Enhancing urban and sub-urban riparian areas through ecosystem services and ecotourism activities

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ABSTRACT

Riparian ecosystems in urban environments are usually degraded. Their sustainable management can reduce water pollution, mitigate climate change while providing recreation opportunities. This study assessed the current condition of the streams/torrents and their riparian areas in the city of Drama in Greece. In addition, practices to improve their functionality and enhance community awareness were recommended. A spatial database of the wider urban setting including suburbs and rural areas (weather, land cover, soils, roads, protected areas, riparian areas, etc.) was developed within GIS. The datasets were then inputted in a hydrologic model to simulate the water balance and stream discharge in the main urban streams and torrents. Field measurements of stream water discharge, and vegetation and stream channel conditions were undertaken using two visual protocols. The results of the protocols indicate that most streams/torrents and their riparian areas are of low ecological quality. Nature-based solutions were recommended to improve their ecological quality. In addition, the implementation of Eco-Routes was recommended to enhance the awareness of their importance and to promote their sustainable management. Overall, the urban streams/torrents and riparian ecosystems of Drama are degraded and innovative management practices should be implemented to conserve them and feature their ecosystem services.

Key words | Eco-Routes, GIS, hydrologic models, riparian, SWAT, visual protocols

HIGHLIGHTS

- The urban streams/torrents and riparian areas of Drama City are degraded.
- Spatial databases should be utilized by the authorities for urban planning.
- Hydrologic models are essential for the sustainable management of urban water resources.
- Nature-based solutions can restore the streams/torrent and their riparian areas.
- Eco-Routes can enhance the awareness on the importance of riparian areas.

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The conservation and protection of riparian areas is a main priority for most regions of the world because of the many ecosystem services they offer (Zaimes & Iakovoglou 2021). In addition, riparian areas have been heavily utilized and are considered as some of the most degraded ecosystems. Climate change is further compounding the pressures on riparian areas (Zaimes 2020). This is particularly true for the Mediterranean region whose inhabitants have been dependent on and have utilized riparian areas for thousands of years. The anthropogenic activities that negatively impact the riparian areas include river transportation (e.g. boats), energy generation, urbanization and agriculture that alter the channel’s morphology and hydrologic regime and/or eliminate, shrink, degrade or reduce of the riparian vegetation diversity (Balzan et al. 2020). Urban sprawl is expected to continue since it has been projected that by 2050, close to 70% of the world’s population will be living in urban environments (Monk et al. 2015). Many urban areas are along streams, rivers and deltas highlighting that the anthropogenic pressure of urbanization on the riparian areas will further increase. Urbanization can have the most aggressive anthropogenic alterations on the structure and functionality of riparian areas (Iakovoglou et al. 2015). The hydrologic regimes are significantly altered in urban watersheds. The pathways that rainwater follows (e.g., evapotranspiration, surface runoff, infiltration, lateral flow) are altered due to the extensive impervious surfaces, elimination of natural vegetation and the urban water infrastructures (Paul & Meyer 2001). Overall, rainwater moves substantially quicker out of the urban watershed because urban drainage systems convey rainwater efficiently and rapidly which can create flash flood events and afterwards ‘hydrologic drought’ of the riparian areas by lowering the water table. The alteration of the hydrologic regime impacts the soil, vegetation, and their ability to remove pollutants. Riparian areas are important corridors and the degradation of their urban segments can lead to the fragmentation of their continuum from the headwaters to the deltas and the disconnection of the stream/rivers to their floodplains (Hudson 2002).

In contrast the sustainable management of urban riparian areas can help revitalize ecologically and socioeconomically urban ecosystems (Wu et al. 2017). This has been recognized worldwide and is why most urban strategies include the maintenance or restoration of riparian areas. The ecosystem services that they can offer in urban settings include: improved stream water quality, protection from flood events, enhanced aesthetics, expanded recreational opportunities, and climate change mitigation. To provide these services, riparian restoration efforts typically include fluvial and geomorphic restoration, active introduction of native plants and re-establishment of the natural floodplain (González et al. 2015).

The reasons behind the many ecosystem services that riparian areas can offer are because they are ecological hotspots that support high biodiversity, disproportionately
larger than their extent in the watershed (Monk et al. 2019). They are highly productive and biodiverse habitats because they have characteristics that are a mixture of both terrestrial and aquatic ecosystems. This is why riparian areas are called semi-aquatic, transition zones between the aquatic and terrestrial ecosystems. The greater presence of groundwater and the frequent flooding, leads to unique soils and geomorphologic formations that affect the vegetation that is primarily hydrophilic and differentiates them from the adjacent ecosystems (Zaimes & Iakovoglou 2021). As transition zones they have biophysical, ecological and biota gradients as you move from the aquatic to the terrestrial ecosystems leading to unique environmental conditions.

In the Mediterranean region, climate change is leading to increasing temperatures and evapotranspiration, while rainfalls are more intense but at the same time less frequent, especially in the summer (Cramer et al. 2018). Consequently, drought frequency and strength are expected to increase, while the hydrological cycle will intensify (more flash floods are expected). Overall, these alterations will reduce water availability in the region (Fader et al. 2020). Streams and rivers in the Mediterranean might shift from perennial to intermittent and from intermittent to ephemeral which could also alter vegetation communities. Overall, riparian areas of the region appear to be very sensitive to climate change impacts (Zaimes 2020), and can be indicators for natural and human systems vulnerability to climate change (Capon et al. 2013).

To sustain the healthy function and structure of riparian ecosystems in relation to their services, is an even greater challenge today due to climate change. Safeguarding these ecosystems through proper management (e.g., ecotourism) becomes a major priority (Iakovoglou et al. 2013). ‘Ecotourism’ is a fast-growing trend in the tourism industry that can provide increased economic growth while also sustaining ecosystems (Ghermandi et al. 2020). The increased diversity and services of the riparian ecosystems in and adjacent to residential areas provide unique ecotourism opportunities that can potentially increase the welfare of the urban area. The sustainable implementation of ecotourism in urban areas can help to educate citizens on the importance of riparian areas and their benefits. This should promote their enhanced protection and conservation, improve the quality of life of the urban dwellers and help the local economy through an increase in the number of visitors.

Urban riparian areas in Greece have not been studied extensively, especially in regard to maintaining and enhancing sustainable cities and helping reduce climate change impacts (Iakovoglou et al. 2013). The aim of this study was to assess the characteristics of the urban streams and riparian areas and based on these, recommend management practices to improve their utility. Firstly, the stream flows for reaches that run through the city of Drama were measured and afterwards utilized in a hydrologic model. The urban riparian areas were assessed via GIS mapping and the implementation of two visual protocols. These data led to suggestions on how to enhance the functionality and ecosystem services of the urban riparian areas. Finally, ecotourism paths were suggested in order to enhance the city’s ecotourism opportunities and improve the quality of life of its residents.

METHODS

Study area

The city of Drama, which is the capital of Regional Unit of Drama, is located in the region of Eastern Macedonia and Thrace, in Northern Greece (see Figure 1(a)). It was built on the foothills of the Falakro Mountain in a verdant area with abundant water sources. The city was originally named Ydrama or Dyrama by the ancient Greeks because of the abundant water sources. The city of Drama has an area of 59.37 km², located at an altitude of 118 m above sea level and with a population of approximately 44,800 people (Population Census of 2011). The climate in Drama is warm and temperate. The Köppen-Geiger climate classification is Csa (typical Mediterranean climate). The average temperature in Drama is 14.2 °C and the yearly precipitation 520 mm. As Drama is an inland city, this has led to the promotion of alternative tourism and not the usual Greek tourism activities of coastal areas. This is the reason why during the Christmas period, the city hosts the Dream Town event (that is a Christmas market and a fun park) that attracts many tourists. Moreover, every year there are additional events such as Drama International Short Film Festival, Wine Festival ‘Draminognosia’, Dramaica Youth Festival. The main sources of revenue are agriculture

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Figure 1 (a) The location of Regional Unit of Drama (in white) in Greece. (b) The four studied urban stream and torrent reaches of Agia Varvara (in green), Monastiraki (in blue), Kalifritos (in red) and Xiropotamos (in yellow). Please refer to the online version of this paper to see this figure in colour: http://dx.doi.org/10.2166/ws.2021.114.
(crops and livestock), marble mining and winemaking. Recently there have been efforts to exploit the unique natural ecosystems that surround the city for ecotourism opportunities. Such an example is the environmentally friendly development of the recreational area of Agia Varvara Springs. In this area the natural riparian vegetation has been maintained in many reaches while the city has constructed eco-friendly paths that make this a 'hot spot' for leisure and recreational activities, concerts and festivals especially during spring and summer. In addition, restaurants, coffee shops and hotels have also been developed that attract many local residents and visitors. In order to further promote tourism and also enhance the quality of life that could lead to an increase in the number of residents, the city plans to further utilize other urban riparian areas with the sustainable exploitation of their ecosystem services. In this study four different (ephemeral to perennial) reaches, typical of the Mediterranean, were studied: (a) Agia Varvara Springs, (b) the Monastiraki torrent, (c) Xiropotamos torrent and (d) Kallifytos torrent, which run through the city (see Figure 1(b)).

Visual protocols

The two visual protocols were utilized: (a) the Ecological Quality of Riparian Habitat (QBR) protocol (Munné et al. 2005) that focus on the riparian vegetation and (b) the Stream Visual Assessment Protocol (SVAP) (Bjorkland et al. 2001) that focus on the stream/torrent channel condition.

The QBR protocol was developed in Spain for Mediterranean riparian areas. Its assessment consists of four different sections: (a) total vegetation cover, (b) vegetation cover structure, (c) cover quality and (d) river channel alterations (Munné et al. 2005). Each section can have a score from 0 to 25 points. The sum of these four different scores provides the final score that can range from 0 to 100. The categories of the protocol based on the final score are: (a) riparian habitat in natural condition, greater or equal than 95, (b) low disturbance, good quality from 75 to 90, (c) disturbance important, fair quality from 55 to 70, (d) strong alteration, poor quality from 30 to 50, and (e) extreme degradation, bad quality less or equal than 25.

The SVAP protocol was developed in the United States and was modified for the Greek and other similar Euro-Mediterranean riparian areas (Savopoulou et al. 2017). Fourteen characteristics are used in order to evaluate the field plots within a score that ranges from 0 to 10. The characteristics evaluated include: (a) channel condition, (b) hydrologic alteration, (c) riparian zone condition, (d) bank stability, (e) water existence, (f) water appearance, (g) presence of livestock shed, (h) instream fish cover, (i) pools, (j) insect/invertebrate habitat, (k) canopy cover, (l) presence of manure, (m) presence of biological wastewater treatment, and (n) presence of garbage. The final score of a plot is calculated as the mean of the above 14 characteristics. Based on the SVAP score there are the following categories: (a) poor condition with mean values less than 6, (b) moderate condition with mean values ranging from 6.1 to 7.4, (c) good condition with mean values ranging from 7.5 to 8.9 and (d) excellent condition with mean values greater than 9 (Koutalakis et al. 2020).

Field measurements were carried out in the reaches of all four studied stream/torrents. In each of them, the total length was measured and further sub-divided into intervals of approximately 150 m that were the locations of the plots. This is the reason why the total number of the plots was different in each reach. The total number of measured plots was 113 and distributed to 50 plots in the Kallifytos torrent, 9 plots in the Monastiraki torrent, 17 plots in the Agia Varvara stream and 37 in the Xiropotamos torrent.

The SWAT model

The Soil and Water Assessment Tool (SWAT) is a continuous-time, semi-distributed, process-based river basin model (Krysanova & Srinivasan 2015). It was developed by the United States Department of Agriculture and specifically the Agricultural Research Service to evaluate the impacts of alternative management decisions on water resources and nonpoint-source pollution in watersheds (Arnold et al. 2012). The SWAT model has been utilized in many different environments, while there is an extensive documentation and a variety of assisted pre- and post-processing software (Gassman et al. 2014). The SWAT uses a large number of input parameters but the necessary input data are: (a) the digital elevation map (DEM), (b) the land use map, (c) the
soil type map, (d) the slope map and (e) weather data (Geza & McCray 2008). Furthermore, the model divides the watersheds into hydrologic response units (HRUs) which are unique combinations of land use, slope and soil type, thus, each sub-watershed may contain multiple HRUs (Reddy & Reddy 2015). The ArcGIS interface (known as ArcSWAT) was used in the current study (Olivera et al. 2006). The first step was the watershed delineation by using the DEM focused on Drama City and its surroundings, an area of approximately 24,243 ha. This step created the reaches, the longest flow paths, the sub-watersheds, and topographic statistics such as the minimum and maximum elevation which were 52 m and 2,174 m, respectively (see Figure 2). The next step developed the slope map based on three categories (0–20%, 20–40% and >40%) that were derived from the topographic statistics (see Figure 2). The soil map of the area was based on the data acquired from the European Union World Soil Harmonised Database (see Figure 3). The dominant soil types of the area are: (a) Dystric Cambisol, (b) Calcaro-chromic Vertisol, (c) Calcaric Fluvisol, (d) Calcaric Leptosol and (e) Chromic Luvisol. The land use map (see Figure 3) was derived from the European Union CORINE land cover types. The land uses of the area included: (a) Urban Residential-High Density (URHD), (b) Urban Residential-Low Density (URLD), (c) Urban Residential-Medium Density (URMD), (d) Urban Industrial (UIDU), (e) Urban Commercial (UCOM), (f) Agricultural Land-General (AGRL), (g) Agricultural Land-Row Crops (AGRR), (h) Pasture (PAST), (i) Cropland/Grassland MOSAIC (CRGR), (j) Agricultural Land-Close-grown (AGRC), (k) Forest-Mixed (FRST), (l) Forest-Deciduous (FRSD), (m) Range-Brush (RNGB), (n) Forest-Evergreen (FRSE), (o) Grassland (GRAS), (p) Shrubland (SHRB) and (q) Barren (BARR) (r) Barren or sparsely vegetation (BSVG). The combination of the above input data created 259 HRUs for the six sub-watersheds and the report of the HRU coverage in each sub-watershed.

**Figure 2** | (a) The hydrographic network (reaches) along with the longest path, the basin, the sub-watershed and the DEM based on the SWAT model. (b) The slope categories of the study area based on the SWAT model.
Finally, the daily weather data (precipitation, low and high temperature, relative humidity, solar radiation and wind velocity) utilized in the model were obtained from the weather station located in the Campus of the International Hellenic University in Drama. The simulated results were produced by using default initial parameters with no calibration data because of the short period of time. On the other hand, field measurements via a current meter allowed us to measure the water quantity in order to determine the hydrologic conditions of the studied streams/torrents and to compare them to the results generated by the SWAT model.

GIS data

The project included the creation of a spatial database focused on the urban area of Drama based on the free software QGIS; a powerful tool for spatial analysis (Pujari & Bhosale 2017). The GIS data included the digitized maps of the hydrographic network, the catchment areas, the land cover, the soil map, the road network, the protected areas, the riparian areas, the weather stations, etc. (see Figure 4). In addition, the digitization included the urban and suburban riparian areas in the study area (see Figure 5) as well as the visual protocol results for both QBR and SVAP assessments (see Figures 6 and 7). The base maps were: (a) the OpenStreetMap (Wiki Free Word Map) and (b) the KTI-MATOLOGIO SA map (Hellenic Mapping and Cadastral Organization). The spatial database was crucial in order to develop the possible routes for ecotourism activities and to prepare the best management plans as future activities.

RESULTS AND DISCUSSION

The QBR protocol showed that the environmental conditions of the riparian vegetation adjacent to the torrent...
and stream urban and sub-urban reaches are degraded (see Figure 6). Specifically, no plots of natural conditions were recorded along the Kallifytos torrent and only 4 plots were of good quality. The vegetation was of fair quality in 16 of the plots while 18 plots were of poor quality and 12 plots of bad quality. In the Monastiraki torrent, 4 plots were characterized as natural, 3 plots were of good quality, 1 of fair and 1 of poor quality. In the Agia Varvara stream 7 plots were of good quality, 3 plots were fair, 6 plots were poor and only 1 was of bad quality. Finally, along the Xiropotamos torrent, 3 plots were in natural conditions, 18 were plots of good quality, 11 plots were of fair quality, while 5 plots were of poor quality.

The SVAP protocol assessment of all reaches resulted in no plots in excellent condition (see Figure 7). The Kallifytos torrent had 10 plots in poor conditions, while 30 of the plots were moderate and 10 were good. Along the Monastiraki torrent, 2 plots were poor, 1 was moderate and 6 (the
majority) were in good condition. For the Agia Varvara stream only 1 was in good condition, 6 plots were poor and 10 plots were in moderate conditions. Finally, the Xiroapotamos torrent had the worst results based on the SVAP, with 29 plots in poor conditions and only 8 plots in moderate condition. These QBR and SVAP results show that the ecological conditions of the urban and sub-urban reaches of the torrents/streams in the area of Drama are highly degraded.

The hydrologic model SWAT was utilized to complement the results of the ecological quality assessment based on the two visual protocols. The model was developed for the greater area of Drama that included both the urban and sub-urban streams and torrents around the city. The simulated annual average hydrologic budget based on SWAT model (see Figure 8) estimated that the 418 mm of yearly precipitation was distributed as following: 10% surface runoff, 6% lateral flow, 28% groundwater that correspond to the total water yield while the remaining 56% was returned to the atmosphere as evapotranspiration (ET).

The simulated results of discharge from the entire watershed of the study area, for the period 2011–2019, based on the SWAT model are depicted in Figure 9. Furthermore, Figure 10 shows the field measurements of Agia Varvara stream in the city of Drama. Field measurements were done in two different cross-sections. The endpoint of the watershed for the SWAT model was located at the village of Kalos Agros (see Figure 11). The simulated discharge resulted in an average flow of 1.06 m$^3$/s. As this point is a confluence of many smaller streams and torrents, this value was expected to be higher than the field measurements taken in Agia Varvara which had average values of 0.55 m$^3$/s and 0.49 m$^3$/s at the two measured cross-sections. The simulated results also highlighted great peaks of runoff after heavy rainfall in the surrounding mountains. These peaks were recorded as high-water events in ephemeral torrents, and should be managed to mitigate soil erosion, tree debris, floods and even failures in infrastructures (e.g., bridges, basements/cellars etc.) that have been recorded in the past. Overall, in these torrents and streams discharge...
appears typically as flash floods and can cause serious damage to infrastructure and also the loss of human lives. Flash floods are the result of land-use changes in the watershed that enhance surface runoff and decrease infiltration such as the increase of impervious surfaces in urban setting. Ecosystem-based approaches such as maintaining and re-establishing healthy riparian areas in the urban areas and also at the watershed scale can help mitigate flash floods. One of the main services of riparian areas is acting as sinks to store rain and flood waters. Measures to improve the riparian areas in the urban and sub-urban areas are imperative based on the results of the two protocols QBR and SVAP. The nature-based solutions can include planting of native riparian species and reshaping of the stream banks. Of course, additional measures might be required such as detention and/or retention ponds, installation of an early warning systems and signs that inform the public areas that they should not cross streams and torrents during storms to avoid human injuries or even loss of life.

Another important measure that can improve the sustainable management of the urban and sub-urban riparian areas is awareness. These awareness activities should focus on presenting to the public the many ecosystems services that riparian areas can offer to humans. This was done by developing ecotourism paths along the riparian and forested areas in the urban area to be constructed in the future. Specifically, two different routes were suggested the: (a) Water-Riparian and (b) Forest-Urban (see Figure 12). The two visual protocols, the SWAT model, the GIS data and potential sites of interest were utilized in order to determine the exact routes. The protocol results identified riparian
areas that in good condition. This would showcase healthy riparian areas and what the potential services could be if all the riparian areas throughout the city were in this condition. The SWAT data provided information on when and where flash floods could happen in the city. This allowed ecotourism routes (Eco-Routes) that are safe from such events to be selected and/or to showcase areas that frequently get flooded. To further enhance awareness five signs and a kiosk will be placed along the routes that are nature-based and environmentally friendly. These signs and the kiosk will provide information on the importance of the ecosystem services that riparian areas offer with real life examples. These signs will also highlight how the microclimatic condition due to the existence of riparian vegetation can alleviate some of the extreme temperatures in cities due to climate change. Finally, in addition to being informative and educational these two routes will

Figure 7 | The categorization of each plot based on the four SVAP categories (represented with different colours) for the four reaches of the study torrents/streams in Drama City.

Figure 8 | The simulated hydrologic budget of the study area in Drama City based on SWAT model.
provide the citizens of the town and also visitors leisure and relaxation opportunities.

**CONCLUSIONS**

Riparian areas are unique ecosystems that if properly managed can be great assets for urban areas. In most cases riparian areas in urban settings are degraded. Visual protocols, stream discharge measurements, the development of a geodatabase and the use of SWAT can provide an assessment of the waterways and adjacent riparian areas ecological and hydrologic conditions in an urban setting. Most of the riparian areas along the urban and sub-urban reaches in Drama City based on the results of the assessment using the two visual protocols indicated degraded environmental conditions. Ecosystem-based approaches and nature-based solutions are recommended to be adopted to improve the riparian areas, which would greatly benefit the city of Drama. This could be based on the practices implemented in a small reach of Agia Varvara stream. Such activities could include replanting native riparian vegetation and alleviating negative anthropogenic activities. Measures for flood mitigation should be implemented, based on the SWAT results, the discharge measurements and past flash flood experiences in the city. Riparian areas if managed properly, along with other engineering works (e.g. blue-grey-green infrastructure) could help mitigate flash floods. Finally, understanding the important services riparian areas can offer in urban ecosystems is a key element of their sustainable management. This is why the establishment of Eco-Routes, which have been suggested to the Municipality of Drama,
Figure 11 | The results of the SWAT model. The stream network, the sub-watersheds and the entire watershed draining through the city of Drama.
are recommended that will be educational and informative. Visiting these routes will highlight the environmental benefits of restoring of riparian areas along with the cultural heritage of the city of Drama. Riparian areas are important for rejuvenating urban ecosystems and with their proper assessment that will lead to the implementation of effective practices (e.g., nature-based solutions, Eco-Routes) their sustainable management can be achieved in urban riparian areas of Greece and the Mediterranean.

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DATA AVAILABILITY STATEMENT

Data cannot be made publicly available; readers should contact the corresponding author for details.

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