Meteorological Early warning systems, a tailor-made **tool for climate change adaptation**

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Abstract

The Climate Research Foundation (FIC) is advancing Early Warning Systems (EWS) as crucial tools for adapting to the impacts of climate change, addressing the increasing frequency of extreme weather events and their effects on vulnerable sectors like agriculture. In developing regions, where disrupted seasonal cycles challenge farmers reliant on ancestral knowledge, EWS integrate agronomic data with probabilistic numeric models to provide actionable forecasts. For instance, Ficlima's statistical models support Nicaragua's coffee sector, while Colombia's cocoa sector employs the DWD's ICON ensemble model. These systems emphasize participatory co-design with experts and users, resulting in widely accepted outputs like mobile app bulletins that summarize adverse event risks through agrometeorological indices and probabilities using a traffic-light system. Tailored forecasts based on user coordinates face reliability issues due to sparse meteorological station networks and limited validation resources; new projects partially address this by installing manual weather stations for user-uploaded data. The European project Urbreath contributes by reducing biases in daily probabilistic forecasts using EMOS (Ensemble Model Output Statistics) and CRPS (Continuous Ranked Probability Score), enhancing daily temperature and precipitation predictions through the R-package '*scoringRules*.' These advancements strengthen climate resilience in urban and agricultural contexts by optimizing forecasts and providing actionable insights for users.

Methodology

Part 1. SSH component:

Through a co-design process, a culture of climate change adaptation is promoted. A solution that combines technology with local expertise is developed, where communities clearly articulate their challenges with extreme weather events to receive alerts that help mitigate their impacts. This approach fosters a stronger sense of ownership among locals, leading to greater acceptance of the tool once completed. Additionally, end-users are more motivated to overcome the learning curve associated with adopting the new technology.

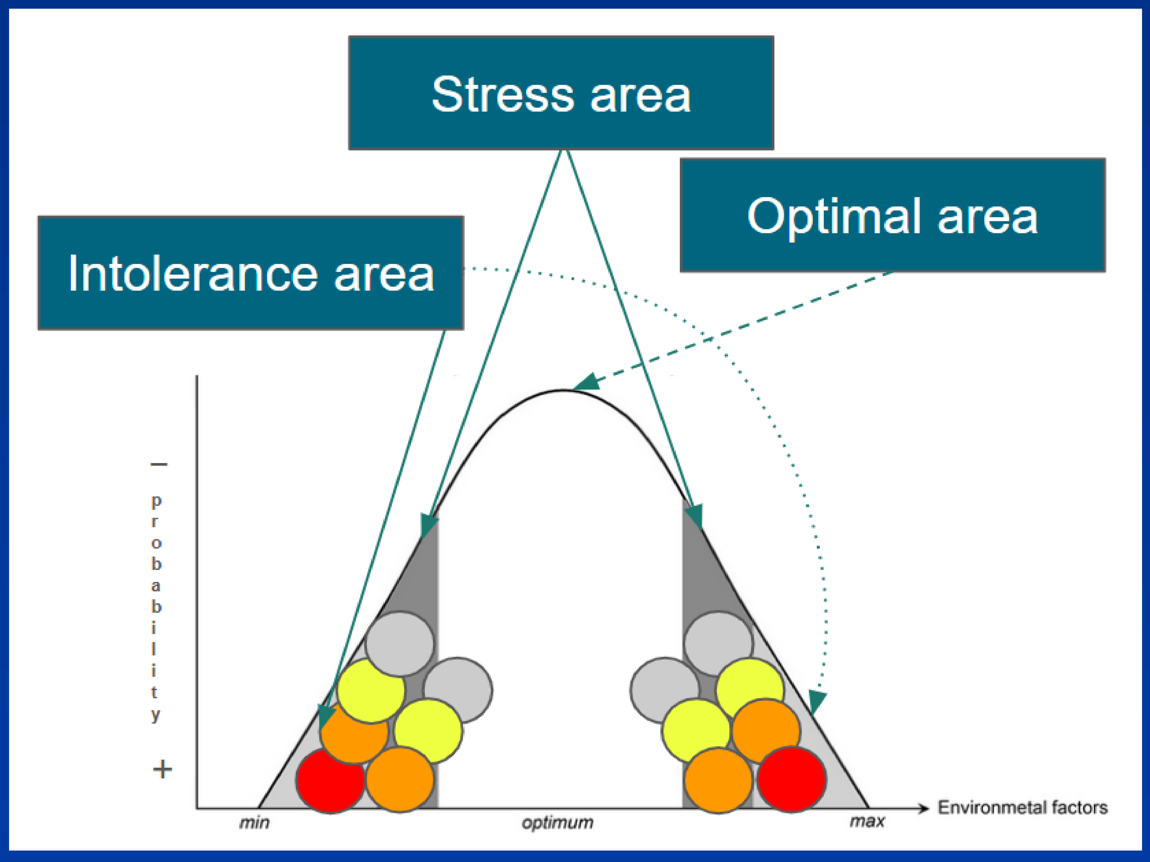
Photo 1: Participatory process during a field visit in 2022 in Estelí. This image captures a meeting of the Innova project in Nicaragua, funded by the Spanish Cooperation Agency (AECID).

Figure 1: Probabilistic distribution areas and locations where forecasts are made.

Table 1: Double input table on which the probabilistic forecast is based by combining two risk thresholds with the probabilities of reaching the thresholds provided by the ensemble model.

Part 2. Probabilistic combined forecast:

Once the events, their magnitude, and persistence have been co-defined, weather models per ensembles are used for each variable, threshold, and time range to display indices operatively to the end-user. Depending on the project, models like ICON-DWD or our analogue model have been applied in cooperation projects. A double-entry table summarises how likely it is for each index to exceed two daily risk thresholds: a more extreme one indicating higher risk and a lower one. To account for the probability given by the model as a risk indicator, different degrees of probability are defined for each threshold. Thus, a red risk level is assigned only to the highest thresholds for each index *(see table 1). Graph 1* shows the statistical distribution of predicted ranges for each index, assuming it is a Gaussian variable like temperature. The aim is that the intolerance zone identified during the co-design process is marked red in the forecast when event probability is high, while the stress zone, which may also be hazardous, is marked with orange or yellow warnings based on the model's probabilities.



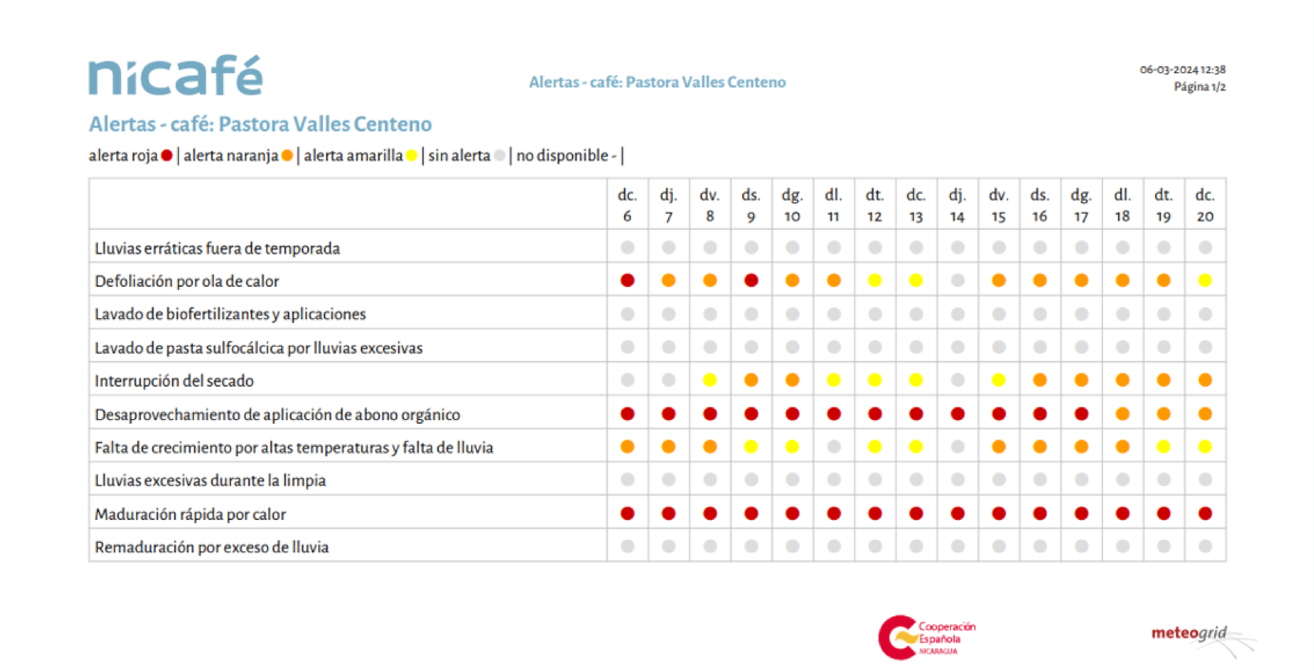
Risk level	Forecast Probability (D+n)	
	Higher risk threshold	Lower risk threshold
Very high	prob. >75%	-
High	50% < prob. <75%	>75%
moderate	25%< prob. <50%	50% < prob. <75%
No alert	prob. <25%	25%< prob. <50%
	-	prob. <25%

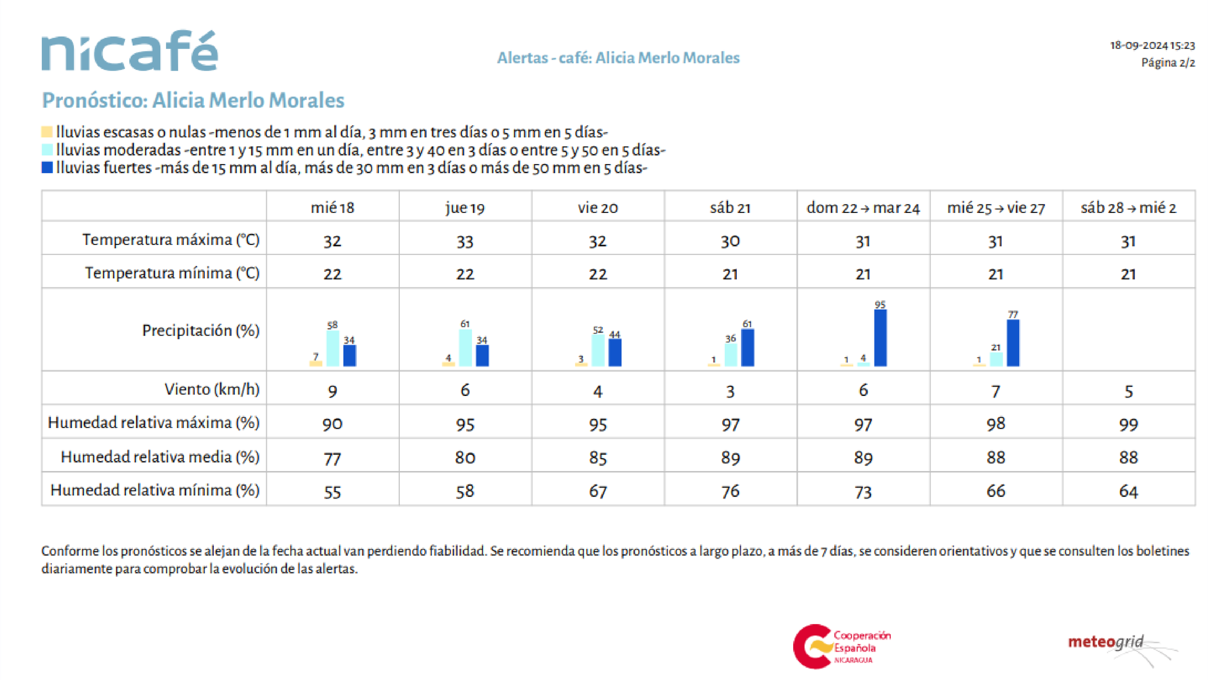
Part 3. Verification process (under developmnent through EU project *URBREATH*):

The system delivers tailored forecasts based on each user's coordinates, but reliability challenges persist with localized meteorological predictions due to limited resources for scientific validation and sparse meteorological station networks in these regions. To address this, new cooperation projects[1] are funding easy-to-use manual weather stations, enabling users to upload daily observed data into the platform. Complementing this, the European project **Urbreath**[2] is developing methodologies to reduce biases in daily probabilistic forecasts, focusing on urban resilience but adaptable to other sectors. By employing EMOS (Ensemble Model Output Statistics) and CRPS (Continuous Ranked Probability Score) through the R-package 'scoringRules'[3], Urbreath aims to optimize daily temperature and precipitation predictions. These advancements enhance the accuracy of forecasts, strengthening climate resilience in both urban and agricultural contexts.

Results

End users receive customized agrometeorological forecasts for their crop coordinates, presented as daily risk traffic-light indicators via a mobile app bulletin (*left below image*). These results are tailored not only during the co-design process but also through user interaction with the app, which allows the easy input of the phenological phase to display only the variables relevant to their specific needs. Furthermore, end users actively contribute to improving the bulletin's accuracy by uploading daily observations. This collaborative effort enhances the precision of key meteorological variables, refining the numeric values of forecasts and enabling their application by agricultural technicians (*right below image*).





	mié 18	jue 19	vie 20	sáb 21	dom 22 → mar 24	mié 25 → vie 27	sáb 28 → mié 2
Temperatura máxima (°C)	32	33	32	30	31	31	31
Temperatura mínima (°C)	22	22	22	21	21	21	21
Precipitación (%)	7 58 34	4 61 34	3 52 44	1 36 61	1 4 95	1 21 77	
Viento (km/h)	9	6	4	3	6	7	5
Humedad relativa máxima (%)	90	95	95	97	97	98	99
Humedad relativa media (%)	77	80	85	89	89	88	88
Humedad relativa mínima (%)	55	58	67	76	73	66	64

Conforme los pronósticos se alejan de la fecha actual van perdiendo fiabilidad. Se recomienda que los pronósticos a largo plazo, a más de 7 días, se consideren orientativos y que se consulten los boletines diariamente para comprobar la evolución de las alertas.

Conclusions

Main developments:

- **Tailor-made EWS solutions for climate change adaptation** to mitigate extreme weather impacts
- **Participatory co-design ensures high user acceptance**: Collaborative design improves usability and adoption among end users.
- **Customizable and targeted predictions**: EWS provide localized forecasts with risk levels via traffic-light indicators.
- **Replicability across disciplines**: EWS methods developed are adaptable to any field affected by meteorological risks.
- **Innovation through Urbreath**: Urbreath will reduce biases in probabilistic forecasts with advanced statistical methods including AI.
- **Enhancing local data accuracy**: User-uploaded observations are key to apply AI improvements for prediction precision and address data gaps.

Acknowledgements

I would like to thank all my colleagues involved at FICLIMA and Meteogrid for their collaboration in moving forward in the development of a tool that optimises forecasting results. This application has real potential in strengthening food security for very vulnerable groups in vulnerable countries and to enhance the optimization of Nature-Based Solutions (NBS) to ensure the livability of EU cities in the future, aligning with the goals of the URBREATH project (101139711).

REFERENCES

1.- "SIG para apoyar a la adaptación al cambio climático de pequeñas caficultoras al Norte de Nicaragua" funded by AECID 2021/ACDE/000399
2.- URBREATH (Project: 101139711 — URBREATH — HORIZON-MISS-2023-CLIMA-CITIES-01). (2024) https://urbreath.eu/
3.- scoringRules package , A. Jordan et al (2024)