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ANALYSIS OF SOME PARAMETERS OF THE HYDROGRAPHIC BASINS IN THE FOREST FUND

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Abstract

The forestry sector, due to its binary nature (biologically specific but also technical), must participate in solving some problems regarding the conservation and improvement of hydrological resources, the inventory and sustainable exploitation of all resources, the research of the structures and compositions of stands in hydrographic basins, in order to improve the hydrological functions of forests and soil protection. The paper presents a series of characteristics and parameters of the Aleu Valley watercourse and at the same time of the hydrographic and forest basin in which it is located. For this purpose, a series of determinations of water flows, parameters of the hydrographic basin (type of longitudinal profile of the course, shape, surface, maximum length and width, perimeter, shape index, average slope of the basin, length of the hydrographic network), as well as the analysis of the degree of total afforestation and partial areas in the Aleu Valley basin. The results of these analyzes may be of interest in order to capitalize on the potential of small watercourses in the forestry sector in the fisheries or energy fields.

Key words*: forest fund, hydrographic basin, parameters.*

INTRODUCTION

Due to the relatively limited values of water resources, compared to the growing needs, the development of human society requires an intensive and well-coordinated management, capitalization of all these resources (Șmuleac et al., 2017; Sandu et al., 2021).

From this perspective, scientific research in forestry must propose changeling its attention to the various problems related to:
- inventory of all forms of water resources existing in the forest fund (including energy ones);
- researching the structures and compositions of forests in the hydrographic basins, in order to improve the hydrological functions of forests and soil protection;
- investigation and evaluation of the potential of small water courses, present in the forest fund;
- capitalizing on hydro potential in order to obtain alternative energy sources in production processes (Arion et al., 2023);
- measurements in the field in order to obtain some parameters and characteristics of the hydrographic basins, relevant under different aspects;
- evaluation of climatic and hydrographic factors, which influence the dynamics of water flows (Costin, 2003);
- analyzes and comparisons of the characteristic parameters of hydrographic and forest basins (Lee, 1980);

The main objective of this paper is the analysis and presentation of a small water course in northwestern Romania, namely from the Aleu Valley hydrographic basin, located in the Crișul Negru river basin, which presents a real potential for its development and exploitation. This course is a flowing water, formed by springs (which are points of discharge of the phreatic layers), shallow water layers, where the water is not under pressure, and/or precipitation, which under the influence of gravity and the slope, moves downstream along the line of greatest slope.

The exploitation of the hydro potential of the rivers and streams in Romania must be viewed with maximum interest, in the perspective of its sustainable management and conservation (Călmuc et al., 2022). Hydraulic resources represent one of the natural riches, characterized by the fact that they are practically inexhaustible and have numerous and varied uses, in all branches of human activity. In view of the special interest that water presents, both for agriculture, forestry, industry, and for human settlements, it is necessary that when using these resources, all these needs should be taken into account, in order to ensure a complex and integral utilization of water courses (Păcurar, 2005; Iovan, 2012).

It is known that the forest directly, strongly, and complexly influences the water regime, regardless of the state of water aggregation (De Azagara et al., 1996), and the simultaneous presence of the two in mountain and hill regions, where I find most springs and watercourses. Due to these connections and influences of the forest on water, the ancient saying "the forest is the house of water" is very well known (Mancia & Mancia, 2003). The phenomena through which the forest intervenes on the water regime are: interception of water through the tree crown, evapotranspiration, water infiltration into the soil, water runoff and definitely its quality (Dumitru et al., 2004).

MATERIALS AND METHODS

The studied water course Aleu Valley originates from the Bihor Mountains and runs on their south-western side (Figures 1 and 2). It is a right tributary of the Crișul Pietros river, has a length of 9.5 km and crosses a forest floor area of 2456 ha after the Arrangement Forest District Sudrigiu.

Figure 1. The location of the water course Aleu Valley (https://www.forajeapa.ro/bihor-oradea)

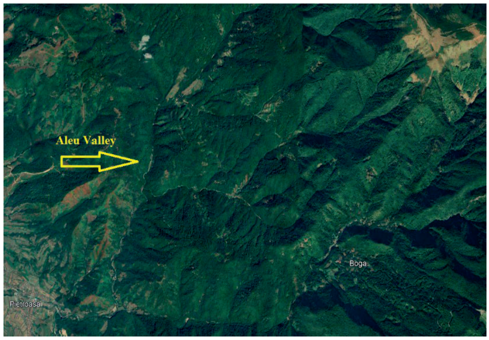

Figure 2. Satellite image of Aleu Valley (https://www.google.com/maps)

The hydrographic basin (reception basin, water collection basin) represents the surface that includes the hydrographic network, from which it collects its waters (Man et al., 2010). Aleu Valley has a hydrographic basin with an area of 3619 ha, it is characterized by a longitudinal profile with an average slope of 95‰, as well as natural slope breaks.

The research method used in the first stage was the experiment, respectively the measurement of the morphometric elements of the sections studied (S1 downstream, respectively at the spillway, S2 in the central part of the basin and S3 in the upper part of the basin), based on which they established, through analytical calculation, the velocities and flow rates of the water course.

For the hydrological characterization of a watercourse, the most important element to be determined is the *flow rate (*Q*)* (Helsel et al., 1992). Thus, this determination of the flow rates of the water courses was carried out in parallel with the help of the method based on the speed measured with floats, and respectively with the hydrometric mill. The method of calculating flows based on velocities measured with floats is a convenient method (Herschy, 1995), and which must meet certain conditions, respectively:

- lack of wind, which can influence the speed of the floats;
- the water level during the determinations should be stable, in order not to influence the trajectory of the floats towards the banks;
- lack of vegetation on the respective portion of the river;
- the most rectilinear shape of the course in the measured portion;

With the help of this method, the speed at the surface of the water current was determined, a speed considered close to the value of the average speed.

After choosing the river sector targeted for measurements, the three sections were established, respectively: the hydrocanate (the main section), the upper section (inlet of the floats), the lower section (outlet of the floats);

Figure 3 shows the layout of the profiles, for calculating the morphometric elements of the measured cross-sections.

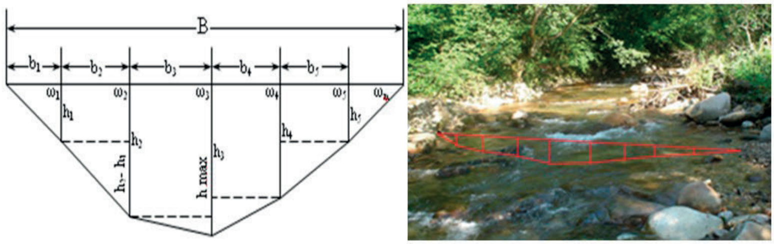

Figure 3. Helping profile to calculate the morphometric elements of the transversal section: $\omega_1 \dots \omega_n$ - surface of the active section; $b_1 \dots b_n$ - distance between the verticals; $h_1 \dots h_n$ - depth of the test verticals; h_{max} - maximum depth; B - width of the river

The most used is the method for determining the flow rate of water courses, it is related to the method of determining velocities with the hydrometric mill.

Through this method, the flow rate is determined as follows:

- the transverse profile of the bed is represented at a suitable scale;
- calculate the surface of the section occupied by water (watered section);
- the average speed of the water is determined using one of the previously presented methods;

The water flow results from relation 1:

$$Q = \omega \cdot V_{med} \text{ [m}^3\text{/s or l/s]} \quad (1)$$

where:

- ω is watered section;
- V_{med} is the average speed of the water.

The hydrometric mill is a powerful, light, convenient and widely used device for measuring water velocities at different points in the stream. The name comes from the paddles, which rotate around an axis, under the influence of water currents. To obtain the magnitude of the speed of the water current, at a certain point, the number of rotations of the paddle in a unit of time, *n*, must be determined, knowing the relationship between the speed of the current (V) and the number of rotations of the paddle per second (*n*):

$$V = f(n) \quad (2)$$

For these measurements, the OTT type hydrometric mill was used (Figure 4), which works according to the Faraday principle (the induction of a uniform magnetic field is a physical vector quantity, whose mode is equal to the ratio between the force with which that magnetic field acts on of a rectilinear conductor, perpendicular to the lines of the magnetic field, and the product of the current intensity in the conductor and the length of the conductor, located in the magnetic field) to determine the speed of the water at the measuring point.

Figure 4. OTT type of hydrometric micro mill

In order to detect the volume of water, this hydrometric mill has a cylindrical sensor included in the body of the dug. The equipment is functional in any fluid with minimal conductivity, and measures the water velocity twice in one second, calculating it as the average of the two readings.

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Next, we moved on to processing the data obtained by the surface float method. For the flow calculation, with the help of this method, the calculation relations proposed by Morariu et al. (1970) were used: the surface of the active section (ω), was determined with the help of relation 3:

$$\omega = \frac{h_1}{2} b_1 + \frac{h_1 + h_2}{2} b_2 + \cdots + \frac{h_{n-1} + h_n}{2} b_{n-1} + \frac{h_n}{2} b_n \quad (3)$$

Based on the measurements made, the flow of the valley in the respective sections was subsequently calculated, as follows: in the first phase the fictitious flow rate Q_Φ, based on relation 4:

$$Q_\Phi = \omega\, V_m \quad (4)$$

and then the real flow rate Q, on the vase of relation 5:

$$Q = K\, Q_\Phi \ [m^3/s] \quad (5)$$

where:

- V_m is average speed;
- K represent transition or reduction coefficient, which is obtained as a ratio between the flow rate measured with the drill and the flow rate calculated based on surface velocities, but in the absence of these data, the value of K is roughly between 0.86 and 0.89.

The method used to measure the flow rates with the hydrometric trowel was the analytical one, which consists in determining the partial flow rates for the surfaces between the velocity verticals and summing them up according to the SEBA Hydrometry user manual, by going through the following steps:

- determining the average speeds for each vertical ($V_1, V_2, \ldots V_n$);
- calculation of the partial surfaces (ω_0, ω_1, ω_2,. ω_n) between the speed verticals;
- the calculation of the average speeds for each of the partial surfaces, as the arithmetic mean of the average speeds of the neighboring verticals; for the first and last portion of the section, the average speed is considered to be 2/3 of the speed of the first, respectively the last vertical;
- determining the partial flow rate by multiplying each area by the average speed;
- adding up the partial flows for the entire section using relation 6, recommended by Morariu et al., 1970, and obtaining the total flow:

$$Q = \frac{2}{3}\omega_0 V_1 + \omega_1 \frac{V_1 + V_2}{2} + \omega_2 \frac{V_2 + V_3}{2} + \cdots \omega_{n-1} \frac{V_{n-1} + V_n}{2} + \frac{2}{3}\omega_n V_n \quad (6)$$

After the effective determination of the measurements on the watercourses, the data was downloaded into the computer system, and with the help of the software provided by the CamdR program, the measured flows and respectively all the elements of the watercourse were obtained, according to the model presented in Figure 6.

Next, the parameters of the hydrographic basin studied were determined, starting from their topographic maps (scale 1:50000 and equidistance of 20m) on which, after delimiting their perimeter, the level curves were introduced (by vectorization), with the help of the MapSys program.

Later, the hydrographic basin surface was divided into partial hydrographic basin surfaces, by means of sections depending on the sections where flow measurements and confluences with tributaries were made. Finally, with the help of the facilities offered by the Surfer program, the spatial model of the terrain (3D) was created.

RESULTS AND DISCUSSIONS

The 3D representation of the Aleu Valley hydrographic basin shows the form in Figure 5, which later determined all the values of the characteristic parameters of the basin, presented in Table 1.

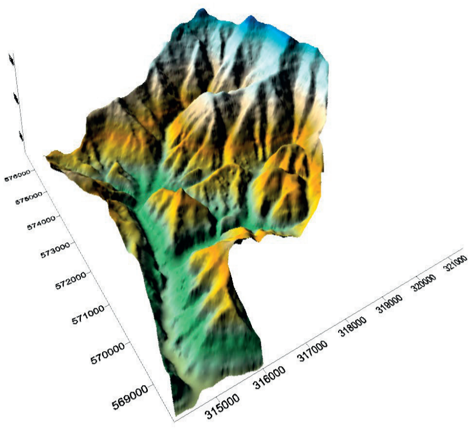


Figure 5. The space model of the field (3D) in the hydrographic basin of Aleu Valley

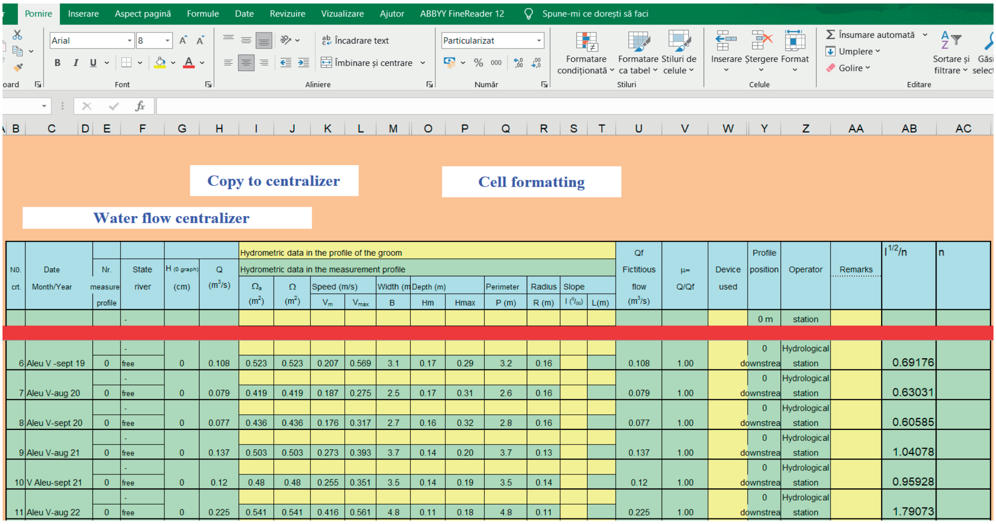
According to the classification of watersheds according to Man et al., 2010, the shape of this basin is close to triangular.

Figure 6 shows a capture from the CamdR program with the partial centralizer of the elements and flows of the water course.

Following the processing carried out, with the help of the MapSys and Surfer programs, the characteristic parameters of the hydrographic basins studied were determined, presented in Table 1.

Table1. Characteristic parameters of the hydrographic basin

Basin parameters	Surface		Lenght maxim	Width maxim	Perimeter	Index of form (φ)
	km²	ha	km	km	km	
Aleu Valley	36.19	3619	9.50	7.20	25.60	0.12



Copy to centralizer

Cell formatting

Water flow centralizer

N0. crt.	Date Month/Year	Nr. measure profile	State river	H (0 graph) (cm)	Q (m³/s)	Hydrometric data in the profile of the groom / Hydrometric data in the measurement profile: Ω_a (m²)	Ω (m²)	Speed (m/s) V_m	Speed (m/s) V_{max}	Width (m) B	Depth (m) Hm	Depth (m) Hmax	Perimeter P (m)	Radius R (m)	Slope I (‰)	Slope L(m)	Qf Fictitious flow (m³/s)	μ= Q/Qf	Device used	Profile position	Operator	Remarks	$I^{1/2}/n$	n
			-																	0 m	station			
6	Aleu V -sept 19	0	- free	0	0.108	0.523	0.523	0.207	0.569	3.1	0.17	0.29	3.2	0.16			0.108	1.00		0 downstrea	Hydrological station		0.69176	
7	Aleu V-aug 20	0	- free	0	0.079	0.419	0.419	0.187	0.275	2.5	0.17	0.31	2.6	0.16			0.079	1.00		0 downstrea	Hydrological station		0.63031	
8	Aleu V-sept 20	0	- free	0	0.077	0.436	0.436	0.176	0.317	2.7	0.16	0.32	2.8	0.16			0.077	1.00		0 downstrea	Hydrological station		0.60585	
9	Aleu V-aug 21	0	- free	0	0.137	0.503	0.503	0.273	0.393	3.7	0.14	0.20	3.7	0.13			0.137	1.00		0 downstrea	Hydrological station		1.04078	
10	V Aleu-sept 21	0	- free	0	0.12	0.48	0.48	0.255	0.351	3.5	0.14	0.19	3.5	0.14			0.12	1.00		0 downstrea	Hydrological station		0.95928	
11	Aleu V-aug 22	0	- free	0	0.225	0.541	0.541	0.416	0.561	4.8	0.11	0.18	4.8	0.11			0.225	1.00		0 downstrea	Hydrological station		1.79073	

Figure 6. The synoptic table of the elements and of the water course flows from the CamdR program

Based on the data obtained from the arrangement of the forestry bypass and processed, the forested surface of the hydrographic basin was also determined, as follows: S_{i1} (partial surface 1, corresponds almost entirely to the total surface), S_{i2} partial surface 2 (located upstream of the flow measurement section S2) and respectively S_{i3} partial surface 3 (located upstream of flow measurement section S3).

Testing the significance of the correlation coefficients, given that a small number of river basins were worked on (one presented in the paper and another 8 used for comparisons), was carried out using the *t*-test (Student) (Timofte et al., 2011).

Following the field measurements on the 3 partial surfaces between the measurement sections (S_{i1}, S_{i2} and S_{i3}) in the months of June, July, August and September (interval 2018-2022), the correlation between the flows and the forested area is shown in Table 2 and Figure 7.

Table 2. Correlation flow/partial basin areas

Month	Correlation coefficient values	t Calculated	t Theoretical	The significance of the correlation coefficient
June	0.6950	1.674370189	1.886	t calc < t theor insignificant correlation
July	0.8829	3.25616062	1.886	t calc > t theor significant correlation
August	0.9975	24.52430108	1.886	t exp > t tabel significant correlation
September	0.7802	2.160490779	1.886	t exp > t tabel significant correlation

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It is found that for the months of July, August and September (2018-2022) the correlations between the measured flow (with floats and hydrometric mill) and the forested area are significant, which means that the variation of the flows is really influenced by the forested area. So, we can say that during these months the forest intervenes significantly and decisively in the process of water retention from precipitation. At the same time, it can be observed that the same correlation for the month of June in the studied interval is insignificant. This fact can be explained by the influence of other factors that lead to relatively close flow rates regardless of the forested area. Even though the correlation is insignificant, the calculated t-test still has a value very close to the theoretical *t*-test.

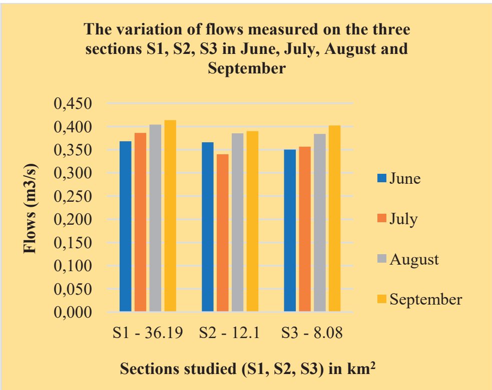

Figure 7. The variation of flows measured on the three sections S1, S2, S3 in the months of June, July, August and September in the interval 2018-2022

In order to analyze the existence of correlations between flows and the characteristic parameters of the hydrographic basin (basin form index, basin length, basin width and forested area), a comparative study was carried out with several hydrographic basins (Iada Valley, Brătcuța Valley, Crăiasa, Galbena Valley, Crișul Pietros Valley, Finiș Valley, Tărcăița Valley and Văratec Valley) from the large hydrographic basins of the Crișul Repede and Crișul Negru rivers. This resulted in significant correlation coefficients between flow rates, the shape index, and the length of the hydrographic network of the basin, respectively between flow rates, the shape index and the surface of the hydrographic basin. At the same time, the correlation between the form index and the multiannual average flows taken from the hydrological station was not relevant.

In another vein, the connection between the average monthly rainfall in l/m^2 (taken from the ANMH-Weather station Stâna de Vale, which is the closest) and the average flows per calendar month (taken from the Cadastral Atlas of Romanian Waters) was tested in the period 2003-2022. From Figure 8 the equation of the distribution of correlation coefficients by calendar months (period 2003-2022) is a polynomial type of the 6th degree, with the coefficient of determination R^2 = 0.6761. Previous determinations for other types of regressions resulted in coefficients of determination with values below 0.5.

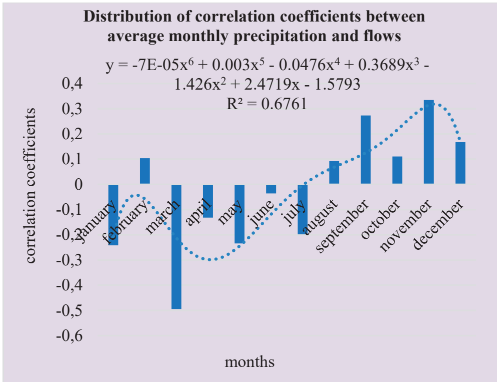

Figure 8. Distribution of correlation coefficients between average monthly precipitation and flows for the period 2003-2022 per calendar month

From the analysis of some correlations between the partial and total flows measured in the three sections (S1-S3) from June-September 2018-2022 (Figure 9), the existence of significant correlations between the calculated *t* and the theoretical *t* was found. This fact is normal due to the influence of flow rates measured upstream on those downstream.

Due to the small amounts of precipitation in the warm season, the flow variation is influenced by the forested surface of the basin. Also, some variations of these flows in the hydrographic and forest basin studied can be explained by the influence of other factors, such as: tree species, the consistency of the forest, the inclination and exposure of the slopes, etc.

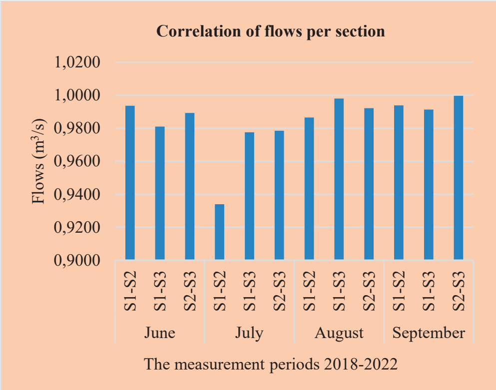

Figure 9. Correlations between partial and total flow rates measured in the three sections

CONCLUSIONS

Through the multivariate statistical analysis of flows according to a series of variables (characteristic parameters), the aim was to establish the degree of similarity (dissimilarity) between them and the partial and total subsurface of the hydrographic basin studied.
The identification of the variables considered to be more strongly correlated led to the conclusion that there are significant correlation coefficients between flow rates, the form index, and the length of the hydrographic network of the basin, respectively between flow rates, the form index and the area of the hydrographic basin.
From the multitude of types of correlative links, those with a higher correlation ratio and statistical significance were selected. Thus, the correlative links with statistical significance selected were those of the polynomial and linear type. Correlative links with statistical significance of the polynomial type suggested a stronger correlation in relation to the linear ones, but the corresponding regression curve indicates a certain reduction in the flow value before its increase, which is more difficult to explain.
The presentation of a flow analysis method was achieved by dividing the hydrographic basins into smaller areas and by characterizing them separately.
In the end, some recommendations can be made, respectively: directing attention to the hydrological resources available in the hydrological forest basins; awareness of the fact that the existence of small constructions (for example, troutery, artificial waterfalls, etc.) contribute to the oxygenation of water in warm periods, when there is a risk of its temperature increasing and negatively affecting fauna (especially fish) or flora; the exploitation of all flowing waters with a low flow in order to obtain some forms of clean energy to serve isolated consumers (troutery, locations for forest management activities) existing in the forest fund, or of some small isolated localities.
Based on the research presented in this paper, it can be recommended to draw attention to the problems related to ensuring the permanence of the water flow, the presence or absence of torrential phenomena, the impact on the environment, etc. during the installation of constructions intended for the exploitation of water energy.
We can say with certainty that the evolution and variation of the flows of a watercourse located totally or partially in the forest floor are influenced by a much larger series of factors than those presented in the paper, such as the variation of the flows of tributaries of different degrees, the permanent or periodic operation of some works of the type of captures and others.
The last conclusion that can be drawn is that the flows of the studied watercourse reach the highest values in the winter-spring period, while the lowest flows are recorded in the warm season.

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***Arrangement Forest District Sudrigiu, Bihor Forestry Directorate

***Cadastral Atlas, Romanian Waters, Directorate of Crișuri Waters

***National Agency of Meteorology and Hydrology (ANMH), Weather station Stâna de Vale

***SEBA HYDROMETRIE - Portable equipment for determining water velocity, User's Manual

***CamdR program

***https://www.forajeapa.ro/bihor-oradea

***https://www.google.com/maps