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A METHODOLOGY TO QUANTIFY THE POTENTIAL OF URBAN RIVERS TO PROVIDE ECOSYSTEM SERVICES BASED ON REMOTE SENSING AND FIELD INDICATORS – THE POCHOTE RIVER, NICARAGUA

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ABSTRACT

Rivers and their corridors are complex and unique habitats that provide a wide range of ecosystem services. Especially in urban areas, rivers are often the only remaining natural ecosystems but are at the same time under an enormous stress. Understanding and quantifying the potential of urban rivers to provide ecosystem services is of crucial importance for their protection and sustainable use. In developing countries, rivers in urban areas are under significant risk due to unplanned urbanization. With this contribution a methodology to assess the ecosystem status and derive the potential to provide ecosystem services of urban rivers and riparian corridors is presented. The assessment of the three ecological status categories: hydromorphology, water quality and riparian land cover, is based on low-cost field data and freely-available high resolution satellite images. These categories are used as proxies for biophysical structures and processes representing ecological functioning that enable urban rivers and riparian areas to provide ecosystem services. The potential to provide ecosystem services is assessed with a weighted combination of the three ecosystem status categories for 100 m long and 100 m wide river sections. The Pochote River, Nicaragua, is used to demonstrate the development and application of the methodology. For individual river sections, the potential to provide different regulating ecosystem services is then visualized and quantified. This spatially distributed information of urban river ecosystem service potential can serve as an important information for decision-making considering the protection and city development of these areas as well as the tailor-made development of nature-based solutions.

Keywords: Urban river, Ecosystem Services, Assessment, Nicaragua

1 INTRODUCTION

The concept of Ecosystem Services describes the benefits that our societies receive from nature (TEEB, 2010). These services are essential to support our lives on earth and for human well-being. By now about 55 % of the world population lives in urban areas, this percentage is about increase to 68 % by 2050 (DESA UN, 2018). The provision of Ecosystem Services in urban areas, thus, becomes more and more important. The relevance of urban ecology and urban ecosystem services has recently been studied with increasing intensity (Elmqvist et al., 2013; Gómez-Baggethun and Barton, 2013; Haase et al., 2014; Schwarz et al., 2017). Rivers an their corridors are important ecological elements in urban areas (A. Auerbach et al., 2014; Brauman et al., 2007) and especially in rapidly urbanizing cities of developing countries the only remaining natural ecosystems (Lüke and Hack, 2018).

Despite of the importance of urban rivers and their ecosystem services, little attation has been paid to examine their potential to provide them. The assessment of the potential of urban rivers to provide ecosystem services can be an important instrument to highlight the influence on human well-being urban rivers can have. This may then lead to prioritizing the protection and sustainable management of urban rivers and river corridors.

In this contribution, Urban River Ecosystem Services (URES) are introduced based on the Common International Classification of Ecosystem Services (CICES; Haines-Young and Potschin, 2018). For the assessment of the potential of an urban river section to provide URES, an innovative methodology is proposed. This methodology is based on information on the important ecosystem status categories: water quality, river hydromorphology and land cover within the urban river corridor. The information on the ecosystem status of the urban river originates from field surveys and freely available high resolution satellite images.

This new methodology allows to quantify and visualize the URES potential in order to highlight locations where this potential has been lost, is endangered or still high. This information can guide management and protection of urban rivers.

The methodology is developed and demonstrate using the case study of the Pochote River in León, the second largest city of Nicaragua.

2 STUDY AREA AND METHODOLOGY

The Pochote River and the City of León are situated in the Northwest of Nicaragua (see Figure 1). The river drains over a length of 10 km in East-West direction from its source area in the Northeast of the city area towards the western periphery of the city. The watershed is relatively flat, only in the north-eastern part the elevation increases up to 220 m a.s.l. The Pochote River represents the northern limit of the city of León. However, first settlements and new city quarters are starting to expand north of the river. Out of town, the watershed is of rural character with a high use of agriculture. The watershed is located in the municipality León with a total population density of 2.33 inhabitants per hectare. Since 80 percent of the population lives in the city León, the urban density is 73.41 inhabitants per hectare, whereas the rural population density is 0.48 inhabitants per hectare (Alcaldía Municipal de León, 2008).

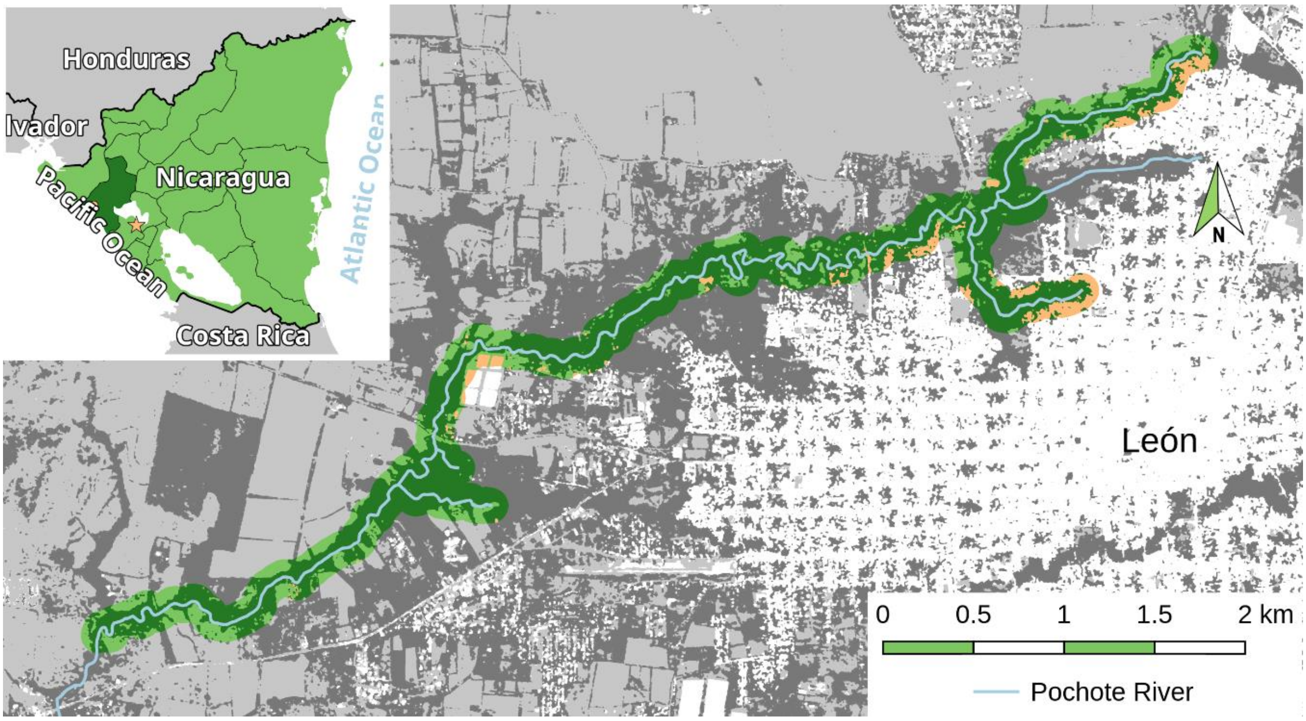

Figure 1. The study area: The Pochote River and the City of León, Nicaragua

2.1 Methodology

The methodology to examine the potential to provide Urban River Ecosystem Services is based on ecosystem status data related to the hydromorphological quality of the river, the river's water quality, and the status of the land cover of the riparian corridor (Figure 2). The classification of the ecosystem status regarding the river's hydromorphology and water quality is based on information from field surveys (geo-referenced photographs of the river, geolocations of river disturbances) and regarding the land cover status based on an use classification of satellite images provided by Google Earth (Figure 2).

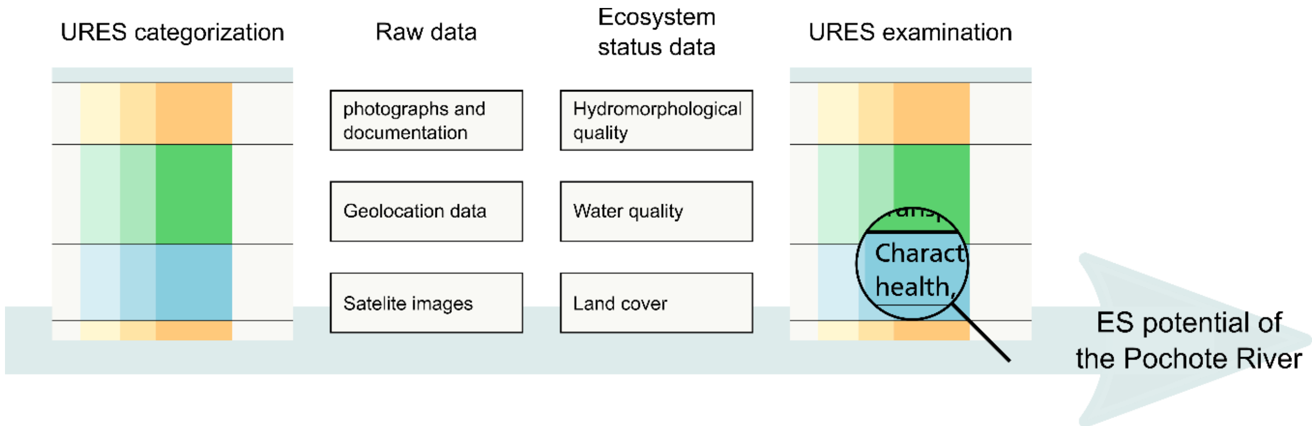

Figure 2. Methodology to examine Urban River Ecosystem Services (URES)

The ecosystem status per 100 m section for the three ecosystem status categories that was used to calculate the URES potential is illustrated in Figure 3.

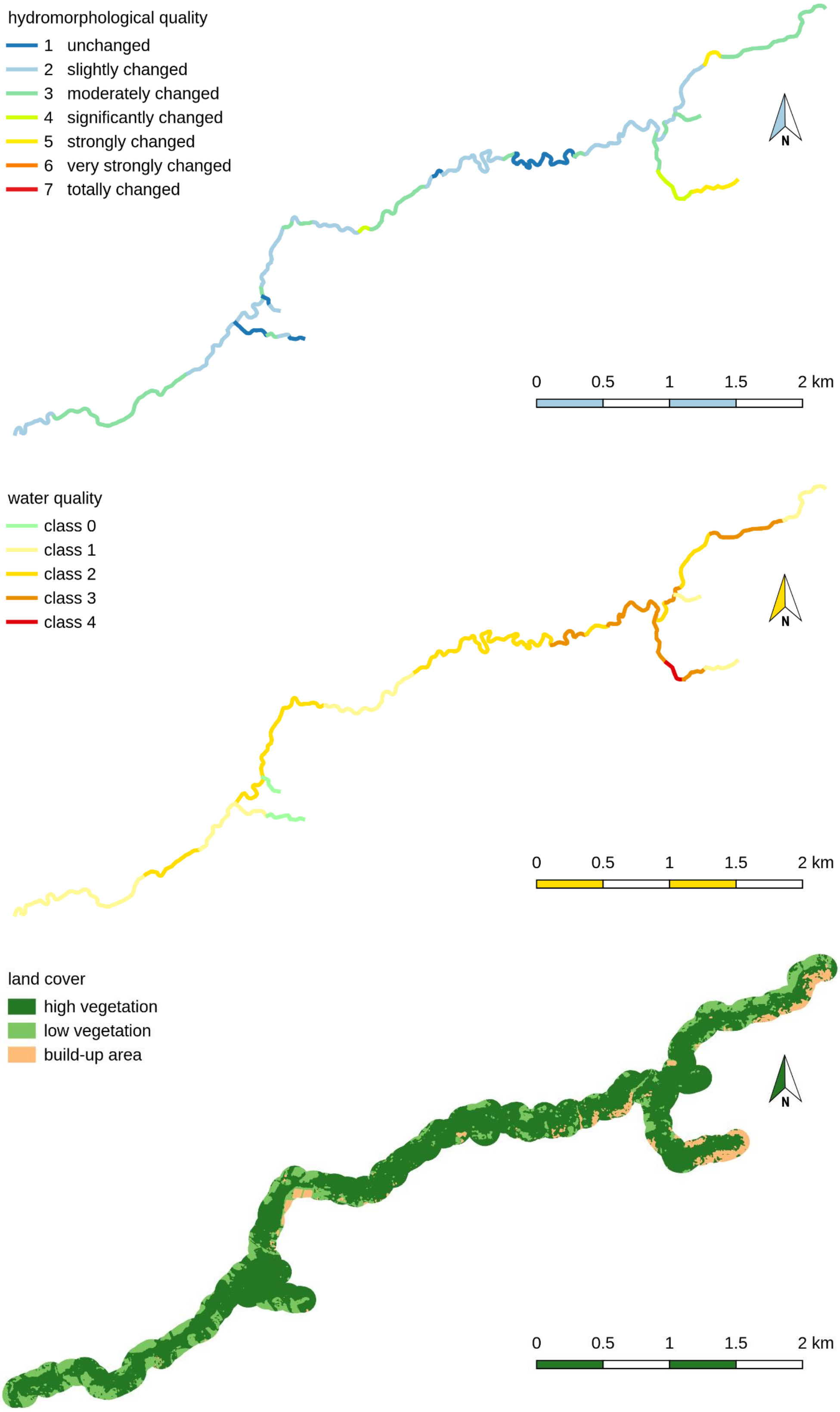

Figure 3. Methodology to examine Urban River Ecosystem Services (URES)

The available qualitative information on the river's ecosystem status (Figure 3) was quantified on the basis of unified values (Table 1) to be able to combine the different ecosystem status categories and to achieve quantitative results on URES.

Table 1. Translation of ecosystem status classes into unified values

hydromorphological quality category	HQ value	water quality category	WQ value	land cover category	LC value
1 unchanged	1.0	category 0	1.0	higher vegetation	1.0
2 slightly unchanged	0.83	category 1	0.9		
3 moderately unchanged	0.67	category 2	0.6	lower vegetation	0.6
4 significantly unchanged	0.50				
5 strongly unchanged	0.33	category 3	0.3		
6 very strongly unchanged	0.17				
7 totally changed	0.0	category 4	0.0	build-up area	0.0

The potential to provide URES is calculated as a weighted combination of the three ecosystem status category values for each 100 m x 100 m river section:

$$URES = \frac{HQ_{value} \cdot HQ_{weight} + WQ_{value} \cdot WQ_{weight} + LC_{value} \cdot LC_{weight}}{HQ_{weight} + WQ_{weight} + LC_{weight}} \qquad [1]$$

The specific weight of each ecosystem status category for the examined URES is shown in Table 2.

Table 2. Weight of ecosystem status categories for different Urban River Ecosystem Services

Urban River Ecosystem Service (URES)	Weight of ecosystem status categories		
	Hydromorphological Quality (HQ)	**Water quality (WQ)**	**Land cover (LC)**
Bio-remediation by micro-organisms, algae, plants, and animals	1	1	1
Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals	1	1	1
Noise attenuation	-	-	1
Hydrological cycle and water flow regulation (Including flood control, and coastal protection)	-	-	1
Maintaining nursery populations and habitats (Including gene pool protection)	1	1	2
Regulation of the chemical condition of freshwaters by living processes	3	1	1
Regulation of temperature and humidity, including ventilation and transpiration	-	-	1

3 RESULTS

The potential to provide URES of the in
dividual river sections of the Pochote River is illustrated in Figure 4. As can be seen, the URES potential does not decrease below 40 %. The river sections with the lowest URES potential are located in the Northwest. These are the river sections closest to the urbanized city area where the riparian land cover is most impaired by built up areas and water quality is heavily deteriorated by untreated

waste water discharges (see Figure 3). However, in general a quite high potential to provide URES for many river sections is revealed. The potential increases with a downstream tendency.

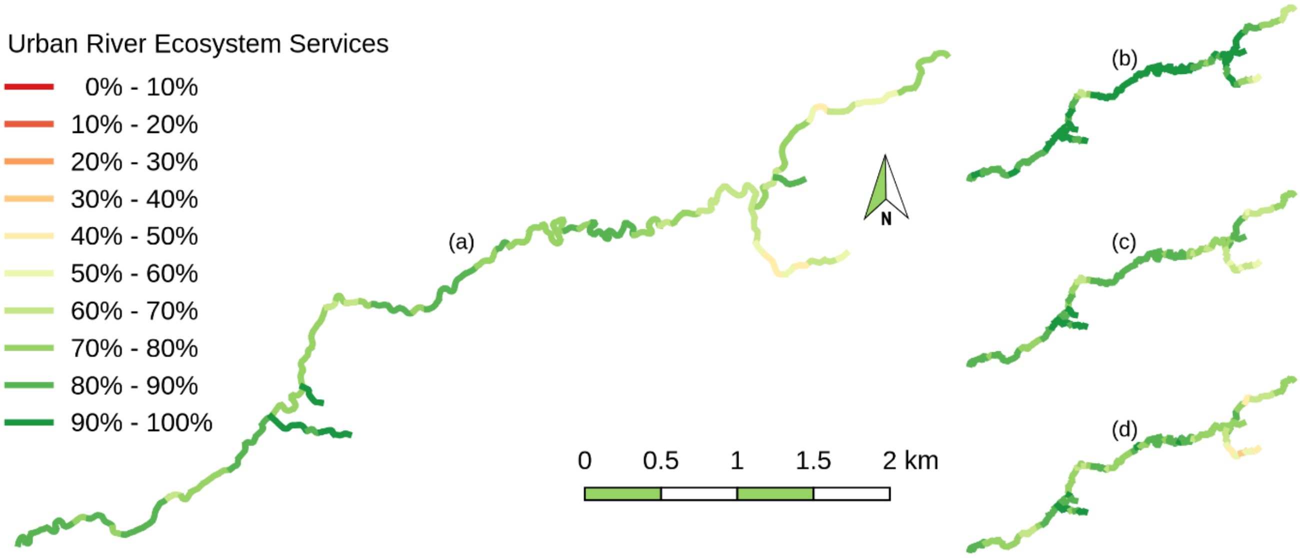

Figure 4. Urban River Ecosystem Services (URES) potential of the Pochote River: (**a**) Bio-remediation by micro-organisms, algae, plants, and animals & Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals; (**b**) Noise attenuation & Hydrological cycle and water flow regulation (Including flood control, and coastal protection) & Regulation of temperature and humidity, including ventilation and transpiration; (**c**) Maintaining nursery populations and habitats (Including gene pool protection); (**d**) Regulation of the chemical condition of freshwaters by living processes

The quantitative results of the URES potential of all sections of the Pochote River are summarized in Table 3. Although the values, in total, have a wide range, the average values are all above 74 %. This reveals that there are only a few sections with lower URES potential. But there are sections with low potential for all the considered URES.

Table 3. Range and average of Urban River Ecosystem Services values of all river sections of the Pochote River.

Urban River Ecosystem Service	**ES status range**	**ES status average**
Bio-remediation by micro-organisms, algae, plants, and animals	45% - 89%	77%
Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, animals	45% - 89%	77%
Noise attenuation	51% - 100%	89%
Hydrological cycle and water flow regulation (Including flood control)	51% - 100%	89%
Maintaining nursery populations and habitats (Including gene pool protection)	52% - 98%	80%
Regulation of the chemical condition of freshwaters by living processes	40% - 99%	76%
Regulation of temperature and humidity, including ventilation and transpiration	51% - 100%	89%

4 DISCUSSION

The introduced methodology has been developed and tested for the Pochote River as a first case study. The results reflect well the conditions of the different river sections. Provided the same information on the three ecosystem status categories, the methodology can easily be applied to other urban rivers. Whether the individual weighting of the ecosystem status categories for the different URES proves robust needs to be tested with additional case studies. The results represent an estimation of the URES provision potential. Whether there are real benefits (i.e. beneficiary) depends on the specific context. Therefore, the results serve the purpose of a first scoping, a subsequent assessment of benefits considering the inhabitants and specific uses in the surroundings of river sections will lead to more insights.

5 CONCLUSIONS

The presented methodology to examine the potential of urban river to provide ecosystem services is based on three ecosystem status categories that cover important biotic and abiotic realms. Moreover, the categories reflect commonly used indicators for ecosystem service examination. These indicators have been proven useful with regard to their relation of survey effort and information content. The ecosystem status date used in this study can easily be obtained at low cost. This is an important criterion when considering the application of the presented methodology in developing countries. The resulting potential of URES provision can be used to guide the protection of urban rivers and for a sustainable use of riparian areas. Ideally, a targeted integration of the URES into recreational and learning spaces of the city for an improved well-being of it's inhabitants is thereby achieved.

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