Deep Neural Network Utilizing Remote Sensing Datasets for Flood Hazard Susceptibility Mapping

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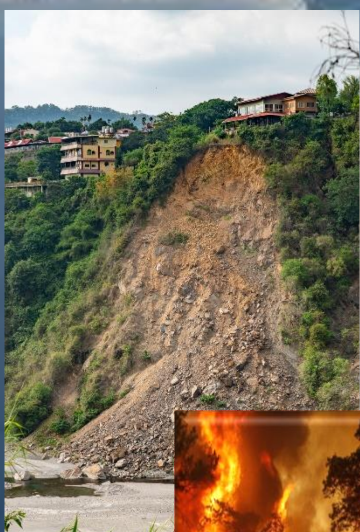


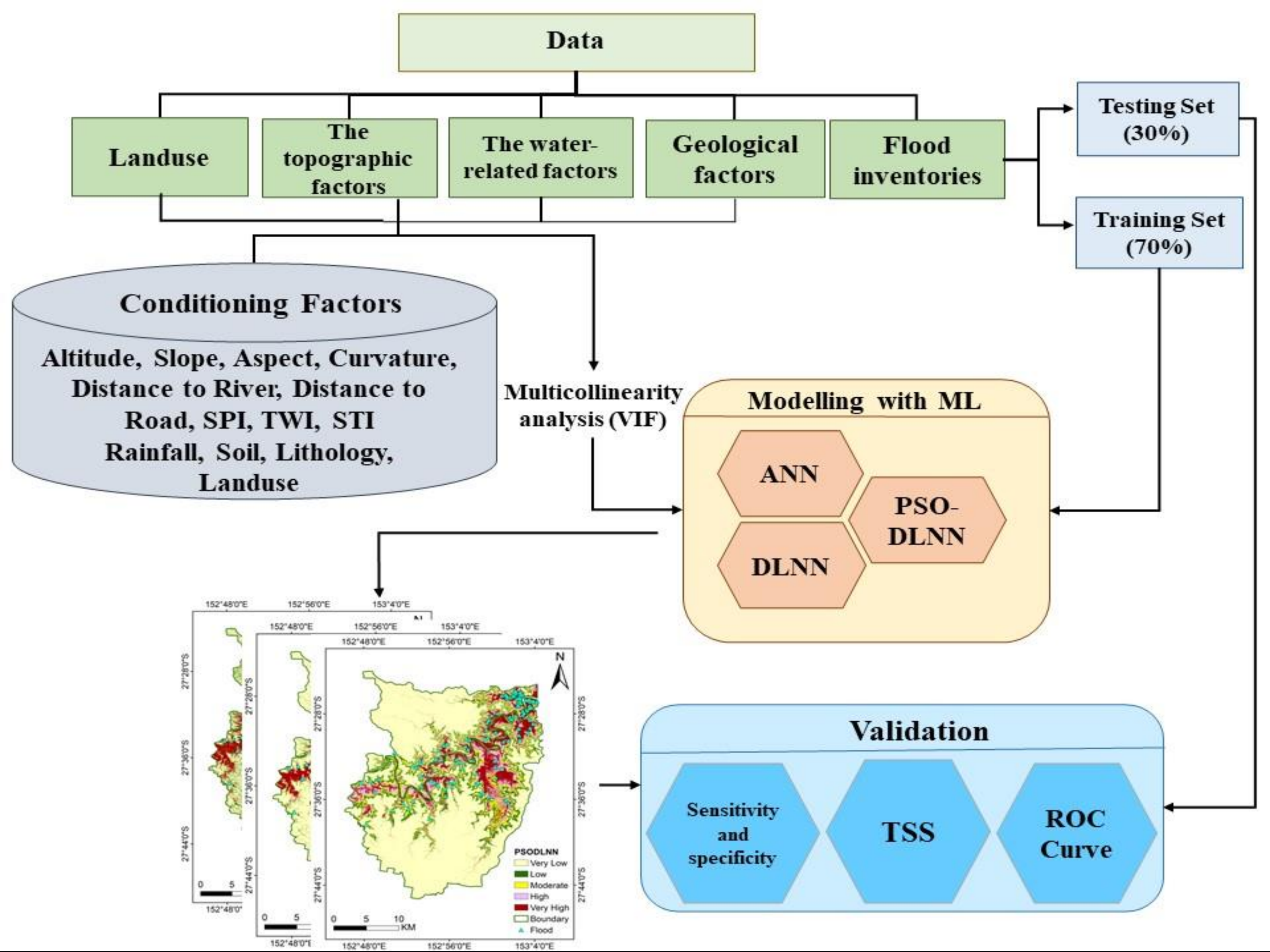
Objectives

To classify the flood susceptible zones using ANN, DLNN, and PSO-DLNN

To assess and compare the accuracy and reliably of the models based on sensitivity, specificity, the area under curve (AUC), and true skill statistic (TSS) tests

To determine the most important factors influencing the flood occurrence, in the subtropical climate region


Altitude: from 0 to 548 m
Average temperature: 20.3 °C
128 historical areas from Brisbane floods
Annual rainfall of 1168 mm
Humid subtropical climate
Brisbane


Data
Landuse
The topographic factors
The water-related factors
Geological factors
Flood inventories
Testing Set (30%)
Training Set (70%)
Conditioning Factors
Altitude, Slope, Aspect, Curvature, Distance to River, Distance to Road, SPI, TWI, STI Rainfall, Soil, Lithology, Landuse
Multicollinearity analysis (VIF)
Modelling with ML
ANN
PSO-DLNN
DLNN
Validation
Sensitivity and specificity
TSS
ROC Curve
PSODLNN
Very Low
Low
Moderate
High
Very High
Boundary
Flood
KM

Methodology

Multicollinearity Analysis

Variables	VIF	Tolerance
Altitude	4.52	0.22
Slope	4.1	0.24
Aspect	1.03	0.97
Curvature	1.31	0.76
Distance from river	2.39	0.42
Distance from road	2.13	0.47
Rainfall	2.07	0.48
Land use	1.59	0.63
Lithology	1.38	0.72
Soil	1.99	0.50
SPI	1.15	0.87
TWI	1.69	0.59
STI	4.04	0.25

$$VIF = \frac{1}{1 - R_i^2}$$

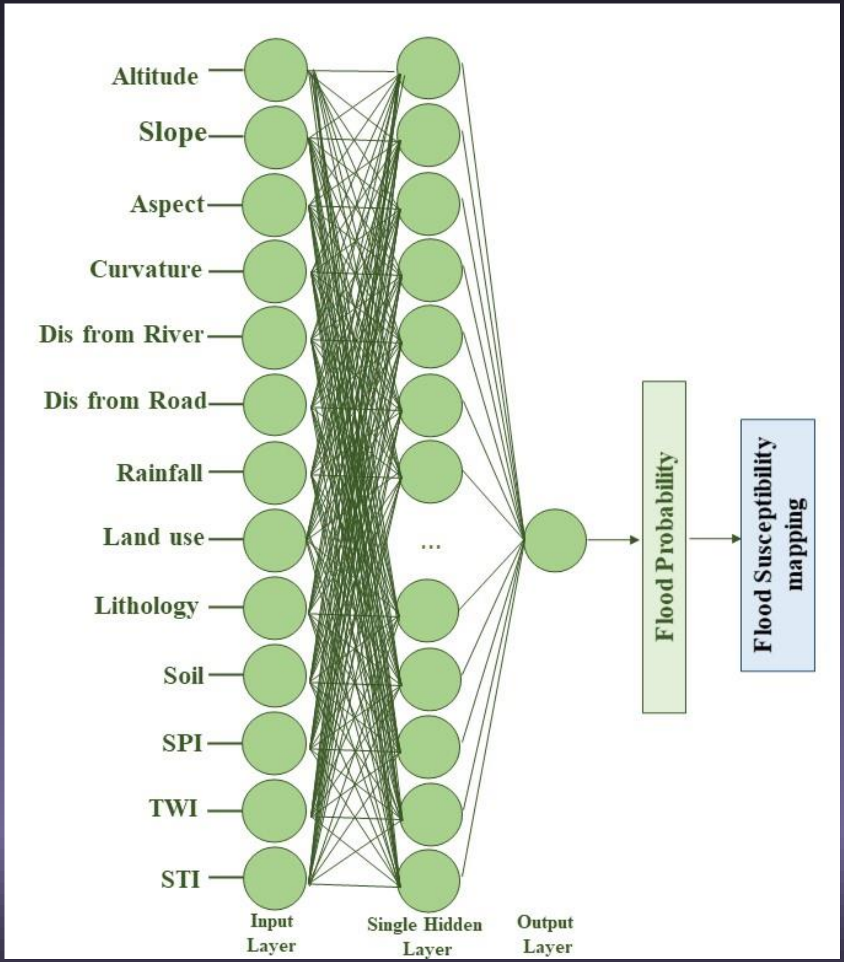
where R_i is the multi correlation coefficient of i^{th} factor on the remaining factors

$$Tolerance = 1 - R_i^2$$

VIF value greater than 5 and the tolerance value less than 0.1

Methodology

Artificial Neural Networks (ANN)

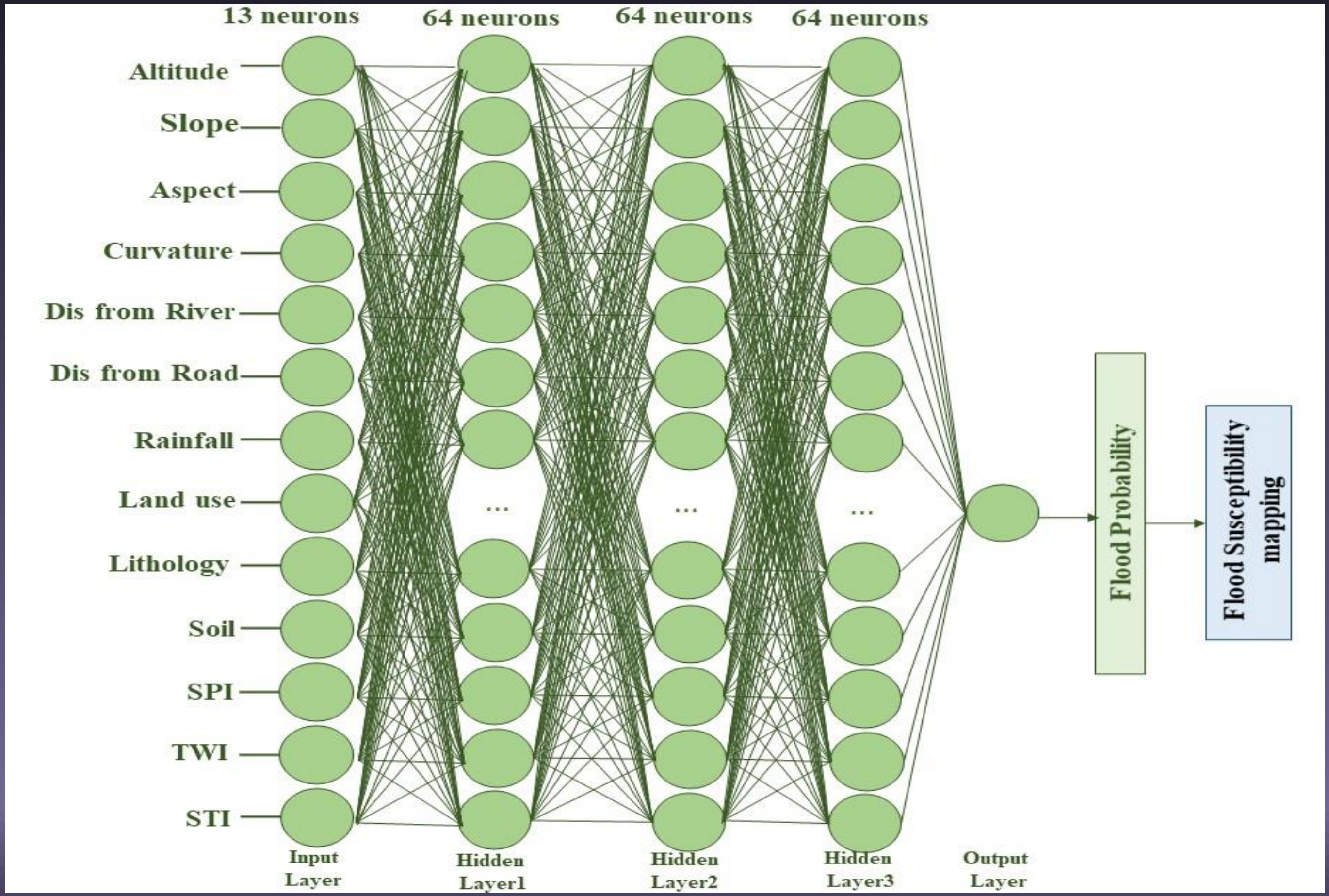


$$Out = f\left(\sum_{j=1}^{n} w_j x_i + \theta_j\right)$$

f is a transfer function
w_j defines the weight vector
x_i is the node flow (causal factors) from the inputs
θ_j represents a threshold value or bias

Methodology

Deep Learning Neural Networks (DLNN)

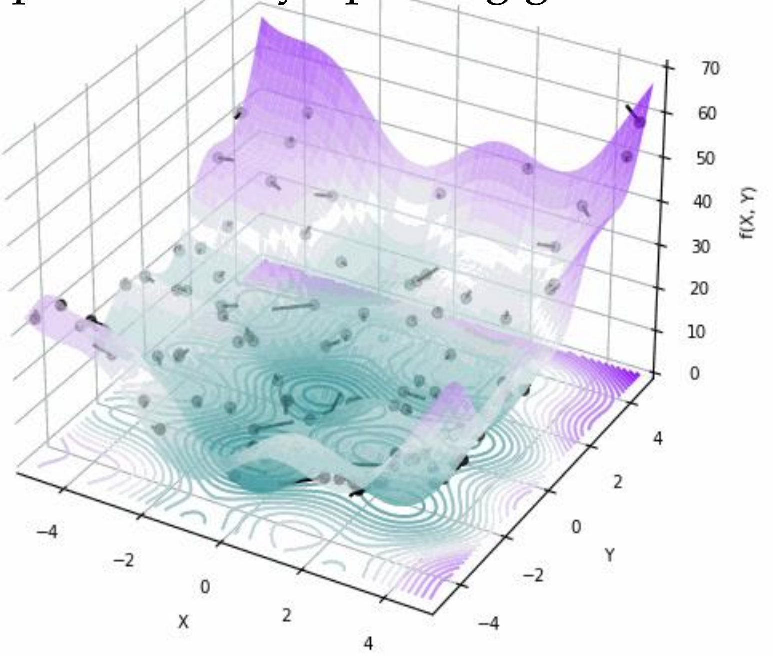


Methodology

Optimized DLNN via particle swarm optimization (PSO)

PSO is a population-based optimization technique.

The system is initialized with a population of random solutions, and the search for the optimal solution is performed by updating generations.



No	Parameter	Model		
		ANN	DLNN	PSO-DLNN
1	Input nodes	13	13	13
2	Output nodes	2	2	2
3	Activation	-	‘relu’	‘relu’
4	Function	-	‘Sigmoid’	‘Sigmoid’
5	reluLeak	-	0.01	0.01
6	Eta	-	0.8	0.8
7	Hidden layer unit	1	3	3
8	Iteration	1000	500	500
10	Phi	-	-	4.1
11	phi1	-	-	2.05
12	Phi2	-	-	2.05
13	W	-	-	0.73
14	C1	-	-	1.49
15	C2	-	-	1.49

Methodology

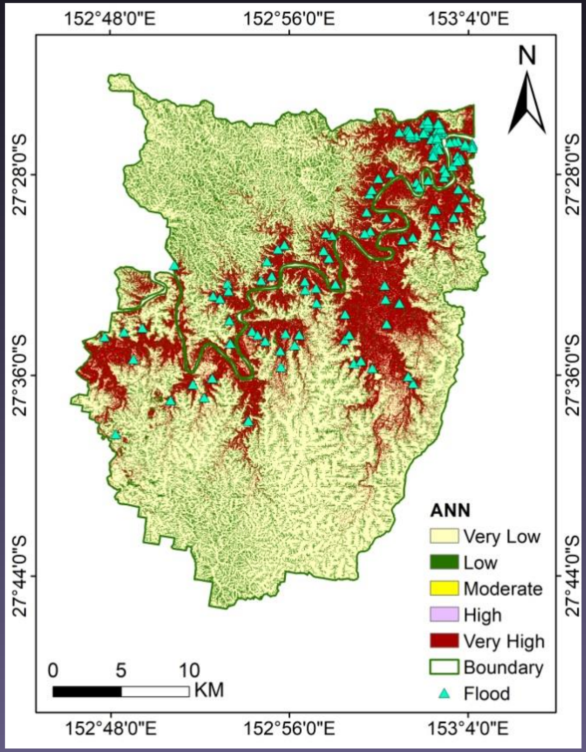
Evaluation methods

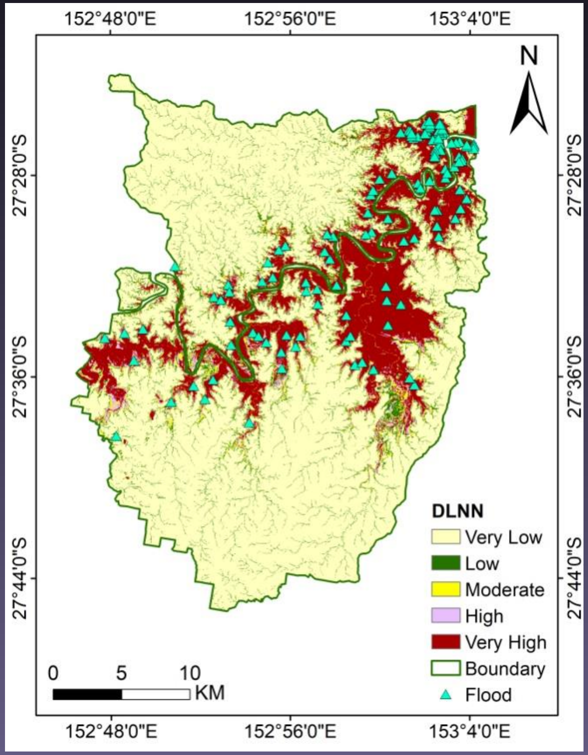
$$\text{Sensitivity} = \frac{\text{TP}}{\text{TP} + \text{FN}} \qquad \text{Specificity} = \frac{\text{TN}}{\text{TN} + \text{FP}}$$

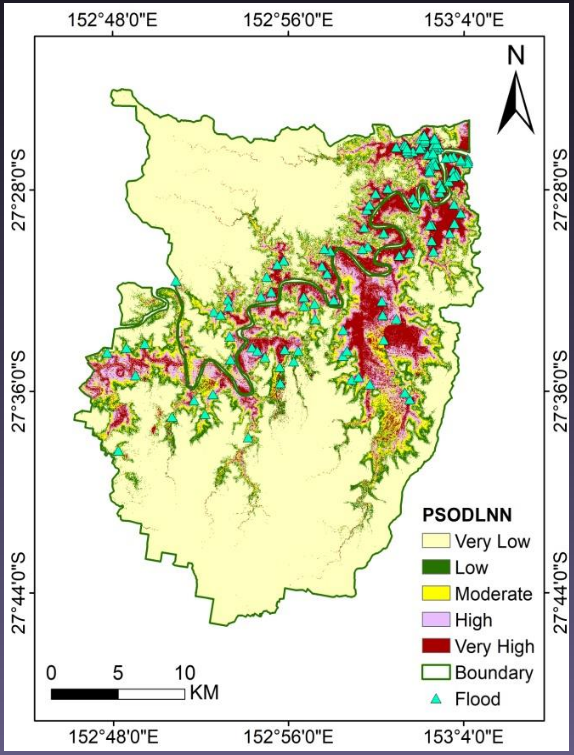
$$\text{TSS} = \text{Sensitivity} + \text{Specificity} - 1$$

TP = true positive
TN=true negative
FN= false negative
FP = false positive

Results


152°48'0"E
152°56'0"E
153°4'0"E
27°28'0"S
27°36'0"S
27°44'0"S
N
ANN
Very Low
Low
Moderate
High
Very High
Boundary
Flood
0 5 10
KM


152°48'0"E
152°56'0"E
153°4'0"E
27°28'0"S
27°36'0"S
27°44'0"S
N
DLNN
Very Low
Low
Moderate
High
Very High
Boundary
Flood
0 5 10
KM


152°48'0"E
152°56'0"E
153°4'0"E
27°28'0"S
27°36'0"S
27°44'0"S
N
PSODLNN
Very Low
Low
Moderate
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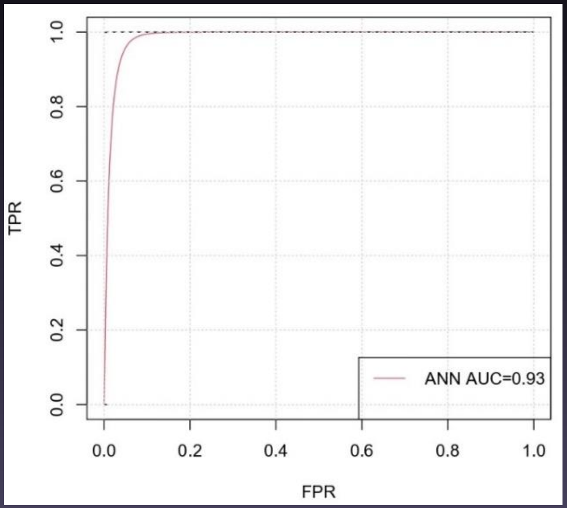
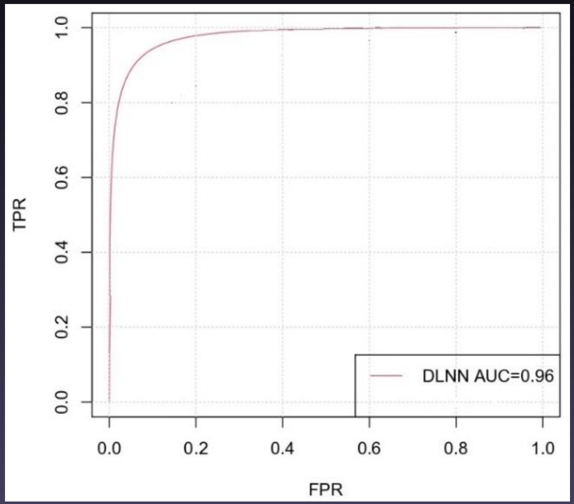
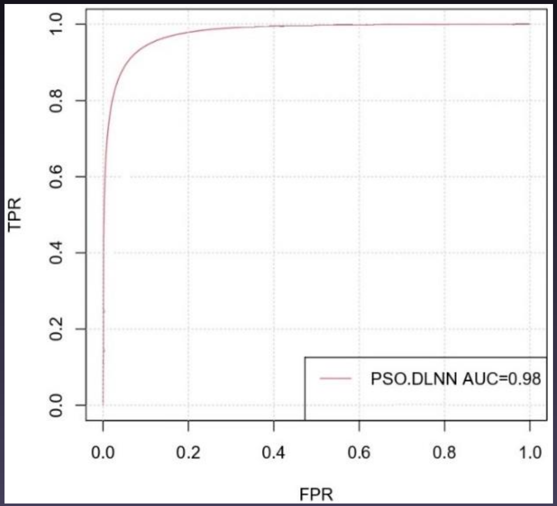
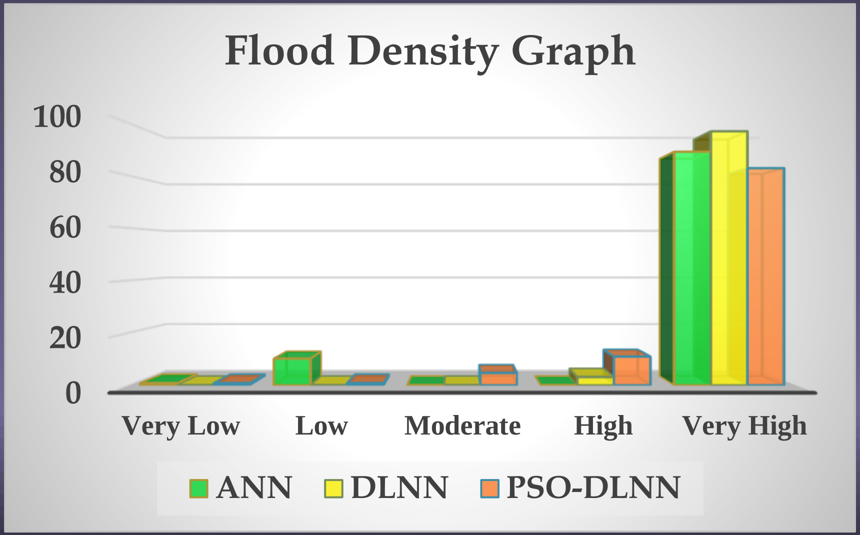
Very High
Boundary
Flood
0 5 10
KM

Results









Models	Stage	Evaluation Tests			
		Sensitivity	Specificity	TSS	AUC
ANN	Train	0.98	0.96	0.94	0.98
	Validation	0.94	0.85	0.79	0.93
DLNN	Train	0.99	0.87	0.86	0.98
	Validation	0.86	0.85	0.71	0.96
PSO-DLNN	Train	0.99	0.89	0.88	0.99
	Validation	0.92	0.98	0.90	0.98

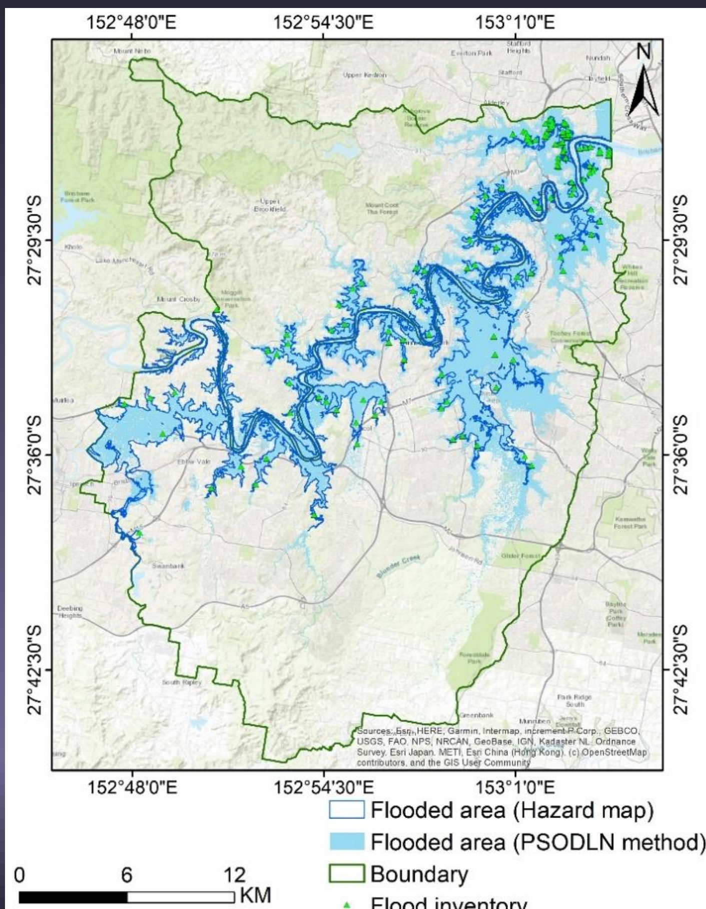
Results

Variable importance analysis derived from PSO-DLNN model.

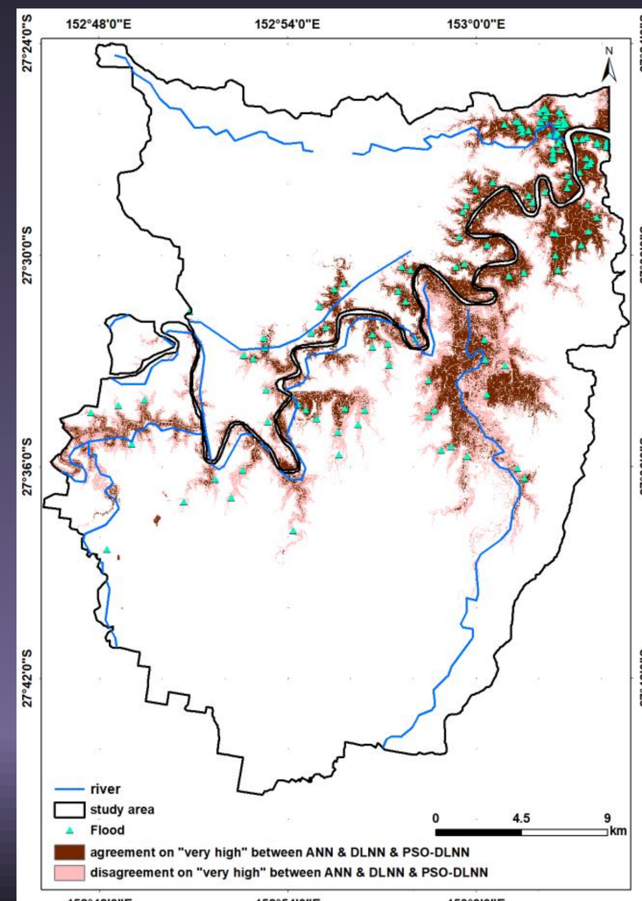
Variables	Importance
Altitude	100
Slope	33.05
Aspect	1.32
Curvature	16.55
Distance from river	55.44
Distance from road	29.21
Rainfall	9.31
Land use	22.63
Lithology	11.29
Soil	1.74
SPI	0
TWI	18.77
STI	39.69

Discussion

Comparison of flooded area predicted by PSO_DLNN method and hazard map.



Agreement and disagreement flood susceptibility for the "very high" class simulated by ANN, DLNN, PSO-DLNN.



Conclusion

- The significance of the conditioning factors analysis for the region highlighted that ***altitude***, ***distance from river***, ***sediment transport index (STI)***, and ***slope*** played the most important roles, whereas stream power index (SPI) did not contribute to the hazardous situation.

- The best accuracies by AUC were evaluated in PSO-DLNN (***0.99*** in training and ***0.98*** in testing datasets), followed by DLNN and ANN.

- Therefore, the ***optimized PSO-DLNN*** proved its robustness to compare with other methods.

remote sensing

Article

Deep Neural Network Utilizing Remote Sensing Datasets for Flood Hazard Susceptibility Mapping in Brisbane, Australia

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Thank you