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Applying the regression kriging method to explore the influence of agricultural activities on estimating spatial distributions of groundwater nitrate-N

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Study purpose

This study used regression kriging (RK) to determine groundwater pollution zones in the Choushui River alluvial fan in Taiwan according to nitrate-N observations and agricultural land uses. Areal ratios of agricultural land-use types within buffering zones were first characterized using geographical information systems. A multivariate linear regression (MLR) model was employed to explore the relationship between groundwater nitrate-N pollution and agricultural land-use types. Then, simple kriging (SK) was adopted to analyze residuals obtained from gaps between nitrate-N observations and MLR predictions; the SK estimates of the residuals with the addition of the MLR predictions served as the RK estimates for groundwater nitrate-N pollution. Finally, groundwater pollution zones were determined according to a specific anthropogenic nitrate-N pollution level.

Study area

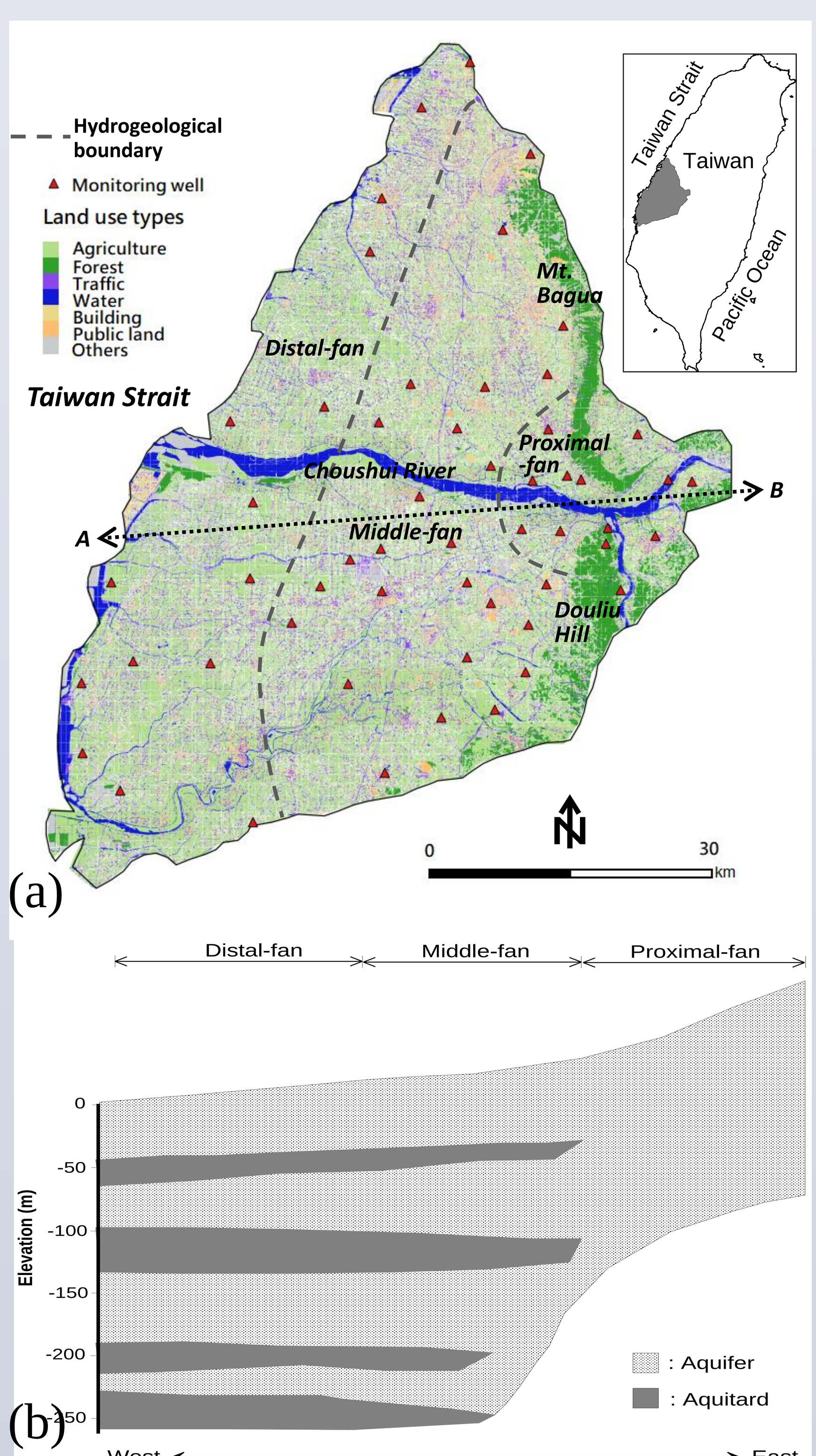

Fig. 1 (a) Study area and (b) hydrogeological profile along the section A-B.

Nitrate-N data

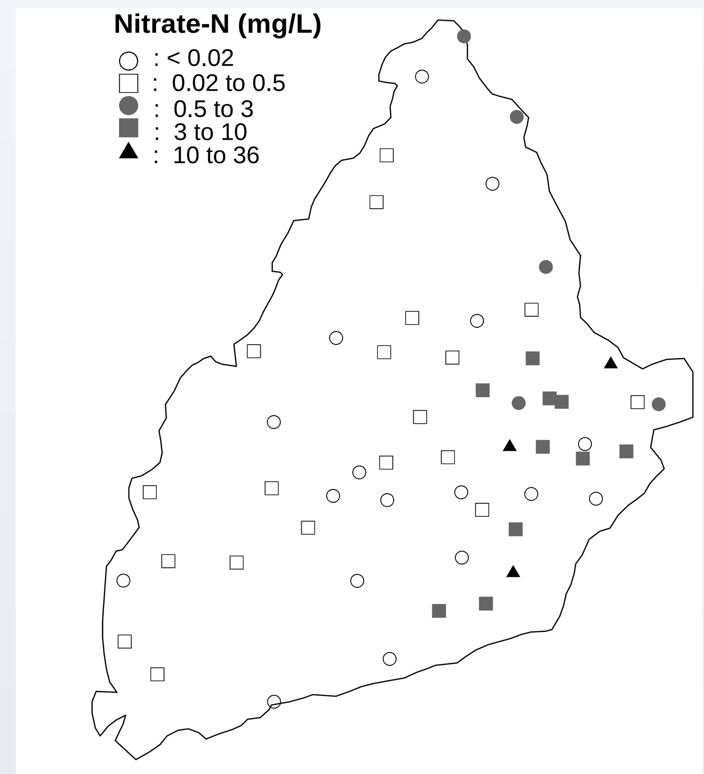

Fig. 2. Observed groundwater NO_3^--N concentrations.

Agricultural land-use data

Table 1. The GIS attribute data involve 16 agricultural land-use types.

The first field	The second field	The third field
Agriculture	Crop	Paddy field
		Dry farmland
		Orchard
		Abandoned field
	Aquaculture	-
	Livestock	Livestock house
		Pasture
	Agricultural facility	Green house
		Storage facility
		Vendor of agricultural products
		Other agricultural facility
Forest	-	-

Regression kriging

This study integrated primary and auxiliary data in the geostatistical technique. The primary data were generated from NO_3^--N observations $Z(\mathbf{u})$, and the auxiliary data were derived from predictions obtained using the MLR model y_{MLR}. In practice, the residual $R(\mathbf{u})$ represents the gaps between the NO_3^--N observations and MLR predictions and was adopted to characterize spatial variability and distributions using SK with a constant mean of zero.

Results

Table 2. Stepwise MLR model for exploring the relationship between log(NO_3^--N) and areal percentages of agricultural land-use types within buffering zones with a 1000-m radius.

Parameters	Coefficients	p-value
Intercept	-0.632	0.010
Orchard	0.063	< 0.001
Agricultural facility	-0.799	0.011
Livestock house	-0.288	0.023

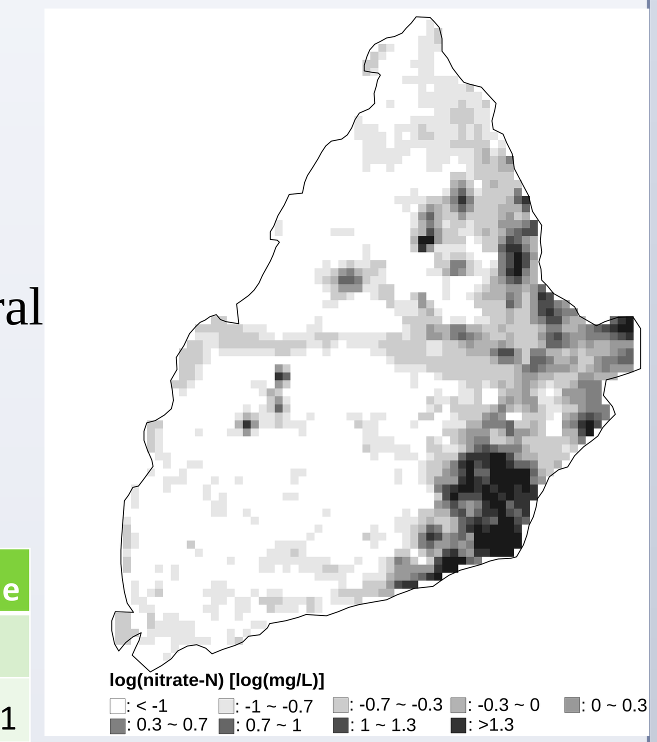

Fig. 3. Predictions of log(NO_3^--N) from the established MLR model.

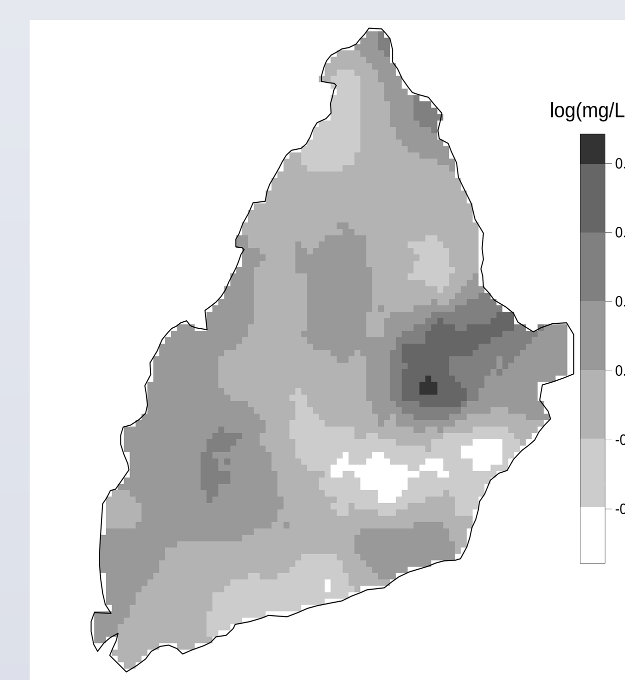

Fig. 4. Spatial estimates of the residuals using SK with a constant mean of zero

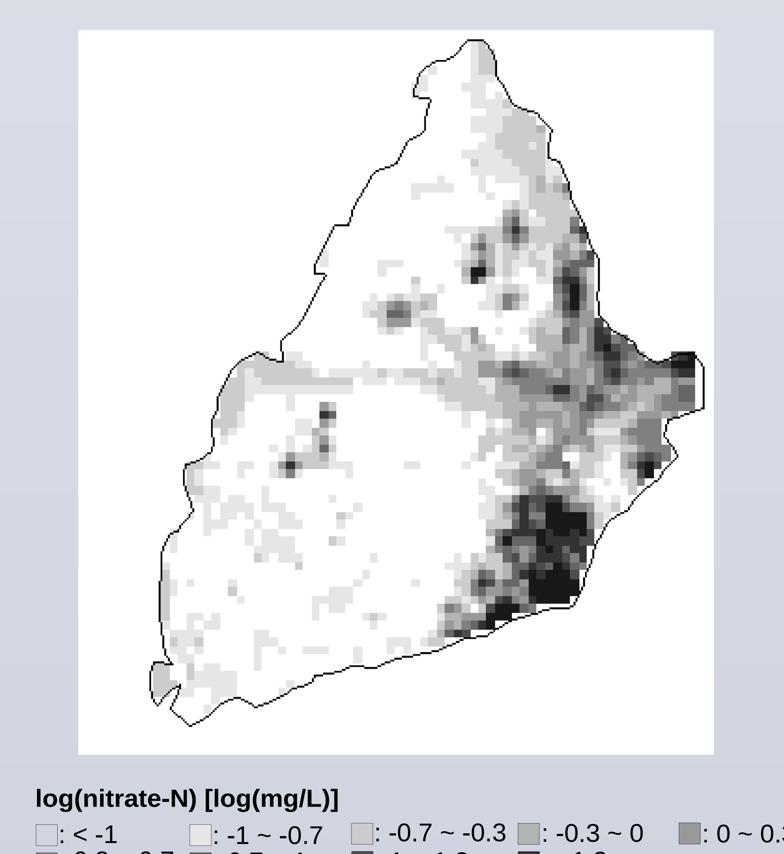

Fig. 5. RK estimates of groundwater log(NO_3^--N)

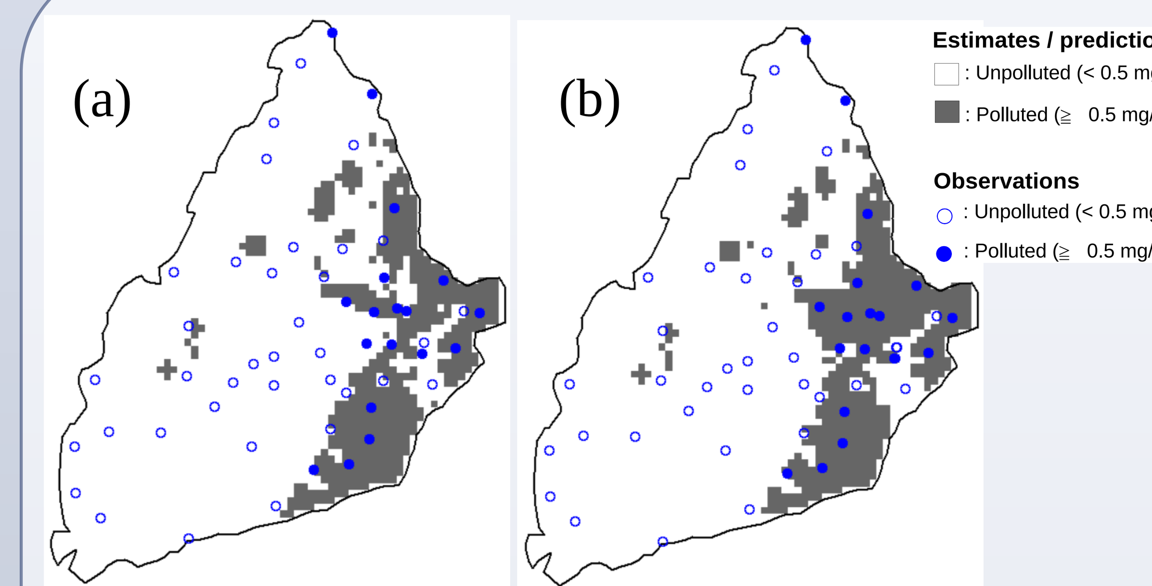

Fig. 6. Delineation of groundwater pollution zones using the (a) MLR model, and (b) RK estimates

Summary

This study adopted RK to identify groundwater pollution zones by combining spatial information on NO_3^--N observations and agricultural land uses in the Choushui River alluvial fan. The relationship between groundwater NO_3^--N observations and agricultural land uses was first explored using a MLR model. The research results revealed that the land-use types of orchard, livestock house, and agricultural facility were associated with groundwater NO_3^--N pollution, with the orchard land-use type as a critical cause of such pollution. This study then applied MLR and RK to determine groundwater pollution zones, revealed to be principally located in the proximal-fan area and the foothills of the Bagua Mountain and Douliu Hill. The RK estimates could be used to characterize the potential pollution source of the orchard land-use type and enhanced the accuracy of the classification of polluted and unpolluted areas through modification of the residuals. Consequently, the RK estimates were more accurate than the MLR predictions for determining groundwater pollution zones. According to the study results, the amount of fertilizer used in the orchards located in the identified groundwater pollution zones must be substantially reduced.

Acknowledgements

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