Drought forecasts and decision-making

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Droughts are periods of drier-than-normal conditions (Douville et al., 2021). They are natural phenomena which cannot be prevented. Drought risk management attempts to reduce the adverse effects of droughts. One drought risk management measure comprises using forecasts to decide whether or not to plant a drought vulnerable crop. The present document comprises a computational example of this measure, explains the theoretical background and shows how forecasts can be used to inform a decision.

Computational example

Suppose a farmer grows a crop that (per unit) costs \$8 to plant and can be sold for \$12. If a drought strikes, the crop will be lost to the farmer. If no drought strikes, the crop will yield \$4 - the difference between the selling price and the cost of planting. Let's use a hypothetical series of 1,000 independent years. The farmer can grow a single unit of crop only. We elaborate three scenarios:

- All 1,000 years are non-drought years;

Figure 1: Drought often has large impacts on the ecosystems and agriculture of affected regions, and causes harm to the local economy.

- All 1,000 years are drought years; and
- In any year, the probability of drought equals 80%.

Non-drought years

If there is never any drought then every year, the farmer will invest \$8 and yield \$12. On balance, she gains \$4,000 over the 1,000 years. This averages out to \$4 per year.

Drought years

If every year is a drought year then the farmer will lose her investment of \$8 and have no yield. In total, this will result in a loss of \$8,000. This averages out to \$8 per year.

80% probability of drought

If, in all years, the probability of a drought is 0.8[1], we expect 800 drought years and 200 non-drought years. If always planting, the 800 drought years will have resulted in 800 (years) $\times$ \$8 = \$6,400 worth of costs and no benefits. In the 200 non-drought years, the crops will

[1] A probability P of 0.8 is equivalent to a probability of 80%. In the remainder of this paper, we use the mathematical notation, i.e. probabilities between 0 and 1.

have yielded 200 × $4 or $1,200. On balance, the farmer will have lost $5,600. This averages out to $5.60 per year.

Note that in above, the ‘no drought’ scenario coincides with a zero probability of drought and the ‘drought’ scenario coincides with a probability of drought equaling 1 (“100%”). That allows us to draft the following table:

Probability of drought P	Expected (annual) value E
0	$ 4.00 (profit)
1	$ 8.00 (loss)
0.8	$ 5.60 (loss)

This raises the question: where is the break-even point? At which probability of drought are expected yields equal to expected losses?

Breaking even

If there is a probability P of drought then the 1,000 years will feature 1,000 × P drought years and 1,000 × (1 - P) non-drought years.

Probability of drought	total number of years	drought years	non-drought years
0	1,000	0	1000
1	1,000	1000	0
0.8	1,000	800	200
P	1,000	1,000 × P	1,000 × (1 - P)

Expected value can then be computed using the following equation:

$$E = \text{drought years} \times (-\$8) + \text{non-drought years} \times (\$12 - \$8) =$$

$$(1,000 \times P) \times (-\$8) + (1,000 \times (1 - P)) \times (\$12 - \$8)$$

$$-8,000P + 4,000 - 4,000P = 4,000 - 12,000P$$

In a graph:

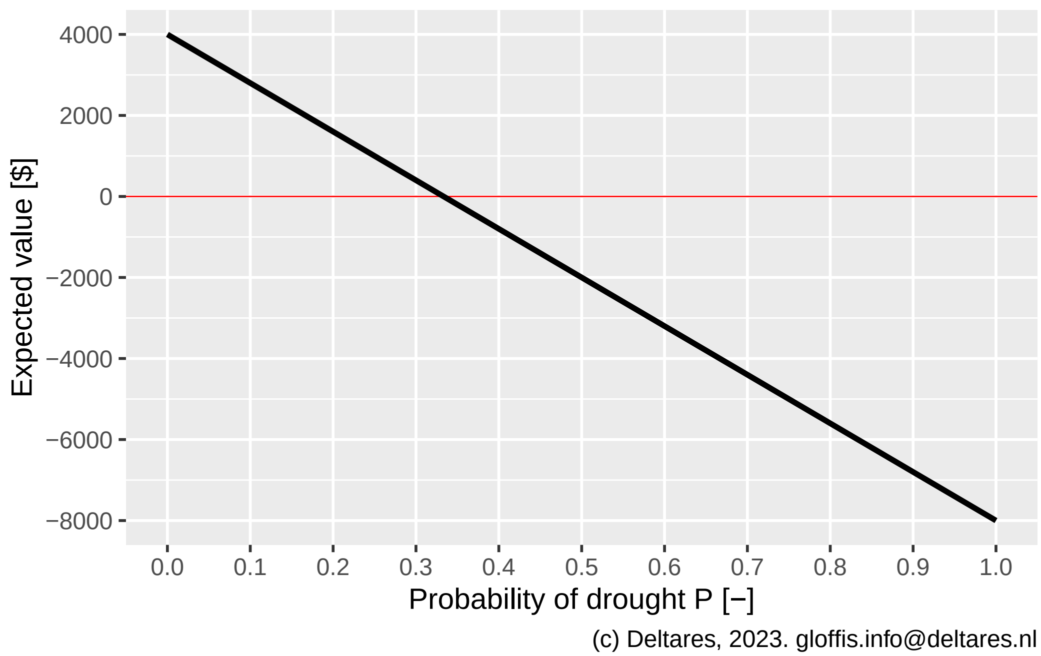

Figure 2: Expected farm yield as a function of probability of drought

The equation and Figure 2 tell us that the expected value equals $0 if the probability of a drought is 0.33. They also tell us that the farmer will yield a net benefit if the drought probability is *less than* 0.33 and a net loss if the drought probability *exceeds* 0.33.

Forecasts for decision-making

A drought forecast can tell us in advance what the probability of a drought is. For example, if a certain crop is sensitive to soil water then the soil water forecast as shown in Figure 3 may be used to decide whether or not to plant.

If the crop is sensitive to soil moisture levels below 0.34mm for a duration of more than 20 days then we can identify the scenarios in which a drought occur. These scenarios are highlighted in below figure Figure 4.

The forecast informs us that 12 out of 51 scenarios show a drought. This comes to drought probability of 0.24. Using the decision criterion from the computational example, the farmer would do well to plant the crop.

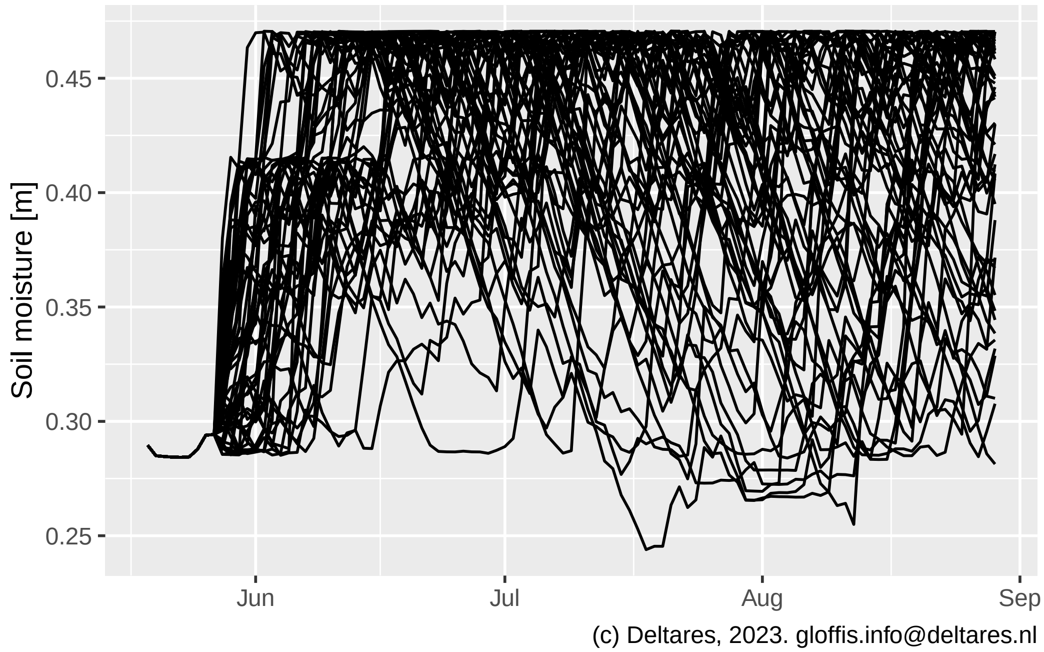

Figure 3: Soil moisture forecast

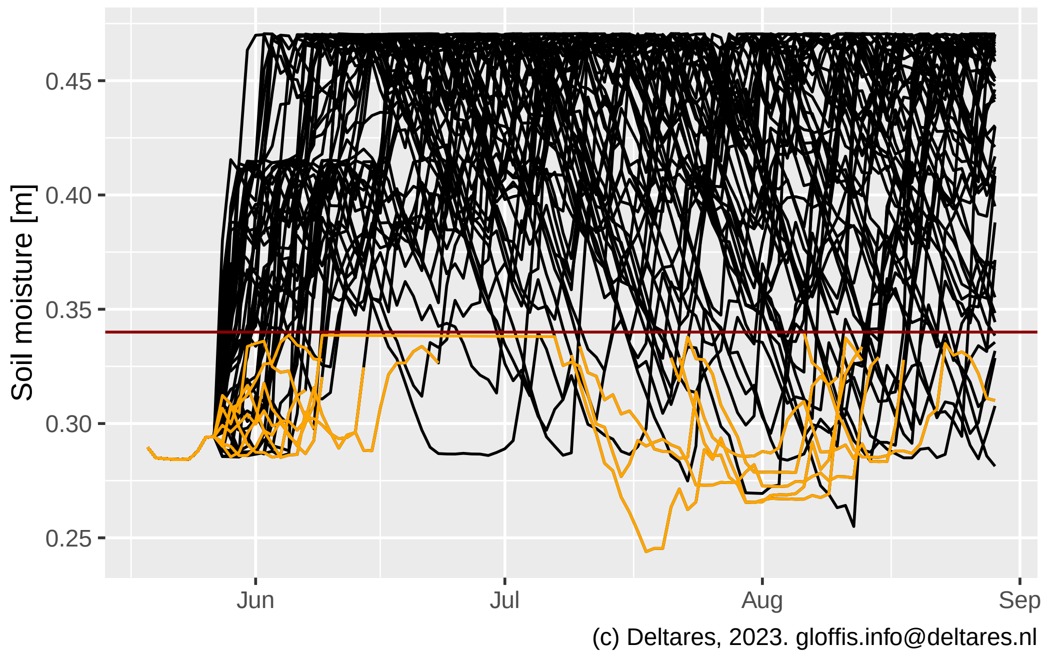

Figure 4: Soil moisture forecast, highlighting the scenarios that feature a drought

About gloffis and Deltares

Deltares is the Dutch national R&D institution in the field of water management and geotechnical engineering. Deltares operates **gloffis**, a global, real-time hydrological forecasting system. The system allows for estimating future flood conditions, with a lead time of up to 10 days and future drought conditions, with a lead time of up to 4 months. The system produces both 'best estimate' conditions as well as probabilistic estimates of future conditions. In addition to the provision of real-time forecasting services, Deltares can assist in the development of appropriate decision rules.

The **gloffis** team is ready to talk to you about your forecasting requirements. Feel free to set up a meeting.

References

Douville, H., Raghavan, K., Renwick, J., Allan, R. P., Arias, P. A., Barlow, M., Cerezo-Mota, R., Cherchi, A., Gan, T. Y., Gergis, J., et al.: Water cycle changes, in: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom; New York, NY, USA, 1055–1210, 2021.