Detecting Unregistered Groundwater Abstraction Using Satellite Data Inconsistencies

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Background.
Groundwater overexploitation in arid and intensively agricultural regions is a major driver of aquifer depletion and land subsidence, resulting in irreversible reductions in storage capacity. However, identifying where unsustainable abstraction occurs at regional scale remains challenging due to sparse in-situ measurements, prevalence of unregistered wells, and strong spatial heterogeneity in irrigation practices. These constraints limit the ability of conventional monitoring systems to detect unregulated extraction and associated impacts. This motivates the need for scalable, observation-based approaches capable of identifying spatial inconsistencies indicative of undocumented groundwater use.

Methods.
This work proposes a multi-source remote sensing pipeline to identify indicators of groundwater stress and prioritise areas of potential overexploitation. The methodology integrates Sentinel-1 SBAS-InSAR time series to quantify land deformation related to aquifer compaction, Sentinel-2 spectral indices with locally calibrated machine-learning classification to map irrigated agricultural extent, and WaPOR precipitation and evapotranspiration datasets to constrain regional water balance and irrigation demand. By linking deformation signals, vegetation dynamics, and water flux proxies, the framework identifies spatial mismatches between inferred groundwater stress and reported infrastructure.

Case Studies
The workflow is applied across two contrasting case study regions of approximately 40,000km^2. The Segura Basin in Spain, representing an arid and intensively irrigated system, and the Moradabad region of India, characterised by significant groundwater stress and observed subsidence. Together, these regions provide end-member conditions for testing robustness across different hydroclimatic and socioeconomic contexts.

Results.
Preliminary qualitative results show spatially coherent subsidence and vegetation anomalies that diverge from registered well distributions, indicating candidate hotspots of undocumented groundwater abstraction. Furthermore, consistent seasonal subsidence signals in these areas correspond with irrigation demand cycles.

Conclusion.
This study demonstrates a scalable Copernicus-based framework for identifying spatial inconsistencies indicative of potential unregistered groundwater abstraction. By integrating independent physical and agricultural proxies, the approach enables prioritisation of field investigation zones where observed water use and subsurface response diverge from reported abstraction data. This provides a foundation for improved groundwater governance, enforcement-oriented monitoring, and inventory refinement in data-scarce regions.

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