A GIS tool for flood risk analysis in Flanders (Belgium)

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Abstract

In recent decades, the low-lying Flanders region (Belgium) has fallen victim to numerous flood events, causing substantial damage to buildings and infrastructure. In response to this, the Flemish government proposed a new approach that considers the level of risk as method of safety measurement. Using geographical information systems, this evolution has led to a comprehensive risk methodology, and more recently to the development of a flood risk assessment tool called LATIS. By estimating the potential damage and the number of casualties during a flood event, LATIS offers the possibility of performing risk analysis in a fast and effective way. This paper presents a brief overview of the currently used methodology for flood risk management in Flanders and its implementation in the LATIS tool. The usefulness of this new tool is demonstrated by a sequence of risk calculations, performed in the framework of climate change impacts on flood risk in Flanders.

Keywords: flood risk analysis, GIS, Flanders, risk assessment tool, LATIS.

1 Introduction

In recent decades, Flanders (northern part of Belgium) has suffered several river floods, causing substantial damage to buildings, roads, agricultural fields, etc. As Flanders is one of the most densely populated and industry-developed regions in

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the world, a decent water management policy is needed. This has brought the Flemish government to an approach that focuses on minimizing the consequences of flood events instead of avoiding high water levels [7]. This has to be done in an integrated approach where measures are evaluated in a social cost benefit analysis. Flemish examples are made for the river Scheldt in the Sigma Plan [9] and for the coastal zone in the integrated coastal safety plan [3].

By means of GISs, a risk-based methodology has been set up to assess a quantitative risk for flood damage, based on a variety of land use information and socio-economic data. This methodology not only considers the probability of a certain disastrous event, but also its consequences. Section 2 presents a brief overview of the method's calculation phases, together with a recent extension to the model: flow velocity as an additional damage factor.

However, the risk-based methodology poses some disadvantages, such as (i) user-unfriendly interface, (ii) time-consuming model start-up, (iii) non-effective data management and (iv) long calculation methods. Through this, the development of a user-friendly, effective tool for flood risk assessment became necessary. The implementation of the risk methodology into the assessment tool LATIS is presented in Section 3. This section also describes the usefulness of the tool for numerous risk calculations within the framework of climate change scenarios on flood risk in Flanders.

Section 4 concludes with a brief outline of possible applications of the tool and further developments to be expected as part of the European Flood Directive.

2 A risk-based methodology

2.1 Calculation of damage and risk

As presented in [7], the calculation of damage and risk consists of three steps, namely (i) defining probability and extent of flooding, (ii) determining expected damage, and (iii) defining risk. The different steps are schematically presented in Figure 1.

The first step is in fact preliminary to damage and risk calculations. It comprehends the estimation of an area's flooding probability through statistical analysis of water levels and flow rates in the past. Researchers calculate the average period of time in which a particular maximum water level may reoccur. Higher water levels and discharge volumes correspond to larger return periods of occurrence. Furthermore, flood maps are created using hydrologic and hydraulic models, together with digital elevation data. These maps not only show maximum water level in each grid cell, but also indirectly indicate the extent of a certain inundation. Additional information such as flow velocity and rise rate of water (especially important for casualty assessment) can also be obtained.

Secondly, land use information and socio-economic data is used to produce maximum damage maps (the present risk-based methodology considers internal monetary damage, both direct and indirect [7]). When combining the latter with the flood maps, expected damage for a given inundation can be calculated. Besides this, land use information can be derived out of a variety of land use maps, based on topographic maps, satellite imagery, orthophotographs, CORINE Land Cover, etc. In addition, socio-economic data is gathered. E.g. the number of persons and vehicles per surface area, values for a great number of goods, land use categories, buildings, etc. Thus, to determine the expected damage for a given flood, the replacement value of goods is used, not the original value of purchase. Based on this information, a maximum damage is computed by unit of surface for each land use category (buildings, industry, pastures, etc.).

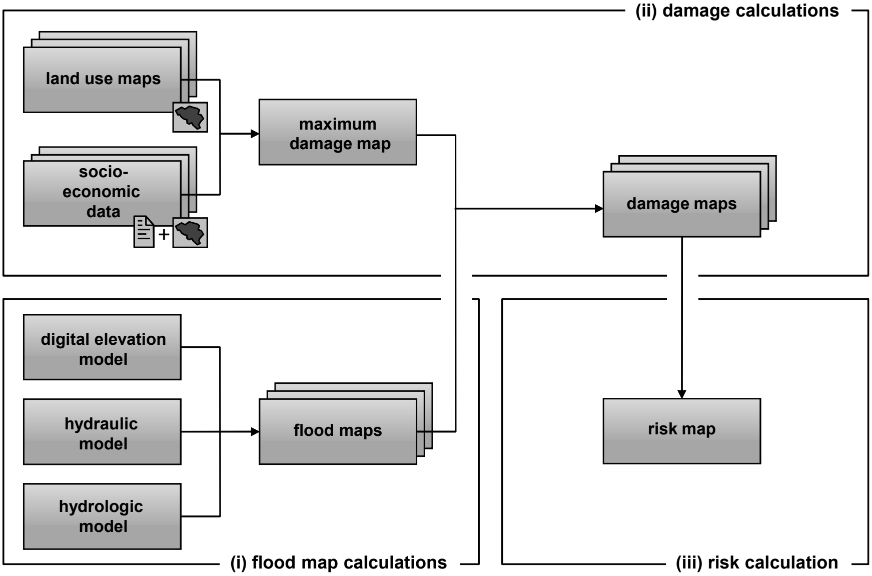

Figure 1: Derivation scheme of risk mapping.

These categories all have different relations between maximum damage and water depth, called damage functions or α-factors [5]. The expected damage inside an inundation area is then calculated by multiplying the maximum damage of each land use category with the corresponding α-factors and by subsequently summarizing these with all different land use categories of a certain area.

Based on the formula *probability * vulnerability*, the damage maps are combined into one risk map, which indicates the expected average annual damage for a given area. The map indicates flood risk as a cost per surface a year (Euro/m².year). A more detailed description of these calculation steps and their mathematical basis can be found in [2,6].

2.2 Flow velocity

Until recently, damage and risk calculations were limited to flood events caused by overflow, restricting the main damage factor to water depth. Obviously, overflow is not the only failure mechanism. In case of geotechnical failures, such as dike/dune breaching, damage to buildings and/or constructions may be much larger compared to overflow. In the vicinity of the breach, high flow velocities can even cause total collapse of buildings. In general, it is assumed that flow velocity generates an additional damage on top of the present damage calculations. Based on findings of [8], new damage functions were developed for levels of water depth in combination with flow velocity [3].

Besides material damage, the number of casualties will also be higher in case of high flow velocities, because of instability of people and building collapse [4].

3 Implementation of the methodology in GIS

3.1 Early GIS model

The development of a risk-based methodology (Section 2) alone is not enough to perform risk management. In addition, the method needs to be translated into a useful model that carries out all necessary steps in a pre-programmed chain of actions. Because of the data properties and the analyzing techniques, a raster-based GIS was chosen above a vector-based. Indeed, most of the computations are point-operations, which can be optimally performed in a raster-based GIS [1].

However, this early GIS model structure poses some disadvantages. First, adaptations and extensions to the model are difficult to process and can result in a disable system. Moreover, the GIS model demands an intensive start-up procedure for each risk computation, as input data is listed in a rather unfriendly user-interface. Finally, the model doesn't have a data management system. On the one hand this leads to an overload of data, because all temporary files are saved. On the other hand it lacks the possibility of using (important) temporary files to skip general calculations, causing long processing time.

All this has lead to the development of LATIS, a GIS application tool that guides the user through each step of the different damage and risk calculations in a user-friendly interface. LATIS is described in more detail in the next section.

3.2 Development of a flood risk assessment tool: LATIS

In 2007, Flanders Hydraulics Research and Ghent University have developed a GIS tool as a substitute for the GIS model structure mentioned in Section 3.1. This tailor-made tool is called LATIS, referring to the Celtic god of water.

LATIS is built on Microsoft.NET technology in combination with the raster GIS package Idrisi (Clark Labs). The user interface of the application and algorithm of the model were implemented in the programming language C#.NET. For all the geospatial operations, LATIS uses the optimal computing capacity and built-in standard modules (stand-alone executable files) of Idrisi. The tool performs all necessary actions with the corresponding parameters so the user only has to take care of the input data. LATIS was developed in English and will be available with an extended help-document. Furthermore, the tool has a data management system that easily allows the administrators to manage the basic land use maps and socio-economic data. These maps and data are gathered in a uniform way for the whole extent of Flanders and are centrally managed on a data server. This leads to a more efficient data storage and easy preprocessing. The application namely selects and cuts the necessary data for the extent of a certain scenario from the data server. Because of this, damage and risk maps are calculated in an easy (the user only has to take care of input flood maps), uniform (same method and data for the whole extent of Flanders) and reproducible way (data management system records the set of input data).

3.3 LATIS in action

The effect calculation of climate change scenarios in Flanders has been one of the first projects for which the LATIS tool is used. These climate change scenarios are based on regional climate models for different emissions scenarios. Based on potential evolutions in rainfall and potential evapotranspiration, a high, mean and low scenario is defined for summer and winter period in Flanders. In general, drought problems will probably increase during summer time, while the evolution during winter time is rather unsure (strong increase in flooding in the high scenario till slightly decrease in the low scenario).

Hydraulic model runs are executed based on the climate change scenarios for Flanders and the available measurement series for water level, discharge and evaporation to derive flood maps with different return periods in the catchments. Besides the extension of the flooded area, the water depth is used in this project as a main factor to derive damage. First, the flood maps for the current situation are recalculated with the most recent socio-economic data available. They are used as a reference to be compared with the flood maps of the climate change scenarios. For all four simulations, the flood risk is based on the same series of return periods for the flood map calculations.

A relative small increase or decrease in water level can cause large differences in damage and risk. Some vulnerable sites in landscape that are only flooded once a century can be flooded more frequently, causing the risk to increase seriously. On the other hand, a serious increase of water depth on agricultural land does not lead to a large increase in damage and risk. Once the crops are rotten the water depth is not that important any more.

Economic damages are generally calculated for housing, industry, agricultural land etc. However, special attention is given to local objects in the landscape, namely those which are (i) sensitive to extreme high damage values (e.g. power supply installations, museums), (ii) important in case of emergency as a control centre (e.g. fire brigades, police stations) and (iii) problematic due to evacuation reasons (e.g. hospitals, elderly houses).

Interpretation of the results of the damage and risk maps from the climate change scenarios has to be done (like for all other risk scenarios) in a relative way and not for each map pixel (in this case 5*5 metres). Comparison of the risk maps of the scenarios with the risk map of the actual situation is in this case the most advisable relative value. In the example of the river Dender catchments below (Table 1) the values are summarized in between two successive sluices and locks. In the master plan for these catchments – where the studies are already

Table 1: Risk calculation for the river Dender (Euro/year).

ZONE	High	Mean	Low
1	1557718	445291	147770
2	793207	336804	89106
3	543266	277973	63033
4	2425749	944274	114940
6	1834810	320294	126108
7	44988	2224	3996
8	5933094	5754488	5085751
9	423236	373823	275777
SUM	**13556068**	**8455170**	**5902487**

going on – the location and dimensioning of the sluices will be evaluated and adapted. The proposed measures also have to be sustainable under the conditions of climate change, so the evaluated scenarios can be reused.

4 Conclusions and further development

At present, the risk-based methodology and risk assessment tool LATIS are used as part of social cost-benefit analyses. Both are decision support tools to evaluate scenarios considering economic social safety, health, etc. These analyses are done for several riverine and coastal management plans.

Further development of the LATIS tool will allow us to fulfil the demands of the European Flood Directive. Therefore, additional modules will be assigned to the model in the following months. Most of the questions in the EU Flood Directive deal with drawing up an inventory of objects in the potentially flooded zones. At the same time the potential flood damage and its likelihood will be evaluated. If the damage is important or largely different from its environment it will be added to the damage and risk calculation modules too.

These future developments will bring LATIS to its real strength, which means an efficient data availability (all data in one file format) and data management (base data only stored once) together with a user friendly interface, allowing to use the same map layout for all catchments and for all questions in the EU flood directive.

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References

[1] Eastman J.R. (2006). *Idrisi Andes, Guide to GIS and Image Processing*, Clark Labs – Clark University, Worchester, USA.

[2] De Maeyer Ph., Vanneuville W., Maeghe K. & Mostaert F., Modélisation des effets de crue dans le bassin de la Dendre, basée sur une méthodologie de risqué (Modelling the Effects of Flooding in the Dender Catchment based on a Risk Methodology), Le Geo Evenement, 4−6 mars 2003, Paris, Actes des conférences sur Cd-rom, pp. 7, 2003. [in French]

[3] Kellens, W., Vanneuville, W. (2007). *Damage and risk calculations,* Report of Action 3b of the Interreg IIIB project SAFECoast, Ghent University and Flanders Hydraulics Research, Antwerp, Belgium, pp. 41[in preparation]

[4] Jonkman B., Loss of life estimation in flood risk assessment, Theory and applications. Doctoral thesis, 354 p., 2007

[5] Penning-Rowsell E., Johnson C., Tunstall S., Tapsell S., Morris J., Chatterton J., Coker A. & Green C. (2003). *The benefits of flood and coastal defence: techniques and data for 2003*, Flood Hazard Research Centre, Middlesex University (book + CD-ROM with damage data).

[6] Vanneuville W., De Maeyer Ph., Maeghe K. & Mostaert F., Model the effects of a flood in the Dender catchment, based on a risk methodology. *Society of Cartography Bulletin*, Vol 37 (2), pp. 59–64, 2003.

[7] Vanneuville W., De Rouck K., Maeghe K., Deschamps M., De Maeyer Ph., Mostaert F., 2005. *Spatial calculation of flood damage and risk ranking*, In: Conference Proceedings of Agile 2005, 8th Conference on Geographic Information Science, pp 549–556.

[8] Vrisou Van Eck, N., Kok, M., Vrouwenvelder, A.C.W.M., Standaardmethode Schade & Slachtoffers als gevolg van overstromingen – deel 2: Achtergronden, HKV-Lijn in Water en TNO Bouw in opdracht van RWS-DWW, 1999

[9] De Nocker, L., Broekx, S., Liekens, I. (2004). Maatschappelijke KostenBatenAnalyse veiligheid tegen overstromen in het Schelde-estuarium: conclusies op hoofdlijnen (Social Cost Benefit Analysis on Safety against Flooding in the River Scheldt Estuary – Conclusions on the outlines). VITO in cooperation with RA-IMDC, s.l., 92 pp. [in Dutch]