Actual in - Stream Mining in Alluvial Rivers: Geomorphological Impact and European Legislation

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Abstract

Throughout Europe, alluvial rivers were intensively mined during the first part of the century. Gravel mining caused incision and narrowing in a non-reversible way. Despite this knowledge, gravel beds are still exploited in some Romania's rivers such as Lower Siret River and Buzău River, located east and south-east of Carpathians Mountains. This study focuses on two particular reaches of these rivers that concentrate historically and nowadays gravel mining and engineering works, being also European protected areas in Natura 2000 network. The aims of this work are to analyze, in a diachronic way, (i) the evolution of gravel mining activity, (ii) to assess the impact of these interventions on river channel and (iii) to evaluate their management in the context of protected area. The study relies on GIS analysis (maps and aerial photos of the last three decades), field survey and discussions with local authorities and managers of the sites. The results show an increasing development of in-stream mining since five years in order to sustain the local economy. On 30-km reach on Lower Siret River, eleven gravel mining extract at least 1.4 million cubic meters of sand and gravel per year. On 20-km reach on Buzău River, one mining removes in-stream 0.12 million cubic meters of sand and gravel per year (and eleven extract from the floodplain). In-stream extraction is explained as necessary to prevent bed aggradation, to protect infrastructures and to limit the bank erosion, whereas this activity accentuates drastically this trend. Near future management projects plan to continue this activity, therefore choosing a short-time over a long-time solution.
Keywords: Buzău River, In-stream mining, Morphological impacts, Natura 2000, Siret River.

Introduction

In-stream mining was widely used throughout Europe especially for construction purposes. The extraction can significantly affect physical, chemical and biological characteristics of mined streams. Among hydromorphological effects, several were already shown: upstream and downstream incision, lateral channel erosion, bed armouring modification, disconnection of the floodplain consequently to channel incision, water table lowering (Kondolf, 1994; Bravard *et al.*, 1997; Kondolf, 1997; Surian and Rinaldi, 2003; Rinaldi *et al.*, 2005). There are three types of in-stream sediment mining (Kondolf, 1994): dry-pit mining, wet-pit mining below the water level and bar skimming consisting of removing all the material in a gravel bar, to which must be added floodplain pit mining. All of them have a specific impact on river system: wet and dry-pit mining directly alter the channel geometry producing a local sediment deficit; floodplain pit mining, commonly close to the active channel, transforms floodplain into an open pit which could capture channel during floods.

Beyond these morphological effects the actual in-stream mining has to be in line with environmental issues and especially with European Directives. European Union demands to evaluate the environmental impact of in-stream mining projects (2011/92/EC), relying on Water

Framework and Flood directives (2000/60/EC and 2007/60/EC), and on Habitats and Birds directives (92/43/EC and 2009/147/EC). In addition, in-stream mining has to be strictly monitored in order to preserve the habitat (European Commission, 2010). Since 2007, Romania conducts the implementation of European directives. Thus, mining activity in river bed and on river banks is legal only for dredging and recalibration purposes (Romanian Water Low 107/1996).

Starting from these concerns on European level, our paper aims at: i) assessing recent in-stream mining; ii) evaluating its morphological impact; iii) analysing EU Legislation application on a regional scale. It is a diachronic study, focusing on examples from Romania, before and after 2007.

Data, methods and presentation of the studied areas

The results of our study rely on three types of data and methodology.

i) The diachronic study comprised maps and aerial photos: topographic maps from 1980, ortophotoplans from 2005 and 2008 provided Romanian National Agency of Cadastre and Real Estate Advertising; and Google Earth images from 2009, 2010, 2011 and 2012. They were analysed in Quantum GIS, by converting all the images in Google Mercator projection. We analysed the braided active-channel (channels and alluvial deposits) and the bed material exploitation perimeters. Consequently, we quantified eroded/accumulated and exploited areas. This digitising operation and, consequently, the results depended on the water level.

ii) In-stream mining management (exploitations – location, volume, area, official role, authorisation period and projects of restoration) resulted from 26 official reports since 2011. These reports (Environmental Impact Assessment, EIA), aiming to obtain authorisation for in-stream mining for various private companies, were elaborated by other private companies specialised on environmental impact studies. Then, they were approved by regional/departmental governmental agencies. They are available on the website of the National Agency for Environment Protection.

iii) The current state of river environment was observed during field surveys from 2009 – 2012.

The Siret River, located east of the Carpathians, has the largest catchment of Romania with a total area of 42,890 km² and is one of the last tributaries of the Danube River (Fig. 1). The mean annual flow is 210 m^3/s at the Lungoci gauging station (situated 105 km upstream of the Danube confluence). The main tributaries are the Putna River, the Râmnicu Sărat River, and the Buzău River on the right bank, and the Bârlad River on the left bank. Buzău River (302 km in length, 5,264 km^2 watershed area, and 29 m^3/s mean annual discharge at Racoviţa gauging station) comes down the Carpathians, crosses the Subcarpathians and the Romanian plain. This study focuses on two areas of the Siret River basin. The first, 30 km long, is located on Lower Siret River, downstream the last dam (Movileni) of the River. The second, 20 km long, is located on Middle Buzău River, in the Romanian plain, in the vicinity of Vadu Paşii Commune. These two studied areas are historically a resource basin of mineral extraction. Engineering control works are various on both, Lower Siret River and Middle Buzău River, and they are designed to control river dynamics and to mitigate fluvial risk linked to floods and bank erosion thanks to a dense network of dykes, dams and groynes. In addition, there are three Natura 2000 sites on Lower Siret River (2 Sites of Community Importance –SCI, *Pădurea Torceşti*/*Torceşti forest* and *Lunca Siretului Inferior/Lower Siret Floodplain*; 1 Special Protection Area –SPA, *Lunca Siretului*

Inferior/Lower Siret Floodplain) and one on Middle Buzău River (1 SCI, *Lunca Buzăului/Buzău Floodplain*).

The recent expansion of in-stream mining in Romania

The Siret River catchment is a historical resource pool of extraction especially between 1960's and 1989. Rivers in Siret Basin represented more than 33% of gravel resources available in Romania riverbed. Since the collapse of communism the exploitation of gravel continues to increase: in 1997, 2 104 000 m^3 were exploited in the Siret River catchment (296 gravel pits among which 164 in-stream mining- Ilie, 2007) whereas it reached 3 017 844 m^3 in 2006 (Ministerul Mediului, 2010).

The mining activity intensified on study reaches in the last years.

Middle Buzău River floodplain is exploited since the communist period. In the vicinity of Vadu Paşii Commune, gravel and sand exploitation peaked probably between 2005 and 2010; since it seems to be decreasing, both, in terms of exploited perimeter and active bars skimming:

- 4 exploitations in 1980 by bar skimming downstream Vadu Paşii bridge (down to 0.3 m below water level) and in dry-pits, in floodplain and on river terrace;
- 8 exploitations in 2005, both, by bar skimming and in dry-pits (exploited perimeter 1.8 km^2) (Fig. 4A);
- 9 exploitations in 2008, both, by bar skimming and in dry-pits;
- 14 exploitations in 2010 in dry-pits (exploited perimeter 1.4 km^2);
- 12 exploitations in 2012 in dry-pits; only 1 gravel pit was authorised to skim the alluvial bar located downstream Vadu Paşii bridge (down to 0.7 m below the water level) (Table 1).

Lower Siret River is a quite new location of exploitation. There are at least 15 new gravel pits between 2010 and 2013 on the Lower Siret River among them, 10 were mining in wet-pits (Fig. 2, the mining is carried out 2 m below the water level with dredges), 2 were mining in-stream for bar skimming and 3 in the alluvial plain.

The recent morphological dynamics of Lower Siret and Middle Buzău rivers and the implication of in-stream mining

Middle Buzău and Lower Siret rivers registered an intense recent dynamics. Between 2005 and 2010 the mean lateral erosion in the Lower Siret River studied area rises 72. 5 m and can reach 292 m. There are three main sectors where the lateral erosion is the highest: downstream the dam (Fig. 3A) the mean erosion reaches 110 m (i); up to the Bârlad confluence (Fig. 3C) (ii); and downstream the bridge (Fig. 3-B) (iii). Field surveys allow us to precise the lateral erosion rate between 2009 and 2011 for this last area: downstream the railway bridge the lateral erosion can be assessed thanks to the deterioration of groynes: it reaches 6 meters. This lateral channel instability is threatening arable land, infrastructure such as dykes and bridge, and urban areas.

Between 2005 and 2010, Middle Buzău River reactivated a part of its abandoned active-channel and formed new alluvial bars, gaining 0.2-0.3 km^2 (function of water level) (Fig. 4 B and C). New alluvial bars formed especially in the vicinity of abandoned bar skimming activity, like in the case of reaches 1 and 2 on Fig. 4. Thus, aggradation seems to be a natural process of evolution in the case of Middle Buzău River.

This lateral widening is recent in both cases. The Lower Siret active channel width was reduced by 54% between 1940 and 1981 due to river embankment and afforestation (Salit *et al*, 2012). Whereas the Middle Buzău River had narrowed by almost 50% between 1980 and 2005 in relation to various engeeniring works from upstream – *i.e.* two reservoir dams construction, river embankment (Ioana-Toroimac *et al*., 2011).

Table 1: Characteristics of some gravel pits on the Lower Siret River and the Middle Buzău River (ANPM, 2011 and 2012).

Name	Location	Licensed volumes m^3	Surface m^2	Official role	Period
		Siret River			
Movileni aval I	Riverbed	139 020	59341	Dredging	-
Movileni aval III	Riverbed	259 200	94 366	Dredging	2012-2018
Movileni	Alluvial plain	291 902	138 295	Fish farming	10 years
Movileni 4	Riverbed	147 907	-	Dredging	2013-2014
Umbrăreşti	Alluvial plain	778 474	137 951	Fish farming	10 years
Condrea	Alluvial plain	619 075	-	Fish farming	2013-2020
Condrea I	Riverbed	51 500	30380	Dredging	-
Lieşti III	Riverbed	35 828	16 000	Dredging	-
Bilieşti I	Riverbed	5 000	6 280	Dredging	2011-2012
Bilieşti III	Riverbed	116 000	58 300	Bed recalibration	10 years
Vadu Roşca 03	Riverbed	66 950	33 500	Dredging	10 years
Calienii Vechi	Riverbed	20 000	6 300	Dredging	10 years
Suraia II	Riverbed	-	15 054	-	-
Vadu Roşca 02	Riverbed	-	-	-	-
Bilieşti 05	Riverbed	-	-	-	-
		Buzău River			
Focşănei 2	Alluvial plain	52 000	17 410	Exploitation	2011-2012
Vadu Paşii	Riverbed	120 000	-	Dredging	2011-2014
Stănceşti 5	Alluvial plain	20 000	-	Exploitation	-

The EIA reports on the Lower Siret River gave several explanations: the lateral erosion is caused by dams upstream, by the historical floods of July 2005 (4,650 m^3/s at Lungoci gauging station) and June 2010, by uncontrolled in-stream mining and by an accumulation of sediment. According to them, the completion of the Movileni dam is the first cause of the increasing of the lateral erosion downstream and the dredging of exceeding sediment is the solution to restore channel capacity. Whereas conducting stream mining downstream a dam, combine the effects of both impacts to produce an even larger sediment deficit. In the case of Middle Buzău River, new alluvial bars seems to show hydrosystem's recover after human interventions. This evolution followed a 10-years flood registered in July 2005 on Middle Buzău River (ABABI, 2013). Consequently, it is difficult to establish the precise role of every factor (bar skimming abandon and important flood) in this evolution.

To conclude it is not possible to determine precisely the role of in-stream mining on the channel lateral dynamics in these two areas. Too many factors could have played a role in the morphological dynamics such as dam completion and major floods of 2005. Thus, this activity may exacerbate the process and disrupt the preexisting balance between sediment supply and transporting capacity (Kondolf, 1997). In addition to the direct alteration of the river morphology, in-stream mining may create environmental issues in protected areas.

The in-stream mining and the EU legislation

Intense in-stream mining activity is motivated at a regional scale by various explanations according to EIAs.

i) It aims limiting lateral erosion and, thus, protecting river banks. Or the results of this study confirm the opposite evolution of the river banks. This lateral erosion threatens villages, especially on the right bank of Lower Siret River. Since 2009, 7 new projects of banks protection were planned; among them 3 were executed; it represents the main issue of water and river management on this part of the River (Fig. 5).

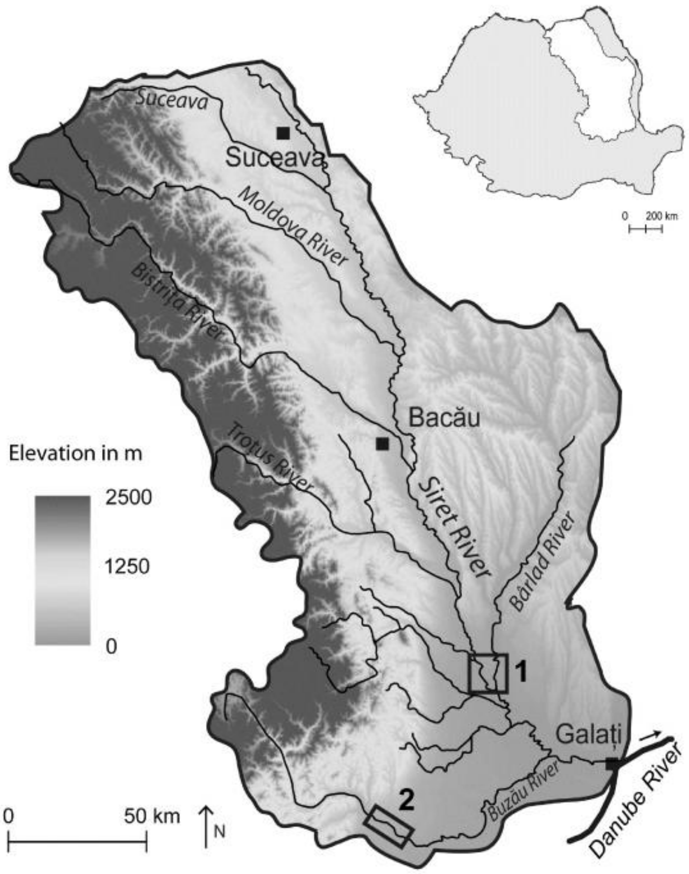

Fig. 1: Location of the Siret Basin and of the studied reaches (1-Lower Siret River; 2-Middle Buzău River).

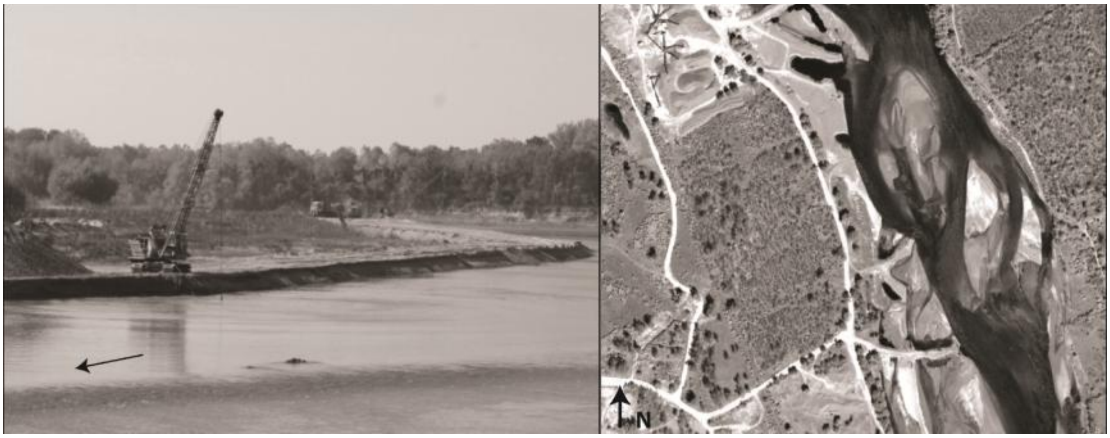

Fig. 2: In-stream mining with a dredge on Lower Siret River – October 2011 (left). Gravel pits on Lower Siret River from Google Earth – June 3th 2010 (right).

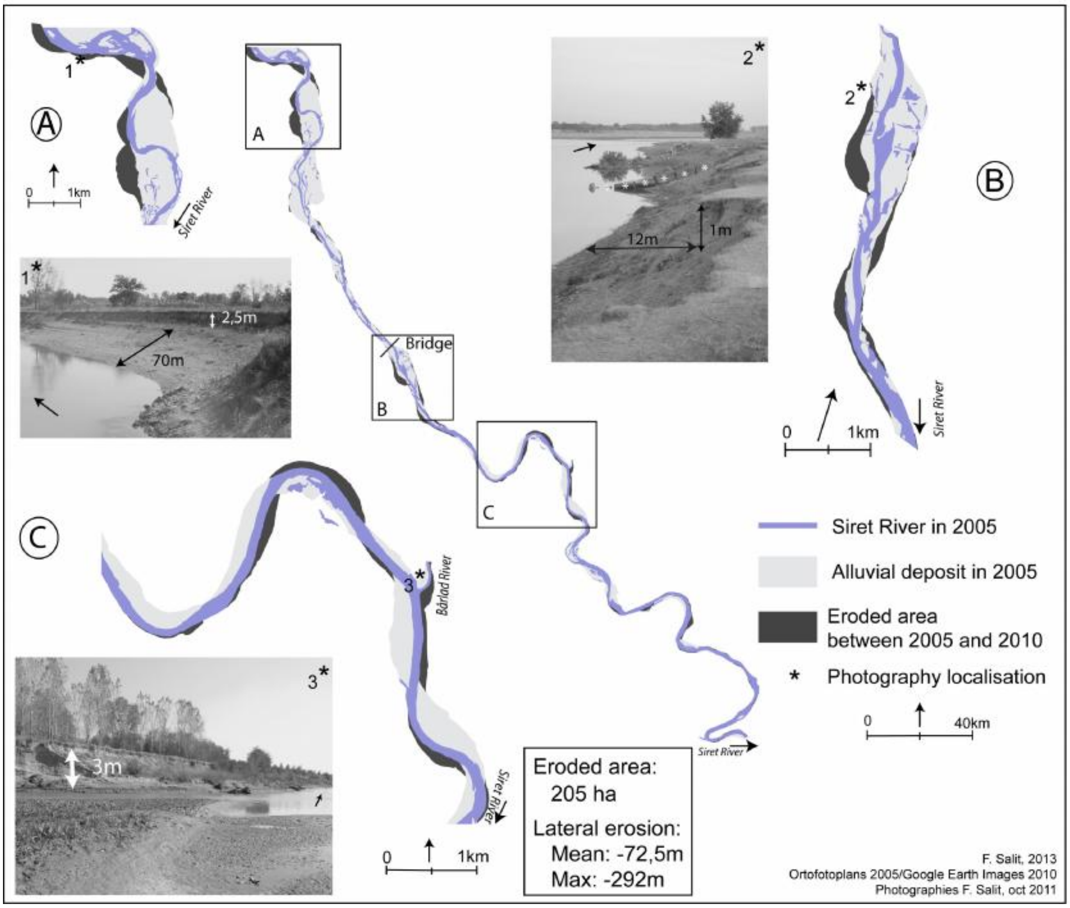

*Fig. 3: Lateral dynamics on Lower Siret River between 2005 and 2010. A- Eroded bank downstream Movileni dam. B- Eroded bank downstream the Railway Bridge. *: Blocks of destroyed groyne. C- Eroded bank at the Bârlad confluence.*

ii) It aims dredging river channel in order to increase its capacity and, thus, to prevent floods. This motivation is in accordance with the Romanian National Strategy for Flood Management (Ministerul Mediului, 2010), which recommends a 30 % increase of the channel capacity by 2035, in order to limit the flooded areas. But Water and Flood directives require adopting an integrative management of water resource and flood at the catchment scale. This involves preventing the downstream effects of any project on the riverbed. Increase channel capacity can limit flooded areas on short term, but, as it was already shown in previous studies, the combined effects of the water retention reduction in the floodplain and of the increasing flood magnitude heighten flood hazard downstream. This practice, based on granting permission to exploit under a motivation largely accepted, is well known; given the number of detrimental effects of sediment mining from active channels, it is imperative to take action and to eliminate it (Rinaldi *et al*., 2005).

iii) It aims dredging alluvial bars in order to assure bridges' stability and to allow floods' passage. In the case of Vadu Paşii Bridge, engineering works, aiming to prevent bed incision under the bridge, amplified, both, this process and lateral erosion downstream (Fig. 4D); thus, future bar skimming seems to be justified. However, some authors recognise this practice as a benefit in aggrading channels (Rinaldi *et al*., 2005).

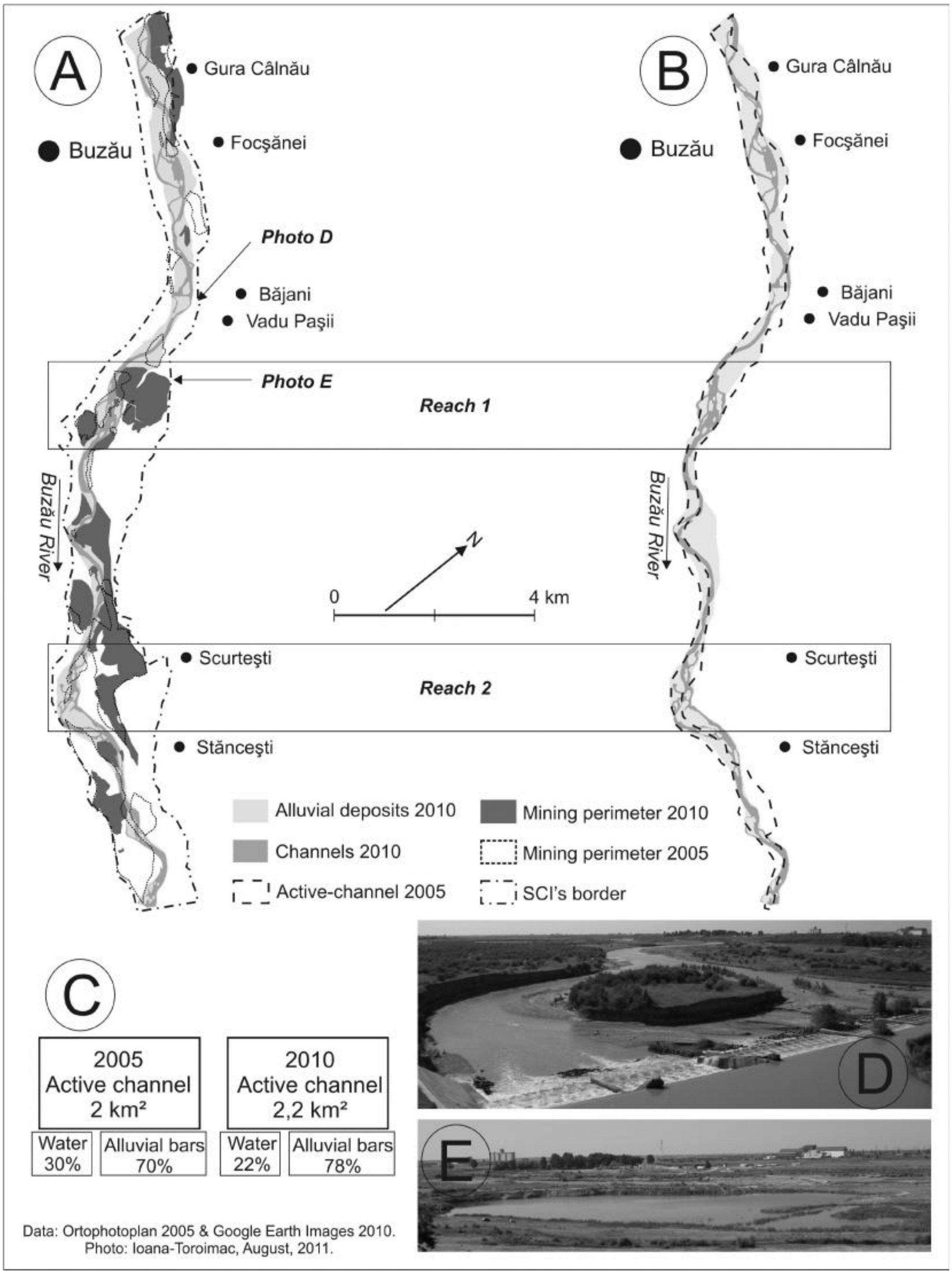

Fig. 4: Middle Buzău River dynamics and in-stream mining. A) Mining perimeters' location in river's alluvial plain. B) Active channel's dynamics between 2005 and 2010. C) Active channel area's evolution between 2005 and 2010. D) Alluvial bar to be skimmed downstream Vadu Paşii bridge. E) Abandoned gravel pit. SCI: Site of Community Importance (Buzău Floodplain).

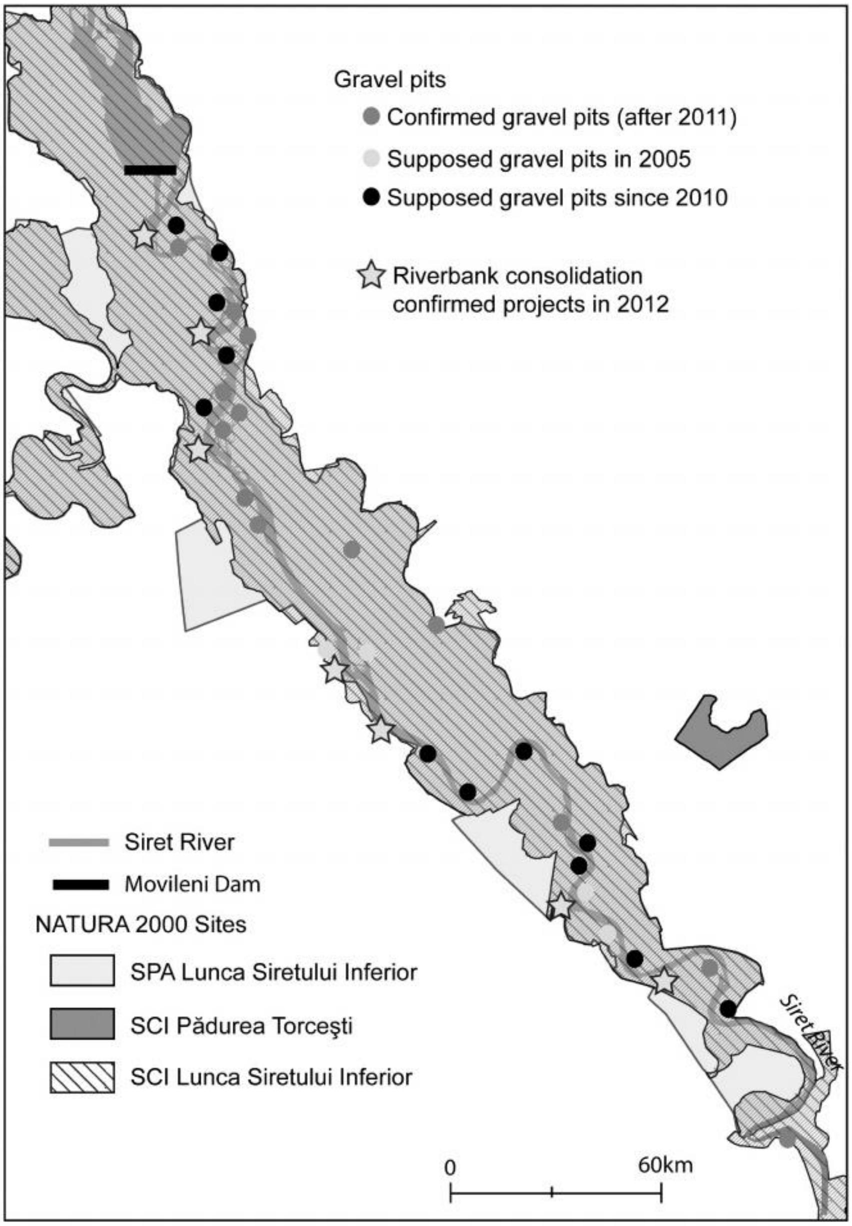

Fig. 5: Location of gravel pits on Lower Siret River since 2005 in the Natura 2000 area. The supposed gravel pits are determined thanks to both Google Earth images and fields survey. SPA: Special Protection Area. SCI: Sites of Community Importance.

Impact on Natura 2000 sites is perceived differently in EIAs.

i) EIAs on Middle Buzău River explain that in-stream mining has a low environmental impact – or there are no protected species on exploited alluvial deposits, or protected animal species are capable to adapt to the new environment. EIAs on Lower Siret River consider that, one year after stopping in-stream mining, the environment will return to its initial state. Thus, one can conclude that these reports ignore several principles of river management (longitudinal and lateral connectivity), neglecting also cumulative impacts on a regional scale.

ii) All EIAs propose the restoration of abandoned pits located in the alluvial plain. EIAs on Middle Buzău River advance the hypothesis of filling and covering by grass; at present, there are no achieved projects (Fig. 4E). However, one pit, active in 1980 and located on a terrace, was reconverted into fish farm. On Lower Siret River, two exploitations, at Umbrăreşti and Condrea, located in an inactive channel of the Siret River are conducted to create fish farms. These projects allow both local economy development and environmental preservation. In order to prevent habitat total destruction, these attenuating or compensatory measures are globally sustained by planners of Natura 2000 netwok, under reserve of achievement and efficiency (European Commision, 2010).

Based on these observations, we bring out a few characteristics of managing in-stream mining activity, in general, and of EIAs reports, in particular. Firstly, they prove lack of vision on watershed scale despite the obligation to manage rivers as components of watersheds. However, we cannot ignore the economic considerations: the gravel and sediment mining plays a major role in the local economy thanks to the employment it creates and limits the rural exodus. Secondly, they show the preoccupation for Natura 2000 sites' management, case by case, function of local particularities and necessities, which is a positive response to European demands (European Commision, 2010).

Conclusion

As a continuity of practices from communist era, in-stream mining increased since 2005 on Lower Siret and Middle Buzău rivers. Lower Siret River and Middle Buzău River provide us an example of highly anthropised fluvial system and allow an assessment of short term effect of in-stream mining. The results show the difficulty to determine the particular morphological effect of this activity: the lateral erosion noticed between 2005 and 2010 could be caused by synchronous and simulations actions of dams, floods and bed material extractions. Despite this consequence, the technical response is to accelerate in-stream mining in order to increase the stream capacity and to prevent channel meandering and divagation; or this strategy already proved to be dangerous for river natural dynamics on long term. This shows an apparent adaptation to European Union's demands. If comparing Lower Siret and Middle Buzău rivers, we notice, generally, a common policy regarding environmental issues; however, on Lower Siret River all these conclusions seems to be more evident; this is probably due to high flood risk and the necessity to find rapid solutions (ABAS, 2013).

Our study confirms previous results on the relation between channel dynamics and in-stream mining. As secondary results, it contributes with a diachronic cartography of exploitations in Natura 2000 site, spotting strategic conflicts.

In perspective, granting authorisation for in-stream mining should rely more on this type of study showing retroaction cycles in river environment dynamics, at watershed scale.

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