HYDROLOGICAL REGIONALISATION OF MULTIANNUAL MEAN DISCHARGE USING GIS TIMIS-BEGA RIVER BASIN APPLICATION

Bogdan Aurel Cheveresan[1], Simona Radu[2], V. Al. Stanescu[3]

[1]S.C. Geosystems Romania, Bucharest, Romania, e-mail: bcheveresan@geosystems.ro
[2]National Institute of Hydrology and Water Management, Bucharest, Romania, e-mail: simona.radu@hidro.ro
[3]National Institute of Hydrology and Water Management, Bucharest, Romania, e-mail: stanescu@hidro.ro

Abstract: Regionalisation technique is used to transfer the point hydrologic information, determined on direct computation in points in which these data are missing. This paper presents one method of geo-referencing of altitude in a raster format based on digital elevation model (DEM) determined by TIN method. The export from TIN model into an integer ArcInfo GRID can be made in ArcMap, by a supplementary operation.

The application was made for Timis-Bega river basin. For each cell of GRID exists in the attribute table information regarding altitude, which was correlated with the specific mean discharge.

In the last part is presented the map of multiannual mean discharge in basin, using DEM and the regionalisation relationship. Is made also a comparison between measured and calculated discharge.
Key words: GIS, DEM, ArcInfo GRID, Specific mean discharge

Zusammenfassung: Die regionalisierungs Methode wird dazu benutzt die punktliche hydrologische Information zu űbermitteln, die durch direkte Berechnung in den Punkten in dennen diese Daten fehlen, festgestellt werden.
Diese Arbeit stellt eine Methode, fur die Űbermittlung der Hőhe in einem Bild bestehend aus Zellen. Dabei wird der sogennante “Digital elevation model (DEM)” benutzt, festgestellt durch die TIN – Methode.
Die Datenumwandlung vom TIN Model in das ArcInfo GRID kann man in der ArcMap Software, durch eine extra Operation machen.

Diese Software wurde fur das Timis-Bega hydrologische Basin entwickelt. Fur jede Zelle des GRID, gibt es Informationen in der Attribut Tabelle uber die Hőhe, die im zusammenhang mit dem spezifischen mittleren Ausfluss steht.

Im letzten Teil wird die Karte des Jährlichen spezifichen mittleren Ausflusses vorgestellt, durch die Benutzung von DEM und des regionalisierungs Verhaltnises. Es wird auch ein Verglich zwischen das gemässte und das berechnete Wert des Ausflusses gemacht.
Schlüsselworte: GIS, DEM, ArcInfo GRID, Specific mean discharge

1. GIS features

In order to obtain a digital elevation model (DEM) for a hydrological river basin we must use the contour lines and elevation points extracted from maps and other sources like GPS. We also must use the limit of the basin, to constrain the building area for the model.

Using elevation information extracted from topographic maps (elevation contours and spots) a digital elevation model (DEM) was generated in TIN (Triangulated Irregular Network) format for Timis-Bega basin. (Figure 1)

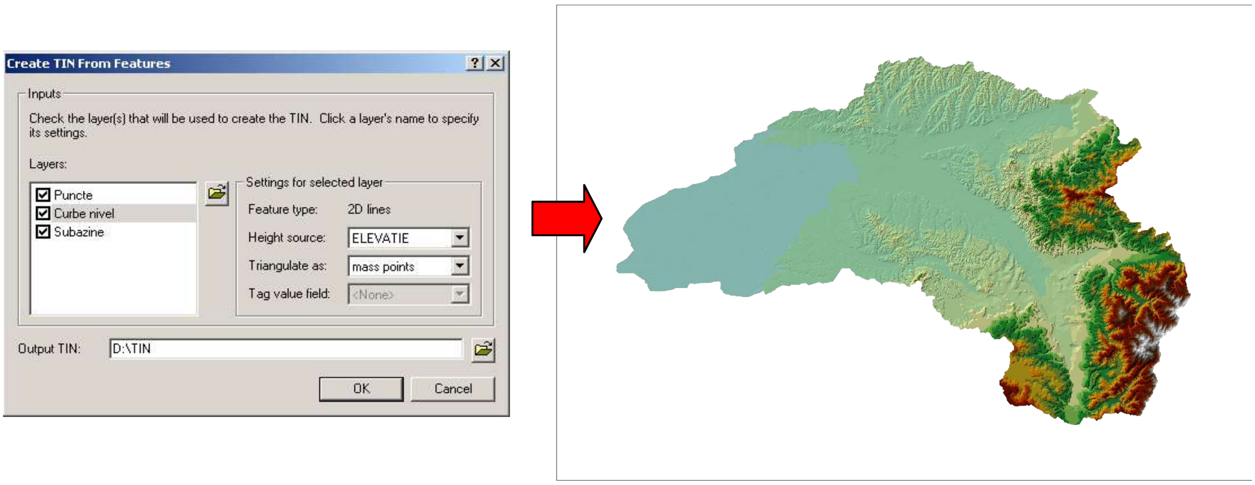

Figure.1 – Digital elevation model of Timis-Bega basin using TIN method

Once we obtained the DEM for the Timis-Bega basin, we must export it from TIN format into integer elevation ArcInfo GRID.

Taking into account the correlation between the specific discharge and the mean elevation, the Timis-Bega basin was divided into five sub-basins (Figure 2). In GIS these sub-basins are polygon entities and their attribute table contains an ID column.

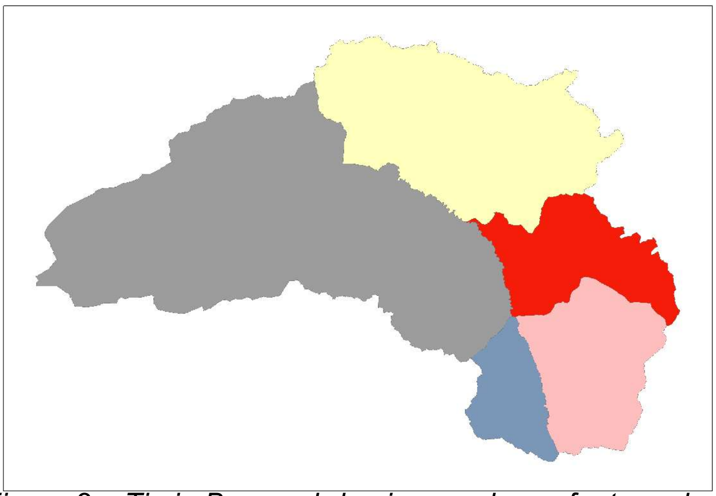

Figure 2 – Timis-Bega sub-basins – polygon feature class

These features will be also exported into ArcInfo GRID format.

Raster datasets use rows and columns of equally spaced cells to model reality. There is a trade-off between file size and how closely you want to model reality. The smaller the cell size, the more detail can be captured. Larger cells do not require as much disk space for storage but also will not capture as much detail.

ArcGIS uses an ESRI raster format called a ArcInfo GRID. Grids may use a collection mechanism called a grid stack, which is used for certain types of analysis.

Some types of grids may have a default attribute table called the value attribute table (VAT). Grids may also store information about the surface, with each cell containing a Z value. The Z value of each cell is calculated as arithmetical average of each altitude from that cell.

2. Grids type

2.1. TIN to ArcInfo GRID

Exporting a digital elevation model TIN, into a integer grid format, each cell of the grid will store the information regarding elevation. More than that, we could have access to the grid attribute table.

There are two ways to export the DEM TIN:

- Directly in ArcToolbox (Figure 3) (operation conditioned by the existence of a server operating system on your computer Windows NT4 or Windows 2000 server family).

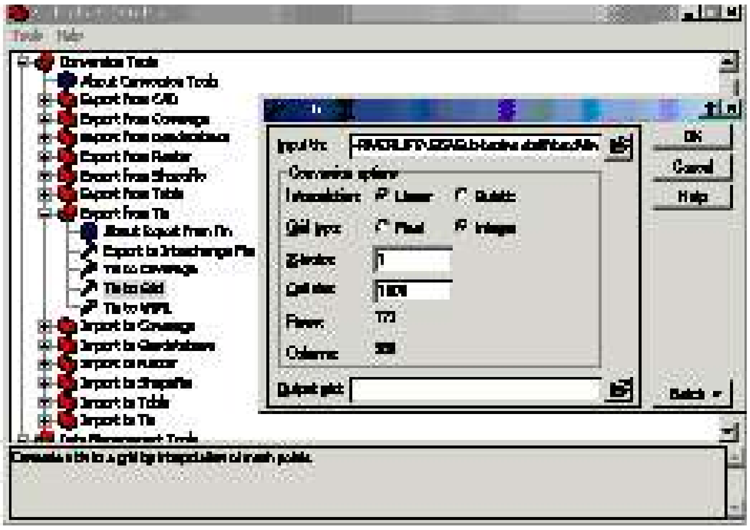

Figure. 3 – Exporting TIN into ArcInfo GRID in ArcToolbox

- In ArcMap application using 3D Analyst and Spatial Analyst extensions. In this case a supplementary operation is required (Figure 4). Using the 3D Analyst extension to export TIN to grid we will obtain a float grid. In this case we can't open the attribute table, we can only see the value of the cells using the identify button.

Figure. 4 – Transforming GRID from float into integer one

The supplementary operation that can let us transform grid format from float into an integer one is in Raster Calculator function (under Spatial Analyst extension).

As result we will obtain an integer grid, and each cell will store the elevation value (Figure 5). The name for this grid will be Timis_1000.

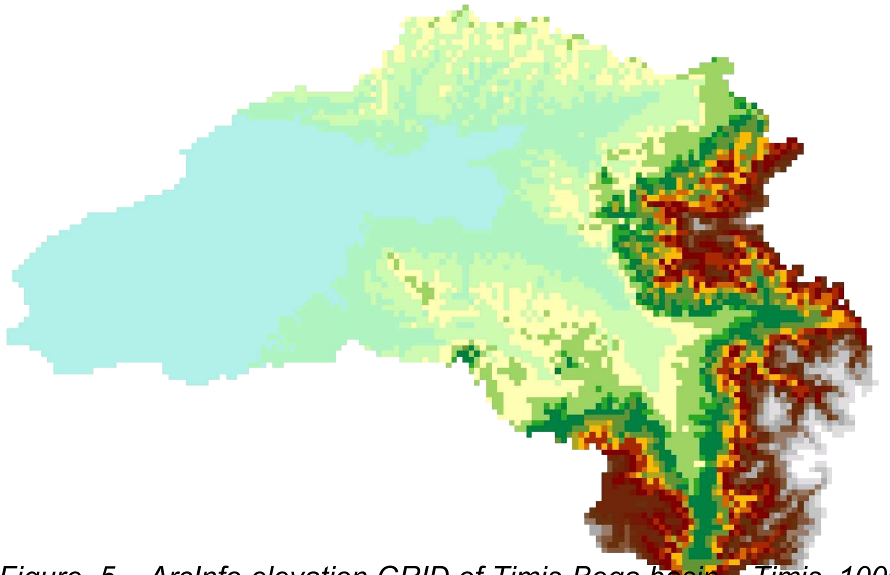

Figure. 5 – ArcInfo elevation GRID of Timis-Bega basin – Timis_1000

2.2. Sub-basin feature class into ArcInfo GRID

Exporting a polygon feature class into an ArcInfo GRID yields to a raster format which will maintain the information regarding the feature ID in the attribute table. The new grid will be named sub_basin.

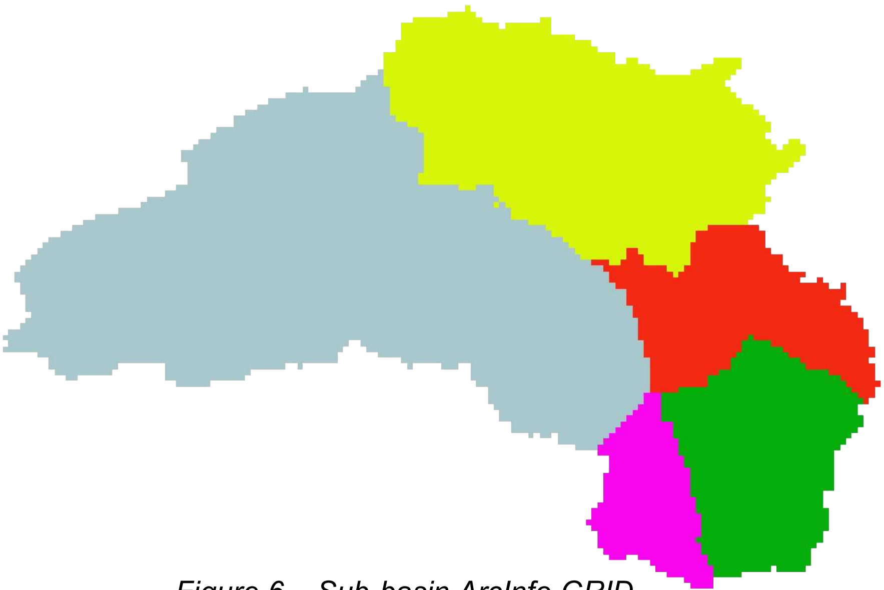

Figure 6 – Sub-basin ArcInfo GRID

Both ArcInfo GRID (Timis_1000 – elevation ArcInfo GRID and Sub-basin ArcInfo GRID) must have the same cell size, in our case one square kilometre.

3. Grids attribute table

The two grids attribute tables will have two column: Object ID and Value. Value represents:

- elevation for ArcInfo elevation GRID – Timis_1000
- ID number for Sub-basin ArcInfo GRID – Sub_basin

Using Spatial Analyst extension (Raster Calculator) we perform the union of these two GRIDs into one GRID named union_grids (Equation 1). The attribute table of the resulted GRID will contain values of both initial GRIDs (Figure 7).

union_grids = [Timis_1000] CAND [Sub_basin] - (Raster Calculator) (1)

Attributes of union_grids

ObjectID	Value	Count	Timis_1000	Sub_basin
583	584	1	790	3
584	585	3	161	5
585	586	1	379	4
586	587	1	439	3
587	588	1	486	3
588	589	1	422	4
589	590	1	561	4
590	591	1	662	4
591	592	1	916	3
592	593	1	851	3
593	594	1	768	3
594	595	1	915	3
595	596	3	739	3

Figure 7 – Resulted GRID attribute table

The union_grids attribute table will be exported in dbase format, and added in ArcMap Table of Contents.

In this table a new column will be added and the equation of multiannual mean discharge for every sub-basin will be applied by selecting every sub-basin cells with the same ID (Calculate Values).

The next step will be to apply *Join/Release* function to join tables (union_grid table and exported table with new values calculated) based on Value field.

The result will be one grid with an attribute table that store his attribute table and the exported table with the calculated values for the multiannual mean discharge (Figure 8). This ArcInfo GRID could be symbolized by these calculated values.

Attributes of union_grids

Value	Count	Timis_1000	Sub_basins	Mean_discharge.OID	Mean_discharge.ObjectID	Mean_discharge.Value	Mean_discharge.Q_med
937	1	423	3	936	936	937	8.25
938	50	400	1	937	937	938	7.77
939	1	529	3	938	938	939	10.43
940	1	707	3	939	939	940	13.99
941	1	627	3	940	940	941	12.41
942	2	744	3	941	941	942	14.72
943	2	980	3	942	942	943	19.22
944	1	979	3	943	943	944	19.2
945	1	1019	3	944	944	945	19.94
946	1	1062	3	945	945	946	20.73
947	1	865	3	946	946	947	17.05
948	2	276	5	947	947	948	4.83
949	2	245	5	948	948	949	4.12
950	4	231	5	949	949	950	3.8
951	4	234	5	950	950	951	3.87
952	1	190	3	951	951	952	3.29
953	1	197	3	952	952	953	3.44
954	1	225	3	953	953	954	4.05
955	1	292	3	954	954	955	5.49
956	1	359	3	955	955	956	6.91
957	1	565	3	956	956	957	11.16
958	24	600	1	957	957	958	11.87
959	1	490	1	958	958	959	9.63
960	2	419	1	959	959	960	8.16

Record: 1 Show: All Selected Records (0 out of 1842 Selected.) Options

Figure 8 – Multiannual mean discharge attribute table

The correctness of the evaluation of this characteristic based on the altitude is assured by a gradual variation of the elevations around the entire basin. Even the areas of the sub-basins decrease gradually as the altitude increases, fact that makes the spatial variation of the runoff would be linked to some extent to the altitude.

These observations concerning the diversity of the liaisons between the morph metrical elements of the catchments explains the fact that the the relationships between the altitude and the mean annual specific discharge might be seen either on the steps of relief or as relations with „zoning" character where the variations with the mean altitude of the basin are continuous but different from one zone to another one.(Diaconu şi Şerban, 1994). How large are these zones and to what extension of the scale should they been considered constitutes the problem of the „Hydrological regionalisation" which is further on discussed. (Stănescu şi Oancea, 1994).

4. Hydrological regionalisation of the mean runoff

While selecting the factors which have the greatest influence on the spatial distribution of the hydrological synthetic characteristics (mean, maximum, minimum runoff) the direct causative factors (the meteorological ones-precipitation and evapotranspiration -) as well as the indirect factors (the morphometric ones) are considered.

Further on an analysis of the degree of influencing of these factors (direct and indirect ones) on the spatial distribution of the hydrological element is made. One way is to make a regression analysis and to keep those factors which have significant coefficients in the resulting linear regression equation. (Stănescu şi Oancea, 1994.

This technique of regionalisation based on the regression equation assumes that the geographical location is the single determinant of the water quantities which are produced in the basin. This hypothesis seems to be reasonable at a large scale, where the factors which influence the runoff formation vary monotonically in space.

The more pronounced the discontinuity the smaller scales are necessary to select. This fact shows that the sub basins or regions which are similar from physiographical points of view should be grouped in order to form zones for which the relationships between the hydrological parameters and the basin characteristics are preserved the same. Often the grouping of the sub-basins on the basis of their contiguousness is not sufficiently substantiated so that this criterion would guarantee the physical and hence the hydrological similarity.

In spite of the advantages of the hydrological regionalisation based on the relationships of the hydrological synthetic elements with the morphological parameters of the basin the discontinuities will continue to exist. In other words, "Which is the true relation at the border of two zones where the relations are very different?" (because if they were not different they would have been unified). A possible solution consists in finding a fractional membership of a catchment to many zones. The weights might be selected making use of the multidimensional analysis or a multiple linear relation obtain by a linear transformation procedure (by logarithm). Nevertheless this weighting procedure means a great volume of data to establish the weighting coefficients. Or, the regionalisation tries to determine the hydrological characteristic values in points which close the ungauged basins. This is the "Regionalisation paradox" which leads to the idea of an optimisation between the quantity of available data and the requested accuracy function of the goals and the implication of the errors in engineering practice.

The mean altitude is the most important morphometric element that characterises in ensemble both the relief and the slopes of the basin and of the rivers as well as the soils, vegetation and especially the climate elements.

The steps of the relief reflected especially by the mean elevation of the basin which, integrates the overall effects many characteristics of relief determines the "punctual capacity" of each square kilometre to produce a certain runoff of a given intensity (potential).

The values of the mean multiannual discharge over the period 1950-2000 at 63 stations of Timis-Bega basin have been considered for the application. On the bases of the mean multiannual discharges Q_{mean} the mean multiannual specific discharges q_{mean} for the stations in the river basin Timis-Bega selected to apply the GIS procedure will be calculated (Equation 2).

$$q_{med} = \frac{Q_m}{F} \cdot 1000 \left[l / skm^2 \right]. \qquad (2)$$

where F is the basin area.

The correlation between the specific discharge and the mean elevation shows many branches, as follows (Figure 9, Figure 10):

- The catchment of Bega River;
- The tributaries of Timis River on the right side from Rece River to Sebes River. This area embeds the upper Bistra Marului River Basin;
- The tributaries of Bistra River on the right side the Bistra River included up to the confluence with Bistra Marului River;
- The Timis River tributaries on the left side the Timis River from the sources to Bistra River confluence included;
- The lowland tributaries of Timis River (Timisana, Surgani, Poganis, L. Birda River)

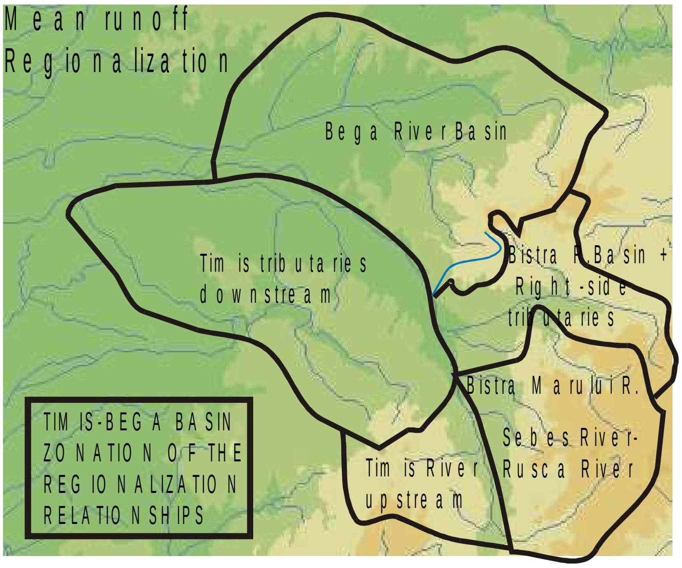

Figure 9. Zonation of the regional regression

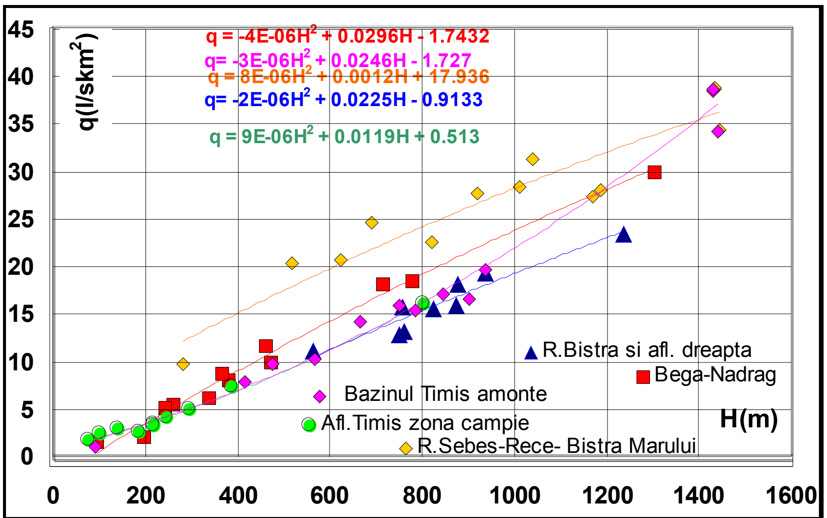

Figure 10. Regional relationships in the Timis-Bega River Basin

The deviation of the plotted points from the regression curves is small enough to allow a quite accurate regionalisation. This will be made through the GIS plan of the elevations given by the Digital Elevation Model (DEM) and further on by applying the equations of the relations which describe the correlations between the mean altitudes and the mean specific runoff.

The zones presented in the Figure 9 which are homogeneous has been assessed by a method of “clusterisation” making the grouping of the points in the field of the graph coefficient of variation – mean specific discharge (Figure 11).

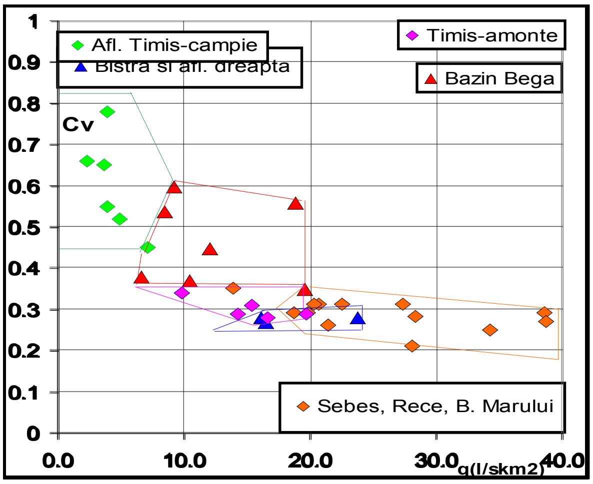

Figure 11- ”Cluster” zones

Making use of the table presented in the Figure 8 the liaison with the GRID using function ’Join/Release’ used on the bases of common columns in our case ‘Value’.

The map of the mean multiannual specific discharges ranged by classes is presented (Figure 12). The limits from the legend refer to the mean specific discharges (l/skm^2).

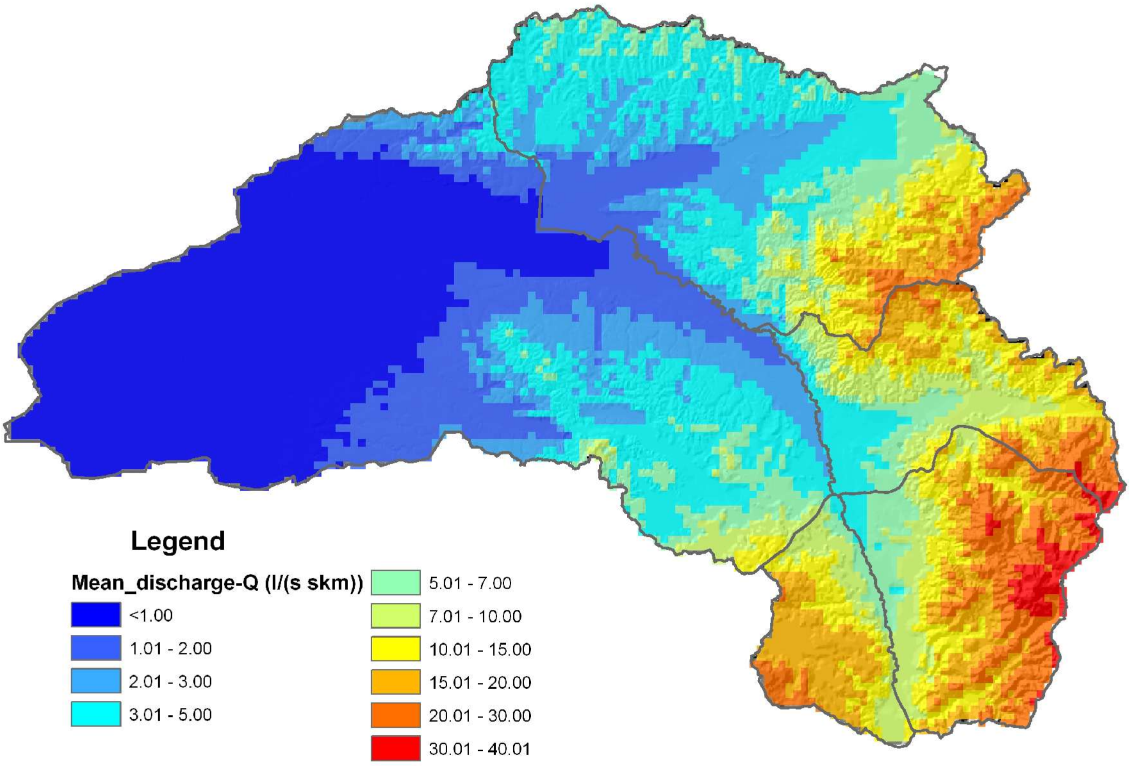

Figure. 12 – Classified symbology of multiannual mean discharge

Further, on the basis of the geo-referenciating the sub-basins corresponding to each gauging station and of the attributive data of the mean multiannual specific discharges from each pixel the mean values of the discharges have been computed. Then, the computed and the recorded estimates are found in reasonable limits of errors.

5. Conclusions

The hydrological regionalisation is a robust base for assessing the synthetic hydrological characteristics of the ungauged catchments.
The procedures of the hydrological regionalisation are inscribed in the international initiative (PUB) of International Association of Hydrological Sciences as one of the most important way of Prediction in Ungauged Basins.

The GIS procedures constitute an efficient tool for the hydrological data processing in view of obtaining the regionalisation relationships.

The application of GIS in this domain is relied on the determination of the Digital Terrain Model and to inscribe in each pixel the geographical attributes of the catchments(the morphological characteristics)

The determination of the relationships between the hydrological elements and morphological characteristics of the basin as well as of the homogeneous zones result in determining the equation valid for each pixel and thereafter to determine the digitised map of mean specific discharge.

A good accuracy is obtained, the errors not exceeding 10%.

The mode of groupings still remains a difficult problem the solution of this depending on the considered spatial scale at which the analysis is made as well as on the skill of the researcher.

6. Refrerences

Diaconu, C., Serban, P., (1994) *Hydrological Synthesis and Regionalisation* (in Romanian). Editura Tehnica, Bucharest, Romania.

Stanescu V. Al., Oancea V.(1994) *Procedures for hydrological regionalisation applied in Romania*. Proceedings of 2nd International Conference FRIEND, Braunschweig,Germany.