Workshop paper at "Tackling Climate Change with Machine Learning", ICLR 2025

DROUGHT FORECASTING USING A HYBRID NEURAL ARCHITECTURE FOR INTEGRATING TIME SERIES AND STATIC DATA

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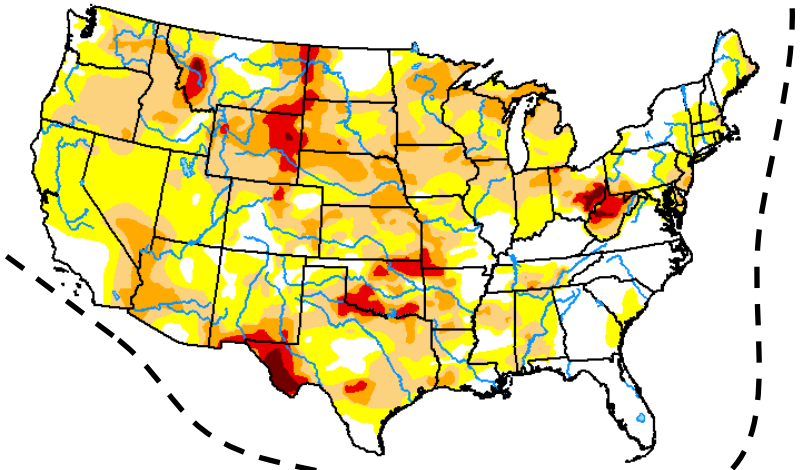
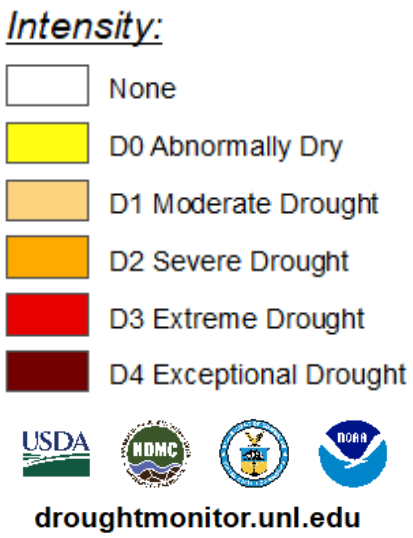
[1] [2]

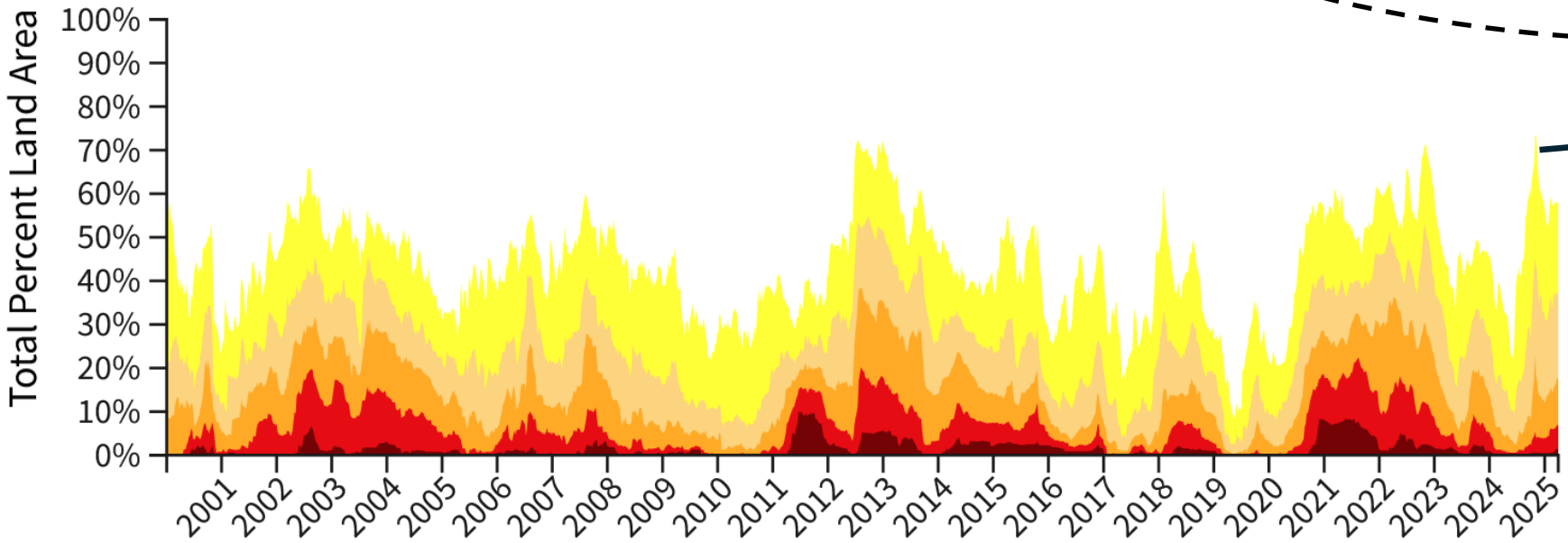
1. INTRODUCTION

Drought is a natural phenomenon characterized by a prolonged period of below-average precipitation

By October 15, 2024, 77 % of the continental US was experiencing drought conditions







1. INTRODUCTION

- Most previous deep learning approaches target **homogeneous regions** and/or use **single-modality data**

- **DroughtED [1]:** public large-scale dataset containing **static data, time series and an expert-informed metric**

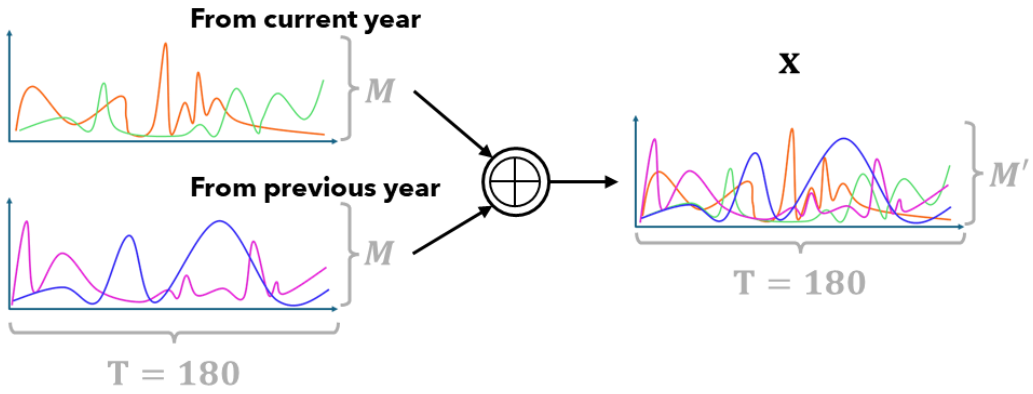
[1] Christoph D Minixhofer, Mark Swan, Calum McMeekin, and Pavlos Andreadis. Droughted: A dataset and methodology for drought forecasting spanning multiple climate zones. In ICML 2021 Workshop on Tackling Climate Change with Machine Learning, 2021.

2. THE DATASET: DroughtED [1]

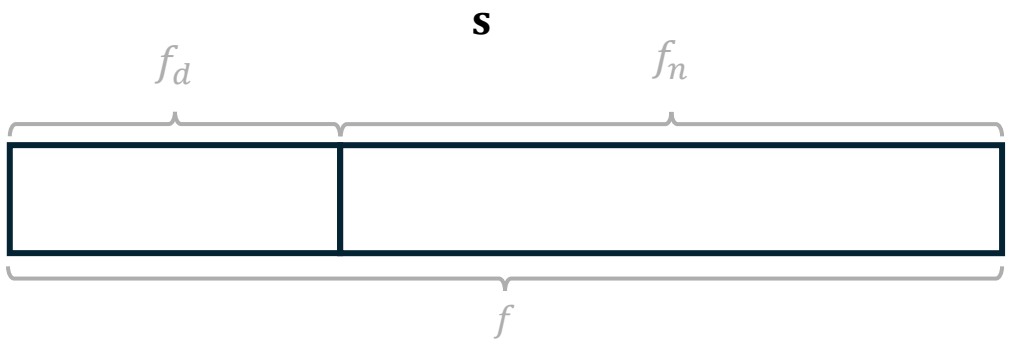
Each observation is described by the tuple (county c, timestamp t) :
So, for each (c, t): $\{\mathbf{x}, \mathbf{s}\} \rightarrow \mathbf{y}$

Inputs

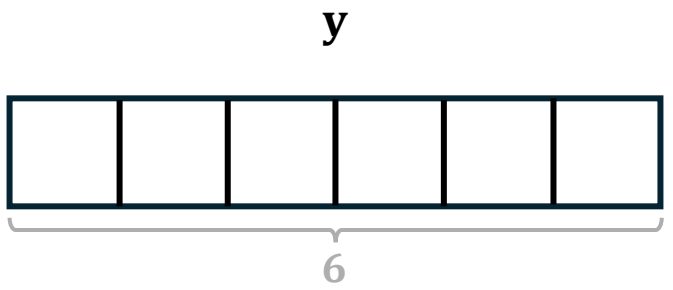
Meteorological Time series



Static soil features



Target



USDM drought categories for the 6 weeks following t in county c

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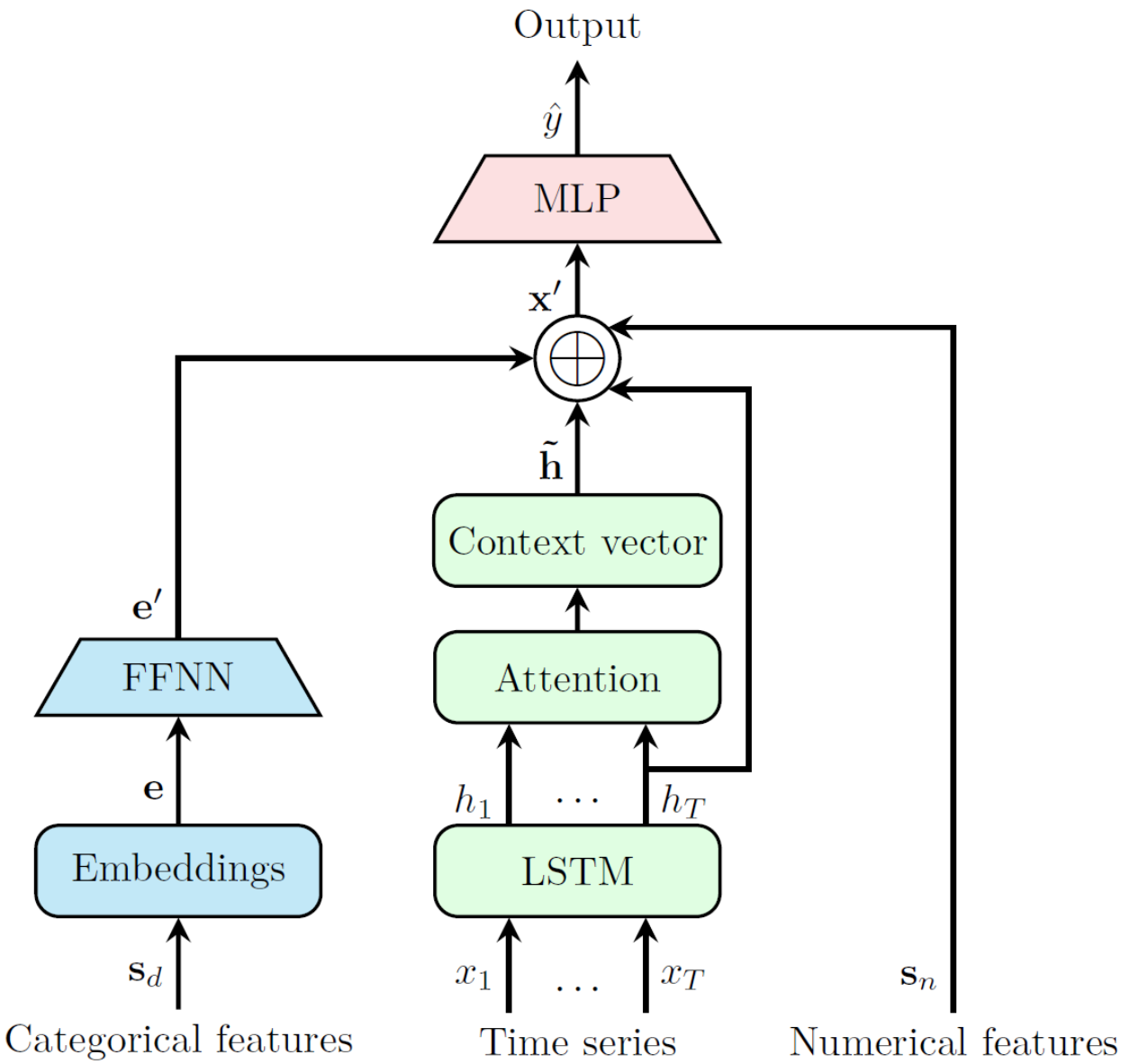
3. THE PROPOSED MODEL



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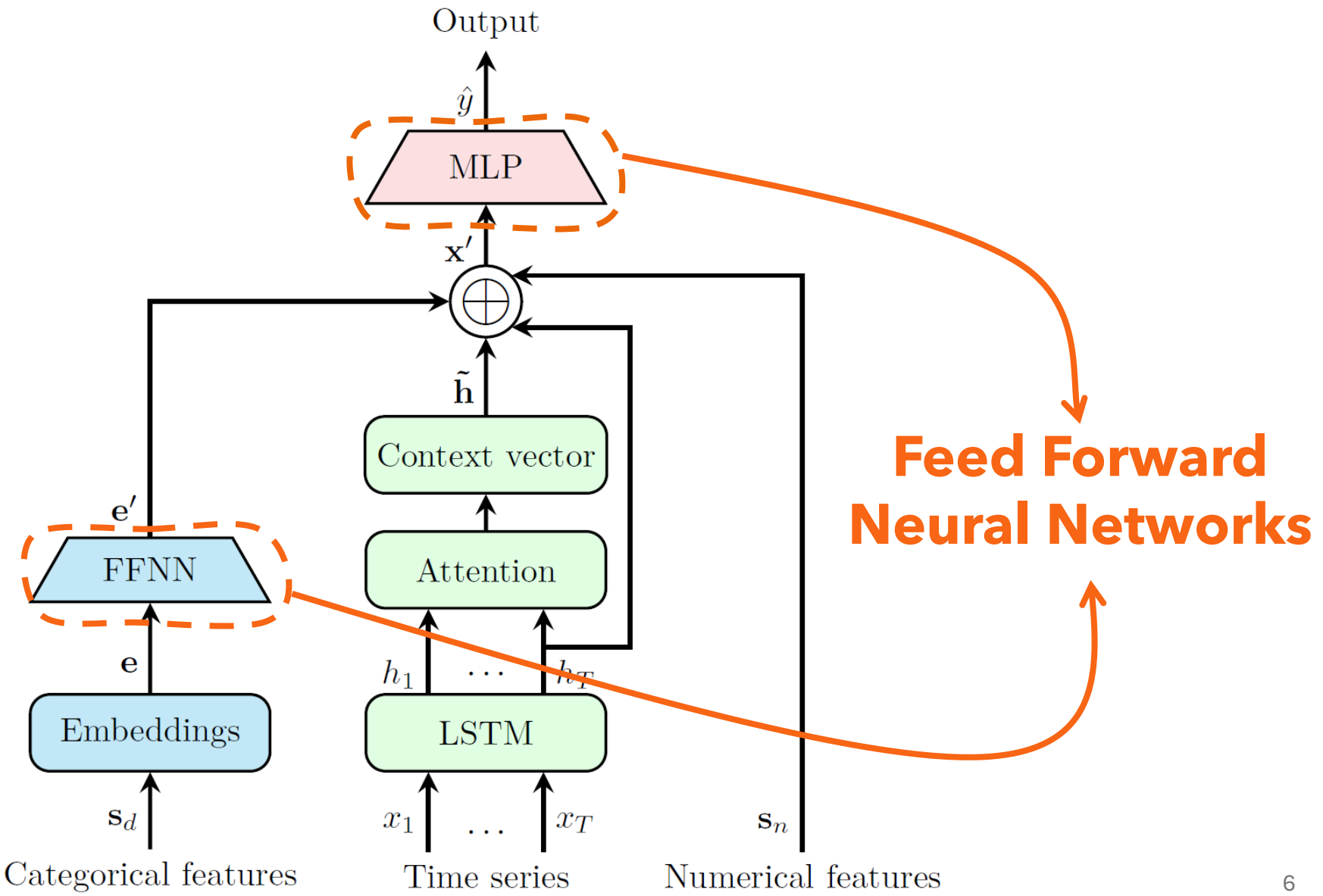

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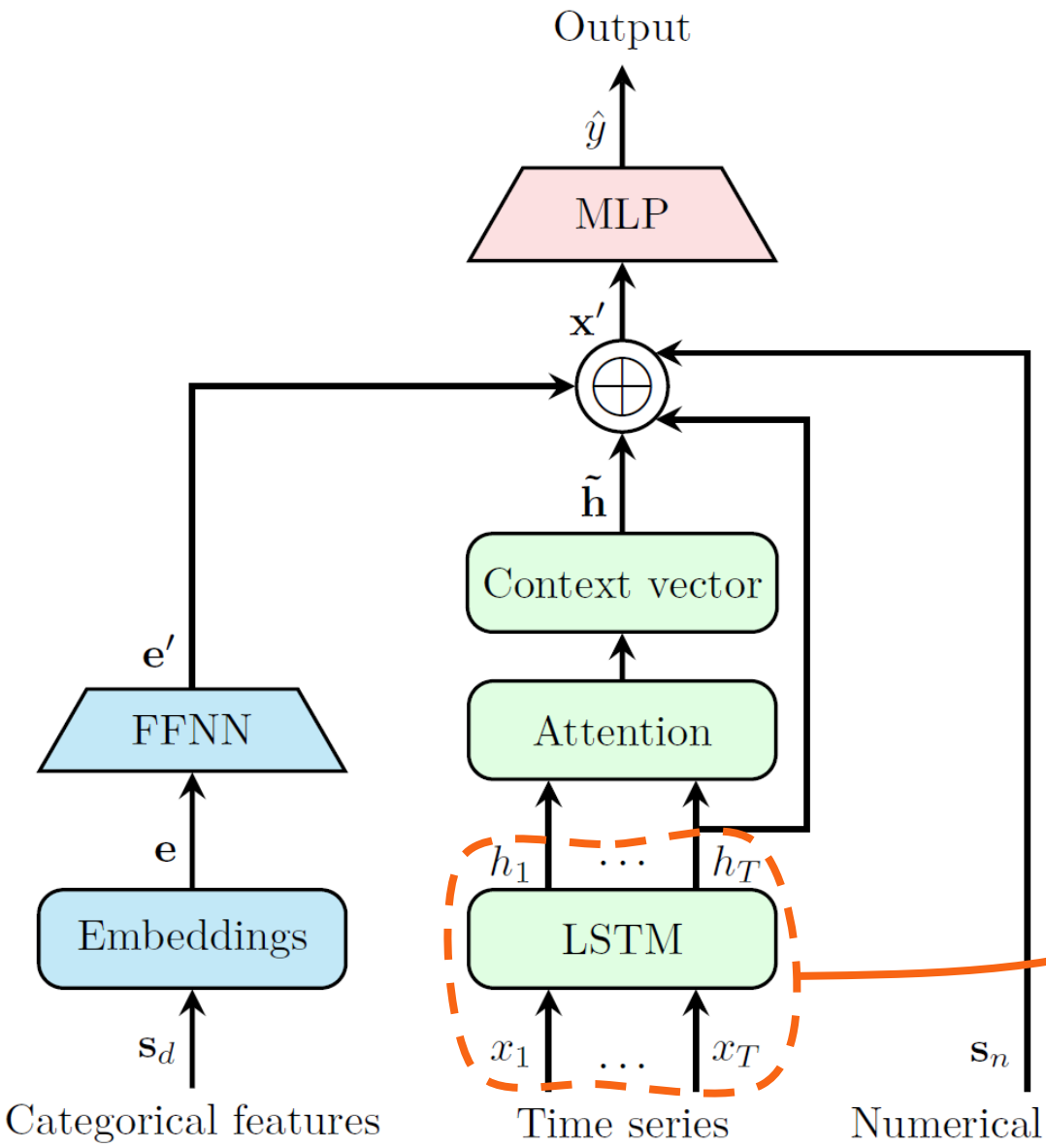
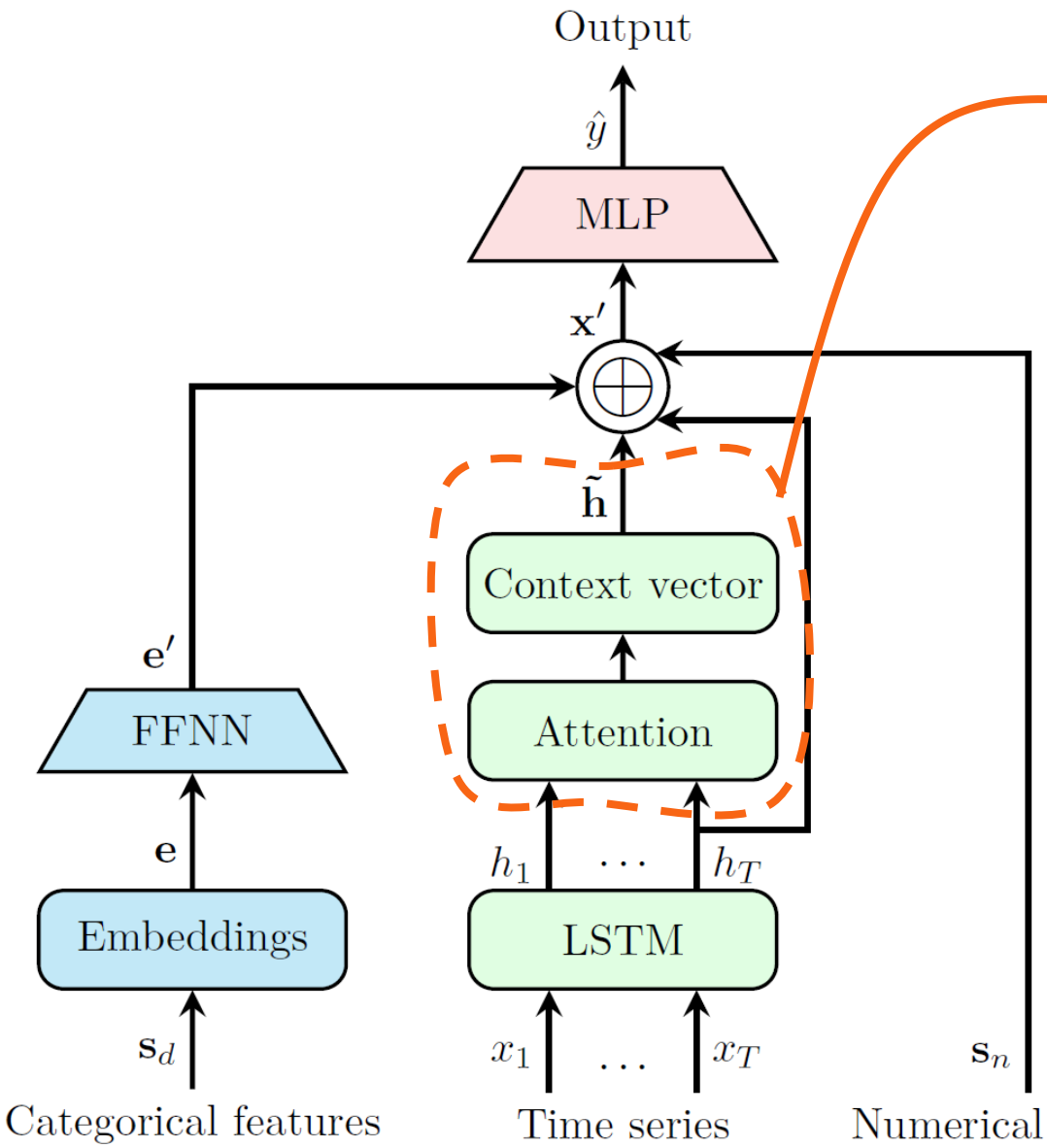


Long short-term memory

Recurrent Neural Network

3. THE PROPOSED MODEL



"Badahun like"

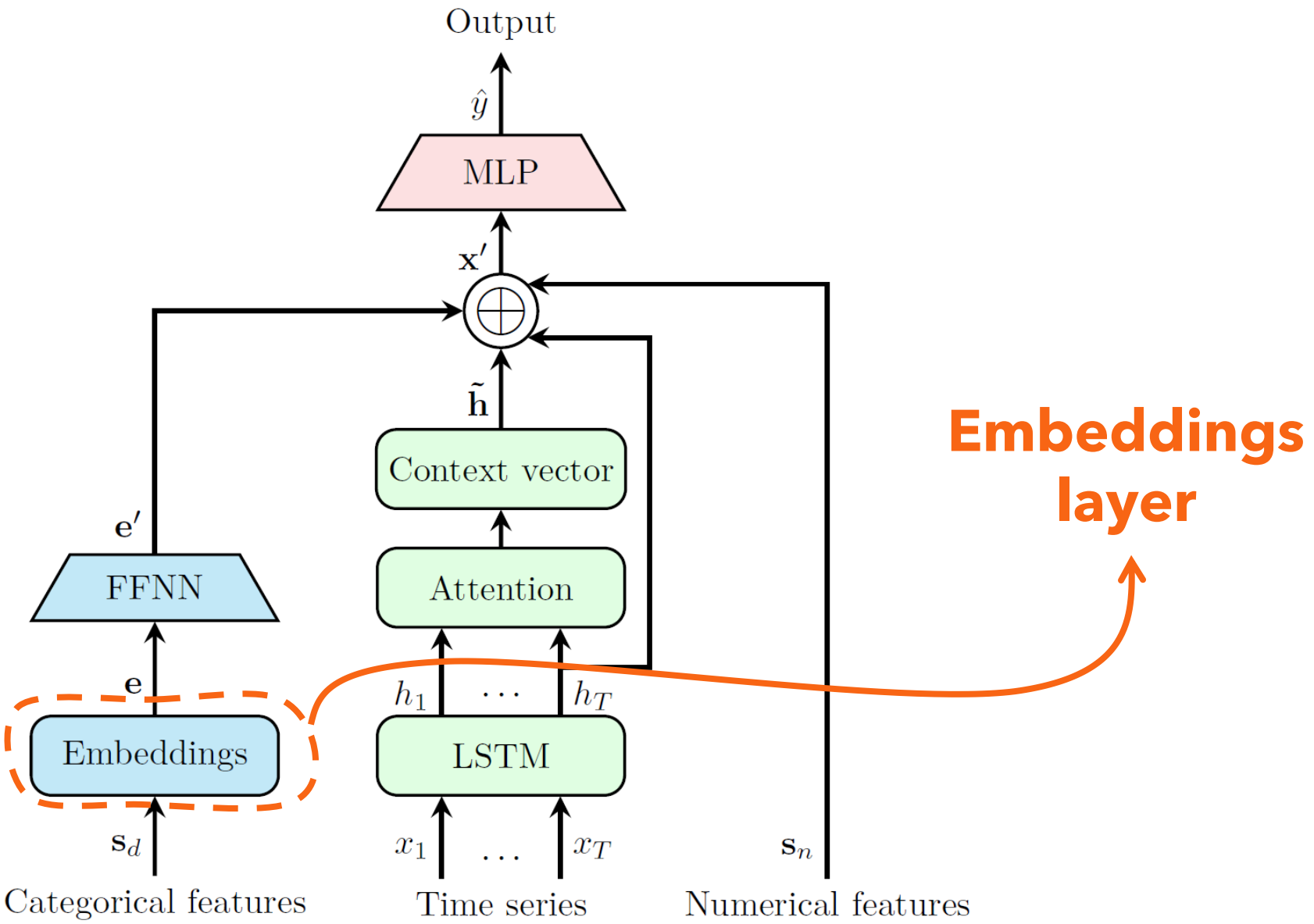
Attention mechanism

$$s_t = Wh_t + b$$

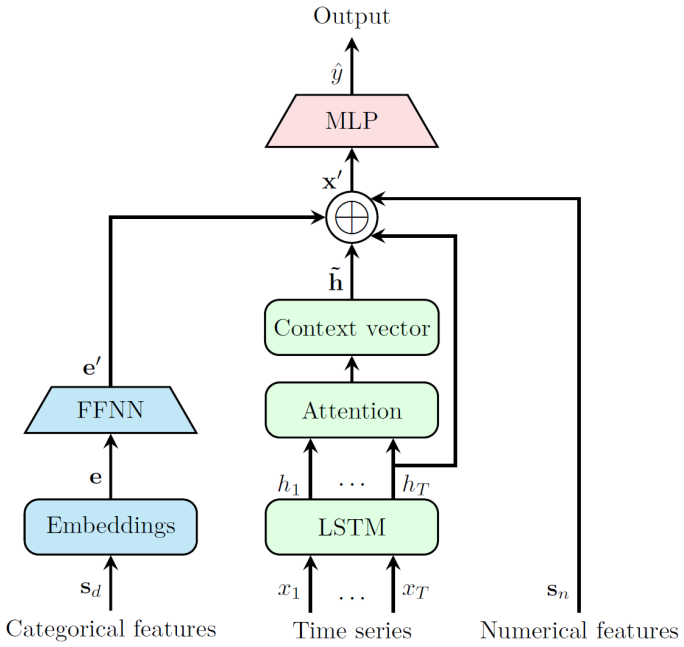
$$\alpha_t = softmax(s_t) = \frac{e^{s_t}}{\sum_{i=1}^{T} e^{s_t}}$$

$$\tilde{\boldsymbol{h}} = \sum_{t=1}^{T} \alpha_t h_t$$

3. THE PROPOSED MODEL



4. MAIN EXPERIMENTS



1. Predictive performance and generalization

- Hyperparameter optimization and direct comparison over the test set.
- 5-fold cross-validation and paired t-test.

2. Ablation study

3. Model introspection

- t-SNE.
- Attention curves.

5. RESULTS

VS Minixhofer et. al [1] best baseline model

1. Predictive performance and generalization

- MAE ⬇30% | 28%$(p = 0.03)$
- F1 ⬆9% | 8%$(p = 0.02)$
- Multi-class weighted ROC-AUC ⬆7% | 6%$(p = 0.03)$

2. Ablation study

Ablation settings					
Static features	Time series	Attention mech.	MAE	RMSE	F1
✓	✓	✓	**0.217**	**0.377**	**66.3**
	✓	✓	0.267	0.419	56.2
	✓		0.271	0.420	56.6
✓	✓		0.280	0.427	57.1
✓			0.755	0.920	21.2

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Most of knowledge sources from time series !

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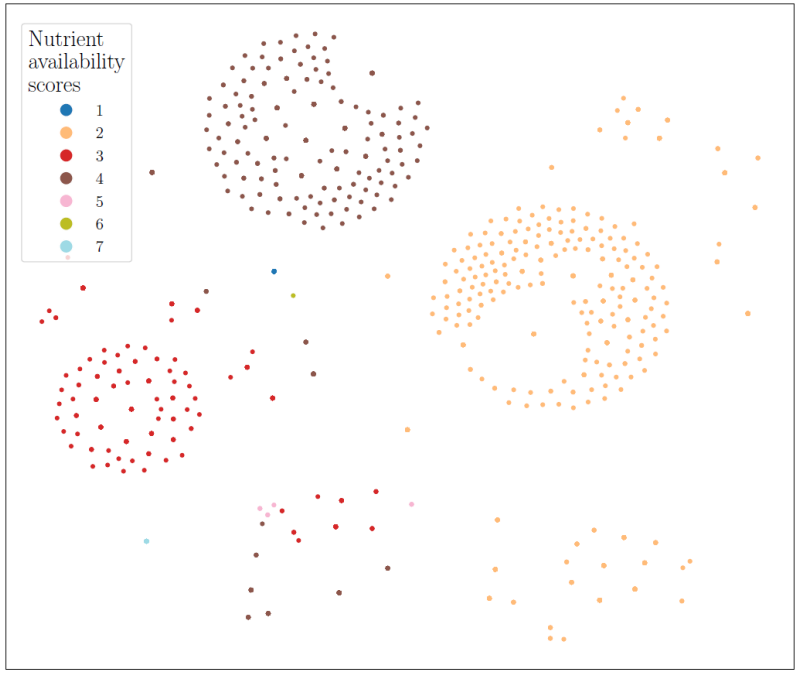
In all setups, attention mechanism improves performance.

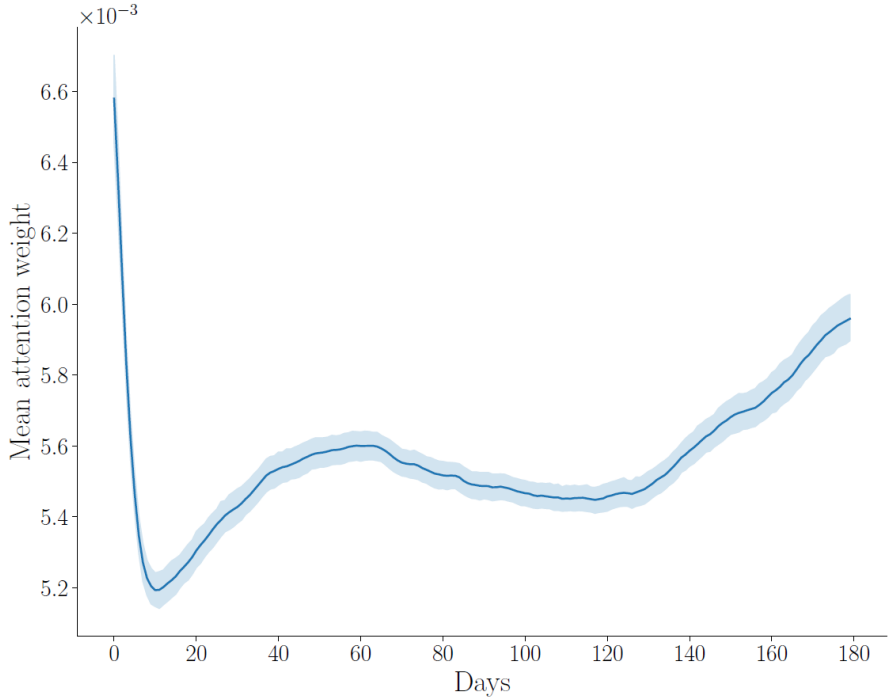
5. RESULTS

3. Model introspection



t-SNE colored by “Nutrient availability”.

As [2] and [3]



Mean attention weights on the test set (95% confidence interval)

[2] Mingzhu He and Feike A. Dijkstra. Drought effect on plant nitrogen and phosphorus: a metaanalysis. New Phytologist, 204(4):924-931, 2014.

[3]Deepesh R. Bista, Scott A. Heckathorn, Dileepa M. Jayawardena, Sasmita Mishra, and Jennifer K. Boldt. Effects of drought on nutrient uptake and the levels of nutrient-uptake proteins in roots of drought-sensitive and -tolerant grasses. Plants, 7(2), 2018.

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