PRECIPITATION MODELING IN THE SLANIC HYDROGRAPHIC BASIN USING ARCMAP

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ABSTRACT: *The purpose of this paper is to explore the indispensable role of GIS in the hydrological modelling of the watersheds. The analysis of precipitation patterns of the watersheds represents one of the first focus in order to perform a drainage analysis. By integrating spatial data and advanced modelling techniques, GIS can be considered an essential tool in understanding and predicting the hydrological processes that govern precipitation distribution within watersheds. The article outlines the use of two crucial methods to delineate the watersheds: Thiessen Polygon and Inverse Distance Weighting Interpolation (IDW), in analysing precipitation patterns within watersheds. The insights gained through these approaches significantly contribute to enhanced water resource management, flood prediction and mitigation, and environmental conservation strategies.*
Keywords: *watershed delineation; hydrological modelling; digital terrain model; hydrology;*

1. Introduction

Watershed hydrological modelling plays an essential role in comprehending the complex dynamics of water movement within natural catchment areas. Among the essential factors influencing the hydrological cycle, precipitation holds paramount importance. Traditional hydrological models often fall short in capturing the spatial variability of precipitation accurately.

However, Geographic Information Systems (GIS) have emerged as an invaluable tool for integrating spatial data into hydrological modelling, providing an enhanced understanding of precipitation distribution and its implications for watersheds.

This article provides an insightful overview of GIS applications in hydrological modelling, highlighting the significance of two key methods: Thiessen Polygon and IDW Interpolation, for analysing precipitation within watersheds.

2. Case study

2.1. Location of study area

The case study has been made on Slănic Moldova watershed (Fig.1). This hydrographic basin is a region that holds significant scientific importance due to its diverse geography, and it is also home to significant watercourse structures. that have located in the. The watershed covers an area of approximately 114 km^2. The catchment is irregular in shape and the mean elevation is about 1000 m. The surrounding relief of the valley is dominated by medium altitudes which emerge from the main ridge of the Nemira Mountains.

Vegetation in the eastern branch of the Romanian Carpathians exhibits distinct characteristics resulting from the climatic and pedological conditions. The most significant influence is determined by altitude, which leads to the stratification of vegetation.

In terms of climatic conditions, the Slănic Moldova watershed stands out for its sheltered mountain depression climate, thanks to the orographic shelter provided by the mountain ridges that surround the valley. Thermal inversions are frequent in this area. The rainfall regime is correlated with the regime thermal and air circulation.

2.2. Data acquisition

In order to perform any hydrological modelling analysis, the first phase of the process involves collecting diverse datasets crucial for analysing the precipitation patterns.

Fig. 1. Aerial image of Slănic Moldova watershed

Historical rainfall data, radar-based precipitation estimates, satellite-derived precipitation records, and meteorological data constitute the primary data sources. Additionally, digital elevation models (DEM), land use/land cover data, and hydrography data are essential for accurate watershed delineation and spatial analysis.

Harnessing the capabilities of GIS, automatic watershed delineation is achieved through processing digital elevation models (DEM). This delineation process ensures spatial precision, which is fundamental for subsequent analyses. Thus, the elevation raster or digital elevation model (DEM) represents one the most important input data necessary for the analysis. The resolution of this raster dataset is approx. 25m x 25m. Shuttle Radar Topography was used to obtain this digital elevation model (Fig. 2) that generate the most complete high resolution digital

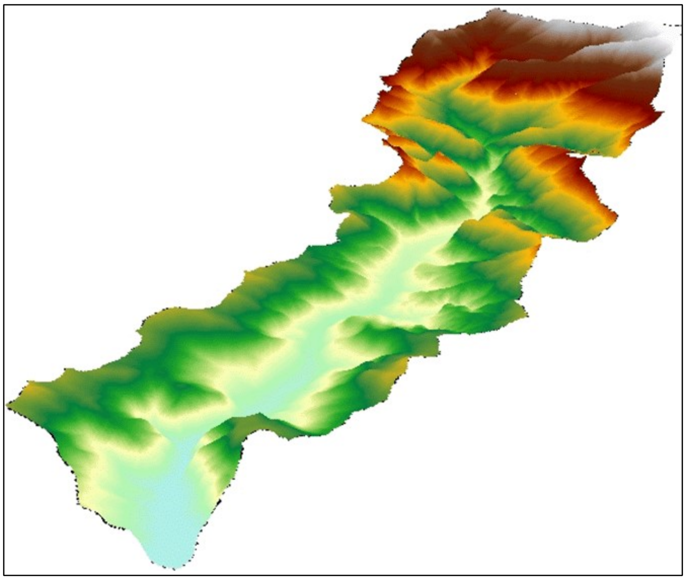
Fig. 2. Digital elevation model of Slănic Moldova watershed

topographic database of Earth. If necessary, the text can be divided into numbered and named "chapters" (the present model contains two chapters named: "Introduction" and "Additions".

Colour printing of the articles is not possible yet (because of high costs). This is the reason why all the figures (drawings, labels, photographs) are black/white (grey).

In regards to atmospheric precipitations that fall withing Slănic Moldova watershed, in the months of May to August, heavy rains occur (75 - 100 liters per square meter), while from September to April, the monthly amount of water from precipitation is 25-50 liters per square meter, with September being the driest month. Summer rains are of short duration.

Precipitation measurements in the Slănic hydrographic basin began around 1970 and continue until today. In the figure 3 is illustrated a graph with the average annual volume of precipitation at the Cire oaia hydrometric station which measure the precipitation on the Slănic Moldova watershed. As can be seen from the graph the average annual volume of precipitation is around 500 mm.

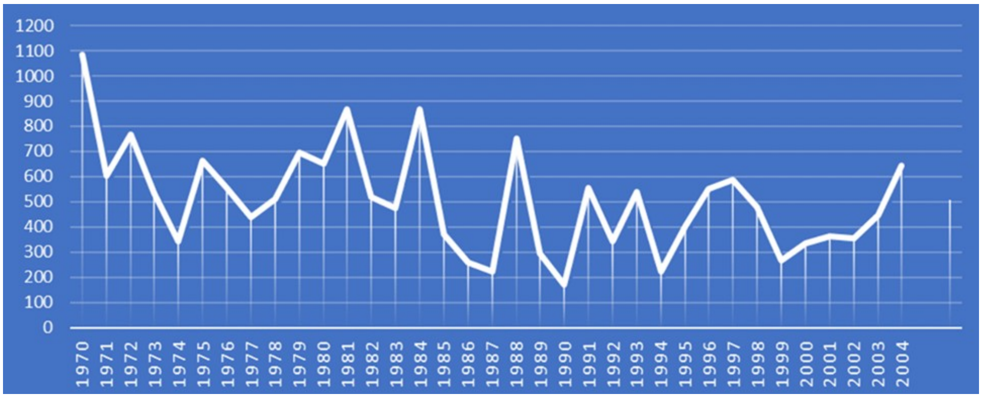

Fig. 3. Graph of the average annual volume of precipitation at the Cireşoaia hydrometric station

The precipitation diagram for Slănic-Moldova (Fig. 4) shows how many days per month a certain amount of precipitation is reached. In tropical and monsoon climates these amounts may be underestimated.

In the table below (Table 1) is represented the total volume distributed on hydrometric station Cire oaia that has been recorded within Slănic Moldova watershed over 35 years (1970 - 2004). This measurement represents the total sum of rainfall or water flow that has occurred and been collected at those stations. This hydrometric data is a fundamental input for hydrological models used to simulate the movement of water within this watershed.

2.3. Unveiling precipitation patterns

Within the realm of GIS- data driven precipitation analysis, two vital techniques stand out: Thiessen Polygon and IDW Interpolation. The Thiessen Polygon method partitions the study area into polygons, each containing a single precipitation gauge or station. Precipitation values from these gauges are assigned to the entire area within the corresponding polygon, assuming uniform precipitation within each boundary. This approach proves valuable when dealing with limited precipitation data.

The zoning of the hydrographic basin was carried out in the ArcGis by ESRI program. Each rain gauge station is assigned a corresponding surface automatically determined according to the layer with the positioning of the rain gauge stations and the layer with the shape of the hydrographic basin. The volume of water related to each surface Fi is given by the following equation 1 (Giurma, 2004):

$$Vi = Fi \; / hi \qquad (1)$$

where:

Vi = the volume of water related to the station

Fi = surface related to the station

hi = precipitation recorded at station i

By relating the total volume precipitated on the basin (and which is obtained by summing the partial volumes), to the surface F of the basin, the average value of the precipitated layer results.

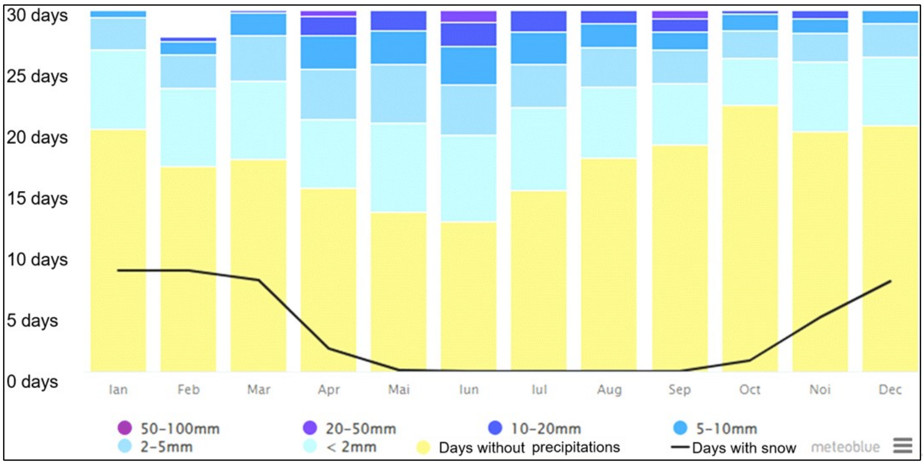

Fig. 4. Graph of the monthly volume of precipitation (Source: meteoblue)

Table 1. Total volume distributed on hydrometric stations (mm)

No.	Year	Ciresoaia hydrometric station-Watershed Slanic Moldova
1	1970	1082,594
2	1971	605,25
3	1972	767,768
4	1973	535,282
5	1974	345,52
6	1975	665,587
7	1976	557,171
8	1977	439,373
9	1978	512,691
10	1979	695,648
11	1980	650,095
12	1981	866,623
13	1982	519,476
14	1983	473,731
15	1984	869,053
16	1985	370,166
17	1986	261,258
18	1987	221,727
19	1988	753,5
20	1989	293,702
21	1990	172,569
22	1991	557,726
23	1992	343,66
24	1993	541,201
25	1994	221,775
26	1995	402,535
27	1996	553,216
28	1997	586,415
29	1998	480,421
30	1999	268,203
31	2000	337,457
32	2001	363,9092
33	2002	354,371
34	2003	446,609
35	2004	643,08
Total (mm)		**507,410 mm**
Mean		**14,49 mm**

Generating Thiessen polygons in ArcGIS can be made using the tool Create Thiessen Polygon (fig. 5). The point location of the rainfall stations was used as input data for the tool.

In scenarios where precipitation gauges are sparse, IDW Interpolation emerges as an effective solution. By estimating precipitation values at unsampled locations based on the weighted average of surrounding gauges, with weights inversely proportional to distance, this method generates continuous precipitation surfaces across the watershed. This approach significantly enhances our comprehension of spatial variations in rainfall distribution.

The Inverse Distance Weighting (IDW) interpolation assumes that each input point has a local influence that decreases with distance. It assigns higher weights to points closer to the processing cell and lower weights to points farther away.

A specified number of points or all points within a specified radius can be used to determine the output value at each location (fig. 6). Using this method assumes that the variable being mapped decreases in influence with distance from its sampled location.

3. Results and discussion

The hydrographic basin was divided into 4 polygons related to the 4 rain gauge stations, each polygon being assigned a certain resulting and automatically calculated area, the result is being illustrated in the map below (fig. 7).

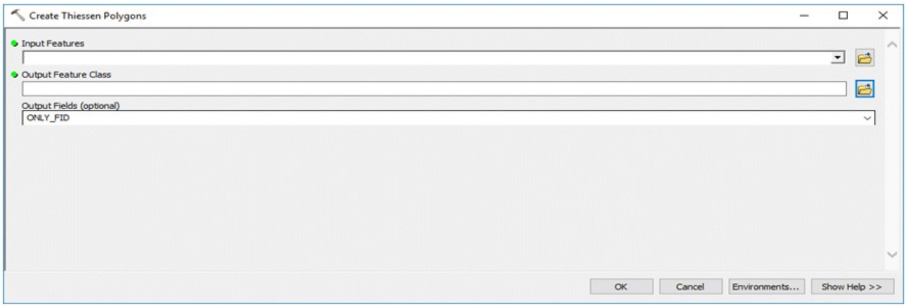

Fig. 5. Create Thiessen Polygon tool

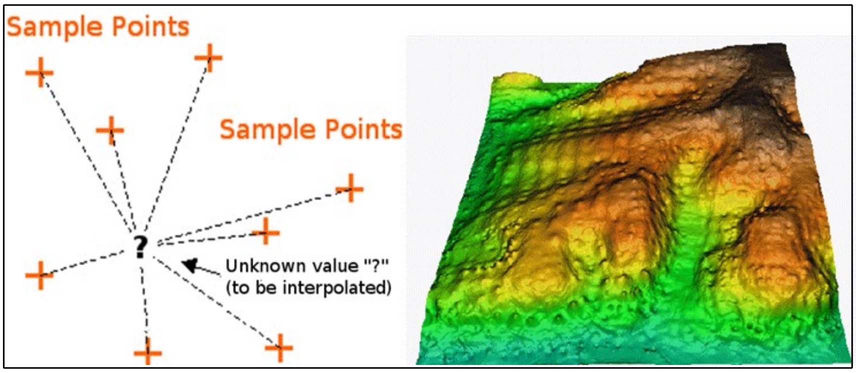

Fig. 6. IDW interpolation principle

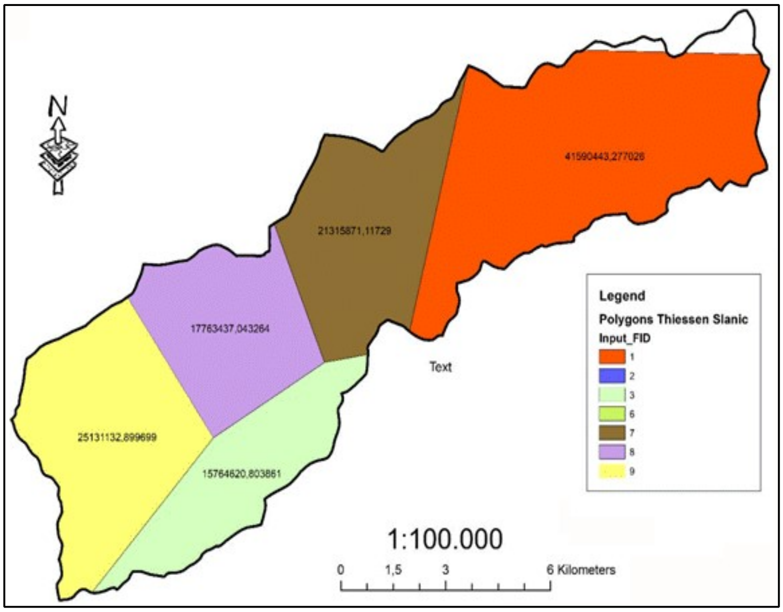

Fig. 7. Thiessen polygons on Slănic catchment

Table 2. Parameters of each Thiessen polygon

ID	Watershed area	Length	Forested area	Slope	Perimeter	Q_1 %	Ordinance
Slănic	123,48	30,37	0,81	14,75	66147,00	345,71	2,00

The heart of GIS-based hydrological modelling lies in the amalgamation of precipitation data, including Thiessen Polygon and IDW Interpolation outputs, with other hydrological parameters.

The result of Thiessen Polygon analysis is being present in the image below (fig. 8).

With the help of these surfaces, the average precipitation on the basin was calculated (Tab. 3).

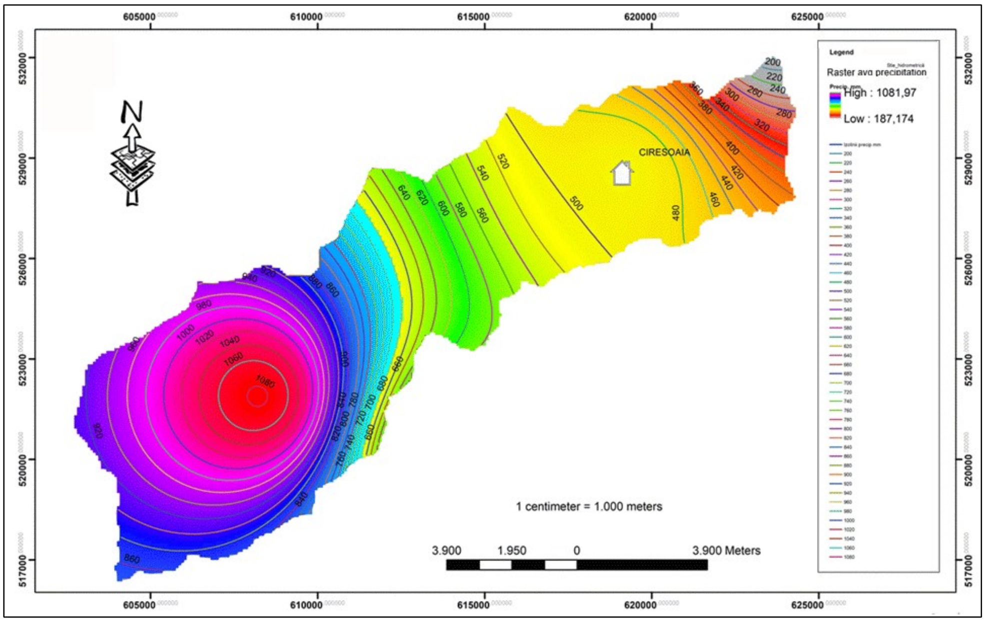

Fig. 8. Distribution of the precipitation in Slănic Moldova watershed

Table 3. Comparasion between manual method versus Thiessen polygon method

The average value – classical calculation	507,41 mm
The average value of the precipitation layer - ArcGis calculation using the Thiessen polygon method	505,71mm

As we can observe, the difference between the arithmetic mean method calculated for a 20-year period and the average value of the precipitate layer obtained using the Thiessen polygons method in GIS for the same period is small when analysing multi-year precipitation data.

4. Conclusions

Generating Thiessen polygons using GIS software represents a novel, rapid, and accurate approach for calculating average precipitation within a basin. The obtained raster data have been instrumental in creating a map displaying the average precipitation distribution within the basin. This approach has proven valuable in automatically extracting the necessary parameters for basin studies. Additionally, data collected from grouped tabular rain gauge stations integrated into the GIS environment have been of significant importance.

Through this study, I propose the development of a GIS methodology to determine the input parameters or data for modelling the rainfall-runoff process. This will aid in anticipating the amount of available water for runoff and integrating the runoff on slopes to estimate the magnitude of potential flash floods.

By using long-term analysed precipitation data with various methods presented in this study, along with daily hourly precipitation data, the knowledge of the water volume reaching the main collector basin is crucial for calibrating the future hydrological model. Consequently, the goal is to estimate the amount of water that will contribute to flood generation and the distribution of this runoff in space and time, given the forecasted precipitation recorded at the rain gauge stations for a specific day, considering the previous moisture conditions and terrain characteristics.

The model will consider the aforementioned factors and will be capable of anticipating the available water for runoff and simulating its movement through the hydrographic basins to estimate the variation of discharge at the basin's outlet.

The primary objective of this future model is to determine, based on landscape characteristics, antecedent precipitation, and forecasted precipitation for a specific day, the amount of water that will generate flooding and its temporal and spatial distribution.

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References

1. Antohi C., Teli că M. (2004), *Monitoringul factorilor de mediu- lucrari practice*, Editura Performantica, 29-39.
2. Administraţia Bazinală de apă „Siret" – arhivă.
3. Crăciun P., et al. (1998), *Sistemele acvifere din depozitele pleistocene în zona bazinelor Suşiţa-Trotuş*, An. Inst.Geol. Rom. Bucureşti.
4. Directiva Parlamentului European si a Consiliului Uniunii Europene 2000/60/EC de stabilire a unui cadru de politica comunitara în domeniul apei (2000).
5. Giurma I. (2003), *Viituri si masuri de apărare*, Editura Gh. Asachi Iaşi.
6. Giurma I. (2004), *Hidrologie specială*, Editura Politehnium, Iaşi.
7. Giurma I. (2000), *Sisteme de gospodărirea apelor*, Editura CERML Iaşi.
8. Giurma I. (1999), *Studii pentru realizarea sistemului de monitorizare a factorilor de mediu în zone urbane*, Contract CNCSU 3574/1999, cod 7. Proiect finanţat de Banca Mondială şi Guvernul României.
9. Gyorgi M.M., *Predicţia viiturilor rapide în condiţii dedate limitate. aplicaţie la râurile mici din Munţii Zarandului şi Săvârşinului*, Teza de doctorat.
10. Marusic G. (2013), *Study on numerical modeling of water quality in „river-type" systems*, Meridian Ingineresc.