Sub-watershed prioritization based on potential zones of Kuttiadi river basin, A Geo-Morphometric approach using GIS

Sumesh. K¹, Vijayan. P.K²

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ABSTRACT

Natural potential zones of river basin provide an insight to developmental activities especially in rural areas. The present work is to identify the potential zones of sub-watersheds of Kuttiadi river basin. The Kuttiadi river basin is been divided into 47 sub-watershed and morphometric features of all sub-watersheds are calculated using Geographic Information System Technique using ArcGIS-10 software. The sub-watersheds were ranked according the value of morphometric parameters. Average of these ranking were used to classify sub-watersheds in three potential zones namely high, medium and high. The lineament, geology, geomorphology, slope and soil parameters of Kuttiadi river basin were also taken into consideration for the prioritization. The feature class data converted to raster based on assigned rank. Weighted sum of the raster layers reveals the potentiality of the each sub-watersheds of the river basin. Based on the potentiality the potential zones of sub-watersheds has been identified and quantified.

Keywords: Morphometry, Potential zone, Sub-watershed, GIS

1. Introduction

The use of natural resources in regional economic development hardly needs to be emphasized. The increasing need for natural resources consequent upon agricultural development may be met by intensive and extensive available resources. For drainage basin, though viewed differently by geologists and hydrologist in terms of form vs. process, is considered as the fundamental landscape unit responsible for the collection and distribution of water and sediment (Ritter et. al.1995).

The quantitative analysis of drainage system is an important aspect of characterization of watersheds (Strahler, 1964). The term morphometry is used in several disciplines to mean the measurement and analysis of form characteristics; in geomorphology it is applied to numerical examination of landform, which may be properly termed Geo-morphometry (Gardiner.V, 1982). Morphological parameters along with hydrological parameters can be used to quantify and simulate the hydrological behavior of the various basins, particularly un-gagged catchments (Maidment, 1993; Chalam et. al., 1996). Geo-Morphometric analysis is the technique used for the quantitative analysis and description of geometric-topologic character of a basin area. Geo-Morphometry of watersheds provides substantial information concerning the surface parameters like relief, hydrological, climatic, basin geometry, surface characteristics of ground, and climatic controls on drainage network organization. This technique has emerged as a power full tool to identify potentiality more accurately, as they
provide a flexible environment and commanding tool for manipulation, integration and analysis of spatial information for better understanding. (Sreedevi. P D, 2004). This paper presents a geo-morphometric methodology, which uses remote sensing and geographical data with Geographical information system-based analysis to quantify the potentiality and prioritize sub-watersheds of Kuttiadi river basin.

1.1 Study Area

The longitudinal extension of the river basin is 75° 34’ 33” to 75° 58’ 55” East and the latitudinal extension is 11° 21’ 45” to 11° 44’ 33”. The Kuttiadi river originating from the Narikota Range of the western slopes of Wayanad Hills, which is a part of Western Ghats situated at an elevation of 1220 m M.S.L. Kuttiadi River flows through two districts namely Kozhikkode and Wayanad (Figure:1.1). The Badagara, Quilandy and Kozhikode are the Taluks in which the river is flowing. (Panchayath level Statistics, Kozhikode 2011). The river is also known as the Murat River in Badagara Taluk. Total area drained by Kuttaidi river is 667 Km². The physiography division of the watershed is classified into three according to the altitude. Coastal plains occupied 1.53% as a narrow stretch in the beach. The lowland with 10-300 meters consists 72.43% of the total area. Highland consists 26.04% of area which is located in the eastern side of the watershed. Maximum height is 1750 m in the watershed.
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2. Objectives

1. To quantify morphometric parameters of Kuttiadi river basin.

2. To identify and quantify the potential areas to prioritize the sub-watersheds of Kuttiadi river basin.

3. Methodology

Kuttiadi watershed and its 47 sub-watersheds are traced, scanned, geometrically corrected and digitized from Kerala watershed atlas prepared by Kerala State land Use Board using ArcGIS 10 software. The Drainage network is digitized from survey of India topographical map at a scale of 1:50,000 (Figure: 1.2). The eleven morphometric parameters, such as mean bifurcation ratio, stream frequency, drainage density, drainage texture, and length of over land flow, form factor, elongation ratio, circulatory ratio, shape factor, compactness ratio and Infiltration number of each sub-watershed is calculated. The value of the morphometric parameters is ranked from 1 to 47 according there prospective to the morphometric potential. The Morphometric compound value ($MC_v$) is calculated by dividing the sum of ranks of all sub-watersheds by the total number of morphometric parameters. Then the sub-watersheds were classified into three classes, namely high, medium and low according to morphometric compound value and converted to raster format based on the weightages 3, 2 and 1 respectively. Geographic compound value ($GC_v$) calculated by using Geology, Geomorphology, Lineament density, slope, and soil parameters of the river basin. Layer of Geology, Geomorphology, Lineament density, and Slope map of the basin, downloaded from Bhuvan, ISRO Geo-portal digitized and converted to raster format based on appropriate rank. Maps of soil parameters prepared by Soil Survey of India, digitized and converted to raster format and appropriate rank is given based on the potentiality to infiltrate and penetration of water. The weightage sum analysis in Arc GIS 10 software used to demarcate potential sub-watersheds of Kuttiadi River Basin for prioritization.

4. Analysis

4.1 Morphometric parameters

Bifurcation ratio ($Rb$), Mean bifurcation ratio ($Rbm$), Stream frequency ($Fs$), Drainage density ($Dd$) (Figure.1.2), Drainage Texture ($Rt$), Length of over land flow ($Lg$), Form factor ($Rf$), Elongation ratio ($Re$), Circulatory ratio ($Rc$), Shape factor ($Bs$), Compactness ratio ($Cr$), and Infiltration Ratio ($If$) are the major parameters taken for morphometric analysis. Table number 1 shows the details and ranking of morphometric parameters.
**Table 1:** Ranking of morphometric parameters

<table>
<thead>
<tr>
<th>Morphometric Parameter</th>
<th>Parameter Symbol</th>
<th>Lowest Value</th>
<th>Highest Value</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Indicators of drainage network</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean bifurcation Ratio</td>
<td>Rbm</td>
<td>0</td>
<td>3.09</td>
<td>1</td>
</tr>
<tr>
<td>Stream frequency</td>
<td>Fs</td>
<td>0.22 km²</td>
<td>10.40 km²</td>
<td>1</td>
</tr>
<tr>
<td>Drainage density</td>
<td>Dd</td>
<td>0.42 km/ km²</td>
<td>3.8 km/ km²</td>
<td>1</td>
</tr>
<tr>
<td>Drainage texture</td>
<td>Rt</td>
<td>0.07</td>
<td>8.65</td>
<td>1</td>
</tr>
<tr>
<td>Length of overland flow</td>
<td>Lg</td>
<td>0.13</td>
<td>1.20</td>
<td>47</td>
</tr>
<tr>
<td>Form Factor</td>
<td>Rf</td>
<td>0.08</td>
<td>0.77</td>
<td>47</td>
</tr>
<tr>
<td>Elongation ratio</td>
<td>Re</td>
<td>0.33</td>
<td>0.99</td>
<td>47</td>
</tr>
<tr>
<td>Circulatory ratio</td>
<td>Rc</td>
<td>0.08</td>
<td>0.70</td>
<td>47</td>
</tr>
<tr>
<td>Shape factor</td>
<td>Bs</td>
<td>1.28</td>
<td>11.67</td>
<td>1</td>
</tr>
<tr>
<td>Compactness ratio</td>
<td>Cr</td>
<td>1.18</td>
<td>1.47</td>
<td>1</td>
</tr>
<tr>
<td>Infiltration Ratio</td>
<td>If</td>
<td>0.13</td>
<td>27.49</td>
<td>1</td>
</tr>
</tbody>
</table>

Source: Compiled by Author

Source: Watershed Atlas Ministry of Agriculture & Kerala State Land Use Board

**Figure 2:** Stream order and sub-water shed
4.2 Morphometric Compound Value (MCv)

The MCv is derived by dividing the sum of rank of all morphometric parameters by total number of morphometric parameters. The MCv value ranges from 9 to 42. The highest value indicated the sub-watershed excellent in potential based on morphometric parameters and lowest values indicate poor in potential.

4.3 Geomorphic parameters

Geomorphic parameters include Lineaments, Geology, Geomorphology, and soil depth, Soil texture and slope of Kuttiadi river basin. Lineaments are ranked according to their density in each sub-watershed.

4.4 Lineaments

A lineament may by a fault, fracture, master joint, a long and linear geological formation, the straight course of streams, vegetation served may be the result of faulting and fracturing and hence it is inferred that they are the areas and zones of increased porosity and permeability in hard rock areas. (O’Leary et al. (1976). The density of lineaments found in the each sub-watershed has been calculated. The sub-watersheds were ranked according to the density of lineaments, (Figure 3).
4.5 Geology

The charnockite rock weathers into low permeability clayey (low resistivity) materials with low groundwater discharge capacity. Gneisses and granites weathers into higher permeability sandy clay and clayey sand and sand with higher groundwater discharge capacity while quartzites fracture excellently to increase permeability. In Kuttiadi river basin two types of geological structures are observed, they are Charnakite, and Horn Blende Gneiss. Charnakite covers area of 101 km², which is 15.14 percentage of the total area, (Figure 1.4). Horn Blende Gneiss occupies 566 km², which is 84.86 percentage of the total area.

4.6 Geomorphology

The geomorphic imprints of an area can be considered as an important indicator for identification of ground water conditions, (Figure: 1.5 and table 2).

Table 2: Details of the geological structure

<table>
<thead>
<tr>
<th>Geomorphic Unit</th>
<th>Area in km²</th>
<th>Area in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valley</td>
<td>73.28</td>
<td>10.99</td>
</tr>
<tr>
<td>Lower Plateau [Lateritic]</td>
<td>319.04</td>
<td>47.83</td>
</tr>
<tr>
<td>Flood Plain</td>
<td>10.95</td>
<td>1.64</td>
</tr>
<tr>
<td>Valley [Denudational Hills]</td>
<td>1.73</td>
<td>0.26</td>
</tr>
<tr>
<td>Young Coastal Plain</td>
<td>23.23</td>
<td>3.48</td>
</tr>
<tr>
<td>Denudational Hills</td>
<td>227.36</td>
<td>34.09</td>
</tr>
<tr>
<td>Islands [River/Kayal]</td>
<td>0.54</td>
<td>0.08</td>
</tr>
<tr>
<td>Waterbody</td>
<td>10.87</td>
<td>1.63</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>667.00</strong></td>
<td><strong>100.00</strong></td>
</tr>
</tbody>
</table>

Source: - Computed by Author

4.7 Soil depth

Soil refers to the top few feet of the land surface. Soil acts as a natural filter to screen out many substances that mix with the water, but water will transport some contaminants into the groundwater, (Figure: 1.6). The soil depth and soil texture (Figure: 1.7) are the major parameters taken for this analysis, the details of soil parameters are shown in table 3.

Table 3 Details of soil parameters

<table>
<thead>
<tr>
<th>Soil parameters</th>
<th>Area km²</th>
<th>Area in %</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Soil Depth</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very deep</td>
<td>465.15</td>
<td>69.74</td>
</tr>
<tr>
<td>Deep</td>
<td>154.27</td>
<td>23.13</td>
</tr>
<tr>
<td>Moderately deep</td>
<td>15.66</td>
<td>2.35</td>
</tr>
<tr>
<td>Moderately shallow</td>
<td>3.95</td>
<td>0.59</td>
</tr>
<tr>
<td>Water body and Tank</td>
<td>27.97</td>
<td>4.19</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>667.00</strong></td>
<td><strong>100</strong></td>
</tr>
<tr>
<td><strong>Soil Texture</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gravelly clay</td>
<td>460.49</td>
<td>69.03</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>Soil Texture</th>
<th>Area in km²</th>
<th>Area in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay</td>
<td>147.68</td>
<td>22.14</td>
</tr>
<tr>
<td>Gravelly loam</td>
<td>29.63</td>
<td>4.442</td>
</tr>
<tr>
<td>Sandy</td>
<td>1.3</td>
<td>0.194</td>
</tr>
<tr>
<td>Water body</td>
<td>27.97</td>
<td>4.182</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>667</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Source: - Computed by Author

Figure 4: Soil Texture

4.8 Slope

Slope of the Kuttiadi river basin is extracted from SRTM data (Figure: 1.3). The distribution of slope in percentage is shown in table number 4.

Table 4: Details of the slope in percentage

<table>
<thead>
<tr>
<th>Slope in %</th>
<th>Descriptions</th>
<th>Area in km²</th>
<th>Area in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5%</td>
<td>Level-gentle</td>
<td>228.81</td>
<td>34.36</td>
</tr>
<tr>
<td>5-15%</td>
<td>Moderately sloping</td>
<td>95.11</td>
<td>14.36</td>
</tr>
<tr>
<td>15-35%</td>
<td>Strongly sloping</td>
<td>183.97</td>
<td>27.58</td>
</tr>
<tr>
<td>35-70%</td>
<td>Moderately steep to steep slope</td>
<td>128.69</td>
<td>19.29</td>
</tr>
<tr>
<td>&gt;70%</td>
<td>Very steep sloping</td>
<td>29.42</td>
<td>4.41</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>667</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Source: Computed by Author
4.9 Ranking of Compound Values (MC\textsubscript{v} and GC\textsubscript{v}) for Raster analysis

The compound values of each group of parameters are classified into three for converting to the raster format. Highest rank of 3 is given for high potential values and the lowest rank of 1 for lowest compound values. The raster maps of geology, geomorphology, soil, and slope are directly converted to raster format by giving appropriate rank according to their indication to ground water potential. The rank given to all parameters are shown in table number 1.5

Table 5: The ranking of compound values

<table>
<thead>
<tr>
<th>Geo_Morphometric Parameters</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MC\textsubscript{v}</strong> Ranges from (9 to 42)</td>
<td></td>
</tr>
<tr>
<td>9 to 20 (Good)</td>
<td>3</td>
</tr>
<tr>
<td>20 to 31 (Moderate)</td>
<td>2</td>
</tr>
<tr>
<td>31 to 42 (Poor)</td>
<td>1</td>
</tr>
<tr>
<td><strong>GC\textsubscript{v}</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Lineaments Density</strong></td>
<td></td>
</tr>
<tr>
<td>Ranges from 0 to 0.67 km</td>
<td></td>
</tr>
<tr>
<td>Nil</td>
<td>0</td>
</tr>
<tr>
<td>Below 0.20</td>
<td>1</td>
</tr>
<tr>
<td>0.20 to 0.4</td>
<td>2</td>
</tr>
<tr>
<td>Above 0.4</td>
<td>3</td>
</tr>
<tr>
<td><strong>Geology</strong></td>
<td></td>
</tr>
<tr>
<td>Charnakite</td>
<td>1</td>
</tr>
<tr>
<td>Horn Blende Gneiss</td>
<td>3</td>
</tr>
<tr>
<td><strong>Geomorphology</strong></td>
<td></td>
</tr>
<tr>
<td>Valley</td>
<td>3</td>
</tr>
<tr>
<td>Lower Plateau [Lateritic]</td>
<td>3</td>
</tr>
<tr>
<td>Flood Plain</td>
<td>3</td>
</tr>
<tr>
<td>Valley [Denudational Hills]</td>
<td>1</td>
</tr>
<tr>
<td>Young Coastal Plain</td>
<td>3</td>
</tr>
<tr>
<td>Denudational Hills</td>
<td>1</td>
</tr>
<tr>
<td>Islands in River/Kayal</td>
<td>3</td>
</tr>
<tr>
<td><strong>Soil Depth</strong></td>
<td></td>
</tr>
<tr>
<td>Very deep</td>
<td>3</td>
</tr>
<tr>
<td>Deep</td>
<td>2</td>
</tr>
<tr>
<td>Moderately deep</td>
<td>1</td>
</tr>
<tr>
<td>Moderately shallow</td>
<td>1</td>
</tr>
<tr>
<td><strong>Soil Texture</strong></td>
<td></td>
</tr>
<tr>
<td>Gravelly clay</td>
<td>3</td>
</tr>
<tr>
<td>Clay</td>
<td>3</td>
</tr>
<tr>
<td>Gravelly loam</td>
<td>1</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>Slope in percentage</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandy</td>
<td>1</td>
</tr>
<tr>
<td>Level-gentle</td>
<td>3</td>
</tr>
<tr>
<td>Moderately sloping</td>
<td>2</td>
</tr>
<tr>
<td>Strongly sloping</td>
<td>1</td>
</tr>
<tr>
<td>Moderately to steep slop</td>
<td>1</td>
</tr>
<tr>
<td>Very steep sloping</td>
<td>1</td>
</tr>
</tbody>
</table>

Source: Compiled by Author

5. Results

The potential zones of Kuttiadi river basin quantified and categorized as high, medium and low, in which high potential area covers 231.63 km$^2$. It is 34.73% of total area of river basin which are mainly concentrated in the low land and also in midland and some valley areas of high lands. Moderate potential area covers 217.51 km$^2$ i.e. 32.61% of the total area especially concentrated in midlands and valleys of high land area. Low potential area covers in high land area and hilly areas of midland and low land of river basin. It covers 190.54 km$^2$. It is 28.57% of the total area of Kuttiadi river basin. Remaining 27.32 km$^2$ area is water body of river basin (Figure 1.8)

![Figure 5: Potential zones](image)

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5.1 Sub-watershed Prioritization

Based on potential area concentration in different sub-watershed, the sub-watersheds have been classified into three category of prioritization namely, High, Medium and Low (Figure: 1.9). The priority classification is based on the area which covers more than 50% in the category of potential zone in a single sub-watershed. There are 21 sub-watersheds has been categorized as Low priority watersheds. There are 12 sub-watersheds comes under Medium priority class. Remaining 14 sub-watersheds fall under High priority sub-watersheds. The table 1.6 shows the area of potential zones in the sub-watersheds of the Kuttiadi river basin.

Table 6: Watershed wise Concentration of potential zones Watershed No.

<table>
<thead>
<tr>
<th>Watershed Number</th>
<th>Potential Zones Area in km²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
</tr>
<tr>
<td>28K39</td>
<td>68.71</td>
</tr>
<tr>
<td>28K13</td>
<td>24.59</td>
</tr>
<tr>
<td>28K9</td>
<td>18.19</td>
</tr>
<tr>
<td>28K44</td>
<td>14.48</td>
</tr>
<tr>
<td>28K8</td>
<td>13.15</td>
</tr>
<tr>
<td>28K12</td>
<td>10.28</td>
</tr>
<tr>
<td>28K40</td>
<td>6.09</td>
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<td>28K7</td>
<td>6.04</td>
</tr>
<tr>
<td>28K45</td>
<td>5.91</td>
</tr>
<tr>
<td>28K37</td>
<td>5.65</td>
</tr>
<tr>
<td>28K4</td>
<td>5.09</td>
</tr>
<tr>
<td>28K42</td>
<td>4.47</td>
</tr>
<tr>
<td>28K46</td>
<td>4.32</td>
</tr>
<tr>
<td>28K38</td>
<td>4.14</td>
</tr>
<tr>
<td>28K41</td>
<td>3.84</td>
</tr>
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<td>28K3</td>
<td>3.51</td>
</tr>
<tr>
<td>28K1</td>
<td>3.49</td>
</tr>
<tr>
<td>28K10</td>
<td>3.38</td>
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<tr>
<td>28K6</td>
<td>3.20</td>
</tr>
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<td>28K2</td>
<td>3.12</td>
</tr>
<tr>
<td>28K47</td>
<td>2.67</td>
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<td>28K36</td>
<td>2.60</td>
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<td>28K5</td>
<td>2.54</td>
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<td>2.13</td>
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<td>2.10</td>
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<td>28K43</td>
<td>1.56</td>
</tr>
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<td>1.30</td>
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<td>28K14</td>
<td>1.26</td>
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<tr>
<td>28K34</td>
<td>1.05</td>
</tr>
<tr>
<td>28K11</td>
<td>0.78</td>
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<tr>
<td>28K21</td>
<td>0.58</td>
</tr>
<tr>
<td>28K26</td>
<td>0.53</td>
</tr>
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<td>28K16</td>
<td>0.25</td>
</tr>
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<td>28K31</td>
<td>0.25</td>
</tr>
<tr>
<td>28K27</td>
<td>0.01</td>
</tr>
<tr>
<td>28K18</td>
<td>0.01</td>
</tr>
<tr>
<td>28K33</td>
<td>0.01</td>
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</table>
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<table>
<thead>
<tr>
<th></th>
<th>PRIORITIZATION OF WATERSHEDS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>KUTTIADI RIVER BASIN</td>
</tr>
<tr>
<td></td>
<td>Watershed Prioritization</td>
</tr>
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**Figure 6:** Prioritization of water sheds

5.2 Conclusion

The result of the analysis shows that the parameters considered for the delineation of potential zone of Kuttiadi river basin found most appropriate according to the field evaluation. The morphometric parameters along with, geomorphic parameters (Geo-Morphometric) is a good indicators to identify the potentiality of resources. The use of Geographical Information System in geo-morphometric analysis provides accurate and precise spatial information in such analysis.

6. References


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