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Flash flood risk assessment: A Case Study in Wadi Abu Sobeira, ASWAN

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الملخص:

تعتبر السيول من المخاطر الطبيعية التي تهاجم محافظة أسوان من وقت لآخر. لذا فإن هناك الكثير من الإجراءات والجهود المبذولة للحد من الأضرار الناجمة عن هذه الفيضانات ومن بين تلك الجهود هو بناء منشئآت لتخزين مياه السيول. ويهدف هذا البحث إلي تقييم نجاح هذه المنشئآت في الحد من هذه المخاطر. لذلك، فمن خلال هذا البحث تم بناء نموذج هيدروديناميكي ثنائي الأبعاد لمحاكاة إنتشار موجة السيول خلال منطقة الدراسة كما يقوم بحساب توزيع الخصائص الفيضانات كسرعة المياه وارتفاعها. ومن ثم يمكن تقدير مقدار وتوزيع مخاطر السيول باستخدام منحنيات تمثل العلاقه بين الفيضانات والضرر المتوقع منها. ولقد أظهرت النتائج أن تقريبا كل الأراضي الزراعية المعرضه لمياه السيل هي معرضة للخطر بشكل كلي، في حين أن المناطق الحضرية معرضة للخطر بشكل جزئي. أيضا تبين من البحث أن تخزين جزء من الفيضانات هو أكثر فعالية في إدارة المخاطر في المناطق الحضرية منه في المناطق الزراعية. لذلك فمنهجية البحث المقترحة تبدو واعدة في حالات متعددة مثل أن تكون هناك محدودية للمناطق المتاحه لتخزين مياه السيل. أو أن تكون الحمايه لأراضي زراعية غير ذات قيمة إقتصادية كبيرة.

Abstract :

Flash flood are considered a dramatic natural hazard that attack Aswan governorate from time to time. A lot of actions and efforts are done to reduce the damages caused by these floods, among those efforts is to build storage structures. This research intends to assessing the success of these structures in reducing the risks. So, the research shows the developing of two dimensions hydrodynamic model that calculates the flood characteristics distribution over the study area. Risks are estimated using flood-damage curves. Results show that almost every agriculture land exposes to flood is at risk, while urban areas are partially in danger. Also, storing a portion of the flood is more effective risk management tool for urban than in agriculture areas. The proposed approach seems a promising where valuable areas are limited in number and area, and where protected areas are mostly of low economic value crops.

Keywords: Flash floods, Wadi hydrology, Surface hydrology, Risk Assessment

Introduction

Flash flood is among the most terrible natural disasters, that cause a huge amount of losses in economic, or human Especially in mountainous regions. Damages caused by floods depends on the flood characteristics (Hazard), and the ability of threatened locations to be damaged (vulnerability). Unfortunately, flood protection structures are very expensive, and require allocating of large land areas. So, finding a protection size that reduces the risk without spending a lot of money is the goal if this work. Or, shall storing just a portion of the total design flood is considered a way to reduce the risk of the flood in important areas?

Large number of publication show that flash flood risk assessment in Egypt and Arab countries focus on the geomorphological characteristics of the watersheds (Soussa et al. 2010; El-Sayed 2010; WRRI 2010; Al-Saif 2010; Omran et al. 2011; Youssef et al. 2011; Ghoneim & Foody 2011; Elmoustafa & Mohamed 2013; Dawod et al. 2011). However, analysing flash flood risks on societies require utilizing a 2D flood flow modelling tool (Balica et al. 2013; Jonkman et al. 2008).

Researchers and designers use the certain probability of exceedance (usually 1%) as a threshold to determine the minimum required characteristics of flood defence structures, (WRRI 2010). On the other hand, applying hydrodynamic modelling allows developing flood risk maps in regards to selecting the most appropriate flood defence system (Baldassarre & Castellarin 2009; Baldassarre et al. 2009). Flash floods risk assessment depends on estimating both of depth and velocity (Vozinaki & Karatzas 2015). Merz et al., (2007) and Humer and Reithofer (2016) assures the efficiency of using flash flood risk maps in management its risks. Developing these maps require predefined relationships between flood characteristics and the expected damages based on only one variable as developed for riverine floods (Klijn & Schweckendiek 2012; Dewan 2013), or depending on two variables (flood depth and flood velocity) as developed by (McLuckie & Babister 2014).

The main goal of the paper is to support decision maker in selecting the most appropriate flash flood defence system. So, a 2D hydrodynamic model is developed to calculate the main components of flood hazard (depth and velocity), calculate the risk based on flood-damage relationships, and finally compare different protection alternatives.

Study area and data collection

The selected case study is the delta of “Abu-Sobeira” watershed that covers an area of about 4 km2, Its climate is generally hot and dry with rare storm events in the winter that probably cause flash floods. Abu-Sobeira flows westward to meet the Nile valley 23km north of the Aswan High Dam, south of Egypt (Figure 3). That area face serious floods in that poor society. Currently, a flood drain is created to protect from flood dangers, but this solution has many negative sides as it divided the lands and needed number of bridges and require continues cleaning works. So, discussing alternatice solution is the goal here.

The topographic data of the delta were obtained from free digital elevation models of 90m resolution (http://srtm.usgs.gov). A 100 years design flood was provided by WRRI (2015), it has a peak discharge of about 55m3/s and total flood volume is about 1.9 Million m3 (Figure 3-C). Land use classes (Figure 4) were digitized using free satellite images from Google Earth.

Abu-Sobeira's delta is formed mainly of Quaternary deposits (mainly fine silts with coarse loose gravels) and Nile silt. There are 10 to 15 thousand people there, most of them in leaves in Brick-built houses. Where most important crops grown alfalfa, sorghum and maize, and there are palm and lemon trees. The study area faced flash floods in (1987, 1997, 2002, and 2010), it led to crop damages, some houses demolition, and three deaths (youm7 2010).

Methodology

The applied approach starts by building a 2D hydrodynamic model using HEC-RAS 5.0 to simulate flood spread and know where the flood will inundate, and calculate the depth and velocity distribution over there. Then automate the ArcGIS to produced risk maps for every studied scenario.

Hydraulic modeling

HEC-RAS 5.0 is selected for this study because its free, simulate dry/wet conditions (Aquaveo 2015). Within HEC-RAS the full 2 dimensional Saint-Venant equations are selected to simulate the propagation of highly dynamic flood waves (Brunner 2016). The studied delta is represented using 2D flow area of a 20mx20m spatial mesh, with representing downstream boundary condition as constant water level (average Nile level in front of the delta), while the upstream boundary condition represents the flood hydrograph (Figure 3-C and Figure 4).

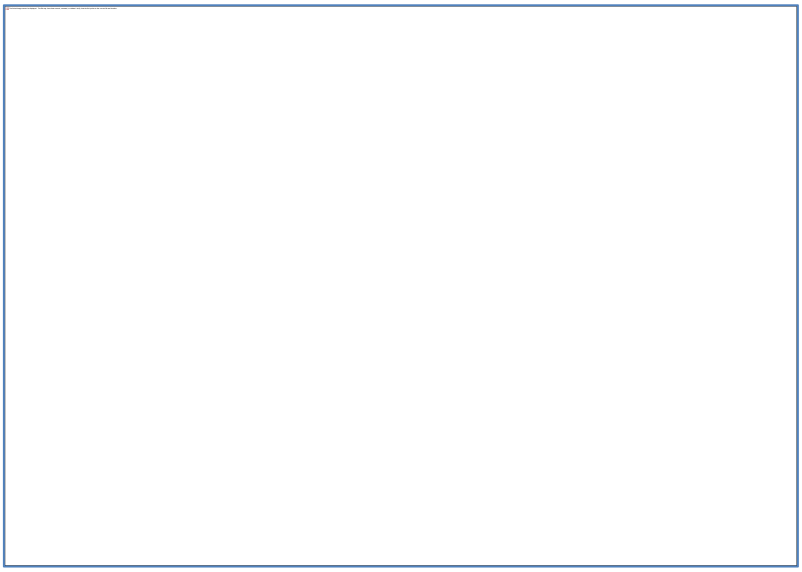


Figure 3 location, design flood and land-use characteristics of the study area.

This model is used to compare eleven alternative flood protection. First one, represent the original case before building any flood protection structures (i.e., no floodwater stored). The remaining scenarios simulate incremental storing volumes. The computational time interval of half a second was used here. soil roughness manning coefficient are considered 0.011 for sheet flow over the croplands, 0.016 for flow through tree areas and 0.25 for water flow within the residential areas (Cronshey 1986; Chow 1959).

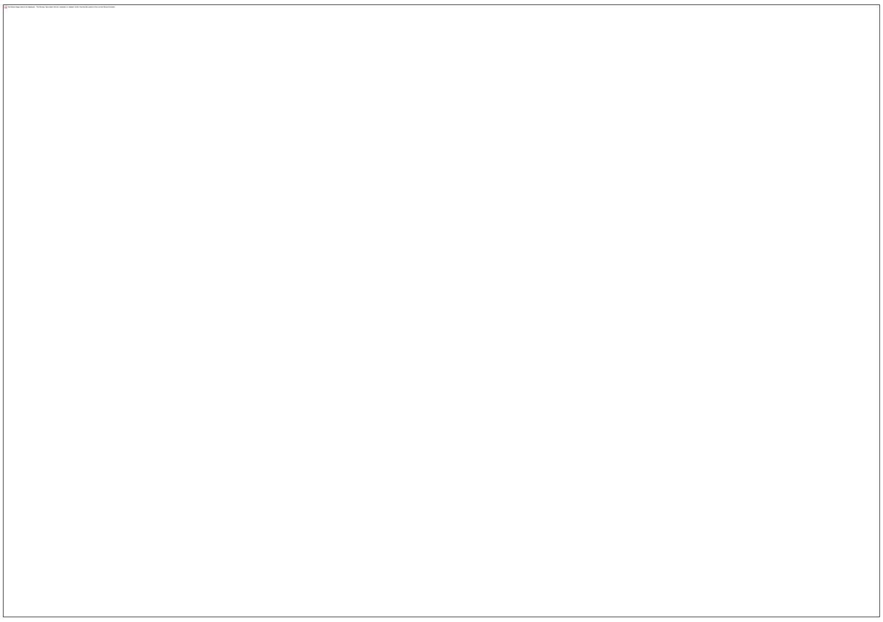


Figure 4 data used to define the required geometric characteristics to simulate a 2D flash flood propagation using HEC-RAS 5.0.

Flood risk assessment

A common way to predict flood risk is to use curves or relationships that give thresholds to determine where a threaten on human or properties is expected. This study use the flood-damage curves for the residential areas as provided by the Australian emergency management institute (2014) that use maximum floodwater depth and velocity (Figure 5).

Estimating flood damage in croplands is much more difficult than resendetial areas due to the great unsimilarity among the crop charactrisics. Therefore, it is uncommon to find flood/damage curves for these kinds. The main crops in the study area in the period of flash flooding is (tomato, Palm, and sugar cane). Based on discussions with specialists and reviewing some related literature, a threshold of flood depth of 0.25 m and flood velocity of 0.25 m/s will be used as a damage level.

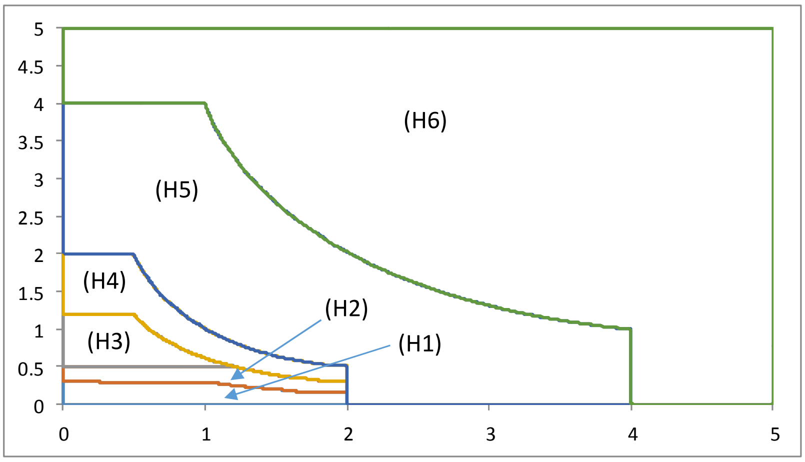


Figure 5 Flood v.s. damage curves. H1 No vulnerability constraints; H2 Unsafe for small vehicles; H3 Unsafe for all vehicles, children and the elderly; H4 Unsafe for all

people and all vehicles; H5 Unsafe for all people and all vehicles. Buildings require special engineering design and construction; H6 Unconditionally dangerous. (McLuckie & Babister 2014)
To automate and speed up the assessment of flood risk, a workflow was defined using the ArcGIS Modelbuilder. Three Modelbuilder models were developed, these models reads outputs of HEC-RAS simulations in raster format, convert it into point file, read land use classification shapefile, apply user specified risk thresholds or damage curves, and finally, draws map risk over delta area (Figure 6).

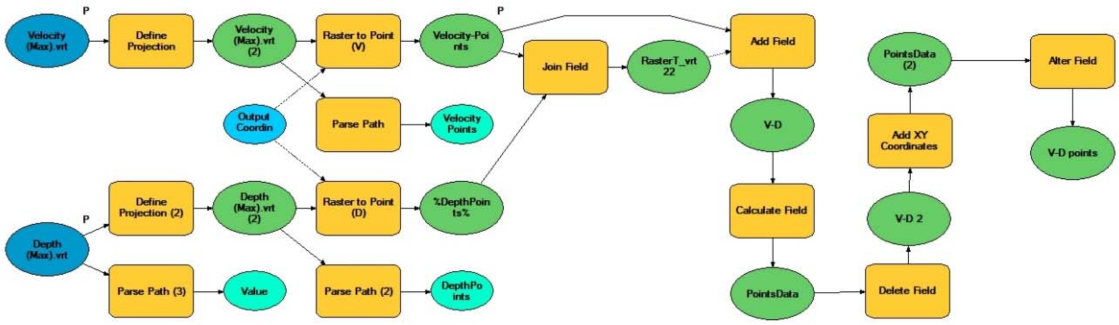
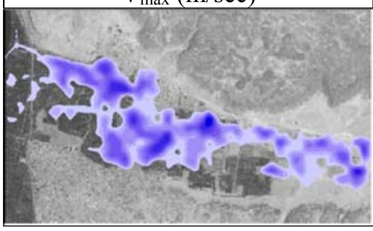
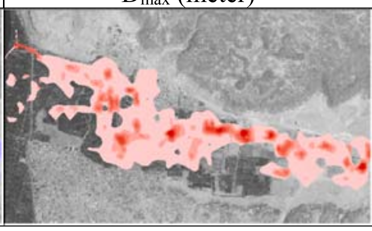
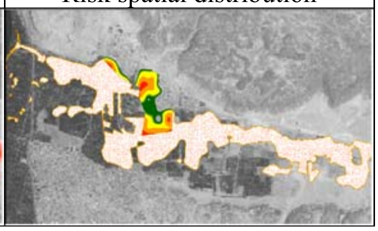


Figure 6 the GIS Model Builder routines developed for mapping flash floods risks

Results and Discussion

The two key components required to predict the flash flood damage (water depth and velocity) were calculated over the study area using a 2D hydrodynamic flow model developed using HEC-RAS. This model was used to compare four scenarios, each represents a different storage capacity of a flood protection structure. That comparison was based on the spatial distribution of flood risk.
The results of the applied approach show that before making any protection there is about half of the arable lands in the study area are flooded while nearly third of tree and urban areas are flooded. Maps show all flood depth, velocity and risk distribution is displayed in Figure 7. The left and middle columns of this figure represent the maximum predicted values of water depth and velocity respectively, while the third column shows the spatial expansion of risk over urban, trees and croplands over the study area. The first row of each column represents a scenario before any protection (i.e., storing = 0 m3), second row represents a scenario of storing 50% of the 100 years design flood. Third row is for 90% storing. Last row represents storing fully the 100 years flood.

V_{max} (m/sec)	D_{max} (meter)	Risk spatial distribution
		

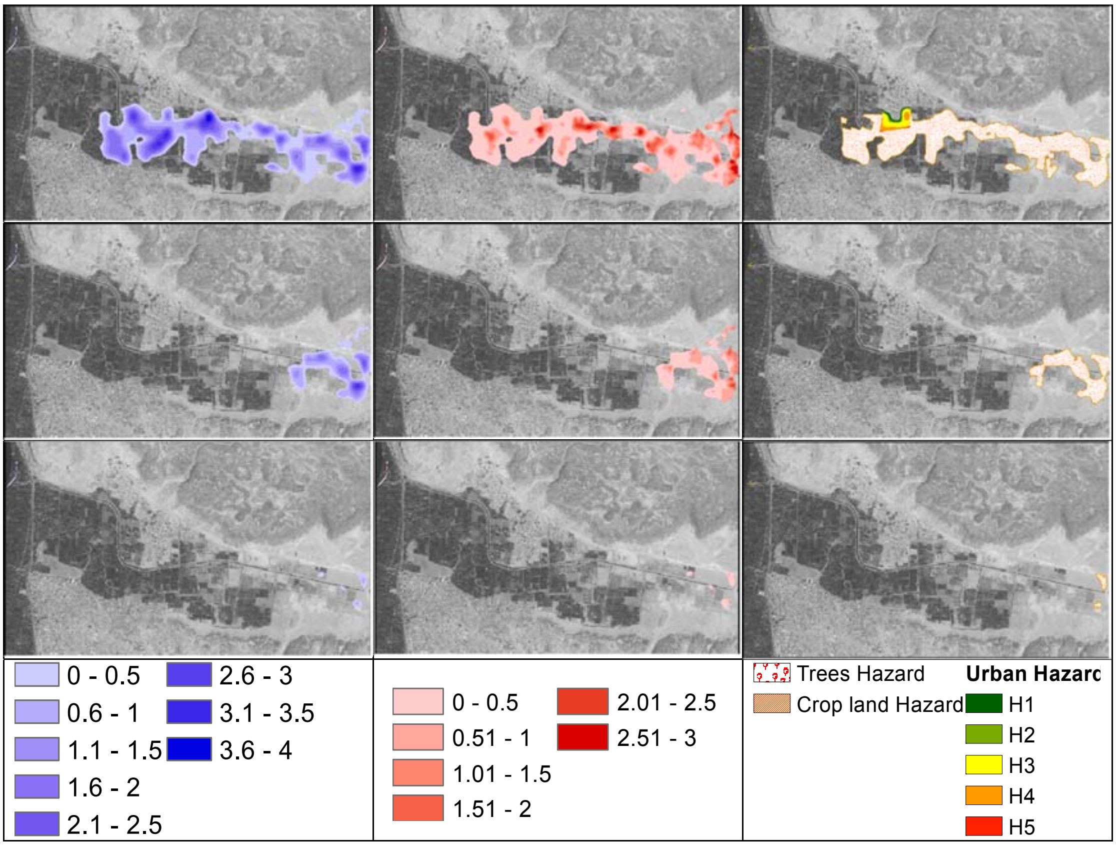


Figure 7 the coloured areas represent the spatial distribution of maximum depth (left column), the spatial distribution of maximum velocity (middle column), and the spatial and degree distribution of flood risks over different land uses in the study area.

To be able to assess flood risks in the study area, it is required to calculate the expected risk per each land use. This is due the huge difference in the consequences of flood according to the differences in Investments on land. It can be shown in Figure 8 that crop lands are the most influenced by the flood. On the other hand, both of residential and tree lands have much fewer areas that exposed to flooded and are much more affected by storing floodwater.

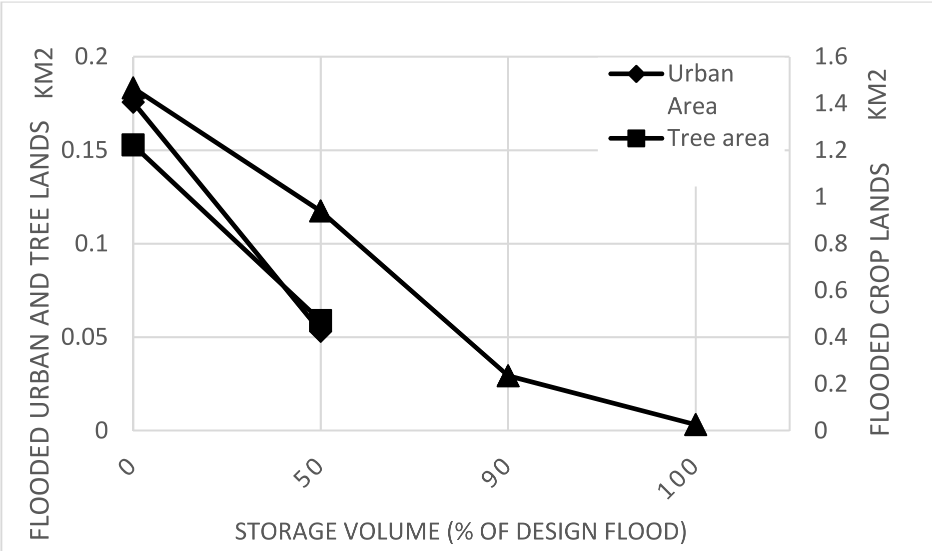


Figure 8 Reduction in affected areas due to storing flood water partially in the upstream of the study area.

Determining areas threatening by serious flood risk within the places face the water require applying flood-damages relationships. For both of crop and tree areas threshold values of flood, features were checked while six successive grades the flood severity were evaluated in the urban areas according to the curves presented in Figure 5. Mapping these estimated risks is presented in the right column of Figure 7. The areas face serious risks in residential and in croplands for each flood protection scenario is shown in Figure 9, while flood characteristics in all three areas didn't cross the threshold limit. Figure 9 shows that storing half of the design flood decreases risk on crop areas by 35% while decreasing risk in crop areas require storing 70% of the total volume of the design flood. In addition, Figure 9 shows flood risk in urban areas, it is clear from the figure that none of the study areas faces the highest flood risk level (I,e., H6), also the H5 level appears in no storing or storing small portion if the flood while it disappears completely by storing half of the flood. Also, the middle-risk degree (I,e., H4) decreases Significantly by increase the storage amount. Finally, the figures show that storing 90% of the design flood eliminates any risk in the urban areas.

To compare the alternative flood protection structures, it is necessary to accumulate the different expected risks into a single value for each alternative. Therefore, analytic hierarchy process (AHP) is used to predict these weights, as shown in Table 3. Then by multiplying the derived relative weights with the area faces that level of risk for each alternative, we got Figure 10 that shows the overall risk. According to this figure, the decline of flood risk takes an inverse relationship with increasing the storage volume of the flood protection structure.

Discussing the results above shows weather or not applying the proposed approach helps in determining an economic design. It could be understood from Figure 9-B that storing only 50% of the design storm relieve us of the highest degrees of risking lives of people.

The large difference among flooded areas of croplands and both of urban and trees face it (Figure 8) may be because croplands are very close to the water entrance while both of urban and trees are more to the downstream. Which causes also large differences when flood risk is assessed (Figure 9).

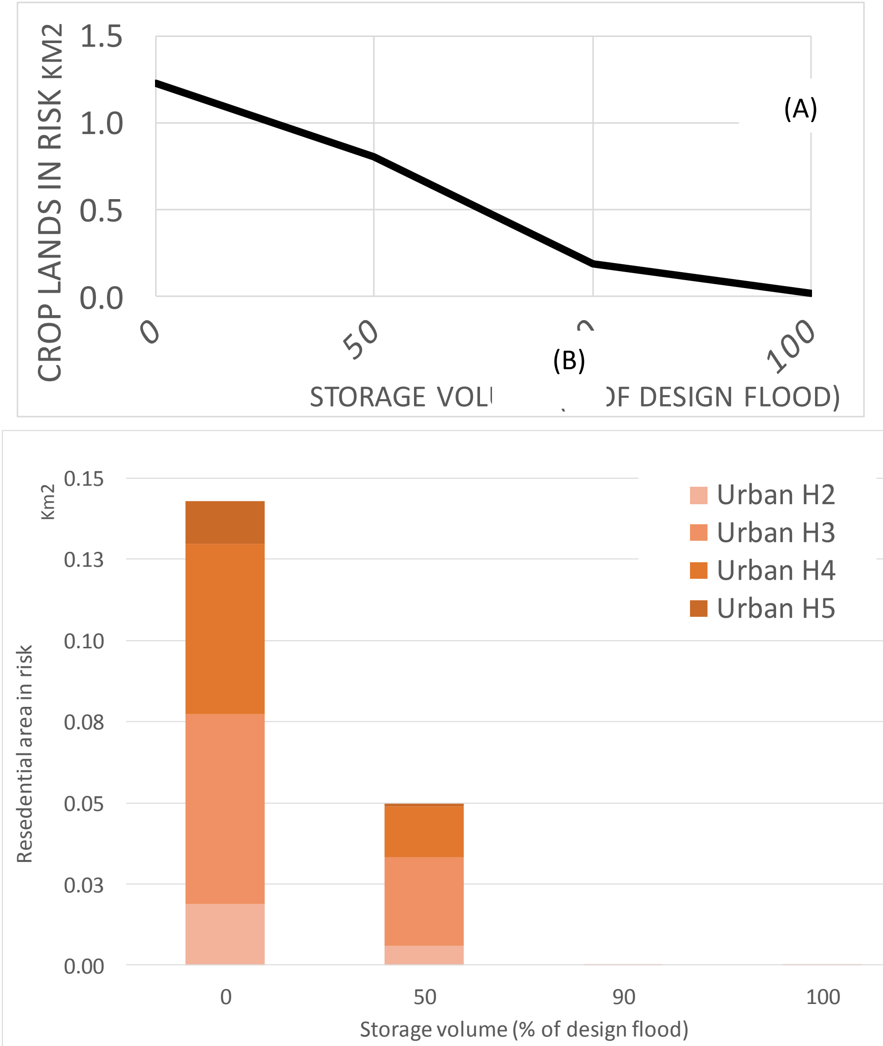


Figure 9 Crop areas under risk w.r.t. each proposed flood protection structure (left), noticing that Urban H1 and Urban H6 were ignored because the first one doesn't cause any harm

Table 3 outputs of Super Decisions ,i.e., normalised percentiles of relative weights of each land use

Name	Crop Risk	UrbanRisk H2	UrbanRisk H3	UrbanRisk H4	UrbanRisk H5
Normalized relative Weights	6.5%	3.9%	12.2%	31.6%	45.9%

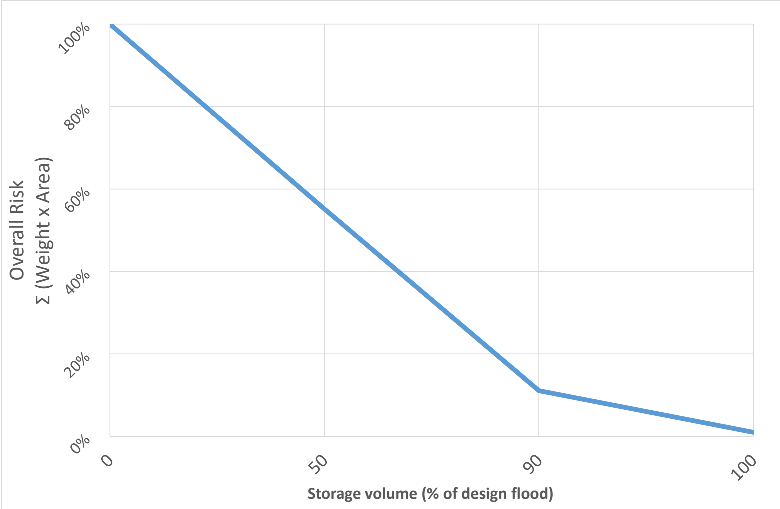


Figure 10 a curve of total percentage of expected risk of each flood protection alternative w.r.t. different storage alternatives.

Conclusions and recommendations

Combining of hydrodynamic flood simulation packages, geographic information systems and decision support tools allow determining an economically reduced storage capacity of flood protection structures without risking of causing serious damages in the threatened areas.

The resultant flood risk maps show that partially storing flood water causing a significant reduction in areas facing high degrees of damage and/or death risk in residential zones. On the other hand, reduction in risk in agricultural areas due to storing flow water declined in small areas, even the risk won't be insignificant tell storing most of flood water. Also, the risk of trees death does almost not exist with any scenario. Finally, if flood protection system suffers from budget shortage so a compromised structure could be agreed about with the design makers that utilise the available budget to reduce the risk. Another solution is to provide decision makers with a list of alternative budgets vs. expected risk reduction. Therefore, applying the proposed approach provides flexibility in selecting the size and hence the cost of flood protection structures.

The discussed work highlights a number of recommendation such as the expected usefulness of applying the proposed approach to land use planning. Also, to get more useful results, it is recommended to repeat this work using more alternatives if storing volumes of flood water. It is useful to consider spatial flood characteristics over the deltas when choosing plants for planting. It is recommended also to widely apply the proposed approach for deltas with mostly urban, low economic value crops or the existence of obstacles to building large protection structures. It is important to develop local water velocity-depth-damage curves for different land uses. Finally, provided accurate topographic land surveying data is required to enhance the hydrodynamic model outputs.

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