Weighing Costs and Losses: A Decision Making Game using Probabilistic Forecasts

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HEPEX — a community of research and practice to advance hydrologic ensemble prediction

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Introduction

Probabilistic forecasts are increasingly recognised as an effective and reliable tool to communicate forecast uncertainties in support of flood and drought warning, reservoir operation and agriculture, amongst others. These have been shown to have more value than deterministic forecasts, where the binary decision to act or to not act in response of a forecast is linked to the ratio of the cost/effort required in taking action with the losses that are avoided when taking a response in reaction to the forecast. This ratio is often referred to as the cost/loss ratio. In many cases the value of taking discussions based on probabilistic forecasts considering the cost/loss ratio has been demonstrated in academic exercises or hindcasting studies, but the practical value of probabilistic forecasts is more difficult as duty forecasters are required to make a decision that weighs the information such as the probability that a threshold is exceeded, with quantitative and qualitative information on the impacts should no action be taken and the threshold is indeed exceeded. While guidance based on several studies made may be provided on the reliability of the forecast may be of use, as well as on the impacts, the interpretation of forecast probabilities and the making of the practical decision is difficult. We explore how users of forecasts interpret probabilities of flood thresholds being exceeded, and how they weigh the ratio of the cost of the mitigation action, against the expected impacts if a response is not taken. We conducted a game, which was played at four separate sessions, where participants were divided into three groups, each with a different cost/loss ratio. Participants were presented with a series of forecasts, and asked to make a decision on whether to take mitigation action.

The Game

Approach: Laboratory-type experiment in which participants are presented information of a hypothetical case and are asked to make decisions based on the information provided. Method adopted from experimental economics (Roulston et al. 2006) and applied previously in previous decision making games played at the EGU (Ramos et al. 2013; Arnal et al. 2016)

Objective: Evaluate how users interpret the information provided in a probabilistic forecast and make decisions on mitigation action to take depending on the losses suffer if flooding occurs, and the costs of mitigation action

Three shops on a River Bank

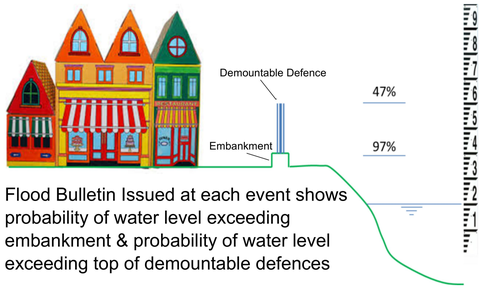
Shop 1: Ferraris

Shop 2: Groceries

Shop 3: Gravestones

	Ferraris	Groceries	Gravestones
Initial Savings	€ 500,000	€ 100,000	€ 25,000
(-) Do Nothing	€ 0	€ 0	€ 0
(D) Raise Defences	€ 10,000	€ 10,000	€ 5,000
(I) Move inventory	€ 25,000	€ 5,000	€ 4,000
(L) Losses if flooded	€ 100,000	€ 20,000	€ 4,000
(P) Profits when open for business	€ 25,000	€ 10,000	€ 5,000

The Game



Flood Bulletin Issued at each event shows probability of water level exceeding embankment & probability of water level exceeding top of demountable defences

Event Number	#1	#2	#3	#4	#5	#6	#7
Prob. of exceeding embankment (%)	59	64	56	40	94	99	47
Prob. of overtopping defences (%)	10	27	10	0	54	37	1
Actual Flood Level (m)	4.6	5.8	3.9	4.1	5.9	6.1	3.8
Embankment overtopped	Yes	Yes	No	Yes	Yes	Yes	No
Temp defences overtopped	No	No	No	No	No	Yes	No

For each flood event participants were presented Flood Bulletin and asked to take one of three actions. After making decisions the outcome was shown and costs/losses accounted
- Do Nothing
- Raise Defences
- Move Inventory

Impression of participants in the game during the 2016 HEPEX meeting in Quebec City, Canada

The proud winner!!!!

Game played at four sessions - total 215 players
- EGU 2016 This same session
- HEPEX Conference 2017, Quebec Canada
- Student group at IHE Delft
- RMetS Conference in Manchester, England

Evaluation

1) Relative frequency with which decisions were made
2) Value Score or Relative Economic Value (Zhu et al. 2002)

$$V = \frac{E_{forecast} - E_{reference}}{E_{perfect} - E_{reference}}$$

E: Expected Expense of forecast
V: Value Score
Reference forecast considered as no

3) Assess if decisions made follow optimal decision rule using cost-loss ratio

$$r_D = \frac{P - D}{-L - P} \qquad r_I = \frac{-I}{-L - P}$$

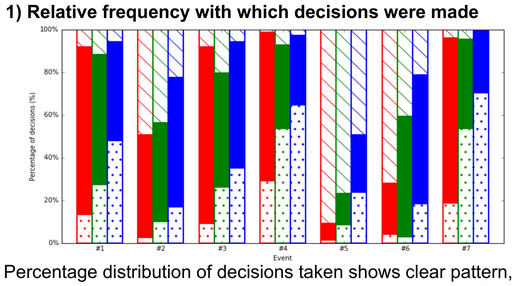
Cost-loss (C/L) ratio calculated considering profit (P) when shop stays open for business as well as when not considering profit

Cost-loss ratios for the decisions to take action, expresses as a percentage. For the action raising the defences, the first figure is the cost-loss ratio that includes the profit (P), while the second considers only the losses and the costs of taking mitigation measures

Action	Ferraris	Groceries	Gravestones
Raising Defences	-12% / 10%	0 % / 50%	0% / 125%
Moving Inventory	20% / 25%	17% / 25%	44% / 100%

Results

1) Relative frequency with which decisions were made

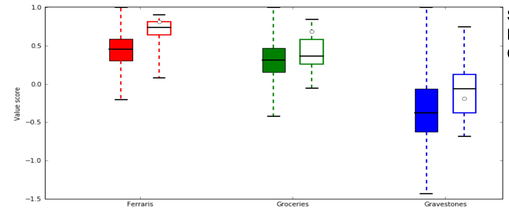


Ferraris
Groceries
Gravestones

Percentage taking no action
Percentage raising defences
Percentage moving inventory

Percentage distribution of decisions taken shows clear pattern, with shops selling Ferraris being most inclined to take action. Likely due to the magnitude of losses, with higher losses leading to higher likelihood of decision to take action. C/L ratios seem to have been considered, but the majority more inclined to take action in line with the C/L that did not include the profits.

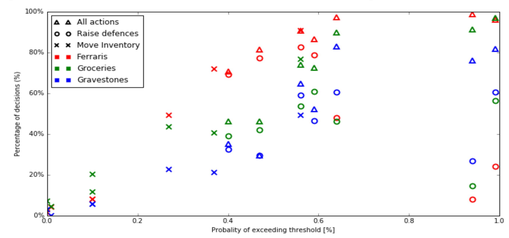
2) Value Score or Relative Economic Value



Solid box plot: All possible strategies
Empty box: Strategies taken by participants
Circle: Optimum decision rule

Full distribution of 2187 possible decisions show potential value of forecast is highest for the Ferrari shop owners. For the Gravestone shops forecasts are of little value. Ferrari shops did well in extracting useful information from forecasts. For groceries shops and Gravestones shops, cost of taking action in vain means extracting value in the forecasts is increasingly difficult.

3) Assess if decisions made follow optimal decision rule using cost-loss ratio



Frequency of taking action reveals inclination to respond to forecast probabilities. Ferrari shop and grocery shops have the same optimal decision rule, but former take more frequent action. Surprisingly, gravestone shops had similar behaviour to grocery shops, despite high cost of action.

Conclusions

Potential value differs substantially due to different C/L ratios, with those with a low C/L ratio easily gaining value by taking action in response to forecasts, even if those actions are at times not perfect leading to false alarms or missed events. For users with high cost-loss ratios the value of forecasts is low; and considering the inherent uncertainty may not be a viable strategy for reducing losses.

Users of forecast information do seem to take the concept of cost-loss into account when making decisions, but are also strongly influenced by the idea that flooding should be avoided, and may therefore be inclined to take action to avoid flooding, despite this action being costly.

Arnal et al. 2016. "Willingness-to-Pay for a Probabilistic Flood Forecast: A Risk-Based Decision-Making Game." HESS 20 (8): 3109–28
Ramos et al. 2013. "Do Probabilistic Forecasts Lead to Better Decisions?" HESS 17 (6): 2219–32.
Roulston et al. 2006. "A Laboratory Study of the Benefits of Including Uncertainty Information in Weather Forecasts." Weather and Forecasting 21 (1): 116–22.
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