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Analytical Hierarchy Process Based Multi-Criteria Decision-Making Model for Groundwater Potential Zones Identification - A Case Study of Kakinada District, Andhra Pradesh, India

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Abstract: Groundwater is a vital natural resource for agricultural, domestic, and industrial uses, especially in coastal regions like Kakinada District, where surface water availability is limited. The increasing demand and over-extraction of groundwater have led to depletion and quality deterioration. Hence, it is essential to identify and delineate potential groundwater zones to ensure sustainable water management. In this study, a multi-criteria decision-making approach integrating the Analytical Hierarchy Process (AHP) and Geospatial techniques was employed to delineate groundwater potential zones. Various thematic layers such as geology, geomorphology, soil, land use/land cover (LULC), slope, drainage density, rainfall, and lineament density were prepared using remote sensing data and processed in ArcGIS. Each parameter was assigned weights and ranks based on its influence on groundwater occurrence through the AHP method. The weighted overlay analysis was performed in ArcGIS to integrate all thematic maps and generate a groundwater potential zone map. The final map classified the area into five zones - very high, high, moderate, low, and very low potential - indicating spatial variations in groundwater availability across the district. Results reveal that regions with alluvial deposits, gentle slopes, high rainfall, and moderate drainage density exhibit high groundwater potential, while areas with hard rock formations and steep slopes show lower potential. The delineated zones provide valuable insights for groundwater resource planning, recharge site identification, and sustainable utilization in Kakinada District. This integrated AHP and GIS-based approach demonstrates an efficient, accurate, and data-driven method for groundwater potential mapping, which can be replicated in other regions facing similar hydrological and environmental challenges.

Keywords: ARC-GIS Software, Analytical Hierarchy Process (AHP), MCDM, GWPZ

I. INTRODUCTION

Groundwater is one of the most vital natural resources supporting domestic, agricultural, and industrial activities, particularly in regions where surface water availability is limited or highly variable. Identifying and evaluating groundwater potential zones has therefore become an essential component of sustainable water resource management. The Kakinada District of Andhra Pradesh, located along the eastern coastal plains of India, experiences significant variations in rainfall distribution, geomorphological settings, and land use patterns. These variations, combined with increasing population pressures and expanding agricultural practices, have resulted in growing stress on the district's groundwater reserves. Consequently, scientific and spatially accurate assessment methods are necessary to delineate areas with high groundwater potential for effective planning and utilization.

The integration of Geographic Information System (GIS) and multi-criteria decision-making techniques such as the Analytical Hierarchy Process (AHP) provides a robust framework for groundwater resource evaluation. GIS allows efficient handling, visualization, and analysis of diverse thematic layers including slope, soil, drainage density, geomorphology, geology, land use/land cover, rainfall, and lineament density. AHP, on the other hand, enables systematic assignment of weights to these criteria based on their relative influence on groundwater occurrence. By combining these tools, a weighted overlay analysis can be performed to generate a comprehensive Groundwater Potential Zone (GWPZ) map.

This study adopts a multi-criterian approach to integrate AHP with GIS for delineating groundwater potential zones in the Kakinada District.

The methodology ensures a scientifically validated and spatially precise identification of groundwater prospects, providing valuable insights for sustainable water resource development, groundwater recharge planning, and policy formulation. The resulting GWPZ map serves as an essential decision-support tool for administrators, planners, and researchers working towards long-term water security in the region.

A. Study Area

Kakinada, the district headquarters of Kakinada District in the state of Andhra Pradesh, is a significant coastal town along the northeast coast of India at latitude 16.57°N and longitude 81.15°E. The city has an area of approximately 31.69 sq. km with an average height of 12 meters above mean sea level. It has a tropical savanna climate with hot and humid conditions and an average annual rainfall of between 110 and 115 cm. The geology of the area is comprised primarily of alluvial and coastal deposits that affect the occurrence and recharge of groundwater.

Nevertheless, as it lies close to the sea and the ground is flat, Kakinada is plagued by saline water intrusion and restricted infiltration, impairing groundwater quality and potential. The city shows mixed land use with residential, commercial, and public areas and a population density of approximately 10,287 people per sq. km based on the 2011 Census. Kakinada is a very important administrative, industrial, and educational center of Andhra Pradesh.

The Kakinada Municipal Corporation (KMC) governs water supply distribution and infrastructure development in the city, assisted by various government departments and programs such as AMRUT and the Smart City Mission. The fast growth of the city and industrialization have resulted in higher demands for water, putting surface and groundwater resources under pressure. Thus, Kakinada was chosen as the study area to identify groundwater potential zones through geospatial and analytical methods. Its distinctive coastal location, heterogeneous geology, and increasing population make it an ideal area for recognizing groundwater distribution and creating sustainable water management practices.

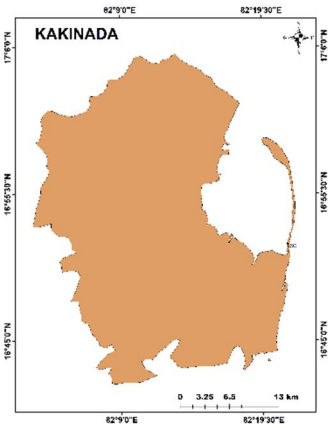

Fig 1. Study Area

II. METHODOLOGY

The methodology of this study combines GIS-based spatial analysis with the Analytical Hierarchy Process (AHP) to identify groundwater potential zones in Kakinada District. This operation starts with the collection of multi-source datasets comprising satellite imagery, geological and soil maps, DEM, rainfall data, and land use information. These datasets are utilized to generate thematic raster layers such as geology, geomorphology, soil, slope, rainfall, drainage density, lineament density, and land use/land cover in ArcGIS. Each layer is reclassified considering its role in groundwater recharge and storage. To ascertain the most significant factor, AHP is used, where pairwise comparison matrices are formed and normalized weights are calculated, and consistency checking is also performed to confirm the reliability of the decisions. After the determination of the weights, they are given to each thematic layer, and then Weighted Overlay Analysis is performed in ArcGIS to combine all the factors into a single groundwater potential index.

Table 1. Data required and sources of data

Types of Data	Scale/Resolution	Parameter	Sources Data
STRM DEM	30 M	Slope, Elevation, curvature, TWI, Drainage density	USGS Earth explorer (https://earthexplorer.usgs.gov)
Geological and Geomorphological	2 M	Geology and Geomorphology	Bhukosh (https://bhukosh.gsi.gov.in)
Rainfall Data	0.25*0.25 Degree	Rainfall Map (2021-2024)	IMD (https://www.imdpune.gov.in)
Sentinel 2A	10 M	LULC	ESRI Land Cover (https://livingatlas.arcgis.com/landcover/)
Soil Data	1:1250000	Soil texture map	FAO Soils Portal (https://www.fao.org/soils-portal)

Table 2. AHP Level ii parameters and Pairwise computations

S.L.NO	Factor	RF	LULC	GM	G	S	DD	SL	CUR	TWI
1	RF	1	1/3	1	1/5	1	1	1/3	1/3	1/3
2	LULC	3	1	3	1/3	1	1	1	1/3	1
3	GM	1	1/3	1	1/3	1	1	1/3	1/5	1/3
4	G	5	3	3	1	1	3	3	1	3
5	S	1	1	1	1	1	3	1	1/5	1
6	DD	1	1	1	1/3	1/3	1	1	1	1
7	SL	3	1	3	1/3	1	1	1	1/3	1
8	CUR	3	3	5	1	5	1	3	1	3
9	TWI	3	1	3	1/3	1	1	1	1/3	1
	SUM	21	12	21	5	12	13	12	5	12

Analytical Hierarchical Method (AHP) can assist the decision-maker in setting goals that lead to the right option. In order to choose the best course of action, these were the steps that were taken:

1) Step 1: Selection of the variables that influence the decision. These are nothing but the variables that affect the water quality and are pre-defined as per the considered index (PARAMETERS). These variables are referred the AHP as level 2 decision parameters, Level I being the main decision making
2) Step 2: The second step is the generation of a pair-wise comparison matrix. This is the most important step in which the level 2 variables are ranked and are assigned with Impact of Importance (ii) values based on the known information on the comparative ranking of the variables on the quality. The concept of ranking the parameters is addressing a question: "how important one attribute is in comparison to other" and soliciting an answer for the same in the form of a 1-9 scale. It is in this step the inferences drawn from cluster analysis are used in association with the ranking decision suggested by Saaty 1980. towards fixing the II values This will result in the II (ixj) matrix containing the pair wise ranks of the decision factors (II values). The upper diagonal matrix is first generated and the lower diagonal matrix is simply inverse of the upper diagonal matrix. The diagonal elements are unity as they represent the weightage of any factor compared with itself. This step is to be repeated for the sub-factors of each of the level 2 decision factors.

3) Step 3: The next step is calculation of Estimated Eigen Element (EEE) for each decision factor followed by normalization of EEEs. These normalized EEEs are referred as the IWI values of each of the level 2 decision parameters. Equations 3.1 and 3.2 (Saaty, 1980) given below enable the computation of EEEs and RIV respectively.

$EEE_i = N_7\sqrt{\pi}_{j=1}^{N_7}[II]_j$……...3.1

$RIW = \frac{EEEi}{\sum_{J=1}^{N7} EEEj}$……..3.2

where, EEEi = Estimated Eigen Element of ith decision factor, N2 = number of decision factors at current (2) level, Ilj = Intensity of Impact of jth decision factor at higher level and RIWi = Relative Importance Weightage of ith decision factor.

4) Step 4: The process of pair-wise comparison requires a consistency check and the same is achieved by calculating a ratio called "Consistency Ratio" (CR). Based on numerous empirical studies, it is suggested that the CR must be less than or equal to 0.10 so that inconsistency can be acceptable within the tolerable limit (Saaty, 1980).

The consistency check involves two further steps. They are:
(i) Generation of a matrix of Consistency Values (CVij),
(ii) Arriving at an array of Consistency Weights (CWi,),
iii) Calculation of an array of Weighted Sum of Criteria Values (WSVI) which is the sum of the products of Criteria Product (CPif)
(iv) Obtaining an array of Consistency Factor denoted as ki and
(v) Calculation of Consistency Index (CI) and Consistency Ration (CR).

CVij = $\frac{\pi ij}{\sum_{i=1}^{n} IIij}$for i = 1, n& j = 1, n ---- (3.3) CVij = $\frac{\pi ij}{\sum_{i=1}^{n} IIij}$ for i=1, n & j = 1, n-----(3.4)
CPij = CWi * CVij for i = 1, n & j =1. n ---- (3.5) WSVi=$\sum CPijnj = 1$ for i=1. n ----- (3.6)
$\lambda i = \frac{wsvi}{cwi}$ for i = 1, n --------(3.7) CI = $\frac{\lambda max - n}{n-1}$ -----(3.9) CI = $\frac{CI}{CI\ std}$ ---------(3.9)

where, λmax = Maximum value of λí and Clstd = Standard consistency index that depends on the number of decision factors involved.

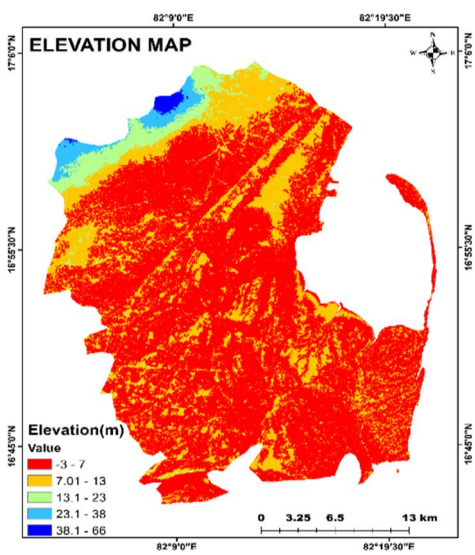

Fig 2. Showing the elevation map of the study area

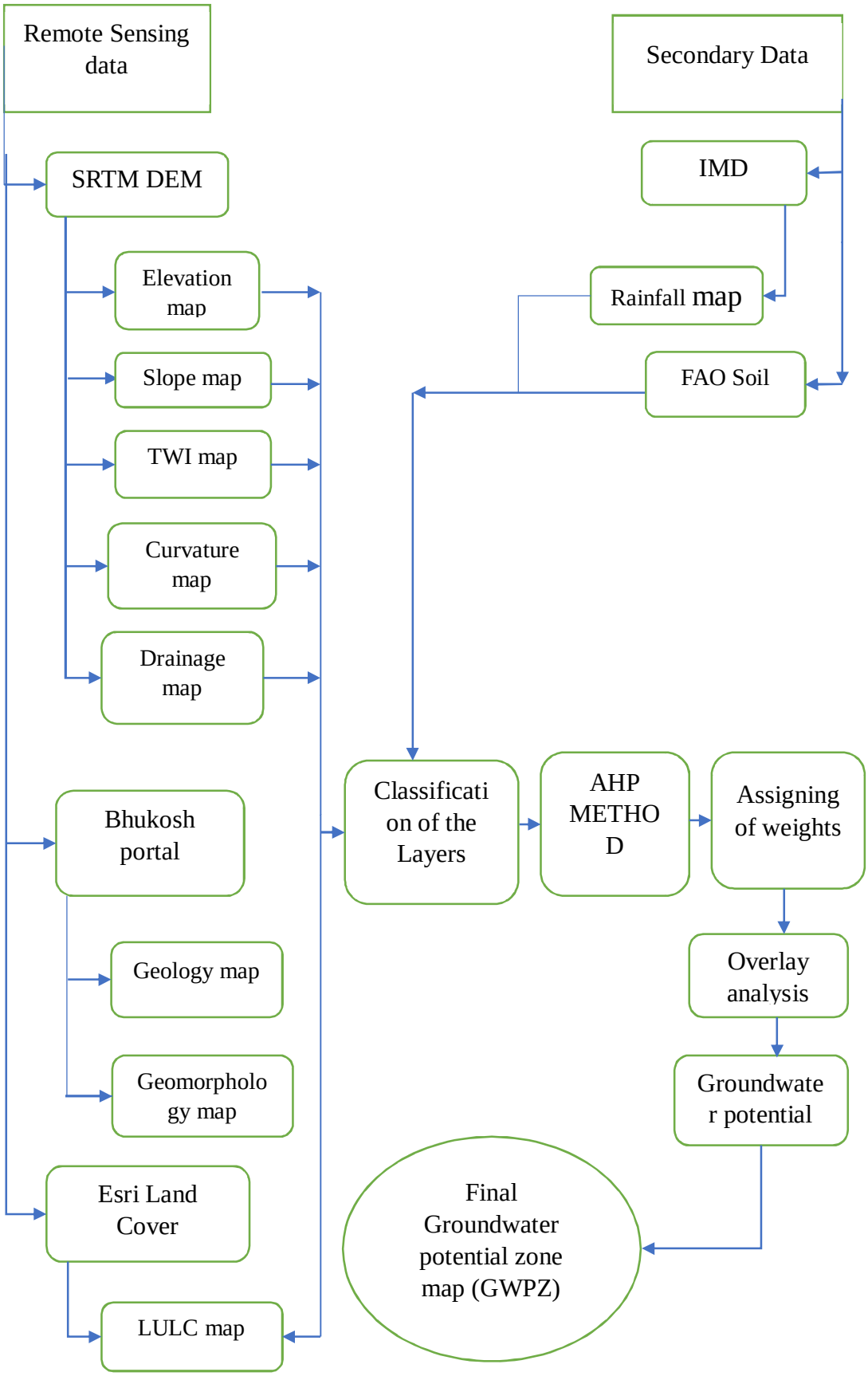
Remote Sensing data
Secondary Data
SRTM DEM
IMD
Elevation map
Rainfall map
Slope map
FAO Soil
TWI map
Curvature map
Drainage map
Classification of the Layers
AHP METHOD
Assigning of weights
Bhukosh portal
Overlay analysis
Geology map
Groundwater potential
Geomorphology map
Esri Land Cover
Final Groundwater potential zone map (GWPZ)
LULC map

Fig 3. Schematic flowchart illustrating the methodological framework employed for the delineation and mapping of groundwater potential zone

Table 3. Normalization Pairwise Comparison Matrix Level ii

S.L.NO	*Factor*	*RF*	*LULC*	*GM*	G	S	DD	SL	CUR	TWI	SUM	Criteria Weights	Criteria weights (%)
1	*RF*	0.048	0.028	0.048	0.040	0.083	0.077	0.028	0.068	0.028	0.448	0.051	5.1
2	*LULC*	0.143	0.083	0.143	0.067	0.083	0.077	0.083	0.067	0.083	0.829	0.094	9.4
3	*GM*	0.048	0.028	0.048	0.067	0.083	0.077	0.028	0.040	0.028	0.445	0.050	5.0
4	*G*	0.238	0.250	0.143	0.200	0.083	0.231	0.250	0.200	0.250	1.845	0.208	20.8
5	*S*	0.048	0.083	0.048	0.200	0.083	0.231	0.083	0.040	0.083	0.899	0.101	10.1
6	*DD*	0.048	0.083	0.048	0.067	0.028	0.077	0.083	0.200	0.083	0.717	0.081	8.1
7	*SL*	0.143	0.083	0.143	0.067	0.083	0.077	0.083	0.067	0.083	0.829	0.094	9.4
8	*CUR*	0.143	0.250	0.238	0.200	0.417	0.077	0.250	0.200	0.250	2.025	0.228	22.8
9	*TWI*	0.143	0.083	0.143	0.067	0.083	0.077	0.083	0.067	0.083	0.829	0.094	9.4
	SUM										8.867	1.000	100

Table 4. Categorization of key factors influencing the spatial distribution of Groundwater Potential Zones in the present study

Parameters	Parameter Class	Area	Area (%)	Rating	AHP weight (%) (From table 5.2)
Rainfall	1156.8 - 1178.5	210.091	22.95	1	5
	1178.6 - 1207.3	179.316	19.59	2	
	1207.4 - 1241.5	116.528	12.73	3	
	1241.6 - 1271.9	181.853	19.87	4	
	1272 - 1295.3	227.851	24.89	5	
LULC	Water	117.362	12.82	5	10
	Tree	137.185	14.99	3	
	Flooded vegetation	2.518	0.28	5	
	Crops	522.519	57.08	5	
	Built Area	124.426	13.59	1	
	Bare ground	0.9378	0.10	1	
	Range land	10.7451	1.17	3	
Geomorphology	Anthropogenic terrain	8.4	0.92	3	5
	Coastal Plain	342.8	37.45	3	
	Deltaic Plain	508.6	55.56	4	
	flood plain	10.01	1.09	3	
	Pediment pedi complex	4.28	0.47	2	
	Waterbody-Others	27.7	3.03	5	
	Waterbody-River	9.63	1.05	3	
Geology	Rajahmundry fm	61.54	6.72	2	21
	Quaternary sediments	854.3	93.33	5	
Soil	Calcaric Fluvisols	306.8	33.52	4	10
	Dystric Fluvisols	445.6	48.68	4	
	Eutric Fluvisols	163.3	17.84	3	

Drainage density	0.335 - 15.3	58.442	6.38	1	8
	15.4 - 30.4	87.015	9.51	2	
	30.5 - 45.4	396.34	43.30	3	
	45.5 - 60.4	277.192	30.28	4	
	60.5 - 75.4	97.171	10.62	5	
Slope	0 - 0.5	285.9	31.23	5	9
	0.6 – 1	335.9	36.70	4	
	2 – 3	203	22.18	3	
	4 – 5	78.71	8.60	2	
	6 – 20	11.84	1.29	1	
Curvature	(-3.7) - (-0.15)	159.084	17.38	1	23
	(-0.14 - 0.094)	509.98	55.71	2	
	0.095 - 0.29	155.5	16.99	3	
	0.3 - 0.82	88.3	9.65	4	
	0.83 - 8.6	2.5	0.27	5	
Topographic wet index	4.4 – 7	210.45	22.99	5	9
	7.1 – 8	285.425	31.18	4	
	8.1 - 8.9	372.505	40.70	3	
	9 - 9.8	31.827	3.48	3	
	9.9 – 13	15.588	1.70	1	

TABLE 5. Standard Consistency Index Values (Sumantha Chakrabarti,2015)

N	1	2	3	4	5	6	7	8	9	10
CI_{std}	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

III. RESULTS AND DISCUSSION

A. Rainfall

Rainfall is the primary source of water for the hydrologic cycle and plays a major role in groundwater recharge in the study area. It directly influences infiltration, runoff, and overall water availability. Long-term rainfall data were used to prepare a rainfall distribution map using geospatial interpolation. The annual rainfall ranges from 1,156.8 mm to 1,295.3 mm in the region. The values were classified into five categories: Low, Moderate-Low, Moderate, High, and Very High rainfall zones. The map shows a clear north-to-south rainfall gradient, with lower rainfall in the north and higher rainfall in the south. This pattern reflects topographic and climatic variations across the district. Higher rainfall areas promote more infiltration and better groundwater recharge. Lower rainfall zones experience greater runoff and reduced recharge. Overall, the rainfall map provides essential information for groundwater potential mapping and water resource planning.

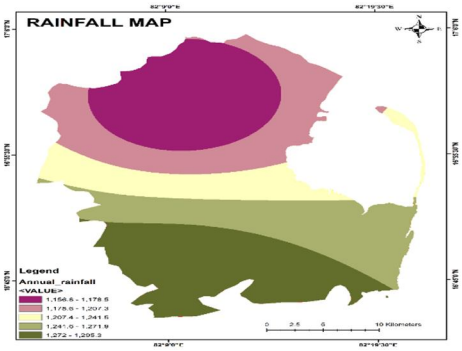

Fig 4. Showing the rainfall map of the study area

B. Land use Land cover

Land Use and Land Cover (LULC) of the Green Valley Watershed provide essential insights into environmental characteristics and key hydrological processes such as infiltration, soil moisture, and surface runoff. The watershed contains a diverse mix of agricultural land, forest cover, and built-up areas, reflecting the interaction between natural ecosystems and human activities.

Agriculture is the dominant land cover, occupying about 55% of the total area, mainly concentrated in the fertile central plains where soil and water availability support intensive cultivation. These croplands significantly influence the local economy and contribute moderately to groundwater recharge through infiltration. Forests form the second major land cover category, covering nearly 30% of the watershed, mostly along higher elevations and slopes. These forested areas help control soil erosion, enhance biodiversity, and support ecological balance. Overall, the LULC distribution highlights the watershed's dependence on agriculture and the ecological importance of forest zones in sustaining hydrological and environmental stability.

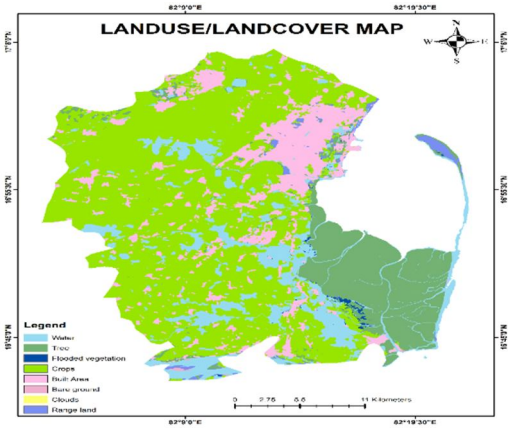

Fig 5. Showing the land use and land cover (LULC) map of the study area

C. Geomorphology

The geomorphology map of the region provides an overall understanding of the major landforms and the geological processes that have shaped the landscape over time. It highlights the influence of soil characteristics, water flow, and land use patterns. The area contains a variety of geomorphic units, including broad floodplains, a significant pediment–Pedi plain complex, and an extensive coastal plain. Floodplains, shown in dark pink, dominate the central and southern parts, representing flat, low-lying terrain formed by continuous river sediment deposition. These zones are fertile but highly prone to flooding. The pediment–Pedi plain complex in the northwest, marked in dark orange, consists of gently sloping rock-cut surfaces developed through long-term erosion at the base of surrounding hills. Along the eastern margin, a wide coastal plain appears in brown, running parallel to the shoreline and formed by marine and fluvial sediment deposition. A small deltaic plain, shown in light blue near the river mouth, represents active sediment accumulation where the river meets the sea.

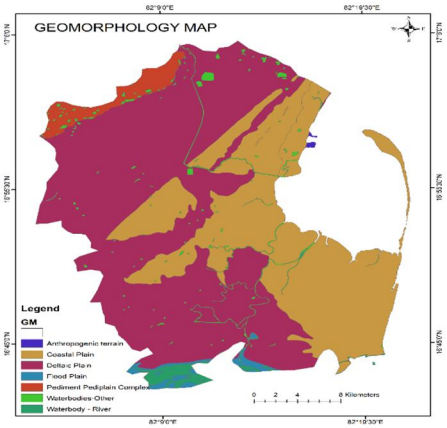

Fig 5. Showing the geomorphology map of the study area

D. Geology

The geology map offers essential information on the subsurface composition of the region, showing the type and distribution of rocks and sediments. It helps in understanding soil fertility, groundwater prospects, and engineering suitability. The map displays a simple but distinct geological pattern dominated by two major units: widespread Quaternary sediments and the localized Rajahmundry Formation. Quaternary deposits, shown in purple, cover most of the central, southern, and eastern parts of the area. These sediments, formed within the last 2.6 million years, consist mainly of sand, silt, and clay deposited by river or coastal processes. Their wide distribution indicates a landscape shaped by recent sedimentation, creating flat, fertile, and highly porous terrain favourable for agriculture and groundwater recharge. In contrast, the Rajahmundry Formation, marked in green in the northern part, represents an older and more consolidated rock unit. This formation stands apart from the younger deposits and signifies an important chapter in the region's deeper geological history. Together, these units define the geological character of the study area.

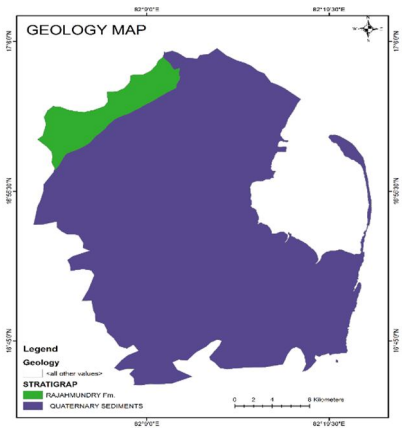

Fig 6. Showing the geology map of the study area

E. Soil

The soil map illustrates the spatial distribution of major soil types in the region, which is essential for agricultural planning, land management, and understanding overall soil fertility. Three primary soil units are identified, all belonging to the Fluvisol group, indicating formation from recent river deposits. The dominant soil type is **Utric Fluvisol**, covering the entire northern part of the map. These soils are rich in essential bases such as calcium, magnesium, and potassium, making them neutral to slightly alkaline and highly fertile for diverse crops. In the central and southwestern areas, **Calcaric Fluvisols** appear, characterized by notable calcium carbonate content. Their alkaline nature may require specific nutrient management to support sensitive crops. The southeastern part of the region contains **Dystric Fluvisols**, which are poorer in soil bases and more acidic compared to the other types. These soils have relatively lower natural fertility and may need amendments to improve productivity. Overall, the soil distribution reflects a varied agricultural landscape with distinct management.

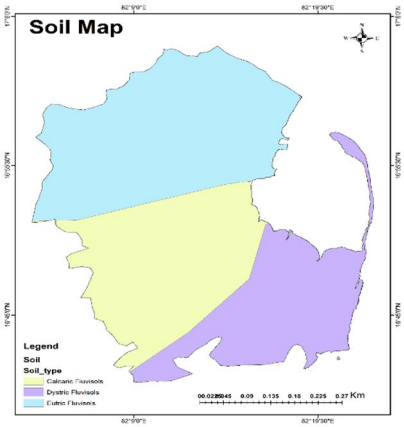

Fig 7. Showing the soil map of the study area

F. Drainage Density

The drainage density map shows the distribution of streams and rivers across the region, helping to understand runoff behaviour and watershed characteristics. Drainage density represents the total length of streams divided by the watershed area, indicating how well the landscape is dissected by the drainage network. The map displays a highly variable pattern, with large zones of high and very high drainage density, mainly in the central and western parts. These areas, marked in magenta and dark blue, suggest rapid surface runoff and limited infiltration due to factors like steep slopes, hard or semi-permeable rocks, and sparse vegetation. Such regions are more prone to quick flow accumulation and potential flash flooding during heavy rains. Moderate drainage density areas, shown in light blue, act as transitional zones between high and low-density regions. These areas indicate more balanced hydrological conditions, where both runoff and groundwater recharge occur. Overall, the drainage density pattern highlights the influence of terrain, geology, and land cover on water movement within the watershed.

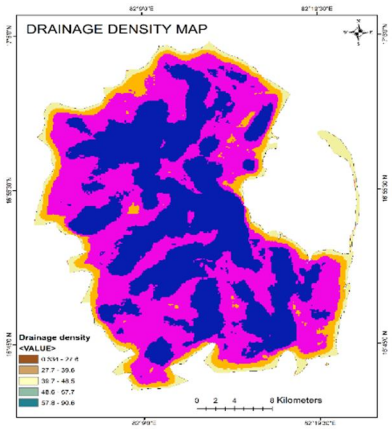

Fig 8. Showing the Drainage density map of the study area

G. Slope

The slope map shows the variation in terrain steepness across the region, an important factor influencing runoff, soil erosion, landslide risk, and land-use suitability. The area exhibits a complex topography with gentle slopes mixed alongside steep gradients. High and very high slope zones, shown in purple and magenta, dominate much of the central and northern parts. These steep areas experience rapid surface runoff, higher erosion rates, and limited suitability for agriculture or construction. They often reflect rugged, elevated terrain shaped by active geomorphic processes. In contrast, low and very low slope areas, shown in yellow and light yellow, occur mainly along the eastern coastal belt and in smaller interior pockets. These gentle zones are stable, fertile, and ideal for agriculture, irrigation, settlement expansion, and infrastructure development. Moderate slope regions, depicted in light blue, form transitional zones between steep and flat areas. Overall, the slope pattern highlights the strong influence of terrain on hydrology, land use, and regional planning

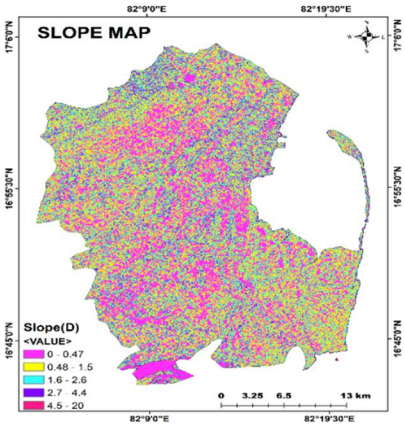

Fig 9. Showing the slope map of the study area

H. Curvature

The curvature map helps interpret how the land surface shape influences water flow, infiltration, and erosion. Curvature describes whether the terrain is flat, concave, or convex, which in turn affects how water accumulates or drains. The region is dominated by flat and slightly concave surfaces, shown in light yellow, green, and orange, covering most of the area. These gentle and inward-curving slopes favor water accumulation, reduced runoff, and higher infiltration, supporting groundwater recharge. Their widespread presence indicates a stable landscape shaped by long-term sediment deposition. In contrast, slightly convex and convex areas, marked in light and dark blue, appear only in small isolated patches. These outward-curving slopes shed water quickly, leading to higher runoff and greater erosion potential. They typically correspond to small hills or elevated terrain within the generally flat region. A few scattered concave pockets, shown in red, further enhance localized water concentration. Overall, the curvature map highlights how subtle variations in surface shape influence hydrological behavior and erosion patterns across the landscape.

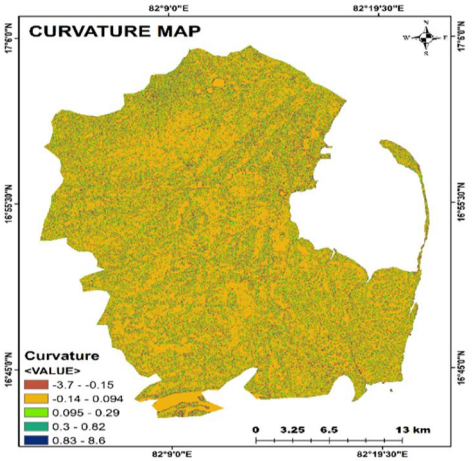

Fig 10. Showing the curvature map of the study area

I. Topographic wet index

Integrating the Topographic Wetness Index (TWI) map with the LULC map helps understand how hydrological conditions relate to human land use. The TWI map shows that most of the region has **moderate TWI values**, indicating balanced water accumulation and neither excessive runoff nor persistent saturation. High TWI pockets, shown in dark blue, occur in depressions, low-lying zones, and natural drainage channels where water tends to collect. Low TWI areas on elevated ground have good drainage and minimal water retention. The LULC map displays a diverse land cover pattern, dominated by **agricultural land** in the central and western regions, highlighting the area's strong farming activity. Forest cover is concentrated mainly in the southeast, with smaller patches elsewhere. Built-up areas appear as small, isolated clusters, while water bodies and wetland vegetation occur in limited pockets. Together, the TWI–LULC integration shows how natural moisture conditions influence land use and how human activities align with hydrological suitability.

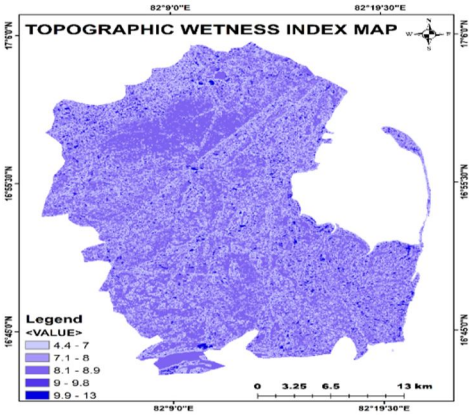

Fig 11. Showing the TWI map of the study area

J. Groundwater Potential Zone Map for Study Area

1) Level ii Map

Table 6. The extent of groundwater potential zones model I identified in the study area

S. No	GWPZ Class	GWPZ Model - 1 (Weighted sum)	
		Area (km^2)	Area (%)
1	Very poor	191.7	21.2
2	Poor	375.8	41.5
3	High	231.0	25.5
4	Very high	106.3	11.8
	Total	904.7	100.0

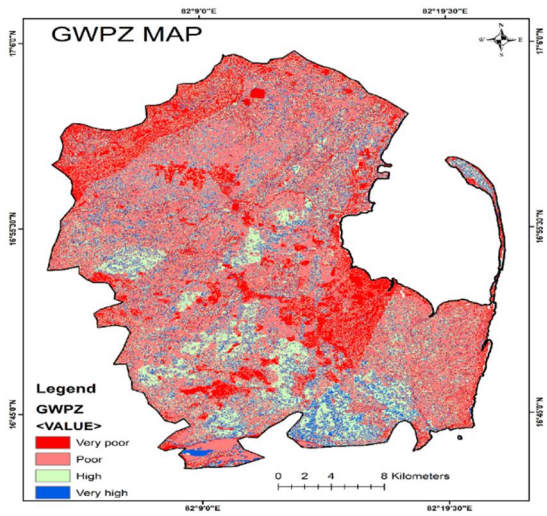

Fig 12. Showing the Model I Groundwater potential zone map of the study area

2) Level iii map

Table 7. The extent of groundwater potential zones model II identified in the study area

S. No	GWPZ Class	GWPZ Model - 2 (Weighted Overlay)	
		Area (km^2)	Area (%)
1	Very poor	0.1	0.0
2	Poor	52.4	5.8
3	High	768.2	84.9
4	Very high	84.0	9.3
	Total	904.7	100.0

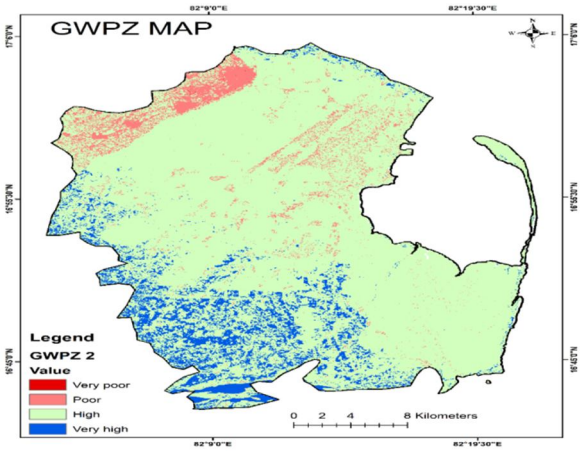

Fig 13. Showing the Model II Groundwater potential zone map of the study area

K. Mandal Wise Groundwater Potential Zone Map Both Models

Table 8. Samaralakota Mandal

S. No	GWPZ Class	GWPZ Model - 1 (Weighted sum)		GWPZ Model - 2 (Weighted Overlay)	
		Area	Area (%)	Area	Area (%)
1	Very poor	41.9	32.5	0.1	0.1
2	Poor	55.0	42.5	31.6	24.4
3	High	22.3	17.2	96.2	74.4
4	Very high	10.0	7.8	1.4	1.1
	Total	129.2	100.0	129.2	100.0

Table 9. Kakinada Mandal

S. No	GWPZ Class	GWPZ Model - 1 (Weighted sum)		GWPZ Model - 2 (Weighted Overlay)	
		Area	Area (%)	Area	Area (%)
1	Very poor	25.8	18.3	0.0	0.0
2	Poor	66.5	47.2	11.8	8.4
3	High	30.7	21.8	128.1	91.0
4	Very high	17.8	12.7	0.9	0.6
	Total	140.8	100.0	140.8	100.0

Table 10. Pedapudi Mandal

S. No	GWPZ Class	GWPZ Model - 1 (Weighted sum)		GWPZ Model - 2 (Weighted Overlay)	
		Area	Area (%)	Area	Area (%)
1	Very poor	21.8	16.6	0.0	0.0
2	Poor	64.0	48.9	2.4	1.8
3	High	29.0	22.1	122.0	93.1
4	Very high	16.2	12.3	6.6	5.0
	Total	131.0	100.0	131.0	100.0

Table 11. Karapa Mandal

S. No	GWPZ Class	GWPZ Model - 1 (Weighted sum)		GWPZ Model - 2 (Weighted Overlay)	
		Area	Area (%)	Area	Area (%)
1	Very poor	19.7	19.8	0.0	0.0
2	Poor	45.4	45.7	2.7	2.7
3	High	22.8	22.9	89.0	89.6
4	Very high	11.4	11.5	7.6	7.6
	Total	99.3	100.0	99.3	100.0

Table 12. Kajuluru Mandal

S. No	GWPZ Class	GWPZ Model - 1 (Weighted sum)		GWPZ Model - 2 (Weighted Overlay)	
		Area	Area (%)	Area	Area (%)
1	Very poor	20.7	14.9	0.0	0.0
2	Poor	66.5	47.8	1.0	0.7
3	High	33.2	23.9	88.5	63.5
4	Very high	18.8	13.5	49.8	35.8
	Total	139.3	100.0	139.3	100.0

Table 13. Tallarevu Mandal

S. No	GWPZ Class	GWPZ Model - 1 (Weighted sum)		GWPZ Model - 2 (Weighted Overlay)	
		Area	Area (%)	Area	Area (%)
1	Very poor	61.8	23.3	0.0	0.0
2	Poor	104.2	39.3	3.0	1.1
3	High	67.1	25.3	244.5	92.2
4	Very high	32.1	12.1	17.7	6.7
	Total	265.2	100.0	265.2	100.0

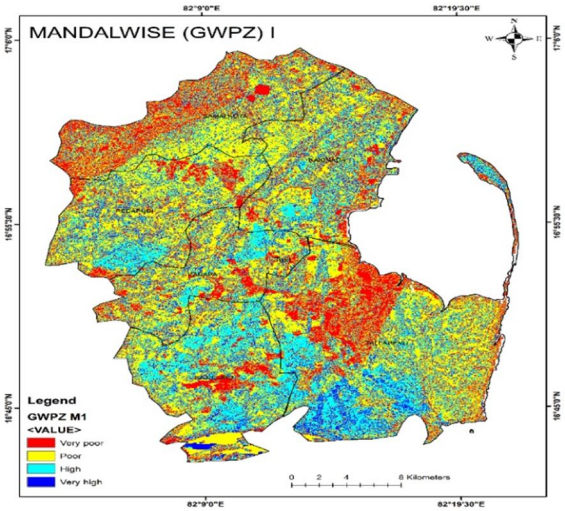

Fig 14. Mandal wise Model 1 Groundwater potential zone map

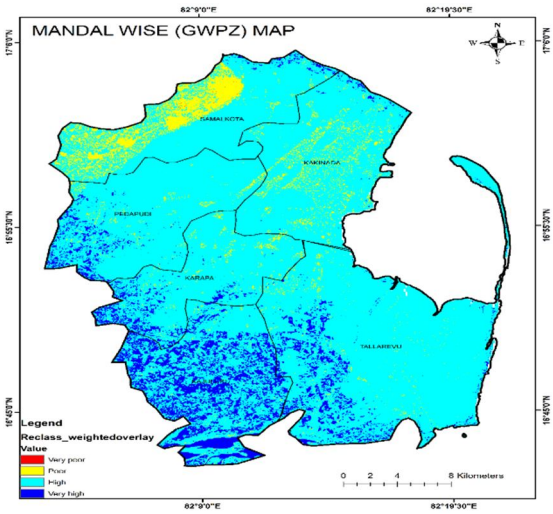

Fig 15. Mandal wise Model 2 Groundwater potential zone map

IV. CONCLUSION

1) The comparison of the two groundwater potential zone maps highlights the influence of methodological approaches on the delineation of favourable zones.
2) The weighted sum map generated using Level II parameters shows extensive areas under high and very high potential, particularly in the southern and central parts of the study area.
3) In contrast, the weighted overlay map based on Level III parameters indicates more conservative results, with large regions falling under poor and very poor categories.
4) Both maps consistently identify the southern zone as favourable for groundwater occurrence, reflecting the control of geology, lineaments, and slope. The differences between the two outputs demonstrate the sensitivity of groundwater potential mapping to parameter selection, ranking, and weighting.
5) The weighted sum approach provides a broader overview useful for general exploration. The weighted overlay approach offers a stricter and more detailed assessment suitable for resource management.
6) Together, these maps complement each other in understanding groundwater distribution. They provide valuable guidance for planning recharge structures and sustainable utilization.
7) Overall, the integrated evaluation enhances the reliability of groundwater potential zoning in the study area.
8) The two-groundwater potential zone (GWPZ) maps were designed using a weighted amount and weighted overlay model for the Kakinada district.
9) Both models integrate several thematic layers through analytical hierarchy process (AHP) and GIS techniques.
10) The weighted sum model shows the dominance of the poor in most poor groundwater potential areas in most parts of the district.
11) The high and very highly possible areas are minimal in the weighted sum map, indicating restricted recharge capacity.
12) On the other hand, the weighted overlay models highlight the wide high and very highly potential areas, especially in the middle, southern and south -western parts.
13) The poor and very poor areas in the weighted overlay map are mainly limited to the northern region.
14) The difference is generated from the modeling point of view: weighted sum uses continuous weight, while weighted overlays apply generalized and regenerated weight.
15) The overlay model more effectively emphasizes favorable conditions, resulting in more optimistic distribution.
16) Both models provide valuable insight, showing a conservative estimate and increased groundwater possibilities with a weighted amount.
17) These results support targeted groundwater recharge and permanent resource management plan in low-affected areas.

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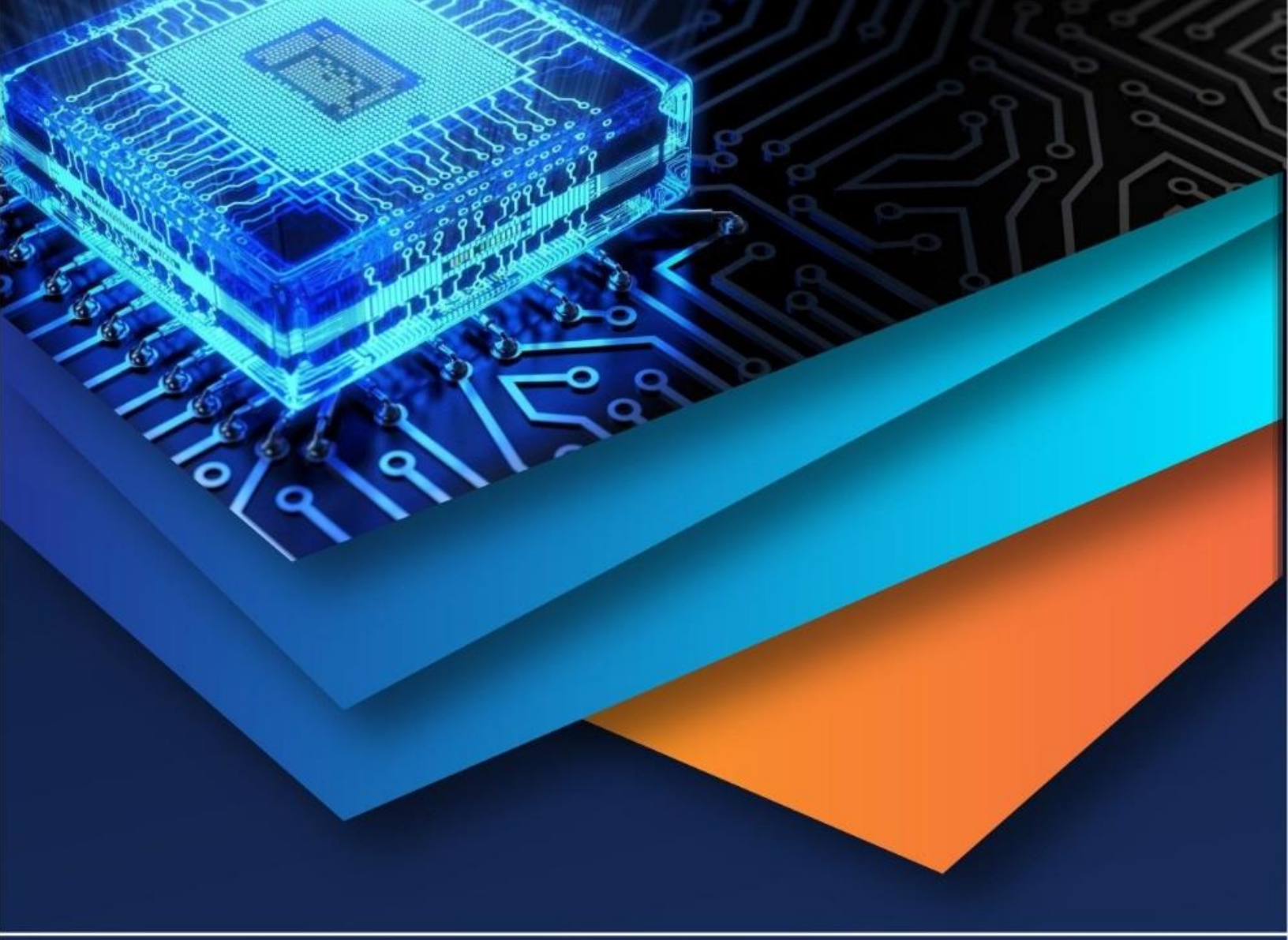

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