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Hydrological disasters reduction: lessons from hydrology

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Abstract:
The hydrological disasters have increased in the last decades, in magnitude and frequency. They are divided in two groups: water-related and sediment-related disasters. Though the natural phenomena that cause such disasters have been researched, their characteristics and hydrological processes are not completely understood until now. Therefore, the distinction of these disasters is not simple, and many societies have not been able to implement adequate mitigation countermeasures. Historically, societies have first settled on the floodplains and subsequently on the hillsides, thus being more used to coexist with floods than landslides and debris flow. During the long development process, hillside areas occupation is increased and some societies begin to suffer more from sediment-related disasters (landslides and debris flows) than from water-related ones (floods). By presenting three case studies done in Santa Catarina State, Brazil, the present work describes the importance to apply the hydrology for the hydrological disasters reduction, with the emphasis of school catchment network implementation. Finally, the philosophical aspects which may be the most important in disasters management are discussed.
Key-words: Hydrological disasters; sediment-related disasters; water-related disasters; school catchment; hydrology.

Resumo:
Os desastres hidrológicos têm aumentado nas últimas décadas, em magnitude e freqüência. Esses desastres são divididos em dois grupos: os relacionados a água e os relacionados a sedimento. Embora os fenômenos que causam tais desastres sejam amplamente estudados, suas características e os processos hidrológicos relacionados a eles ainda não são completamente compreendidos. Assim, a diferenciação desses desastres não é simples, e as sociedades ainda não conseguem implementar medidas mitigadoras satisfatórias para a redução de danos. Historicamente, ocupações são feitas nas planícies inundáveis antes das áreas de encostas, por isso as comunidades aprendem a conviver mais com as inundações do que com os escorregamentos. Ao longo do tempo, a ocupação das áreas de encostas avança, e conseqüentemente as sociedades vêm sofrendo mais com desastres relacionados a sedimentos do que com desastres relacionados a água. Neste contexto, apresentamos três estudos de caso, realizados no estado de Santa Catarina, Brasil, mostrando a importância da aplicação da hidrologia para a

redução de desastres hidrológicos, com ênfase de implementação de rede de bacias-escola. Finalmente, alguns aspectos filosóficos que podem ser mais importantes para o gerenciamento de desastres são discutidos.
Palavras-chave: Desastres hidrológicos; desastres relacionados a sedimento; desastres relacionados à água; bacia escola; hidrologia.

1. Introduction

During the period of 1992-2001, natural disasters killed in average 60,000 people per year. The total lives affected in those ten years were 200 million and the economic losses sum up to US$ 61 billion (Twing, 2004). Ismail-Zadeh & Takeuchi (2007) argued that there is a worldwide increasing trend of natural disasters frequency and their negative impacts, mainly due to the population growth and the high concentration of urban areas in natural hazards zones. McDonald (2003) reported that the damages associated to the natural disasters increased ten times in the last decades, partially because of the occupation of risk areas due to the population growth, and partially because of the economic conditions of people that occupy hazard zones forming a high vulnerability settlement.

The International Strategy for Disaster Reduction (UN-ISDR) classifies the natural disasters in five groups: hydrological, meteorological, geophysical, climatological and biological. The hydrological disasters are those related to extremes in the hydrological cycle, and are divided in two main-types: wet mass movement and flood. The former includes landslides, debris flows and other sediment-related disasters. And the latter includes river flood (or simply flood), flash flood and coastal flood (Below et al., 2009).

An increase of the water-related disasters' occurrence and magnitude has been reported in the last decade (Rodriguez et al., 2009). Among all the natural disasters, the hydrological ones are the most common in the world (Figure 1). The same tendency can be seen in Brazil (Figure 2a), which implies an urgent necessity to implement more structural and non-structural countermeasures for reducing the hydrological disasters.

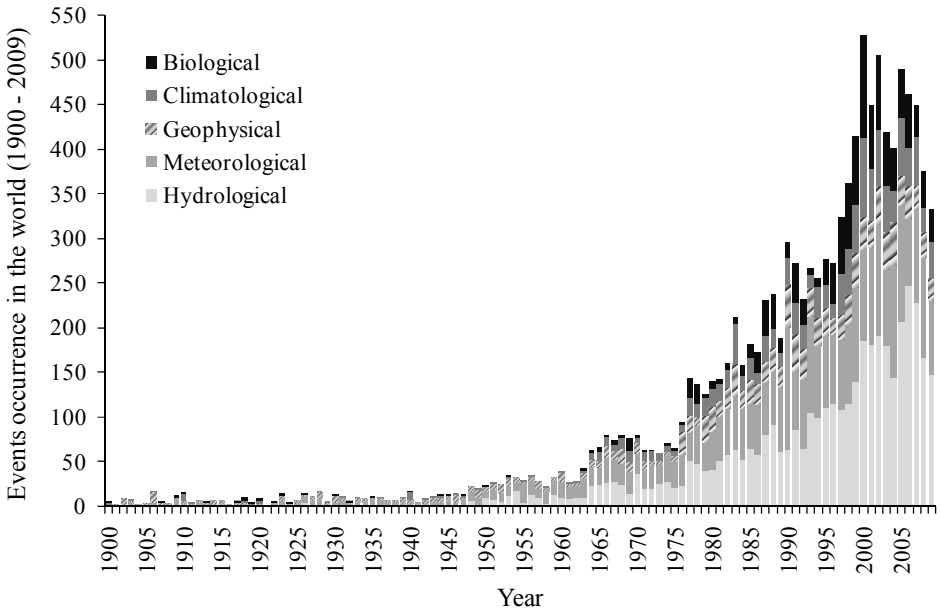
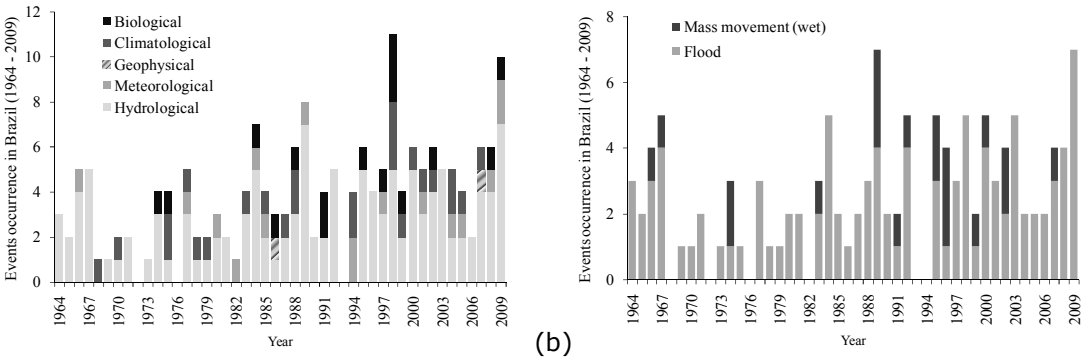


Figure 1 – Natural disasters occurrence in the World during the period from 1900 to 2009.



(a) (b)

Figure 2 - Events occurrence in Brazil during the period 1964 – 2009: (a) Natural disasters; (b) Hydrological disasters.

In this chapter, we present three case-studies that have been carried out in Santa Catarina State (SC), Southern Brazil. By doing so, we want to emphasize the importance of hydrology application for reducing the hydrological disasters, especially through the implementation of the school catchment network. Finally, we discuss the philosophical aspects which we believe might be the most important ones in disasters management.

2. Concept

In case of a very large-scale and high intensity hydrological disaster, both wet mass movement and flood occur simultaneously. It becomes quite difficult to distinguish between one another, which may lead to errors in disasters registration. For example, in November 2008, a heavy rainfall triggered wet mass movements at many locations inside the Itajaí Valley, Santa Catarina State. These movements were responsible for more than 97% of the deaths occurred in the disaster (Brasil, 2009). However, this disaster was registered in the international

disaster databases as a flood, not a mass movement (Figure 2b). Although many mass movements and floods have occurred concurrently, many of them were only registered as floods. It implies that the historical series for hydrological disasters at least in Brazil may not demonstrate the occurrences of mass movement correctly, and there is a tendency to underestimate the number of mass movement occurrences.

The hydrological disasters consist of the flood and wet mass movement types, and it could be argued that these disasters are water-related and sediment-related, respectively. That is where the problems in distinction begin. Debris flow is clearly considered as a sort of sediment-related disaster, however, it is treated as water-related one because a rainfall triggers it. On the other hand, flood is considered as water-related disaster. However, in occurring, it transports and deposits lots of sediments that play an important role in watershed riparian system. As we can see, there is a need to improve the methods of identification of each type of the hydrological disasters.

Flood and flash flood are the main disasters that damage our society. Each type requires its own structural and non-structural countermeasures. Flood occurs when the water flow in a stretch of the river exceeds the bankfull flow. Then, the water overflows the riverbanks and spreads through the floodplain. While the flood occurrence depends on the physical and climatological characteristics of the river basin, the flood disaster is a consequence of the human settlement on the floodplain (Leopold, 1994).

Flash floods take place in a sudden, violent and unexpected way, usually in small areas, and result in a greater danger to life and severe structural damages. They are normally triggered by intense rainfalls. It must be emphasized that the early warning system is indispensable for the reduction in damages associated with flash floods (Kobiyama & Goerl, 2007).

The difficulty to distinguish the gradual (or river) flood and flash flood is similar to the case to distinguish the water-related and sediment-related disasters. There are various definitions for both of them. The definitions themselves are not clear. Then, Kobiyama and Goerl (2007) proposed a quantitative method to distinguish them, by introducing the Operation Efficiency Index which is defined as the rate of the time of flood concentration (*Tc*) to the operational response time (*To*) in the institution-community system. *Tc* and *To* are associated with physical and social factors, respectively. This proposal remains to be examined in a practical way.

The wet and dry mass movements are triggered mainly by heavy rainfall and earthquakes, respectively. Though there are many different classifications for the wet mass movements, the classification proposed by Varnes (1978) may be the most common in use. In the Varnes classification, phenomena are classified in terms of movement: falls, slides and flows. Furthermore, the slides are divided by material (soil or rock) and the flows are divided by the water amount (from dry to wet). According to the Varnes classification, landslide is the gravity-induced movement of a portion of soil. And the debris flow is the gravity-induced flow movement of wet and coarse debris. By no means this classification provides definite clues about the boundaries between the different phenomena.

Focusing just on the flows, Costa (1988) classified the possible flow processes into three categories: water floods, hyperconcentrated flows and debris flows, and described them with the rheologic, geomorphic and sedimentologic aspects in order to differentiate them. Since the author treated the flow processes which occurred in small and mountainous basins, this flood might be equivalent to the flash flood. The rheologic differentiation of these three types of flow is in Table

1. Nevertheless, even using rheology, the boundaries between these flow processes are difficult to be understood.

Table 1 – Rheologic differentiation of the flow types

Flow	Sediment concentration	Bulk density (g/cm^3)	Shear strength ($dyne/cm^2$)	Fluid type	Flow type	Sediment con. profile
Water flood	1 - 40% by wt. 0.4-20% by vol.	1.01 - 1.33	0 - 100	Newtonian	Turbulent	Non-uniform
Hyperconcentrated flow	40-70% by wt. 20-47% by vol.	1.33 - 1.80	100 - 400	Non-Newtonian	Turbulent to laminar	Non-uniform to uniform
Debris flow	70-90% by wt. 47-77% by vol.	1.80 - 2.30	> 400	Non-Newtonian Viscoplastic or dilatant	Laminar	Uniform

(Adapted from Costa, 1988)

Because of its destructive power and consequent disasters, the debris flow has been studied intensively and widely, for example, by Jacob and Hungr (2005) and Takahashi (2007). However, the understanding is not satisfactory, and more field data are necessary to advance this understanding. The difficulty in standardizing the phenomena classification brings problems to many actions on disaster management: phenomena registration, database construction, countermeasure choice, policy establishment, etc.

Based on the description above mentioned, Figure 3 shows the conceptual classification of the hydrological disasters in terms of velocity and sediment concentration. The speed of a phenomenon influences on the prediction performance, and in general, it is more difficult to predict the phenomena that occur rapidly. On the other hand, the sediment concentration influences the impact characteristics. In SC in 2008, it was observed that the impacts of the sediment-related disasters were much more severe and prolonged than those of the water-related ones. Consequently, a recovery and reconstruction processes of society damaged by the sediment-related disasters were more complicated than those by the water-related ones.

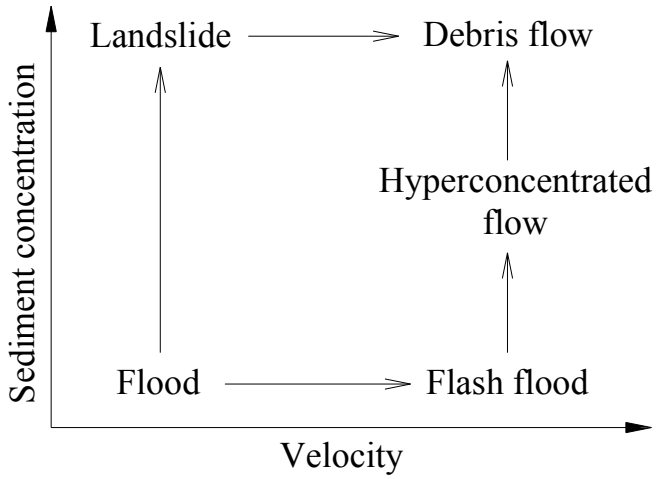


Figure 3 – Conceptual classification of the hydrological disasters.

In the flooded areas, various plantations were lost, many buildings and houses were inundated and various transport systems were out of function for a few days. In these areas, the local inhabitants could return to their houses and immediately started to clean the flooded areas and to reconstruct the destructed structures when the water level fell down and the river presented its normal

course. The major damage was associated to the economic aspect, and the local re-stabilization needed some days.

A situation of the areas where landslides and debris flows occurred is different. There were economic damages as well as a lot of human losses. Besides, a lot of refugees were not able to return to their houses, even after the rain ceased, because of several reasons: the prohibition of house entrance by civil defense because of new landslide occurrence possibility; structural impairment of the house; complete destruction of the house, land loss by land-filling without the possibility of reconstructing new residence on the same site, and so forth. More than one year after the event, the disaster still remained.

As discussed above, when a sediment-related disaster occurs, the risk assessment of involved houses and infrastructure is more difficult. This assessment includes: evaluating whether the house/infrastructure is structurally compromised by the mass movement; analyzing whether more landslides will occur and whether these potential events will affect the house/infrastructure; and deciding whether residents can stay at their houses. This assessment procedure requires expertise and a very deep understanding of mass movements such as landslides and debris flow. Moreover, the evaluation in general has to be carried out for each house, which makes the procedure more slow.

The entrance prohibition decision of the civil defense must be as accurate as possible, because both the overestimation an underestimation of risk may increase the disaster. The risk underestimation leads to prohibition entrance to houses less than necessary, which makes people more vulnerable to the next mass movements. The risk overestimation leads to ban on larger areas than necessary. This generates an overcrowding in shelters, and the refugees begin to distrust the effectiveness of the Civil Defense. This distrust, in turn, puts in doubt the necessity of the ban. In the case that families return to their forbidden houses, they might become victims of future mass movements.

In the case of floods, the above mentioned difficulty is very rare, because the risk is apparent. When the water level in a river rises, the inhabitants know that they have to evacuate. And when the level goes down, they know that they can return. The difficulty in the flood case is related to the process speed, not to a lack of knowledge on the flood mechanism. Therefore, there is an evident need to improve the understanding of mass movement mechanisms.

When the heavy rainfall occurs, natural phenomena (flood, landslide, flash flood, hyperconcentrated flow and debris flow) that cause disasters are triggered. If the occurrence localities of such phenomena possess any kind of relation with human activities, these phenomena are considered as natural disasters. That is why all the natural disasters always contain human or social factors; meanwhile the natural phenomena have only natural factors. In other words, the natural disaster analysis must consider human-related factors which are fundamental in disaster occurrence and affect all of their prevention stages (i.e. mitigation, preparedness, response and reconstruction) (Kobiyama & Goerl, 2007).

One of the most important human-related factors for triggering the hydrological disasters must be the land-use. Normally, a settlement of a city starts with floodplains occupation. It has been observed since the Four Ancient River Civilizations (Tigris and Euphrates, Nile, Indus, and Yellow Rivers). It is very natural that a community initially suffers from floods because of its settlement locality. After occupying most of the floodplains, a growing community begins to use hillside areas. These areas have much more potential for sediment-related disasters than the floodplains, and that is when the sediment-related disasters start to take place. After some time, the number of occurrences and/or the

damage quantity of sediment-related disasters might well overtake those of water-related disasters.

Figure 4 shows the scenario of this disaster evolution (water-related to sediment-related disasters) in a city due to the land occupation change. Analyzing the disasters occurrences in SC, during the last decades, this evolution can be observed. According to Tachini et al. (2009) the people in SC are historically prepared for floods, but not for flash floods and for wet mass movements, which were the principal cause of the tragedy which occurred in Itajaí Valley, SC, in November 2008.

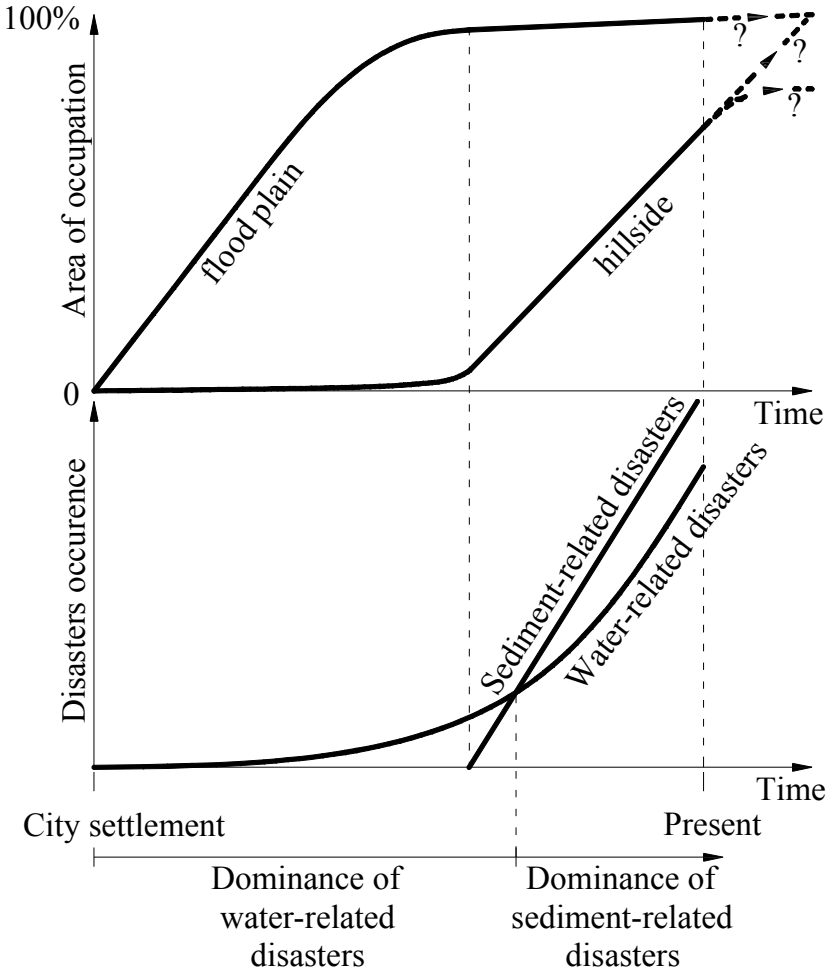


Figure 4 – Hydrological disasters evolution due to the land occupation change.

3. Case study

It is essential to apply hydrological knowledge for reducing the hydrological disasters. Without this application, it is impossible to reduce them. In this section we present three cases of the application of hydrology for disaster reduction in the localities of Joinville city, Rio dos Cedros city and Rio Negrinho city, SC (Figure 5).

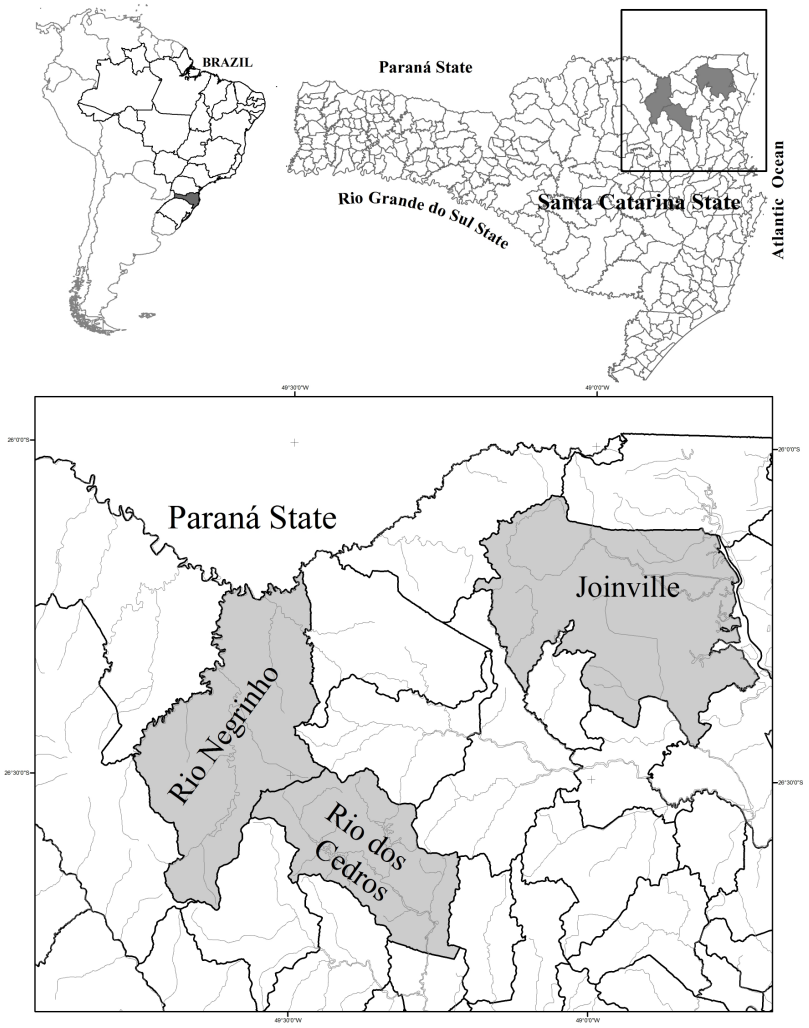


Figure 5 – Localities of case study in Santa Catarina State, Brazil.

3.1. Joinville city

In terms of population and economy, Joinville (1135 km^2) is the largest city in Santa Catarina, with 497,331 inhabitants and a GDP *per capita* of US$ 7771.00. The city was developed on a very flat fluvio-marine lowland and most of its urban areas are located only 2 m above the sea level. Thus, Joinville is naturally susceptible to flooding. Figure 6 shows that both the evolutions of population and urban area are similar and that they started to grow quickly at the middle of the twentieth century.

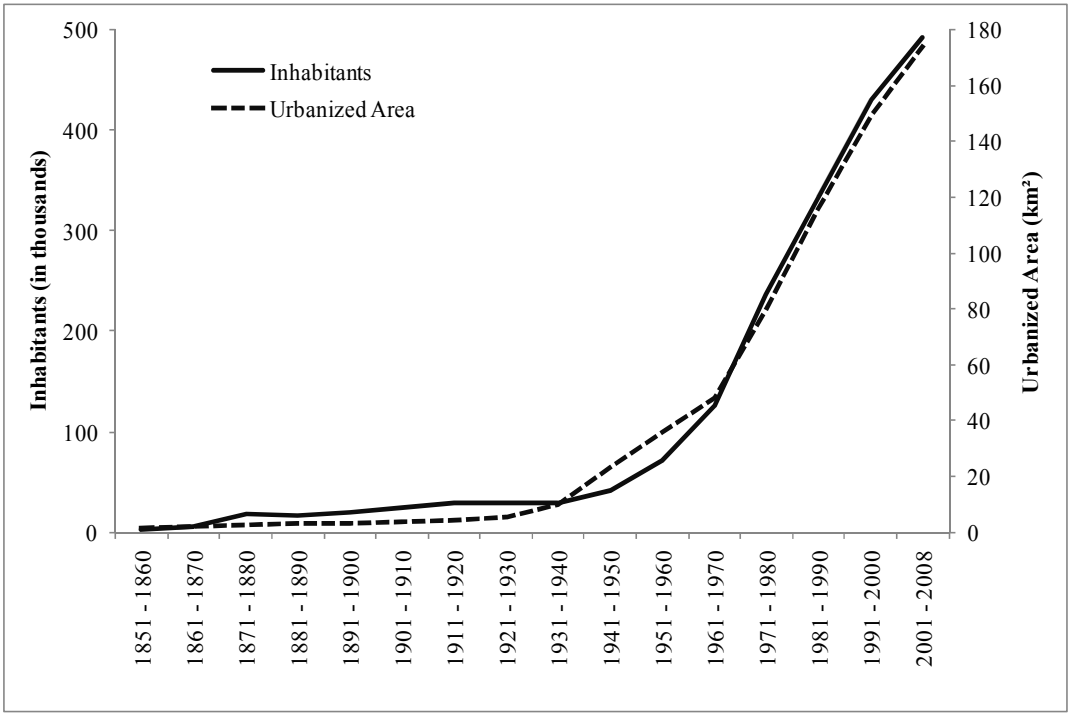


Figure 6 – Evolution of population and urban area during the period 1851 – 2008 (Source: Silveira et al., 2010).

This city has been suffering from floods and registering them since its foundation in 1851. In order to contribute to flood management, Silveira et al. (2009) searched all the documents that reported the floods in this city for the period from 1851 to 2008. According to the authors, the floods in Joinville have more relation with urbanization (human-related factor) than with annual rainfall (natural factor) (Figures 7 and 8). Figure 8 shows that the annual rainfall is slightly decreasing and the flood frequency is rapidly increasing.

Although the floods are usually considered as the hydrological disasters, the floods in Joinville seem to be human-related disasters. Then Silveira et al. (2009) alerted that the flood problems are not due to the climate change problem but due to the human activities problems. In this sense, there is a solution, i.e., making the watershed management more correct and adequate. If the flood problems were only due to the climate change, the solutions could be much more difficult to accomplish.

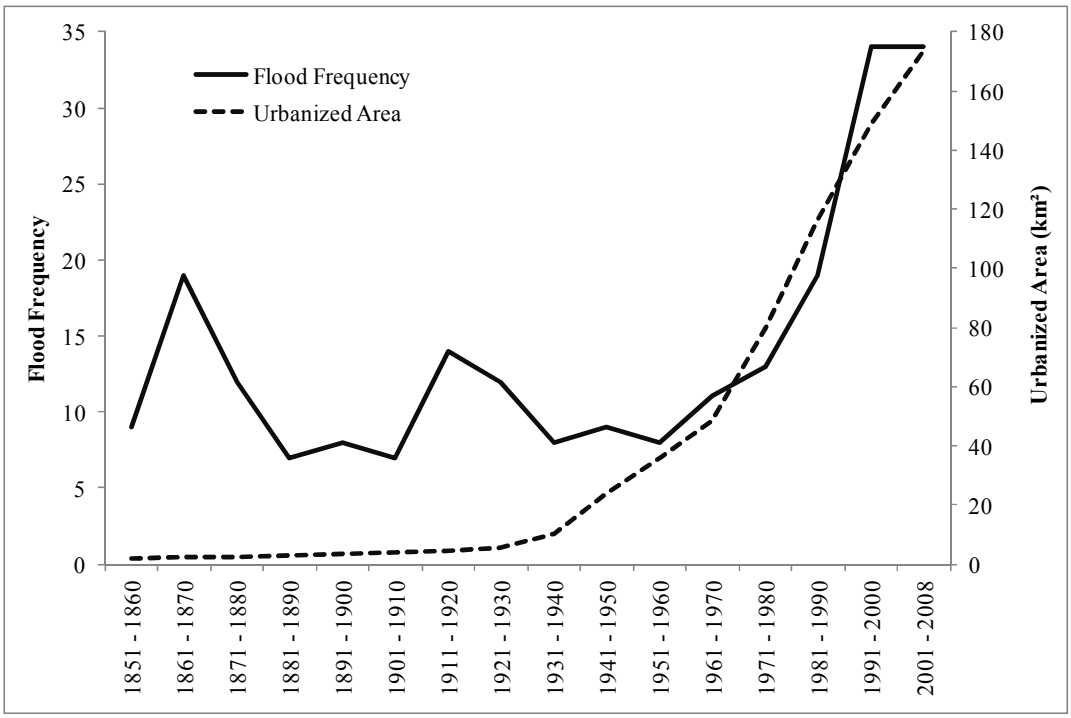


Figure 7 – Change of the flood frequency and the urban area of Joinville city during the period 1851 – 2008 (Source: Silveira et al., 2010).

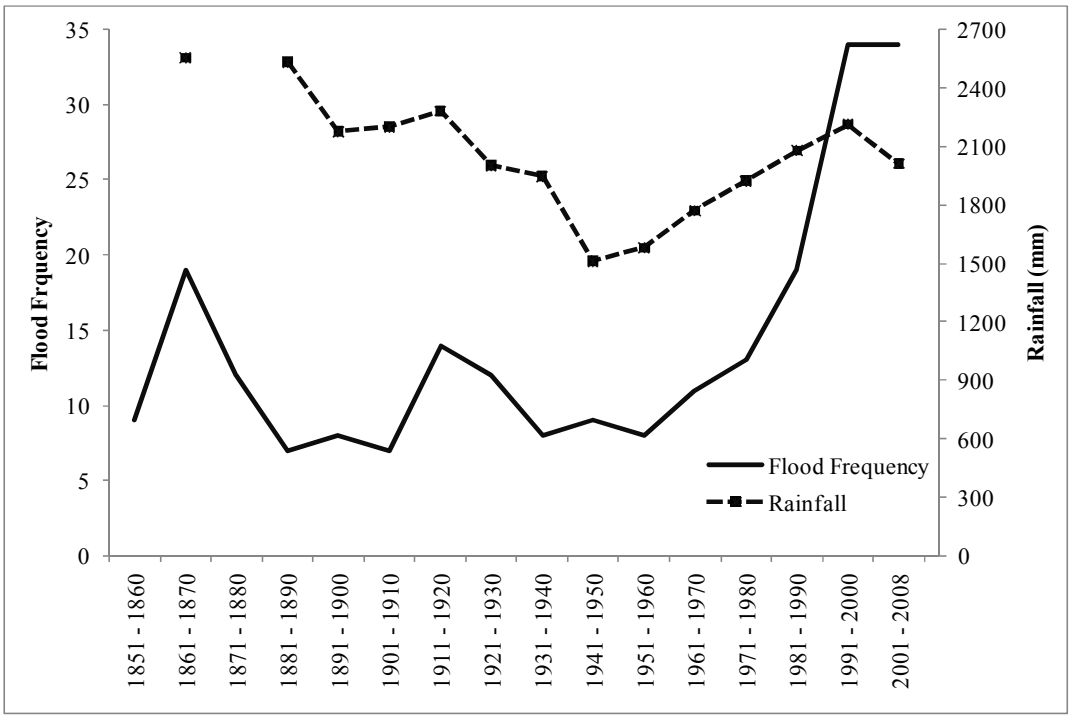


Figure 8 – Change of the flood frequency and the annual rainfall of Joinville city during the period 1851 – 2008 (Source: Silveira et al., 2010).

The historical analysis done by Silveira et al. (2009) can be a good example of how important it is to correctly register the disaster occurrences and that we should also treat the disasters with a historical point of view. Then this work gives a good lesson (the importance of disaster registration) to other Brazilian cities as

well as to hydrologists. Observation, measurement and registration are essential activities in hydrology.

3.2. Rio dos Cedros city

In November 2008, an extremely-intense rainfall event triggered floods and landslides in SC, especially in the Itajaí Valley. This event might be the worst in the whole history of SC. Rocha et al. (2009) analyzed the daily rainfall data obtained in Blumenau city which is located in the Itajaí Valley, and concluded that the daily rainfall of 347.2 mm registered on 23rd November corresponds to the return period of more than 10,000 years for this city. Among 293 cities in SC, 63 declared a state of emergency and 14 a state of public calamity in November 2008. According to the State Civil Defense Report 31/Dec/2008 which presented the total damages caused by these disasters in SC, there were 32,853 homeless, 135 dead and 2 missing.

Rio dos Cedros (10,170 inhabitants and 555.65 km^2 in 2009), city located in the Itajaí Valley, at a distance from Blumenau about 30 km, declared a state of pubic calamity due to the intense rainfall in November 2008. It was reported that 8561 peoples were directly affected, 96 homeless, no dead, and economic losses of agriculture, livestock, industry and basic sanitation infra-structures in the range of US$1.34 million, 300 thousands, 40 thousands, and 390 thousands, respectively. The floods occurred in the urban area, whereas the debris flows occurred predominantly in many rural areas (Goerl et al., 2009).

Since the frequency of debris flow disasters has increased recently, there are only a few studies on this phenomenon in Brazil until now. The debris flow research can be, therefore, considered as one of the priorities in the Brazilian society. In this context, Kobiyama et al. (2010) analyzed the meteorological and geomorphic aspects of two debris flow features which occurred in Rio dos Cedros city in November 2008.

An analysis of the historical data of the annual rainfall from 1942 to 2008 showed that the mean value was 1651 mm/year, the highest value was the total of 2863 mm in the year 1983; meanwhile 2008 was the second rainiest year with a total amount of 2509 mm The total rainfall of October and November 2008 was 1085 mm which represented about 43.3% of the 2008 annual rainfall. On 3rd October, the most intense rainfall (122 mm/day) was recorded, and after this event no high rainfall intensity took place. In November, the values of the daily rainfall were not very high (less than 80 mm/day), but the occurrence was much higher than in October and the accumulated rainfall was very high (Figure 9).

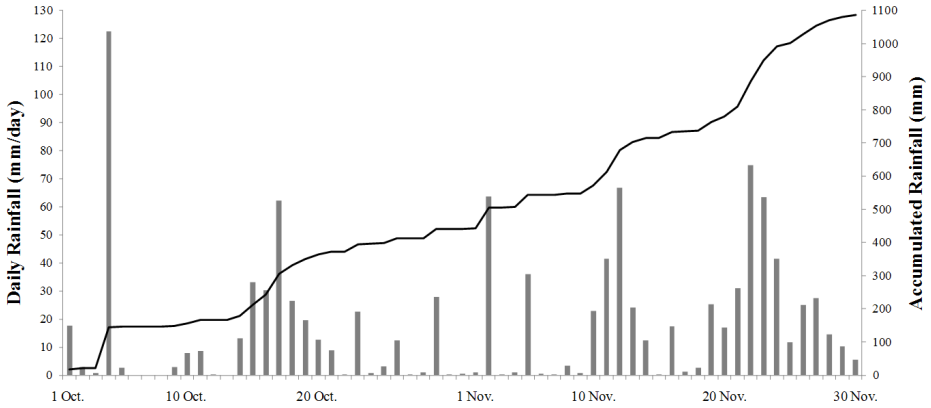


Figure 9 – Daily and accumulated rainfalls in Rio dos Cedros from October to November 2008 (Source: Kobiyama et al., 2010).

The analyzed debris flow took place in three stages, the first at 1:15 a.m., the second at 2:00 a.m. and the third at 3:00 on 24th November. The observed rainfall data in Rio dos Cedros showed that during the period from 0:00 a.m. to 3:00 a.m. on the same day, it rained 10 mm which might not be able to cause such a terrible and intense phenomenon. The accumulated rainfall from 0:00 a.m. on 23rd November to 3:00 a.m. on 24th November was 95 mm. Only for one week from 18th to 24th November, it rained totally 256 mm, more than twice the value of the mean monthly rainfall for November. October and November of 2008 had the highest values of monthly rainfall in the same months during the period from 1942 to 2008, with 441 mm and 644 mm, respectively (Figure 10). It may be said that in this case the triggering factor was the accumulated value of the rainfall, not its intensity.

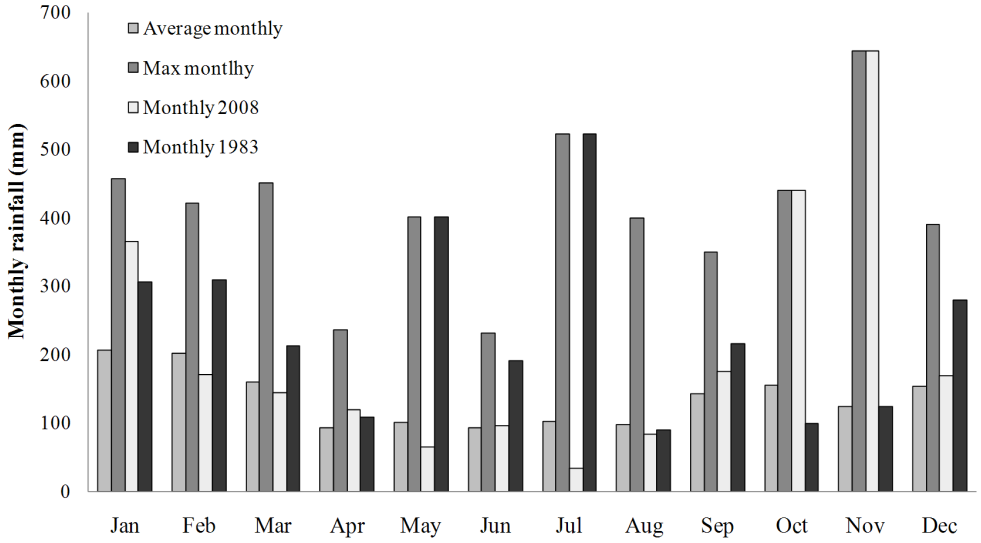


Figure 10 – Monthly rainfall data from Rio dos Cedros: Mean monthly rainfall from 1942 to 2007, maximum monthly record between 1942 and 2008, monthly rainfall of 2008, and monthly rainfall of 1983 (Source: Kobiyama et al., 2010).

Kobiyama et al. (2010) carried out the field survey of two comparatively-larger debris flows in the Cunha River watershed, Rio dos Cedros (Figure 11). Both cases (Debris A and Debris B) had two different starting areas, i.e., two initial movements. In other words, four landslides occurred and formed two large debris flows. Based on the field observations, the volume (V) of mass movement, elevation (H), travel distance (L) and reach angle (β) were estimated. The value of V was also estimated by using the equations proposed by Corominas (1996) and Rickenmann (1999). The V values obtained by three methods (field data analysis, equation of Corominas and equation of Rickenmann) were all different, which implies the difficulty to estimate the mass movement volume.

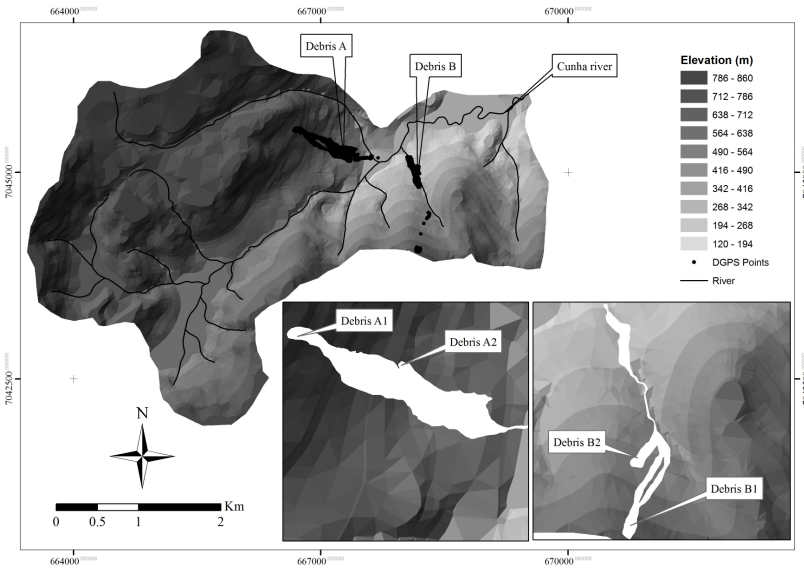


Figure 11 - Localities of two debris flows (Debris A and Debris B) in Cunha River watershed (Source: Kobiyama et al., 2010).

Futhermore, Kobiyama et al. (2010) plotted the values of the Debris A and B obtained with field data analysis, on the diagram originally elaborated by Rickenmann (2005) which relates tanβ to V (Figure 12). In the tropical environments, the soil layer tends to become thicker (~20 m) than that in the temperate regions. In both the debris flow localities, the average of the soil layer depth was 15 m. And the soil texture was characterized with large quantity of clay and silt. Furthermore there was a lot of vegetation on the occurrence localities, predominantly trunks with 20-30 m height, which might characterize the woody debris flows. In spite of these conditions, it is observed that two cases of Rio dos Cedros had the similar behavior to other cases shown by Rickenmann (2005), especially to Swiss debris flows. It implies that the geomorphic effects are predominant in the debris flow controls. Since debris flow disasters in Brazil have been increasing in frequency and magnitude, their research must be more enhanced in this country, by analyzing various aspects of this hydrological hazard. Urgently, field survey database should be constructed. Since the event is very rapid, automatic monitoring systems are necessary, which can be a great contribution from hydrology.

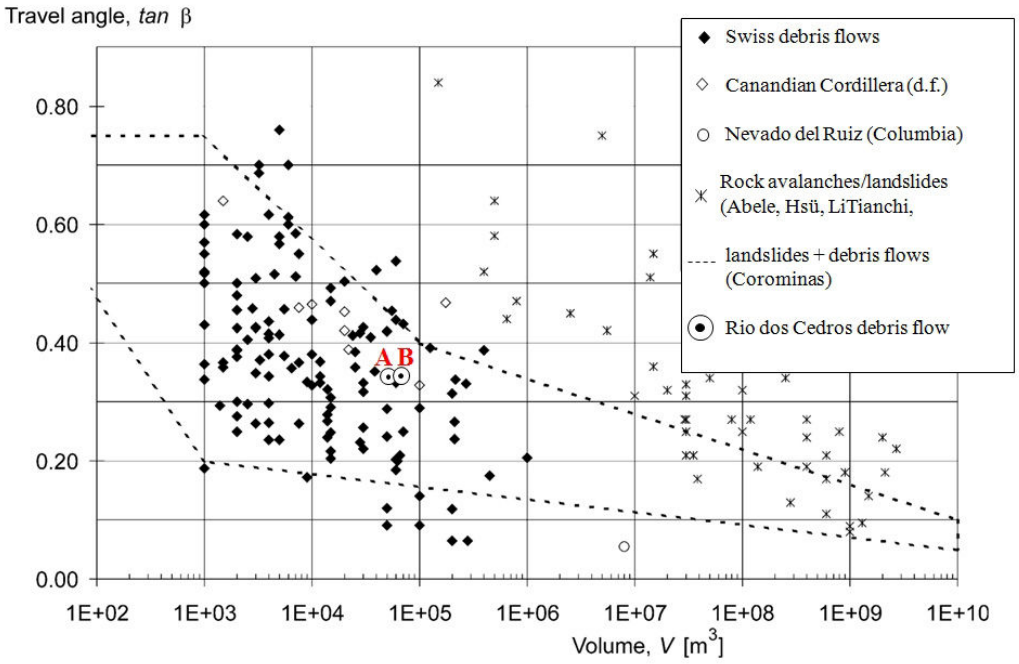


Figure 12 – Relation between the travel angle and volume of the mass movement (Source: Kobiyama et al., 2010).

Field survey provides a lot of opportunities to think what should be done for disasters reduction in practice. In case of Rio dos Cedros, it was observed that a kind of training course must be done at community levels. The inhabitants did not know that debris flows have been frequently triggered in their city. The features of the paleo-landslides and paleo-debris flows are encountered on a lot of hillsides in rural areas. As most of these features are covered by vegetation, the inhabitants cannot recognize the frequency in occurrence and that there are large areas susceptible to the sediment-related disasters in their city. Thus, it is clear the necessity to orient them how to observe the natural phenomena which cause the natural disasters, especially debris flows and landslides.

Furthermore, it was noticed the importance to preserve the riparian zone. In SC, the preserved buffer strip width for the riparian vegetation has been discussed recently. According to the federal law, the minimum width for the riparian buffer strip is 30 m, meanwhile, the SC state government has attempted to reduce it to 5 m. This reduction may induce some economical benefits to some, but certainly can increase the hydrological disasters, especially those related to the debris flows. Figure 13 shows how woody-debris flow destructs the riversides and the riparian buffer strip. In general, the height of riparian forests characterized with the Tropical and Subtropical Ombrophilous Forests in SC is about 20 – 30 m (Figure 13a).

When the debris flow occurs, woods are longitudinally transported along the watercourse. In this case, the damage generated with wood transport can be encountered very near the watercourse (Figure 13b). However, when woods are transported transversely to the course, the woody-debris flow destroys larger areas whose width is nearly equal to the wood height (Figure 13c). That is why the riparian forest has the protection roles against the hydrological disasters as well as the environmental roles. Though the riparian buffer zones have been treated as permanent preservation areas in an environmental sense, it must be protected as

permanent hazard areas. It is a very important and evident lesson from the field survey just after the debris flow occurrences.

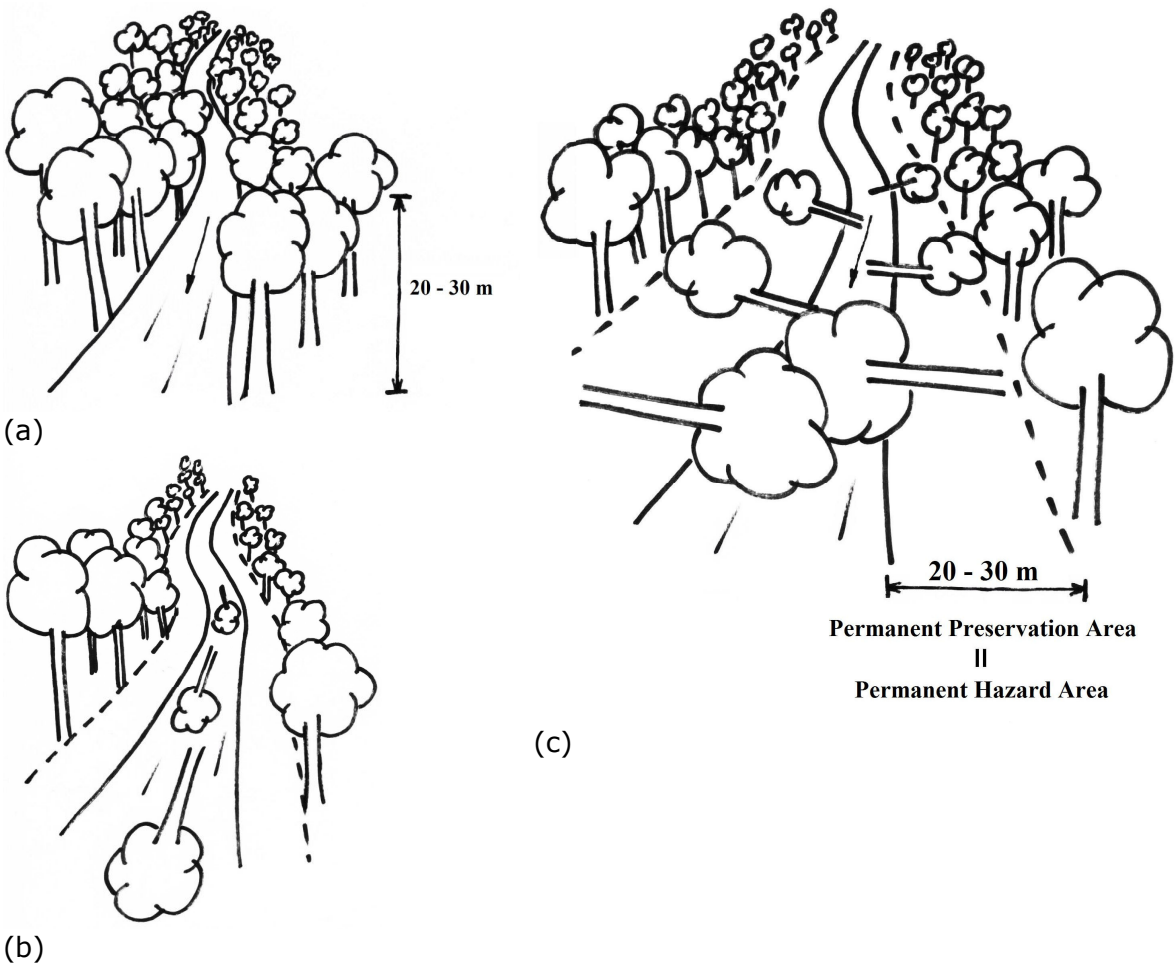


Figure 13 – Riparian forest destruction due to debris flow: (a) before debris flow occurrence, (b) longitudinal woody transport, and (c) transverse woody transport.

3.3. Rio Negrinho city and its neighboring areas

In possessing a high value of the specific discharge, the Iguaçu River basin located in the Southern Brazil is characterized with a very high potential to generate the hydroelectric energy. This basin is also characterized with the Subtropical Ombrophilous Forest. Since the remainders of this forest which formerly covered the plateau region of the Southern Brazil are now only 2% of its original area, this ecosystem must be preserved. Recently the conversion of the pine reforestation areas to the Subtropical Ombrophilous Forest has been strongly requested without the consideration that the regional economy depends mainly on the reforestation activities. Rio Negrinho city (42,144 inhabitants and 908.39 km^2 in 2007), located in the Upper Iguaçu River basin and with an economy based in the industrial reforestation, suffers with flood since its settlement. Therefore, the ecological and hydrological researches in this basin are indispensable to reduce the damages caused by the water-related disasters and it is necessary to comprehend how the operations of the dams change the regional hydrological processes. In

these circumstances, seven small experimental catchments (0.1 to 10 km^2 scales) with hydrological monitoring in the Upper Negro River (UNR) basin (3552 km²) which is one of the headwater areas of the Iguaçu River basin were constructed in order to answer the question about what kind of land-use is best for the water resources management. With these small experimental catchments and some preexistent relatively-large experimental catchments, the school catchments network has been implemented in the UNR basin (Kobiyama et al., 2009). Here the school catchment is defined as an experimental catchment which serves for scientific researches and environmental education activities. Figure 14 shows the school catchment construction processes.

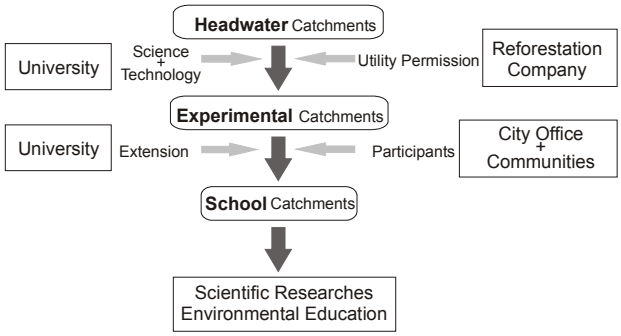


Figure 14 – Construction of school catchments (Source: Kobiyama et al., 2009).

In the case of the UNR, various school catchments were required because of the necessity to understand hydrological effects of land-uses, dams' operations and catchment scales. This is the reason why the network (a set of school catchments) has been implemented. The concept of catchment network is not new. In justifying the 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. These networks seem to be established just for the scientific researches. The concept of such networks is, therefore, very different from that proposed by Kobiyama et al. (2009) where the school catchment network contributes not only to the scientific researches but also to the environmental education activities.

Since the natural disasters management mainly aims (1) to understand the natural phenomena that trigger the natural disasters and (2) to raise society's resistance to such phenomena, the School Catchment Network implementation certainly contributes to the natural disasters management in the headwater regions (Figure 15). In this way, school catchments increase an individual's knowledge of hydrology, which enhances his (or her) participation in the community in terms of water resources management. Consequently, an enhanced participation of each member elevates the quantity and quality of the community action. According to Hillman and Brierley (2005), the community-based management is essential for the recent stream rehabilitation programs. Such a management with governmental supports must be executed for any program that treats catchments and water resources.

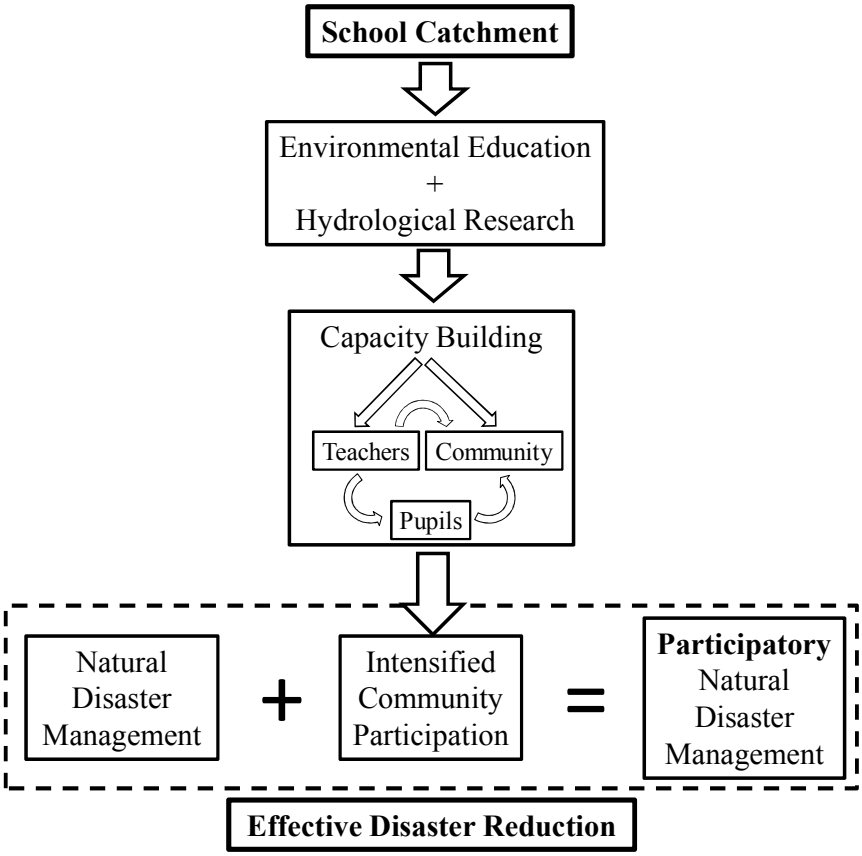


Figure 15 – Contribution of the school catchment network to disaster reduction.

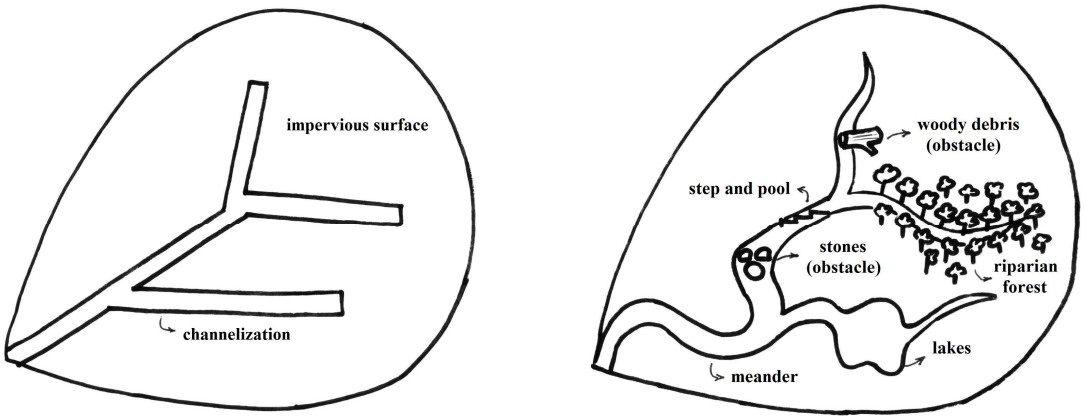
It is worth mentioning that school catchments are important not only for local communities but also for the hydrological sciences community. These catchments are fundamental fields (objects) for achieving catchment hydrology. According to Uhlenbrook (2006), in catchment hydrology pure scientific interests overlap with practical water management to support sustainable development. One of these examples is Chaffe et al. (2010) which investigated whether interception information is important for simulating rainfall-runoff or not. The interception and discharge data used were from one of the school catchments described by Kobiyama et al. (2009). This study used three different model formulations (Tank Model of Sugawara (1995) using gross rainfall as input; using net rainfall as input; and coupled with the Sparse Rutter Model of Valente et al. (1997) using gross rainfall as input) for the analysis of the effects of interception information in rainfall-runoff modeling. The results permitted to conclude that: (i) the interception information is more important to study the rainfall-runoff processes in dry condition than in wet condition; and (ii) the consideration of the interception information in the hydrological models results better performance in any situation. Thus, it is very clear that the hydrological monitoring and modeling are fundamental and they can be achieved by using the school catchment network.

4. Philosophical aspects in hydrology

In all of the human (individual and social) actions, philosophy plays a very important role. Philosophy might be a proper guide to direct our activities. In the

case of the water resources, watershed and natural disasters managements, a kind of philosophy called “Small is Beautiful” and proposed by E.F. Schumacher may be one of the most important guides. According to Schumacher (1973), the methods and tools employed in education, urbanization, industry, agriculture, and so on, should be low-priced and small enough that everyone can acquire, apply and modify, thus encouraging his (her) own creativity.

In this similar sense, Tsuji (2001) wrote the book "Slow is beautiful". If such a concept "Slow" is applied to hydrology, the necessity to reduce the water flux in the hydrological processes, especially in the urban drainage system, emerges. This reduction can be mainly achieved in three ways: (1) by increasing the roughness coefficient with obstacles on the land and river surfaces; (2) by increasing the meandering of the watercourses; and (3) by increasing the water storage capacity in watersheds. Thus, the water dynamics in the hydrological cycle become slower. However, in order to attempt to "solve" the problems caused by the rainwater excess in urban areas, ordinal and usual drainage works were to reduce roughness and sinuosity of the channels, and to increase the flow velocity, which consequently resulted in increasing the frequency and magnitude of floods downstream. Those drainage works are designed to reject rainwater in the urban areas (Figure 16a). It is clear that there is a strong inconsistency between the previous philosophy and the actual urban hydrology practice. To have slower hydrologic cycle, the drainage network in watersheds must become the storage network. In other words, the drainage basin must change to the STORAGE BASIN (Figure 16b).



(a) (b)

Figure 16 – Watershed management concepts: (a) drainage basin; (b) storage basin.

What type of countermeasures can slow the water flow at the smaller scale? Probably, it is necessary to create as simple countermeasures as possible. It is believed that in general the simplicity allows lower costs, larger accessibility and lower energy consumption. Thus, there is "Simple is beautiful". Good examples of the simple technology might be rainfall harvesting systems in urban areas and agroforestry in rural areas.

To perform simple countermeasures at the small scale which allow the slower water dynamics, the society needs a more adequate science. In other words, the society requires more beauties for the water resources, watersheds and natural disasters management, i.e., the science of hydrology. The more beautiful hydrology is, the more it becomes useful, contributing to such managements and, consequently, part of the sustainable development. Then, naturally appears

"Science is beautiful". In this context, the university role should be to make a more beautiful hydrology (research), to inform it to students (education) and to disseminate it to the community (extension).

Historically, scientists have discovered the mechanisms of nature (beauties) which have been later applied to various types of managements. In hydrology, the runoff generation mechanism has been investigated as its main theme. Up to now, it can be seen the concept evolution: Hortonian overland flow (Horton, 1933) – Variable source area (Hewlett & Hibbert, 1967) – Hydrological connectivity (Pringle, 2001, 2002). The beautiful hydrology surely contributes to obtain slow hydrologic cycle and to realize the water resources and watershed managements with small scale and simple technology, which is indispensable for the hydrological disasters reduction. The sustainable development is the challenge of the humanity, and needs these four beauties: Small, Slow, Simple and Science.

5. Final considerations

All the types of natural disasters taking place have been increasing in frequency and magnitude. Among them, the increase of the hydrological disasters is the most dominant both in the world and in Brazil. To reduce the hydrological disasters, the water resources and watershed managements are essential. Then, the application of hydrology emerges naturally.

In practice, each municipal should construct the school catchments network for the two main purposes: (i) for the hydrological sciences community to advance the knowledge on hydrological processes; and (ii) for educators to accomplish the environmental education in local communities. These two purposes contribute to understand the hydrological phenomena that trigger the hydrological disasters and to raise society's resistance to such phenomena, respectively. The information and knowledge obtained through the hydrological researches with school catchments network will let all the people recognize the natural catchment as STORAGE BASIN not as DRAINAGE BASIN. We believe that a society must perform the hydrological monitoring in such school catchment networks, whereas everybody must have a capacity to register any kind of disaster by putting the historical aspects into the hydrology.

An accumulation of the information and knowledge will make the hydrology more beautiful. Then, the more beautiful hydrology will support to perform simple countermeasures at a small scale which allow the slower water dynamics. Hence, these four beauties (Small, Slow, Simple and Science) certainly contributes to reduce the hydrological disasters.

Such hydrological disasters are conventionally classified into two groups: water-related and sediment-related disasters which are usually represented with flood and mass movements (landslide and debris flow), respectively. Since the land occupation style normally changes during the municipal development processes in a city, some society suffers from water-related disasters at the early stage of the developing processes and sediment-related disasters at later stage. This might be a kind of the disasters evolution. In this way, the sediment-related disasters seem to be dominant in several cities in Santa Catarina State, Brazil. Therefore, in this type of city, hydrologists and society must start to pay much more attention for sediment-related phenomena.

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