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Stochastic characteristics of flood impacts for agricultural insurance practices

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1. Abstract

During the last decades, the rising **demand** for crops for human consumption and industrial processes has led to a growth of investments and search for innovative solutions across the field of agriculture. However, one major **risk** that both **investors** and **low-income farmers** encounter worldwide is the impact of extreme weather events on their crop yield. The risk caused by **extreme weather** is an inhibitor of growth of agriculture and, apparently, agricultural insurance is strategically important for dealing with that risk. In particular, crop-yield **insurance** is purchased by agricultural producers, and in many cases is subsidized by governments, to protect them against the loss of their crops due to **natural disasters**, such as extreme flood events. In this context, the main subject of this research is to **apply a stochastic approach of extremes** for evaluating the impact of flood risk on agricultural insurance practices. We investigate **stochastic aspects of extreme flows** such as the right tail of the distribution of extremes and the existence of clustering mechanisms. For this purpose, we **analyze daily flow series from the CAMELS** dataset. Furthermore, we review current insurance practices in the agriculture domain in Greece and inspect the underlying **stochastic assumptions**, while evaluating changes in the **estimated flood risk** in the case that these assumptions are not valid.

2. Review of the agricultural insurance practices in Greece

The agricultural insurance market in Greece is mainly supported by **ELGA***, which is supervised by the **Ministry of Agriculture** and is wholly **owned** by the State. ELGA covers all crop damages caused by both natural (such as **extreme flood events**) and non-natural disasters. The annual maximum amount of compensation that ELGA may pay to its beneficials is defined as:

- *per beneficiary of compensation*: the maximum amount of 250,000€ per year,
- *per parcel*: 80% of the insurable value of the production of the damaged parcel.

Compensation shall be paid by ELGA when the damage is greater than **20%** of the production and it is **equal to 88% of the over 15% of the loss**. The 15% of loss that is not covered by ELGA can be covered by **private insurance companies**, such as ERGO Hellas*. These additional private insurance products operate in addition to ELGA's coverage and cover the quantitative loss of the insured product. Private providers ensure that, in cooperation with ELGA, the total amount of compensation will be 85% of the total loss (up to 10,000€), based on **ELGA's experts reports**. However, these insurance products are being estimated with deterministic and **non-stochastic** methods, which systematically **underestimate or overestimate** the risk.

3. Methodology and dataset

Recent research has indicated the significance of **Hurst-Kolmogorov dynamics**, **persistence** and **inherent uncertainties** in real-world hydrometeorological processes (*Koutsoyiannis, 2011; Dimitriadis, 2017*), flood inundation and flood mapping (*Dimitriadis et al., 2016*). In this context, the aim of this research is to apply a stochastic approach of extremes (*Serinaldi et al., 2016*) for evaluating the impact of **collective flood risk** *S* on agricultural insurance practices. We investigate the dynamics of daily streamflow series from a collective risk viewpoint, treating the **exceedences over given thresholds** as **proxies** for claim amounts, and defining *S* as the accumulation of claim amounts over fixed one-year time windows. The dataset on which we applied this methodology for the collective risk assessment is the **CAMELS** dataset (*Newman et al., 2014*). As the assessment of *S* is a **typical problem** faced in insurance and reinsurance practice, we investigate the effect of flood and precipitation **clustering mechanisms** on this insurance variable. Moreover, we briefly present, through an exploratory analysis, the effect of these mechanisms on *S*, in comparison to **classical assumption of independence** of extreme events, which is often made by the insurance companies for the estimation of extreme events risk (including flood risk). Furthermore, regarding **precipitation** mechanisms, we expect the presence of persistence in annual rainfall (*Iliopoulou et al., 2018*) to induce clustering in **rainfall extremes**, which should be manifested by clustering of floods. Therefore, in the framework of a **case study**, we investigated whether the *S* estimated using the former as a proxy, i.e. the magnitude of the rainfall peak over threshold events in a year, is correlated with the actual **compensations** given.

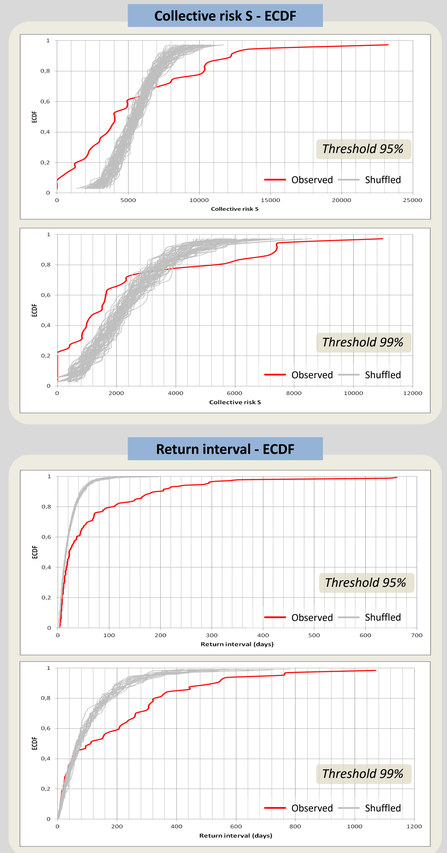
References

- Koutsoyiannis, D., 2011. Hurst-Kolmogorov Dynamics and Uncertainty. Journal of the American Water Resources Association, 47(3), pp.481-495.
- Dimitriadis, P., 2017. Hurst-Kolmogorov dynamics in hydrometeorological processes and in the microscale of turbulence. PhD thesis, Department of Water Resources and Environmental Engineering, National Technical University of Athens, Greece.
- Dimitriadis, P., Tegos, A., Oikonomou, A., Pagana, V., Koukouvinos, A., Mamassis, N., Koutsoyiannis, D., and Efstratiadis, A., 2016. Comparative evaluation of 1D and quasi-2D hydraulic models based on benchmark and real-world applications for uncertainty assessment in flood mapping. Journal of Hydrology, 534, 478–492.
- Serinaldi, F., and Kilsby, C.G., 2016. Understanding Persistence to Avoid Underestimation of Collective Flood Risk. Water2016, 8, 152.
- Newman, A., Sampson, K., Clark, M.P., Bock, A., Viger, R.J., and Blodgett, D., 2014. A large-sample watershed-scale hydrometeorological dataset for the contiguous USA. Boulder, CO: UCAR/NCAR.
- Iliopoulou, T., Papalexiou, S.M., Markonis, Y. and Koutsoyiannis, D., 2018. Revisiting long-range dependence in annual precipitation. Journal of Hydrology, 556, pp.891-900.

Exploratory analysis

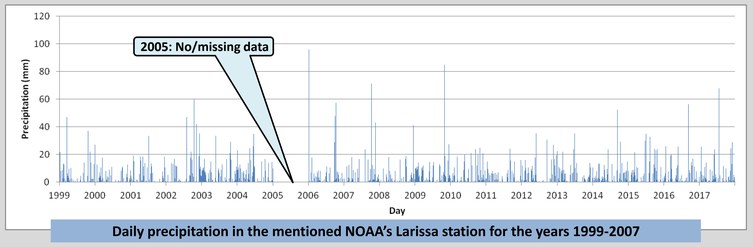
4. The critical underlying role of streamflows clustering mechanisms in the estimation of collective flood risk in global insurance market

*We process the **671 daily flow (Q) series** of the CAMELS dataset (years 1980-2014) and we choose to investigate more extensively the behavior, in terms of clustering mechanisms, of the one that had the **least missing values** (0,13%), which was the **USGS 07067000** (Current River) at Van Buren, State of Missouri, USA. Two thresholds (**95%** and **99%**) are selected as **proxies** for estimating the annual collective flood risk of the **observed** timeseries. Besides, in order to evaluate on both thresholds the effect of **independence** on the collective flood risk, we **shuffle** the elements of the mentioned timeseries and estimate once again the annual collective flood risk. In addition, we calculate the Average Yi parameter, which is defined as the annual average peak over threshold flow, and we **correlate** it with the annual number of the (peak over threshold) events. Furthermore, we develop the diagrams of **the empirical cumulative distribution function (ECDF)** of Collective risk and Return interval for the selected thresholds and for both observed and shuffled (60) timeseries.*

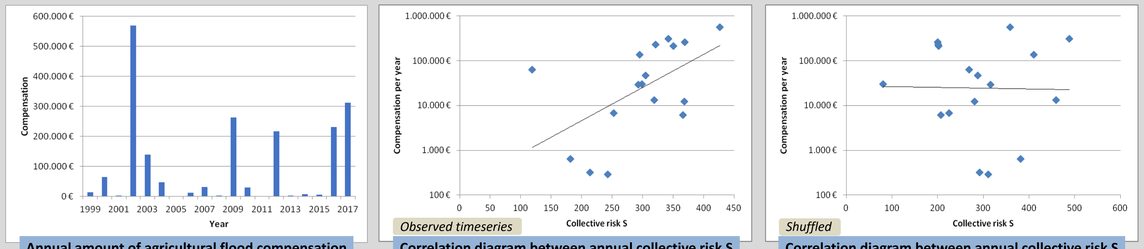


5. Precipitation clustering mechanisms: The interplay between rainfall extremes and flood compensations - Case study: Larissa (Thessaly), Greece

NOAA station in Larissa, Greece, ID: GR000016648



Daily precipitation in the mentioned NOAA's Larissa station for the years 1999-2007

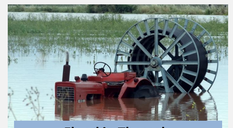


Annual amount of agricultural flood compensation in Larissa Prefecture, Greece (1999-2017)

Correlation diagram between annual collective risk S and compensation - *Correlation coefficient = 0.58*

Correlation diagram between annual collective risk S and compensation - *Correlation coefficient = 0.19*

Exploiting the compensation data (1999-2017) that ELGA provided us, we evaluate the correlation between the annual precipitation's **collective risk S** (threshold 95%) and the annual **agricultural flood compensation** in Larissa, for both observed and shuffled daily precipitation timeseries.*



Flood in Thessaly
Central Greece, May 2016
56 km² of agricultural land flooded

Controlled flood in Evros river
Northern Greece, March 2018
5.5 km² of agricultural land flooded

Flood in Evrotas river
Southern Greece, January 2019
Major damages in orange trees

6. Conclusions

- The assumption of the **independence** of extreme flood events, which implies that collective risk is **identically distributed** over long-term time windows, is not **realistic**. In fact, disregarding clustering mechanisms may lead to **underestimation** of the risk by the insurance companies. As a consequence, companies may have to compensate their clients with large amounts of money in **short periods**, stressing their reserves.
- The **ECDF** diagrams show that **Hurst-Kolmogorov dynamics** and **clustering** mechanisms should be included in the design of insurance products to avoid **underestimation** of the **exceedence probability** of collective risk.
- As expected, years that are more active in terms of **number of events** tend to exhibit more extreme events also in terms of **average magnitude**.
- Regarding **precipitation** clustering mechanisms, the case study in Larissa region highlights a remarkable **correlation** between the annual **collective risk** of the observed timeseries and the **compensations**, in contrast to the shuffled ones.

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