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Assessment of Land Use/Land Cover Change, Rainfall Pattern and NDVI in Nandyal District, Andhra Pradesh: Using Geo-Informatics

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***Abstract*: Nandyal District is blessed with pilgrimage heritage sites and spans over 9,681 square kilometres, with diverse ecosystems and varieties of trees occupying about 32% of the land. Looking at the land usage pattern from 2017 to 2024, it is evident that the main activity is farming. Crops occupy about 52.74% of the land in 2024, with rangelands and forests slightly decreasing. It is evident that the rainfall pattern is diverse during these years. It is clear that the growth of crops depends on the rainfall pattern. NDVI shows the diversity in the growth of vegetation. It is evident that the areas with high rainfall are occupied by moderate to dense greenery. It is also evident that the relationship between rainfall and NDVI is not straightforward. More rainfall does not imply the growth of vegetation in all areas, especially those with low rainfall. In summary, it is evident that the change in land usage, the distribution of rainfall, and the growth of vegetation show the importance of sustainable land usage. It is important to maintain the requirements of farming while protecting the land. Continuous research is required to come up with strategies to address the challenges brought about by global warming and urbanization.**

***Keywords*: Climate Change, LULC, NDVI, Rainfall in mm, RS & GIS.**

1. Introduction

The relationship between land use and vegetation cover is an important one, especially in areas such as Nandyal District in the state of Andhra Pradesh, where changes are occurring rapidly. Kumar and Kumar (2018) carried out research on the subject using remote sensing and GIS techniques. Their research revealed the significant changes occurring in the land use pattern. It is evident that the application of technology is required to understand the changes in the land use pattern for the better management of the land. Reddy and Reddy (2020) carried out research to understand the effect of changes in rainfall on the vegetation cover. Their research revealed the importance of the role played by rainfall in the maintenance of the health of the vegetation cover. It is evident that the changes in the land use pattern, as revealed by Kumar and Kumar, can be further aggravated by the changes in the rainfall pattern. Understanding the relationship between the factors that affect the land cover is important. Ghosh and Dey (2019) carried out research using the geospatial techniques to understand the effect of urbanization and agricultural growth on the vegetation cover in Nandyal District. Singh and Gupta (2021) carried out research using remote sensing techniques to understand the effect of rainfall on the vegetation cover. It is evident that the application of remote sensing techniques is important to understand the effects of the changes in the rainfall pattern on the vegetation cover.

A. Study Area

Nandyal district in Rayalaseema region is historically significant as a place of pilgrimage due to the presence of nine Nandi temples. It is a place of confluence of various geographical features and cultural influences. Nandyal district is located between northern latitudes of 15º 27' 49" and eastern longitudes of 78º 28' 43". The altitude of the district is ranging from 100 ft above the mean sea level. It is bounded by Krishna River in the north and by other districts on either side. It covers an area of 9,681 square kilometres and has 29 mandals, 4 revenue divisions and a population of 1,781,777 as per Census 2011.

The district physiographic is characterized by the presence of Nallamalas and Erramalas mountain ranges, which form a tract of land and thus make the place different in climate too. It has an average rainfall of 724.9 mm per year and thus is rich in flora and fauna, including forest areas inhabited by different species of wild animals. The land use is in a way balanced as 32% of the area is under forest conservation and a considerable area is under crop cultivation too (fig. 1).

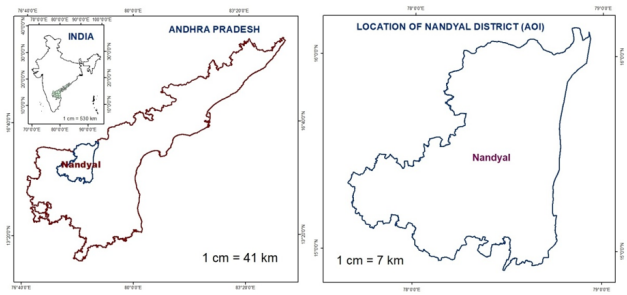

Fig. 1.

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B. Objectives:

- To study land use and land cover utilization from 2017 to 2024 using Sentinel -2 L2A data
- To analysis healthy vegetation using NDVI from 2017 to 2024 with Landsat 8-9 OLI/TIRS C2 L1data
- To interpretation of distribution of Rainfall in mm from 2017-2024 with NetCDF data a high spatial resolution from IMD, Pune.

2. Methodology

The research utilizes a systematic approach in collecting satellite imagery data by focusing on Sentinel-2 L2A and Landsat 8-9 OLI/TIRS C2 imagery data from 2017 to 2024. Emphasis is given to acquiring cloud-free images of the same season. A high-resolution rainfall data set is obtained from the Indian Meteorological Department, ranging from 1901 to 2024. It gives daily rainfall information in millimetres.

During the pre-processing step atmospheric correction is done by applying specific algorithms based on satellite imagery data. Geometric correction is then done by bringing all images into a standard coordinate system.

Software used: ArcGIS 10.3 and M.S. office

3. Result & Discussion

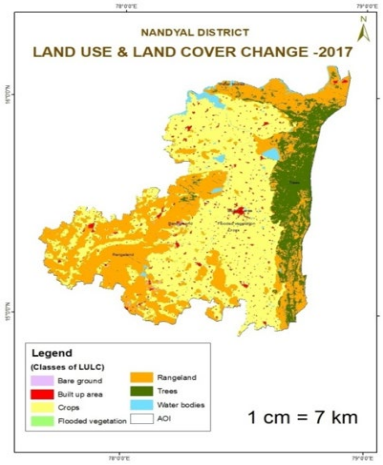

Fig. 2.

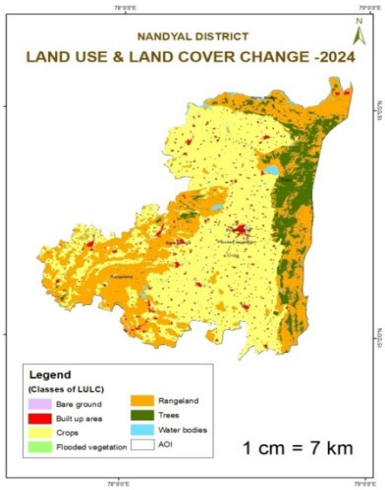

Fig. 3.

Table 1
Land use & Land cover change in Nandyal District-2017

S.No.	Name of the Class	Area Sq. km	Percent
1	Water bodies	204.61	2.1
2	Trees	1166.12	11.97
3	Flooded vegetation	2.07	0.02
4	Crops	4656.64	47.81
5	Built up area	211.67	2.17
6	Bare ground	25.64	0.26
7	Rangeland	3473.27	35.66

A detailed overview of the changes in land use and land cover in the Nandyal district as of 2017. It is evident that the data is categorized into different classes, which represent different types of land cover. Along with this, the area it covers is also mentioned in square kilometres. Furthermore, the percentage of the total land area is also mentioned (table.1 & fig.2).

The largest type of land cover identified in the Nandyal region is agricultural crops, which cover a huge area of 4,656.64 square kilometres, making up approximately 47.81% of the total land use. It is evident that the economy of the region might be dependent on agricultural crops. After crops, the next largest type of land cover is rangeland, which covers an area of 3,473.27 square kilometres, making up approximately 35.66% of the total land cover. It is evident that the region might be dependent on livestock rearing, as it is one of the largest types of land cover.

In terms of forested areas, trees cover 1,166.12 square kilometres, which is 11.97% of land use in the district. This indicates a significant level of tree cover, but this level is dwarfed by agricultural and rangeland areas. Further, water bodies, which include lake and river water, cover 204.61 square kilometres, which is 2.1% of land use in the district. This small percentage may indicate a lack of water resources in this district.

Other land covers include built-up areas, which cover 211.67 square kilometres, equivalent to 2.17% of land use in the district, and bare grounds, which cover 25.64 square kilometres, equivalent to 0.26% of land use in this district. This indicates a lack of both urbanization and bare grounds in this district, as these two land covers are significantly dwarfed by agricultural and rangeland areas. Finally, flooded vegetation, which is the least represented land cover in this district, covers 2.07 square kilometres, equivalent to 0.02% of land use in this district.

The data presented for indicates a land use pattern in which agricultural activities and rangeland are dominant, while there is a significant lack of both urbanization and water bodies in this district. This indicates a socio-economic pattern in this district, which needs to be addressed through sustainable land management strategies.

Table 2
Land use & Land cover change in Nandyal District-2024

S.No.	Name of the Class	Area Sq. km	Percent
1	Water bodies	122.54	1.26
2	Trees	992.23	10.19
3	Flooded vegetation	1.53	0.02
4	Crops	5136.77	52.74
5	Built up area	272.25	2.8
6	Bare ground	12.4	0.13
7	Rangeland	3202.3	32.88

A detailed overview of the land use and land cover changes in the Nandyal district for the year 2024. It is evident that the data is grouped into different classes, which represent different types of land use and cover, along with the respective areas in square kilometres and the percentage contributed to the total land area (table 2 & fig. 3).

It is evident from the data that the largest type of land use in the Nandyal district is crops, which covers an area of 5,136.77 square kilometres, accounting for 52.74% of the total land cover. This shows the importance of agricultural activities in the region, which is indicative of the fact that farming activities play a significant role in the region. It is followed by the land use for rangeland, which covers the next largest area, measuring 3,202.3 square kilometres, which is equivalent to 32.88% of the total land cover. This shows that the region is using a significant portion of the land for grazing animals, which might be essential for the people living in the region. Further, the data shows that the land allocated for trees is smaller, measuring 992.23 square kilometres, which is equivalent to 10.19% of the total land cover.

The water bodies, which include rivers, lakes, and other aquatic systems, cover 122.54 square kilometres and contribute 1.26% to the area. This low percentage may bring into focus some concerns regarding the management of water resources in the context of agricultural requirements and possible climate effects. The built-up area includes all the urban and infrastructure development activities and covers 272.25 square kilometres, contributing 2.8% to the area.

These statistics highlight the level of urbanization in the district area. Other types of land use include flooded vegetation, which is minimal and covers 1.53 square kilometres (0.02%) and bare ground, covering 12.4 square kilometres (0.13%). These statistics highlight the limited extent of land that is temporarily submerged in water and is devoid of vegetation.

The statistics highlight the dominance of agricultural land use in the Nandyal district area, as crops and rangelands contribute a significant majority to the area. This information is significant in understanding the management of land in the region and possible effects on the ecosystem.

Table 3
LULC change detection in Nandyal district: 2017-2024

Change Detection	**Area Sq. km**
Bare ground -Built up area	4.58
Bare ground -Crops	3.25
Bare ground -Flooded vegetation	0
Bare ground -Rangeland	7.82
Bare ground -Trees	0
Bare ground -Water bodies	1.47
Built up area -Bare ground	0.27
Built up area -Built up area	200.72
Built up area -Crops	8.99
Built up area -Rangeland	1.48
Built up area -Trees	0.08
Built up area -Water bodies	0.13
Crops -Bare ground	0.5
Crops -Built up area	45.92
Crops -Crops	4528.28
Crops -Flooded vegetation	0.67
Crops -Rangeland	68.35
Crops -Trees	3.72
Crops -Water bodies	9.17
Flooded vegetation -Bare ground	0.01
Flooded vegetation -Built up area	0.55
Flooded vegetation -Crops	0.76
Flooded vegetation -Flooded vegetation	0.38
Flooded vegetation -Rangeland	0.09
Flooded vegetation -Trees	0
Flooded vegetation -Water bodies	0.27
Rangeland -Bare ground	2.52
Rangeland -Built up area	19.92
Rangeland -Crops	516.24
Rangeland -Flooded vegetation	0.15
Rangeland -Rangeland	2745.57
Rangeland -Trees	182.19
Rangeland -Water bodies	6.61
Trees -Bare ground	0
Trees -Built up area	0.18
Trees -Crops	2.92
Trees -Flooded vegetation	0
Trees -Rangeland	356.74
Trees -Trees	806.14
Trees -Water bodies	0.12
Water bodies -Bare ground	0.59
Water bodies -Built up area	0.38
Water bodies -Crops	76.28
Water bodies -Flooded vegetation	0.33
Water bodies -Rangeland	22.18
Water bodies -Trees	0.08
Water bodies -Water bodies	104.76

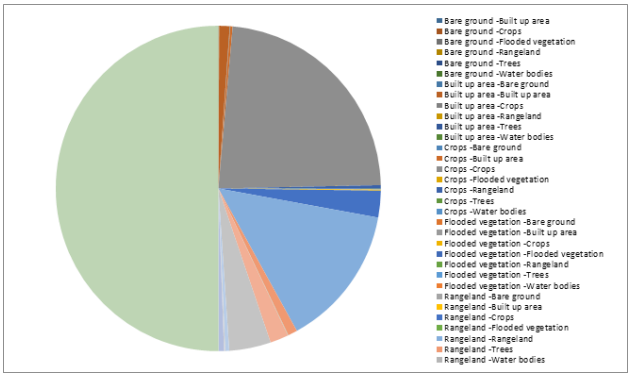

Fig. 4. LULC change detection: 2017-2024

A comprehensive analysis of land use and land cover change in the Nandyal district over a seven-year period from 2017 to 2024. The data is presented in a manner that highlights changes in land cover, measured in square kilometres (table 3 & fig. 4). The table highlights a number of changes, with a significant change in built-up areas, which have increased significantly, as highlighted by a change in 200.72 square kilometres from built-up to built-up.

The change in land cover from crops to built-up areas is also significant, with 45.92 square kilometres indicating a change from agricultural land to built-up areas. With regard to agricultural land, the data indicates that there is a significant change in crops, with 4,528.28 square kilometres remaining constant, indicating a strong persistence in agricultural activities in the region. The change in land cover from crops to rangeland, which is 68.35 square kilometres, indicates a change in land use from agricultural activities to rangeland activities.

It also points out the low rates of change in some types, such as the flooded vegetation, where the rates to and from other types are minimal, indicating the existence of this type of ecosystem. The existence of bare ground converting to different

types, such as rangeland (7.82 square kilometres) indicates the changing nature of the land type due to various reasons.

Water bodies also exhibit some changes, where 76.28 square kilometres of crops are changing to water bodies. This indicates the possible irrigation techniques employed in the region. The grand total of 9,739.87 square kilometres includes the entire region analyzed, giving an overall view of the changing nature of the land cover in the Nandyal region. In conclusion, the information provided by the data indicates the changing nature of the region due to the effects of urbanization, agriculture, and natural ecosystems in the Nandyal region. This information is vital in understanding the effects of the changing nature of the land cover on the ecosystem, agriculture and urbanization.

Distribution of Annual Rainfall in Nandyal District:

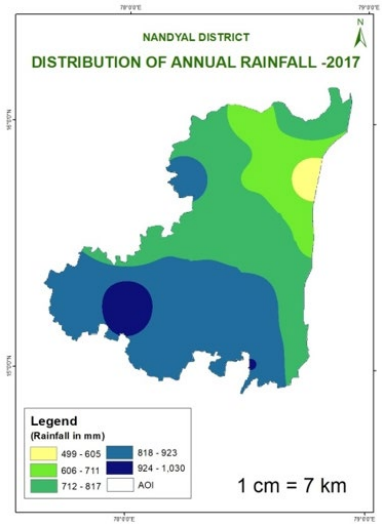

Fig. 5. Distribution of annual rainfall-2017

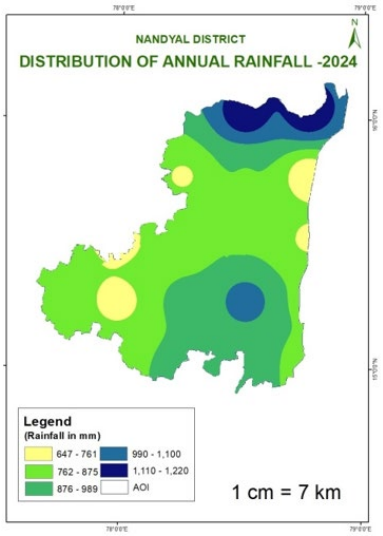

Fig. 6. Distribution of annual rainfall-2024

Spatial Distribution of Annual Rainfall in Nandyal District-2017:

The rainfall pattern in Nandyal District in 2017, with a categorization of rainfall values into distinct intervals. The data is divided into five distinct categories based on the total rainfall values in millimetres recorded during the year 2017. The category of very low rainfall is based on rainfall values ranging from 499 to 605 mm. This shows that rainfall in these regions is very limited and may have a significant impact on how rain is managed in these regions in terms of agricultural activities. The low rainfall category is based on rainfall values ranging from 606 to 711 mm. This shows that rainfall in these regions is very limited and may have a significant impact on how rain is managed in these regions in terms of agricultural activities (fig. 5).

Continuing with the categorization of rainfall values in Nandyal District in 2017, the moderate rainfall category is based on rainfall values ranging from 712 to 817 mm. This category is very useful in determining how rainfall can be managed in these regions in terms of agricultural activities because rainfall in these regions is balanced and can support agricultural activities. The high rainfall category is based on rainfall values ranging from 818 to 923 mm. This category shows that rainfall in these regions is quite high and may have a significant impact on how rain is managed in these regions in terms of agricultural activities.

Finally, there is a category of very high rainfall based on rainfall values ranging from 924 to 1030 mm. This category shows that rainfall in these regions is extreme and may have a significant impact on how rain is managed in these regions in terms of agricultural activities. The categorization of rainfall in Nandyal district in 2017 is very useful in understanding how rainfall is managed in these regions in terms of agricultural activities and how rainfall can have a significant impact on these regions in terms of agricultural activities.

Spatial Distribution of Rainfall in Nandyal District-2024:

The pattern of rainfall in Nandyal district for the year 2024, showing different ranges of rainfall amounts. The data has been divided into five different categories on the basis of total rainfall in millimetres. The first category has been marked as very low rainfall, in which the rainfall amounts vary from 647 to 761 mm. This can be interpreted as a dry spell in the district, which can have implications for farming activities in the region (fig.6).

The next category is marked as low rainfall, in which the rainfall varies from 762 to 875 mm. This can be interpreted as a slight increase in rainfall in the region, which is not enough for farming activities. The next category of rainfall, i.e., moderate rainfall, in which the rainfall varies from 876 to 989 mm, can be interpreted as a balance in rainfall in the region, which can support farming activities in the region. When moving further to the higher end of the scale, the category of high rainfall in which the rainfall varies from 990 to 1,100 mm can be interpreted as a significant increase in rainfall in the region, which can have implications for farming activities in the region. The next category of rainfall, i.e., very high rainfall, in which the rainfall varies from 1,110 to 1,220 mm, can have significant implications for the region. Thus, the classification of rainfall in Nandyal districts for the year 2024 can be interpreted in the above manner.

Normalized Difference Vegetation Index (NDVI):

The Normalized Difference Vegetation Index (NDVI) is a commonly used index in remote sensing, which measures the

health and density of vegetation. NDVI is of significant value in agricultural, forestry and environmental studies. NDVI takes advantage of the unique reflectance properties of vegetation, especially in the red and near-infrared (NIR) regions of the electromagnetic spectrum to assess vegetation health.

Calculation of NDVI: NDVI= BAND 5- BAND 4/ BAND 5+BAND 4 or NIR-RED/NIR+RED

Analysis of NDVI in Nandyal District During, 2017 & 2024:

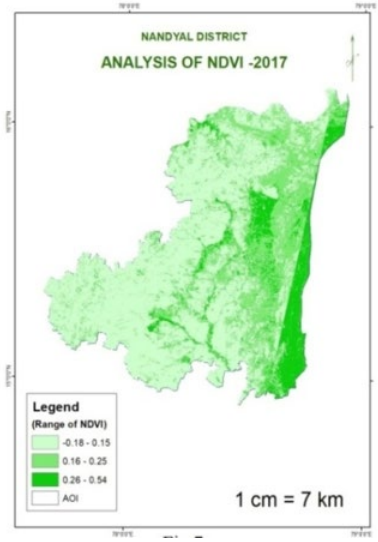

Fig. 7. Analysis of NDVI-2017

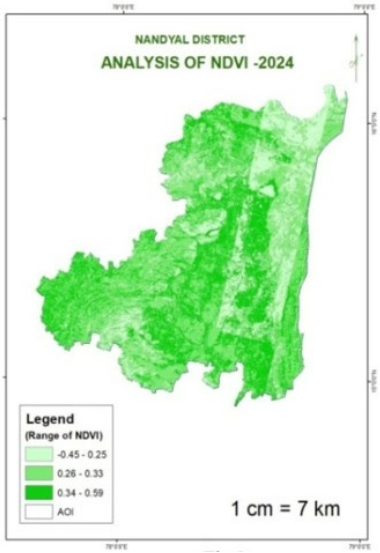

Fig. 8. Analysis of NDVI-2024

Analysis of NDVI-2017:

An analysis of the Normalized Difference Vegetation Index (NDVI) for the Nandyal region in 2017 offers interesting information on the region's vegetation cover. NDVI is an important index used in the assessment of vegetation cover through the use of satellite images. The results are categorized into three different ranges of NDVI (fig. 7).

The first class is characterized by an NDVI range from -0.18 to 0.15. This class is defined as non-vegetation or very sparse vegetation cover. The class includes water bodies, barren lands, built-up areas, rocky areas and dry soil. The information suggests that the region is not suitable for vegetation growth. The second class is characterized by an NDVI range from 0.16 to 0.25. This class is defined as sparse vegetation cover. The class includes areas with grasslands, shrubs and areas with low vegetation cover. The information suggests that the region is not ecologically healthy with the presence of vegetation cover. The vegetation cover is not dominant in the region.

The third class is characterized by an NDVI range from 0.26 to 0.54. This class is defined as moderate to dense vegetation cover. The class includes areas with croplands, areas with vegetation cover, and areas with healthy vegetation cover. The information suggests that the region is ecologically healthy with the presence of vegetation cover. The vegetation cover is important for agricultural productivity. The delineation of such areas is important for understanding the potential agricultural productivity in the region. In conclusion, the NDVI analysis for the Nandyal region suggests that the region is characterized by different types of vegetation cover, including barren lands, built-up areas and areas with agricultural productivity.

Analysis of NDVI-2024:

The analysis of Normalized Difference Vegetation Index (NDVI) in Nandyal district in 2024 indicates unique vegetation classes with unique NDVI value ranges. NDVI is a commonly used index in remote sensing techniques, which measures the density of vegetation using near-infrared and red reflectance. The analysis indicates three unique types of vegetation, with unique NDVI value ranges, as presented in (fig. 8).

The first type of vegetation, with a value range of -0.45 to 0.25, indicates areas with no vegetation or very sparse vegetation growth. This value range indicates areas with little or no vegetation growth, which may be due to various environmental conditions. The second type of vegetation, with a value range of 0.26 to 0.33, indicates sparse vegetation growth. This value range indicates areas with vegetation growth, but not in a densely packed manner, which may indicate areas with less vegetation growth.

The third type of vegetation, with a value range of 0.34 to 0.59, indicates areas with moderate to dense vegetation growth. This value range indicates areas with healthy and robust vegetation growth, which may include forests, agricultural lands, and other areas with high biomass growth. The analysis of Normalized Difference Vegetation Index in Nandyal district indicates unique insights on areas with healthy and robust vegetation growth, which may include forests, agricultural lands and other areas with high biomass growth.

Comparison of Rainfall and NDVI in Nandyal District, 2017-2024:

The table presents a comparative analysis of annual rainfall and the Normalized Difference Vegetation Index for Nandyal district across two distinct years, 2017 and 2024. The rainfall categories are delineated into five classifications based on the amount of precipitation received, ranging from very low rainfall to very high rainfall. In 2017, the very low rainfall category encompassed rainfall amounts between 499 mm and 605 mm, while in 2024, this range increased to between 647 mm and 761

mm. Correspondingly, the NDVI values for this category shifted from a range of -0.18 to 0.15 in 2017 to -0.45 to 0.25 in 2024, indicating a potential decline in vegetation health or density despite the increase in rainfall.

As we progress through the rainfall categories, the low rainfall classification shows an increase in rainfall from 606 mm to 711 mm in 2017 to a range of 762 mm to 875 mm in 2024. The NDVI values for this category also reflect a positive trend, moving from 0.16 to 0.25 in 2017 to 0.26 to 0.33 in 2024, suggesting an improvement in vegetation cover associated with the increased rainfall. In the moderate rainfall category, the rainfall amounts rose from 712 mm to 817 mm in 2017 to 876 mm to 989 mm in 2024. The NDVI values for this category exhibited a similar upward trend, increasing from 0.26 to 0.54 in 2017 to 0.34 to 0.59 in 2024, indicating a correlation between moderate rainfall and enhanced vegetation health.

The high rainfall and very high rainfall categories, while not explicitly detailed in terms of NDVI values for 2024, suggest a continuation of the trend observed in the previous categories, where increased rainfall is likely to support greater vegetation density and health. Overall, the data indicates a complex relationship between annual rainfall and NDVI, where increases in precipitation do not uniformly translate to improvements in vegetation health, particularly in the lower rainfall categories. This analysis underscores the importance of considering both climatic and ecological factors when assessing vegetation dynamics in response to changing rainfall patterns.

4. Conclusion

The analysis of land use, distribution of rainfall and vegetation dynamics NDVI in Nandyal district from 2017 to 2024 reveals significant trends. Agricultural land remains predominant, with crops increasing from 4,656.64 km² (47.81%) in 2017 to 5,136.77 km² (52.74%) in 2024, indicating a strong agricultural focus. Rangeland has decreased, while urbanization has expanded, particularly in built-up areas. Variability is evident in rainfall patterns despite a general increase across rainfall categories, the relationship between rainfall and vegetation health as indicated by NDVI remains complex. While moderate rainfall appears to enhance vegetation health, NDVI values decline in categories characterized by lower rainfall. This suggests that increased rainfall does not uniformly boost vegetation density. Against the backdrop of changing climatic conditions, this underscores the necessity of sustainable land management practices that take into account both agricultural productivity and environmental health.

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