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VISUAL PROTOCOLS AND GIS AS PRELIMINARY INVESTIGATIVE TOOLS TO LOCATE POTENTIAL ECOENGINEERING IN STREAMS AND RIPARIAN AREAS*

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Abstract

The conservation and protection of riparian areas is a worldwide priority. The main reason is because humans have utilized riparian areas for thousands of years for agricultural or urbanization purposes. Establishing tools that quickly and accurately assess these areas that can help make proper management decision is the objective of this study. Specifically, the visual protocol of “Stream Visual Assessment Protocol (SVAP)”, along with the buffer function of the Geographic Information System (GIS) were utilized and evaluated. The SVAP was developed in the United States and is a "rapid assessment protocol" that provides a quick, visual and systematic assessment of these natural ecosystems without interfering and altering them. This protocol has been applied in many regions and the version used has been modified for the Greek environment. GIS was used to estimate the land-uses of the riparian areas and is a program that integrates, stores, analyzes and presents geographic correlated data. These two tools were applied in Aggitis stream and its adjacent riparian areas that flows through the Drama Prefecture in Northern Greece. It is well known in the region because of a cave that the stream runs through, but also because it has a unique riparian forest. Lately, visitation has increased along the stream and the cave that has led to concerns that the stream and its riparian areas could be degraded if a sustainable management plan is not developed. This has made it imperative to assess the current condition along Aggitis stream. Both tools indicate degraded stream and riparian conditions with ecoengineering methods recommend improving the Aggitis ecosystem’s integrity.

Key words: assessment, anthropogenic pressure, restoration

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1. Introduction

Effective and efficient monitoring of riparian areas is a priority since their role in environmental management is extremely important, especially in human-modified environments. Human pressures such as river regulation, agricultural development, forestry, gravel mining and urban sprawl, particularly in the last centuries, have progressively altered and led riparian areas to be considered heavily degraded worldwide because of their intensive use, especially in populated areas (Magdaleno et al., 2011; NRC, 2002; Schultz et al., 2002). The re-establishment, restoration or protection of riparian areas will allow these ecosystems to offer the many ecosystem services and social benefits to humans and perform their critical hydrological and biogeochemical functions, especially in semi-arid and arid regions (Naiman and Décamps, 1997; Zaimes et al., 2010). These services, benefits and functions are due to the greater water availability and different nutrient rich soils of the riparian areas that lead to higher productivity and biological diversity, compared to the upland counterparts (Naiman et al., 2005; Sabo et al., 2005). Further, they occupy a small area proportionally in the watershed (Patten, 1998) and their resilience makes restoration efforts more easily accepted and adopted by the general public.

Southern Europe riparian areas are of great need of restoration and re-establishment (Decamps et al., 1988; Corbacho et al., 2003). This region has been inhabited for thousands of years with agriculture transforming many riparian areas into cultivated fields and completely eliminating most of their vegetation (Salinas et al., 2000) and human settlements established along water bodies reducing their quality and leading to their fragmentation (Iakovoglou et al., 2013a). This is also the situation in Greece, where agricultural activities have transformed most lowland natural riparian vegetation to agricultural fields that are severely degraded or extinct while mountainous riparian areas are still vegetated with woody vegetation (Zaimes et al., 2010; Zaimes et al., 2011a).

Ecoengineering is a new approach that is gaining great acceptance worldwide because it can sustainably and environmentally friendly promote the re-establishment and restoration of natural ecosystems. Its innovation is that it combines technical (protection and stabilization), ecological (ecosystem-based restoration), landscape (integration of landscape aspects) and socioeconomic (more efficient and source of employment) aspects. Specifically, living plants or cut plant material, either alone or in combination with inert structures (e.g. soil, rock, timber), provide the long-term protection and mitigation against all forms of soil loss and erosion (Schiechtl, 1988). The semi-empirical nature of ecoengineering makes the transfer of the know-how of successful and failed ecoengineering interventions essential for its proper adaptations (Tardio et al., 2017). With erosion one of the major problems that degrade riparian ecosystems (Zaimes at al., 2011c) primarily due to anthropogenic activities (Naiman et al., 2005) new innovative methods need to be utilized for their re-establishment and restoration. Ecoengineering is an environmentally friendly tool that improves its resilience against soil loss and soil degradation in riparian areas.

While in Northern America, most European countries and Australia the understanding, protection and restoration of these ecosystems has been in the forefront of scientific research for decades (Naiman et al., 1993; Hughes, 2003) this is not the case with the Mediterranean region and particularly Greece (Zaimes et al., 2011b). This is the reason why monitoring, specialized for Mediterranean riparian ecosystems, needs to be developed (Magdaleno and Martinez, 2014) in order to assess the impacts of human activities on ecological functioning and the effectiveness of changes in the management of riparian areas (NRC, 2002).

2. Objectives

The main objective of this study was to evaluate simple and easily applicable tools for the quick assessment of riparian areas in Greece. This will help develop tools for land managers and the appropriate agencies, organizations and authorities for the fast and accurate assessment for the riparian areas in Greece. These tools will allow land managers to find the areas of the riparian ecosystems that need to be targeted with ecoengineering methods. Specifically in this study one field visual assessment tool used worldwide and Geographic Information Systems (GIS) were utilized. The assessment tool was modified to the characteristics of the Euro-Mediterranean environment.

3. Materials and methods

3.1. Study area

The study was conducted along Aggitis stream that flows in the region of Eastern Macedonia in northern Greece (Fig. 1). The selected stream reach is in the prefecture of Drama, near the rural settlement of Aggitis that is located 25 km west from its capital that is also called Drama. The average yearly temperature and annual mean rainfall of the prefecture are 15 OC and 540 mm, respectively. The specific stream was selected because it touristic hotspot in the prefecture. Specifically there is a highly visited cave that the stream actually flows through. In addition is also has a unique Mediterranean riparian forest that is an ecotouristic attraction. The cave and the riparian forest have led to substantial increase in visitation of Aggitis stream. This makes it imperative to monitor the condition of the stream and its adjacent riparian forest. This information will provide preliminary in order to develop a management plan for the stream along with potential measures that need be taken (e.g. ecoengineering) to maintain its ecological intertie. The total stream length investigate was 30.7 km.

3.2. Geographic Information Systems (GIS)

Geographical Information Systems (GIS) are more and more used to provide important information in regards to field studies. Their utility is because of they are a) easy to use, b) used for large areas relatively inexpensively and c) provide information in spatial form (maps) that easy to understand. The initial assessment of the riparian areas of the studied reach was done through the use of GIS. Specifically in this project the "buffer" function was to estimate the area of the different land-uses/cover adjacent to the studied stream were. The buffers lengths used were of 20 and 50 m from the stream bank, typical the extents of riparian areas in s Mediterranean streams (Corbacho et al., 2003). Overall this is an effective tool since it allows the quick assessment from the office of large lengths of riparian areas. This provides preliminary data on the condition of the riparian areas should is validated with visual assessment tools.

3.3. Stream Visual Assessment Protocol (SVAP)

One of the visual assessment tools, to evaluate the validity of the GIS results, selected was the: a) Stream Visual Assessment Protocol (SVAP) (Bjorkland et al., 2001). The SVAP has been used worldwide and provides information on the ecological status of streams and riparian areas and was developed in the United States (Bjorkland et al., 2001).

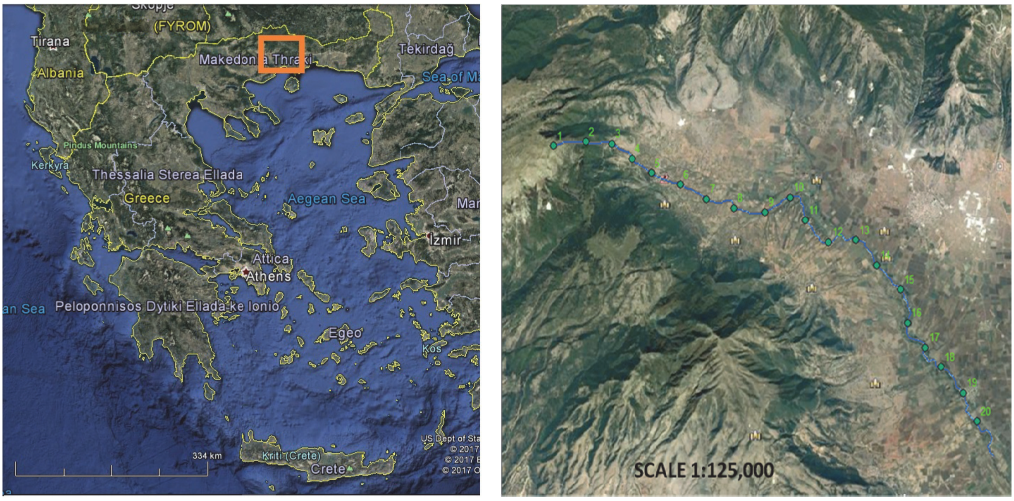

Fig. 1. Aggitis stream was the studied stream (the red box - photo on the left, indicates the location of the stream in Greece while the green dots - photo on the right, indicate the survey points where the assessment tool was used)

It focuses primarily on the stream and hydrologic processes. The modified SVAP for riparian areas in Greek environments that could be applied to other Euro-Mediterranean countries was used in this study (Iakovoglou et al., 2013b). The data collected for each plot initially include general information (location, date, weather conditions etc.). Following specific stream and riparian characteristics were examined that include: 1) Channel condition, 2) Hydrologic alteration, 3) Riparian zone condition, 4) Bank stability, 5) Water existence, 6) Water appearance, 7) Livestock shed presence, 8) Instream fish cover, 9) Pools, 10)Insect/invertebrate habitat, 11) Canopy cover, 12) Manure presence, 13) Biological wastewater treatment presence, and 14) Garbage presence. The overall score for the plot was the average of the 14 characteristics that can get values from 0-10. The final categorization of the plot can be seen in Table 1. A total of 20 plots equidistant from each other along the 30.7 km selected stream reach were surveyed (Fig. 1). The survey was conducted by the same personnel in one day.

Table 1. The categorization of a plot based on the Stream Visual Assessment Protocol (SVAP)

SVAP score	*SVAP Categorization*
> 9	EXCELLENT
7.6 - 9.0	GOOD
6.1 - 7.5	MODERATE
< 6	POOR

4. Results and discussion

The different types of land-uses/vegetation cover of the riparian areas were first determined through the use of GIS. This was done for 2 different buffer widths of 20 and 50 m since the type of the vegetation and existence of anthropogenic can have a major impact of the stream and riparian ecosystem integrity. Overall there were six different land-uses/vegetation covers and they areas they occupied can be seen in Table 2. This allowed a first evaluation of the conditions of the studied reach. Specifically it is worrisome the low percentage of natural vegetation that is broadleaved forest since it both cases it is below 5 %

(4.5% and 4.6% for the 20 m and 50m buffer, respectively). The cultivated areas occupied more than 86% of the area in both buffers. Specifically, the agricultural land with natural vegetation occupied 6.2% and 6.1 %, the non-irrigated agricultural land 45.3% and 45.2 % and irrigated agricultural land 34.9% and 35.1% from the 20 m and 50m buffer, respectively. A large percentage was also classified as rangelands (8.9% and 8.7% for the 20 m and 50m buffer, respectively). Finally the rural infrastructure was relatively low (0.3% and 0.4% & for the 20 m and 50m buffer, respectively) although we did see a 33% in the 50 m buffer compared to 20 m.

Table 2. The land-uses/vegetation covers adjacent to the studied reach with a 20 m and 50 m buffer width along both sides of the reach estimated with GIS

Riparian land-uses/vegetation covers	*20 m buffer width (ha)*	*50 m buffer width (ha)*
Broadleaved Forest	5.51	14.03
Rangelands	10.86	26.32
Agricultural land with natural vegetation	7.58	18.49
Non irrigated agricultural land	55.33	137.27
Irrigated agricultural land	42,69	106.44
Rural infrastructure	0,31	1.10
TOTAL	**122.28**	**303.65**

The SVAP assessment provided actual field measurements. Overall the scores were not very encouraging (Fig. 2, Table 3) and correspond well with results from the GIS since the majority approximately 95% of the land-uses/vegetation cover are agricultural (cultivated field and rangelands) for both buffers. There were no sub-reaches with scores to classify them as Excellent and only one that was classified as **good**. Most sub-reaches were classified as **moderate** and four were classified **poor.** The results clearly indicate that measures need to be taken in order to improve the conditions of both the stream and riparian areas. The main activities for the degraded conditions of the stream reach are agricultural and grazing along and near the riparian area, increased visitation because of cave and ecotourism and dumping of waste and trash especially near the villages.

Table 3. The total number of sub-reaches and the specific sub-reaches (numbering starting from up-stream to down-stream) in each SVAP category

SVAP Categorization	*Tot. # of sub-reaches*	*Specific sub-reaches*
EXCELLENT	0	None
GOOD	1	# 6
MODERATE	15	# 4, 7 - 20
POOR	4	# 1, 2, 3, 5

Looking at the specific characteristics of the SVAP the Riparian Area Condition received overall high scores but other characteristics were problematic. The number one priority for the stream reach would be the establishment of a biological wastewater treatment that does not exists despite the fact that there are several villages along or near the stream. In addition, the instream fish cover and pools were missing in many sub-reaches that led to low scores. Stream bank stability also had some low scores on some of the sub-reaches. To improve these three characteristics, engineering, but especially ecoengineering techniques should be utilized.

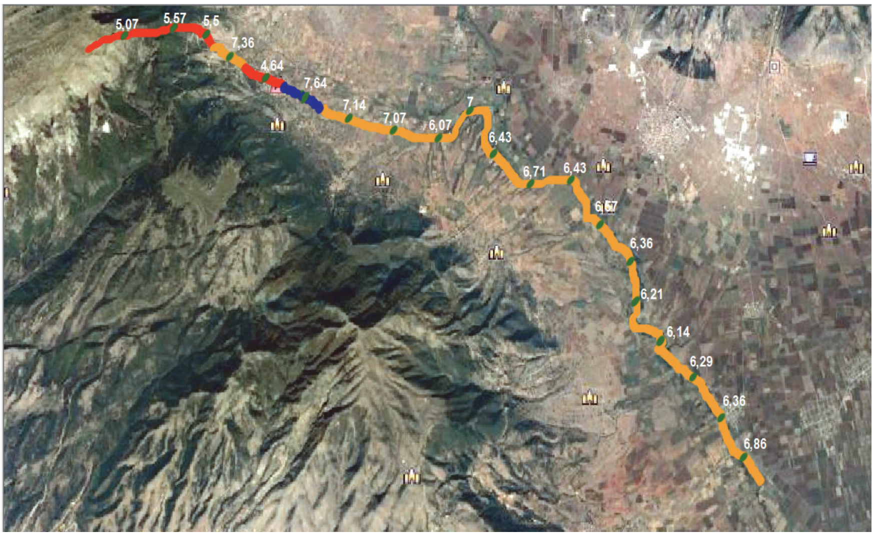

Fig. 2. The values for each point that was surveyed using the SVAP tool (red colored sub-reaches indicate poor riparian areas, orange moderate and blue good; there no sub-reaches classified excellent)

More specifically, to enhance the pool/riffle habitat *wing deflectors*, *vortex rock weirs*, *cross vanes*, and even the *placement of random boulders* in the stream channel should be implemented (Nyman, 2004). Wing deflectors are V-shaped low-profile jetties constructed out of large boulders with cobble fill-in, installed adjacent and an approximate 30^{o} angle to the stream bank. The vortex rock weirs are very low-head structures constructed out of boulders that have gaps among them and placed on the stream bed across the width of the normal flow channel.

In regards to cross vanes they are similar to vortex rock weirs but are placed together without gaps. Finally, even when boulders are placed singly or in clusters in random locations can add different "micro-structure" to the channel bed-form. These boulders can also provide in-stream habitat cover such as feeding lies, and resting areas for fish. For fish instream cover even simple such placement of *logs* in the stream channel and *planting aquatic vegetation* can provide protection and spawning and food-production areas (Water and Rivers Commission, 2000). Other methods to improve fish instream cover include *tree revetments*, *root wad revetments* and *lunkers structures* (Nyman, 2004) Tree revetments if the placement of trees along the stream bank (in many cases old Christmas trees can be used). In the root wad revetment the tree trunk with the root wad are placed on a foundation of logs and boulders. This structure enhances fisheries habitat by developing scour pools and providing overhead cover, shade, insect habitat, and a source of organic detritus. The lunkers structures are more complicated with planking or logs used to construct an open-sided box that is buried in the stream bank but extends over the top of bank surface. The interior is accessible to aquatic organisms and provides an undercut bank effect and hiding cover for fish. Of course the final decision on what methods to be used will depend on what the native fish are and which are prioritize for protection.

A number of different methods could be used to improve stream bank stability (FISRWG, 1998; USDA–NRCS, 2007). Some of the major are described in the following sentences. *Live fascines* are long bundle of live cuttings bound together into a rope and provide immediate protection for the toe. Cuttings of dormant stems, branches, or trunks of live, woody plant material are inserted into the ground to grow and support other ecoengineering methods are called *live stakes*. The *live cribwalls* are constructed with interlocking logs in the shape of box that are filled rock, soil, and live cuttings, or rooted plants. The *brushmattress* are a layer of live cuttings placed flat against the sloped face of the bank with dead stakes and string to anchor it to the bank. Finally the *erosion control blankets* are produced from natural and synthetic materials and placed on the eroding bank. More complicated structures can also be utilized such as *vegetated riprap* and *vegetated gabions* can also be used (USDA–NRCS, 2007). In the vegetated riprap, live cuttings of rootable plant material are paced into the soil between the joints or open spaces in rocks. Similarly trees growing in gabions can further enhance their stability. A gabion is a box filled with rocks, concrete, or sometimes sand and soil to stabilized slopes and banks.

Overall both tools allow preliminary identification of the sub-reaches that are more heavily degraded and were ecoengineering methods should be implemented in streams and riparian areas. With funds limited for conservation a more targeted approach in all watersheds is a necessity. Adopting a geographically targeting approach to enhance certain ecosystems or reduce nonpoint source pollutions at multiple scales, including the watershed scale is preferred because it leads to more cost-effective and efficient management. For example by targeting the areas that produce the highest 10% of sediment in the watershed stream sediment loads can be reduced by 20% (Diebel et al., 2009).

5. Conclusions

Aggitis stream and riparian ecosystems is experiencing many anthropogenic pressures such as cultivation, grazing, tourism and garbage dumping. This was verified with both utilized tools. The GIS results found that 95% of the riparian area along both 20 and 50 m was in cultivated fields and grazed areas. The SVAP results also indicate degrade condition since most of the sub-reaches received a **moderate** classification, four classed as **poor**, one as **good** and none as **excellent.** This clearly indicates that measures need to be taken that can include eco-engineering for enhancing pool and instream fish habitat along with stream bank stabilization. In addition, a biological wastewater treatment for the neighboring villages and minimizing garbage dumping and grazing in riparian areas should be implemented.

The results also show that the tools allow preliminary identification of the sub-reaches that are more heavily degraded. These tools will allow land managers in Greece and the Balkans to adopt a geographically targeting approach for conservation measures that should lead to the cost-effective management of these areas.

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