A Composite Index for Socio-economic Vulnerability: Integrating Geospatial and Demographic Datafor Gram Panchayats in Bapatla District, India

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Abstract

Coastal areas are prone to different kinds of environmental and anthropogenic pressures, which make the evaluation of their vulnerability a crucial instrument for sustainable planning. This study focuses on the socio-economic vulnerability of the Bapatla district, a coastal district newly formed in Andhra Pradesh, India, that is densely populated, mainly depends on agriculture, and is being affected by climate-related hazards. The researchers used the Geographic Information System (GIS) and remote sensing to gather data for demographic, ecosystem, and socio-economic indicators, to measure the composite vulnerability index. Ten factors relevant to population structure, education, livelihood, and resource pressure were normalised and merged to locate the spatial risk variations.
The findings indicate that there are considerable differences within the district, as the villages Addanki, Korisapadu, and JanakavaramPanguluru demonstrate extreme vulnerability resulting from their low adaptive capacity, extensively used land, and environmental degradation. Conversely, places like Karamchedu and Repalle seem to be more resistant due to good infrastructure and a varied economic base. These findings point to the necessity of local adaptation measures and the execution of equitable policy instruments for socio-economic resilience in the coastal zones. Further, integrating GIS-based modelling for vulnerability assessment with community data is a powerful tool for uncovering the spatial dynamics of vulnerability that thereby making citizens' engagement in planning and regional adaptation .

Keywords: *Socio-economic vulnerability, Coastal resilience, Geographic Information System (GIS), Climate-induced risks, Demographic disparityand Vulnerability index.*

INTRODUCTION

Vulnerability is a phenomenon that changes over time and describes the condition of being exposed to the risk of suffering damage due to changes in the environment, society, economy, or physical aspect, especially if there is no capability to react or adjust properly to such conditions [2; 16]. A different definition of vulnerability would be the possibility of a system sufferinglosses that can be presented in monetary terms or human victims [29]. The state of a region is considered to be better;thus, the vulnerability will be lower[17].

Vulnerability is never a fixed concept. It is affected not only by changes of the environment but also by socio-economic factors, which determine the condition of the communities and their ability to respond to the change. Consequently, an assessment of vulnerability requires understanding not only the social processes involved but also the material outcomes in the complex and interrelated space and time [2]. Social vulnerability indicator-based approaches have been the focus of numerous global studies. One of the key models is the Social Vulnerability Index (SoVI) that has been developed in order to show how demographic and socio-economic factors such as population density, age structure, education, and economic livelihood influence the different vulnerability levels of the communities.

That constitutes a conceptual platform for selecting demographic and socio-economic indicators in the current research.

Moreover, the research upon which the present study is based also recognises that human vulnerability is a complex issue and largely depends on the interactions between the biophysical exposure and the social conditions. For instance, the Environmental Vulnerability Index (EVI) sheds light on a number of factors, including ecological, climatic, and socio-economic ones that altogether determine the level of regional fragility [5]. Also, [7]convey that the willingness to change is influenced by both the institution and the socio-economic structures, which, in turn, imply the urgent necessity of integrated assessment.

The evaluation of socio-economic vulnerability is based on the socio-economic background of a person or the society at large. Various parts of the world are at different levels and kinds of vulnerabilities, which have been the result of factors such as socio-economic, environmental, and infrastructural ones [22]. Social vulnerability expresses the degree to which people, households, or communities are susceptible to harm, which comes not only from the fact that they are physically in danger but also because of their social, economic, and institutional characteristics.

It accepts that at different scales, ranging from the individual and household levels to local, regional, and global, people's experiences and reactions to risks are affected by the bigger social structures, processes, and discourses[2; 29]. The possibility of losing financial resources and output is considered economic vulnerability. This encompasses the loss of the means of subsistence that these assets provide, the wealth and economic autonomy they generate, as well as financial hardship, reliance on debt, and the capacity to bounce back from setbacks[29]. Numerous subsequent studies adopted indicator-based models to capture spatial variations in social vulnerability. [3]Demonstrated the effectiveness of multi-criteria frameworks in mapping heterogeneous vulnerabilities across communities. Similarly, [1] showed that composite indicators, when combined with PCA, can reveal underlying structural drivers of social vulnerability. These works support the relevance of index-based methods for deriving standardised vulnerability scores across diverse regions.

There are multiple variables to determine socio-economic vulnerability of a region which includes land use,land tenure, population density,agestructure, race and ethnicity, family structure, gender, wealth, literacy, occupation, housing, health, transportation,coping capacity, functional needs, language proficiency, risk perception, income,economic status,proportion of agricultural labors and primacy sector percentage of workers, resource dependency and cultural heritage[10; 32; 22; 26].[11]Further contributed to indicator-based vulnerability assessment through the Livelihood Vulnerability Index (LVI), which groups variables into profiles such as socio-demographic, livelihood strategies, and social networks. Their framework highlights the usefulness of organizing vulnerability determinants into thematic profiles, supporting the structure of the present study, which groups indicators into demographic, socio-economic, and ecosystem profiles.

Other studies have expanded these frameworks by proposing multi-scale or region-specific indices. For instance,[27] integrated demographic and livelihood indicators with hazard exposure metrics to produce a multi-hazard vulnerability index. Similarly, [14] pointed to how different weighting schemes and sets of indicators changed the scoring of vulnerability, thereby emphasising the significance of contextualising the selection of indicators. Studies comparing different regions, such as coastal and non-coastal areas, also show that these demographic and economic factors have a considerable impact. For instance, [19] revealed that household composition, type of livelihood, and access to basic services are the major factors that determine the regional pattern of vulnerability[24]. Also came to the same conclusion that land-use patterns and socio-economic pressures are fundamental in understanding community sensitivity to environmental change.

[4]For example, created the Coastal Vulnerability Index (CVI), integrating physical, hydrological and socio-economic parameters to measure differential risk along coastlines. Their study illustrates the necessity of mixing human and environmental factors when assessing coastal vulnerability, which is the main direct effect of the integrated framework adopted in this research. The coastal environment is the most vulnerable area to the effects of disasters because of rapid urbanisation, high human population density, and economic activities such as agriculture, tourism, aquaculture, industries, trades, and transportation that are closely related to the high population [13].

Conversely, the low-lying coastal areas mainly suffer from climate-induced risks such as sea-level rise, storms, and coastal erosion [10]. The variety of natural disasters points out the vulnerability of coastal regions worldwide. The coastal regions are the most vulnerable regions because of dense population, urbanisation, and rapid development due to coastal resources. Each coastal region has different patterns of vulnerability that are influenced by various factors such as population density, land-use practices, access to infrastructure, and adaptive capacity [22]. Different index-based and GIS-supported techniques have been used globally for coastal vulnerability evaluations with success. [9]For example, illustrated that CVI could identify vulnerability to coastal hazards at a local level in areas with low population density. [23]Also employed CVI to emphasise the spatial differences in the risk of erosion and flooding. Localised studies in India have done the same in proving the strength of index-based coastal assessments with RS/GIS data sources[20; 15]. The latest developments in remote sensing and geospatial modelling have, furthermore, contributed greatly to the coastal vulnerability assessment. The works of [25] and [6] provide evidence of the ways in which the combination of satellite data with socio-economic indicators results in the production of accurate and spatially consistent vulnerability maps. This research used the reference parameters to figure out the socio-economic vulnerability index that is related to coastal areas. This approach has adjusted some indices depending on the demographic dataset available and is consistent with the physical characteristics of the study area. There are ten indicators that can be divided into two categories as social indicators and economic variables. With the help of Remote Sensing (RS) and Geographic Information Systems (GIS) technologies, the spatial and temporal changes in coastal features can be effectively studied to reveal the patterns of vulnerability. These instruments allow the integration of data from different sources to create precise models for anticipating and lessening the effects of coastal hazards [13].

1. STUDY AREA

The selected study area for the research is the district of Bapatla, which is located in Andhra Pradesh, the southern part of India. Situated along the eastern coast of Andhra Pradesh and facing the Bay of Bengal, Bapatla is a recently created district. Bapatla District is an area that lies within latitudes 15°39′N to 16°15′N and longitudes 80°00′E to 80°45′E. Its environment is very much influenced by the sea, and this has been the factor which has determined its socio-economic and ecological settings. The location not only enables the district to have a varied landscape, starting from the agricultural plains to the coastal areas, but it also significantly influences the socio-economic and environmental characteristics of the district. Bapatla is bounded by the districts of Palnadu, Guntur, Krishna, and Prakasam. Thus, the district becomes an essential area for the regional development dynamics of the state of Andhra Pradesh.

The district of Bapatla is made up of several administrative mandals. Each one of these mandals has its own unique local features and community structures.Some of the powerful mandals in the region that are the subject of the study are Chirala, Vetapalem, Karamchedu, Martur, JanakavaramPanguluru, Addanki, and Korisapadu etc. These divisions are the typical rural and semi-urban settlements in which the main source of incomeis agricultural production. The district is also famous for the high-yield paddy fields and as well as for the aquaculture and horticulture, which are both the main sources of the local economy and the people's livelihoods.
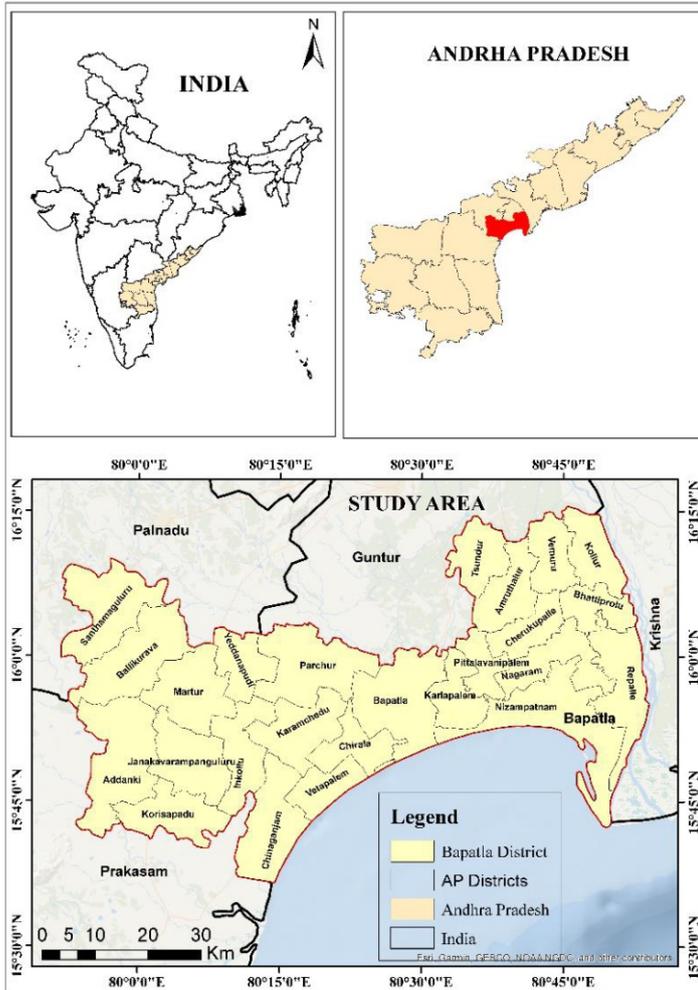
Fig. 1: Location map of the Study area

The proximity of the area to the sea has led to the growth of local economic activities such as fishing and coastal trade. However, it also makes the region vulnerable to cyclonic storms and coastal flooding, which frequently occur along India's eastern seaboard. On the socio-economic side, Bapatla is a good example of the kind of districts that are coming up in India, and they are complex in nature. Though agriculture is still the major economic base, there is a significant change in the diversification of the occupational structures, especially around the urbanisingcentres like Bapatla town and Chirala. The coexistence of traditional farming communities with newly-emerged service-sector opportunities has impacted migration patterns and social mobility. Besides agriculture and fisheries, the district has witnessed the rise of small-scale industries and the retail trade, which reflect the rural transformation that is in progress. The district's population is made up of different social groups, of which marginalised communities make up a major proportion. These groups are generally located in such vulnerable areas as flood-coastal villages and resource-poor inland regions.

Environmental issues form the core of the profile of the area under study. The region's coastal tracts that are low-lying are very vulnerable to periodic flooding, saline intrusion, and the impacts of climate change in the long run. The risk of cyclones being the main one is always considered in the preparation of disaster strategies, as well as the socio-economic resilience of the affected people. On the other hand, the issues that surround groundwater, which include dynamics, soil salinity, and agricultural sustainability, soil erosion and deforestation, are very serious problems that the local people in the area face as

they plan for land use and their development programs. They have fertile land to farm on, but at the same time, they also have to deal with the climatic challenges,which is a paradox that the policy-makers and local administrations have to deal with, especially when they take intoaccount the demographic and infrastructural changes that are happening in the area.

From the perspective of administration, the recent district reorganisation has put Bapatla in a stage of institutional consolidation. There are marked improvements in these areas of Governance, distribution of resources, and the delivery of public services. Moreover, an increasing number of local communities are being involved in broader development processes. Additionally, the fact that the district is at the crossroads of both resource-rich and disaster-prone areas makes it a significant subject for the study of socio-economic vulnerability, adaptation, and resilience.Because of the district's diverse natural environment, economic changes, and administrative frameworks that are still developing, Bapatla is an ideal location for such studies that intend to shed light on socio-economic vulnerability indices and rural development paradigms in India.

2. DATA AND METHODOLOGY
Coastal areas are absolutely dynamic from both an inherent and anthropogenic perspective. Coastal authority needs a doom of order of the day about the coastal loss of residence, nautical depreciation and sea on the rise. Coastal managers have up to a generation and undeniable information regarding the coastal processes.

2.1 Dataused

Table 1: Data sets used for analysis

Sl. No.	Profiles	Variables	Source
1	Demographic Profile	House Holds	Census of India
2		Total Population	Census of India
3		Age Below 6	Census of India
4		Sex Ratio	Census of India
5		Weaker Section	Census of India
6		Dependent Population	Census of India
7	Ecosystem Profile	Groundwater Extraction	AP-WRIS
8		Wetland Area	Sentinel-2A
9		Land Use/Land Cover	Sentinel-2A
10	Socio-Economic Profile	Literacy Rate	Census of India
11		Non-Dependent	Census of India
12		Cultivator	Census of India
13		Agriculture Labours	Census of India
14		Population Density	Census of India

2.2 Methodology
2.2.1 Data Collection and Preparation
The data that have been gathered are only related to non-spatial aspects (such as Households, Total population, Age below 6, Sex ratio, Weaker section, and Dependent population), which are not georeferenced.

Every single data item is thoroughly investigated and prepared for the next GIS analysis.

2.2.2 Data Validation and Classification
After the inspection of data, they are sub-classified reflecting risk parameters of vulnerability.

Initially, data are segregated into three major profiles, each of whichcomprises different variables derived from the following:

- **Demographic Profile:** (Households, Total population, Age below 6, Sex ratio, Weaker section, and Dependent population)

- **Ecosystem Profile:** (Groundwater extraction, Wetland area and Land use/land cover)
- **Socio-Economic Profile:** (Literacy rate, Non-dependent population, Cultivator population, Agricultural labours and Population density.
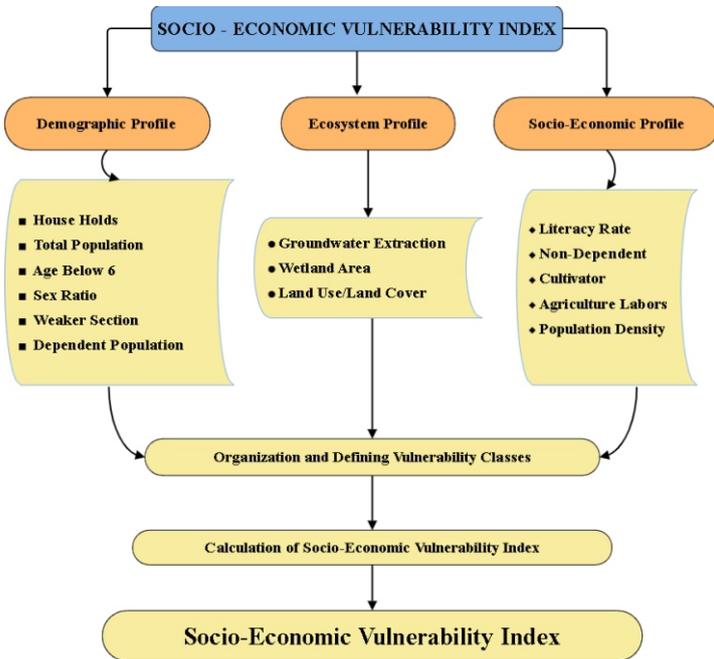

Fig: 2. Socio-Economic Vulnerability Assessment Flow Chart. (Murali et al., 2013)

2.2.3 Organisation and Vulnerability Definition

The information has been methodically organised, and through the application of suitable classification systems, the categories of vulnerability have been identified.

The levels of vulnerability are arranged based on the given literature and criteria.

2.2.4 Weighting and Vulnerability Level Assessment

The profile in each expression assigns weights for every part of the text.

Social vulnerability is measured at different scales and using different approaches by scientific methods.

The standardised scores for each variable are then combined by means of overlay techniques in GIS analysis.

For any unit of analysis, the sum of scores over all variables in that cell gives a measure of socio-economic vulnerability, the Social Vulnerability Index (SVI).

3. RESULT AND DISCUSSION

3.1 Demographic Profile Analysis

The demographic profile of the research is a detailed account of the number of households, total population, the number of children under six years, sex ratio, and the existence of vulnerable social groups. These vital socio-economic factors together reveal the household structures, population size, age distribution, gender balance, and the ratio of disadvantaged communities such as the Scheduled Castes and Scheduled Tribes in the Bapatla District, thus providing essential information for a targeted developmental intervention and policy planning.

Table 2: Demographic Profile Vulnerability Weightage

		Very Low 1	Low 2	Moderate 3	High 4	Very High 5
Sl. **No.**	**Variable**					
1	House Holds	-0.56 - 0.52	-0.51 - 0.39	-0.38 - 0.02	-0.01 - 1.07	1.08 - 4.26
2	Total Population	-0.55 - 0.51	-0.5 - 0.39	-0.38 - 0.02	-0.01 - 1.06	1.07 - 4.24
3	Age Below 6	1.17 - 4.18	-0.52 - 0.38	-0.37 - 0.04	0.05 - 1.16	1.17 - 4.18
4	Sex Ratio	-0.59 - 0.53	-0.59 - 0.43	-0.42 - 0.01	0.02 - 1.19	1.2 - 4.39
5	Weaker Section	0.66 - -0.52	-0.51 - -0.49	-0.48 - -0.34	-0.33 - 0.39	0.4 - 4.1
6	Dependent Population	-0.51 - -0.49	-0.48 - -0.40	-0.39 - -0.1	-0.09 - 0.9	0.91 - 4.27

3.1.1 Households Vulnerability: The household vulnerability map based on the census indicates that panchayats around the district centre, particularly Bapatla and Vedampudi, are the most vulnerable, which may indicate that larger households or more people are living in the same dwelling.
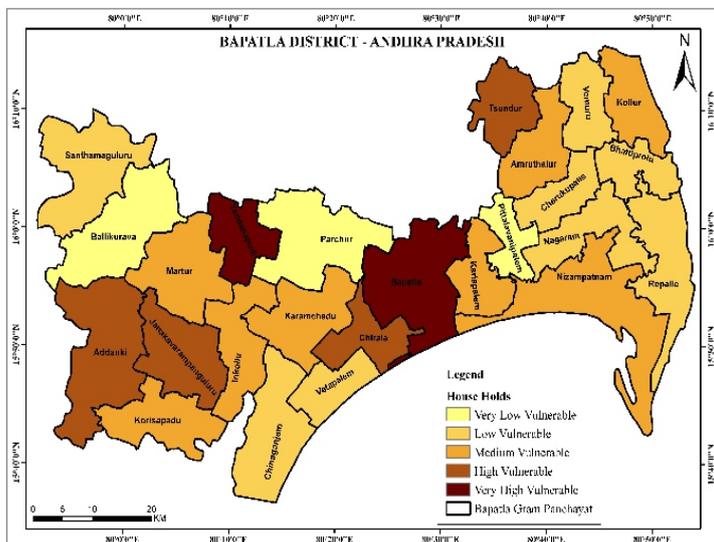

Fig. 3: Map of Households Vulnerability

Elevated household vulnerability may indicate a higher incidence of unsanitary housing conditions and limited access to basic amenities, which can distort socioeconomic outcomes and increase the risk of disease transmission. Localities with medium or low household vulnerability have a better chance of implementing housing and sanitation reforms, while those at high risk require an urgent intervention in the provision of affordable housing, sanitation facilities, and urban planning to improve living standards.

3.1.2 Total Population Vulnerability: The mapping of population vulnerability across Bapatla district unveils the variance of demographic pressure in different areas, where the central panchayats Bapatla and Vedampudi are showing the highest levels of vulnerability. It conveys a large population concentration that may exhaust local resources, infrastructure, and services, especially health and education, thus the social interventions might be in great demand.
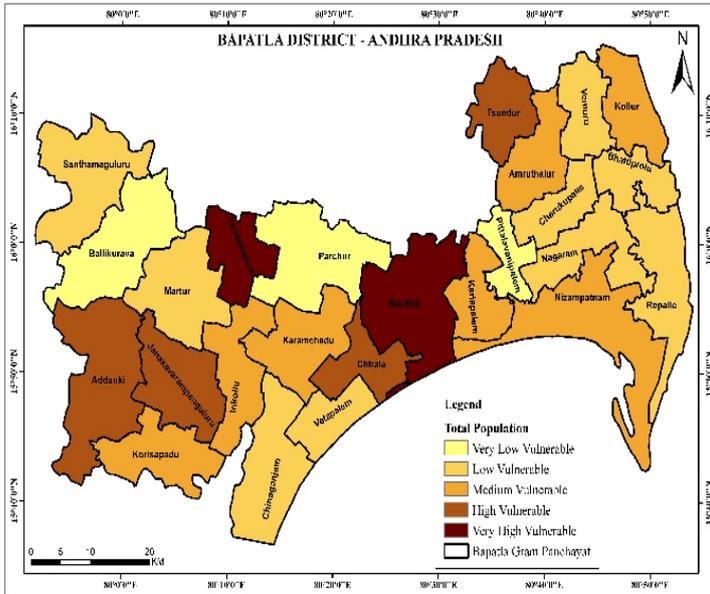
Fig. 4: Map of Total Population Vulnerability

The panchayats located at the edge of the district, such as Ballikurava, Santhamaguluru, and Parchur, are less likely to be at risk, which implies that the population densities in these areas might be holding at a level that facilitates the provision of civic amenities. Moreover, the places with high and very high levels of vulnerability should be at the forefront of sustainable development, capacity-building, and resource distribution to not only tackle the shortfalls but also enhance the living standards. These differences in population call for localised policy changes to manage the impacts of population growth in an equitable way and ensure that development programs get to the areas that are most in need.

3.1.3 AgeBelow 6 Vulnerability: The vulnerability map visually displays those panchayats, Bapatla, Vedampudi, and Chirala, whose figures of the children under six years category are so high as to be almost off the charts, thus signifying that these are the areas with the largest number of young dependents. Such localities demand, along with a likely increase in general pediatric healthcare, early childhood education, and nutrition programs; in these cases, if tentative solutions are impossible, the issue of health inequalities will continue to exist and constitute an obstacle to human development in the long run.
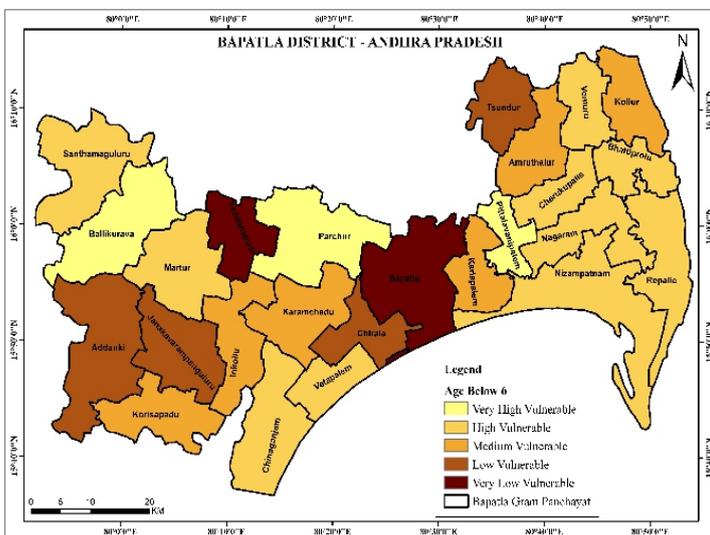

Fig. 5: Map of Age below 6 Vulnerability

On the other hand, the outlying residential areas of Ballikurava and Santhamaguluru correspond to lesser vulnerability, and thus it is inferred that lower birthrate or better supportive systems for young children may be the reasons. International development organisations and local governments have to turn their attention and energy to providing places for children's care, carrying out immunisation drives and maternal education programs in the districts experiencing elevated vulnerability. They should also harness the capacity of less vulnerable panchayats as intervention models for the possible extension of their work.

3.1.4 Sex Ratio Vulnerability: Imbalance of the sex ratio-related vulnerability in Kollur and Bhattiprolu shows very strong differences, which can point to the possible gender disparities that not only reflect the gender-selective migration but also social preferences and inequitable access to resources. Such inequalities may have a tremendous effect on the social welfare system over time and the realisationof gender equality goals may lead to gender-based violence situations and restrictwomen's economic and social participation.
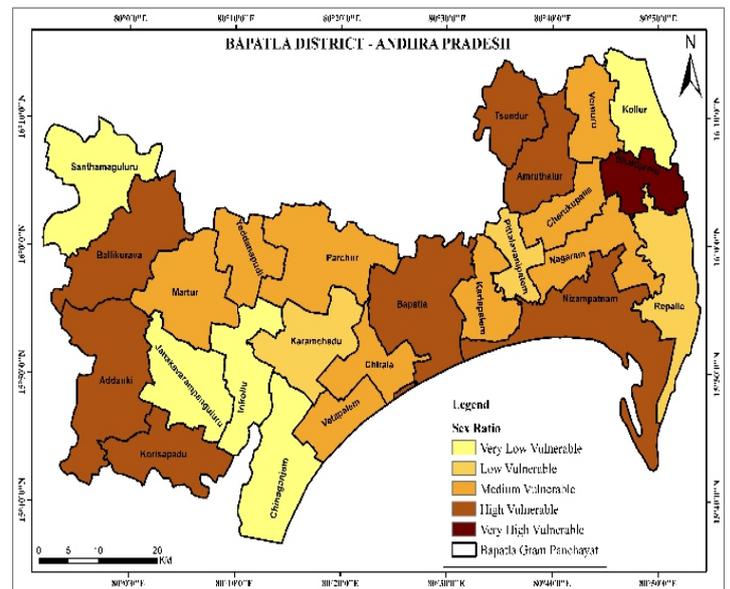

Fig. 6: Map of Sex Ratio Vulnerability

The problem of sex ratios skew should be solved through the use of gender-sensitive policies, community education, and empowerment strategies, which can help to stabilize the sex ratio and further support the principles ofinclusiveness and sustainable societal development.

3.1.5 Weaker Section Vulnerability: The regions that have been identified as highly sensitive in terms of the prevalence of weaker sections, for instance, Addanki and Bapatla, are the areas which have a very high population of marginalized groups. This condition makes it necessary to take immediate measures to provide support through affirmative actions, welfare programs that are targeted at specific groups, and anti-discrimination policies aimed at increasing social inclusion and lessening the differences in access to health, education, and employment opportunities.
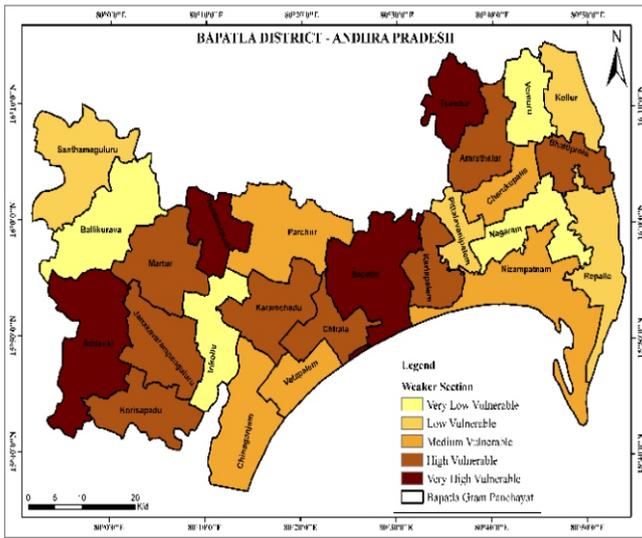
Fig. 7: Map of Weaker Section Vulnerability

Even if some peripheral panchayats like Santhamaguluru and Ballikurava are less vulnerable, it does not, however, lessen the significance of the need for constant monitoring and the provision of support to minority communities throughout the district.

3.1.6 Dependent Population Vulnerability: The vulnerability of a panchayat population such as Bapatla and Vedampudi has been identified as extremely highly sensitive, which means that a considerable number of substantial dependent groups such as children, the elderly, or people with disabilities have been highlighted.
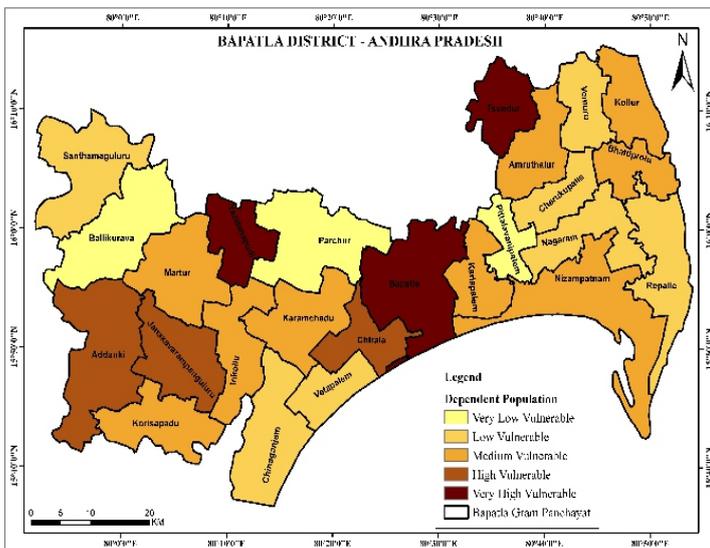

Fig. 8: Map of Dependent Population Vulnerability

High dependency ratios can become a challenge for economic productivity and can put double pressure on caregiving and health support systems. At the same time, international agencies and local governments should direct these supports as

social pensions, community childcare, and inclusive public health programs to these areas so that their come out stronger. On the other hand, the remote areas with lower vulnerability may become a source of the best method for dealing with dependency.

3.1.7 Demography Profile
The image "Demography Profile" shows the ranking of panchayats in terms of demographic vulnerability. The ranking is based on criteria, population density, composition, and maybe growth trends. The regions like Addanki and Bapatla have been identified as extremely demographically vulnerable, which could mean that there is a rapid rise in population, an imbalanced age structure, or a high percentage of dependent people. On the other hand, Tsundur, Kollur, and Repalle have been found to have very low demographic vulnerability, indicating that they are more stable.
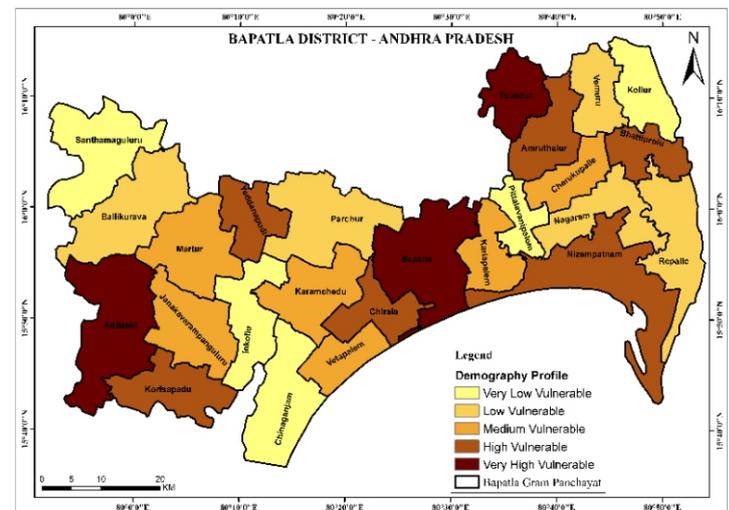

Fig. 9: Map of Demography Profile

The demographic vulnerability study is very significant for the organisation of health, education, and social services. It uncovers the places where more community services investment may be needed most to handle demographic issues and ensure fair growth, thus, directing attention to panchayats with higher population pressure or social fragility.

3.2 Ecosystem Profile Analysis
The ecosystem profile of the study site largely depends on these three factors: the patterns of groundwater withdrawal, the area and conservation status of the wetlands, and the variations of the land use and land cover, which together have a significant impact on the environmental health and the sustainability of the resources of the region. The interactions between the elements of the system that constitute the local ecological balance, as the heavy use of groundwater and the conversion of land for other purposes, can reduce the functions of wetlands and change the natural habitats, thus, it is very important to have integrated management in the Bapatla District.

Table 3: Demographic Profile Vulnerability Weightage

Ecosystem Profile Vulnerability Weightage					
Sl. No.	Variable	Very Low 1	Low 2	Moderate 3	High 4	Very High 5
1	Groundwater Extraction	-1.04 – -0.84	-0.83 - -0.79	-0.78 - -0.58	-0.57 – 0.25	0.26 – 3.6
2	Wetland Area	00 - 0.05	0.06 - 0.14	0.15 - 0.27	0.28 - 0.50	0.51 - 0.87
3	Land Use/Land Cover	Rocky Area	Built up	Salt & Sandy	Agriculture	Water Bodies

3.2.1 Groundwater Extraction: Maps showing groundwater extraction for the Bapatla District have revealed significant differences between panchayats, and these differences are being used to guide both local and international water management policies. The district of Bapatla, which includes the panchayats of Addanki, Santhamaguluru, Korisapadu, and Vemuru, has been identified as very highly vulnerable, implying that the withdrawal of groundwater has been far in excess of the recharge rates.
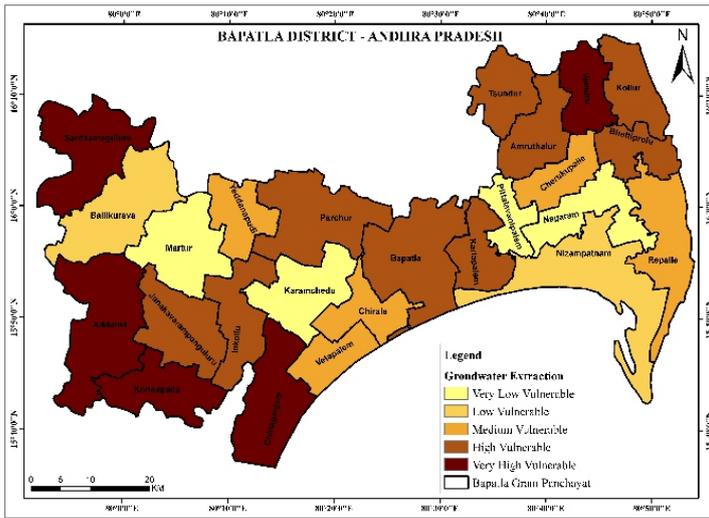

Fig. 10: Map of Groundwater Extraction

These types of withdrawals may lead to the depletion of the aquifer, sinking of the ground, and shortage of water, thus severely threatening the sustainability of agriculture and even water security for a long time. In contrast, villages such as Martur, Ballikurava, and Nizampatnam are considered very low-risk panchayats, which means that these places may have achieved good water management or have been naturally blessed with favourable hydrogeological conditions. It is not only vital to safeguard water resources in these panchayats, but also to revitalise high-risk areas; local resilience can be strengthened with the help of international know-how in the field of advanced monitoring technology, community-based management, and water-saving agricultural practices.

3.2.2 Wetland Area Vulnerability: Wetland vulnerability in Bapatla district has been identified in specific panchayats such as Santhamaguluru and Ballikurava that have been showing the maximum sensitivity due to widely spread wetlands there. These lands are nature-dependent and highly vulnerable to the risk of developmental encroachments, pollution, and climate change, like flooding. Keeping wetlands alive is necessary for climate mitigation, biodiversity conservation, and the long-term viability of aquatic resources. Therefore, international initiatives may be of benefit to the local ones, as they can offer technical know-how and financial resources to rejuvenate and protect these indispensable ecological areas.
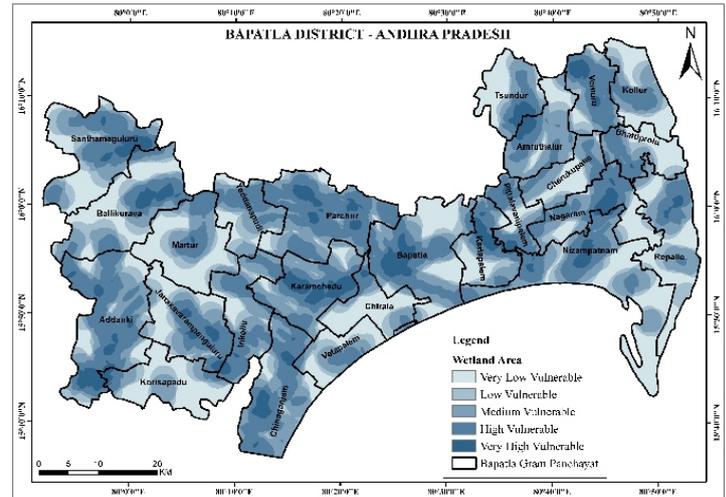

Fig. 11: Map of Wetland Area Vulnerability

3.2.3 Land Use/Land Cover: The Land Use Land Cover (LULC) map of Bapatla District depicts the area to be dominated by agriculture, where the rural panchayats of Martur, Parchur, and Karamchedu are covered with widespread crop fields which are the mainstay of the region's agrarian economy.
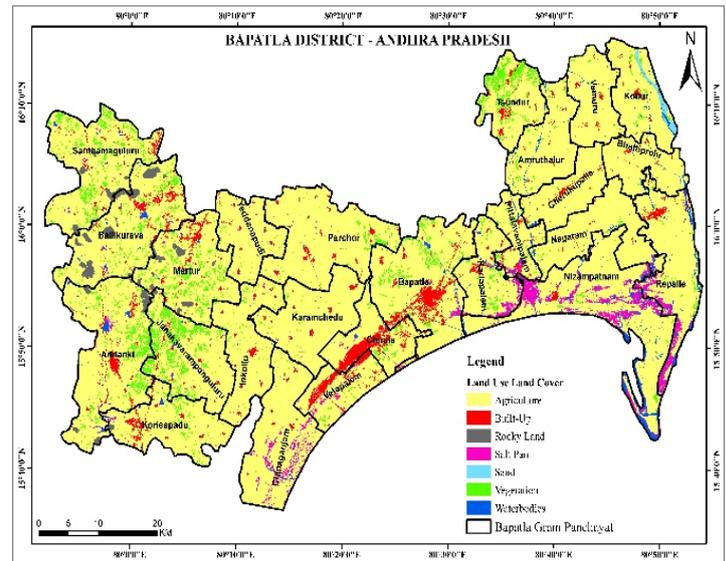

Fig. 12: Map of Land Use/Land Cover

Urban centres like Bapatla and Chirala have concentrated built-up areas which indicate dense residential and commercial development, while the district is dotted with the rocky terrain (Addanki, Ballikurava), salt pans and sandy stretches (Vetapalem, Nizampatnam), and large water bodies (Repalle, Kollur) that feature diversified ecology. Such spatial arrangements offer vital directions for sustainable planning, economic growth, and environmental conservation.

3.2.4 Ecosystem Profile: The "Ecosystem Profile" map of Bapatla District in Andhra Pradesh visually represents the environmental vulnerability of each panchayat using different colours. For example, Addanki, Korisapadu, and Santhamaguluru are some of the places that depict very high vulnerability, which means these are the regions that are at risk due to environmental factors and possibly unhealthy ecosystems and require the immediate intervention of policies. On the other hand, Karamchedu, Maruru, and Repalle are some of the locations that have a very low level of vulnerability, and these areas have been able to resist environmental pressures.
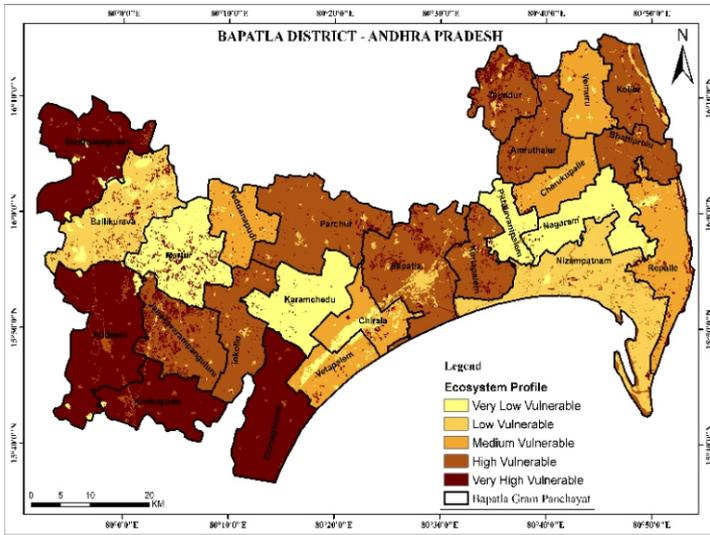

Fig. 13: Map of Ecosystem Profile

The pattern of distribution is likely to have been influenced by characteristic features of the earth, the ways of using the land, and being exposed to stressors such as pollution, water scarcity, or deforestation. The ecosystem vulnerability ranking is essential to the implementation of conservation and adaptation initiatives that are prioritised by panchayats, in which those that are most vulnerable will be the first to receive attention in order to achieve ecological stability and sustainability.

3.3 Socio-Economic Profile Analysis

The socio-economic profile of the study area is determined by literacy rates that directly affect the share of non-dependent individuals who can make a productive contribution to the economy. The local economy is therefore largely based on the activities of the numerous household cultivators and agricultural labourers. These aspects are well exemplified by the population density of the district, which, together with the above variables, gives a fair idea of land use patterns and the economic engagement of the local communities.

Table 4: Demographic Profile Vulnerability Weightage

Socio-Economic Profile Vulnerability Weightage					
Sl. No.	Variable	Very Low 1	Low 2	Moderate 3	High 4	Very High 5
1	Literacy Rate	1.06 - 4.31	0.00 - 1.05	-0.35 - -0.01	-0.46 - -0.36	-0.51 - -0.47
2	Non-Dependent	1.30 - 4.16	0.14 - 1.29	-0.34 - 0.13	-0.53 - -0.35	-0.62 - -0.54
3	Cultivator	0.72 - 2.75	-0.19 - 0.71	-0.59 - -0.2	-0.77 - -0.6	-1.19 - -0.78
4	Agriculture Labours	1.22 - 2.53	0.30 - 1.21	-0.34 - 0.29	-0.78 - -0.35	-1.11 - -0.79
5	Population Density	-0.49 – -0.43	-0.42 - -0.42	-0.41 – -0.36	-0.35 – 0.15	0.16 – 4.57

3.3.1 Literacy Rate Vulnerability: Areas that have the greatest literacy problems, Bapatla, Vedampudi, and Chirala, are indications of significant education gaps, which in turn, limit the development of human capital in the whole region. Low levels of literacy are the main causes of poverty that are being passed from one generation to another, limit the types of jobs that can be done, and make it difficult for people to get information about health, rights, and governance.

Fig. 14: Map of Literacy Rate Vulnerability

On one hand, extending basic educational facilities in these panchayats will be a good start to breaking the cycle of illiteracy. On the other hand, adult literacy programs and the provision of incentives for children going to school will surely lead to the social and economic mobility of the upcoming generations.
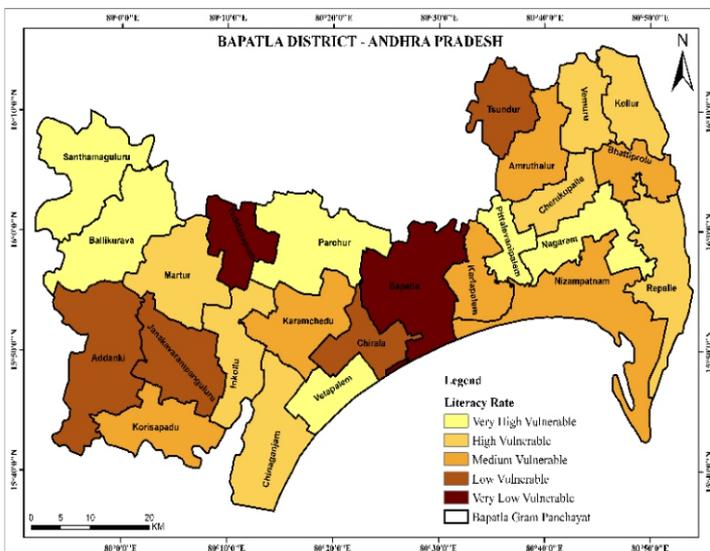
3.3.2 Non-Dependent Population Vulnerability: Panchayats like Bapatla and Vedampudi are characterised by very high vulnerability in terms of non-dependent populations. Such situations usually imply areas that have a concentrated number of the working-age groups which are facing some kind of socioeconomic constraints. Most of the time, high vulnerability in these areas may indicate situations such as underemployment or the existence of some barriers to economic participation, even though there is a demographic potential.
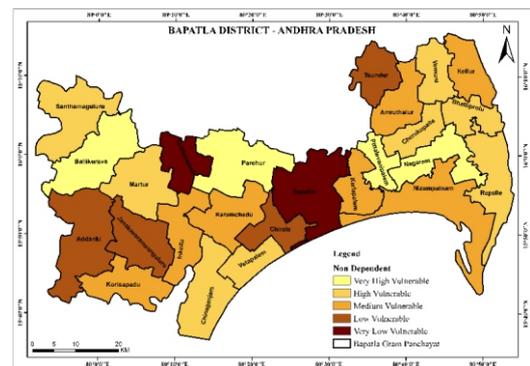

Fig. 15: Map of Non-Dependent Population Vulnerability

Proper interventions through local economic development, skill training, and entrepreneurship programs might be the right tools to open the economic potential of non-dependent groups and to lessen the differences between regions. The enabling of such people is a necessary steptowards the general progress of the district.

3.3.3 Cultivator Vulnerability: Data on the vulnerability of cultivators show that the panchayats of Addanki and Bapatla are the areas where the most serious problems exist, with a large percentage of self-cultivating farmers. The high level of vulnerability in these localities indicates that the inhabitants are more exposed to risks in agriculture, that their landholdings are insecure and that their farming incomes are fluctuating.
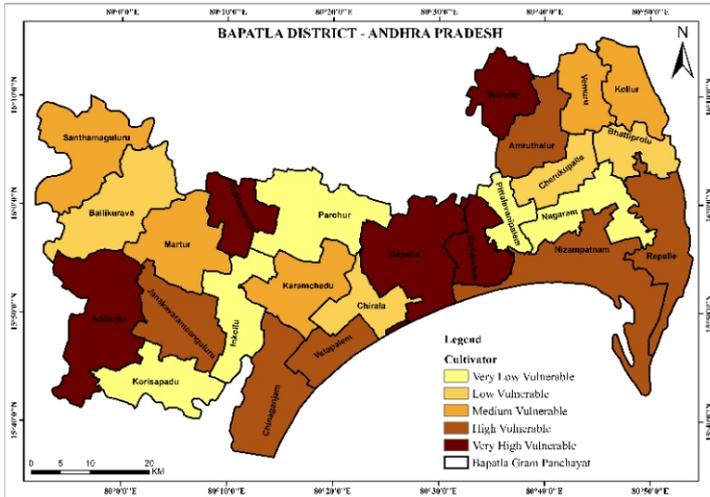

Fig. 16: Map of Cultivator Vulnerability

Initiatives aimed at improving land rights, irrigation and facilitating access to the market are most important for these people. Besides the measures mentioned above, these households can be assisted by the agricultural cooperatives that are strengthened and by the promotion of other income sources, which will serve as a safety cushion for cyclical rural distress typical for these households that depend on cultivators.

3.3.4 Agriculture Labours Vulnerability: Agriculture labourers' vulnerabilities in Bapatla, Vedampudi, and Chirala signify the presence of numerous landless and marginal farmworkers, who are usually identified as the most economically and socially frail. These groups are highly prone to impoverishment, subjection to exploitative labour conditions, and lack of social security, and thus they need an immediate response of policy and welfare.
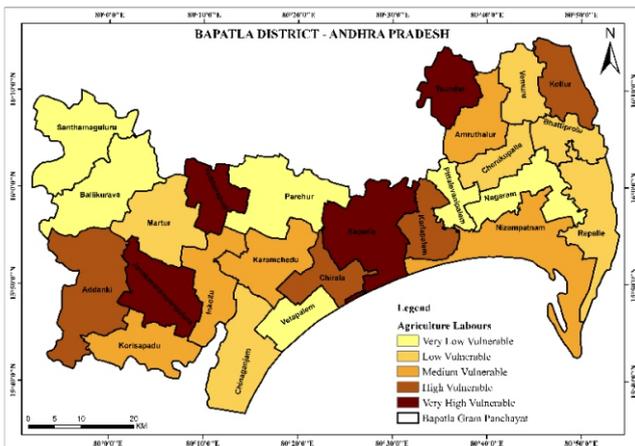

Fig. 17: Map of Agriculture labours vulnerability

The rural employment schemes, minimum wage enforcement, and skill development can be a great change in the socioeconomic condition of these vulnerable communities. Thereby, these interventions are necessary tobridge the gap between high vulnerability and inclusive rural prosperity.

3.3.5 PopulationDensity: Population density is a major factor that provide a lot of information in Bapatla District to understand the differences in access to resources, the levelof the infrastructure, as well as the urbanization trends, where Bapatla, Chirala, Karapalem, Tsundur, and Vedampudi have been recognized as panchayats with very high population density vulnerability which is a cause of strain on public utilities, living spaces, transportation, and provision of essential services thus they require urban planning strategies centering on health, social, economic effects, and upgrading of the infrastructure of the urbanizing areas.
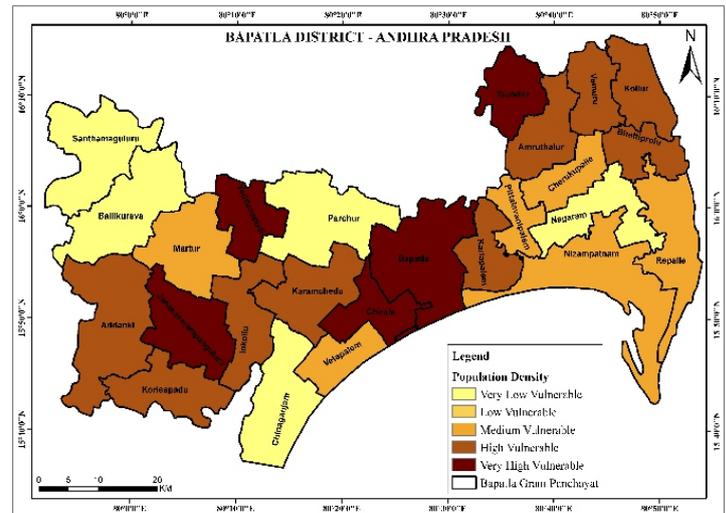

Fig. 18: Map of Population Density

Meanwhile, panchayats like Santhamaguluru, Ballikurava, Parchur, and Nizampatnam are at very low to low population density risk, which is indicative of their rural nature, lower populations, or efficient land-use management and as such, they can serve as a source of inspiration for the rural infrastructure and social services sector through the involvement of international development agencies to support the regional development sustainably.

3.3.6 Socio-Economic Profile
The socio-economic profile of Bapatla district, based on the map "Socio-Economic Profile" of Bapatla District,records in detail the 'levels of panchayats: very low, low, medium, high, and very high. The emphasis on the differences within the district, which can be derived from this map, is so pronounced that the local panchayats of Ballikurava, Parchur, Vetapalem, and Nagarampalem are ranked as the most socio-economically vulnerable with the "Very High" category. These places may be experiencing a variety of problems that may be caused by such limited access to income opportunities, infrastructural weakness, as well as poor access to the health and educational sectors. On the other hand, the panchayats of Bapatla, Pedanampadu, and Karamchedu were found to have "Very Low" vulnerability, which means that they have better development indicators and socio-economic stability.
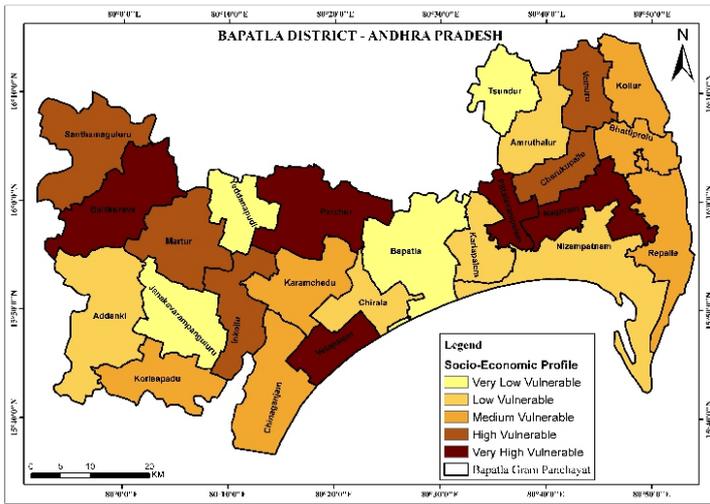
Fig. 19: Map of Socio-EconomicProfile

The existence of this distinction is important for international development organisations and policy-makers. It helps in targeting intervention and the allocation of resources. The spatial patterns emphasise the necessity of having different development strategies for different regions. The panchayats where the concentration of high vulnerability is mostly pointed should be the areas to which the concentrated efforts to reduce the disparities and achieve inclusive growth should be oriented. The table below presents an overview of the different major panchayats' vulnerability levels, thus doing away with the colour gradients and instead directly associating the vulnerability labels for international readers' clarity and accessibility.

3.4 Socio-Economic Vulnerability Index

Bapatla District's Socio-Economic Vulnerability Index (SVI) map reveals the vulnerability levels of various panchayats in a detailed manner. The map visually distinguishes the five degrees (very low, low, medium, high, and very high) of socio-economic risk for each area based on an integration of income, livelihood, infrastructure, and demographic pressures. It can be seen that Addanki, Korisapadu, Bhattiprolu, and Parchur panchayats are 'Very High Vulnerable', indicating that these areas are not only suffering from ecological but also from social disadvantage. Karamchedu, Bapatla, Chirala, and Repalle, however, have been identified as 'Very Low' or 'Low Vulnerable' respectively, thus indicating a certain degree of socio-economic stability and resilience.
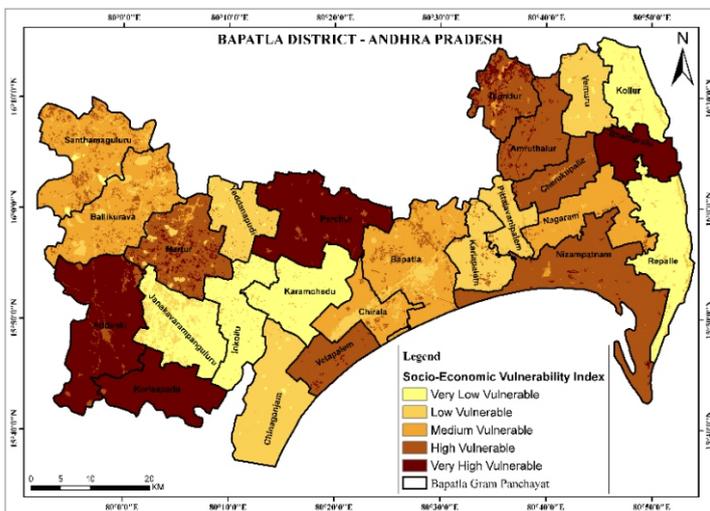

Fig. 20: Map of Socio-Economic Vulnerability Index

The investigation further uncovers substantial differences in the geographical distribution of the socio-economic vulnerabilities within the district that, according to the hypothesis, are directly proportional to the district's resource and infrastructure development and the quality of its governance. The presence of a cluster of highly vulnerable panchayats in the district's western and central parts, particularly in the areas of Addanki, Korisapadu, and JanakavaramPanguluru, is indicative of these being regions which have either been in a state of prolonged deprivation or have been subjected to a series of external shocks. Identifying these spatial concentrations is vital for the policy makers and development agencies, as it grants them the opportunity to devise precise countermeasures–targeting assistance to those who are the most vulnerable and bridging the socio-economic divide.

Table 5: Area wise Socio-EconomicVulnerability index

Sl. No.	Categories	Area (sq. Km.)
1	Very Low Vulnerable	724.3272
2	Low Vulnerable	695.8872
3	Medium **Vulnerable**	820.2483
4	High Vulnerable	921.4227
5	Very High Vulnerable	770.7339
	Total	**3932.6193**

By integrating local quantitative data (see the attached table), the interpretation becomes even richer because it depicts the geographic area linked with each vulnerability class. To be precise, the 'High Vulnerable' areas account for the largest part of the district (921.42 sq. km), while 'Very High' and 'Medium Vulnerable' categories also cover extensive portions of the district (770.73 sq. km and 820.25 sq. km respectively). It follows that more than half of Bapatla's land,the rural areas of many panchayats,is at either a high or very high risk of socio-economic vulnerability. These pieces of information serve as a well-grounded empirical basis for the global audience, thus stressing the problem-solving urgency and the scale that the challenges of development in Bapatla District.

4. CONCLUSION

This spatial analysis of Bapatla District brings to the fore a meticulously detailed and vividly intricate pattern of vulnerabilities which is highly dependent on the geographic location and due to the interaction of demographic demands, ecosystem degradation, and socio-economic restrictions. The combined regional study leading to the creation of the Socio-Economic Vulnerability Index (SVI) vividly portrays that the issue of vulnerability is not prevalent everywhere to the same extent, but rather, it is more obvious in certain localised areas.

Based on the data, the panchayats located in the central and western parts, namely Addanki, Korisapadu, and Bapatla, have been found to exhibit extremely high levels of total vulnerability. These places are full of very intense demographic pressures that include high population density, a broad range of dependent people and a high proportion of children under the age of six. At the same time, significant ecological strain is due to the over-extraction of groundwater and changes in land use. From the socio-economic point of view, the populations of these regions are characterised by low literacy levels, a great number of agricultural labourers and small-scale farmers who are vulnerable and have low incomes, and a large number of people belonging to the marginalised social groups. In contrast, the panchayats located in the eastern and northern parts of the district, such as Karamchedu, Repalle, and Ballikurava, are most likely to have less vulnerability and thus have more advantages

in terms of demographic structures, ecosystems, and socio-economic factors.

The research points out that demographic issues may lead to ecosystem problems, which, in turn, result in socio-economic issues, thus forming a vicious circle of deprivation that prevents sustainable development. The existence of such a large geographical area of the district that is classified under the "High" or "Very High" vulnerability category (covering 1,692.16 sq. km) is an indication of the magnitude of the problem.

The study, therefore, arrives at the conclusion that there is a dire need for quickly implemented, multifaceted and targeted interventions. The first step for policy and development efforts should be to identify sectors where the highly vulnerable panchayats will benefit the most and then proceed to break the cycle of disadvantage. Effective measures should include the combination of activated resource management (especially sustainable water use and wetland conservation), human capital (education and health), and economic empowerment (by means of skill-development and livelihood security for agricultural workers and cultivators) strategies. The spatial and quantitative evidence contained in this report serves as an essential platform from which decision-makers and development partners can make sound, efficient resource allocation decisions and lay down feasible, localised plans that can result in lowering disparities and promoting equitable, resilient growth across the Bapatla District area.

Acknowledgements

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