VULNERABILITY OF MOUNTAIN RIVERS TO WASTE DUMPING FROM NEAMT COUNTY, ROMANIA

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Abstract: *Lack of waste management facilities from mountain region often lead to uncontrolled disposal of waste on river banks polluting the local environment and damaging the tourism potential. Geographical conditions influences the distribution of human settlements which are located along the rivers and its tributaries. This paper aims to estimate the amounts of household waste generated and uncollected disposed into mountain rivers, taking into account several factors such as:proximity of rivers to the human settlements, the morphology of villages, length of river that crosses the locality(built up areas), local population, the access to waste collection services and waste management infrastructure. Vulnerability of rivers to illegal dumping is performed using GIS techniques, highlighting the localities pressure on rivers in close proximity. For this purpose, it developed a calculation model for estimation the amounts of waste (kg) that are dumped on a river section (m) that crosses a locality (village) or it is in close proximity. This estimation is based on the "principle of proximity and minimum effort" it can be applied in any mountainous region that are lacking or partially access to waste collection services. It is an assessment tool of mountain rivers vulnerability to waste dumping, taking into account the geographical and demographic conditions of the study area. Also the current dysfunctions are analyzed based on field observations.*

Key-words: waste dumping, indicators, assessment tool, GIS techniques, mountain rivers

1 Introduction

Waste management is a complex activity regulated at EU-27 level in order to improve current systems and to mitigate the existing disparities (Mazzanti and Zoboli, 2008;Mihai and Apostol, 2012). Also, the performance of a waste management system must take into account the geographical context of the region concerned (Chen, 2010, Passarini et al., 2011). Romania as the other new Member States is facing partial access of population to waste collection services particularly in rural territory (Mihai et al., 2012a;Apostol and Mihai, 2012). This leads to the uncontrolled waste disposal and environmental pollution (Lămăşanu and Mihai, 2011). Furthermore, local geographic conditions influence how to dispose the household waste in the context of poor waste management services (Mihai, et al., 2012b). In mountainous region, waste dumping into rivers is a common bad practice in the proximity of human settlements. The aim of this article is to develop a methodology that highlight the vulnerability of rivers and tributaries to waste dumping at local scale. In this regard, new indicators and formulas were proposed and the results are mapping using GIS techniques.

2 Materials and methods

This paper starts from the Q_{ud} indicator (quantity of waste uncontrolled disposed, t/yr per commune) which was performed according to the methodology developed by Mihai (2012) for 2003 and 2010 but applied to the villages scale from mountain region, using data from population census in 2002 because the new census data (2011) were not yet published at this level (village population).

Furthermore, this indicator was calculated even for villages from communes which were connected to waste collection facilities in 2010 (Farcasa, P. Teiului, Pipirig, Ceahlău, Grințies,

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Pângărați and Alexandru cel Bun). The share of rural population served in Neamt County for 2010 was only 35. 13% respectively 123042 inhabitants. In this context, the Q_{ud} indicator should be calculated according to the share of population with access to sanitation services. Unfortunately, there are no conclusive data for 2010 (neither for 2003) held by local authorities concerning the precise number of people connected to these services at commune level and on the other hand, field observations confirm that waste dumping takes place in these localities, although there are facilities for waste collection. Therefore, the population is only partially served by waste collection services and the presence of certain facilities does not ensure an efficient and widespread collection of household waste generated from the locality concerned. Because of these uncertainties, the analysis for 2010 and 2003 took into account following scenario: 60 % rate of collection in 2010 and 30 % in 2003 for localities which was connected to waste collection services. In these cases, the Q_{ud} is diminished by these shares. Starting from this indicator, it can be calculated according to the proximity of villages to rivers and tributaries, the Q_{wr} indicator for each locality in the study area:

(1) Q_{wr} (kg/yr) = Q_{ud} (kg/yr)*Sd,

Q_{wr} - waste estimated to be disposed on river banks /into rivers or streams by a locality (village)

Q_{ud} (kg/yr) = amounts of waste uncontrolled disposed by a locality (waste dumping or burning)

Sd= share of indicator according to the average distance between the built-up area of a locality and the river/stream in the proximity.

Rivers exposed to illegal dumping are those that cross the village (residential area) or pas to its proximity (<1km). Depending on the average distance calculated for each village, it is performed a weighting of Q_{ud} indicator according to [Table. 1.]

Table. 1 Correlation with the average distance of Q_{ud} indicator

Average distance between built-up area and rivers/streams in the proximity (m)	Share of Q_{ud} indicator (Sd)
1000 -800	0. 2
799-600	0. 4
599-400	0. 6
399-200	0. 8
199-1	0. 9

Calculation model for Bicaz-Chei village (average distance - 269. 6 m, so Sd=0. 8):

Q_{wr2003}=212. 546*0. 8= 170. 036 (t/yr) / Q_{wr2010}=223. 975*0. 8=179. 18 (t/yr)

Thus, an important role plays the calculation of average distance between settlements and rivers /streams in the proximity which are vulnerable to waste dumping. Therefore is calculated the distance to the hydrographic network within the localities, in other words, the distance between the border of village (line of last households) and rivers/streams that cross the locality. But first, it is calculated the distance for both sides of the course in 3 -5 points (for each side where appropriate) and calculate the average for the right and left side then the final average. In the mountainous region, this situation is very common and if a village is developed only on one riverbank, this average is the final one. Secondly, it is calculated the distance to the hydrographic network from outside localities in other words from rivers or streams that pass near settlements (<1 km) being also vulnerable to pollution from waste. This distance is related to river/stream that has the longest sector through village spot. Thus, can be found settlements developed only along the river Bistrita (Lunca, Madei, Soci) or developed on its tributaries (Farcasa, Sabasa, Poiana Largului, Hangu).

In other cases, a village is balanced developed on the Bistrita riverbank and on its tributary, thus, the measurement points of average distance were taken for both branches of the the village, such as Borca. These distances were measured based on topographic maps (scale of 1:25 000) using GoogleEarth program and Corine Land Cover (CLC) creating a database for all vilages from study area, an example is shown in [Fig 1].

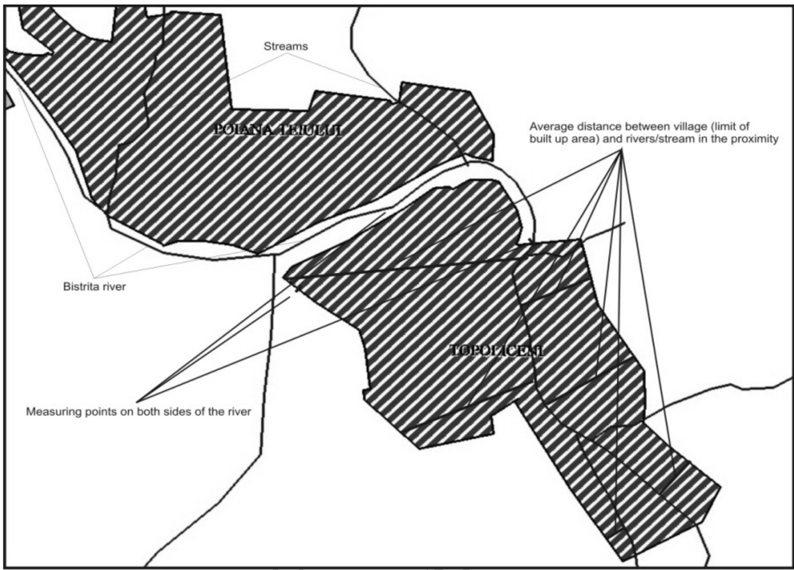

Fig. 1 Measurement points for calculating the average distance

Qwr indicator provides a quantitative estimate of potential waste to be disposed into rivers /streams which pass through villages. The assessment of this vulnerability is based on the pressure of a locality (village) on the river section by household waste dumping of local population

(2) $L_{wr} = Q_{wr}/ L_r$

L_{wr} = locality pressure by waste dumping on river/stream

L_r = the lenght of rivers/stream section (m) vulnerable to waste dumping (that passes the built-areas of village or its proximity < 1 km).

Often, villages are crossed by several streams and their length are added together as total sum (such as settlements developed on tributaries of Bistrița and Bicaz rivers), L_r being calculated for each village. Calculation model for Bicaz-Chei village (Lr- 5215 m):

L_{wr2003}=170.036/5125*1000 = 33.177 kg/m/yr,

$L_{wr2010=}$ 179.18/5125*1000 = 34.961 kg/m/yr

Vulnerability of rivers to waste dumping is reflected on the one hand by values of Q_{wr} indicator (kg/yr per village) and on the other hand by values of L_{wr} indicator (kg/m/yr), these calculations are made for each village from the study area.

Therefore, localities pressure on rivers by waste dumping are assessed according to the following values of L_{wr} (kg/m/yr):

- ✓ 0. 1 -2 low
- ✓ >2-5 moderate
- ✓ 5-10 significant
- ✓ >10 high

3. Results and discussion

Vulnerability of rivers to waste dumping is more significant in 2003, because the communes from study area had no access to sanitation services, except Gârcina and Alexandru cel Bun where the population was partially covered with these services. In the mountainous region, often villages are crossed by rivers and their tributaries, these streams being vulnerable to waste pollution.

Most distant households are located generally below 500 m from rivers, in this context Q_{wr} values have a significant share of Q_{ud}.

Morphology of a village through linear, compact or tentacular development of buildable area on riverbanks or in their proximity, causes the differentiations between Q_{wr} and L_{wr} indicator as it is outlined in [Table. 2.]

Table . 2. Maximun and minimum values of L_{wr} indicator in 2003

2003	Village	Top 5- maximum values of Lwr		River/tributary in the proximity
		L_{wr} (kg/m/yr)	Q_{wr} sat (t/yr)	
1	Bicaz-Chei	**33. 177**	170. 036	Bicaz, Dămuc
2	Ticoş-Floarea	**27. 908**	21. 545	Bicaz
3	Farcaşa	**19. 942**	66. 828	Farcaşa, Bistriţa
4	Borca	**17. 853**	58. 755	Borca, Bistriţa
5	Nechit	**17. 75**	96. 982	Nechit
		Top 5 – minimum values		
1	Trei Fântâni	**0. 082**	1. 035	Bicăjel, Soloc
2	Ardeluţa	**0. 372**	1. 656	Tarcău
3	Gherman	**0. 398**	4. 466	Bicaz, Gherman
4	Roşeni	**0. 9**	3. 753	Roşeni, Bistriţa
5	Schitu Tarcău	**0. 989**	2. 61	Tarcău

In this context, some streams have a significant vulnerability (>10. 5 kg/m/year) on area of following villages such as Hangu, Bicazu-Ardelean, Ivaneş, Luminiş, Neguleşti, Tarcău, Cuejdi, Gârcina and Almaş. Tributaries of Bistriţa river, upstream of Izvoru Muntelui lake are most exposed to waste pollution such as Borca, Farcaşa or Pârâul Cârjei. Also, certain sections of Bistriţa river are highly or significantly exposed to waste dumping on the area of following villages located upstream of Izvoru Muntelui lake:Lunca, Madei, Popeşti, Frumosu, Poiana Teiului, Ruseni, Topoliceni, Săvineşti, see [Fig2].

This situation was characteristic for 2003-2009 period when waste collection services were limited and uncontrolled waste disposal was tolerated by local authorities. Waste dumped on rivers or its tributaries were transported downstream by floods to Izvoru Muntelui lake, several waste accumulating behind the dam (especially PET and wood waste). Localities near the dam (Chiriţeni, Grozăveşti, Rugineşti, Potoci) had a moderate impact, these localities being built on the slopes.

Downstream of the dam, the most vulnerable sections of Bistrita river were on the area of Capşa (included in territorial administrative unit of Bicaz City) Tarcău and Straja villages.

The villages near of Vaduri, Pângăraţi and Bâtca Doamnei lakes had a moderate pressure on Bistrita river, ussually household waste is disposed in open dumps located on larger alluvial plains but localities pressure is higher for villages developed along tributaries (Pângăraţi, Agarcia or Bistriţa). Also the waste collection services from Alexandru cel Bun commune (formerly Viişoara) reduced the potential impact on streams in the proximity.

The upper course of Ozana river is significantly exposed to waste dumping on area of following localities Boboieşti, Pipirig and Leghin, regarding the river Bicaz most vulnerable sectors are those which cross Bicaz-Chei and Bicazu-Ardelean villages,

Implementation of the EU acquis requires on the one hand, the closure of rural dumpsites until July 16, 2009 and on the other hand requires local authorities to provide waste collection facilities (Apostol and Mihai, 2011). Therefore, at county level, the share of rural population connected to sanitation services was 15. 4% in 2009 and increased to 35. 13% in 2010, but these new waste management services were still in the development stage and they did not cover the full population of a commune. On other side, local population do not give up easily to illegal dumping of household waste into rivers or on their banks in the proximity.

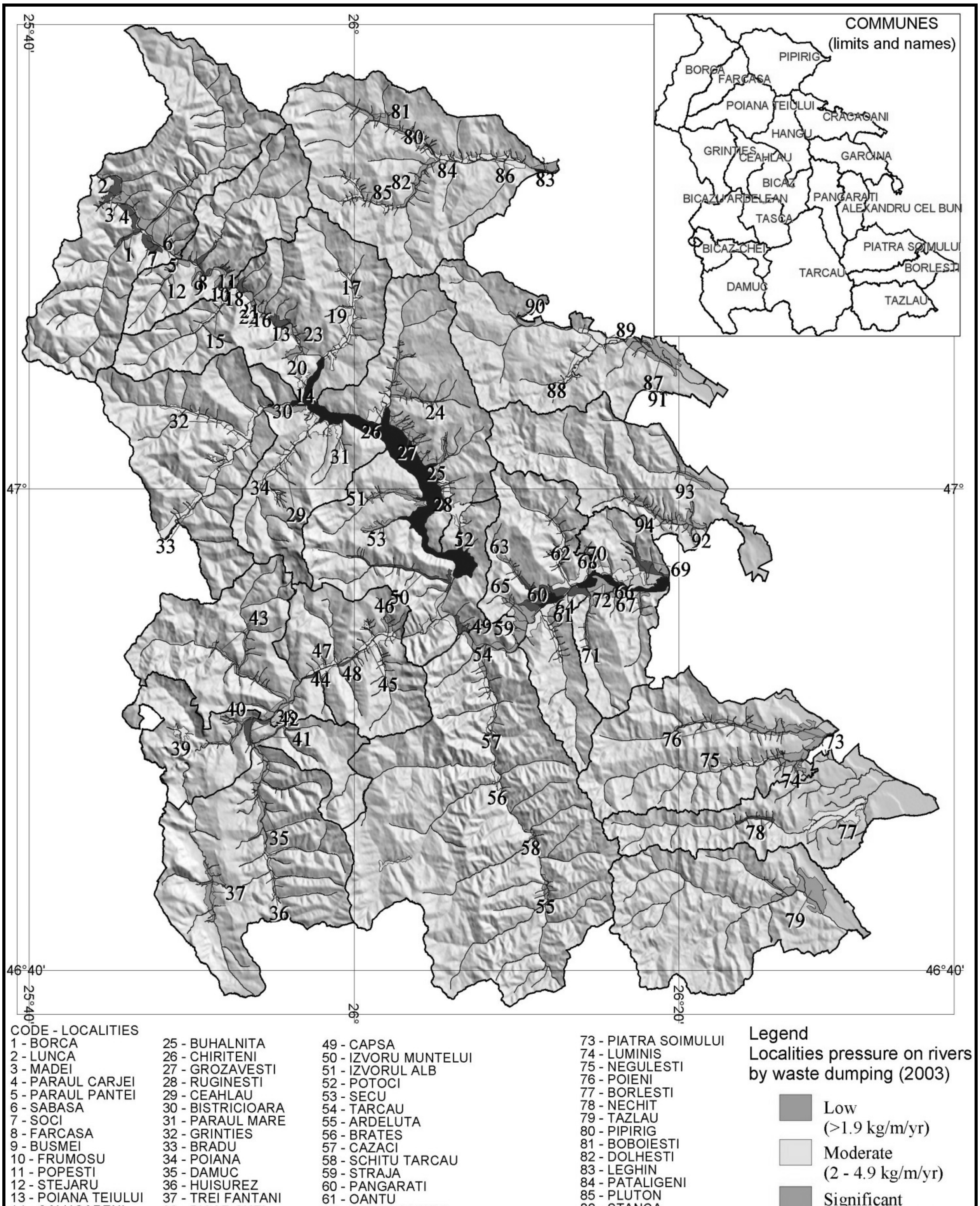

Fig. 2 Localities pressure on rivers by waste dumping in mountain region (2003)

Table . 3. Maximun and minimum values of Lwr indicator in 2010

2010	Village	Top 5- maximum values of L_{wr}		River/tributary in the proximity
		L_{wr} (kg/m/yr)	Q_{wr} sat (t/yr)	
1	Bicaz-Chei	**34.961**	179.18	Bicaz, Dămuc
2	Ticoş-Floarea	**29.3**	22.703	Bicaz
3	Borca	**18. 813**	61. 915	Borca, Bistriţa
4	Nechit	**18. 713**	102. 196	Nechit
5	Ticoş	**12. 992**	19. 276	Ticoş, Bicaz
		Top 5 – minimum values		
1	Trei Fântâni	**0. 084**	1. 0512	Bicăjel, Soloc
2	Roşeni	**0. 379**	1. 582	Roşeni, Bistriţa
3	Ardeluța	**0. 42**	1. 746	Tarcau
4	Gherman	**0. 9**	4. 707	Bistriţa, Gherman
5	Schitu Tarcău	**1. 046**	2. 706	Tarcău

This fact is outlined in mountain villages developed linearly along the rivers where bins or collection points are located to sizeable distances (> 300m), in these circumstances the waste collection services is inefficient. Frequently, the distant households from these collection points prefer waste dumping on riverbanks or to burning them. Door to door collection is a more proper method in this context.

However, localities pressure on rivers by waste dumping is more limited (often moderate or low) compared to 2003 in the villages of following communes such as Farcaşa, Poiana Teiului, Pipirig, Ceahlău, Pângăraţi or Alexandru cel Bun. Lack of sanitation servicces from others communes maintain the high and significant pressure on rivers in the proximity.

The touristic region of Bicaz Valley was highly vulnerable to waste pollution on the territory of Dămuc, Bicaz-Chei and Bicazu-Ardelean localities except of small villages such as Trei Fântâni and Gherman noted in [Fig 3].

The project on the development of selective waste collection facilities in this region and the building a transfer station in Tasca commune was not yet finished in 2010. The lack of these facilities has a negative impact of local environmental factors and tourism potential.

In top five localities with the highest values of L_{wr}, three are from this region respectively Bicaz-Chei, Ticoş-Floarea and Ticoş. This fact highlights the high vulnerability of Bicaz river and its tributaries (Dămuc, Ivaneş, Ticoş, Jidan) to waste dumping. Development of waste management services in 2011-2012 will improve this situation.

Comparative analysis of the top [Table1] and [Table 2] between 2003 and 2010 on the maximum and minimum values of L_{wr} indicator shows the same structure with little changes, thus highlighting particularly for maximum values, the lack of concrete steps for the development of waste management facilities in 2003-2010.

Bistrita River remains the most important “waste collector” of household waste on its course, being generated by following communes such as Borca, Farcaşa, Poiana Teiului, Tarcău, Pângărati plus the waste dumped on smaller tributaries (high pressure or moderate), like Borca, Sabasa, Farcaşa, Hangu, Iapa, Calu and Nechit. Also exposed to waste pollution are the rivers Tazlău (on area of Tazlău village) and Cracău (on area of Crăcăoani village) as in [Fig. 4.]

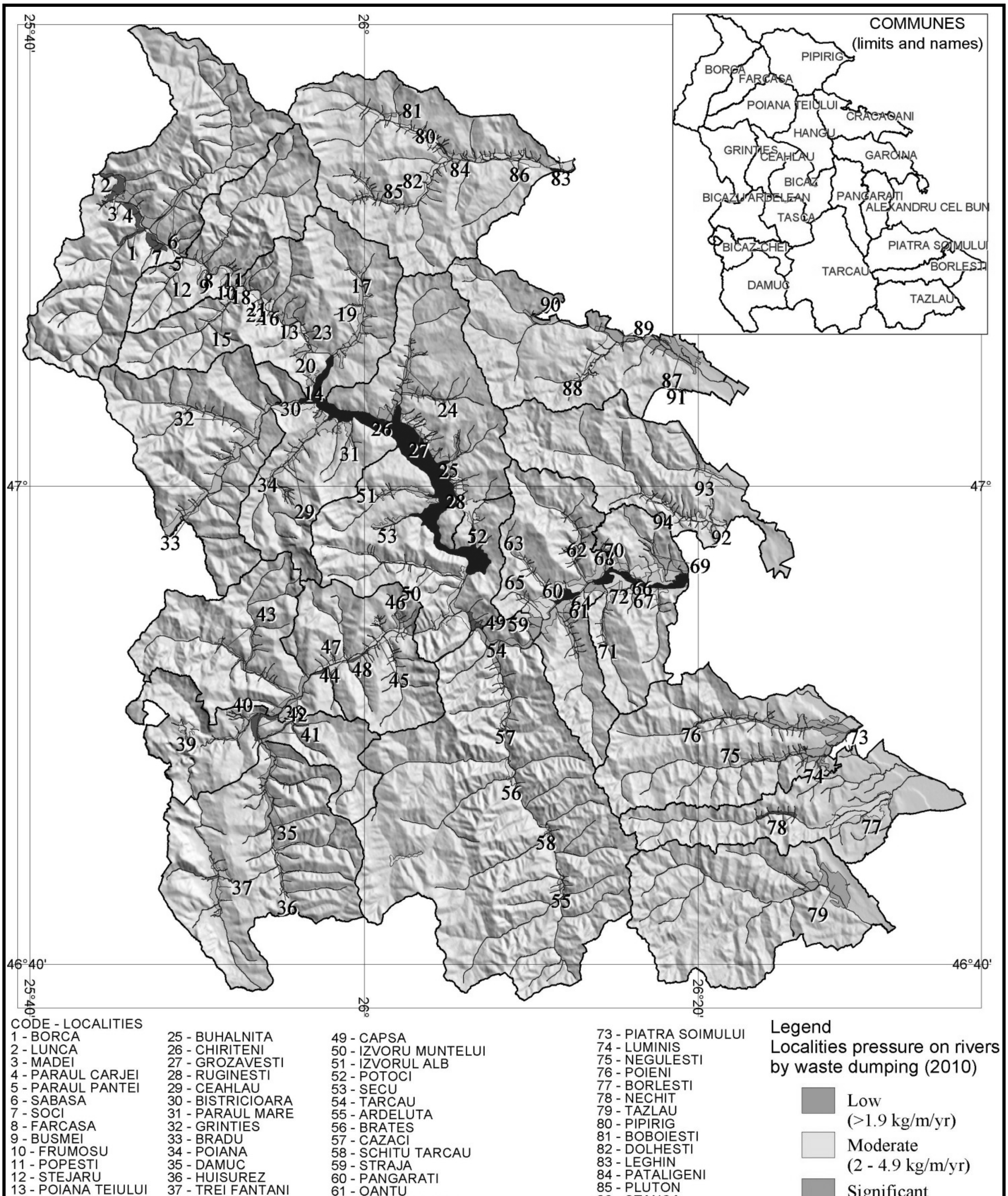

Fig. 3 Localities pressure on rivers by waste dumping in mountain region (2010)

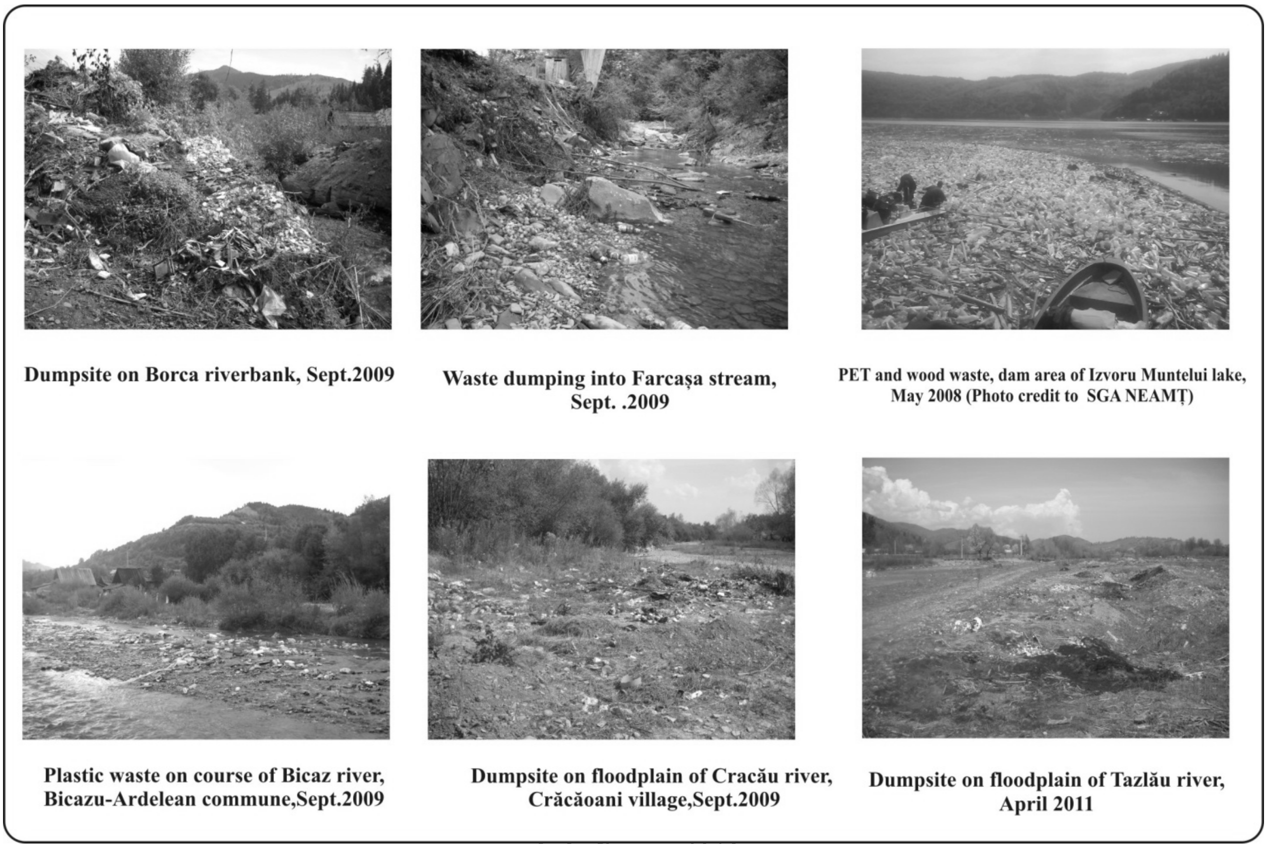

Fig. 4 Rivers exposed to illegal dumping of waste in study area (field observations)

4 Conclusion

This paper proposes a new method to assess the vulnerability of mountain rivers to waste dumping on the area of villages from Neamt County. L_{wr} indicator allows a quantitative analysis of potential waste dumped on a river/stream section within a village. Also it is highlighted different degrees of vulnerability for major rivers (Bistriţa and Bicaz) on short distances, as they pass through various localities. This method may be a necessary tool for EIA studies of rural communities.

High and significant vulnerability to waste dumping for many sectors of rivers and its tributaries in 2003 (as well until 2009), outlining the priority to develop waste collection facilities in this region of county. Extension of waste management services after 16 July 2009 has improved the situation compared to 2003 but still at a low level. Rivers are still vulnerable to illegal dumping of waste due to the implementation of a rudimentary and inefficient waste management system or due to partially access of population to these services. Local people should have facilities for separate collection of biodegradable and recyclable fractions.

The new transfer station from Taşca commune will serve most of rural communities of study area and will lead to improved quality of waste management services in this region.

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