

# An interpretable machine learning approach for mapping urban pluvial flood susceptibility

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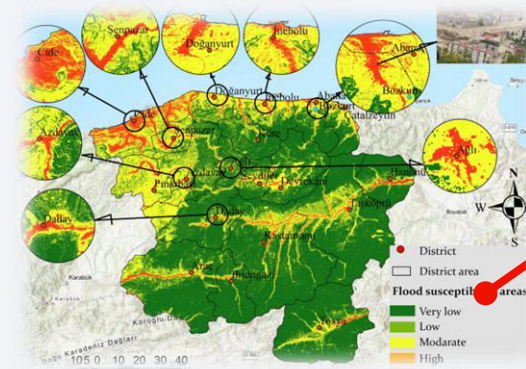
# Content

- **Backgrounds**
- **Methods**
- **Results**
- **Conclusions**

- Pluvial flood is one of the most destructive natural disasters in urban areas

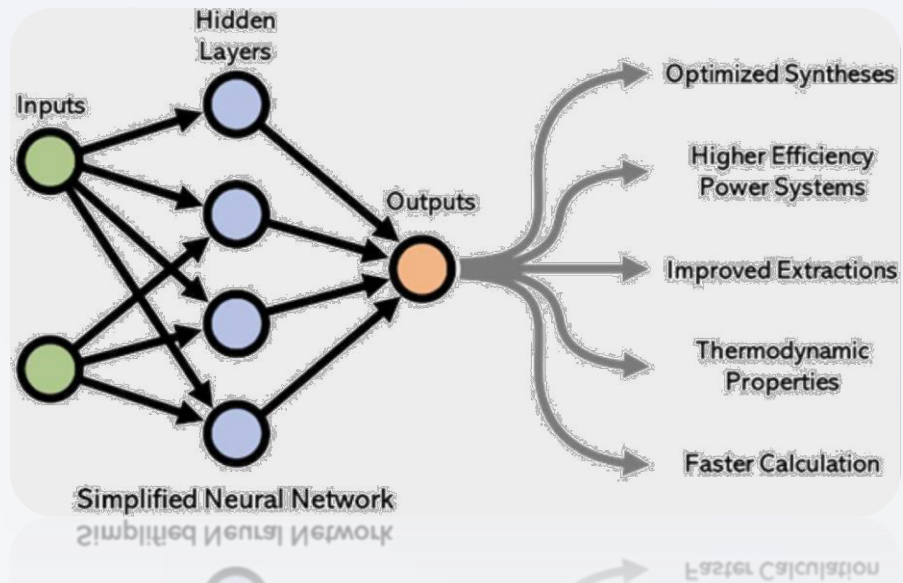


- Credible flood susceptibility map is required for flood preparation and mitigation

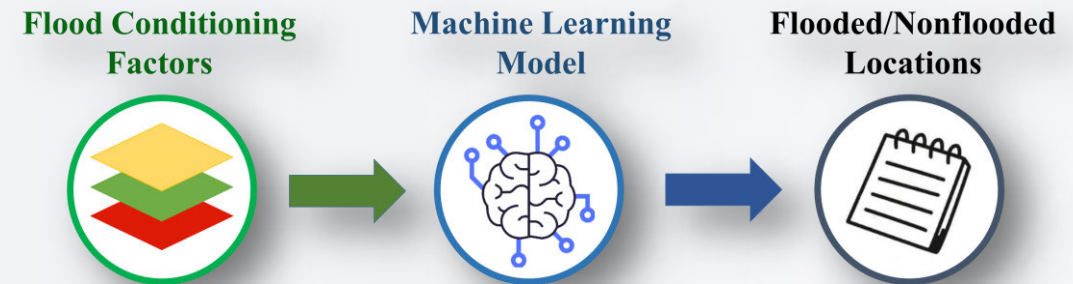


*“Flood susceptibility  
The probability of an area  
being flooded”*

## □ Machine Learning is becoming a conventional tool for flood susceptibility mapping



✓ **High computational efficiency**

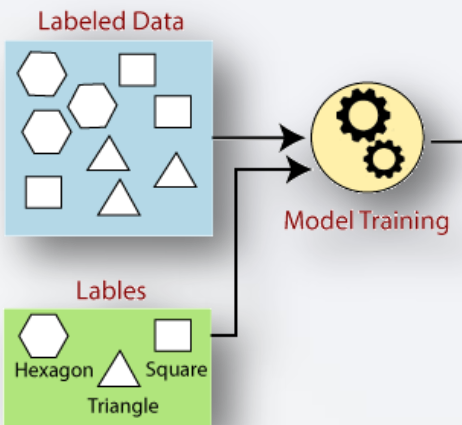


✓ **Efficiently Establish mapping relationships**

## □ Data Scarcity



Limited observations

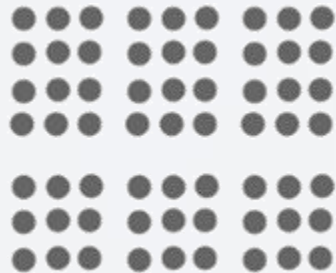


Supervised learning

Small-scale labeled locations

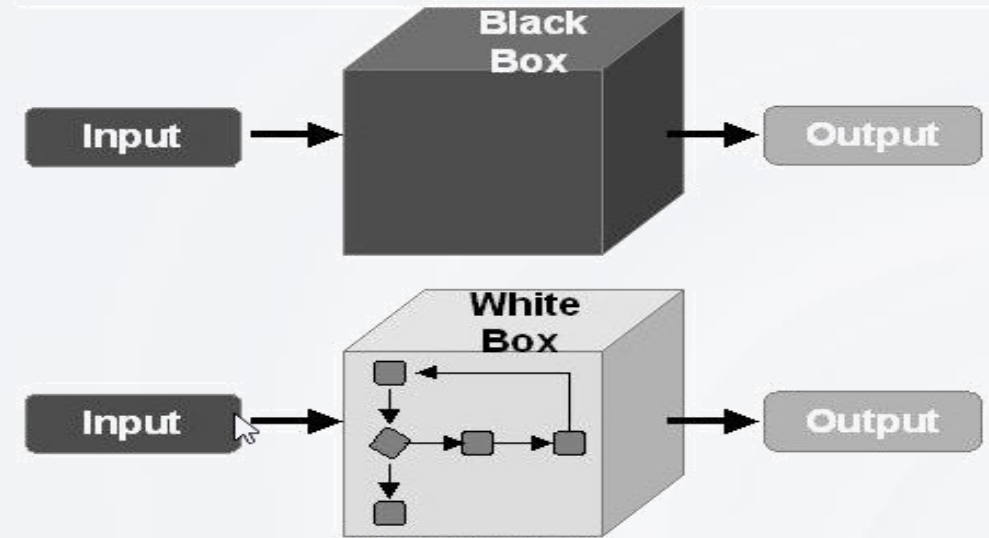


Large-scale unlabeled locations



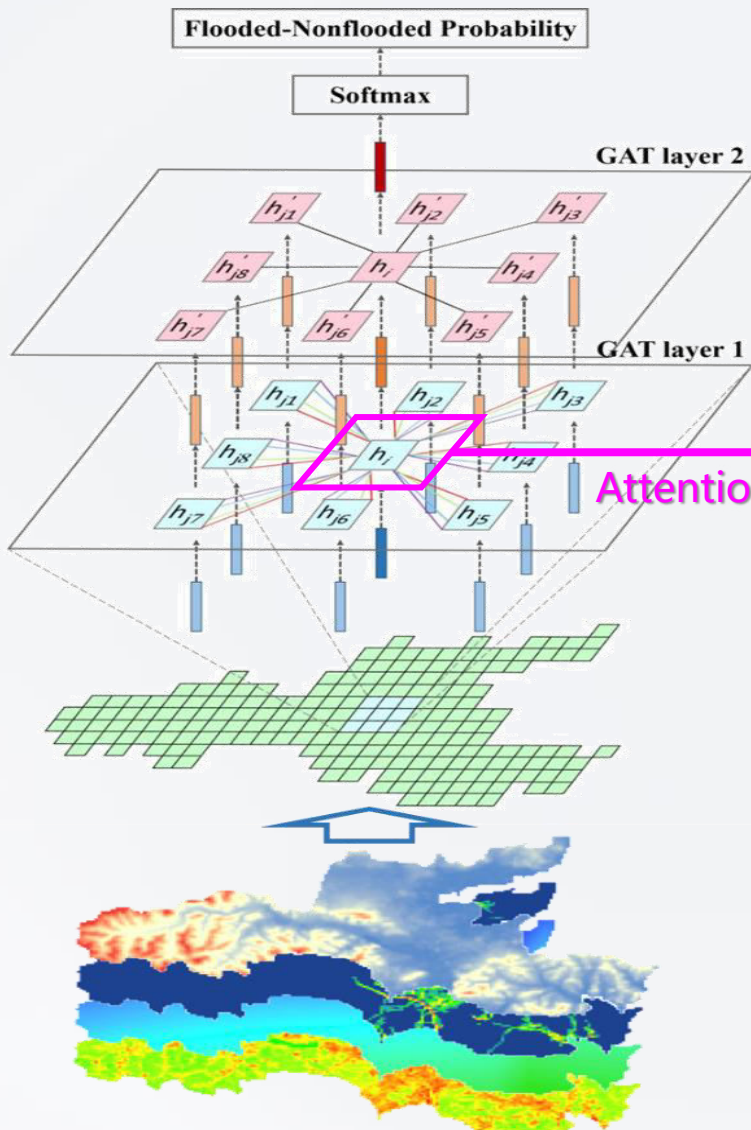
- ✗ Information hidden in unlabeled data
- ✗ Spatial relationships among data

## □ Lack of Interpretability



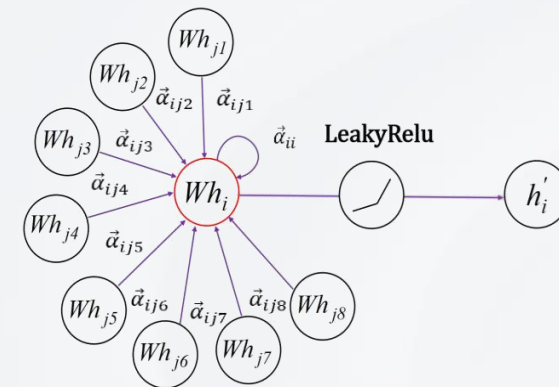
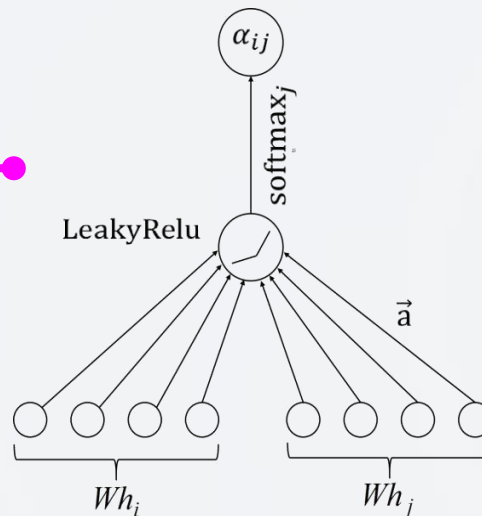
Black Box V.S. White Box

- ✗ Quantification of hydrological responses
- ✗ Understanding of flooding mechanism



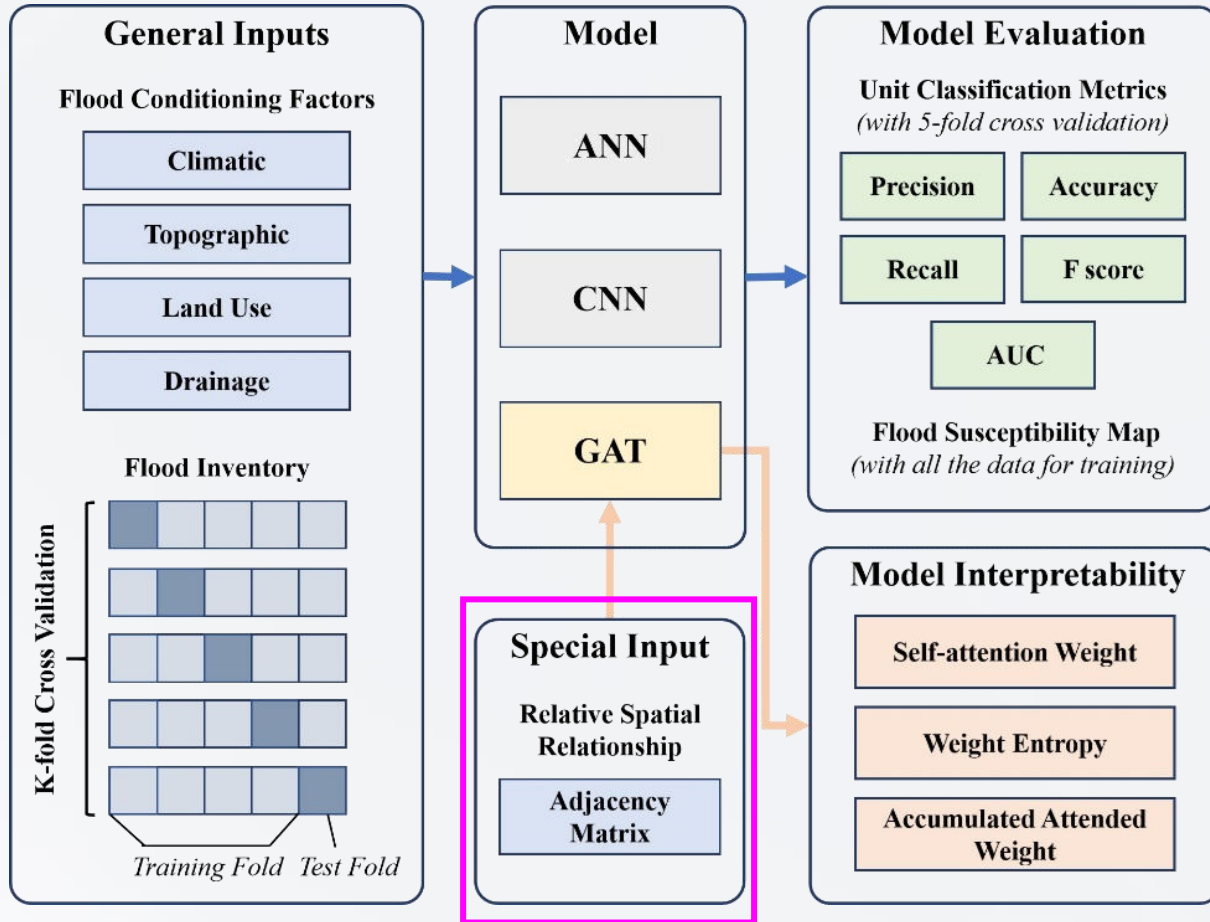
## Graph Attention Network (GAT)

- ❑ **Semi-supervised model** handles labeled and unlabeled samples
- ❑ **Graph neural networks** process unstructured data and extract spatial features

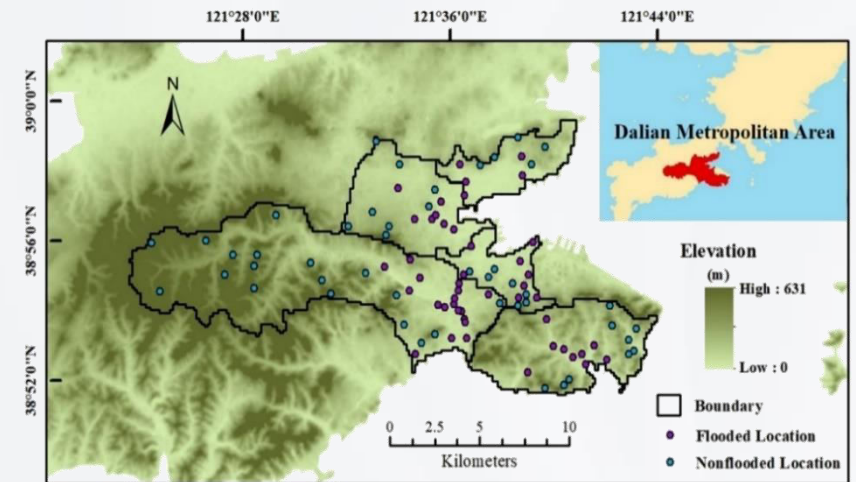
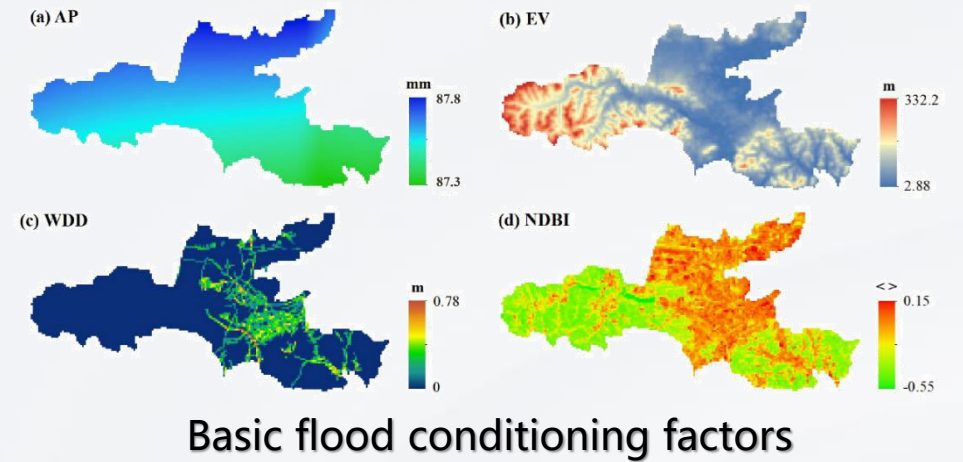


- ✓ Overcome **data scarcity** challenge through a **waterflow-like information propagation pattern**.
- ✓ Enable **quantification of hydrological responses** among spatial units based on **attention mechanism**

## □ GAT was applied in the metropolitan area of Dalian



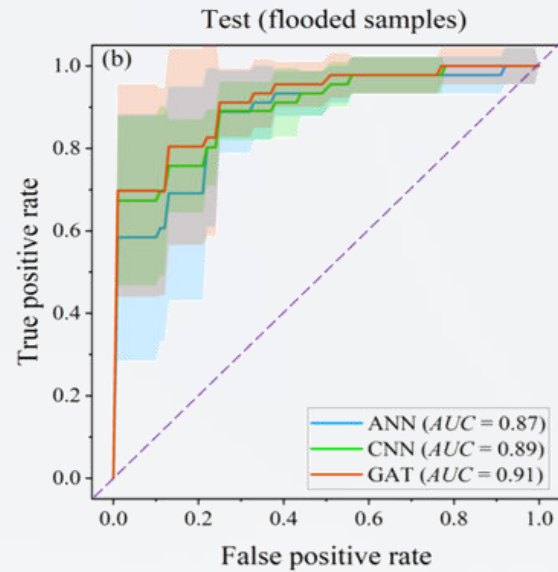
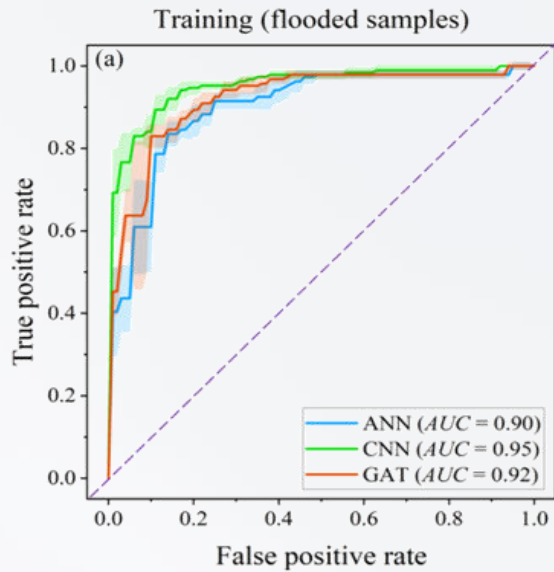
The overview of data flow and workflow for GAT, ANN, and CNN.



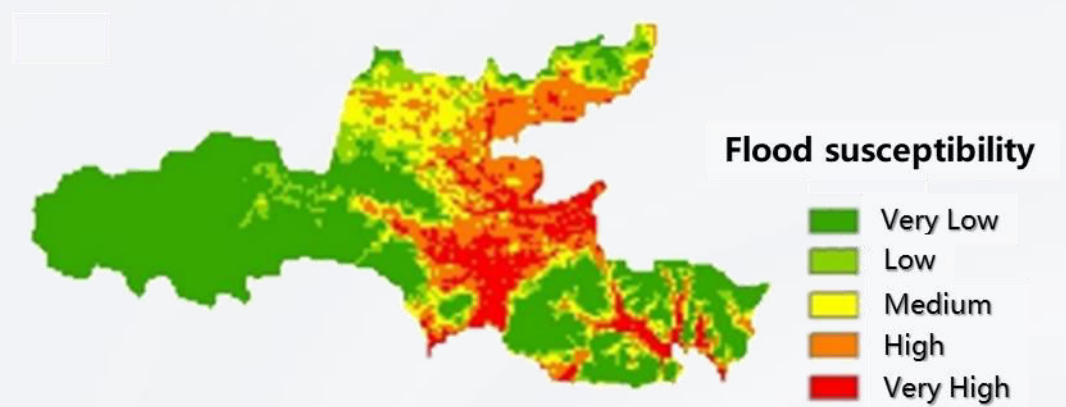
Flood Inventory

## ✓ GAT outperformed in flooded-nonflooded classification

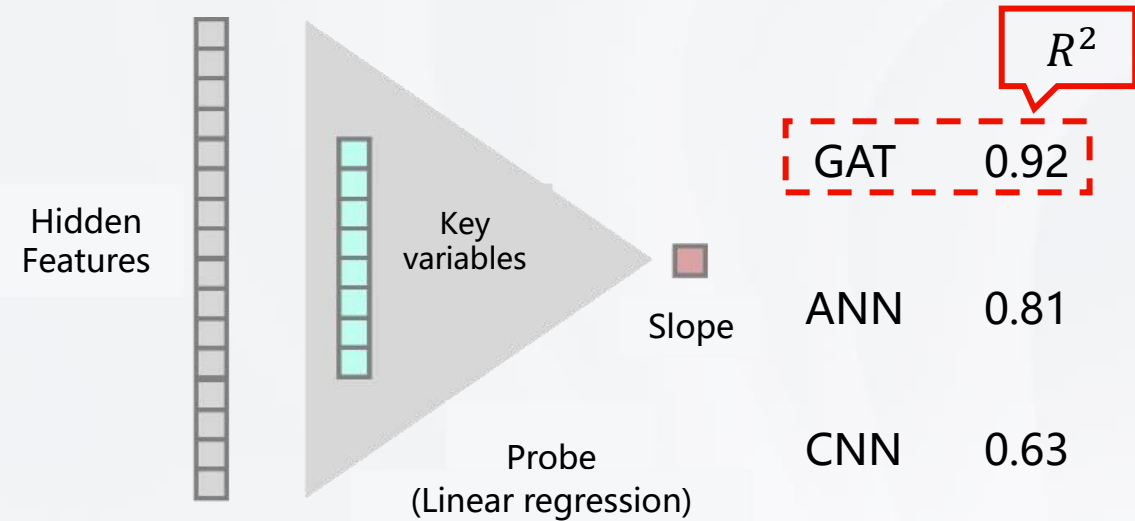
Model	Phase	Accuracy	Precision	Recall	F score
ANN	Training	0.84 (0.02)	0.85 (0.02)	0.84 (0.02)	0.84 (0.02)
	Test	0.82 (0.07)	0.86 (0.12)	0.81 (0.08)	0.83 (0.06)
CNN	Training	0.89 (0.02)	0.86 (0.03)	0.93 (0.04)	0.90 (0.02)
	Test	0.84 (0.06)	0.84 (0.07)	0.87 (0.05)	0.85 (0.06)
GAT	Training	0.85 (0.02)	0.85 (0.02)	0.85 (0.01)	0.85 (0.01)
	Test	<b>0.85 (0.05)</b>	<b>0.87 (0.09)</b>	<b>0.87 (0.04)</b>	<b>0.87 (0.04)</b>



## ✓ GAT provided rational flood susceptibility map



## ✓ GAT can extract informative high-order features

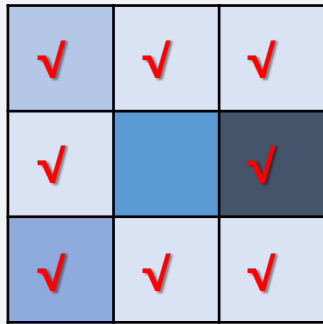




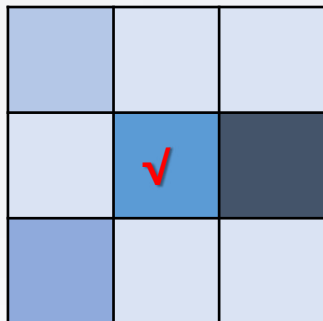
## □ Attention-based interpretability indicators

### Self-attention weight

the degree to which the local flood is attributed to surroundings or the site itself.

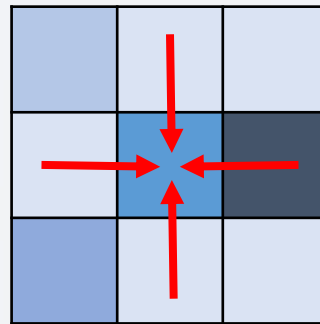


or

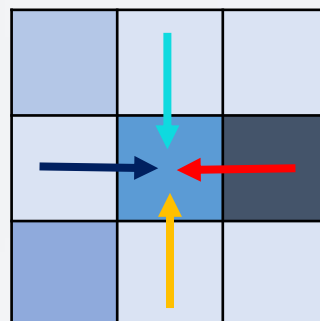


### Weight entropy

Whether the neighboring units uniformly affect the flood in a unit.

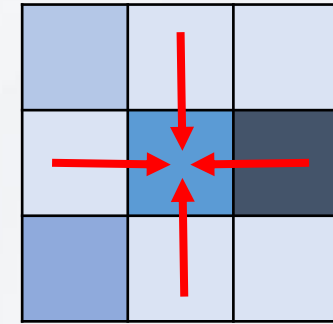


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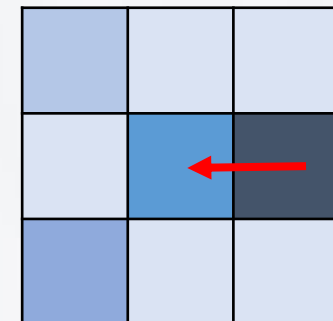


### Accumulated attended weight

The level of attention that a unit receives from others.

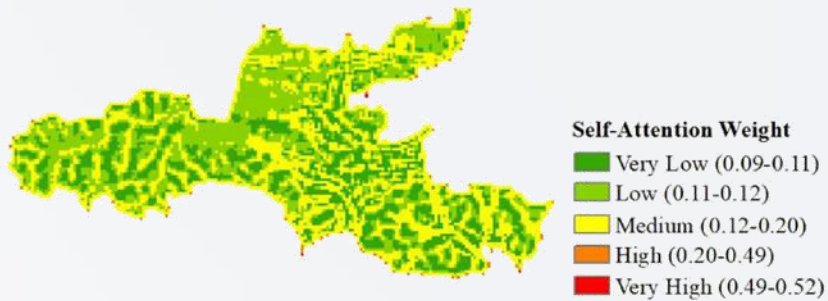


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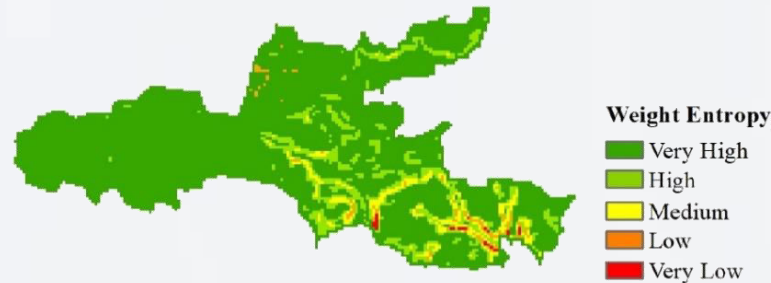
## □ Implications for flood interpretation and management

➤ High flood susceptibility is related more to the environment of the surroundings than to that of the sites themselves.



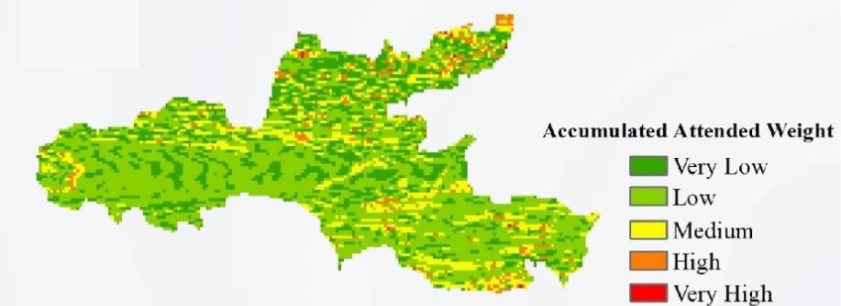
**Systematic management**  
"Local -> Regional"

➤ The local flood typically sources from neighbors in multiple directions, while mainly along roads.



**Critical Path**  
"Road with impervious surface"

➤ The key locations are mostly located in the paths from source to sink, and their distributions are decentralized.



**Crucial Node**  
"Decentralized"

- GAT demonstrates the superiority in **classification performance** and **the flood susceptibility distribution**.
- GAT allows for the **interpretability** by quantifying the hydrological responses among different spatial units.
- GAT has moved a step to interpretable machine learning model, and can be an effective tool in **practical urban flood management**

# Thank you!

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Applications of AI in urban hydrology

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