Morphologic Parameters Inter-correlation of a Basin

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ABSTRACT

Based on, regions and watersheds area classification map of Cyprus, 4th and 5th regions were studied using 1/5000 topographic maps and 139 basins were delineated manually. For each basin, 79 morphometric dimensional and non-dimensional parameters were gathered using wherever possible the Horton's Stream Ordering approach and also for each basin 1-hr. synthetic Mockus hydrograph was generated using lagging technique. By using Principal Component Analysis 'PCA' with the help of eViews package, the linear inter-correlation of 58 parameters were studied. With the help of the established correlation coefficient matrix the strong correlation values (greater than Pearson 'r' 0.80) were determined and ordered based n strongest to weakest for each parameter. Using weighted sum analysis 'WSA', the prioritization of the studied 139 basins from the sustainable development and the water conservation aspect were determined. From this study it is has been identified that, the most linearly inter-correlated parameter is the Mean Bifurcation Ratio 'R_{b-av}' whereas no strong linear inter-correlation exists among the other parameters are the Basin Perimeter 'P', and the Elongation Ratio 'R_e'.

Keywords: eViews, linear inter-correlation, Mockus, morphologic, prioritization

ÖZ

Bu çalışmada Kıbrıs bölgeler ve havza alanları sınıflaması haritasındaki 4. ve 5. bölgeler, 1/5000 ölçekli topoğrafik harita kullanılmış ve 139 havza sınırları elde (manuel) belirlenmiştir. Belirlenen her havza için 79 morfometrik boyutlu ve boyutsuz parametreler gerekli görülen parameterler için Horton Nehir Derecelendirme (mertebelendirme) yaklaşımı derlenmiş ve ayrıca yine her havza için 1-sa sentetik Mockus birim hidrografı, kaydırma metodu ile elde edilmiştir. eViews paket programı yardımı ile, Temel Bileşen Analizi ‘PCA’ yapılarak 58 parametrenin birbirine olan lineer bağımlılığı çalışılmıştır. Oluşturulan bağımlılık katsayısı matrisi yardımı ile kuvvetli bağımlılık değerleri (Pearson ‘r’ mutlak değeri 0.80 esas alınarak) kuvvetliden daha az kuvvetli olarak belirlenip önemlerine (mertebelerine) göre sıralandırıldı. Ağırlıklı toplam analiz ‘WSA’ yaklaşımı ile, 139 havza sürdürülebilir gelişme ve su korunumu açısından önceliklendirildi. Bu çalışmada, diğer parametrelerle en çok lineer bağımlılığı Ortalama Çatallanma Oranı (Mean Bifurcation Ratio) ‘R_{b-av}’ parametresi, ve hiç kuvvetli lineer bağımlılığı olamayanlar da Havza Çeperi (Basin Perimeter) ‘P’, ve Uzama Oranı (Elongation Ratio) ‘R_e’ parametreleri olarak belirlenmiştir.

Anahtar Kelimeler: eViews, lineer inter-korelasyon, Mockus, morfolojik, önceliklendirme

To My Family

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A	Basin (Watershed) Area
B	Basin Width
C_c	Compactness Coefficient
C_{Sch}	Schumm Coefficient
D_{area}	Diameter of the Circle based on Basin Area
D_d	Drainage Density
D_i	Drainage Intensity
D_{peri}	Diameter of the Circle based on Basin Perimeter
D_S	Stream Density
$D_{S(i)}$	Stream Segment Density of Order i
$D_{S(1)}$	Stream Segment Density of Order 1
$D_{S(2)}$	Stream Segment Density of Order 2
$D_{S(3)}$	Stream Segment Density of Order 3
F	Fineness Ratio
F_f	Horton's Form Factor
F_{POTTER}	Potter's Factor
F_R	Fitness Ratio
h_o	Basin Minimum Elevation
h_a	Unit Depth Over the Basin Area
H_{max}	Basin Maximum Elevation
H_{mean}	Mean Basin Height
H_S	Maximum Topographic Stream Elevation
h_S	Minimum Topographic Stream Elevation
I_{Dis}	Dissection Index
If	Infiltration Number
I_p	Mean Slope of Water Divide
k	Basin Coefficient Constant 0.208
L	Equivalent Length
L_i	Length of i^{th} Order Stream
L_1	Length of 1^{st} Order Stream
L_2	Length of 2^{nd} Order Stream
L_3	Length of 3^{rd} Order Stream
$\bar{L}_{total}$	Mean Length of All Order Streams
L_b	Basin Length
L_{ca}	Length to the Basin Center of Area
L_{ch}	Length of the Main Channel
L_d	Stream Length Density
L_T	Length of All Order Streams
MR_u	Melton's Ruggedness Number
N_i	Total Number of i^{th} Order Stream
N_1	Total Number of 1^{st} Order Stream
N_2	Total Number of 2^{nd} Order Stream
N_3	Total Number of 3^{rd} Order Stream
N_4	Total Number of 4^{th} Order Stream
N_5	Total Number of 5^{th} Order Stream

N_T	Total Number of All Order Streams
P	Basin Perimeter
P_{area}	Perimeter of the Circle based on Basin Area
P_r	Basin Relative Perimeter
Q_p	Peak Discharge
r_{area}	Basin Radius Based on Area
R	Basin Relief
R_{b-av}	Mean Bifurcation Ratio
R_c	Circularity Ratio
R_e	Elongation Ratio
RF	Apollov's Form Factor
RHO	Horton's Term
$\overline{R}_L$	Overall Mean Stream Length Ratio
R_{mean}	Mean Basin Relief
R_p	Relative Relief
r_{peri}	Basin Radius based on Perimeter
R_r	Relief Ratio
R_u	Ruggedness Number
S	Main Channel Gross Slope
S_{av-ari}	Arithmetic Average based Slope of Main Stream
S_{av-har}	Harmonic Average based Slope of Main Stream
t_b	Base Time
T	Time of Concentration
t_f	Time of Recession
t_p	Time of Rise
t_r	Rainfall Duration
T_r	Drainage Texture Ratio
T_{r-i}	Drainage Texture Ratio Order i
T_{r-1}	Drainage Texture Ratio Order 1
T_{r-2}	Drainage Texture Ratio Order 2
W_R	Wandering Ratio
ΔR_{stream}	Stream Relief
Θ	Basin Slope Angle
Ω	Stream Order

Chapter 1

INTRODUCTION

1.1 Aim and Objectives of the Study

Water is one of the most vital matters of the world and especially for the islands, in which water supply depends mainly on precipitation and available ground water resources. In the case of North Cyprus, the amount and intensity of the rainfall are scanty and unstable and the replenishment of the available aquifers are quite poor especially.

In North Cyprus, the significant amount of precipitation ecologically it is good to have flowing into sea or evaporated back into atmosphere in a very short time due to rough topography and very hot weather in summers.

Unfortunately, in North Cyprus, since all the basins are ungaged, there is no proper rainfall-runoff information. Hence, this study is carried out to investigate the relationship between the characteristics of the basins to the hydrologic response.

For this reason, both Girne North shore (Hydrologic Region 4) and Karpaz Peninsula (Hydrologic Region 5) as detailed in Fig. 1.1 were selected and their existing watersheds were delineated. As a part of this study.For each basin, the important geomorphologic characteristics were determined. The details of these characteristics are given in Appendix 1,

a. Mockus Synthetic Unit Hydrograph was generated for each basin,
b. Linear inter-correlation of geomorphologic parameters were investigated, and
c. Priority order of the studied 139 basins from the hydrological aspect was determined.

1.2 Study Region

Cyprus, being an island covering 9250 km^2 is situated in the north-eastern corner of the Mediterranean sea centered on latitude of 35^o00' N and longitude of 33^o15' E. Based on Water Resources Department (1970), Cyprus is divided into 9 hydrological regions as indicated on the regions and watersheds area classification map, in Figure 1. The criteria used for the division into regions were primarily hydrological and hydrogeological although administrational aspects were also considered as far as practicable since the ethnic division boundary is not overlapping with the administrative one based on pre-1974, Water Resources Department (1970). Note that, even each of these 9 regions was in turn subdivided into watersheds or group of watersheds where the maximum number of subdivision with in each region is not exceeding 9.

In this study, the 4^{th} and the 5^{th} hydrological regions of Cyprus, called Girne North Shore and Karpaz Peninsula respectively were selected. The longitudinal boundaries of the studied region are 35^o 69' N and 34^o 58' N.

Figure 1: The Regions and Watershed Area Classification Map of Cyprus. (Adopted from Water Resources Division, 1970)

1.3 Previous Studies

Girne North Shore region ('4th' hydrological regions including all the 9 subdivisions) was studied by Özkuş, (2002) as a part of his MSc. Thesis. The topographical features of the Girne North Shore region is bounded by the Mediterranean Sea from the North and the peaks of the Beşparmak Mountains from South. The West and Eastern ranges are the Sadrazamköy and the Balalan villages respectively. This region, based on 1/5000 scale topographic maps, 82 catchments were delineated. For each basin besides 10 geomorphological dimensional and non-dimensional parameters were determined but also Mockus and Gray Synthetic Unit Hydrographs were generated.

Karpaz Peninsula region ('5th' hydrological regions including all the 9 subdivisions) was studied by Ünal, (2004) as a part of his MSc. Thesis. The Karpaz Peninsula region is at the tip of Cyprus that is bounded from the East by Topçuköy village and the remaining boundaries are surrounded by the Mediterranean Sea from North, South and West. This region, based on 1/5000 scale topographic maps 57 catchments were delineated. Like the study of Özkuş 2002, for each basin Mockus and Gray Synthetic Unit Hydrographs were also generated but instead of 10, 18 geomorphological dimensional and non-dimensional parameters were determined.

This study investigated both of those hydrologic regions. A total number of 139 basins based on 1/5000 scale topographic maps were delineated. For linear inter-correlation studies among the geomorphologic parameters 52 dimensional and non-dimensional (basic and derived) geomorphologic parameters were calculated for each basin. The details of these parameters are given in Appendix 1. Also for each basin, using the appropriate geomorphological parameters, Mockus Synthetic Unit

Hydrographs were regenerated so as to obtain three important unit hydrograph parameter (peak discharge 'Q_p', time of basin 't_b', and time to peak 't_p') that will be used for inter-correlation studies.

1.4 Literature Survey

1932, Sherman proposed the well-known theory of unit hydrographs. The unit hydrograph (originally named uni-graph) of a drainage basin is defined as a hydrograph of direct runoff resulting from 1 in. of effective rainfall generated uniformly over the basin area at a uniform rate during a specified period of time or duration. Sherman originally used the word "unit" to denote the specified period of time or a 'unit time'' of the effective rainfall. Later however, the word "unit" was often misinterpreted to denote 1 in. or "unit depth" of the effective rainfall. Sherman classified the runoff only into surface runoff and groundwater flow since subsurface flow was not recognized during his time. Consequently, he defined the unit hydrograph only for the use of surface runoff, Chow (1964).

In 1938, McCarthy proposed a method of synthesis of unit hydrographs. In this method, a correlation analysis was made between three unit hydrograph parameters (peak discharge 'Q_p', lag time from the beginning of rain to the peak flow 't_p', and the total base time 't_b') and three basin characteristics (size of the basin area 'A', the slope of basin area elevation curve 'S' and number of major streams within the basin'N_T'). From the resulting correlation curves, it was possible to estimate the three unit hydrograph parameters for an ungauged basin when the three basin characteristics are known, Chow (1964).

In the same year, Snyder pioneered the concept of developing a generic unit hydrograph based on analysis of gauged watersheds that can be applied to ungauged basins using measurements of basin geomorphologic characteristics. He developed a set of formulas relating the physical geometry of the watershed to parameters of the unit hydrographs, Wurbs and James (2002).

The Soil Conservation Service (SCS) method that is based on triangular hydrograph shape is generally known as Mockus method. In this method, the suggested formulations are empirical but the calculations are more practical and the drawing of the triangular hydrograph is easier. This method requires detail information about the vegetation and the topographic characteristics of that basin. So called Curve Numbers (CN), are usually generated to represent these characteristics, Bayazıt (1999).

Hence, for the determination of the unit hydrographs for each basin within the study area, since there is no measured data exists (i.e., ungauged basins) imposing to apply synthetic hydrograph method. Hence, Mockus synthetic unit hydrograph method was selected for this study.

Determining the geomorphologic parameters of a basin was first introduced by Horton in 1932 and amended by him on 1945. Then on, different researchers studied on this approach and categorize the generated various dimensional and non-dimensional parameters into linear, areal and relief aspects. Some of these parameters were measured or read directly from the relevant topographic maps that were used to delineate that basin and referred as basic morphometric parameters, and the others were named as derived morphometric parameters since they were calculated based on suggested formulations (Horton, 1932; Horton, 1945; Smith, 1950; Pareta, 2011, Singh, 2013; Rama, 2014).

Human being is closely attached with the development and conservation of natural resources like soil and water. In this regard, for the sustainable development of the existing water resources, prioritization of watershed on the basis of quantitative analysis that considers geomorphological parameters plays an important role. This study was carried out by different researchers in the recent decade where correlation coefficients values were used for ranking the priority (Saha, 2015).

1.5 Outline of Thesis

This thesis is compiled into two volumes. Volume 1 (this volume) composed of 5 chapters and the references part. Chapter 2, briefly explains the morphometric parameters, the Mockus hydrograph, the correlation matrix, and the prioritization methodologies. Analysis and application details were given in Chapter 3. In Chapter 4, Results were detailed. In the last chapter (Chapter 5), Conclusions and Recommendations for Future Studies were presented. Volume 2 is the Appendices, where Appendix I, details the definitions, symbols, dimensional units of the basic and derived morphologic parameters, and Appendix II mainly gives morphometric details and relevant 1 hr. Mockus hydrograph of each basin.

Chapter 2

METHODOLOGY

2.1 Introduction

This study is composed of 5 parts. In the first part, delineation of each basin was done. For this purpose appropriate 254 topographic maps of 1/5000 scale that bounds the hydrologic regions 4 and 5 were obtained from Harita Dairesi of the Government of North Cyprus and 139 basins were generated. In the second part, 76 dimensional and non-dimensional basic and derived morphologic parameters were determined. Among these parameters as the third part of this study, Mockus synthetic unit hydrographs were generated for each basin. Linear inter-correlation study among the determined morphologic parameters was carried using the eViews package where a correlation coefficient matrix was established. As the fifth part, a prioritization of 139 basins from the water resources sustainability aspect was investigated and ranked based on those determined morphologic parameters.

2.2 The Watershed

The concept of a watershed which is also referred as basin or catchment is basic to all hydrologic designs. Watershed is an ideal unit for planning and management of land and water resources. In fact, it is the natural entity that allows surface runoff to a defined channel where the physiographic characteristics of the drainage basin are all interrelated (Al-Rawas, 2010; Gregory, 1973).

It is necessary to define the watershed in terms of a point. This point is usually the location at which the design is being made and is referred to as the watershed outlet or mouth. In fact, the watershed consists of all land area that sheds the water to the outlet during a rainfall. Using the concept that water runs downhill due to gravity, a watershed is enclosed all the points within an area from which the rain is falling and contributing to the outlet (Black, 1991). Fig. 2.1 shows the general basin (watershed) components such as watershed boundary, stream order, and outlet (mouth) briefly.

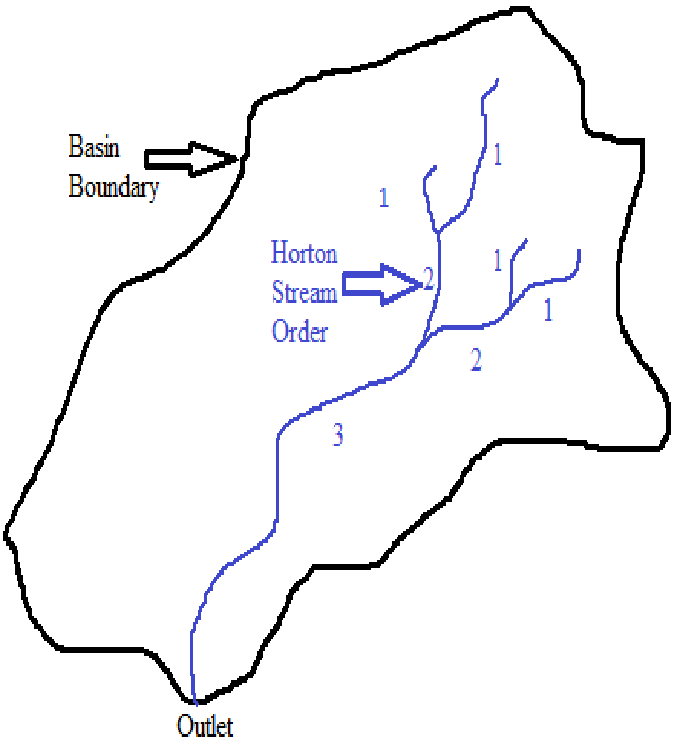

Figure 2.1: The General Components of a Basin.

2.3 The Delineation Process of Watershed

2.3.1 Information Sources of Topographic Maps

The fundamental source of data, that is used for delineating and studying watersheds is a map. These maps give a wealth of information including topographic contour lines, locations of cities, water bodies, forested land, stream networks with stream gauging stations and benchmarks. Maps typically have a scale of 1/5000 (1 cm on the map corresponds to 50 m in the field). Usually, the contour intervals of the elevation data, which is given in metric units, are multiple of 5. For watershed delineation, these maps offer the best starting point. These topographic maps are available at Harita Dairesi of the Government of North Cyprus (Harita Dairesi).

2.3.2 Delineating a Watershed Using a Topographic Map

First determine the outlet point of the watershed. This is generally the point of interest for designing a structure or monitoring location or the place where the stream discharges to a sea or a lake. To delineate the watershed boundary perpendicular lines are drawn across the elevation contour lines for land that drains to the point of interest.

Basic steps for the watershed delineation are finding the outlet or the downstream point of the studied part, highlight both sides of the watercourse, by working the way upstream towards the headwaters of the watershed, draw a line connecting along the watercourse noting that this line should always cross the contours at right angles (i.e. it should be perpendicular to each contour line it crosses) and eventually connect the line by forming enclosed shape. Hence, the watershed of the studied area being delineated (Chorley et al, 1957, and McCuen et al, 1998).

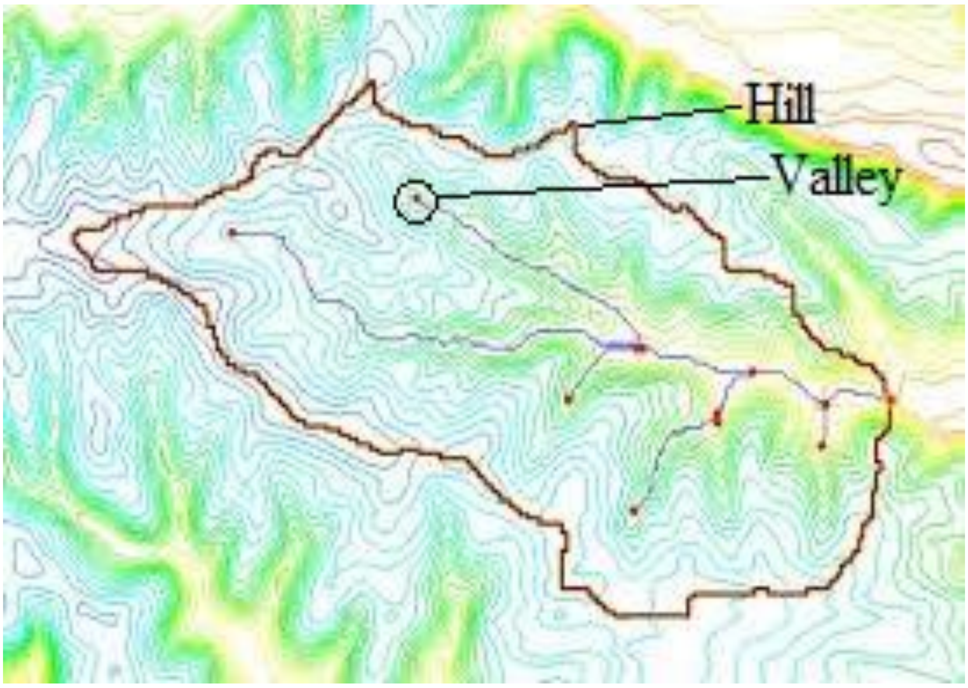

Figure 2.2: Delineating a Watershed Boundary.

2.3 Morphometric Parameters of a Watershed

Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimensions of its landform [Clarke, 1966; Gravelius, 1914]. Morphometric analysis is important in any hydrologic investigation and it is inevitable in development and management of drainage basin. The quantitative analysis of morphometric parameters giving important guidelines in river basin evaluations, watershed prioritization for soil and water conservation, and natural resources management especially on micro level (Miller, 1953; Mueller, 1968; Sreedevi et al. 2005; Zavoianu, 1985).

Morphological analysis of the basin is utmost important to evaluate and understand the behavior of hydrological system that provides quantitative specification of the basin geometry, structural controls and the geomorphic history of the drainage basin. Hence, spatial and temporal analysis of various essential morphological parameters would be helpful to the decision maker for framing required measure at critically affected areas. Moreover, appropriate use of land and water resources of a catchment is essential for the optimal production and minimum hazard to natural water resources. To investigate this, in this study, a prioritization approach was adopted that ranks the importance of the catchments based mainly on their geomorphological aspects (Faniran, 1968; Jha, 2005).

Morphometric analysis of a basin, provides an indication about permeability and the storage capacity of the soil by giving an indication of the yield of the basin where providing useful clues regarding broad relationship among the geological framework of the basin. Some of these geomorphologic characteristics of the basin, such as area 'A', perimeter 'P' or slope 'S' are assumed to be constant: since any morphologic change in them takes very long time. As a matter of fact, all the watershed characteristics are function of the topography, which also influences the velocity and even the direction of the surface water flow [Maxwell, 1960; Schumm, 1956; Schumm, 1963; Usul, 2013]. Hence, it is an essential first step, toward basic understanding of watershed dynamics. This is achieved through the measurement of linear, areal and relief aspects of the basins (Dov, 1957, Melton, 1965, and Saha, 2015).

Since the pioneer study carried by Horton, 1932, several other researchers amended his studies and generated different valuable basic and derived dimensional and non-dimensional parameters (Horton, 1932, Strahler, 1957, and Strahler, 1964). Brief detail of the studied 76 morphologic parameters is given in Appendix I.

2.4 Mockus Hydrograph

If there is no measuring device exists over the basin (catchment) to detect the rainfall-runoff relationship, a synthetic unit hydrograph method is an appropriate choice. To establish a synthetic hydrograph depending on its derivation approach, different morphometric parameters of the basin are used. The Soil Conservation Service (SCS) method that is based in triangular hydrograph shape is generally known Mockus method. In this method, the calculations are more practical and the drawing of the triangular hydrograph is easier. Mockus method is applicable if the time of rise (t) is smaller than 2 hr (i.e., $t < 2$ hr). Thus, if $t > 2$ hr, this method is not valid (Ağaçlıoğlu, 2000, and Şen, 2004). In this method, instead of Curve Number (CN) of a basin, the time of concentration (T_c) is related with the rainfall duration (t_r) empirically. Mockus method is valid when the time of concentration (T_c) is not bigger than 30 hr ($T_c \leq 30$ hr) where the T_c is defined as, the time required for a particle of water to flow hydraulically from the furthest location in the watershed to the outlet or to the design point (Woodward, 1999). The selection of the unit rainfall duration (t_r) is also important (Özdemir, 1978). The relation between t_r and T_c given as:

$$T_c \leq 3 \text{ hr} \qquad t_r = \tfrac{1}{2} \text{ hr.}$$

$$3 < T_c \leq 6 \text{ hr} \qquad t_r = 1 \text{ hr.}$$

$$6 < T_c \leq 10 \text{ hr} \qquad t_r = 1.5 \text{ hr.}$$

$$10 < T_c \leq 15 \text{ hr} \qquad t_r = 2 \text{ hr.}$$

$$15 < T_c \leq 30 \text{ hr} \qquad t_r = 3 \text{ hr.}$$

Note that, in this study, while determining the value of t_r, the calculated T_c values are rounded to the nearest whole numbers.

For this method, the time rise (t_p) and the peak discharge (Q_p) are obtained by the following empirical equations:

$$T_c = 0.00032 \frac{L_{ch}^{0.77}}{S_{av-harm}^{0.385}} \tag{2.1}$$

$$t_r = 2\sqrt{T_c} \tag{2.2}$$

$$t_p = (0.5\ t_r) + (0.6\ T_c) \tag{2.3}$$

$$t_f = 1.67\ t_p \tag{2.4}$$

$$t_b = t_p + t_f \tag{2.5}$$

$$Q_p = \frac{k.A.h_a}{t_p} \tag{2.6}$$

where;

A : watershed drainage area (km^2),

T_c : time of concentration (hr),

L_{ch} : length of the main channel (m),

$S_{av\text{-}harm}$: harmonic slope of the main channel (m/m),

t_r : rainfall duration (hr),

t_p : time of rise (hr),

t_f : time of recession (hr),

Q_p : peak discharge (m^3/s),

k : 0.208, basin coefficient (dimensionless) and

h_a : unit depth over the basin area (mm).

2.5 Correlation Matrix

To highlight the inter-dependency among the parameters, a statistical eViews package is used that linearly interpret the correlation coefficient value and presented as a matrix form. In order to achieve a better performance in this correlation study, a consistency and homogeneity of the datasets play an important role. For this reason, all the dimensional and non-dimensional parameters are non-dimensionalized based on simple standardization ratio method. To apply this method, the maximum value among each parameter set was determined. Then, each value within that set was divided by this (relevant) maximum value. By this way, all the parameter sets are non-dimensionally standardized within the range of 0.00 - 1.00.

The values within this established matrix in fact, imply the Pearson correlation coefficients referred as Pearson ‘r’ (i.e., the Pearson product-moment correlation coefficient which is the square-root of the coefficient of determination R^2 value). So this statistical measure correlates how close the dataset groups are fitted with each other linearly (i.e., multi-linear regression).

Since the level the correlation of parameters are not known in prior, these linear inter-correlation values are used to measure the strength and the direction among those parameters. The value of Pearson ‘r’ within the established matrix lies between +ve 1.00 and –ve 1.00 where the +ve correlation coefficient value is implying a direct relationship and the –ve one implies an inverse relationship.

If Pearson ‘r’ value within the matrix is exactly equals to 1.00, implies the repetition of the parameter or redundancy, i.e., different parameters having exactly the same effect. By this way the repeated (redundant) parameters are detected and eliminated so as to compile the effective principal parameters.

Different studies have offered guidelines for the interpretation of the correlation coefficient values. However, all such criteria are in some ways arbitrary. In fact, the interpretation of a correlation coefficient depends on the context and the purposes.

The Table 2.1 details the general classification of the absolute Pearson 'r' value interpretation suggested by the author for this study.

Table 2.1: General Classification of the Absolute Pearson 'r' Value Interpretation

Absolute Pearson 'r'	Interpretation
0.95 – 1.00	very strong
0.80 – 0.95	strong
0.60 – 0.80	good
0.30 – 0.60	weak
0.00 – 0.30	very weak

2.6 Prioritization

It is the activity that arranges items in order of importance relative to each other. In this study, to prioritize the basins based on morphometric parameters, the Weighted Sum Analysis 'WSA' technique was applied. The standardized non-dimensional both the morphometric parameters and the important hydrograph parameters are used where a statistical square correlation matrix 'i X j' (47 X 47 for this study) was established. From the correlation coefficient values, the final weightage $\sum_{i=1}^{n=47} W_i$ for each parameter was calculated by dividing the sum of the correlation coefficient of each parameter $\sum_{i=1}^{n=47} C_i$ by the grand total of the correlation coefficient value $\sum_{j=1}^{47}\sum_{i=1}^{47} C_{ij}$. Then, by multiplying these obtained weightages 'W_i' to each and every selected 47 (hydrologically important 3; morphometric 44) non-dimensional parameters π_i respectively, a Weighted Sum Analysis 'WSA' values are obtained for each basin. The related formulation is given as:

$$WSA_{basin} = \sum_{i=1}^{n=47} (W_i . \pi_i) \quad (2.7)$$

Then, for watershed prioritization based on morphometric parameters, the Weighted Sum Analysis 'WSA' technique was applied. The calculated WSA values was gathered and ranked where rank 1 was assigned for the highest WSA value, implying highest care has to be taken from the water conservation implementation, the sustainable development and the environmental degradation studies aspect.

Chapter 3

DETAILS OF ANALYSES AND APPLICATIONS

3.1 Establishment of 1 hr. Mockus Hydrograph

Within the studied 139 catchments, due to limitations while establishing the Mockus synthetic hydrograph, some of the basins generated having ½ hr. and some were having effective rainfall duration of 1 hr. unit hydrographs. Hence, to have uniformity among these generated synthetic unit hydrographs for further statistical studies, a lagging approach (one of the well-known methodology used for generating unit hydrograph of different effective rainfall durations from the detected duration), was applied and 1 hr. Mockus synthetic unit hydrographs were generated for all the basins. Then, those three hydrologically important hydrograph indices (parameters, variables), based on 1 hr. Mockus hydrograph, the peak discharge 'Q_{peak}', the time to peak 't_p' and the hydrograph base time 't_b' were calculated and gathered for each basin. Their value range were detailed in Table 3.1. To have a proper correlation calculation these three parameters were non-dimensionally standardized using the simple standardization approach.

3.1.1 Generating a Mockus Hydrograph

3.1.2 Obtaining 1-hr Unit Hydrograph by Lagging Method

In order to apply the lagging method for 0.5-hr so as to generate 1.0-hr unit hydrograph, the established 0.5-hr time to peak value 't_p' plays an important role.

The methodology applied to generate this is given in steps below.

1. Obtaion 't_p' due to 'Q_p'.
2. To ease the lagging common time intervals Δt should be selected. Here depending on the value of 'tp' the Δt is selected as a multiple of 'tp', i.e.

finding a common denominator of 0.5 hr and ‘tp’ value. In this study the simplest one which is in fact taking $\Delta t = 0.1$ hr is selected.

3. For each 0.1 hr interval, by linear interpolation, the corresponding Q values are calculated. By this way a common time intervals are determined.
4. Once Δt-Q values are obtained they are tabulated appropriately.
5. Lagging 0.5 hr of this table and summing their row values once, (having common time interval Δt) twice of UH_1 is obtained.

   1 $UH_{0.5}$ + 0.5 hr lag 1 $UH_{0.5}$ = $2UH_1$
6. Getting the half of this summed data UH_1 is generated.

$$\frac{2UH_1}{2} = UH_1$$

3.1.3 Sample Calculation of Mockus 1-hr Unit Hydrograph using Lagging Method

As a sample calculation Davar (# 41) watershed is selected and the final result based on lagging method is tabulated in Table 3.1. From this calculation for the studied watershed the three important hydrograph parameters are:

$$Q_p = 1.24 \ m^3/s/mm$$

$$t_p = 1.2 \ hr$$

$$t_b = 2.5 \ hr$$

Table 3.1: Obtaining 1-hr Unit Hydrograph using 0.5- hr Unit Hydrograph by Applying Lagging Method

Davar Watershed (# 41)					
t (hr)	Q (m^3/s/mm)		$2UH_1$	UH_1	
0	0		0	0	
0.1	0.2138		0.2138	0.1069	
0.2	0.4276		0.4276	0.2138	
0.3	0.6413		0.6413	0.3207	
0.4	0.8551		0.8551	0.4276	
0.5	1.0689	0	1.0689	0.5344	
0.6	1.2827	0.2138	1.4965	0.7482	
0.7	1.4965	0.4276	1.9240	0.9620	
0.8	1.4837	0.6413	2.1250	1.0625	
0.9	1.3600	0.8551	2.2152	1.1076	
1.0	1.2364	1.0689	2.3053	1.1526	
1.1	1.1128	1.2827	2.3954	1.1977	
1.2	0.9891	1.4965	2.4856	1.2428	Peak
1.3	0.8655	1.4837	2.3492	1.1746	
1.4	0.7418	1.3600	2.1019	1.0509	
1.5	0.6182	1.2364	1.8546	0.9273	
1.6	0.4946	1.1128	1.6073	0.8037	
1.7	0.3709	0.9891	1.3600	0.6800	
1.8	0.2473	0.8655	1.1128	0.5564	
1.9	0.1236	0.7418	0.8655	0.4327	
2.0	0	0.6182	0.6182	0.3091	
2.1		0.4946	0.4946	0.2473	
2.2		0.3709	0.3709	0.1855	
2.3		0.2473	0.2473	0.1236	
2.4		0.1236	0.1236	0.0618	
2.5		0	0.0000	0.0000	

3.2 Selection of Morphometric Parameters

Based on 254 topographic maps of 1/5000 scale, 139 (observation) catchments within Hydrological Regions 4 and 5 of Cyprus were manually delineated. For each basin, a total of 76 basic and derived dimensional and non-dimensional morphometric parameters (variables) based on, hierarchical, linear, areal and relief aspects were obtained manually. Since, different stream orders exists some of the parameters became undefined. Hence, to have a consistency within correlation calculations, 55 dimensional and non-dimensional parameters from 76 parameters were selected and used in this study.

The eliminated dimensional and non-dimensional parameters are.

1) Stream Order ‘Ω’
2) Total number of more than 1st Order Stream ‘$N_u > N_1$’
3) Total length of more than 1st Order Stream ‘$L_u > L_1$’
4) Basin Minimum Elevation ‘h_o’
5) Minimum Topographic Stream Elevation ‘h_S’
6) Bifurcation Ratio of any Order u:u+1 ‘$R_{b\ u:u+1}$ ’
7) Mean Length of any Order Stream ‘$\bar{L}_u$’
8) Drainage Texture Ratio of any Order u ‘$T_{r\text{-}u}$’
9) Mean Stream Length Ratio of any Order u+1:u ‘$R_{L\ u+1:u}$ ’
10) Stream Segment Density of any Order u ‘$D_{S(u)}$’

Use a total of 58 selected (55 morphometric and 3 hydrologic) dimensional and non-dimensional parameters (variables) of 139 basins (population; observation) used in the correlation study were having a wide range of extreme values as detailed in Table 3.2. So, they were also non-dimensionally standardized using the simple standardization approach for the correlation calculations.

Table 3.2: Ranges of 55 Morphometric (basic (10) and derived (45)), and 3 Hydrologic Parameters Used in This Study

Basic Morphometric Parameters			
No.	Name with Symbol	Unit	Range
1	Stream Order 'Ω'	-	1 - 5
	a) Total Number of 1st Order Stream 'N_1'	-	1 - 215
	b) Total Number of All Order Streams 'N_T'	-	1 - 342
2	Basin Length 'L_b'	km	1.09 - 16.64
3	Basin Perimeter 'P'	km	3.55 – 31.63
4	Length to the Basin Center of Area 'L_{ca}'	km	0.61 - 10.62
5	Length of Main Channel 'L_{ch}'	km	16.53-0.61
6	a) Length of 1st Order Stream 'L_1'	km	0.3 - 30.12
	b) Length of All Order Streams 'L_T'	km	0.61 - 65.67
7	Basin Area 'A'	km^2	0.37 - 47.75
8	Basin Maximum Elevation 'H_{max}'	m	75 - 970.5
9	Basin Minimum Elevation 'h_o'	m	0
10	Topographic Stream Elevation:		
	a) Maximum 'H_S'	m	78.7 – 1023
	b) Minimum'h_S'	m	0

Derived Morphometric Parameters			
No.	Name with Symbol	Unit	Value
1	Mean Bifurcation Ratio 'R_{b-av}'	-	0 - 12
2	Basin Width 'B'	km	0.22 - 2.87
3	Basin Relative Perimeter 'P_r'	km	0.09 - 1.51
4	Basin Radius based on Area 'r_{area}'	km	0.34 - 3.89
5	Basin Radius based on Perimeter 'r_{peri}''	km	0.57 - 5.04
6	Diameter of the Circle based on Basin Area 'D_{area}'	km	1.85 – 9.74
7	Diameter of the Circle based on Basin Perimeter 'D_{peri}'	km	1.13 – 10.07
8	Perimeter of the Circle based on Basin Area 'P_{area}'	km	3.71 – 19.47
9	Equivalent Length 'L'	km	0.89 - 7.91
10	Mean Length of All Order Streams '$\bar{L}_{total}$'	km	0.13 - 9.20
11	Stream Length Density 'L_d'	km	0.03 - 9.93
12	Potter's Factor 'F_{POTTER}'	km	0.21 - 16.53
13	Drainage Density 'D_d'	km^{-1}	0.22 - 9.59
14	Drainage Texture Ratio 'T_r'	km^{-1}	0.04 - 18.39
	a) Drainage Texture Ratio Order 1 'T_{r-1}'	km^{-1}	0.04 - 11.56
15	Drainage Intensity 'D_i'	km^{-1}	0.11 - 7.68
16	Fineness Ratio 'F'	-	0.14 – 3.00
17	Fitness Ratio 'F_R'	-	0.15 – 0.59
18	Wandering Ratio 'W_R'	-	0.34 - 1.25
19	Overall Mean Stream Length Ratio '$\bar{R}_L$'	-	0 - 4.99
20	Horton's term 'RHO'	-	0 - 1.99
21	Horton's Form Factor 'F_f'	-	0.06 - 0.89
22	Apollov's Form Factor 'RF'	-	0.24 - 1.14
23	Circularity Ratio 'R_c'	-	0.19 - 0.89
24	Elongation Ratio 'R_e'	-	0.89 - 3.35
26	Schumm Coefficient 'C_{Sch}'	-	0.93 - 4.87
27	Compactness Coefficient 'C_c'	-	1.06 – 2.30
28	Stream Density 'D_S'	km^{-2}	0.06 - 51.63
29	Infiltration Number 'If'	km^{-3}	0.03 - 495.26
30	Basin Relief 'R'	m	78.7 – 1023.0

Derived Morphometric Parameters Cont'd			
No.	Name with Symbol	Unit	Value
31	Mean Basin Relief 'R_{mean}'	m	39.35 - 511.50
32	Mean Basin Height 'H_{mean}'	m	39.35 - 511.50
33	Stream Relief 'ΔR_{stream}'	m	78.7 – 1023.0
34	Dissection Index 'I_{Dis}'matrix ekle	m^{-1}	0.03 – 0.28
35	Relief Ratio 'R_r'	-	9.42 - 255.65
36	Relative Relief 'R_p'	-	4.15 - 94.21
37	Ruggedness Number 'R_u'	-	33.61 - 3850.1
38	Melton's Ruggedness Number 'MR_u'	-	19.69 - 540.92
39	Mean Slope of Water Divide 'I_p'	-	8.29 - 188.42
40	Basin Slope Angle 'θ'	°	1.46 – 1.56
41	Main Channel Gross Slope 'S'	-	0.008 – 0.265
42	Average Slope of Main Stream based on:		
	a) Arithmetic 'S_{av-ari}'	%	0.53 - 11.82
	b) Harmonic 'S_{av-har}'	%	0.43 12.65
Important Hydrologic Parameters			
No.	Name with Symbol	Unit	Value
1	Peak discharge 'Q_p'	m^3/s/mm	0.12 – 3.78
2	Time to peak 't_p'	hr	0.80 – 2.90
3	Base time 't_b'	hr	1.50 – 7.00

3.3 Principal Component Analysis

For the study of statistical correlation relationship using eViews package, by applying Principal Component Analysis (PCA), based on 58 (55 + 3) non-dimensionalized standardized parameters (variables), a 58 X 58 square matrix was established and the correlation coefficient values were generated. From the result of this component matrix, it was observed that, a total of 15 non-dimensional standardized parameters were having a correlation coefficient exactly equal to 1.00 that were implying reputation (redundancy) of parameters in 5 different variable sets.

Table 3.3 below, details the redundant parameter sets and the selected representative parameter for each set among those redundant parameters (Jolliffe, 1986).

Table 3.3: The Redundant Parameter Sets and the Selected Representative Parameter for Each Set

Set Number	**Parameters**	
	Redundunt	**Selected Representative**
1	P, r_{peri}, L	r_{peri}
2	R_P, I_P	R_P
3	R, R_{mean}, H_{mean}, H_S, Δr_{stream}	R
4	RF, Rc	RF
5	C_{SCH}, D_{area}, D_{peri}, P_{area}	C_{SCH}

Hence, 47 (44 + 3) non-dimensionally standardized parameters (variables) were used and 47 X 47 inter-correlation coefficient matrix was established based on eViews principal component analysis and given in Table 3.3.

Table 3.4 The Established Inter-correlation Coefficient 47 X 47 Matrix Values Based on eViews Principal Component Analysis

3.4 Determination of Prioritization Coefficient Values

In order to apply the prioritization to the generated 139 basins (observations; number of population), based on 47 effective standardized non-dimensional parameters, a kind of coefficient of weightages were generated for each parameter. The below given steps were detailing this procedure.

Step 1: Obtain the absolute value of the standardized non-dimensional linear inter-correlation coefficient for each parameter 'π_{ij}', that was determined in the correlation studies of principal component analysis after the elimination of the redundant ones, i.e. ABS(π_{ij}), as detailed in Table 3.4.

Step 2: Sum, the absolute values of the standardized non-dimensional linear inter-correlation coefficient that was obtained in Step 1 for each column 'j' separately, so as to obtain the cumulative absolute value of each parameter along column 'j'; $\sum_{i=1}^{n=47} \mathrm{ABS}(\pi_{ij})$, as detailed in Table 3.4.

Step 3: To obtain the grand total 'GT', the cumulative absolute value of each parameter along column 'j' obtained in Step 2 were added; $\mathrm{GT} = \sum_{j=1}^{47} \sum_{i=1}^{47} \mathrm{ABS}(\pi_{ij})$ as detailed Table 3.4.

Step 4: In order to determine the coefficient of weightage 'W_j' of each parameter separately, the previously calculated cumulative absolute value of each parameter found in Step 2 was divided by the grand total 'GT' value calculated in Step 3; $W_j = \frac{\sum_{i=1}^{n=47} \mathrm{ABS}(\pi_{ij})}{\sum_{j=1}^{47} \sum_{i=1}^{47} \mathrm{ABS}(\pi_{ij})}$ as detailed in Table 3.4.

Step 5: This calculated weightage ‘W_j’ of each parameter was then multiplied by the relevant selected 47 non-dimensional parameter ‘π_{ij}’, respectively and added for each basin, i.e. 139 separately. So a simple priority equation where each weighted parameter was added linearly was established. Hence, the summation value obtained from this equation is the Weighted Sum Analysis ‘WSA’ value of each basin; $WSA = \sum_{j=1}^{47} \pi_{ij}.W_j$

Step 6: Ranking the results of the WSA in descending order for 139 basins, the prioritization mainly based on morphometric importance was determined.

Table 3.5 The Prioritization Weightage Details of the Studied Basins

Chapter 4

RESULTS

Based on the regions and watersheds area classification map of Cyprus, the studied regions are 4th and 5th [Water Resources Division (1970)]. A total of 254 topographic map with 1/5000 scale was used and 139 basins were delineated.

1- Based on Horton Stream Ordering Level of classification, the obtained basins are grouped and tabulated in Table 4.1.

Table 4.1: Number of Basins Falling in Each Group Based on Horton Stream Ordering Level Classification.

Horton Stream Order Level	**Number of Basins**
1	7
2	35
3	45
4	44
5	8

2- In Appendix II, for each basin.

a) the plan view (shape),

b) 76 morphologic (basic and derived) dimensional and non-dimensional parameters were determined and tabulated,

c) 1 hr. Mockus Unit Hydrograph was generated and presented, 3- The matrix of 58 X 58 that is established based on hydrologic and morphometric parameters (obtained by linear, areal and relief approaches) is given in Table 4.2. This matrix is presenting the calculated linear inter-correlation coefficient values based on Principal Component Analysis applying the eViews statistical package. As it is observed, in this Table.

   i) there are some negative ($-^{ve}$) values, implying inverse correlation among the parameters,

   ii) having 15 non-dimensionalized parameters with a coefficient value of exactly equal to 1.00, implying redundancy.

4- The reduced matrix of 47 X 47 that is given in Table 4.3 in fact, is detailing the most effective inter-correlated parameters (considering only at least the strong correlations due Pearson 'r' > absolute 0.80 ($r > |0.80|$), based on Principal Component Analysis), through the assigned ranking numbers. These assigned ranking numbers are implying the descending order of importance among the parameters, i.e. the rank number 1 is implying the highest importance.

5- From the reduced matrix of 47 X 47 that is given in Table 4.3, it was also observed that, the Basin Radius based on Perimeter 'r_{peri}' having strong linear correlation with 12 parameters. On the other hand, the Mean Bifurcation Ratio 'R_{b-av}' and the Wandering Ratio 'W_R' were not presenting strong linear correlation with any parameter.

6- For the peak discharge 'Q_{peak}' obtained based on 1 hr. Mockus synthetic hydrograph, 10 parameters were having strong linear inter-correlation. These parameters are detailed in the order of importance as:

Table 4.2

Table 4.3

i. Basin Radius based on Area 'r_{area}'

ii. Basin Relative Perimeter 'Pr',

iii. Basin Width 'B',

iv. Basin Area 'A',

v. Basin Length 'L_b'

vi. Length of the main flow path (channel) 'L_{ch}'

vii. Total Length of All Stream Channel Orders 'L_T'

viii. Length to the Center of Area 'L_{ca}'

ix. Base time 't_b'

7- To generate the synthetic unit hydrograph by Mockus method, although the length of the main channel 'L_{ch}', the harmonic average based slope of the main channel 'S_{av-har}', and basin area 'A' were used and 3 important hydrograph parameters (Q_p, t_p, and t_b) were calculated, but interestingly in this Principal Component Analysis study 'S_{av-har}' parameter was not showing any strong linear inter-correlation with 'Q_p', 't_p', and 't_b'.

8- The existing 139 basins based on 47 effective dimensional and non-dimensional hydrologic (hydrograph) and morphometric parameters coefficient of weightages were used and the prioritization for the sustainable development of the existing water resources was generated and detailed in the order of descending importance as detailed in Table 4.4.

Table 4.4: The Prioritization Order of the Studied Basins.

Priority		Basin		Priority		Basin	
Order	Value	No.	Name	Order	Value	No.	Name
1	0.561	36	Alakadın	43	0.338	75	Temeller
2	0.561	137	Karamağra	44	0.337	16	Boz
3	0.493	139	Yayvan	45	0.337	95	Beyaztaş
4	0.486	34	Kapbar	46	0.334	73	Güroluk
5	0.470	64	Zeytinli	47	0.334	13	Başeğmez
6	0.463	70	Çamlı	48	0.331	74	Ocaklar
7	0.448	59	Sarmısaklı	49	0.331	28	Zeytin
8	0.434	27	Büyükdepo	50	0.330	2	Ambar
9	0.428	138	Yılan	51	0.330	26	Evlek
10	0.426	129	Yassıtarla	52	0.329	76	Hamsi
11	0.423	41	Davar	53	0.329	47	Umarlar
12	0.420	30	Dolunay	54	0.327	99	Kamışlı
13	0.414	72	Baltalık	55	0.327	57	Kötü
14	0.414	42	Delikayası	56	0.321	78	Kargasekmez
15	0.409	38	Dumlu	57	0.319	61	Mandıra
16	0.409	32	Bostan	58	0.319	58	Kanlı
17	0.390	67	Evler	59	0.317	56	Oluk
18	0.384	10	Kemerli	60	0.312	54	Kuruhendek
19	0.383	44	Kamelya	61	0.312	29	Doğu Uzun
20	0.382	60	Çatal	62	0.312	35	Hacı
21	0.379	24	Cehennem	63	0.308	7	Batıuzun
22	0.378	23	Boğaz	64	0.308	82	Doğu Derin
23	0.372	53	Anasu	65	0.307	117	Kanlıca
24	0.371	71	Köy	66	0.307	3	Batıderin
25	0.367	45	Kekikli	67	0.303	126	Akseki
26	0.364	9	Beykaya	68	0.302	6	Kumlukaya
27	0.361	14	Gölgeli	69	0.301	80	Taşlıca
28	0.359	65	Karanlık	70	0.301	52	Çalılı
29	0.358	63	Yalı	71	0.299	18	Acısu
30	0.358	21	Kurupınar	72	0.299	46	Kınalı
31	0.357	12	Kocagölet	73	0.299	62	Göl
32	0.357	25	Elma	74	0.298	55	Yağlı
33	0.356	49	Seranlı	75	0.297	81	Şalvarlı
34	0.353	128	Çukur	76	0.297	31	Daryeri
35	0.349	48	Manastır	77	0.296	11	Derin
36	0.349	135	Eskideğirmen	78	0.296	39	Gölekler
37	0.347	5	Darboğaz	79	0.295	79	Sarp
38	0.344	69	Parçalı	80	0.295	122	Sarma Tepe
39	0.343	127	Mollabucağı	81	0.294	50	Köprülü
40	0.341	22	Köprü	82	0.294	125	Akyokuş
41	0.341	20	Bükümlü	83	0.292	77	Darı
42	0.339	96	Yılanlı	84	0.291	121	Esencik

Table 4.4: The Prioritization Order of the Studied Basins (con'd).

Priority		Basin	
Order	Value	No.	Name
85	0.291	88	Çayır
86	0.290	132	Büyük
87	0.289	40	Eskikuyu
88	0.283	84	Kurtulan
89	0.283	104	Dikilikaya
90	0.283	113	Derin2
91	0.281	114	Kargalı
92	0.280	51	Koçak
93	0.277	120	Zeytinli Vadi
94	0.276	4	Döküktaş
95	0.276	87	Derebaşı
96	0.275	112	Kara
97	0.274	115	Çamlıbel
98	0.272	83	Kayabaşı
99	0.270	93	Bostan
100	0.270	116	Kuru
101	0.268	97	Derin1
102	0.267	94	Enginar
103	0.263	91	Koca
104	0.261	8	Ahmetler
105	0.260	66	Ağıllar
106	0.259	131	Derin3
107	0.257	19	Sekili
108	0.254	123	Çıralı
109	0.254	1	Dereağzı
110	0.254	119	Karanlık
111	0.251	89	Oluk
112	0.249	92	Seyis
113	0.247	103	Uluçam
114	0.246	17	Anıt
115	0.245	124	Sıla
116	0.245	90	Değirmen
117	0.245	43	Kamışlı
118	0.242	86	İncirli
119	0.242	107	Çağlar
120	0.242	68	Güneşli
121	0.241	134	Dikenli
122	0.239	105	Tekağaç
123	0.238	106	Alkaya
124	0.237	108	Pınar
125	0.236	130	Kereviz
126	0.230	33	Gemikonağı
127	0.229	85	Pınarlar
128	0.229	110	Bican
129	0.226	109	Çakmak
130	0.226	118	Sulu
131	0.224	133	Köprü
132	0.214	111	Çalılı
133	0.213	15	Peçeli
134	0.212	37	Yayla
135	0.211	101	Karaağaç
136	0.209	102	Aygören
137	0.208	98	Beyaz Gölek
138	0.190	100	Çukurlar
139	0.186	136	Kuru2

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Based on the regions and watersheds area classification map of Cyprus, 4^{th} and 5^{th} regions were only studied in this thesis. Among these studied regions, 139 basins with 5 different stream order groups, 79 morphometric and 3 hydrograph parameters were statistically studied as a single dataset, so as to investigate their linear inter-correlation levels by apply linear correlation matrix using the eViews package through Principal Component Analysis approach.

Due to the inconsistency of data sizes in some of the parameters, enforces the elimination of those parameters from this statistical study so as to have uniformity among the parameters from the size of data aspect.

Pearson 'r' correlation greater than absolute 0.80 value ($r > |0.80|$) was selected to determine strong linear inter-correlation among the parameters that were ranked in descending order. Table 5 is detailing the total number of morphometric and hydrologic parameters having strong linear inter-correlation with each parameter.

Table 5: Total Number of Morphometric and Hydrologic Parameters that are having Strong Linear Inter-correlation with Other Parameters.

r_{peri}	12	L_d	3
A	11	L_{total}	3
L_b	11	$\bar{L}_{total}$	3
L_{ch}	11	MR_u	3
L_{ca}	10	S_{av}	3
Q_p	10	S_{har}	3
r_{area}	10	D_d	2
t_p	10	If	2
L_T	9	R	2
t_b	9	RF	2
T_{POTTER}	9	Rp	2
P_r	8	C_C	1
F	6	CS_{ch}	1
N_1	6	D_i	1
N_T	5	F_f	1
R_r	5	F_R	1
B	4	H_{max}	1
L_1	4	R_e	1
S	4	RHO	1
SO	4	R_L	1
T_{r-1}	4	R_u	1
T_r	4	R_{b-av}	0
θ	3	W_R	0
D_S	3		

5.2 Recommendations for Future Studies

Among 4th and 5th regions of the regions and watersheds area classification map of Cyprus, a total of 139 basins with 5 stream order groups were determined. Some of the ordered groups were having small observation size that bans the use of separate statistical correlations based on stream ordering. Hence, the other regions like 6th and 7th can be as well studied separately at least in a similar way, since they were mainly situated within the boundaries of T.R.N.C. and then the obtained parameter value set can be amended to the row data set of this study for further statistical studies. By this way, it is expected that, the data sizes will increase and not only the eliminated parameters due to small sizes will have a possibility to be considered for linear inter-correlation studies but even can be studied under separate stream ordering groups so as to have more detailed results.

Since among the parameters linear inter-correlations was statistically studied, it will be an interesting further study to investigate the non-linear inter-correlation of these parameters with appropriate statistical approaches.

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