The anatomy of the geomorphic framework of the entire study region is discussed in chapter 1. The morphological characteristics of the Mahana river, a tributary of Tons, have exfoliated the petals of geomorphic variables in third and fourth chapters whereas, the internal and external setup of the study region has been unfolded in first and second chapters of the present study. The present chapter is an attempt to reassemble the exfoliated petals together so that ‘sub-system’ of homogenous components may be restructured and constant system of morpho-geological features may be identified. The present chapter deals with the Geographical Information System (GIS) based statistical analysis of patterns described in third and fourth chapters.

The ‘morphological regionalization refers to the identification, delimitation and characterization of similar units of topographical mosaic having identical response to the dialectic alternative effects of external and internal morpho-geological and morphodynamics structure of terrain, at varying hierarchical scales’ (Dubey, Alok, 1990). For the identification and determination of morphological units, Principal Components (Table 6.4) have been derived from the correlation matrix (Table 6.1) involving geomorphic variables.

In the present chapter on geo-morphological regionalization, an attempt has been made to classify the whole study region in different geomorphic and geological units on the basis of geospatial technology (GIS) based statistically prepared pseudo-band layering and Principal Component Analysis (PCA) involving three relief variables viz. relative relief, dissection index and average slope, and three drainage variables viz. stream frequency, drainage density and drainage texture. Apart from this, an attempt has been made to compare the empirically generated map viz. geomorphic and geological maps (Figure 2.6 respectively) with GIS based statistically prepared pseudo- false colour composites (FCC) through pseudo-band layering to delineate geologic and geomorphic units through supervised and unsupervised classification of pseudo bands.
In fact, the present chapter on geo-morphological regionalization, is the culmination of preceding chapters through the use of GIS techniques and this chapter establishes a link between preceding second and third chapters and succeeding chapters, which will throw light on the river basin system management and mechanism of environmental processes responsible for building the landforms ranging from micro to macro scale.

6.1 Morpho-Dynamic Features of Landform

6.1.1 Morpho-dynamic Concept:

‘Morpho’ means ‘form’ and ‘dynamic’ means ‘change’ or ‘motion’. Hence ‘morphodynamic’ represents the changing nature of landforms or forms of the earth with the passage of time through geological and geomorphic processes. The dynamic characteristics of landform change the morphology of that landform with the pass of time because ‘the same physical processes and laws that operated today throughout geological time, although not necessarily always with the same intensity as now’ (Thornbury, W.D. 1954). According to W.M Davis (1899) ‘there is sequential change in landforms through
successive stages and the changes are directed towards a definite end i.e. attainment of featureless plain (peneplain). This shows the dynamic character of landforms. There are three factors which control the morpho-dynamic characteristics of any landform, ‘landscape is function of structure, process and time’ (Davis, W.M., 1899).

These three factors are termed as ‘Trio of Davis’. On the basis of ‘trio of Davis’ three approaches of study of landforms gradually became popular:

1- Structure- Form Approach
2- Process- Form Approach
3- Dynamic- Form Approach

Chronological Approach or Morphogenic Approach) Thornbury, W.D. (1954), The structure – form approach of landform study is based on the basic principle of geology that, ‘geological structure is a dominant control factor in the evolution of landform’, whereas process-form approach is based on the fundamental concept of climatic geomorphology that “each climatic type produces its own characteristic assemblage of landform”. The third approach i.e. Chronological approach or morpho-dynamic approach is based on the ‘concept of uniformitarianism’ and Davisian cyclic concept. According to this approach the changes in the form of landforms of any region must be studied through the passage of time.

6.1.2 Landform Classification:

The classification of landform of any region is performed in three different ways viz.

(i) Based on morphometric analysis

(ii) Based on false clour composite (FCC)

(iii) Based on morpho-genetic processes

In the present chapter, geomorphic classification of Mahana river basin has been performed on the basis of false colour composite (FCC) and morphogenetic processes, through intensive field work and with the help of following data. Classification based on morphometric analysis is performed in Chapter 4.
1- Topographical sheet (63 H/5, H/6, H/9, H/10, L/1 & L/2) of survey of India (SOI) having 1:50,000 scale (Figure 2.5).

2- Satellite Imagery, IRS-1C LISS III (Figure 2.6)

3- Digital Elevation model (DEM) (Figure 5.3).

The morphogenetic classification of Mahana river basin are performed through delineation of first order (macro) second order (meso) and third order (micro) geomorphic units of various categories, on the basis of genesis and processes involved in the development with the passage of time. The landscape characteristics of absolute relief of the Mahana basin is divided into four physiographic regions. The geomorphic classification of Mahana basin is shown in Figure 2.6.

(i) Alluvial plain or river plain
(ii) Rewa Scarps or Escarpment Zone/ Vindhyan flat
(iii) Rewa plateau
(iv) Kaimur range

6.1.2.1 The Alluvial Plain / Riverine Plain Zone:

The alluvial plain of Mahana basin covers an area along the Mahana river, a few parts of Gorma river basin and Rewa Scarp region or Rewa Escarpment Zone which divides the region in two parts i.e. eastern and western. The alluvial plain extends from the foothill and a zone of Rewa Scarps. The Mahana region lies in between and slopes gently from south to north, and a small part towards the north- east (Sohagi Pahar) covers an area of Vindhyan region. The region is the outcome of combined action of all tributaries, nallas and many small and major water falls of the river basin. The northern riverine plain is formed by quaternary sediments brought down by Mahana river and its tributaries. The region has an altitude 66<135 m. The general elevation of the region ranges between 100 – 120 m and gently slopes from south to north. The Vindhyan bedrocks are covered by, thick alluvium deposits, composed of clay, sand, gravel and silt, carried by streams and deposited where the streams slow down. The soil of this region is loamy to sandy-loam in texture. Alluvial plain approximately covers 88.80 sq. km of the study area in out of 1239.25 sq. km of total geographical area. The most striking feature in the entire region is the development of ravines and gullies, farming badland topography. Lack of vegetation,
over grazing of natural vegetation and deforestation, over cutting etc. are responsible for badland topography. This region is a cultivated area and there are no forests or very little open mixed forests and scrub-like vegetation

6.1.2.1.1 Riverine Alluvium:

The alluvium are present along the Mahana river bank and mouth of the Mahana river and spread in the form of patches over the entire study region. These alluviums are the result of constant denudation of sandstone and Vindhyan shale. This is an agriculturally fertile land, and alluvial soil is best suitable for agricultural and crops. Alluvial deposits are dissected by gullies and rills due to their soft nature. The recently deposited soil layers and buried soil layers are in sequential order from bottom to top, ranging from Pliocene to Holocene periods. Almost all sections of this region are covered with Quaternary alluvial deposits which have been exposed on both sides of Mahana river and its tributaries. In the study region almost all the alluvium deposits present are in northern parts of study area, in Teonthar block, which consist of clay, silt and gravel and the alluvial thickness is more in the marginal areas of river basins. Very small patches of alluvial deposits are present in Sirmaur block. These materials are also present in the central part of Mangava block and are yellow-greyish in colour mixed with lime kankars.

6.1.2.2 Rewa Scarp or Escarpment Zone/ Vindhyan Flat:

Rewa escarpment zone is also known as Vindhyan escarpment or Rewa scarp. This escarpment represents the northern rim of Rewa plateau. It is located in between plain area in the north and Rewa plateau in south, covering an area of 55.36 sq. km. From the Mahana basin, the scarps register an abrupt rise of about 200 m. The region is drained by tributaries of Mahana, which have their sources on the northern flanks of Vindhyan ranges and make famous waterfall Kevati (98m) and deep gorges, while descending through these escarpments. The Vindhyan uplands or flat lands represent the highly denuded Vindhyan ranges with relief ranging between 120 m to 340 m. This region is composed of mudstones and shales and Quartzitic sandstone beds. Basically these types hard stones are responsible for the backwasting and scarp retreat. The tributaries erode the scarps and divide them into a number of residual isolated hills. The Himalayan
I orogeny rejuvenates the fluvial processes of the region, and the region has been uplifted many times due to this orogeny. In this region many high and deep waterfalls of different sizes and long and narrow gorges. The waterfalls indicate heads of rejuvenation of fluvial processes. There is a great fall line from west to east in the region which is a result of Tertiary upliftment. Numerous waterfalls are located along this fall line. The highest water fall of the region is Odda fall (148m) high on the Odda river and other prominent waterfalls are Chachai fall, (120m) on the Bihar river, Kevati fall, (98m) on the Mahana river, Devlaha, Amda, Gorma and Jura falls. Deep gorges present at the base of these falls show that the process of retreat and lowering of waterfalls is active in this region. Scars have stony wastelands on the flat topped surface where thin layer of infertile grey and red soils have developed. In this region, deciduous dense and open mixed forests of tendu and kodai trees with patches of salai and bamboo are present in rectilinear and concave parts of the area, while freeface area is devoid of any vegetation.

### 6.1.2.3 Rewa Plateau:

Rewa plateau known as central tableland (Singh, Savindra, 1998) covers the eastern part of extensive Rewa plateau, surrounded by Rewa Scarps, Vindhyan range in north and Kaimur scarps towards south and east. This region covers an area of 1122.93 sq. km of the total area which is approximately two-thirds of whole study region. The plateau covers the Huzur, Sirmaur and Mangawan tehsils of Rewa district. The gradient is from south to north.

The Rewa plateau region has a general elevation ranging between 340 m to 400 m and the area gently slopes from south-east to north-west. This tableland is a combination of shales and sandstones, and is a part of ancient Deccan plateau which is composed of rocks of the Vindhyan system. The vast Rewa plateau is characterized by rolling and flat surface with stony wasteland, residual hills and stony surfaces and the Mahana river has developed broad, flat and shallow valleys on this area. This plateau is more affected by erosion and sheetwash.

The whole region is composed of stony surfaces, stony wastelands and residual hills which are mainly composed of sandstones and characterized by topographic discordance presenting a good example of ‘uplifted peneplain’. The study region is a
deforested zone, where only shrubs and trees are present and rich soils cover the cultivated fields.

6.1.2.4 Kaimur Range:

Kaimur ranges, running parallel to the Son river from southern boundary of Mahana river, stretches east to west in the southern part and has highest absolute relief i.e. about 400 m to 480 m. In the entire study region the Kaimur ranges have most important geomorphological features because they consist of a series of scarps and exhibit various physiographic at features. The extension of Vindhyan range of central India is also known as Kaimur highland. This Kaimur range covers some parts of the study region.

The Kaimur range present in the southern part of the study region covers a small portion. By a survey of this region it seems that this region is a result of upliftment of during older periods with long and narrow gaps left undisturbed. This part is composed of quarzitic sandstone, shale, greenish flagstones and sandy siltstones. The southern range i.e. Kaimur range is divided into two separate hill ranges due to the presence of occasional and seasonal streams in the region.

6.2 Geomorphological Regionalization: An Explanation

‘Morphology’ is a term that forms from the combination of two Greek words– ‘morpho’ meaning ‘form’ and ‘logos’ meaning ‘discourse’. Infact, the true scope of morphology includes the description and analysis of external and internal forms of landforms of the earth at micro, meso and macro levels. Term ‘morpho-unit’ has been derived from the word ‘morphology’ meaning ‘the science of form especially that of the outer form, inner structure, external forms of rocks and land features’ (Chambers Dictionary, 1974). A morpho-unit is defined as an assemblage of landform units of similar levels which, having coherent form characteristics due to the homogenous environmental processes, actively take part in sculpturing the aforesaid combination and amalgamation of landforms in a particular region, of the our study area.

Many geomorphologists have suggested various definitions of morpho-units and adopted various methods for the regionalization and delimitation of morpho-units. Scholars like Fenneman (1914), Joerg (1914), Bourne (1931) and Hammond (1954) have
made various attempts and significant contributions in this field. Joerg (1914) was the first scholar who suggested two approaches i.e inductive and deductive for the determination of morpho-units of any study region. He also divided North America into various morphological regions and named to them ‘natural regions’. Another Scholar Fenneman (1914), also divided America into morphological regions, in the same year and he demarcated the boundaries of these regions on the basis of chronology and uniformity of geological history of the physiographic regions. But still, the concept of morpho-units was not fully evolved. Bourne (1931) was another scholar, who proposed to apply the concept of morph unit through ‘Characteristics-Site-Assemblage’ at two levels.

The concept of morpho-units acquired a proper shape by the work of Bourne (1931) based on basic assumption of ‘Characteristics-Site-Assemblage’. In there two levels of ‘Characteristics-Site-Assemblage’, the regions of ‘first level’ have been distinguished and demarcated on the basis of topographic features produced by erosional and depositional processes, whereas the regions of ‘second level’ were based on those units which are having similar environmental conditions for the development of natural vegetation and pedogenic processes etc. Various statistical methods and techniques were proposed by several scholars at the time of beginning of quantitative revolution in 1950 for the determination of morpho-units of a given geomorphic region. Hammond (1954, and 1964) was the first person who proposed a new technique for mapping and regionalization of any geomorphic region on the basis of terrain characteristics of landscape components. Savigear (1965), a renowned geomorphologist, explained the concept of morpho-units and classified them into different orders by superimposition of maps of different geomorphic variables within the framework of natural region and he named his morpho-units on the basis of natural regions. During the time J. F. Gellert, made another attempt in this field and tried to establish principle of geomorphic regionalization (1982a) and also recognized a uniform system of surface forms, morpho units and geomorphological classification and regionalization (1982b) through the ‘study of the morpho-genesis and morphogenetic classification of earth surface forms, as the basis of the conception of geomorphological maps’ (1969) and ‘geomorphological regionalization’ (1982 a) where he recognized the basic unit of ‘morpho-top or morpho-
facies’ and suggested the uniform shape (morphology, morphometry). The characteristic features for the identification of geomorphological regional units are uniform origin, homogenous lithological structure and uniform present day processes (morpho-dynamics) and development (morpho-genesis, morpho-chronology). He also stated that ‘the morpho-tops or morpho-facies never occur as isolated forms but they also form joined regional units in the form of complexes and form groups with similar but heterogeneous geomorphological marks of orographical, morphographical, morphometric, lithological, sedimentological, morpho-genetics and morpho-structural kind’ (1982a, p.238). He identified and recognized basically five geomorphological units from the smallest to largest spatial unit, viz. (i) MT morpho-tops or morpho-facies (ii) MTG or MNCh groups of morpho-tops or morpho-nanochores, (iii) MMiCh morpho-microchores, (iv) MMeCh morpho-mesochores and (v) MMaCh morpho-macrochores. So, on the basis of environmental processes, regionalizations of morpho-units or landforms at macro-level of such features are called ‘morpho genetic regions’. Peltier (1950) has made an attempt to divide the globe into different morpho-genetic regions and also demarcated them on the region of high, moderate and low intensity of morpho-dynamic processes like erosion, weathering and mass wasting etc. In the present chapter, the attempt has been made to determine the morpho-units on the basis of geomorphic variables by using principal component analysis (PCA) and component scores. In the present study, the concept of mopho-units proposed by Savigear has been adopted for the analysis purpose.
6.3 Methodology

6.3.1 Determination and Spatial Regionalization of Morpho-Units

The ‘multivariate’ morphological regional classification, one of the two basically similar statistical procedures is used, the first i.e. ‘Principal Component Analysis’ (PCA) and another one is called ‘Factor analysis’. Both the methods have a basic difference, that is Factor analysis assumes that only a part of morphological variation of the given region is contained within the variables, used to define morphological landscape whereas, in ‘Component analysis’ assumes that all the morphological variation in a given region are contained within the variables, defined as morphological landscape. The morphological variation of the Mahana basin contained within six drainage and relief variables, which are used to describe morphological characteristics of geomorphic landscape. That is why, in the present study, the procedure of principal component analysis (PCA) is chosen as primary step of GIS based statistical calculation.

6.3.2 Morphological Units: Methodological Aspect

In the present study for the identification and determination of morpho-units, principal components (Table 6.4) have been derived from the correlation matrix (Table 6.1) involving six geomorphic variables, three relief variables viz. relative relief, dissection index and average slope and three drainage variables viz. drainage density, stream frequency, drainage texture. The principal components are computed through ‘Centroid method’ (Holzinger and Herman, 1941).

6.3.3 GIS Based Principle Component Analysis: A Basic Algorithm

The basic algorithm is involved in the determination of GIS based principal component analysis (PCA). The principal components are determined through ‘Centroid Method’ (Holzinger and Herman, 1941), instead of principal axis method (Rummel, 1970) because centroid method is manageable manually.
6.4 Principal Component Analysis:-

The Principal Component Analysis (PCA) is a method of data processing consisting of the extraction of a small number of synthetic variables, called principal components, from a very large number of variables measured in order to explain a certain phenomenon. Principal Components Analysis (PCA) is a practical and very standard statistical tool in modern data analysis that has found application in many different areas such as face recognition and image compression. It has been called one of the most precious results from applied linear algebra. The PCA is a straightforward, non-parametric method for extracting pertinent information from confusing data sets. A multivariate analysis extracts the main information from a large number of variables and offer additional details that can support the decision process. The computation of such methods is quite complicated but the modern information systems can assist the researchers, academicians and scientists to obtain the best information. PCA is a statistical approach used for reducing the number of variables which is most widely used in face recognition. In PCA, every image in the training set is represented as a linear combination of weighted eigen vectors called eigen faces. These eigen vectors are obtained from covariance matrix of a training image set. The weights are found out after selecting a set of most relevant eigen faces. Recognition is performed by projecting a test image onto the subspace spanned by the eigen faces and then classification is done by measuring minimum Euclidean distance.

6.4.1 Methodology:-

As stated previously, the approach proposed in this chapter, combines Geographical Information Systems (GIS) modeling and Principal Component Analysis (PCA). PCA is a statistical method aiming for the reduction of data, identifying components that account for the overall variability within the variables taken into consideration; the principal components are linear combinations of these variables accounting for the common and unique variability explained by them. The steps involved by the application of PCA are (1) extraction of initial components (2) determination of significant components, retained in a model (3) rotation of the matrix based on factor loadings to obtain a solution (4) interpretation of the solution, (5) computation of scores for each factor and of general scores and (6) synthesis of results in a table.
PCA METHODOLOGY FLOW CHART

**METHODOLOGY**

1. Extraction of initial components
2. Determination of significant components, retained in a model
3. Rotation of the matrix based on factor loadings to obtain a solution
4. Interpretation of the solution
5. Computation of scores for each factor and of general scores
6. Synthesis of results in a table
In SPSS, the application of this method produces two tables, the first one identifies the principal components and indicates the percentage of variability explained by them and the second one shows their correlation with the actual variables. The components correspond to the variables to which they are correlated mostly, either positively or negatively, as shown by the value of the correlation coefficient. In this research, the weights are given by PCA, and adjusted to sum to 100 i.e., if all principal components explain a percentage of the variability, X, less than 100%, the percentage explained by each of them is increased 100/X times. The approach was used in four case studies. For some of them, additional analyses or data transformations were required.

Using the Regression model with many variables that are highly correlated each other will not return the best estimators. In such cases, when we try to analyse a large set of \( p \) variables that are usually much correlated and generate the multicollinearity phenomenon, the PCA is recommended.

PCA is also known in literature as ‘Factor analysis’ even if the critics consider the two methods as being different from each other. Talking about ‘Factor analysis’, there are two major classes of research purposes: Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA). EFA is heuristic and the investigator has no expectations of the number or nature of the variables. It allows the researchers to explore the main dimensions to generate a theory or model from a relatively large set of latent constructs. In contrast with EFA, in CFA the researcher uses this approach to test a proposed theory or model. We can see that both Principal Components Analysis and Factor Analysis deal with more variables that usually are correlated in order to reduce the dimension of the analysis to a small number of factors that are not correlated (independent factors). Thus the negative effects of the multicollinearity are avoided. In conclusion, the Principal Component Analysis carries information about not only the patterns of variations in individual variables but also the relationships between variables. Principal Components Analysis is considered a useful tool for dimension reduction and compression as the resulted factors are orthogonal and every factor explains a large part of the variation given by the variables that satisfy a certain condition. The principal components that are to be taken into consideration are those factors that can explain the
largest part of the information given by the initial variables. In this respect, the number of factors which should be retained in the analysis is a decision matter for the researcher. For plotting purposes, two or three principal components are usually sufficient, but for modeling purposes, the number of significant components should be properly determined.

There are many extraction rules and approaches in the determination of the number of factors that are to be retained. One of the most popular is ‘Kaiser’s criteria’ which states that only those factors with eigen value higher than 1 will be retained in the model. Also through the scree test, the cumulative percent of variance extracted and parallel analysis could be used. However, the logical judgment of the researcher should be involved in this selection process in order to determine the meaning of every factor retained in the model. For a better interpretation of the results, it is recommended to use a rotational method, which maximises high item loadings and minimises low item loadings. The most popular rotation technique is Orthogonal Varimax.

6.4.2 Applying the PCA

In applying the PCA, we have to ensure that the variables used are metric ones (measure with interval or ratio scale). The sample size is also important even if there is not a general agreement in the literature regarding the number of observations and the ratio between the sample size and the number of variables. The number of observations have to be bigger than the number of variables included in the analysis, with the mention that big samples can lead to more accurate results.

6.4.2.1 Computation of Components:

The first step is to determine the correlation – coefficient matrix, for the calculation of principal component of any given data matrix. The basic data matrix ‘X’ of the present study is composed of six relief and drainage variables as discussed above and presented by the flow chart (Figure 6.1), calculated in 1 km² grid viz. relative relief, dissection index, average slope, drainage density, stream frequency and drainage texture, each of them having 1320 grid data. Thus, the basic data matrix ‘X’ (1320 x 6) of Mahana river basin has 1320 rows (number of grid data) and 6 columns (number of relief and drainage variables). For calculation of ‘Correlation - Coefficient Matrix’ ‘R’ from the basic data matrix ‘X’ ( 1320 x 6 ), first of all, it is transformed into matrix of standard scores ‘Z’
(1320 x 6) and then the correlation-coefficient matrix ‘R’ (6 x 6) is calculated (Table 6.1).

\[ R (6 \times 6) = Z (6 \times 1320) \times Z^T (1320 \times 6) / N (1 \times 1) \]

### Table 6.1: Component Loadings of Six Morphometric Component

<table>
<thead>
<tr>
<th></th>
<th>Relative relief</th>
<th>Stream frequency</th>
<th>Average slope</th>
<th>Drainage density</th>
<th>Dissection index</th>
<th>Drainage texture</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rr</strong></td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sf</strong></td>
<td>0.68</td>
<td><strong>1.00</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>As</strong></td>
<td>0.91</td>
<td>0.64</td>
<td><strong>1.00</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Dd</strong></td>
<td>0.53</td>
<td>0.86</td>
<td>0.49</td>
<td><strong>1.00</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Di</strong></td>
<td>0.99</td>
<td>0.69</td>
<td>0.9</td>
<td>0.54</td>
<td><strong>1.00</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Dt</strong></td>
<td>-0.42</td>
<td>-0.68</td>
<td>-0.4</td>
<td>-0.66</td>
<td>-0.43</td>
<td><strong>1.00</strong></td>
</tr>
</tbody>
</table>

With the help of SPSS software, six components have been computed, having different loadings of relief and drainage variables (Table 6.1). Table 6.1 shows that the first component is correlated quite highly with each of the six variables of derivatives of relief and drainage aspects of the study region because it accounts nearly 16.81% of the variation in data matrix (1320 x 6) of six morphometric variables taken from each grid of one sq. km. That is why only the first component has been used for the mapping of morpho-units hence this is termed as ‘morpho-component’. Beside this variance, Eigen values and percentage of total variance also have been computed with the help of component loadings for each relief and drainage variables (Table 6.1).

#### 6.4.2.2 Computation of ‘Component Scores’:

Table 6.1 shows various statistical parameters of the computed six components showing loading and variance of six relief and drainage variables of morphometric analysis. All six components have been used in this study for calculation and then mapping of morphological units. For calculation and mapping of separate morphological units of Mahana river basin, component scores are calculated. Six component score maps (each
having (1320) grids of Mahana basin), have been obtained by using loading of each component in all the six variables and modify as the original standard data and termed as PC1, PC2 and PC3 etc. images and each component score map represents specific dimensions of that component. But still they are not images and only weighted component scores given to each grid of six component-score maps. In the present study the ‘component-score matrix’, ‘R’ (1319 x 6) of all six component loadings, ‘L’ (6 x 6) (Table 6.1) obtained by the multiplication of standardized data matrix ‘Z’ (1320 x 6) with matrix of all six component loadings ‘L’ (6 x 6) as given below:

\[
R \ (1320 \times 6) = Z \ (1320 \times 6) \times L \ (6 \times 6)
\]

The variables of relief aspects like relative relief and average slope contain great deal with component 1 i.e. principal component while drainage density is positively associated with component 2 rather than component 1, while negatively associated with component 1. The variables of drainage aspect like drainage density, stream frequency and drainage texture has positively and negatively less association with component 1 and 2, the drainage density and stream frequency is negatively associated with component 1 while drainage density is positively associated with component 2 whereas stream frequency is positively less associated with component 1 and negatively less associated with component 2.

The PCA used in this chapter for exemplification purpose, takes into consideration 6 variables that measure all components regarding various aspects of their drainage and altrimetric aspects. Starting from the assumption that these variables are collinear, the purpose of PCA is to reduce the number of variables that measure the ‘drainage densities’ to a small number of factors that are not correlated. For the beginning of the analysis, a testing step is necessary in order to determine the suitability of data for such a method. In this respect Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity are computed by SPSS system.
Table 6.2: KMO and Bartlett's Test

<table>
<thead>
<tr>
<th>Kaiser-Meyer-Olkin Measure of Sampling Adequacy</th>
<th>.570</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bartlett's Test of Sphericity</td>
<td></td>
</tr>
<tr>
<td>Approx. Chi-Square</td>
<td>5194.568</td>
</tr>
<tr>
<td>df</td>
<td>15</td>
</tr>
<tr>
<td>Sig.</td>
<td>.000</td>
</tr>
</tbody>
</table>

The KMO index ranges from 0 to 1 and the sample is considered suitable for PCA if this index is equal or higher than 0.50. The Bartlett's Test of Sphericity should also be significant (p<0.05). The results presented in Table 6.2 reveal that the data used in our example are adequate for PCA. After these tests, we have to take a decision regarding the number of factors (principal components) that should be retained in the model. In the initial solution the number of components is equal to the number of variables included in the model (see Table 6.3). Every component has an eigen value which represents the amount of variance that is accounted for by a given component. Usually the first variables have the greatest eigenvalues. One of the most commonly used criteria for principal component selection is the Kaiser’s criterion known also as eigen value-one criterion. According to this one only the variables with the eigen value greater than 1 will be retained in the model. Using of eigen value-one criterion is not considered the best decision when the actual differences between the eigen values of successive variables are quite small. Thus, the variable with an eigen value of 0.99 will be excluded from the model inspite of its significant contribution to the total variance. For these reasons, the proportion of variance accounted for by every factor and the cumulative percentage of variance could be used in the process of factor selection. We can establish to retain in the model, all those factors that account for at least 10% or 5% of variance.
Table 6.3: Total Variance Explained of the Mahana Basin

<table>
<thead>
<tr>
<th>Component</th>
<th>Initial Eigenvalues</th>
<th>Extraction Sums of Squared Loadings</th>
<th>Rotation Sums of Squared Loadings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>% of Variance</td>
<td>Cumulative %</td>
</tr>
<tr>
<td>1</td>
<td>2.410</td>
<td>40.172</td>
<td>40.172</td>
</tr>
<tr>
<td>2</td>
<td>1.908</td>
<td>31.803</td>
<td>71.975</td>
</tr>
<tr>
<td>3</td>
<td>.979</td>
<td>16.322</td>
<td>88.297</td>
</tr>
<tr>
<td>4</td>
<td>.482</td>
<td>8.040</td>
<td>96.337</td>
</tr>
<tr>
<td>5</td>
<td>.188</td>
<td>3.142</td>
<td>99.478</td>
</tr>
<tr>
<td>6</td>
<td>.031</td>
<td>.522</td>
<td>100.000</td>
</tr>
</tbody>
</table>

In table 6.3 we can see that only the first two components have the eigen value greater than 1 but the value of the third component is very close to below 1 and it explains .522% of the total variance. Taking into account the cumulative percent of variance explained, according to Hair et al. cited by Williams et al.
Another method used for factor extraction is the analysis of the Scree plot. This is a subjective method which requires the researcher’s judgement. According to this criterion, the significant factors are disposed, like a cliff, having a big slope while the trivial factors are disposed at the base of the cliff. In the Figure 6.2 we can appreciate that starting with the fourth factor the slope of the curve is quite small and these factors could be excluded from the model. Never the less the method is very subjective because the cut-off point of the curve is not very clear in the above chart. Whatever method of factor extraction is used, it is recommended to analyse the meaning of every principal component according to the variables, with significant loadings on the retained factors. In order to apply this meaning interpretation, a rotated solution is computed. A rotation is a linear transformation that is performed on the initial factor solution for the purpose of making an easier interpretation. The most common rotation method is Orthogonal Varimax, which is provided by the majority of statistical software.

Figure 6.2: Scree plot, between the six principal components and the eigen values.
Table 6.4: Rotated Component Matrix

<table>
<thead>
<tr>
<th>Variable</th>
<th>Component Matrix</th>
<th>Principal Component</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PCA - 1</td>
<td>PCA - 2</td>
</tr>
<tr>
<td>Di</td>
<td>-.768</td>
<td>.548</td>
</tr>
<tr>
<td>Rr</td>
<td>-.734</td>
<td>.565</td>
</tr>
<tr>
<td>Fs</td>
<td>.734</td>
<td>.612</td>
</tr>
<tr>
<td>Dd</td>
<td>.699</td>
<td>.616</td>
</tr>
<tr>
<td>As</td>
<td>.623</td>
<td>.153</td>
</tr>
<tr>
<td>Dt</td>
<td>.309</td>
<td>-.453</td>
</tr>
</tbody>
</table>

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

Table 6.5: Component Transformation Matrix

<table>
<thead>
<tr>
<th>Component</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.675</td>
<td>-.650</td>
<td>.347</td>
</tr>
<tr>
<td>2</td>
<td>.735</td>
<td>.628</td>
<td>-.256</td>
</tr>
<tr>
<td>3</td>
<td>-.052</td>
<td>.428</td>
<td>.902</td>
</tr>
</tbody>
</table>

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

When we apply the rotation method, a factor pattern matrix is obtained, which contains the loadings of every variable on the retained factors, see (Table 6.4). In order to make the interpretation of the meaning of every factor, the variables that have the greatest loadings on a factor, are analysed in terms of their similarity, regarding the measured construct. After this, interpretation of the principal components could be labelled according to their relevant meaning. If the groups of variables that determine a factor are meaningless, we have to reconsider the number of factors that are included in the model.
Figure 6.3: Spatial pattern of the first principal component score

Figure 6.4: Areal coverage of the first principal component score
Figure 6.5: Spatial pattern of the second principal component score

Figure 6.6: Areal coverage of the second principal component score
Figure 6.7: Spatial pattern of the third principal component score

Figure 6.8: Areal coverage of the third principal component score
6.4.3 Discussions and conclusions

The Principal Component Analysis can be used when many variables are used to measure the same construct. In such cases, the multicollinearity phenomenon appears and the use of other analysis methods like regression model is not proper. The most important steps in performing PCA consist of testing the data suitability for this method and in selection of the best factors that describe the total variance produced by the initial variables. In table 6.1 we can see that the first component of stream frequency is the most dominant variable in whole region and its cover to approximately one third region of the entire study area. The second component of drainage density is the second principal component among all six variables in whole area and its cover more than 35% area of entire study region. The third component of drainage texture covers more than 25% area of entire study region. Using the above validation criterion is very important because finally the interpretation of the results should lead to components with a certain meaning for the research purpose. The resulted factors (principal components) could be used in further analysis regarding drainage and relief description as explanatory variables in regression models. The computation of the new variables that represent the principal components could be made as a linear combination of the initial variable. Such variables are directly computed by SPSS system as standardized values. We can also obtain new variables by simply adding the values of every variable that determine a certain component or by computing the mean of these values. In conclusion, the Principal Component Analysis could be considered a powerful tool in computing marketing information.
6.5 Conclusion

In the present study, we can conclude that an attempt has been made to use the geomorphological map for proper understanding of the geomorphology of the basin, which is further used for study of their impact on basin ecosystem. An attempt has also been made to use the Principal Component and Component Scores for the determination of morpho-units on the basis of geomorphic variables. In this chapter, the concept of morpho–unit proposed by Savigear (1965) has been adopted. In the present study, the principal component analysis instead of factorial analysis has been chosen as the first primary step of GIS based statistical computation and specially use to SPSS software in PCA regarding to all six variables and multivariate morpho-geological classification of the study region.