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Flah Floods Modelling in an Arid Zone Based on Remotely Sensing Data and GIS Application

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Abstract:
In recent years, flash floods are common phenomena in many parts of the world, which cause severe hazards to an urban area, economy and humans' lives. Floods are one of the most hydrological hazards as a result of heavy rain in a short period of fewer than six hours. Thus, this phenomenon can be the most significant natural hazards occurring in aridity lands. However, humans cannot avoid the occurring of floods and the impact it is on both an urban area and environment, but also, they can reduce their effects. Hence, there are many hydrological models have applied to predict of risk of floods in tropical lands and arid zones. This paper aims to give information about the floods, including hydrology models and the possibility of Remote Sensing (RS) and Remote Sensing Data (RSD) to model and management of floods in arid zones. Also, the application of Geographical Information System GIS and RS extract of floods based on RSD. RS is essential sources for observation of the Earth, and it makes that is easy to study environmental risk. Thus, this study found that floods are the most frequent natural risk in global. Also, it is the most significant potential risks that threaten an urban area and human activity. That quality of RS and its accuracy based on pixel size is effects on images value. However, the integration between (RSD) and Geographical Information System (GIS) are significant to enhance urban flooding prediction and risk management.

***Keywords**: Floods, An arid zones, Remote Sensing (RS), Urban area,Modelling, Geographical Information System (GIS).*

I. Introduction

In recent years, there has been increasing a more insignificant focus placed upon natural hazards studies. So, hazards have increased in global, have caused a lot of environmental, and also urban areas damages and in sometimes a direct causing for death. Hazards occur everywherein global and can be classified into two categories a) Naturality and b) Humans made (Guha-Sapir et al., 2012).However, natural disasters are a major adverse event resulted from processes of the Earth dynamic without the interference of humans such as metrologies, ecologies and geomorphologies events.Natural disasters are a primary reason to destroy humans activities (Tien Bui et al., 2019) and sometimes, death such as earthquakes, volcanos, landslide and floods(Dilley et al., 2005). Among natural disasters, floods are considered the most of the hazards causing losses in urban areas and responsible for more significant humans death, especially in those nations of developing(Kron, 2005), floods are killed more than 20,000 lives every year (Sarhadi et al., (2012).Thus, flooding is the primary natural phenomenon that affects both economic and urban systems (Singh, 1987) and human life (Gaňová et al., 2014). According to Pregnolato et al. (2016), "an increasing number of [destructive] phenomena [have been witnessed as] weather-related events across the globe". Flood sits in the top of natural hazards in occurrence, killed, affected and damage in global, and its percentage has reached to 41.3%, 41.7%, 32.1% and 44.5% by the end of 2013(Center, 2014). The UN estimates that floods affect more than 500 million people every year around the world (De Groeve et al. (2015). Furthermore, On 25 and 26 November 1967 in Portugal, a flash flood caused more than 500 fatalities (Trigo et al., 2016). On 9 October 2014, a flash flood caused deaths and massive damage in the central Liguria Region in Italy (Silvestro et al., (2016). A flash flood that happened in France in 2014 led to 17 fatalities (Boudou et al., (2016). Other flash floods that occurred between 1959 and 2008 led to deaths due to the drowning of more than 93 individuals (Sharif et al., (2015).Aridity lands which classified based on hottest zones in global are facing massive natural hazards, and flash floods are the most these hazards impact on urbanisation and humans activities in these zones. The Aridity lands have distinctive phenomena very different from the humid lands(Pilgrim et al., 1988) ; (Wheater, 2002). The arid zones get not enough of rainfall which less than 40 cm every year and that is causing weak of plants and fragile of soil.

Technology of Remote Sensing is the best way to observe Earth surface and atmosphere events; also, this technology has improved since it started in 1909 from aeroplanes photography up to right now in high quality of the digital image (Morain, 1998). The atmosphere is a domain for considerable of many satellites operated by many companies for multiple uses. Thus, and as a result of enhancement of quality of monitoring environment from space, humans have been able to understand the natural risk and risk management on the ground. Therefore, this paper gives a brief about floods and hydrological modelling, which used to base methods to investigate and predict urban flooding, including data used in terms of aridity flash floods. Besides, RSD has made several valuable contributions to hydrological modelling, flood simulation and risk management in these lands. Although there have been many applications in integration of RS and GIS technologies, in this thesis, the integration method will be used for land cover/use change detection analysis of the case area.

II. Background

Floods definition-Types.

A flood is an excess of water (inundation) in an area where humans and ecosystems do not need it, and is also a majority of natural hazards causing of problem in the population activities (Mogil et al., 1978), and and loosing of economic (Singh, 1987); human life (Gaňová et al., 2014); (Klemesova, 2014).Therfore,Water (2007) has defined floods as follows when flows generated by rainfall overtop the banks of a river, creek or constructed channel, or when the capacity of rainfall exceeds the capacity of underground drainage systems (Water, 2007,2).Floods are the most devastating of natural hazards on human activities. Floods may cause an immeasurable impact on an urban future (Rozalis et al. 2010).It is covering of the land by water when the land has typically not covered by water previously (Prinos, 2009). Thus, a flood is a large body of water that affects human activities such as urbanisation and economics.

Hydrological community scientists are interested in water movement on land and for this aim they have developed many mathematical modelling in order to understand these movements in order to water management. However, Floods have classified into three main groups in each of which reason for inundation urban and economic lands. The first group is a river floodwhichusually occurs in lowland, especially along the banks of a river and distributes among the urban area. It has a positive effect on agricultural lands as it refreshes the soil, but much damage can occur to both agricultural and urban area. Next group of floods is a coastal flood occurs in coastal areas resulting from two natural factors which as a result of earthquakes and intense storms which occurs in oceans or seas(Water, 2007). For example, in 2011, floods killed 910 people in seven Brazilian coastal cities (Ultramari, 2013). The last group is also a flash flood,which also occurs in a short time, and this is characteristic of arid zones (Xia et al., (2011). In overall, floods are referring to much water in the wrong place that human usually does not needs it, such as in the urban area agriculture practises.Humanscannot be able to avoid floods risk, but it mayreducetheir impacts in an urban area using proper management. Floods management needs many inputs of data, including ground data such as inundation boundary and rainfall record to analysis and estimates the risk of floods in an urban area and human's activities.

Causes of Floods-Flash floods.

Floods occur everywhere in the global and causing many environmental damages. On the other hands, many reasons beyond these phenomena and the most important in order to understand this issue what these reasons are?. Hence, according to many hydrological authorities in global, such as the Hydrological Engineering Center (HEC), many factors that are responsible for floods. However, there are two causatives of floods, which is climate changes and multiple humans activities in catchments. `

Therefore, without a doubt, the climate has been changing rapidly at present, and global warming is the mater issue in our environment and the biggest challenges facing Earth planet. Hence, why climate has changed? This question is not the aim of this paper. However, the results of these changes caused increase sea level, droughts and heavy rainfall around the world (Simpkins, 2017). The IPCC has noted that already climate at present is changed resulted from global warming (Pachauri et al., 2014), and that reason for many weather conditions.Thus, Ciabatta (2016) reported that a negative impact of climate change is torrential rains (Ciabatta et al., 2016).Although the primary reason for flooding is climate change and global warming, the increase in both population and activities is also reasoned the increasing flood risks as well.

Humans have used to change the land surface for urbanisation and different activities such as economic and agriculture, and with doubt, that caused a significant challenge to the ecosystem (Rainis, 2003). As a result of human activities, a system of surface hydrology changed (Yin et al., 2017). Therefore, many floods have occurred around the world as a result of human behaviour in land-use changes. For example, some floods happened in Malaysia due to humans activities that changed the land surface character and hydrology systems(Weng Chan, 1997); in Santiago de Chile, Urban expansion had influenced the events of the flood during the period 1991-2000(Ebert and Mc, 2009). In African countries, flooding has also been characterised as frequent localised slum flooding due to poor drainage; Small stream flooding due to inadequate culverts and blocked culverts; Major river flooding exacerbated by land-use change, expansion of populations in the area of the rivers(Bhattacharya & Lamond, 2011).Furthermore, the increase in the number of the population leads to flooding using change land cover. Some trends stated that the problem of urban flooding looks likely to increase result the growing number of people that live in cities; the world's population is becoming increasingly urban (Hammond et al., 2015), and maybe climate change has become effected on emigration population to cities.

Floods and flash floods in aridity lands.

Arid zones locate between 30° North-South of the equator in several countries. The aridity zones have classified based on temperature as hot land; also, it classified based on rainfall amount per year, which get less than 40 cm. Hence, rainfall amount is the primary input for the water resources in these lands, and an understanding of that characters is significantly essential to estimate flows while catchment.Furthermore, aridity lands are very different in many factors from those of tropical lands, which is caused by a different climate and including rainfall(Lin, 1999). There are complexities of hydrology features and response in aridity regions are related to multiple factors including intense rainfall, storms, slopes within a drainage basin, a lack of vegetation cover, and high velocity flows where there is nothing to reduce of floodwaters. So, temperature and evaporation are generally much higher than humidity lands, and this has a high impact on the lack of vegetation cover.

Flash flood Modelling and data used.

Environment Modelling.

Due to that environmental changing around the world, and to be better understand these changes. Modelling theories became the most methods for providing us to monitor ground changes and enhancements our ability also for environmental management.There has been an increase in the interested in environment modelling, which helps the researcher to understand an environment changes. Therefore, the developments in the field of computing programs have led to an interest in environmental modelling. There is much-applied research in the environment to understand multiple relationships between different factors; an example of that is time serious. Moreover, modelling the changes relating to human-induced climate change (Wainwright & Mulligan, 2002).

In the environmental studies, the model is simplified conceptual representations of essential aspects of phenomena (process, object, element, system, etc.) and simulation each element to another or one to all. Wainwright and Mulligan (2002) " Modelling is not an alternative to observation but, under certain circumstances, can be a powerful tool in understanding observations and in developing and testing theory (Wainwright & Mulligan, 2002). ". Also, modelling of floods in both aridity and humidity lands are based on hydrological models, and that need massive input data and software to reach a good result.

Hydrology Modelling

Hydrological models are built based on a variety of methods which often aims to establish understanding the relationships between rainfall and runoff. So,the surface land of aridity areas differs in many hydrological characters such as rainfall character, land cover and physical of soil conditions. Most of the hydrological models are developed in humid areas for all humid climatic, including a large variety of rainfall-runoff models (Alahmadi et al., 2016). In fact, in aridity lands,there is a lack of data in many developing nations; usually, hydrological models are applied directly to arid and semi-arid areas without adjustment. As a consequence, Still, rainfall-runoff models still needing improvement (El-Hames & Richards, 1998).

However, hydrologic models can be classified according to a wide range of categories, for which there are many criteria and several different aspects. Also, hydrological modelling can be classified into many shapes depends on catchment shape and topography. Al-Ahmadi (2005) has classified that hydrological modelling into three main categories based on literature reviews, and the first category is assembly and degree of complexity. The second category is a description of the hydrological process. The final one is a physical model(Al-Ahmadi, 2005). Jan et al. (2017) have established a list of hydrological modelling based on many literature reviews and, classify it into three main categories depends on: a) model structure such as a) Empirical Models, b) Conceptual Models and c) Physical Models. Furthermore, this study divided the hydrological model into three main groups depends on a particular processing an example: a) Lumped Model, b) Semi- Distributed Model and c) Distributed Model (Jan Sitterson et al., 2017). Table (1) shows the classify of hydrological models based on two aspects.

Table1

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Categories the classification of hydrological modelling

No	Category	Model	Methodology
1	Structure	Empirical	non-linear relationship between inputs/outputs.black box concept.
		Conceptual	Simplified equations represent water storage in a catchment.
		Physical	Physical laws and equations based on real hydrologic responses.
2	Processes	Lumped	disregarded; entire catchment is modelled as one unit
		Semi-Distrib	Series of lumped and distributed parameters
		Distributed	Spatial variability is accounted for all data in cell

Source: table (1) (Jan Sittreson et al (2017, p:11-19).

However, the types of studies that take a hydrological perspective attempt to use watershed characteristics to predict how much water may be a runoff or understand the mechanisms leading to flash floods — hydrological modelling base on many mathematics equations on which are aimed to estimate runoff on the catchment. Therefore, Hydrologic models vary from simple lumped models to semi-distributed models and more complex distributed models. Moreover, applications of these models in water resources vary from event-based modelling to water balance modelling and continuous stream flow modelling. The number of parameters and state variables needed to calibrate a model may differ depending on the model type and complexity. Physically based distributed models need an enormous amount of data, which is difficult to obtain, especially in remote areas. Figure (1) shows the main hydrologic models based on data input (Land Use, Rainfall Record, Topography, Soil Types) into three models A-Lumped, B- Semi Distributed and C-Distributed Model.

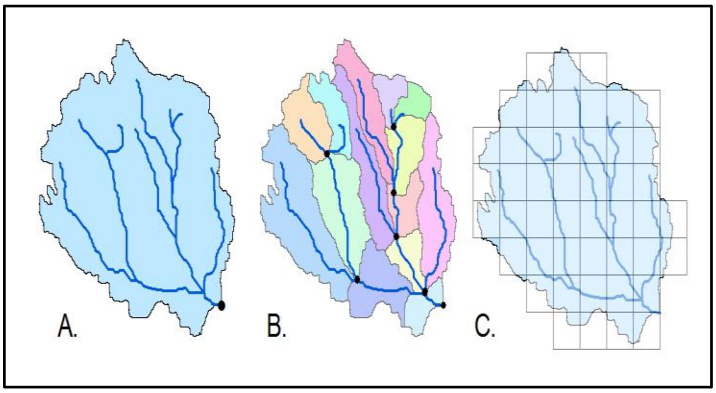

Figure 1. Character of Hydrological models-based input data.

Source: figure (1) (Jan Sittreson et al (2017, p:16).

Remote Sensing and GIS application for floods.

Remote Sensing

RS and GIS are currently the most critical methods to establish floods models everywhere. RS technologies can detect changes on the earth's surface through space-borne sensors (Ramachandra & Kumar, 2004). The techniques of RS are very critical for mapping resources of water. The techniques of remote sensing Satelite will make up to date, and continuous measurements with widely globally coverage depending on their features (orbital), development and validation of algorithms count on observation of groundwater (Schmugge et al. 2002). For instance, the MODIS (Moderate Resolution Imaging Spectroradiometer) has been globally providing the snow cover since the year 2000 (Hall et al.2002). The techniques widely have been used and applied the various field of studies ranging from climate studies, agriculture and hydrology (Wang et al., 2017). The series of Landsat because of its higher resolution of images is useful in recovering and monitoring the state of global glaciers mountain, and this makes it easy and possible to bring up to date of the inventory of global glaciers at confidence and high accuracy.

Floods are monitoring and mapping with remote sensing data obtained by aircraft or satellite or ground-based on platform sensor. The data and sensors techniques of processing that derive information for flooding are massive. Instruments that record of floods events might operate in visible waves, microwave. As a result of limit data posed by adverse weather conditions during a flood event, radar wave active is invaluable for monitoring floods; however, if a visible image of flooding can be acquired, retrieving useful information from this is often more straightforward (Schumann, 2015).

RS can be classified based on sensor wave into two primary categories. The first category is passive wave: which sensor receives energy naturally resected by or emitted from the earth's surface. The second category is active wave: sensor provides its “illumination and records the amount of incident energy returned from the imaged surface (Smith, 1997)”. The passive wave is visible, including many sensor data. Multiple sensors include all of the visible and infrared instruments such as the Landsat (MSS) Multi-Spectral Scanner, (TM) Thematic Mapper (ETM) Enhanced Thematic Mapperand OLIOperational Land Imager. Also, the Advanced Very High-Resolution Radiometer (AVHRR), the Satellite Pour observation, and (SPOT). Advanced Spaceborne Thermal Emission, and Reflection Radiometer (ASTER); also, Moderate-Resolution Imaging Spectroradiometer(MODIS).Hence, hydrologic analysis needs a variety of remote sensing data to reach the main aim of estimation rainfall and runoff and evaluation of its risk in the environment; thus RS is the best sources to monitor environmental hazards (Joyce et al., 2009); most of the hydrological state variables and fluxes can be estimated using RSD (Schmugge et al., 2002).

The second category is active, and the active satellite consists of imaging radar and radar altimeter. Radars could penetrate clouds, darkness and, at the longer wavelengths, tree canopies (Ernst & Sixsmith, 2018). Cloud penetration is particularly most signific for monitoring flood events, as they commonly occur during periods of sensitive rainfall(Benoudjit & Guida, 2019). Also, interpretation of synthetic aperture radar (SAR) imagery is less straightforward than for the visible/infrared range(Benoudjit & Guida, 2019).Furthermore, there are classifications based on pixel resolution in raster images. So, many RS operated rise to enhance pixel resolution, and there are massive technical traying to construct a high-resolution sensor in order to better product an example for that arsIkonos, QuickBird and worldview. These sensors have used widely to predict ground change and disaster(Abdu, 2019). The table (2) shows satellite sensor classify into three groups based on the quality of resolution.

Table 2
character of satellites that used to monitor ground

Resolution	Satellite	Character	Website References
Low	AVHR R	-low cost. -large cover. -Useful for large scale changes.	https://www.sat.dundee.ac.uk/satellites.html
	Spot-Veg		http://www.spot-vegetation.com/
	MODIS		https://modis.gsfc.nasa.gov/
Medium	Landsat	-low or free. -useful for detect floods.	https://landsat.gsfc.nasa.gov/
	Spot		https://space.skyrocket.de/doc_sdat/spot-5.htm
	ASTER		https://asterweb.jpl.nasa.gov/
High	IKONOS	-local scale. -better to detect change and flood.	http://uregina.ca/piwowarj/Satellites/IKONOS.html
	Quick Bird		http://www.landinfo.com/QuickBird.htm
	Worl-View		http://worldview3.digitalglobe.com/

Source: (2) (Alqurashi & Kumar, 2013).

There are multiple methods using satellite images to monitor and manage floods. Analysing of satellite images are based on many prosses to get clear of evidence on for flood hazards. This is named image processing which bases in pixel resolution. However, in the history of development sensor, the pixel has been thought of as a critical factor in image resolution. An essential approach for unsupervised land cover classification in remote sensing images is the clustering of pixels in the spectral domain into several methods partitions. A hight resolution of pixel value allows the prediction of ground observations(Amatulli et al., 2018). The resolution of a pixel has a value in hydrological studies, especially in the event of extract catchment boundary and simulation of flood in the basin area. Table (3) shows the most application of GIS-based on RSD.

Geographical Information System**.**

GIS became more significance analysis tool in hydrology researches. Due to recent climate change and the increase in an urban flood, there are immediate needs for higher interest in water resources and more knowledge related to this field. As every hydrologist knows, the water is in a constant movement and variation through space and time, so its study using computer systems (in this case, GIS) makes the tasks of water management more effortless. Although GIS systems were initially built to be static in data representation, they became more and more dynamic with time, helping reduce the gap between historical data and actual reality in hydrology (Maidment, 2003).Besides, GIS and some software programs have made a prediction of

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runoff possible and faster than the manual method and made it easy to understand the character of a catchment and which hydrology model is suitable for analysis runoff as well.

III. Conclusion

Remote Sensing has made a substantial contribution to flood monitoring and damage assessment that leads the disaster management authorities to contribute significantly. In this paper,techniques for mapping flood extent and assessing flood damages have been developed which can be served as a guideline for Remote Sensing (RS) and Geographical Information System (GIS) operationsto improve the efficiency of flood disaster monitoring and management.High temporal resolution played a major role in Remote Sensing data for flood monitoring to

IV. References

[1] Abdu, H. A. (2019). Classification accuracy and trend assessments of land cover-land use changes from principal components of land satellite images. *International journal of remote sensing, 40*(4), 1275-1300.
[2] Al-Ahmadi, F. S. (2005). Rainfall-runoff modeling in arid regions using geographic information systems and remote sensing: case study; a western region of Saudi Arabia. *Dep. of Hydrology and Water Resources Management, King Abdulaziz University, p441*.
[3] Alahmadi, F., Rahman, N. A., & Yusop, Z. (2016). HYDROLOGICAL MODELLING OF UNGAUGED ARID VOLCANIC ENVIRONMENTS AT UPPER BATHAN CATCHMENT, MADINAH, SAUDI ARABIA. *Jurnal Teknologi, 78*(9-4).
[4] Alqurashi, A. F., & Kumar, L. (2013). Investigating the Use of Remote Sensing and GIS Techniques to Detect Land Use and Land Cover Change: A Review. *Advances in Remote Sensing, 02*(02), 193-204. DOI:10.4236/ars.2013.22022
[5] Amatulli, G., Domisch, S., Kiesel, J., Sethi, T., Yamazaki, D., & Raymond, P. (2018). *High-resolution stream network delineation using digital elevation models: assessing the spatial accuracy* (2167-9843). Retrieved from
[6] Benoudjit, A., & Guida, R. (2019). A Novel Fully Automated Mapping of the Flood Extent on SAR Images Using a Supervised Classifier. *Remote Sensing, 11*(7), 779.
[7] Bhattacharya, N., & Lamond, J. (2011). *A review of urban flood risk situation in African growing economies*: na.
[8] Boudou, M., Lang, M., Vinet, F., & Cœur, D. (2016). Comparative hazard analysis of processes leading to remarkable flash floods (France, 1930–1999). *Journal of Hydrology, 541*, 533-552.
[9] Center, A. D. R. (2014). Natural disaster data book 2013. In: Kobe: Asian Disaster Reduction Center (ADRC).
[10] Ciabatta, L., Camici, S., Brocca, L., Ponziani, F., Stelluti, M., Berni, N., & Moramarco, T. (2016). Assessing the impact of climate-change scenarios on landslide occurrence in Umbria Region, Italy. *Journal of Hydrology, 541*, 285-295.
[11] De Groeve, T., Thielen-del Pozo, J., Brakenridge, R., Adler, R., Alfieri, L., Kull, D., . . . Wyjad, K. (2015). Joining Forces in a Global Flood Partnership. *Bulletin of the American Meteorological Society, 96*(5), ES97-ES100. doi:10.1175/bams-d-14-00147.1
[12] Dilley, M., Chen, R. S., Deichmann, U., Lerner-Lam, A. L., & Arnold, M. (2005). *Natural disaster hotspots: a global risk analysis*: The World Bank.
[13] El-Hames, A., & Richards, K. (1998). An integrated, physically based model for arid region flash flood prediction capable of simulating dynamic transmission loss. *Hydrological processes, 12*(8), 1219-1232.
[14] Ernst, S., Lymburner, L., & Sixsmith, J. (2018). Implications of Pixel Quality Flags on the Observation Density of a Continental Landsat Archive. *Remote Sensing, 10*(10), 1570.
[15] Guha-Sapir, D., Vos, F., Below, R., & Ponserre, S. (2012). *Annual disaster statistical review 2011: the numbers and trends*. Retrieved from
[16] Hall, D. K., Riggs, G. A., Salomonson, V. V., DiGirolamo, N. E., & Bayr, K. J. (2002). MODIS snow-cover products. *Remote sensing of Environment, 83*(1-2), 181-194.
[17] Hammond, M. J., Chen, A. S., Djordjević, S., Butler, D., & Mark, O. (2015). Urban flood impact assessment: A state-of-the-art review. *Urban Water Journal, 12*(1), 14-29.
[18] Jan Sitterson, Chris Knightes, Rajbir Parmar, Kurt Wolfe, Muluken Muche, & Avant, B. (2017). An Overview of Rainfall-Runoff Model Types. *EPA*.
[19] Jermsittiparsert, K. & Chankoson, T. (2019). Behavior of Tourism Industry under the Situation of Environmental Threats and Carbon Emission: Time Series Analysis from Thailand. *International Journal of Energy Economics and Policy, 9*(6), 366-372.
[20] Joyce, K. E., Belliss, S. E., Samsonov, S. V., McNeill, S. J., & Glassey, P. J. (2009). A review of the status of satellite remote sensing and image processing techniques for mapping natural hazards and disasters. *Progress in Physical Geography, 33*(2), 183-207.
[21] Kron, W. (2005). Flood risk= hazard• values• vulnerability. *Water International, 30*(1), 58-68.

Published by: The Mattingley Publishing Co., Inc.

January - February 2020
ISSN: 0193-4120 Page No. 3379 - 3385

[22] Lin, X. (1999). Flash floods in arid and semi-arid zones. In *Technical documents in hydrology*: UNESCO.

[23] Maidment, D. (2003). Arc Hydro: GIS for water resources. ESRI Press, Redlands, CA. *Arc Hydro: GIS for water resources. ESRI Press, Redlands, CA.*, -.

[24] Pilgrim, D., Chapman, T., & Doran, D. (1988). Problems of rainfall-runoff modelling in arid and semiarid regions. *Hydrological Sciences Journal, 33*(4), 379-400.

[25] Pregnolato, M., Ford, A., Robson, C., Glenis, V., Barr, S., & Dawson, R. (2016). Assessing urban strategies for reducing the impacts of extreme weather on infrastructure networks. *R Soc Open Sci*, *3*(5), 160023. doi:10.1098/rsos.160023

[26] Rainis, R. (2003). 16 APPLICATION OF GIS AND LANDSCAPE METRICS IN MONITORING URBAN LAND USE CHANGE. *Urban ecosystem studies in Malaysia: A study of change*, 266.

[27] Ramachandra, T., & Kumar, U. (2004). *Geographic Resources Decision Support System for land use, land cover dynamics analysis.* Paper presented at the Proceedings of the FOSS/GRASS users conference.

[28] Rozalis, S., Morin, E., Yair, Y., & Price, C. (2010). Flash flood prediction using an uncalibrated hydrological model and radar rainfall data in a Mediterranean watershed under changing hydrological conditions. *Journal of Hydrology, 394*(1-2), 245-255.

[29] Sarhadi, A., Soltani, S., & Modarres, R. (2012). Probabilistic flood inundation mapping of ungauged rivers: Linking GIS techniques and frequency analysis. *Journal of Hydrology, 458*, 68-86.

[30] Schmugge, T. J., Kustas, W. P., Ritchie, J. C., Jackson, T. J., & Rango, A. (2002). Remote sensing in hydrology. *Advances in water resources, 25*(8-12), 1367-1385.

[31] Schumann, G. (2015). Preface: Remote sensing in flood monitoring and management. In: Multidisciplinary Digital Publishing Institute.

[32] Sharif, H. O., Jackson, T. L., Hossain, M. M., & Zane, D. (2015). Analysis of Flood Fatalities in Texas. *Natural Hazards Review, 16*(1), 04014016. doi:10.1061/(asce)nh.1527-6996.0000145

[33] Silvestro, F., Rebora, N., Giannoni, F., Cavallo, A., & Ferraris, L. (2016). The flash flood of the Bisagno Creek on 9th October 2014: an “unfortunate” combination of spatial and temporal scales. *Journal of Hydrology, 541*, 50-62.

[34] Simpkins, G. (2017). Hydrology: Increasing river flood risk. *Nature Climate Change, 7*(3), 172-172.

[35] Smith, L. C. (1997). Satellite remote sensing of river inundation area, stage, and discharge: A review. *Hydrological processes, 11*(10), 1427-1439.

[36] Tien Bui, D., Khosravi, K., Shahabi, H., Daggupati, P., Adamowski, J. F., M Melesse, A., . . . Bahrami, S. (2019). Flood Spatial Modeling in Northern Iran Using Remote Sensing and GIS: A Comparison between Evidential Belief Functions and Its Ensemble with a Multivariate Logistic Regression Model. *Remote Sensing, 11*(13), 1589.

[37] Trigo, R. M., Ramos, C., Pereira, S. S., Ramos, A. M., Zêzere, J. L., & Liberato, M. L. (2016). The deadliest storm of the 20th century striking Portugal: Flood impacts and atmospheric circulation. *Journal of Hydrology, 541*, 597-610.

[38] Ultramari, C. (2013). 910; 7; 365. *Land Use Policy, 34*, 125-133. doi:10.1016/j.landusepol.2013.02.009

[39] Wainwright, J., & Mulligan, M. (2002). *Environmental modelling*: Wiley Online Library.

[40] Wang, X., Zhu, Y., Chen, Y., Zheng, H., Liu, H., Huang, H., . . . Liu, L. (2017). Influences of forest on MODIS snow cover mapping and snow variations in the Amur River basin in Northeast Asia during 2000–2014. *Hydrological processes, 31*(18), 3225-3241.

[41] Water, M. (2007). Port Phillip and Westernport Region Flood Management and Drainage Strategy. *Melbourne, Australia*.

[42] Weng Chan, N. (1997). Increasing flood risk in Malaysia: causes and solutions. *Disaster Prevention and Management: An International Journal, 6*(2), 72-86.

[43] Wheater, H. S. (2002). Hydrological processes in arid and semiarid areas. *Hydrology of wadi systems, IHP-V, Technical documents in hydrology, 55*, 5-22.

[44] Xia, J., Falconer, R. A., Lin, B., & Tan, G. (2011). Modelling flash flood risk in urban areas. *Proc Inst Civil Eng Water Manag, 164*, 267-282.

[45] Yin, J., He, F., Xiong, Y. J., & Qiu, G. Y. (2017). Effects of land use/land cover and climate changes on surface runoff in a semi-humid and semi-arid transition zone in northwest China. *Hydrology and Earth System Sciences, 21*(1), 183-196.