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## Topographical Analysis on the Formation and Assemblage of Lakes

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### Abstract

Lakes are formed naturally as well by human interference. Most of the time the landforms act as a congenial element in the formation of human based lakes. In the case of the natural lakes, the formation itself is an interesting aspect on the relief and topographical phenomenon. The study area is the Kabini, the main tributary of the Cauvery river. The river basin location is between 11° 37' 10" to 12° 50' 30" North latitude and 75° 22' 25" to 76° 58' 02" East longitude. In this research paper, the Remote sensing techniques and GIS (Geographical Information System) environment is used to analyze the formation and assemblage of lakes. The research area is delineated using ALOS PULSAR 12.5 DEM. The water bodies are extracted using the satellite image of 1993 and 2021, the Sentinel 2 satellite image. The main objective of this research paper is to understand the topography over the formation and assemblage of lakes. The lakes are studied on the basis of its Geomorphological assemblage which signifies the paleo climate, the present climate as well the future scenario of lakes. Secondly, it signifies the geology of that region and also a clear indicator of the underground water. Thus, this analysis is based on the Geomorphological analysis of lakes has been done on the basis of the lake location and its assemblage in relationship and influence with the Geology, slope, rainfall, relief, drainage density and land use and land cover. The research paper examines the inter-relationship between each one of these parameters and its limitations.

**Keywords:** Alos Pulsar; Dem (Digital Elevation Model); Sentinel 2; Paleo Climate

### Introduction

The lakes are the largest water body which is surrounded by land. The flowing river gets space in lower landform, and it becomes lakes. The lakes are formed by the earth movement, erosion, deposition, vulcanicity. Lakes are essential to

recharge underground water, positively influence the water quality of downstream watercourse. The study is based on remote sensing and GIS techniques for assessing of the drainage basin/watershed which are used as a powerful tool for the manipulation and analysis of spatial information.

Lakes are the natural manifestation of nature, which is governed by geomorphology, geology, relief, rainfall, Land use and land cover, climate, slope, and the drainage system. Among the above-mentioned determinants relief plays a significant role in the formation of lakes. Generally, the higher the relief, greater the rainfall and greater the scope for the water accumulation. In contrast to this, the lower the relief greater the flow accumulation and greater will be the scope for the formation of lakes.

## Objective

Realizing the fact of changing Climatic conditions and anthropogenic activities and examining their impact on the drying lakes in the Deccan plateau region, few objectives have been framed. Lakes are formed naturally as well by human interference. Most of the time the landforms act as a congenial element in the formation of human based lakes. In the case of the natural lakes, the formation itself is an interesting aspect on the relief and topographical phenomenon. Hence, to Understand the Influence of Topography over the Formation and Assemblage of Lakes is the objective of this research paper.

## Methodology

Different inferences are possible to be drawn on the concentration of the lakes in a region. The extraction of lakes of 1993 is based on spectral water index, especially Normalized Difference Water Index (MNDWI) calculated from the green and shortwave -Infrared (SWIR) bands. From this point of view, the geomorphologic analysis of lakes has been done on the basis of the lake location and its Assemblage in relationship and influence with the local physical parameters which govern in its formation (origin) as well in its drying or vanish or extinction. Thus, this analysis was considered important. Lakes are the natural manifestation of nature which are governed by relief, rainfall, slope, geomorphology, geology, land use and land cover drainage system. Hence, all the parameters map is generated with the intersection of 1993 year lakes and results are analysed in detail.

## Study area

Mid Cauvery river Basin is the largest sub Basin with the area of 57,280.98 sq.Km and comprising 86 watersheds. The mid Cauvery river Basin lies in Tamil Nadu and Karnataka. In Karnataka it covers Mysore, Chamarajanagar, Ramanagara Districts. In the Mid segment of mid Cauveri river Basin, Kabini River and its tributaries flow. The main source of water in Mysore and Chamarajanagar District is Kabini River. In Chamarajanagar Districts water scarcity is increasing. To understand the causes of problems and its scenario, the mid segment of Mid Cauvery river Basin is selected as the study

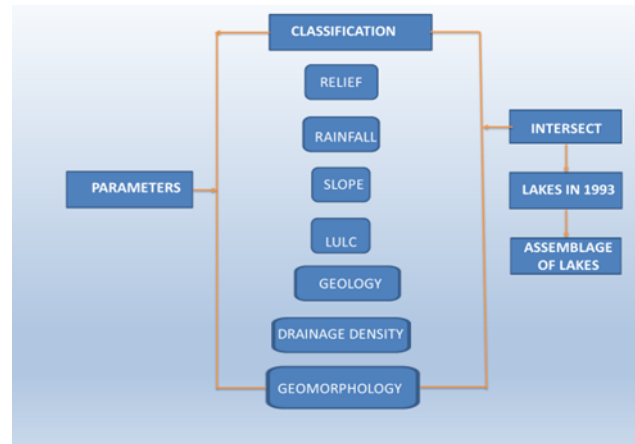


Fig. 1. Methodology of Assemblage of Lakes

area of the research topic and it gains much more importance because it is the large river basin comprising Mysore and Chamarajanagar districts.

Kabini River is the main tributary of the Cauvery River. The location of the river basin is between 11° 37' 10" to 12° 50' 30" North latitude and 75° 22' 25" to 76° 58' 02" east longitude. It originates in the Pakramthalam hills of Wayanad district of Kerala state. The confluence of the Panamaram river and the Mananthavady river takes place at an elevation of 2140 mt. The length of the river is 230 km, and the drainage area is 7808sq. Km. Kabini river enters Karnataka and its channel path starts from Heggadadevanakote and flows through Hunsur, Nanjangud, Gundlupet, and Mysore. Nanjangud, Heggadadevanakote taluks are drained 100% by kabini. The major portion of Mysore city drains towards Kabini river basin which accounts to 70% and only 30% by Cauvery River. The Kabini river takes its path towards southwest of Nanjangud that is up to Gundlupet and the main river cauvery flows north of Kabini and both flows eastwards and both join at Tirumakudalu Narasipura in Karnataka.

For the detail study of the Kabini River Watershed it is sub divided into five sub watersheds.

- Gundal Watershed
- Nugu Watershed
- Upper Kabini Watershed
- Mid Kabini Watershed
- Lower Kabini Watershed

## Analysis based on different parameters and Geomorphological assemblage of lakes in mid Cauvery river basin

The physiographic parameters considered in lake formation and vanish are the following. These parameters provide the clue to understand the reason behind its extinction. The following are the few chosen parameters. Assemblage of

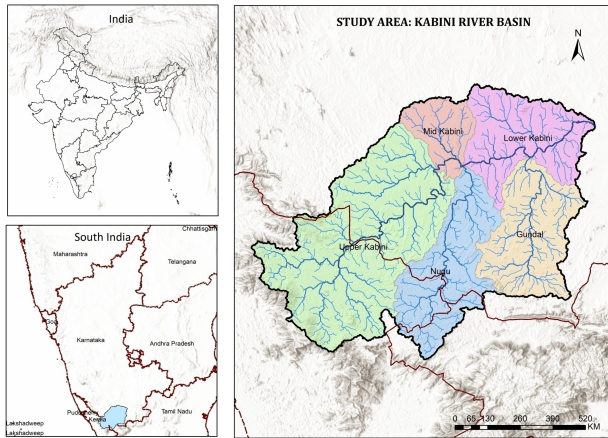


Fig. 2. Map representing Study area

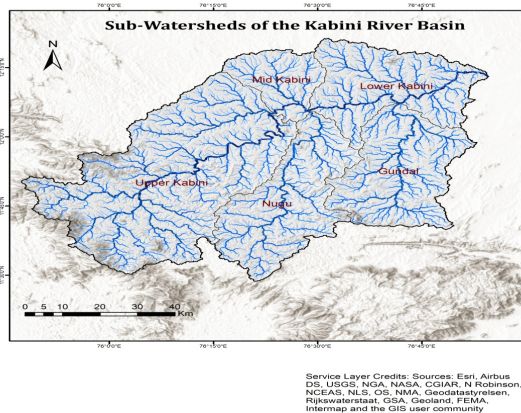


Fig. 3. Map representing Sub watersheds of the Kabini River Basin

lakes based on relief, Assemblage of lakes based on rainfall, Assemblage of lakes based on Slope, Assemblage of lakes based on Geomorphology, Assemblage of lakes based on Drainage density.

#### *Assemblage of Lakes Analysis on the basis of Relief*

The assemblage of lakes with respect to relief provides a direct correlation. As the Relief increases the formation of lakes has decreased. It is obvious that the flow of water will be towards the lower Relief. From the statistics obtained, it is evident that the assemblage of lakes are predominant in the lower Relief rather than in the higher Relief which is contradictory to the glaciated regions of the world.

Among the sub watersheds the upper kabini show a remarkable correlation with respect to relief and lake for-

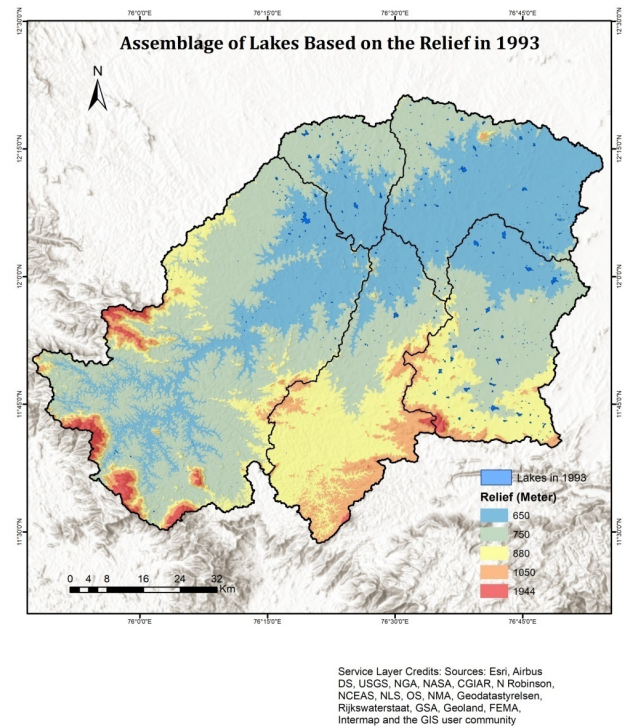


Fig. 4. Relief of Mid Cauvery River Basin.

mation and assemblage. Assemblage of lakes based on relief between 0 – 650-meter relief in the study area is the lowest Relief. This land is surrounded by undulating topography and its altitude ranges between 650 to 750 mts Relief. The Kabini river basin consists mainly of five basins. Such as Gundal, Nugu, Upper Kabini Basin, Mid Kabini basin, and lower kabini basin.

From the data obtained from thematic mapper SRTM satellite image, it establishes that the entire study area comprises 871 lakes in the year 1993. Out of which 474 lakes are located at less than 650mt Relief. Among the various sub watersheds, the mid kabini basin comprises 44.93% followed by upper kabini basin 23.8%, Mid kabini 11.18%, Gundal 15% and the Nugu watershed is 4.8%.

The distribution of

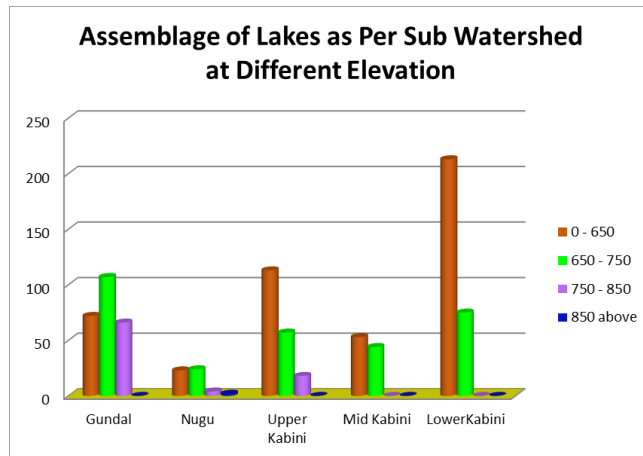
lakes in this Relief depicts that lower kabini basin has a greater number of lakes i.e. 213, whereas upper kabini is possessing 113 lakes, and in Gundal it has 72 lakes, Mid kabini 53 lakes and Nugu 23 number of lakes respectively.

In correspondence to the relief the formation of lakes and its assemblage is fascinating. Among the five sub watersheds in the study area, there are 474 lakes formed within the Relief of 650 meters. This is followed by 307 lakes in 650 to 750 meters, 88 lakes in 750 to 850 meters and there



**Table 1.** Relief of Sub Watersheds in Mid Cauvery River Basin

| Watershed Name | Relief in meters |           |           |           | Total |
|----------------|------------------|-----------|-----------|-----------|-------|
|                | 0 - 650          | 650 - 750 | 750 - 850 | 850 above |       |
| Gundal         | 72               | 107       | 66        | 0         | 245   |
| Nugu           | 23               | 24        | 4         | 2         | 53    |
| Upper Kabini   | 113              | 57        | 18        | 0         | 188   |
| Mid Kabini     | 53               | 44        | 0         | 0         | 97    |
| LowerKabini    | 213              | 75        | 0         | 0         | 288   |
| Total          | 474              | 307       | 88        | 2         | 871   |

**Fig. 5.** Assemblage of Lakes at Different Relief in Sub Watershed

are only 3 lakes in the altitude of more than 850 meters. From these statistics, it is evident that the distribution and assemblage of lakes is having direct correlation with relief. Secondly the lakes are also determined by the undulating geomorphological landforms. A good example for this is the Gundal sub watershed. At an altitude of 750 to 850 meters this region possesses 66 lakes. Similar to Gundal, the upper kabini also possesses 18 lakes and 4 lakes in the Nugu sub watershed. Whereas the other two watersheds possess zero lakes at this altitude. Hence it is proved that in addition with the relief, the geomorphology of a region plays a dominant role.

#### Findings.

1. Lakes according to the sub watershed wise and the relief it envisages, the number of lakes keep decreasing from lower to higher altitude.
2. The formation of lakes in the category of less than 650 mts envisages that 474 lakes have formed at this altitude out of the total 871 lakes formed in the study area.
3. Between the altitude of 650 to 750 mts, Gundal sub watershed is possessing 107 lakes out of 307 no of lakes under 750 mt Relief and all other watersheds possess less number of lakes in this Relief.

4. At an altitude of 750 to 850 Gundal sub watershed possesses the highest number of lakes with 66 lakes out of the total 88 lakes in the entire study area falling at the above-mentioned altitude.
5. Greater the Relief, the number of lakes has decreased in its formation at the higher Relief. Nugu watershed is the land located above 1050 mts Relief and it possesses only 2 lakes. Rest of the watershed does not possess lakes because they are situated in the lower Relief.
6. From the above findings it can be concluded that, the variation in the assemblage of lakes clearly envisages that, the Relief is the significant element in determining lake formation.
7. Comparing the assemblage of the lakes and the relief, it is clear that Relief plays a major role despite the vastness of the watershed. Based on the above information it is clearly understood that lower the Relief more lakes are formed.
8. It is also evident that the size of the lakes is too small in the higher altitude of all the sub watersheds and it is vice versa in the case of lower altitudes of the sub watershed.

#### Assemblage of lakes Analysis based on Rainfall

Rainfall of a region determines the surface run off, stream orders, stream density, percolation and also the ground water table. All these conditions together determine the formation of lakes in a region. From this point of view the rainfall distribution in the study area and its impact in the formation of lakes in accordance with the rainfall zones is the most vital aspect to be studied and analyzed. For the entire study area, the rainfall data has been downloaded from the satellite for the two periods 1993 and 2021. Using this data, the study area has been categorized into four rainfall zones.

The entire Mid Kabini Watershed has been classified into four rainfall regions such as Less than 1200 MM, 1200 to 1800, 1800 to 2400 and greater than 2400MM. The statistics illustrate that there is high concentration of 719 lakes in the low rainfall region i.e less than 1200 mm. This clearly reflects that there is an inverse relationship in the assemblage of lakes with respect to rainfall. As the rainfall increases the number of lakes in the region decreases. In the region 1200 to 1800

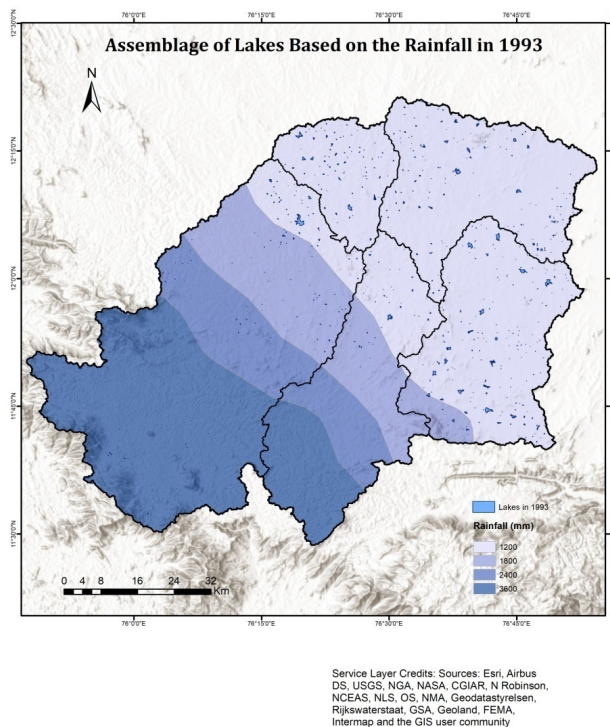


Fig. 6. Rainfall of Mid Cauvery River Basin

mm rainfall, the number of lakes formed are 78 followed by 41 and 33 respectively. This trend is most obvious in the moderate gradient landforms. As such the flow accumulation is situated in the low rainfall region leading to more number of lakes in this rainfall zone. The analysis illustrates that there is no relationship between the gradient, rainfall and the number of lakes with respect to the upper Kabini higher rainfall region. Secondly, this region even though it is located at high altitude in the Study area, this region is covered by high mountain ranges in three directions. As a result of the piedmont landform situation, the entire Upper Kabini Sub watershed has become a good place for flow accumulation from the higher rainfall region towards the lower rainfall zones, all through the watershed as an emerging cause in the formation of lakes.

Hence it is an interesting landform which has garnered a good number of lakes, compared to other rainfall zones of other Watersheds. It is also a place of research from the point of view of ground water and geomorphology.

#### Findings.

1. There is a drastic variation in the distribution of rainfall in the Kabini River basin with respect to each SWS. Lower Kabin, Mid Kabini and Gundal experience less

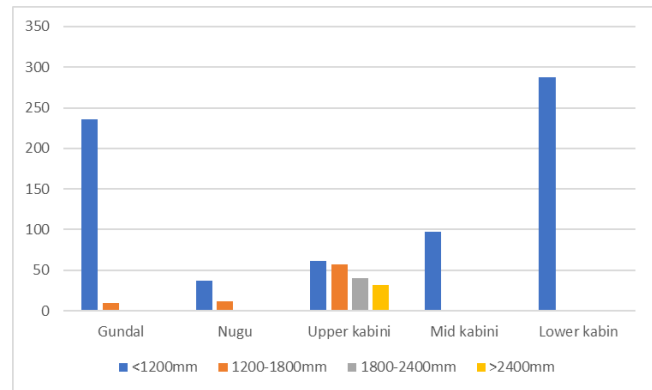


Fig. 7. Assemblage of Lakes in 1993 on the Basis of Rainfall in Mid Cauvery Sub Watershed

than 1200 mm of rainfall. Upper Kabini and Nugu experience high rainfall.

2. Rainfall situations and the formation of lakes are unique in each SWS. The statistics illustrate that there is a high concentration of 719 lakes in the low rainfall region i.e less than 1200 mm.
3. This clearly reflects that there is an inverse relationship in the assemblage of lakes with respect to rainfall.
4. As the rainfall increases the number of lakes in the region decreases
5. In the region below 1200 MM, 1200 to 1800, 1800 to 2400 and greater than 2400MM, the number of lakes formed are 719 followed by 78, 41, and 33 respectively. The distribution of lakes is highly prevalent in the moderate gradient landforms.
6. Due to the gradient variations, the surface runoff is higher than the accumulation. As such the flow accumulation is situated in the low rainfall region leading to a greater number of lakes in this rainfall zone.

#### Assemblage of lakes based on Slope

Slope is a significant determinant in the formation of lakes. Generally, the gentle slope paves way for the formation of lakes. Secondly the lakes can also be formed in the steep slopes, provided if the land attains an abrupt gentle condition. Most of the lakes which are formed in the mountains come under this category. Slope determines the flow accumulation point. Obviously, the flow accumulation point will result in the formation of a lake.

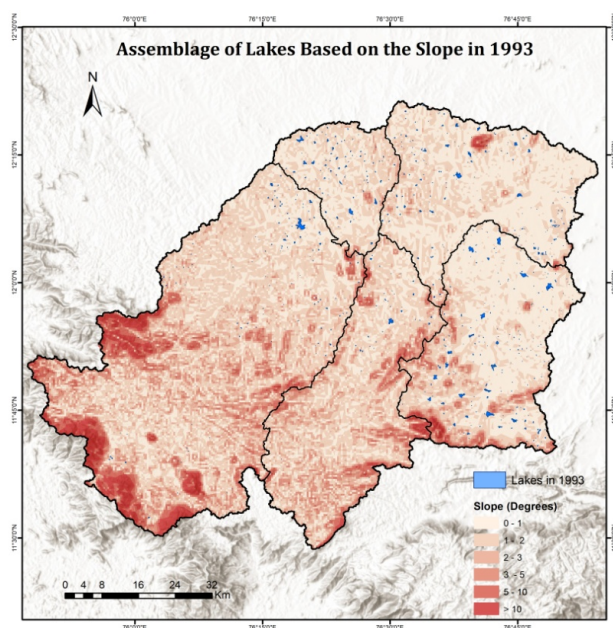
In a river basin the survival of lakes is determined by the surrounding slope condition. Greater the gentleness of the slope greater the survivability of the lakes. Having said this, it is Not only by the slope but also the underlying bedrock and its aquiferous condition that also determines the life of the lake. Lakes formed due to Erosion have greater life than the lakes formed by deposition. The site of erosion always keeps

**Table 2.** Assemblage of Lakes in 1993 on the Basis of Rainfall in Mid Cauvery Sub Watershed

| Sub Watershed | <1200mm | 1200-1800mm | 1800-2400mm | >2400mm | Total |
|---------------|---------|-------------|-------------|---------|-------|
| Gundal        | 236     | 9           | 0           | 0       | 245   |
| Nugu          | 37      | 12          | 1           | 1       | 51    |
| Upper kabini  | 61      | 57          | 40          | 32      | 190   |
| Mid kabini    | 97      | 0           | 0           | 0       | 97    |
| Lower kabin   | 288     | 0           | 0           | 0       | 288   |
| Total         | 719     | 78          | 41          | 33      | 871   |

the phase of erosion and keep the flow accumulation point intact, whereas in the case of deposition it is most uncertain. Therefore, most of the lakes are formed due to erosion. In the study area the upper regions with higher altitude are formed by erosion and in the case of the lower altitude with less rainfall and gentle slope are the result of the spring action added with flow accumulation.

In the present study on the basis of the slope, the river basin has been categorized into five types, such as Nearly Level (0 - 1°), Most Gentle (1 - 2°), Gentle (2 - 3°), Moderate (3 - 5°) and Strong Slope (5 - 10°).



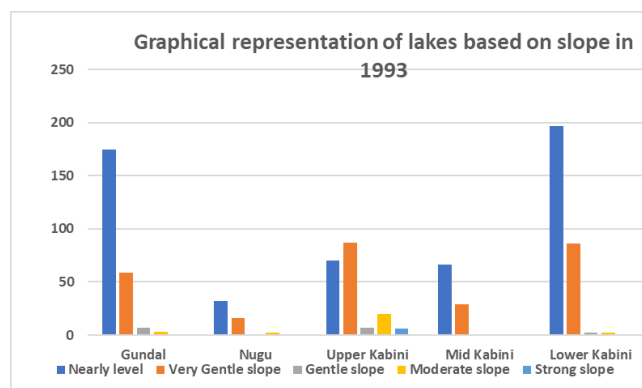
Service Layer Credits: Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NIMA, Geodataservleiden, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community

**Fig. 8.** Slope of Mid Cauvery River Basin

Lakes formed under different slope conditions are an eye opener to the landform analyst. Because the true cause for

the formation of lakes can be understood. Generally, lakes are highly prevalent in the plain lands rather than in the sloped land. In the study area the assemblage of lake is positive in correlation to the slope. Nearly gentle slope land possesses 540 number of lakes in the study area. This clearly indicates that the lakes are formed either due to the flow accumulation or due to spring action.

The land possessing 1° - 2° slope, that is, mostly gentle category region holds 277 lakes in the study area. The lakes formed at this condition of slope are formed due to the flow accumulation point. Nearly 94 percent of the lakes in the study area fall under the first two slope conditions. In the category of Gentle Slope 18 lakes have been formed. In the fourth category that is Moderate Slope condition there are 28 lakes; this is a clear sign of piedmont lake formation. The southern, south western and southeastern parts of Kabini river basin is covered by mountains. The lakes that are formed in the strong degree of slope that is between 5° - 10° slope is a clear indication of tectonically influenced lakes or due to spring action. In the study there are 8 lakes formed in the Strong Slope category.

**Fig. 9.** Graphical representation of lakes based on slope in 1993

## Findings.

1. Generally, lakes are highly prevalent in the plain lands rather than in the sloped land.
2. In the study area the assemblage of lakes is positively correlated with slope

**Table 3.** Assemblage Lakes in 1993 on the Basis of Slope in Mid Cauvery Basin's Sub watersheds wise

| <b>Assemblage of Lakes based on Slope in 1993</b> |               |             |                     |                   |                     |
|---|---------------|-------------|---------------------|-------------------|---------------------|
|   | <b>Gundal</b> | <b>Nugu</b> | <b>Upper Kabini</b> | <b>Mid Kabini</b> | <b>Lower Kabini</b> |
| Nearly level                                      | 175           | 32          | 70                  | 66                | 197                 |
| Very Gentle slope                                 | 59            | 16          | 87                  | 29                | 86                  |
| Gentle slope                                      | 7             | 1           | 7                   | 1                 | 2                   |
| Moderate slope                                    | 3             | 2           | 20                  | 1                 | 2                   |
| Strong slope                                      | 1             | 0           | 6                   | 0                 | 1                   |
| Total   | 245           | 51          | 190                 | 97                | 288                 |

- Nearly gentle slope i.e.  $0^\circ$  -  $1^\circ$  land possesses 540 number of lakes in the study area. This clearly indicates that the lakes are either formed due to the flow accumulation or due to spring action.
- The Mostly gentle slope category land ( $1^\circ$  -  $2^\circ$  slope) is possessing 277 lakes in the study area. The lakes formed at this slope condition are due to the flow accumulation point.
- Nearly 94 percent of the lakes in the study area fall under the first two slope conditions.
- The lakes that are formed in the strong degree of slope that is between  $5^\circ$  -  $10^\circ$  slope is a clear indication of tectonically influenced lakes or due to spring action. In the study there are 8 lakes formed in the Strong Slope category.
- In the study area the upper regions with higher altitude are formed by erosion and in the case of the lower altitude with less rainfall and gentle slope are the result of the spring action added with flow accumulation.

### Assemblage of lakes based on Geomorphology

Geomorphology plays a significant role in the formation of lakes. The type of landform decides the location and the origin of the lakes. Lake origin is a geomorphic process except in the glaciated regions and the volcanic crater lakes. The geomorphic agents active in the past determine the formation of the lakes. Similarly, for the vanishing of lakes the present geomorphic process and the prevailing climate influences. Undulating topography acts as a prime element in the origin of the lakes. The Geomorphology of the Mid Cauvery River basin is filled with undulating topography. Due to which the formation of lakes is more in number in this form of land. The minor geomorphological setups like the escarpments play a major role in the formation of the lakes. Understanding the role of geomorphology on the basis of its assemblage presents an interesting output.

#### Geomorphologic classification of the study area

- Active flood plain
- Dam and Reservoir
- Highly Dissected Denudation Hills and Valleys

- Highly Dissected Structural Hills and Valleys
- Low Dissected Denudation Hills and Valleys
- Moderately Dissected Denudation Hills and Valleys
- Residual hills of low land
- Floodplain deposited land
- Water bodies
- River
- Nugu dam and water bodies
- Moderately Dissected Structural Hills and Valleys
- Active Quarry
- Moderately Dissected Denudation Lower complex
- Abandoned Quarry

#### Assemblage of lakes in Gundal SW

In Gundal SW 142 lakes are formed in flood plain deposited land and it accounts for 58% of the Gundal SW total lakes. It includes 90 water bodies such as different streams, rivers and reservoirs. It accounts for 36.7 % of the total lakes of SW. In the active quarry region due to human intervention 6 lakes are formed. The Gundal reservoir sites had 7 lakes in 1993. The total number of lakes in Gundal are 245. It is possessing the second highest lakes based on Geomorphology in 1993.

#### Assemblage of lakes in Nugu SW

In the Nugu SW, the highest no of lakes are formed in the Pedi plain region i.e., 26 lakes and it accounts for 49% of the lakes in the Nugu SW. In the pediment Pedi plain complex 19 no of lakes are formed and it accounts for 40% of lakes of this SW. In stream confluence and stream paths 3 lakes are assembled each. In moderately dissected denudational lower plateau 2 lakes are formed.

#### Assemblage of lakes in Upper Kabini SW

The Upper Kabini SW possess complex Geomorphology. It is highly elevated region with plateaus and valleys. In the Upper Kabini SW, 86 no of lakes are formed in Pedi plain and it accounts for 45% of the Upper Kabini SW. In the pediment Pedi plain, complex region 40 lakes are assembled and it accounts for 21% of the SW. In river valley 34 lakes are formed and it possess 18%. The stream confluence



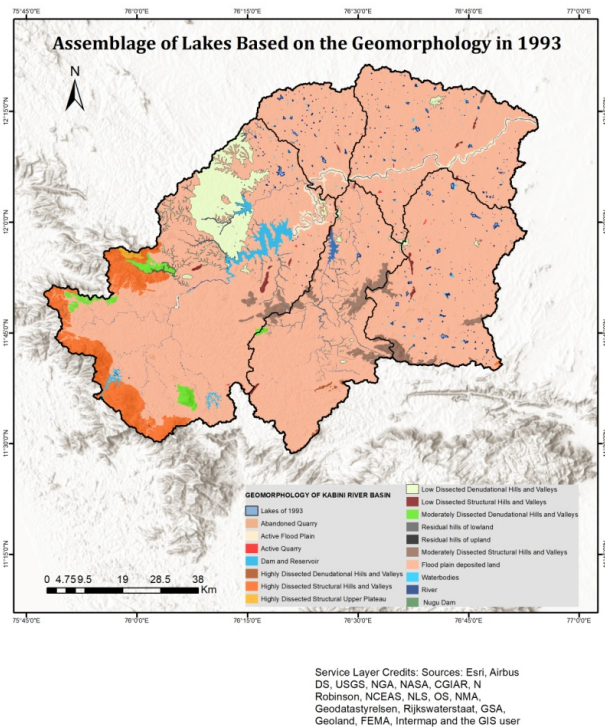


Fig. 10. Geomorphology of Mid Cauvery River Basin

region possesses 2 lakes. In highly dissected denudational hills and valleys, highly dissected structural hills and valleys, moderately dissected denudational hills and valleys, low dissected denudational hills and valleys, active flood plain only one lake is formed respectively. The total no of lakes in Upper Kabini SW is 188 and based on Geomorphology, it possesses third highest no of lakes.

#### Assemblage of lakes in Mid Kabini SW

In the Mid Kabini SW the Pedi plain region comprises 69 no of lakes and it accounts for 71.1%. The highest no of lakes is formed in this region. In the pediment Pedi plain region 22 no of lakes are formed and accounts for 22.6%. In the unclassified waterbodies 6 lakes are formed.

#### Assemblage of lakes in Lower Kabini SW

In the Lower Kabini SW, the flood plain deposited land comprising the highest number of lakes within the Watershed and also total Kabini study area. There are 200 lakes and accounts for 70% of lakes. The other water bodies such as streams, river have supported the formation of 88 lakes. The total no of lakes in this SW is 53.

#### Findings.

1. Moderate density regions of each watershed possess more than 80 percent of lakes in the study area.
2. The lakes formation and assemblage is inversely related with density in the study area since higher and lower density regions are having less number of lakes as shown in the graph.
3. Lower Kabini Sub watershed possess the highest lakes i.e, 288
4. In the moderate drainage density zone 263 lakes are formed and it accounts for 91.3%.
5. Only 25 lakes are situated at low drainage density zones and accounts for 8.6%.

### Assemblage of Lakes based on Drainage Density

Drainage density is one of the key components in the formation of lakes. Higher the number of stream orders greater the scope for the formation of lakes. Drainage density is the length of streams in a channel per unit of drainage basin. It is also a sum of lengths of all the streams divided by the catchment area. In this connection the level of stream density in the watershed and the number of lakes should hold direct correlation. But if this relationship is missing and it is vice versa this indicates some strange development in the formation of the lakes.

Drainage density= (Total Length of Channels/ Catchment Area)

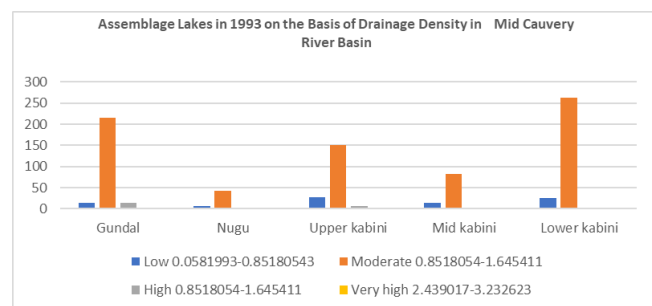


Fig. 11. Assemblage Lakes in 1993 on the Basis of Drainage Density in Mid Cauvery River Basin

#### Gundal Sub Watershed and Drainage Density

In the Gundal SW, moderate drainage density possesses the high lakes i.e., 215 and it accounts for 87.75% of the Gundal SW. In low drainage density and high drainage density there are 15 lakes in each.

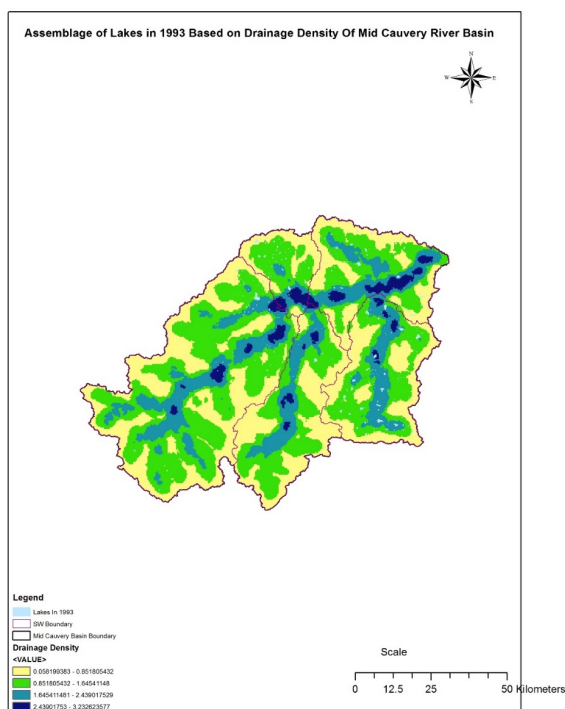
#### Nugu Sub Watershed and Drainage Density

In the Nugu SW, 43 lakes are situated in moderate drainage density zones. It only accounts for 84% of the lakes of Nugu SW.



**Table 4.** Assemblage Lakes in 1993 on the Basis of Drainage Density in Mid Cauvery River Basin

| SWs/Value    | Low                  | Moderate           | High               | Very high         |
|--------------|----------------------|--------------------|--------------------|-------------------|
|              | 0.0581993-0.85180543 | 0.8518054-1.645411 | 0.8518054-1.645411 | 2.439017-3.232623 |
| Gundal       | 15                   | 215                | 15                 | 0                 |
| Nugu         | 6                    | 43                 | 2                  | 0                 |
| Upper kabini | 28                   | 151                | 7                  | 2                 |
| Mid kabini   | 15                   | 82                 | 0                  | 0                 |
| Lower kabini | 25                   | 263                | 2                  | 0                 |
| Total        | 89                   | 754                | 26                 | 2                 |

**Fig. 12.** Drainage Density of Mid Cauvery River Basin

#### Upper Kabini Sub Watershed and Drainage Density

In the Upper Kabini SW 151 lakes are formed in moderate drainage density zones. It accounts for 80% of the lakes of Upper Kabini SW. In the high drainage density and very high drainage density just 7 lakes and 2 are formed in the SW.

#### Kabini Sub Watershed and Drainage Density

In the Mid Kabini SW 82 lakes are formed in the moderate drainage density zone. It accounts for 84.53% and 15 lakes are situated at low drainage density and accounts for 15.4%.

#### Lower Kabini Sub Watershed and Drainage Density

Lower Kabini SW possess the highest lakes i.e., 288. In the total 288 lakes the moderate drainage density zone has 263 lakes formed, and it accounts for 91.3 %. Only 25 lakes are situated at low drainage density zones and it accounts to 8.6%.

#### Findings.

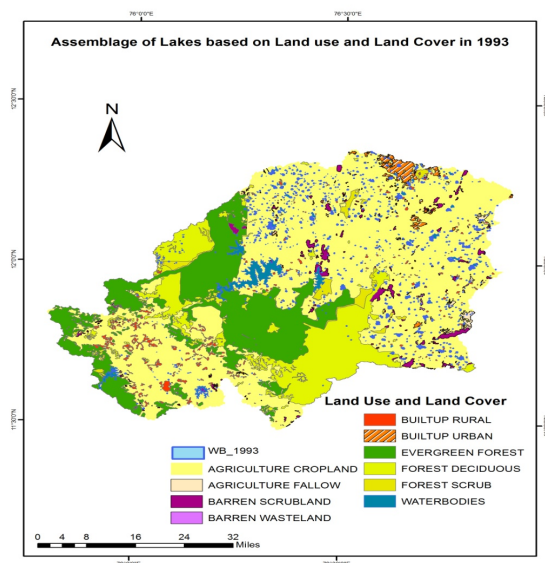
1. Moderate density regions of each watershed possess more than 80 percent of lakes in the study area.
2. The lakes formation and assemblage is inversely related with density in the study area since higher and lower density regions are having less number of lakes as shown in the graph.
3. The higher density and moderate drainage density are found in the lower altitude of the Lower Kabini and Gundal sub watersheds.
4. Lower Kabini SW possesses the highest lakes i.e., 288 and around 200 lakes are situated in flood plain deposited lands.

#### Assemblage of lakes based on Land use and Land Cover

Land Use/ Land Cover (LULC) generally refers to the categorization or classification of human activities and natural elements on the landscape within a specific time frame based on established scientific and statistical methods of appropriate source materials. It has various type of LULC elements is there like Agriculture land, Forest land, built up rural, Built up Urban, Water bodies and many more.

#### Findings.

1. In the Gundal Sub Watershed highest number of lakes are formed in the Agriculture cropland. 222 lakes are formed in this feature.
2. It accounts for 90.61% of the watershed. Gundal is an important tributary of Kabini river and some streams are found and it is about 8. in agriculture fallow land 6 lakes are formed and in Barren scrubland three lakes are found.



**Fig. 13.** Assemblage of Lakes on The Basis Of Land use Land Cover of Mid Cauvery River Basin

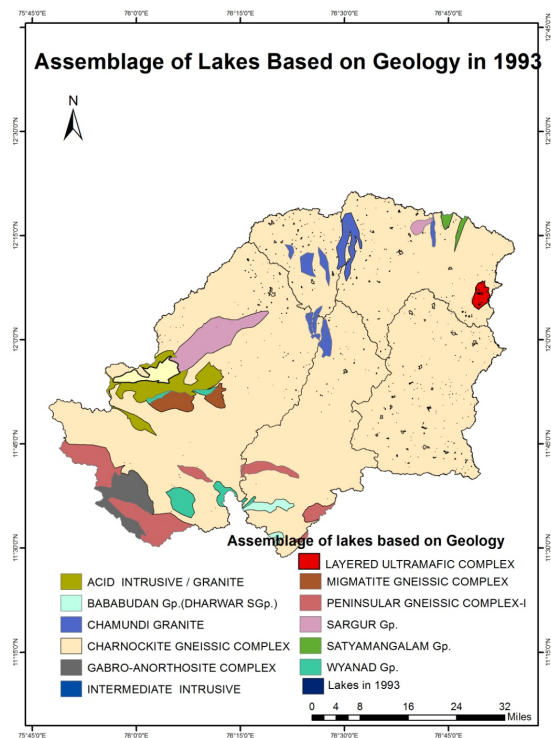
3. In barren wasteland about four lakes are assembled. Near by the forest there are two lakes formed in the Gundal Sub watershed.
4. Totally 245 lakes are found in the Gundal Sub Watershed. It accounts for 28.1% of the total number lakes formed in the Kabini River Basin.
5. In the Nugu Sub Watershed highest number of lakes are formed in the Agriculture cropland. 38 lakes are formed in this feature. It accounts for 77.3% of the watershed. In Barren Scrubland 2 lakes are formed and in Evergreen Forest four lakes are formed. In Deciduous forest five lakes are formed in the Nugu Sub watershed. Totally 51 lakes are found in the Nugu Sub Watershed. It accounts for 6.08% of the total number lakes formed in the Kabini River Basin.
6. In the Upper Kabini Sub Watershed highest number of lakes are formed in the Agriculture cropland i.e. is 117 lakes are formed under this land use. It accounts for 62.23% of the watershed. In the Evergreen Forest 18 lakes are formed and it accounts for 9.57 % and in Barren Scrubland only 1 lake is formed. In the Bandipur Deciduous forest 24 lakes are formed accounts for 12.77 % in the Upper Kabini Sub Watershed.
7. The Kabini river is origin in the Wayanad Mountains ranges and it includes many streams and it accounts for 19 waterbodies.
8. The Upper Kabini River Basin comprises the important taluks such as Manantawadi, Vayittiri, Sultan Battery, Virajpete, Heggadadevana kote, Sargur and in these taluks 19 lakes are developed surrounded by Built up Rural. It accounts for 10.11%.
9. Totally 188 lakes are formed in the Upper Kabini Sub Watershed. It accounts for 21.58% of the total number lakes formed in the Kabini River Basin.
10. In the Mid Kabini Sub Watershed highest number of lakes are formed in the Agriculture cropland i.e. is 92 lakes are formed under this land use. It accounts for 94.84% of the watershed. In Barren Scrubland only 1 lake is formed. In the Mid Kabini Sub Watershed the total number of lakes are formed are 93 and it accounts for 10.6 % of the Kabini River Basin.
11. The Lower Kabini Sub Watershed includes the villages of Mysore, Chamarajnagar, T. Narsipura, Nanjangud, and a few parts of Chamarajnagar. Kabini is the important source of irrigation and drinking water supply.
12. In the Lower Kabini Sub Watershed highest number of lakes are formed in the Agriculture cropland. 247 lakes are formed. It accounts for 85.76% of the watershed. The Mysore city is the Important built up urban in the Lower Kabini Sub watershed and hence 10 lakes are formed. In agriculture fallow land 6 lakes are formed and in Barren scrubland 5 lakes are found.
13. In barren wasteland about 3 lakes are assembled. Near by the forest scrub land there are 8 lakes and in the deciduous forest 5 lakes are formed in the Lower Kabini Sub watershed.
14. Totally 288 lakes are found in the Lower Kabini Sub Watershed. It accounts the highest number of lakes compare to another Sub Watershed. It accounts for 33.06% of the total number lakes formed in the Kabini River Basin.

### Assemblage of lakes based on Geology

Geology is the determined element in the formation of lakes and ground water percolation. In the study of formation of lakes, the type of geology prevailing as the bed rock controls the percolation of water. Greater the porosity of the underlined bed rock, greater the scope for the storage of underground water. The surface bed rock itself happens to be non-porous in nature will not allow the water to percolate and where ever there are eroded depression are formed, those points becomes the seasonal lakes.

Suppose the catchment of area of the Sub watershed happens to be aquiferous in nature, this condition will positively impact on the flow hydrology from the higher altitude to lower altitude given scope for the formation of lakes at the lower altitude.

From this point of view, the distribution of Geological formations and the analysis of lake formation are important aspect of research in understanding the formation lakes.



**Fig. 14.** Assemblage of Lakes Based on Land Use and Land Cover of Mid Cauvery River Basin

### Findings

1. The Gundal Sub Watershed possess lakes only in Peninsular Gneissic complex i.e. 245 lakes are formed in this Geological structure and it accounts for 28% of total lakes of the sub watershed.
2. The Nugu Sub Watershed comprises highest number lakes in the Peninsular Gneissic Complex i.e. 48 out of 51 lakes in the Nugu Sub Watershed. It accounts for 94.1 %.
3. In Sargur group geology, three lakes are assembled and accounts for 5.8%.
4. In the Upper Kabini Sub Watershed, 164 number of lakes lies in the Peninsular Gneissic Complex and accounts for 87.2% and the highest number of lakes formed under this Geology.
5. Ten lakes are formed in the Migmatite Gneissic (Southern Granulite Terrain). It accounts for 5.3% of the total lakes formed in this Sub Watershed.
6. Three lakes are formed in the Granite rock structure and in the Chamundi Granite rock structure each and it accounts for 1.5%.
7. Two lakes are formed in the Charnockite Gneissic complex and account for 1.06%. In the Sargur group, only one lake is situated in the Upper Kabini Sub Watershed.
8. In the Mid Kabini Sub Watershed 86 lakes are formed in the Peninsular Gneissic Complex and it accounts for 88.65% of the number of lakes in this basin. It is said to be the highest number of lakes in the Sub Watershed that are formed in the Peninsular Gneissic Complex.
9. In Sargur group Geology, eleven lakes are formed. It accounts for 11.34% of the lakes of this Sub Watershed. The total number of lakes are 97 in the year 1993 in the Mid Kabini Basin formed under Peninsular Gneissic Complex and Sargur group Geology
10. In the Lower Kabini Sub Watershed 235 lakes are formed in the under Peninsular Gneissic out of 288 total number lakes in this Sub Watershed. It accounts for 81.5% of the lakes and the highest lakes are formed under this geological structure.
11. 37 lakes are assemblage in the Layered Ultramafic Complex and it accounts for 12.8% and they are the second highest number lakes formed under this Geological structure in the Sub Watershed in 1993.
12. In the Sargur group Geological structure, six lakes are assembled. It accounts for 20.8% of the lakes in the Sub Watershed. Five lakes are formed in the Dharwad group and also in Chamundi Granite Geological structure. Hence the highest number of lakes are assembled in the Lower Kabini Sub watershed.
13. The highest number of lakes i.e., is 288 are assembled in the Lower Kabini Sub watershed.
14. The 778 lakes are formed in the Peninsular Gneissic Complex and it is the major Geological structure of the Kabini River Basin.
15. 89% of lakes are situated in the Peninsular Gneissic Complex.
16. 4.2% of lakes are assembled in the Layered Ultramafic complex.

### Conclusion

Among the above-mentioned determinants, relief plays a significant role in the formation of lakes. Generally higher the relief, greater the rainfall and greater the scope for water accumulation at the lower level of the basin. In this context, lower the relief, greater the flow accumulation and greater will be the scope for the formation of lakes. Greater the elevation, the number of lakes has decreased in its formation at the higher elevation. The study clearly envisages that, the elevation is the significant element in determining lake formation. As per research as a result of piedmont landform situation, the entire upper kabini sub watershed has become good place for flow accumulation from the higher rainfall



region towards the lower rainfall zones, all through the watershed emerging into formation of lakes.

There is inverse relationship in the assemblage of lakes with respect to rainfall. Lakes are highly prevalent in the plain lands rather in the slope land. In the study the assemblage of lakes positively correlated with slope, 540 number of lakes are formed in 0-1 degree (nearly gentle slope). Based on geomorphology, highest number of lakes are formed in flood plain and Padi plains of lower Kabini sub watershed.

With respect to drainage density, highest number of lakes (80%) of lakes are formed in the moderate drainage density zone (0.8518054-1.645411). Geology plays major role in the formation of lakes and 778 lakes are formed in the peninsular Gneissic complex which is considered as the major geological structure of the basin. From this point of view, assemblage of lakes according to the relief, rainfall, geology, geomorphology, gradient and drainage network were considered as the prime factors determining the number of lakes at different locations.