VERTICAL DYNAMICS OF THE UPPER OLT RIVERBED

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Abstract. Vertical dynamics of the upper Olt River channel. The upper course of the Olt River traverses two major intramontane depressions in the Carpathians: the Ciuc Depression and the Brașov Depression, separated by the Tușnad Gorge. The differentiated origin of the surrounding mountainous areas is reflected in the characteristics of the relief and the substratum, which directly influence the vertical dynamics of the river channel. The analysis focuses on cross-sections at four hydrometric stations: Tomești, Sâncrăieni, Micfalău, and Feldioara. Based on the difference between water level elevation and maximum depth, the thickness of the rock layer (hp) was calculated relative to the zero datum of the hydrometric gauge. The monthly variation of this value expresses channel aggradation in the respective sections. Differences are identified with respect to the range of vertical dynamics, characteristic periods, and linear and polynomial trends.

Keywords. water level, maximum depth, mean depth, cross section, relative stability, degradation, aggradation, characteristic period, trend

1.INTRODUCTION

Water constitutes the most dynamic agent shaping relief. This action manifests through four types of energy, depending on the characteristics of impact and water movement. Thus, one can distinguish the energy of rainfall, of areal runoff and concentrated hillslope runoff, as well as the energy of fluvial flow (Pandi, 1997). The system of forces - water erosivity and the erodibility of the adjacent surface - determines the character of landform development. Of the four types of energy, only the last is characterized by continuity. For this reason, riverbeds are subject to continuous transformations, and this dynamics also affects the adjacent slopes. Beginning in the late twentieth century, researchers - especially from regions with oceanic and temperate climates—conducted intensive studies on riverbed dynamics (Castaldini & Piacente, 1995; Paige & Hickin, 2000; Winterbottom, 2000; Amsler, Ramonell & Toniolo, 2005). They highlighted the complexity of shaping processes within a continuous and synergetic system.

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According to legend, “the two brothers” rise from the Hășmașul Mare Massif. The Mureș flows northward, the Olt southward, and their waters meet in the Danube and calm in the Black Sea.

The Olt has a narrow, north–south-oriented valley as far as the town of Bălan. Southward, the Olt enters the Ciuc Depression, bordered by the Harghita Mountains of volcanic origin and the Giurgeu Mountains, composed of a mixture of crystalline rocks, Triassic limestones, basalts, and andesites. After the Tușnad Gorge, the Olt continues to flow south within the northern extension, in corridor form, of the Brașov Depression, known as the Sfântu Gheorghe Depression. After the confluence with the Negru River, a vast subsidence area follows, where the river makes a 180° turn and flows northward between the Baraolt and Perșani Mountains. After the Baraolt Depression, the Olt leaves the Eastern Carpathians region (Fig. 1).

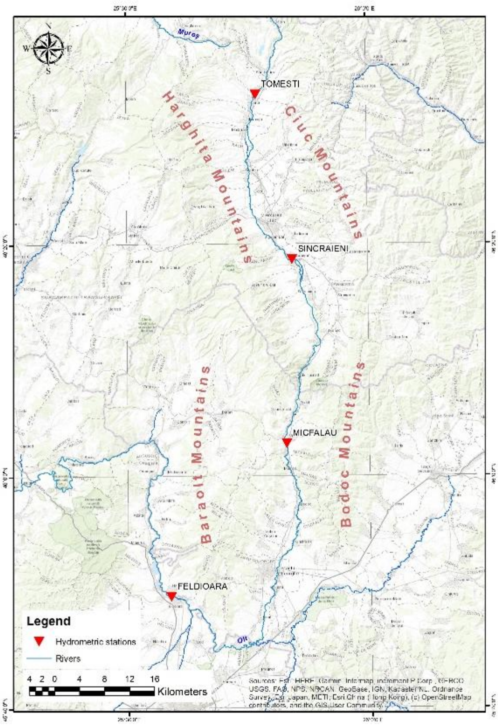

Fig1. Landforms and hydrometric stations

Among Romania’s major hydrographic systems, the upper Olt displays the highest mean runoff, exceeding 200 mm. Draining a succession of depressions bordered by mountains with varied petrography, it benefits from a wide and rich variety of water sources (Ujvári, 1972). Consequently, the Olt has a balanced hydrological regime, which is also reflected in the vertical dynamics of its riverbed.

The reservoirs in the upper basin of the Olt River are small in size. Their operation does not significantly influence the runoff regime of the main collector and, therefore, does not affect the vertical dynamics of the riverbed. Upstream of the town of Bălan, the valley was dammed in 1966, forming the Mesteacănul Reservoir. The catchment area is 65 km², and the stored volume is 858,000 m³. The main function of the reservoir was to supply water to the Bălan mining area. The Frumoasa Reservoir is located on the river of the same name, a left-bank tributary in the Ciuc Depression. It collects water from an area of 45 km², and its 10 million m³ of water are used to supply the city of Miercurea Ciuc.

The Târlung–Săcele Reservoir was constructed on the Târlung River, with the main functions of supplying water to Brașov and attenuating flood waves. The catchment area is 170 km², and the stored volume is 28 million m³ (Tugui, 2000).

2.METODOLOGY

Methods for evaluating riverbed dynamics can be grouped into geomorphological and hydrological approaches. The former are based on the analysis of alluvium transported by the river, focusing on the distribution of alluvial types along the longitudinal profile and on granulometric assessment of the particles. Hydrological methods rely on the analysis of water-level variations, that is, on the resultant of aggradation or degradation processes, while also taking extreme water levels into account.

The present analysis is based on the assessment of riverbed dynamics using discharge measurement data, in which the water stage and the maximum water depth are employed for calculations. This method has the advantage of allowing the analysis of long time periods, while its disadvantage is that the analyses are limited to the cross-sections of hydrometric stations (Pandi & Sorocovschi, 2009). At each discharge measurement, the water stage is recorded and the maximum depth is measured; the latter parameter represents the position of the thalweg relative to the water level. The pairs of values H and h max are referenced to the same zero datum of the hydrometric staff gauge. The difference between these pairs of values (hp) expresses the thickness of the rock layer between H"0"G and the thalweg of the riverbed (Pandi, 2007).

$$h_p = H - h_{\max}$$

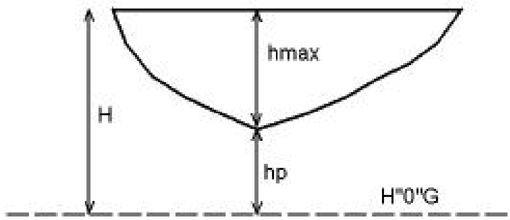

Fig 2. Calculation elements of hp value (Pandi)

Its variation expresses the dynamics of the riverbed bottom relative to an imaginary fixed plane. A decrease in the value of hp indicates an erosion process, that is, degradation, whereas an increase in hp represents a process of infilling (colmation) and, consequently, aggradation of the riverbed. These geomorphological terms describe variations of the riverbed over long time spans, on the order of years (Rădoane M., Pandi, Rădoane N., 2010).

For the analysis of riverbed dynamics, graphs of hp = f(T) were compiled for each station individually. In order to eliminate residual variations and possible reading errors in the H or h max values, five-day moving averages were calculated and the graphs hp5 = f(T) were produced. From the analysis of these graphs, periods of aggradation, degradation, or relative stability of the riverbed can be identified, as well as linear and polynomial trends over the entire period (Pandi & Horváth, 2012).

The analysis refers to four hydrometric stations along the Olt River: Tomești, Sâncrăieni, Micfalău, and Feldioara. The first is located immediately downstream of the river's exit from the mountain area. Sâncrăieni lies in the lower third of the Ciuc Depression, while Micfalău is situated downstream of the Tușnad Gorge, in the Sfântu Gheorghe Depression. Feldioara monitors the discharge at the outlet of the Brașov Depression.

The area of the contributing catchments increases substantially, by a factor of 26, from 214 km^2 to 5,678 km^2. Mean elevations decrease moderately due to the succession of different landforms comprising the drainage basins. The length of the controlled river reach increases sixfold, from 25 km to 159 km. The elevation difference between the staff gauge at Tomești and that at Feldioara is large-over 240 m. These morphometric data, together with river discharge regimes and the petrographic composition of the relief, determine the vertical dynamics of the riverbeds.

Table 1. ***Morphometric elements of the hydrometric stations***

Hidrometric station	**A (km^2)**	**Hm (m)**	**L am. (km)**	**L av. (km)**	**Plan "0" G (m)**
Tomești	214	1070	25	590	723.43
Sâncrăieni	902	937	58	557	647.70
Micfalău	1424	912	91	524	563.92
Feldioara	5678	820	159	456	482.58

The database comprises water-stage values and maximum depth values extracted from the summaries of liquid discharge measurements. For each month, one pair of data was extracted, on the basis of which hp and hp5 were calculated. The periods of analysis do not overlap exactly but cover sufficiently long intervals. With the exception of the Micfalău station, the analysis periods exceed 30 years.

In general, the configuration of the graphs and the characteristic periods of riverbed re-aggradation are influenced by both natural and anthropogenic factors (Pandi & Horváth, 2019). In the analysed river sector, there are no major anthropogenic factors that influence these graphs.

3.REZULTS

3.1. Analysis of Hydrometric Station Cross-Sections

The upper courses of rivers are usually characterized by relative stability. From this perspective, the Tomești station represents a relevant example. Located 25 km from the source, it closes a relatively small associated drainage basin of 214 km², developed in hard metamorphic rocks. For this reason, the river has not managed to incise deeply into the substrate, and the range of its dynamics is small (Δhp = 24 cm). For the moving averages, this difference is reduced to 18 cm. Two short periods of aggradation (1960–1962 and 1965–1968) and two short periods of degradation (1963–1964 and 1985–1987) can be identified. Overall, however, the riverbed at Tomești can be characterized by relative stability, illustrated by two long periods of this type: 15 years between 1969 and 1984 and 8 years between 1988 and 1996. It can be observed that the successive flood events of the 1970–1980 decade did not succeed in destabilizing the riverbed.

The linear trend indicates slight aggradation, with a range of only 4 cm. The 6th-degree polynomial trend illustrates degradation at the beginning of the period, followed by a long interval of relative stability.

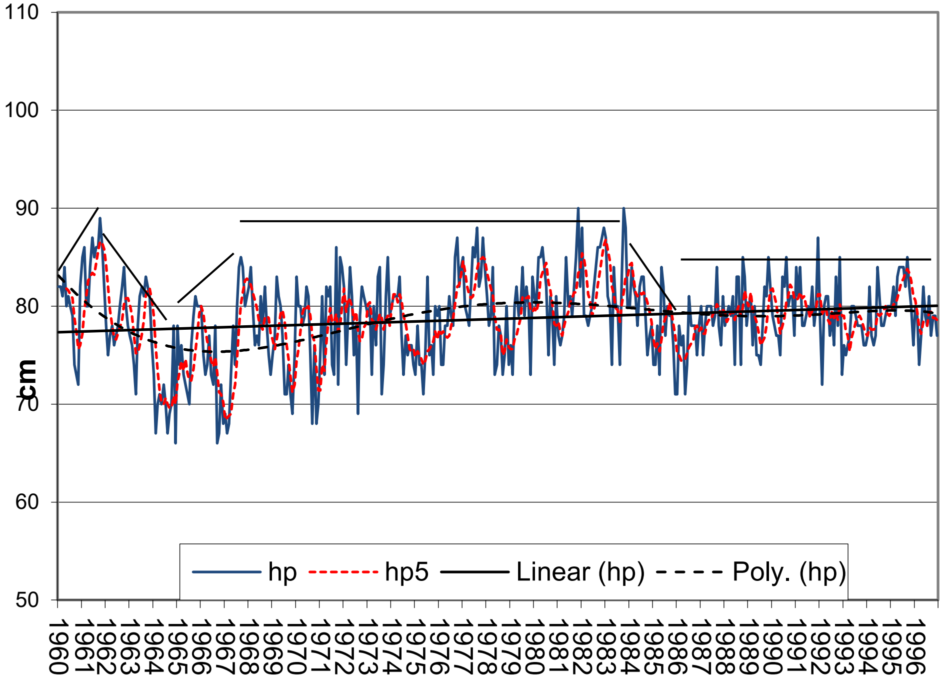

Fig 3. Re-aggradation of the riverbed at the Tomești Hydrometric Station

The Sâncrăieni station is located in the Ciuc Depression, characterized by the presence of a friable substrate composed of gravels, sands, and clays. The upstream length of the river doubles, and the area of the contributing drainage basin increases to 902 km². The mean basin elevation decreases by more than 100 m, and the zero datum of the hydrometric staff gauge also drops significantly. Within the depression, the Olt flows gently and, in some sectors, even meanders, as a result of subsidence movements of the crystalline basement and the Cretaceous flysch (Ciupagea, Paucă & Ichim, 1970). These characteristics have left a clear imprint on the vertical evolution of the riverbed. The range of hp is much greater than at Tomești (68 cm) and remains high for hp5 as well (54 cm).

The significant re-aggradation of the riverbed is also evident in the succession of characteristic periods. Numerous short periods with large ranges can be distinguished. Twelve periods were delimited, although several display a certain degree of relativity. The main characteristic is the alternation of degradation and aggradation periods, in most cases very abrupt. Five aggradation periods and six degradation periods were identified. The interval 1979–1997 is characterized by strong dynamics, with ranges sometimes exceeding 30–40 cm. Only at the beginning and the end of the analysed interval can relatively calmer periods of aggradation and degradation be observed. Only a single period of relative stability was identified, between 1983 and 1985.

The linear trend indicates an upward tendency, with a range of six centimeters. The 6th-degree polynomial trend highlights the instability of the riverbed, describing pronounced loops.

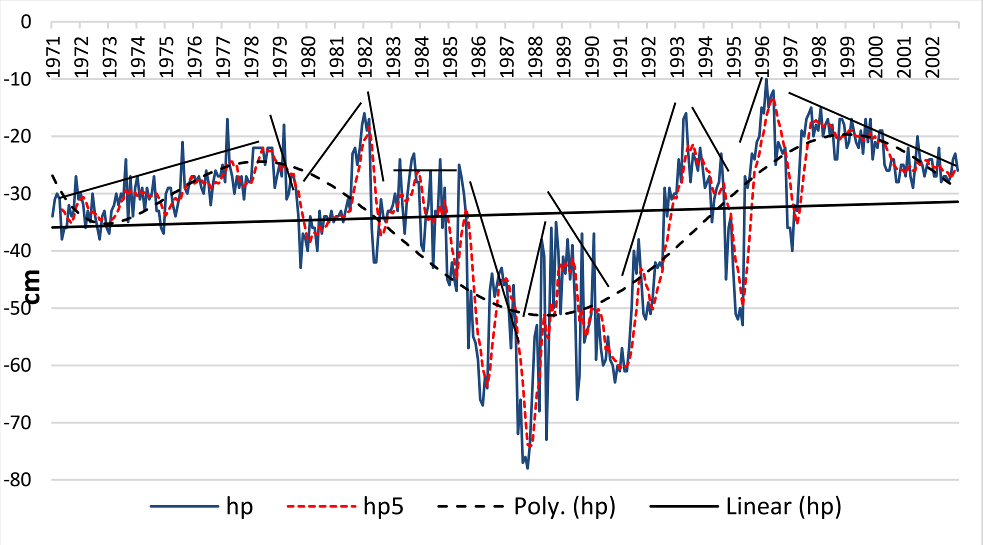

Fig 4. Re-aggradation of the riverbed at the Sâncrăieni Hydrometric Station

The Micfalău hydrometric station is located downstream of the Tușnad Gorge, in the upper part of the Sfântu Gheorghe Depression. Here, the substrate contains friable sediments similar to those found in the Ciuc Depression. These characteristics have left a clear imprint on the vertical dynamics of the riverbed. Accordingly, the range of re-aggradation is relatively large (Δhp = 49 cm; Δhp5 = 36 cm). Six characteristic periods of riverbed evolution can be delineated. There are three periods of stability: 1992–1996, 1998–2001, and 2005–2006. These are separated by a degradation period in 1997, an aggradation period between 2002–2003, and another degradation period in 2004. It is noteworthy that the slope of the aggradation phase is much steeper than the gentler slopes of the two degradation phases.

The linear trend is ascending, with the difference between the ends of the relationship amounting to only 7 cm. The 6th-degree polynomial trend indicates riverbed stability at the beginning of the interval, followed by a harmonic pattern of variation.

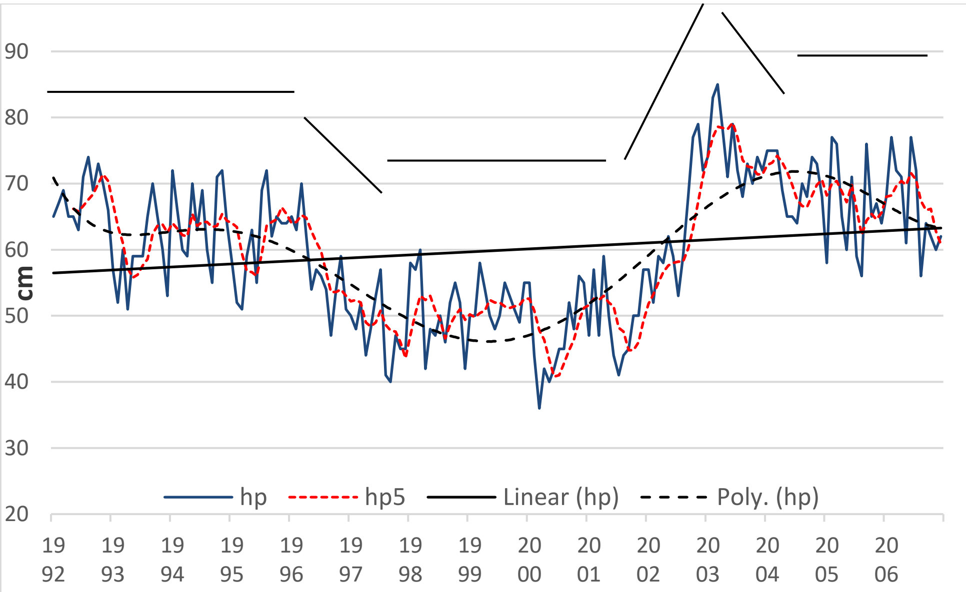

Fig 5. Re-aggradation of the riverbed at the Micfalău Hydrometric Station

The profile of the Feldioara station is located at the exit of the Brașov Depression, near a major water-collection area. The vertical dynamics of the riverbed display a completely different pattern compared to the upstream stations. The amplitude of variation is very large, 235 cm for hp and 208 cm for hp5. The small difference between these two values also indicates pronounced riverbed dynamics in this cross-section. Similar to the Sâncrăieni station, numerous periods were identified at Feldioara as well; however, here the longer periods are dominated by relative stability, interrupted by abrupt instabilities. The four stability periods encompass the years 1974–1976, 1982–1987, 1989–1996, and 2000–2004. It should be noted, however, that even within these periods there are sometimes significant variations of the riverbed. There are two periods of aggradation: one with a gentler slope in 1977–1978 and another very abrupt one in 1997. The three periods of degradation indicate sudden deepening of the riverbed: 1979–1981, 1988, and 1998–1999.

The linear trend is strongly downward, with the range of the line measuring 165 cm. The 6th-degree polynomial trend curve indicates the general tendency toward riverbed deepening, while displaying sinusoidal variations.

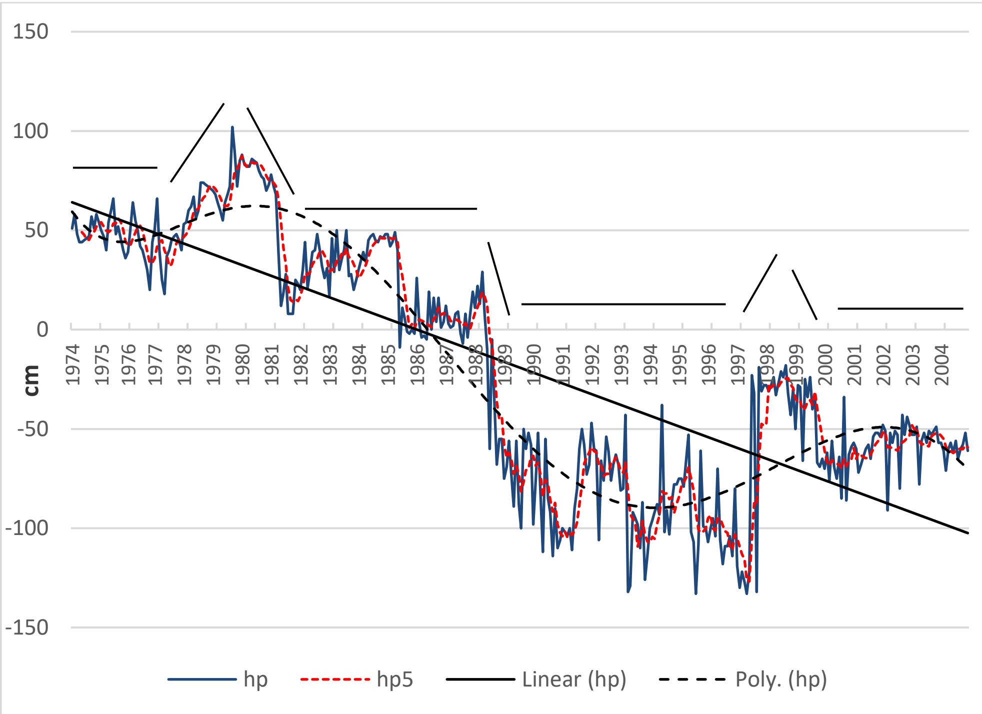

Fig 6. Re-aggradation of the riverbed at the Feldioara Hydrometric Station

3.2. **Comparative Data of the Stations**

The dynamics of the riverbeds at the four hydrometric stations differ according to the number of characteristic periods identified. The highest number of periods is recorded at the Sâncrăieni and Feldioara stations (12 and 9, respectively). The other two stations display the same number of periods (six each). In total, 33 characteristic periods were identified across the four hydrometric stations, of which 13 correspond to degradation and 10 to aggradation. Ten periods are characterized by relative stability. If only one type of period at a time is considered, the following observations can be made:

- Regarding degradation, Sâncrăieni has six periods, while Tomești and Micfalău each have only two.
- Aggradation is characteristic of only one period at Micfalău, but of five periods at Sâncrăieni.
- In terms of relative stability, Feldioara records four periods, whereas Sâncrăieni has only one.

Tabel 2. ***Characteristic Periods of Riverbed Evolution***

Hm.St.	Time interval	Degradation	Aggradation	Relative stability	Nr of periods	Lin.trend deviation
Tomești	1960-1996	1962-1964	1960-1961	1968-1984	6	+4 cm
		1985-1986	1965-1967	1987-1996		
Sâncrăieni	1971-2002	1979	1971-1978	1983-1984	12	+6 cm
		1982	1980-1981			
		1985-1986	1987			
		1988-1990	1991-1992			
		1993-1994	1995			
		1996-2002				
Micfalău	1992-2006	1997	2002-2003	1992-1996	6	+7 cm
		2004		1998-2001		
				2005-2006		
Feldioara	1974-2004	1979-1981	1977-1978	1974-1976	9	-165 cm
		1988	1997	1982-1987		
		1998-1999		1989-1996		
				2000-2004		

From Table 2, the frequencies of the three characteristic periods identified along the upper course of the Olt River can be calculated. The results indicate a state of relative equilibrium among them. Upward tendency (aggradation) and stability have the same frequency, at 30.3%, while the downward tendency (degradation) shows a certain dominance, accounting for 39.4%.

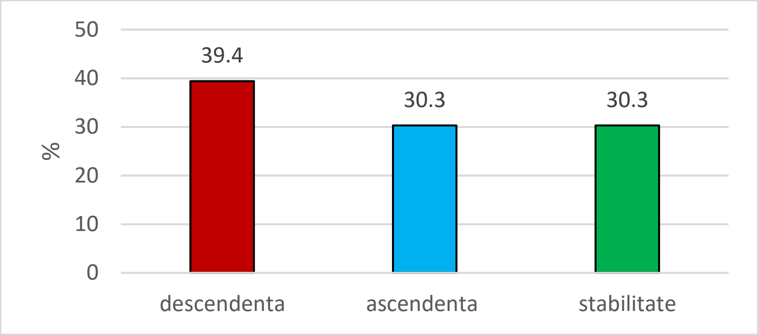

Fig 7. Frequency of the Characteristic Periods

Periods of downward and upward tendency, respectively, display different ranges (Δ, in cm). Depending on these ranges, the number of cases can be identified. In total, across the four hydrometric stations, there are 13 periods of downward tendency, with the number of cases varying between four (in the 20–30 cm interval) and zero (in the 40–50 cm, 70–90 cm, and 100–120 cm intervals). For upward tendency, 10 periods were identified, with the number of cases at the extremes also ranging between four (40–50 cm) and zero (30–40 cm, 50–80 cm, and 90–110 cm intervals).

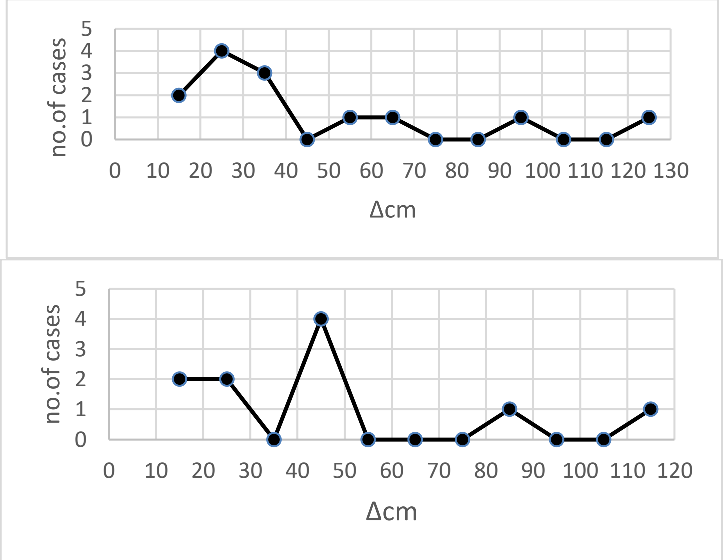

Fig 8. Number of Periods as a Function of Ranges During Downward and Upward Trends

The linear trend is positive at the first three hydrometric stations. The slopes are very weak, ranging between 4 cm and 7 cm. These small values indicate a generally good relative stability of the Olt River bed in this sector. A completely different trend is observed at Feldioara, where a very strong negative slope is evident, indicating very active deepening of the riverbed.

With regard to the 6th-degree polynomial trends, cyclicity cannot be distinguished due to the insufficient length of the databases. At Tomești, the inflection points are very weak, but they increase markedly at the subsequent three hydrometric stations. These characteristics depend on the number of delineated periods and on the amplitude of each period.

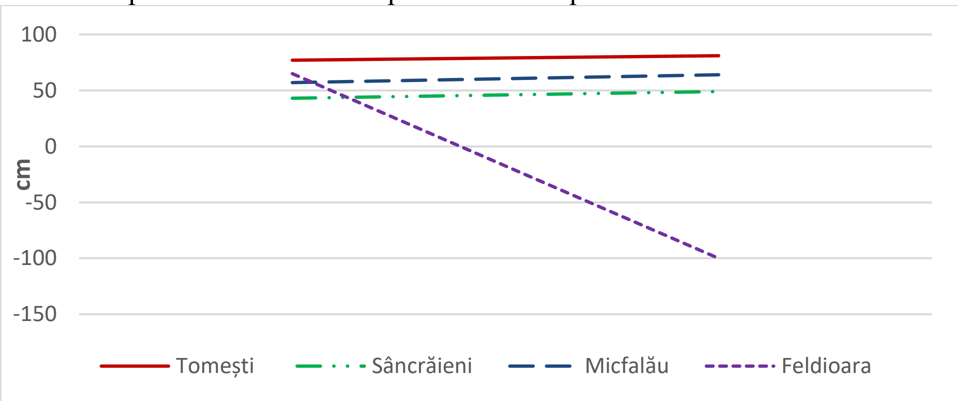

Fig 9. Comparison of Linear Trends

4.CONCLUSIONS

The dynamics of the upper Olt River bed display differentiated characteristics due to the relief units it traverses and the forces generated by the alternation of substrate types. At Tomești, where the cross-section of the hydrometric station is located in hard rocks, the range of re-aggradation is small (24 cm). At the next two stations, the amplitude of re-aggradation increases to about half a meter, because the cross-sections are situated within the friable deposits of the Ciuc and Sfântu Gheorghe depressions. At Feldioara, located at the outlet of the Brașov Depression, re-aggradation is very strong, with a pronounced negative trend. The number of characteristic periods varies from simple to double, and the slopes of the variations differ substantially. It is noteworthy that at the first three stations the general trend of vertical riverbed dynamics is positive, whereas at the last station it abruptly changes into a trend of marked deepening.

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