基於改良機器學習方法的地下水與可壓縮層考量之地層下陷模擬

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摘要

北京平原地區的地層下陷是一個嚴重問題，主要由地下水過度開採所引起。隨著南水北調工程（SWDP）提供外部水源，區域性的地層下陷出現了新的發展趨勢。本研究提出一種結合「證據權重法（WOE）」與「LightGBM 輕量梯度提升機器」的新型模擬模型，用來探討 SWDP 實施後地層下陷的成因。該模型透過對類別變數進行編碼，整合各項資訊與證據，不僅降低了資料中的雜訊，也提升了解釋性與模型穩定性，並能將輸入特徵轉換成更具資訊價值的表徵。研究結果顯示，SWDP 有效緩解了 2011 至 2018 年期間北京平原的地層下陷現象，地層下陷面積從 78% 減少到 58%，最大下陷速率從每年 135 公釐降至 110 公釐。在 SWDP 實施後，地層下陷主要由地下水與可壓縮黏土層的共同作用所導致，並與其他建設用地上的工程活動有關。儘管用水結構已有所改善，但第二與第三承壓含水層的水位變化仍主導著下陷發展。與以往的機器學習方法不同，本研究所提出的模型能直接處理離散數據，並更擅長預測劇烈的地層下陷變化。此研究結果可作為規劃區域性地層下陷整治策略的重要依據。

關鍵字：南水北調工程、干涉合成孔徑雷達、地下水變化、地層下陷、機器學習。

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Land subsidence simulation considering groundwater and compressible layers based on an improved machine learning method

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ABSTRACT

Land subsidence is a significant issue in the Beijing Plain, China, induced by groundwater overexploitation. The regional land subsidence is experiencing a new development trend with the external water source provided by the South-to-North Water Diversion Project (SWDP). The study proposes a novel model to simulate large-scale land subsidence that combines the weight of evidence (WOE) with the light gradient boosting machine (LightGBM) to explore the causes of land subsidence development after SWDP. The model encodes categorical variables to integrate information and evidence, reducing noise in the data, improving their interpretability, and enhancing robustness by transforming input features into more informative representations. The research findings show that SWDP has effectively mitigated subsidence development in the Beijing Plain from 2011 to 2018, reducing the subsidence area from 78 % to 58 % and the maximum rate from 135 mm/y to 110 mm/y. After SWDP, regional land subsidence is mainly attributed to the effects of groundwater and compressible clay layer and is related to engineering activities occurring on other construction land. Despite improved water use structures, water level changes in the second and third confined aquifers continue dominating the subsidence development. Unlike previous machine learning approaches, the proposed method can directly handle discrete data and is more adept at predicting severe subsidence changes. This study can be used to plan remediation strategies for regional land subsidence.