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SOME CONSIDERATIONS ON SOCIOGEOMORPHOLOGY AND ITS IMPORTANCE IN INTEGRATED MANAGEMENT OF NATURAL RESOURCES

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ABSTRACT

Natural landscapes have lost some of their characteristics due to human actions over time. Several sciences study natural processes based on non-social and non-political concepts that externalize the effects of human activities on systems. In this sense, emerging sciences such as socio-hydrology and sociogeomorphology face this lack of integration between natural sciences and society. The interdisciplinarity of sociogeomorphology allows identifying the hybrid production between humans and nature. The landscape is modified not only by natural processes but also by the decisions taken within the communities. Likewise, social development is influenced by natural processes, which establishes a bidirectional relationship between them. The present study examined the basic concepts of sociogeomorphology with a view to establishing a baseline. It will surely allow directing future work in the area of natural resource management. The concept of sociogeomorphology and human-nature interactions were discussed. The bibliographical review used the Google Scholar database In order to verify that there are some researches in this area at the national and international level. However, the lack of delimitation of this science does not allow its full identification. The potential for applying sociogeomorphology in studies of restoration of natural systems, land use planning and management, and natural disaster management is glimpsed.

Keywords – landscape coproduction, geomorphology, society

RESUMO

Paisagens naturais têm sido profundamente alteradas devido às ações antrópicas ao longo do tempo. Diversas ciências estudam processos naturais baseados em conceitos associas e apolíticos que externalizam os efeitos das ações do homem sobre os sistemas. Nesse sentido, ciências como a socio-hidrologia e a sociogeomorfologia enfatizam esta falta de integração entre ciências naturais e a sociedade. A interdisciplinaridade da sociogeomorfologia permite identificar a produção híbrida entre homem e natureza, em que a paisagem não é modificada unicamente pelos processos naturais, senão pelas decisões tomadas dentro das comunidades. Da mesma forma, o desenvolvimento da sociedade é influenciado pelos processos naturais, estabelecendo uma relação bidirecional. Reconhece-se a importância deste tema, pelo que o presente estudo examina os conceitos básicos da

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sociogeomorfologia com vista ao estabelecimento da linha base que permita direcionar trabalhos futuros na área de manejo de recursos naturais. Foi discutido o conceito e as interações da sociogeomorfologia. A revisão bibliográfica utilizou a base de dados *Google Scholar,* e permitiu identificar que existem algumas pesquisas nesta área a nível nacional e internacional. No entanto, a falta de delimitação desta ciência não permite sua plena identificação. Se vislumbra potencial de aplicação da sociogeomorfologia em estudos de restauração de sistemas naturais, ordenamento e gestão territorial, e gerenciamento de desastres naturais.

Palavras-Chave – coprodução da paisagem, geomorfologia, sociedade

INTRODUCTION

There is a worldwide growing concern to make the landscapes more natural. It takes place because the natural features of landscapes have been diminished due to anthropogenic action in the world over time. In this sense, many natural sciences such as hydrology, geology, geography, geomorphology, and ecology support understanding landscape processes and trying to establish the best path for the "landscape's renaturalization" (e.g., Frascaroli *et al*., 2020). On the other hand, human sciences seek to solve current social problems (Wright, 2009) and contribute to the improvement of natural systems because natural systems always interact with society. In the present work, the term of society described in Kobiyama *et al*. (2020) is adopted, i.e., the group of people who interact and have their functions and structure. This group develops events or activities that individually or jointly have an objective, which are called social activities. Certain social activities are addressed to landscape´s renaturalizations. Some examples of social activities to manage natural resources may include: i) mapping areas of environmental interest; ii) creating policies and mechanisms for environmental protection; iii) environmental education; and iv) implementation of sustainable infrastructure.

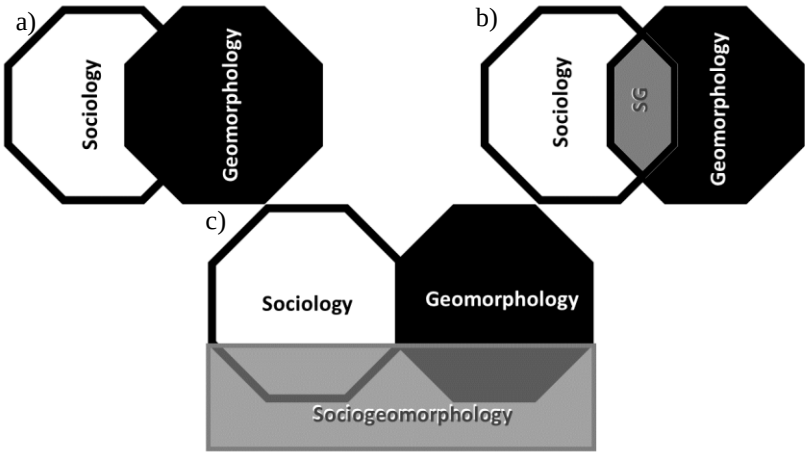
Society has created sciences to understand the interactions between the natural and the societal processes. Socio-hydrology, for example, studies the dynamics and coevolution of the human-water system and is defined as the science of people and water (Sivapalan *et al*., 2012). Socio-hydrology promotes the responsible use of water resources, improving the relationship between humans and water. Some researchers consider socio-hydrology as one of hyphenated hydrology (McCurley and Jawitz, 2017) which resulted from the advance of the proper hydrology. However, this type of science brings other scientific supports, which reflects its interdisciplinary aspects. For example, the hydrosocial cycle (socio-hydrology) differs widely from the hydrological cycle (hydrology). The former considers biophysical and socio-political processes, meanwhile the latter associative and apolitical concepts (Budds *et al*., 2014).

A science parallel to socio-hydrology may be sociogeomorphology. Analogically, it can be considered hyphenated geomorphology that provides knowledge and tools for the optimal management of natural and geomorphological resources that improves human-nature relationships. Sociogeomorphology introduces human beings into landscape processes, highlighting their coevolution with natural elements and processes, and eliminating the concept of man as an external object to the landscape Ashmore (2015). Geomorphic processes studied by geomorphology are also study subject of sociogeomorphology, for example, coastal and surface erosion, faults and mass movement on slopes, change in river channels, volcanism, and earthquake. These processes alter the Earth's surface and can be controlled by natural or human-induced factors. Geomorphic processes could be analyzed as geomorphic hazards when human factors are present. Thus, on this interface among geomorphology and human-induced factors, sociogeomorphology exerts an important role. Through recognition and understanding of geomorphic hazards (e.g., Zêzere, 2020; Nature Geoscience, 2021), the importance of sociogeomorphology becomes naturally clear. In practical terms, sociogeomorphology can recognize and understand both landscape and human

processes and their interactions. There is possible to consider the spiral cycle to understand bidirectional interactions. It means that the society modifies the landscape and geomorphic processes, then these modifications interfere with society and so on. Sociogeomorphology brings the coevolutionary framework to develop social and scientific activities which are integrated.

The relationship between sociology and geomorphology, in the present study, is established in three conceptual models (Fig. 1). The model in Figure 1a highlights the overlap of the sociology and geomorphology sciences concerning their common areas, but there is no interaction between them. In this case sociogeomorphology is not defined. Fig. 1b deals with the intersection between sociology and geomorphology, creating an interface without overlapping the other sciences. The last model (Fig. 1c) concerns sociogeomorphology as a science that has its proper attributes and incorporates elements of sociology and geomorphology.

Figure 1 – Sociogeomorphology Conceptual Model



In this sense, the objective of the present work was to examine the basic concepts of sociogeomorphology as a science parallel to socio-hydrology. Then, it will be possible to establish a baseline of the term "sociogeomorphology" that allows the direction and improvement in the management work of natural resources, especially in the Brazilian condition.

CONCEPTING SOCIOGEOMORFOLOGY

Geomorphology is a multidisciplinary and empirical science that studies (assessment, understanding, and classification) the landforms and landscape. It tries to understand the processes and dynamics that characterize landscapes' genesis and evolution and its relationship with other structures and processes (hydrological, climatic, biotic, tectonic, and anthropic) (Christofoletti, 1988; Goerl *et al*., 2012).

To refer to issues related to social impacts on geomorphology, the geomorphologists frequently use the term "Anthropocene" (Jefferson *et al.*, 2013). Anthropocene is a proposal for a geological epoch in which the significant impact of human beings on ecosystems on the Earth is recognized. In the Anthropocene, endogenous, exogenous, and artificial geomorphic processes occur at a specific epoch time. However, this epoch proposal has not been yet clearly defined or officially determined by the International Stratigraphy Commission (Trischler, 2016). This non-official term has been widely used for scientific researches in applied geomorphology. Thus, anthropogenic geomorphology or anthropogeomorphology, or Anthropocene geomorphology has been mentioned referring to the study of the direct impact of society on geomorphic processes and

landforms, in a unidirectional scope (Goudie, 1993; Girão and Correa, 2004; Jefferson *et al.*, 2013). Considering that anthropogenic geomorphology encompasses the study of all types of geomorphological/geological processes (artificial and non-artificial), it should be remarked that many of these studies are not intended to study bidirectional interactions between man and landscape dynamics (e.g., Farhan *et al.*, 2015). Thereby, there is a dilemma to say that anthropogenic geomorphology is the science to study societal relationships and interactions with geomorphological processes.

The term sociogeomorphology was used firstly by Ashmore (2015). This author made a holistic proposal to highlight the complexity of urban rivers and the need for an interdisciplinary approach, referring to these rivers as hybrid and socio-natural. Sociogeomorphology has also been used in other studies (Mould *et al.*, 2018a and 2018b), which reinforced the focus of science and its importance. Mould *et al*. (2018a) emphasized the dialogue among stakeholders as a relevant point in river management. These authors showed how non-technical knowledge must be also considered to look for opportunities to improve the research and management of landscapes.

Here we define sociogeomorphology as the science to study the bidirectional interactions between the geomorphological system (physical characteristics of the landforms and geomorphic processes) and the development of social activities. Thus, as a co-producer agent of the system, the the society and their elements are is integrated into the geomorphological analysis procedures for a better understanding of the man-nature relationship.

Concerning an establishment of an analysis unit, landscapes and fluvial-hillslope systems (or geomorphic systems) are recommended for sociogeomorphological studies. Fluvial-hillslope (or geomorphic) systems are delimited places (e.g., river basins) that integrate social activities, adding elements that allow characterizing partially the landscape complexity (Ramos *et al.*, 2017; Chaffin and Scown, 2018; Brierley *et al.*, 2019; Nascimento *et al.*, 2020). However, sociogeomorphological processes are not limited to basins. The extension of the community helps to delimit the unit of analysis (e.g. floodplain occupation). From a geographic point of view, landscapes are structures that allow to explain and represent in an integrated way the relationship between society and nature throughout history. Thus, sociogeomorphology analyses issues that drive or are consequences of changes in the landscape (Ashmore, 2015) such as political processes, local legislation, the history of the place, and the concerns of residents.

The analysis unit of sociogeomorphology is impacted by modifiers as structuring geomorphological actors as processes related to pedology and geology (Ashmore, 2015). However, man is the main geomorphic modifier that can sculpt or modify the landscape at high rates (Hooke, 2000; Wainwright & Millington, 2010). Human activities could rapidly transform the landscape. The changes made by man would take centuries to happen naturally or would not even occur. In this sense, human-natural interactions need to be studied deeply. The development of sociogeomorphological models to simulate the behavior of society facing geomorphic processes is an alternative to study interactions. This kind of model allows capturing and schematizing some dynamics between humans-nature.

SOCIOGEOMORPHIC INTERACTIONS

The disruption of the balance of natural systems by human activities has resulted in the acceleration of alteration of river basins, leading to impactful changes in the landscape during a short period. The adaptation of society in the face of geomorphic characteristics and the behavior of natural systems in front of anthropic action have significantly altered nature-society relationships. For example, indirect impacts of human activities on water bodies occur when anthropic actions derived from urbanization and changes in land use modify the channel's capacity, fluvial and

sedimentological processes. On the other hand, the direct impacts result from the engineering works built inside the channels, such as dam construction and hydroelectric plants, causing changes in the dynamics of river channels (Pereira, 2014; Girão and Barros, 2015).

Society-landscapes interaction could be considered in the sense of society over landscapes and vice-versa. In Brazil, there are changes in the land use with silting and flooding of channels, which have occurred since colonial periods; engineering interventions such as channel rectification, barrier, and irrigation are performed in recent urban and agricultural expansion processes. The society-landscapes interaction is observed when the geomorphic process transcends into a disaster and disrupts society's equilibrium.

This type of human history has taken palce not only in Brazil but also in other countries. In 1985, in Armero municipality (Colombia), the Nevado del Ruiz Volcano erupted and the lahar flowed down. Then, large amounts of precipitation triggered a flow of debris and woody debris. Both events wiped out the city because they were not prepared to face any of these geomorphic hazards. The estimated number of deaths was around 25,000. Furthermore, 5,000 injured and 9,000 survivors (Mojica *et al.*, 1985). This historical example demonstrates how a geomorphic process dramatically changed society's balance. As a consequence, this city had to be rebuilt in another place.

Many people live in mountain regions in Japan, where flash floods and mass movements have caused serious damages. Since such mountain disasters take place every year, local communities feel the necessity to strengthen themselves by several laws. Therefore, the landslides became objects for the public infrastructure construction business. Hence, society has begun to treat landslides from an economic point of view. In other words, landslides, which were originally just geomorphic phenomena, are now subject to economic interest (Takaya, 2008). This social situation has been noted not only in Japan but also in many countries, including Brazil (Fraga, 2001). Landslide-related disasters can be reduced based on a fusion of natural sciences (geomorphology, earth surface dynamics, etc.) and social sciences (sociology, economy, etc.) It implies the importance and necessity of sociogeomorphology.

Thus, populations that suffer catastrophic events create memory and acquire valuable knowledge in sociogeomorphology. However, when managers or scientific researchers do not consider such a memory, this knowledge will usually desapper soon later. It is necessary to think and propose a less degrading and more conscious social development model. The development model needs to go beyond conservative actions' expansion, redirecting all society towards the use and conservation resources in a more "intelligent" way (Coelho, 2008) and inside sustainability context (UN, 2015).

BIBLIOGRAPHIC REVIEW AND ANALYSIS

Among several sources of scientific references, we chose to search sociogeomorphology information in 3 free-access databases, being one international and two Brazilian:

- Google Scholar;
- Brazilian Digital Library of Theses and Dissertations (BDTD);
- Catalog of Theses and Dissertations (CAPES)

For each dataset, the searched keywords were "sociogeomorphology" and "*sociogeomorfologia*", and we considered scientific materials both in English and in Portuguese. The search delimited by these keywords considered the entire document (title, abstract, keywords, and text). A period for the investigation was not established to cover as many materials as possible.

Thus, to understand the context of sociogeomorphology, the scientific works were checked one by one, which allowed organizing their contents and discarding unrelated works. Lately, we

computed the year of publication, authorship, title, type of publication, and the source database. The general trend of sociogeomorphology in Brazil was identified by the relative number of studies on specif topics.

RESULTS AND DISCUSSION

We identified 51 works related to the word "sociogeomorphology" and/or "*sociogeomorfologia*" among the consulted databases (Table 1). The presence of sociogeomorphology was identified in several kinds of research fields such as natural disasters, ethnogeomorphology, critical physical geography, land planning and management, and restoration or rehabilitation of rivers. The multidisciplinarity of sociogeomorphology studies was verified. In addition, the interlinkages between natural science and societal structures were verified. In this sense, may be said that the current world is developing inside Socio-Natural Sites (SNS), places where human practices interact with the material world and all SNS are subject to natural laws (Haumann *et al.*, 2020).

Table 1– Identification of sociogeomorphological studies in the databases.

Locality	**Number of studies related to sociogeomorphology**	**Topic**	**Number of studies by Topic**	
	Absolute		**Absolut**	**Percentage**
Brazil	13	Natural Disaster	3	23.1
		Etnogeomorphology	3	23.1
		Critical Physical Geography	2	15.4
		Land planning and management	5	38.5
Others	38	Anthropocene	3	7.9
		Natural Disaster	1	2.6
		Etnogeomorphology	1	2.6
		Critical Physical Geography	3	7.9
		Geographic Geomorphology	1	2.6
		Land planning and management	9	23.7
		Resilience	6	15.8
		River Restoration	13	34.2
		Socio-Natural Sites	1	2.6

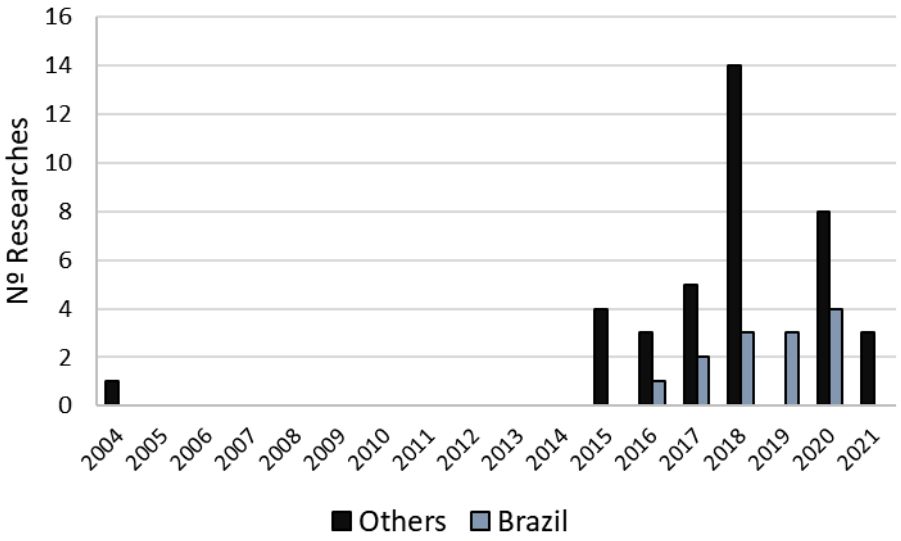
The numbers of sociogeomorphological studies carried out in Brazil and other countries were 13 and 38, respectively. Most of the studies belong to scientific papers. International works were published in journals such as "Geomorphology", "Society and Natural Resources", and "Earth Surface Processes and Landforms". Brazilian journals such as "Revista do Geociencias do Nordeste", "Acta Geográfca" and "Caminhos da Geografía" published papers on this subject. In a smaller proportion, doctoral dissertations and master's theses were identified. The category "Land planning and management" was the theme with the most studies encountered in Brazil. In addition, the category variation in Brazil was smaller than that in other countries. The category of river restoration outside Brazil was the theme with the highest percentage of the whole samples. It might result from a strong concern of international populations to recover the fluvial environment as well as to reduce flood-related disasters. The close relationship among sociogeomorphology, socio-hydrology, and socio-ecology is observed, and it is explained due to exploring the coevolution of human-natural system.

It is worth mentioning that the number of studies related to etnogeomorphology was higher in Brazil than in other countries. This fact might be explained by native people's history in the Brazilian territory and its current effort to claiming attention toward their problems.

Nature Geoscience (2021) mentioned that there must be a physical understanding of the geomorphic processes combined with effective communication to the community to minimize the disaster risks. However, in both international and Brazilian scenarios, the lack of works together between geoscientists and social scientists is evident. There is a lower number of studies on natural disasters that use sociogeomorphology keywords compared with all the analyzed studies. We highlight that anthropogenic activities have a negative effect on the occurrence of geological/geomorphic processes. According to Nature Geoscience (2021), society interacts with natural processes and exacerbates the associated risks creating complex cascades of hazards.

Figure 2 shows the number of publications in Brazil and other countries during the period from 2004 to the present. No study on sociogeomorphology was found from 2005 to 2014 in the world. We identify just one study before 2015 that considered the sociogeomorphology principles. McDonald *et al*. (2004) developed a conceptual model for river restoration, where ecological and geomorphological principles were considered and mixed with social and economic aspects. A more significant number of studies is seen in 2018 when there is a peak in international studies. Even though the increasing tendency of the works in Brazil is observed, the total number of the works is still small.

Figure 2 – Records of sociogeomorphological studies listed by the databases (research carried out on 4/5/21)



FINAL REMARKS

The 2030 Agenda for Sustainable Development (UN, 2015) seeks to achieve harmony between social progress and nature, and tries to establish three dimensions that lead to sustainable development: economic, social, and environmental. Thus, sociogeomorphology is embedded in social and environmental dimensions. Sociogeomorphology is a part of the sciences that use the concepts of social sciences and natural sciences to understand the relationships between social activities and natural processes that are, in this case, geomorphic processes. The application of sociogeomorphology can return natural features to the landscape, which has been disturbed by anthropic actions over time. Sociogeomorphology highlights the co-producer role of man, the man is not only longer conceived as the agent that impacts the natural system. In this science, historical, political, and environmental conditions are crucial to making the right landscape changes. Sociogeomorphological studies suggest managers and scientists should use the holistic view and integrate the different elements in the landscapes.

Thus, sociogeomorphology can be very suitable for developing projects within the framework of the Sustainable Development Goals. This type of knowledge and its applications in community planning must be disseminated, for example, river restoration, reduction of natural disasters, water resources management, and increasing society's resilience. Although all aforementioned statements seem logical in natural resources and natural disaster management context, in countries like Brazil, a growing but still not very popular acceptance of sociogeomorphological studies can be observed. Knowing this actual situation, communities of scientists and managers interested in integrated management of water resources, natural disasters, and so forth should try to advance the sociogeomorphology in Brazil.

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REFERENCES

ASHMORE, P. (2015). *"Towards a sociogeomorphology of rivers*". Geomorphology, 251, 149-156.

BRIERLEY, G., FRYIRS, K., MARCAL, M., & LIMA, R. (2019). *"The use of the River Styles Framework as a tool to'work with nature'in managing rivers in Brazil: examples from the Macaé Catchment"*. Revista Brasileira de Geomorfologia, 20 (4). http://dx.doi.org/10.20502/rbg.v20i4.1559.

BUDDS, J., LINTON, J., MCDONNELL, R. (2014). "*The hydrosocial cycle"*. Geoforum 57, 167-169.

CHAFFIN, B. C., & SCOWN, M. (2018). *"Social-ecological resilience and geomorphic systems"*. Geomorphology, 305, 221-230.

CHRISTOFOLETTI, A. *Geomorfologia*. Editora Blucher, 1988.

COELHO, A. L. N. (2008). *"Geomorfologia fluvial de rios impactados por barragens-Fluvial Geomorphology of Rivers Impacted From Dams".* Caminhos de Geografia, 9(26).

FARHAN, Y., ANBAR, A., ENABA, O., & AL-SHAIKH, N. (2015). *"Quantitative analysis of geomorphometric parameters of Wadi Kerak, Jordan, using remote sensing and GIS"*. Journal of Water Resource and Protection, 7(06), 456.

FRAGA, N. C. (2001). *"As enchentes no Vale do Itajaí-Açú/SC: das obras de contenção à indústria da enchente–a problemática ambiental e a relação homem/natureza na busca de soluções*". RAEGA-O Espaço Geográfico em Análise, 5(1).

FRASCAROLI, F., PARRINELLO, G., & ROOT-BERNSTEIN, M. (2020). *"Linking contemporary river restoration to economics, technology, politics, and society: Perspectives from a historical case study of the Po River Basin, Italy"*. Ambio, 1-13.

GIRÃO, O., & CORREA, A. D. B. (2004). *"A contribuição da geomorfologia para o planejamento da ocupação de novas áreas*". Revista de Geografia, Recife, 21(2), 36-58.

GIRÃO, O., & de BARROS, A. C. (2015). Progressos nos estudos de geomorfologia fluvial urbana ao final do século XX. Geo Uerj, (26), 245-269.

GOERL, R. F., KOBIYAMA, M., & SANTOS, I. (2012). *"Hidrogeomorfologia: princípios, conceitos, processos e aplicações hydrogeomorphology: principles, concepts, processes and aplications."* Revista Brasileira de Geomorfologia, 13(2).

GOUDIE, A. S. *"The Human Impacts on the Natural Environment*". 4 ed. Oxford: Blackwell. 1993.

HAUMANN, S., KNOLL, M. and MARES, D. (2020). *"Concepts of Urban-Environmental History"*, Bielefeld: transcript-Verlag. https://doi.org/10.14361/9783839443750.

HOOKE, R. L. (2000). *"On the history of humans as geomorphic agents".* Geology, 28(9), 843-846.

JEFFERSON, A. J., WEGMANN, K. W., & CHIN, A. (2013). *"Geomorphology of the Anthropocene: Understanding the surficial legacy of past and present human activities"*. Anthropocene, (2), 1-3.

MCCURLEY, K. L., & JAWITZ, J. W. (2017). *"Hyphenated hydrology: Interdisciplinary evolution of water resource Science"*. Water Resources Research, 53(4), 2972-2982.

MOJICA, J., COLMENARES, F., VILLARROEL, C., MACIA, C., & MORENO, M. (1985). *"Características del flujo de lodo ocurrido el 13 de Noviembre de 1985 en el valle de Armero (Tolima, Colombia): Historia y comentarios de los flujos de 1595 y 1845"*. Geología Colombiana, 14, 107-140.

MOULD, S. A., FRYIRS, K., & HOWITT, R. (2018a). *"Practicing Sociogeomorphology: Relationships and dialog in river research and management"*. Society & Natural Resources, 31(1), 106-120.

MOULD, S., FRYIRS, K., & HOWITT, R. (2018b). *"Sociogeomorphic river recovery: integrating human and physical processes in rehabilitation"*. In Australian Stream Management Conference (9th: 2018) (pp. 33-40). River Basin Management Society.

NASCIMENTO, F. H., SILVA, A. F., RANGEL, S. D. A. S., & DOS SANTOS, F. B. (2020). *"Avaliação visual rápida de rios urbanos: o caso do baixo curso da bacia hidrográfica do rio reis magos e do rio jacaraípe, espírito santo".* Caminhos de Geografia, 21(73), 492-505.

NATURE GEOSCIENCE. *"Hazard cascades".* Nature Geoscience 14, 179 (2021). https://doi.org/10.1038/s41561-021-00738-9

PEREIRA, A. (2014). *"Impactos sócio-ambientais da Hidrelétrica do Funil na comunidade de Ponta Negra"*. Sinapse Múltipla, v. 3, n. 2, p. 135-146.

RAMOS, A. L. D., SARTÓRIO, M. V. O., SALDANHA, M. C., & COELHO, A. L. N. (2017). *"Avaliação visual de rios urbanos: metodologia e aplicação"*. Acta Geográfica, 11(25), 159-184.

SIVAPALAN, M., SAVENIJE, H. H., & BLÖSCHL, G. (2012). *"Socio-hydrology: A new science of people and water".* Hydrol. Process, 26(8), 1270-1276.

TAKAYA, S. (2008) "*Knowledge on landslides and rock falls, necessary for engineers*". Tokyo: Kajima Publishing Co., 151p. (in Japanese)

TRISCHLER, H. (2016). "*The Anthropocene. NTM Zeitschrift für Geschichte der Wissenschaften"*, Technik und Medizin, 24(3), 309-335.

UN. (2015). *"Transforming our world: The 2030 agenda for sustainable development"*. United Nations.

WAINWRIGHT, J., & MILLINGTON, J. D. (2010). *"Mind, the gap in landscape-evolution modelling"*. Earth Surface Processes and Landforms: The Journal of the British Geomorphological Research Group, 35(7), 842-855.

Zêzere J.L. (2020). *"Geomorphological Hazards"*. In: Vieira G., Zêzere J., Mora C. (eds) Landscapes and Landforms of Portugal. World Geomorphological Landscapes. Springer, Cham. https://doi.org/10.1007/978-3-319-03641-0_3