XXIII SIMPÓSIO BRASILEIRO DE RECURSOS HÍDRICOS

SCHOOL CATCHMENT FOR HYDROLOGY EDUCATION AND WATER RESOURCES MANAGEMENT AT LOCAL COMMUNITY LEVEL

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RESUMO – O objetivo do presente trabalho foi revisitar o conceito de bacia-escola por meio de revisão de literatura, apresentar como construí-la e discutir como ela é útil para a educação sobre a água e a gestão de recursos hídricos. Aqui, a bacia-escola é redefinida como bacia experimental que instiga os cidadãos a aprender ciências ao mesmo tempo em que recebem educação ambiental e treinamento profissional. O estabelecimento de bacias-escola certamente promove a ciência cidadã ou transforma a hidrologia para a ciência cidadã, o que por sua vez melhora a aprendizagem social e a gestão de recursos hídricos de maneira integrada.

ABSTRACT – The objective of the present work was to revisit the concept of school catchment through a literature review, to present how to construct it, and to discuss how it is useful for hydrology education and water resources management. Here school catchment is redefined as an experimental catchment that incites citizens to learn sciences while at the same time receiving environmental education and professional training. The establishment of school catchments certainly promotes citizen science or transforms hydrology to citizen science, which in turn enhances social learning and the water resources management in an integrated manner.

Palavras-Chave – bacia-escola, educação, ciência cidadã.

1 – INTRODUCTION

Bales (2015) defined catchment as an area in which water falling on or flowing across the land surface drains into a particular stream or river and flows ultimately through a single outlet. The term “school catchment” was first introduced by Kobiyama et al. (2007) to translate the Portuguese term “bacia-escola”. In this study, a school catchment, basin or watershed is defined as an experimental catchment that includes several measuring devices and serves not only for scientific research, but also for environmental education activities (Kobiyama et al., 2007). It addresses subjects related to hydrology, geomorphology, among others and it can be employed for protection education and training and civil defense.

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To the best of our knowledge, Dr. Geraldo Silveira, former professor of Federal University of Santa Maria (UFSM), was the first person who used this innovative term "bacia-escola". This term was introduced in a proposal for a scientific project by Silveira (2000). However, even though the term "bacia-escola" was mentioned by Silveira (2000), its concept and definition were not fully explored. Later, Silveira (2001) further divulged his idea to the Brazilian Association of Water Resources, highlighting that "school catchment" projects are teaching tools suitable for training human resources. After his pioneering works, various researchers in Brazil started using this term for various scientific research and extension projects. Due to its relevance, the school catchment strategy was inserted into the Integrated Environmental Management of Urban Waters as an innovative concept in order to solve urban drainage problems (Mendiondo, 2002b).

The objective of the present work was to revisit the concept of school catchment and discuss how it is useful for hydrology education and water resources management. Further, the potential use of school catchment for promoting social learning and democratizing science by involving citizens in hydrological and environmental data collection, interpretation and analysis is evaluated. Since the Portuguese word "bacia" can be translated to catchment, watershed and basin, school catchment can be denominated also school watershed as well as school basin.

2 – AN OVERVIEW OF THE SCHOOL CATCHMENT CONCEPT

According to Mendiondo (2002a), school catchment is a broader concept when compared to experimental catchments as it becomes a support infrastructure. In this regard, scientific research and technological development in the field of urban water resources open the possibilities for social participation. For this author, the main purpose of school catchment is to advance science and technology. Therefore, Mendiondo (2002b) mentioned that the development of school catchments opens up the opportunity to support research and projects that meet social demands in the face of the control of urban water resources.

To advance the scientific knowledge about forest hydrology, the Laboratory of Hydrology of Federal University of Santa Catarina established several experimental catchments with one local company of reforestation in southern Brazil. In this case, one of the main objectives of the project was to use these experimental catchments for environmental education for local people. Then, Kobiyama *et al*. (2007) defined, as school catchment, any experimental catchment which serves for scientific researches and environmental education activities.

In adopting the above-mentioned definition, Kobiyama *et al*. (2009) implemented the school catchments network in order to verify what kind of land-use is best for the water resources management in the Upper Negro River at the border between Paraná and Santa Catarina states, southern Brazil.

In contrast to the term school catchment, the concept of catchment network is not new. In justifying catchment studies and the long term monitoring system for the investigation of hydrological effects of forest, Whitehead and Robinson (1993) reported some European examples of the catchment networks. Besides, O'Connell et al. (2007) introduced the Catchment Hydrology and Sustainable Management (CHASM) research program that contains the catchment network in the UK and that adopts a common multiscale experimental design. Nevertheless, these networks seem to be established only for the purpose of scientific research. The concept of such networks is, therefore, quite distinct from that of the present study where the school catchment network contributes not only to the scientific researches but also to the environmental education activities. This idea of combining scientific research with environmental education was introduced to the European community by Haigh (2009).

By searching the definition of school various results can be found, including: (i) school is an organization that provides instruction; (ii) a source of knowledge; (iii) an institution for educating children; (iv) any institution at which instruction is given in a particular discipline; and so on. The (i) and (ii) items are from https://www.merriam-webster.com/dictionary/school meanwhile the (iii) and (iv) from https://en.oxforddictionaries.com/definition/school. Normally, the item (iii) is what people usually associate with the word of school. However, in the present work, we prefer the definitions of (i) and (ii). In these cases, school is capable to create knowledge for all the citizens. It supports that the school catchment is for all, not only pupils and students but also those who have finished other types of education levels (primary, secondary and higher education). It implies that school catchment serves for science learning, scientific research, recreation, environmental education, professional training, etc.

Some works just used the term school catchment, and they did not utilize its concept in their works. For example, Barros *et al*. (2007) carried out a mapping of flood areas to discuss the Master Plan of Urban Drainage in São Carlos city, putting the term school catchment in the title of the work, however, they did not use this term at all in a whole text. It implies that some researchers use this term just to get attention.

Considering the discussion above mentioned, we redefine school catchment as experimental catchment that serves for all the citizens to learn sciences, to receive environmental education and any type of professional training.

3 – CONSTRUCTION OF SCHOOL CATCHMENT

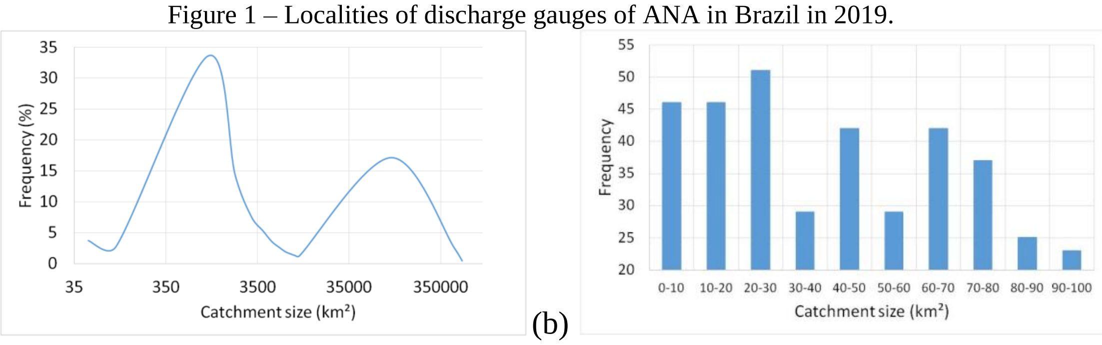
As above mentioned, experimental catchment can become school catchment. Therefore, firstly experimental catchment should be constructed. Usually, we install some apparatuses to monitor some environmental (or hydrological) parameters automatically. If apparatuses are expensive, we can do just measurement or observation frequently in order to exercise the monitoring manually. The former way permits the short time interval (seconds, minutes and hours) meanwhile the latter the longer interval (days, weeks, months, years, etc.). Independent of the time interval, we can call experimental catchment if the measurement is continuous, i.e., the monitoring is performed.

For hydrology and water resources management, rainfall and water discharge monitoring is considered principal in experimental and school catchments. Hence, the construction of rainfall gauge and water discharge station have been dealt over the world (WMO, 2008; ANA, 2011).

For education (training) facility, rainfall gauge and discharge gauge can be closely constructed. The location of the discharge gauge is considered outlet of the experimental catchment. In case that the catchment is very large and/or the catchment has a kind of mountain environment, the construction of rainfall gauge on the top of the catchment (headwater region) is often desired.

Any case, the construction of one rainfall gauge and one discharge gauge permits a simple water balance analysis, which is the principle in hydrology, and consequently contributes to water resources management. Hence ANA, ANEEL and so forth have been constructing many gauge stations in a whole Brazilian territory (Figure 1). Analyzing the statistics of all the discharge gauge stations of ANA, we clearly observe that large scale catchments are monitored more than small catchments in Brazil (Figure 2). Even though there are many stations for discharge monitoring, the mean and median values of the contribution areas are 35,297 km^2 and 1,690 km^2, respectively, among the totally 9,161 stations. It is, therefore, required to install the discharge gauge whose locality constructs a small size of the experimental catchment.

Figure 1 – Localities of discharge gauges of ANA in Brazil in 2019.



(a) (b)

Figure 2 – Frequency of catchment sizes of discharge gauges of ANA in Brazil: (a) All the gauges; and (b) catchment sizes less than 100 km^2.

In a comparison between rainfall and discharge, rainfall can be considered more important for hydrology education and water management, because of its importance as well as its easy measurement. Measured data of rainfall can support weather forecasting, an alert system establishment, hazard mapping, and construction such as dams, bridges, roads, ports, dikes, and so forth. Besides, rainfall records can be very useful for many hydrological studies such as estimates of the maximum flood flows and the flood frequency. As floods are totally weather-dependent, rainfall measurement is indispensable in order to minimize flood damage. Though weather radars are strongly desired in large countries like Brazil, it is difficult to install them due to their high cost.

Hence the easiest way to measure is to perform a manual measurement. Rain measurements not only generate rainfall data. Such measurement activities carried out by the community will certainly contribute to the awareness of the measurement itself, water resources, natural disasters, etc., being part of environmental education and citizen training.

Despite the importance of rainfall measurement, the number of rainfall gauge stations is still insufficient in Brazil (for example, Cristaldo *et al*., 2017), which requires to organize the communities, based on the initiative of the citizens, to join efforts in order to increase the number of rainfall gauge stations with daily rainfall measurement (Kobiyama *et al*., 2006). Hence, first of all, it is ideal for all the primary and secondary schools to have a rain gauge and measure rain every day. Then each school teaches all the pupils and/or students how to measure rainfall with hand-made apparatus. The advantage is the low cost of the equipment, and the challenge is the long-term data collection in these places, and the proper installation and maintenance of the apparatus.

Nowadays, the water quality of large rivers that used to supply drinking water to many municipalities has been deteriorated. In this situation, a lot of municipalities are obligated to seek for small catchments where natural vegetation covers are preserved without intensive urbanization nor land-transformation to agriculture. Furthermore, many urban areas in cities have suffered from floods which are often considered flash-flood types. Because of the short values of time of concentration due to large urbanized-areas as well as to the small catchment-size, the flash floods have been occurring more frequently in such catchments (Kobiyama and Goerl, 2007).

Thus, in order to manage water resource areas (headwater regions), to reduce urban-floods disasters, to utilize mountain catchments for ecotourism and recreation, it is necessary to create a lot of small experimental catchments. After the construction of experimental catchments, any community just uses them for education and training. Then, they become small school-catchments. Based on the idea of E.F. Schumacher “Small is beautiful”, the small size of school catchments certainly serve for science and education with more efficiency (Kobiyama *et al*., 2016)

4 – USE OF SCHOOL CATCHMENT

In the school catchment, rainfall and discharge can be observed with naked eyes. Eye-observation together with confirming monitoring values certainly increases the perception capacity of learning/training inhabitants as well as increase their awareness. Water-level observation itself allows people to recognize directly water quantity. These data of community-based observations contribute for monitoring and alert system and they can supports the man-decision about early area evacuation, for example.

Hydrometry on the field also increases perspective. For local inhabitants, the velocity of surface flow can be measured directly with a floating method. Velocity perspective is very important so that one person decides to walk or run across the water flowing on roads during (flash) floods. If he has a knowledge of hazard index proposed by Stephenson (2002), i.e., $HI = v \cdot h$ where HI is the hazard index, v is the flow velocity and h is the water depth, and if he can recognize the values of v and h, he is able to know if he can cross the water flow or not.

According to Paul *et al*. (2018), many projects involve community-based responses to river flooding, taking a preventive approach or providing real-time observation and mitigation. However, in the majority of this projects, the role of scientists is limited to data gathering, rather than leveraging the full potential of actionable knowledge co-generation and on training the project participants properly.

Field hydrologists and geomorphologists usually measure several parameters by using very simple to very expensive and sophisticated apparatuses. However, just for increasing perception of citizens, it is not necessary to use expensive and sophisticated ones. The local inhabitants have the potential to offer timely and low-cost solutions to the data collection in the school catchment (Starkey *et al*. 2017).

In an international journal Hydrology and Earth System Sciences (HESS), Seibert et al. (2013) reported the HESS Special Issue on “Hydrology education in a changing world”. Indeed, the hydrology education can be considered one of the six themes of the Eighth Phase of the International Hydrological Programme of UNESCO (Jimenez-Cisneros, 2015). According to Wagener et al. (2007), hydrology educators are necessarily influenced by their background and their expertise when designing hydrology classes and therefore require new educational tools and resources to educate the next generation of interdisciplinary hydrologists.

In this context, various trials for hydrology education have been done at various levels and in various countries. For example, primary school in Finland (Havu-Nuutinen *et al*., 2011), junior high school in Israel (Ben-zvi-Assarf and Orion, 2005), secondary school in Swiss (Reinfried et al., 2012), undergraduate levels in 43 countries (Wagener *et al*., 2012), graduate school level (Blöschl *et al*., 2012) and any citizens in the Netherlands (Minkman *et al*., 2017) which showed the importance of community participation for water resources management.

5 – CITIZEN SCIENCE

The community involvement in the generation of new knowledge about the natural environment refers to the citizen science (Buytaert *et al*. 2014). Other terms also be used (e.g. crowdsourcing, volunteered geographical information – VGI), it depends of degree of involvement and the technique adopted (Starkey *et al*. 2017).

Since school catchment is constructed for all the citizens, its use is naturally very suitable for citizen science. In other words, school catchment is considered as very adequate tool for changing hydrology to citizen science. Local inhabitant learn about hydrology and their participation in the data collection activities is encouraged. Thus, the increased community involvement generates more information quantity about that catchment. Besides of the improvement of citizen perception may help them early recognize natural disaster (risk awareness). According to Buytaert *et al*. (2014), the concept and potential of citizen science only recently received increasing scientific attention, despite being an intrinsic part of the scientific knowledge generation process.

This approach between society and natural environment contributes to the advances to socio-hydrology. The cooperation among the community and professional generates data about the natural phenomena and the bidirectional interaction human-water. These data considering the catchment as the territorial unit. Hence, the school catchment is a part of the socio-hydrology supporting the Integrated Management of Water Resources and Natural Disaster (Figure 3).

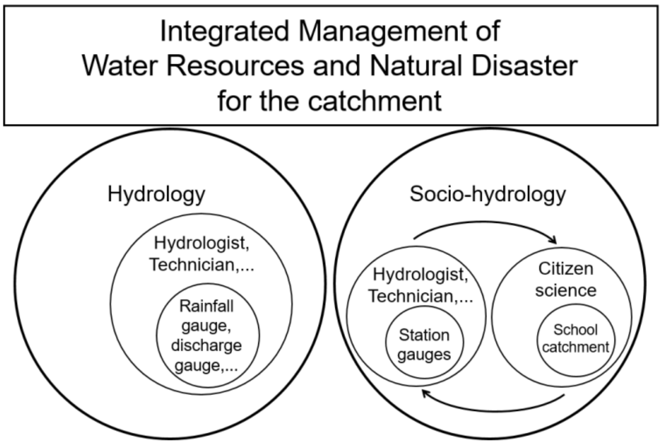


Figure 3 – School catchment as part of the Integrated Management of Water Resources and Natural Disaster for the catchment as territorial unit supported by hydrology and socio-hydrology.

6 – INTEGRATED MANAGEMENTS BASED ON SCHOOL CATCHMENTS

Management of natural disasters, water resources, and catchments should be carried out in an integrated manner, which can be supported by socio-hydrology whose base is school catchment construction and use (Kobiyama *et al*., 2018). Santos *et al*. (2011) constructed the Catu River school catchment located 70 km north to Salvador-BA, in order to create a link among the CPRM, users of collected data, equipment manufacturers, scientific communities and society in general. Hence, school catchment possesses the integration characteristics to integrate diverse elements, sectors, approaches, and so on. It can be one of the essences to be "school".

Furthermore, school is for all the citizens, and analogically school catchment, too. It means that school catchment needs the citizens' participation and vice versa. Recently, floods, especially flash floods have been causing serious damages to communities and their reduction requires citizens' observation and monitoring which can be more extensive and intensive (Starkey *et al*., 2017). These authors mentioned that many small catchments suffering from flash floods still remain ungauged in the UK, and demonstrated how useful and successful community-based rainfall, river-level and flood observation were for catchment modeling and management.

Thus, integrated management of water resources and natural disasters can be established with school catchment that promotes citizen science. According to Silvertown (2009), citizen science is not a new concept and it has been becoming commoner in natural sciences. Though such citizen science is becoming more popular, there are still a small number of works in Brazil (Cunha et al., 2017).

7 – FINAL REMARKS

The present work firstly introduced the historical review on scientific literature which dealt with school catchment concept in Brazil. Showing the definition, use and potential of school catchment, the relationship among the integrated management, school catchment and citizen science was discussed. Resuming, school catchment promotes citizen science in a community, which consolidates the integrated management of water resources and natural disaster.

Considering the fact that the management success depends on the education for all the citizens, hydrology education at all the levels should be more valued. The special concern on hydrology education is not very new, for example, Hufschmidt (1967). In order to carry out an adequate management of water resources as well as natural disasters, the relations, interactions and interfaces among hydrology education, school catchment and citizen science should be more discussed broadly.

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