation of vegetables crops. The next weights are precipitation, followed by land use land cover and temperature. The weights calculated are assigned to the thematic layers created in Arc map. The weighted overlay analysis is performed in GIS tool and the final result for the agro-climatic zonation is obtained. The agro-climatic zonation map is shown in the figure 8.

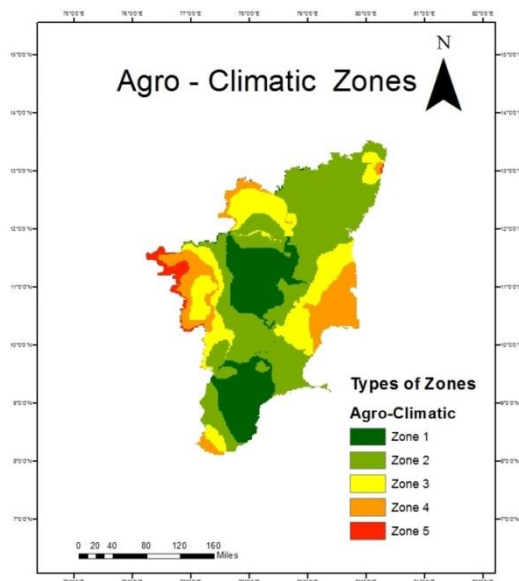


Figure 8: Agro-climatic Zonation of Tamil Nadu

The study region is divided into five different zones as per the results obtained in the weighted overlay analysis performed in Arc GIS. Zone 1 covers southern part of Tamil Nadu and a part central belt in which rainfall is relatively high and soil is more fertile. The crops such as coconut, sugarcane are feasible for the zone 1. Similarly five zones are divided and the feasible crop recommendations are given for each zone and are indicated in the table 2.

Table 2: Zonation of recommended crop

S.NO	Zone	Recommended Crop
1.	Zone 1	Sugarcane, Pulses, Cereals and Millets
2.	Zone 2	Groundnut, Gingelly, sunflower, castor and cotton
3.	Zone 3	Coriander and Chillies
4.	Zone 4	Paddy, Cholam and ragi
5.	Zone 5	Gingelly and Chillies

4. Conclusions

Climatic variability affects agriculture production and these affects are severe in mountain regions as these regions more prone to climate change. The agro climatic suitability assessment needs to be given greater thrust for meeting future food demand and ensuring food security. By using geospatial techniques and GIS based models this research performs suitability assessment of crops to be cultivated in Tamil Nadu. Application of GIS-based multi-criteria analysis proved to be useful to assess climatic (temperature and precipitation), soil and topographic suitability for crops

in Tamil Nadu region. The agro climatic suitability assessment need to be given greater thrust for meeting future food demand and ensuring food security.

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