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Modelling the Financial Impact of Flood Risk

This article[1] describes how to model the financial impact of flood risk for specific Dutch portfolios, which is insufficiently covered by the commonly used global flood models as these models often ignore specific flood risk characteristics within the Netherlands. First, we describe the available Dutch flood risk data. Then we show how we can link these to individual addresses. Subsequently, we show how this can be combined in impact per flooding scenario on a portfolio level. Finally, this is translated to a financial impact for either a portfolio or an individual address. Every region in the world has its own specific climate risk profile. For the Netherlands, one of the largest climate risks is flooding[2], as considerable parts of the nation lie below sea level and several major European rivers run through it and flow out to sea. In the past, flood was not insured in the Netherlands as the state provided for appropriate protection. However, despite a sophisticated water management system, events in Limburg and the IJssel in 2021 and 2023 prove that nevertheless the exposure exists and show the relevance of insuring and modeling such flood risks. Sophisticated open-source models and data exist to assess the risks of flooding, but no tools exist that can assess the associated financial impact for the Netherlands.

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Climate risk models for determining the financial impact generally involve three elements: hazard, exposure, and an impact function, which maps the hazard and exposure to a financial impact. The hazard depicts the region and intensity of the climate catastrophe, and the exposure is the maximum value at risk, where the value is typically defined in financial terms. The impact function is then used to determine the realized financial impact as a percentage of the exposure given the realized hazard.

For our proposed model, we model the hazard, exposure, and impact function in the following way:

- **Hazard:** The Klimaat Effecten Atlas (KEA) is an open-source tool for the Netherlands that contains high resolution maps with the maximum flood-depth for four different catastrophic events, namely 1 in 10/100/1,000/10,000 years-events. These charts can be used to map flood hazards onto individual houses in an insurer's portfolio.
- **Exposure:** Typically, an insurer will have access to data on maximum insured amounts or expert estimates of the value of the residential property, though for our example we will use asking prices from a source of publicly available housing ask-prices as a proxy. This can be tailored more specific to an individual insurer's data.
- **Impact function:** To translate the hazards and exposures into financial impacts, we use depth-damage curves that were established in the scientific literature. Similar to exposure, insurers have more specific information and can calibrate these functions on their own data.

In the following sections, we set out our developed methodology in more detail. First, we discuss an image recognition algorithm, which is used to map flood hazards onto housing for various municipalities in the province of Zuid-Holland. Then we briefly discuss the data used for exposures and the impact functions. Everything is brought together in a stylized example for two insurance portfolios with residential properties located in the province of Zuid-Holland. Finally, we will discuss applications of the method for pricing and risk management.

HAZARD: IMAGE RECOGNITION ALGORITHM

To estimate the financial impact of flood risks on insurance portfolios located in Zuid-Holland, we first quantify flood hazards. For this purpose, we apply an image recognition algorithm to obtain the hazards based on the KEA flood maps. To showcase how the image recognition algorithm works, we use a single municipality Gouda as our prime example. However, note that this model is suitable on larger scales (provinces) or smaller scales (individual addresses). The image recognition algorithm performs three steps to assign flood depths to grids of residential buildings:

1. The algorithm identifies the municipality's borders using a land registry map. We show this map for Gouda in the top left of Figure 1. Here the borders are clearly marked by the black solid line. After this step the algorithm will clearly know which areas are and are not part of the municipality.
2. Given the municipality's borders, the algorithm will then determine which parts of the map are buildings and which are not based on color codes. After this step, we know where the buildings of the municipality are located, which we have visualized in the bottom left of Figure 1.
3. Finally, we map the KEA charts on the buildings to see how deep a building is flooded in a 1-in-X event. In the top right plot of Figure 1, we show the flood depth for the 1-in-10,000 event. The bottom right plot shows the buildings that are affected and the severity of the flood depth. Note that similar maps can be made for the other 1-in-X event.

After running the image recognition algorithm, we know the flood depth for buildings in Gouda in various 1-in-X events. Note that the algorithm is easily extended to other municipalities or could even be used on provincial or national level.

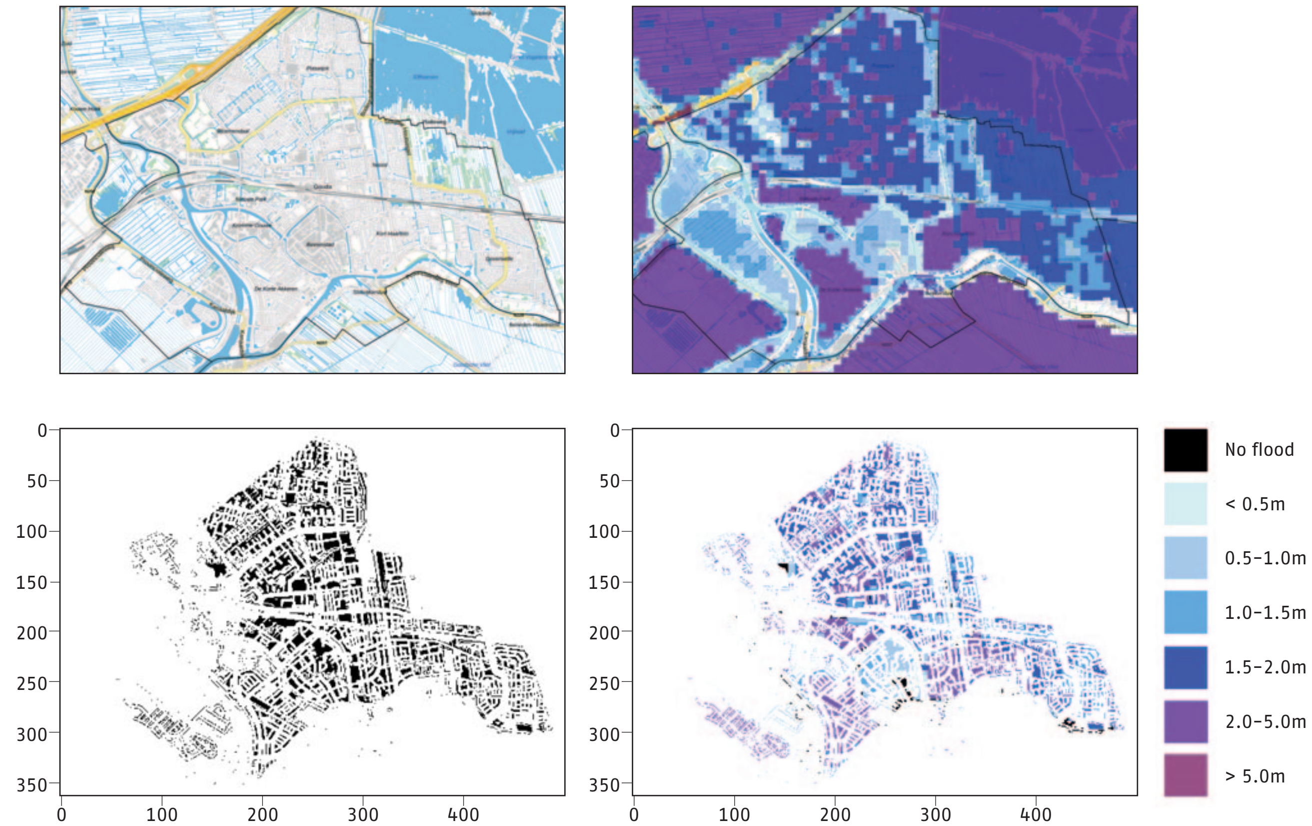

Figure 1. Image recognition algorithm input and output.
The top left and top right figures are screenshots taken from Klimaateffectenatlas, 2023.

EXPOSURE AND IMPACT FUNCTION

To model the exposure, we require a proxy for the value of a residential building. As stated before, financial exposure information comes naturally to insurers. However, for this example we use the ask-prices that were publicly available for this insurers' portfolio as the property values. Given the exposures and flood hazards, we can then estimate the financial impact of a corresponding flood with an impact function. For the impact function, we will use the depth-damage curves from Huizinga et al. (2017) that contain impact functions regarding the sum insured for residential buildings and content in the Netherlands and other European countries. Note that these curves were developed based on expert judgement and historical data and generalized for the Netherlands, but insurers can tailor more specific curves, e.g., using data specific to Gouda or their own portfolio's exposure.

INSURERS' PORTFOLIO

Given the flood hazards, exposures, and impact function per municipality, the climate risk impact is calculated for two stylized portfolios: P1 and P2. Each containing ten randomly selected residential properties. These properties were selected randomly within the province Zuid-Holland. For the exposure, we take the asking price of the house for sale.

Frequency (years)	P1 (%)	P2 (%)
1-in-10	0	0
1-in-100	0.1	1.0
1-in-1000	7.5	4.4
1-in-10000	15.4	8.8

Table 1. Portfolio percentage losses due to flood risk

We report results in Table 1 for the two portfolios in various 1-in-X flood events as percentage losses of the total exposure value. The results are shown as a percentage of the total exposure value of P1 and P2, for which total exposures are respectively 4.6m and 5.6m euros. It clearly shows how the financial impact of flood risk may vary substantially for different insurance portfolios. For instance, the 1-in-10,000 event for P1 equals 15.4% of the total exposure in estimated damages, while that of P2 equals a lower 8.8%. Conversely, in the 1-in-100 event, P1 is smaller with only 0.1%, with the losses for P2 being 1.0%. Indicating that even though the residential properties of both portfolios are in the same province, the possible damage can differ widely. Therefore, clarity and insights on the financial impact of flood risk are essential for insurers. Note that the use of the flood risk model is not limited to just estimating possible damages, but may also contribute to:

- Determining the financial impact of including or excluding a house in a portfolio.
- Using quantile fitting with heavy tailed distributions to assess the portfolio's financial impact for multiple flood events, not restricted to the four 1-in-X flood events. This distribution fit can also be used for calculating other risk measures such as expected shortfall.
- Incorporating future climate change scenarios into the hazards to get deeper insights into flood risk.
- Performing sensitivity analyses for flood risk uncertainty within the portfolio.

CONCLUSION

Here, we demonstrated a novel and flexible flood risk model for financial impact based on the KEA. Using the model described above you can assess the financial impact of flood risk on a national level as well as on insurers' portfolio level. We showed that the financial impact of flood risk can vary substantially among insurers' portfolios, which illustrates the importance of this topic. For cases such as reporting and risk management, this will provide additional value within the risk assessment because of deeper and quantifiable insights on flood risk. The model fits within the Solvency II format since the model can help with calculating best estimates for reserving and obtaining cost-covering premiums that are able to incorporate climate change or to use in a Solvency II Internal Model. Additionally, the model can be used for ORSA requirements regarding stress testing multiple scenarios for assessment of materialized climate risks.
In doing so, we advise the following:

- Calibrating impact functions based on the exposure of the specific insurers' portfolio.
- Using specific insurer portfolio characteristics to get a realistic proxy for the financial exposure.

WE EXPECT CATASTROPHE RISK TO INCREASE AND HENCE THE NEED FOR CLARITY ON THE FINANCIAL IMPACT OF FLOOD RISK ON THE INSURERS' PORTFOLIO

As follow-ups, you want to do the following, depending on the relevance of the application:

- Back-testing of known catastrophic events and claim data and evaluate model assumptions.
- Investigating the insurers' portfolio from an underwriting perspective and discuss how the company wants to operate within the competitive market.
- Assess reinsurance strategies with multiple loss function optimizations to reallocate flood risk away from the insurance company.

While flood risk is currently excluded from catastrophic risk module of the SCR for the Netherlands, we expect catastrophe risk to increase and hence the need for clarity on the financial impact of flood risk on the insurers' portfolio. Additionally, we expect more guidance within the coming year regarding quantification of flood risk, which helps with providing a more robust framework for flood risk modeling as a whole. ■

References

Huizinga, J., De Moel, H., Szewczyk, W., et al. (2017). Global flood depth-damage functions: Methodology and the database with guidelines. Technical report, Joint Research Centre (Seville site).

1 – This article is based on the master's thesis of Vincent de Quelerij.

2 – In this context, a flooding includes solely coastal and fluvial floods.