Subsidence in Hanoi, Vietnam; is it all due to groundwater abstraction?

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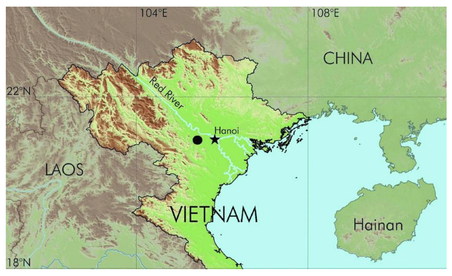
Hanoi Subsidence and Urban Development

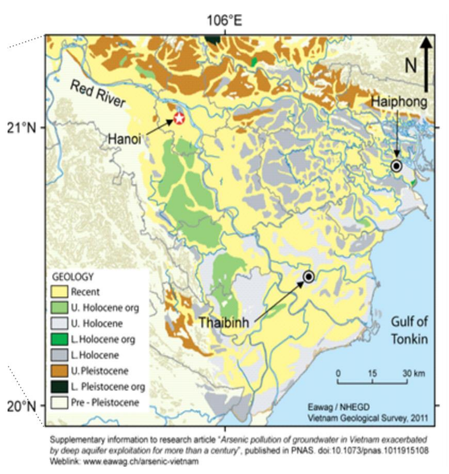
We set out to study the link between subsidence and groundwater abstraction, using Sentinel 1 InSAR data. We observed that whilst earlier studies demonstrated a relationship between subsidence and groundwater abstraction the relationship appears to be less clear now. Instead we found a spatial and temporal link between subsidence and urban development. This appears to relate to the loading of the ground by aggregate rather than the loading from the building of new buildings since these are founded on deep piled foundations.

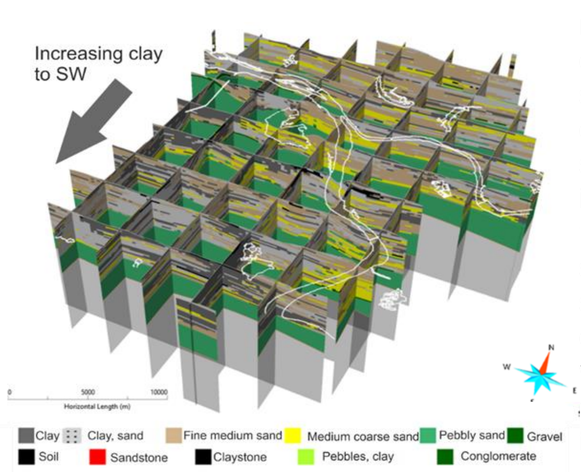
We developed a methodology to extract rates of motion for each year following ground loading and studied the evolution of the subsidence. We present derived rates of motion for each year following the development of flooded agricultural land into urban areas.

Hanoi Geological Setting

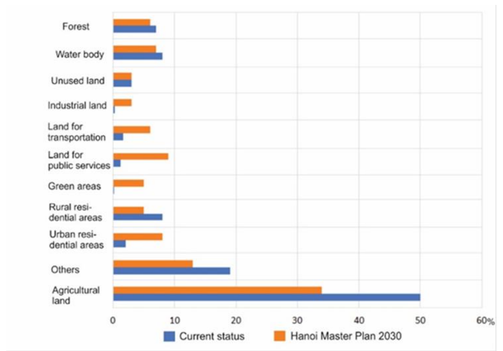


The city of Hanoi sits on the Red River delta plain in northern Vietnam. As such the subsurface consists of unconsolidated Quaternary sediments of fluvial and marine origin. These are between 50-90m thick and sit on Neogene gravel deposits.





Geological modelling based on 270 boreholes shows a decrease in sands and an increase in clays towards the south and southwest of the city centre, where development is focused

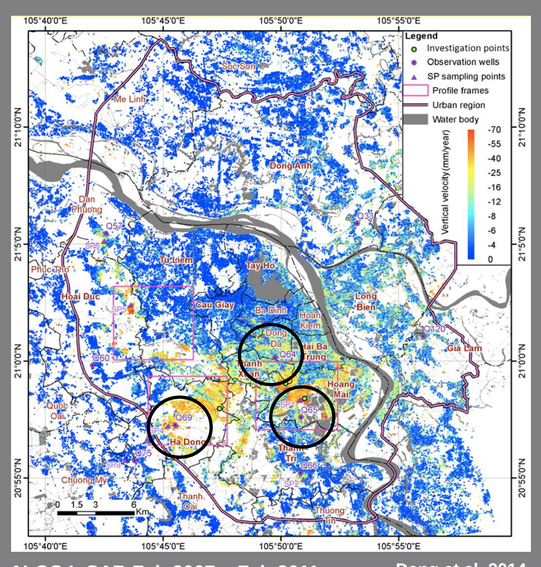


Hanoi Urban Development: Master Plan

The population of Hanoi is currently 7.4 million and is projected to reach over 9 million by 2030. Over the last 50 years there has been a 15.5% increase in artificial surfaces. The Hanoi Master Plan has been created to guide the development focusing on the creation of new towns to the west and southwest of Hanoi centre.

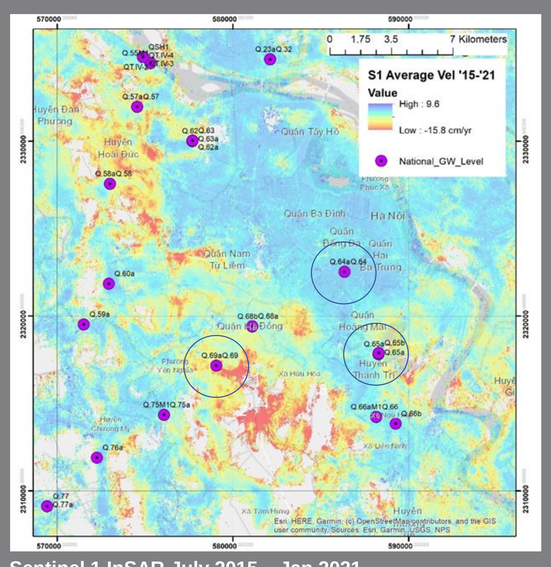
The image above shows a typical new development, where flooded ground (in the foreground) is recovered, by loading with aggregate, and built upon.

InSAR and Groundwater Abstraction



ALOS InSAR Feb 2007 – Feb 2011

Dang et al, 2014

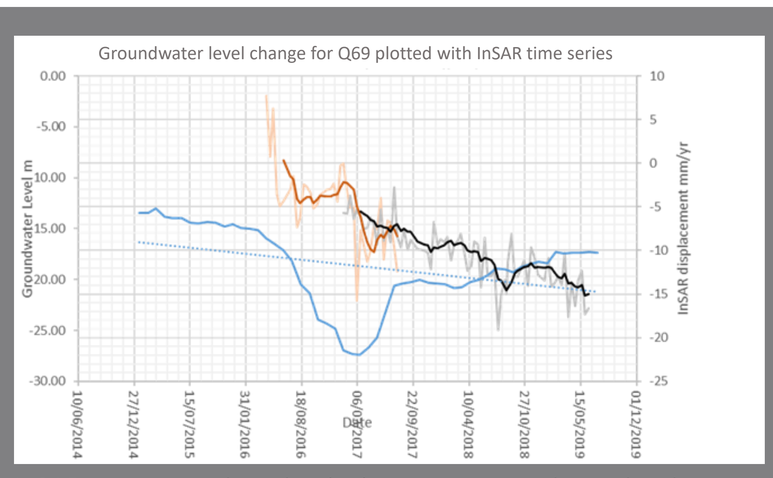


Sentinel 1 InSAR July 2015 – Jan 2021

Dang et al, 2014 found motion in 2007- 2011 corresponded to groundwater abstraction boreholes (black circles).

Between 2015 and 2021 the northern borehole has become stable, and ground motion appears to now be focused to the south east of the other two boreholes

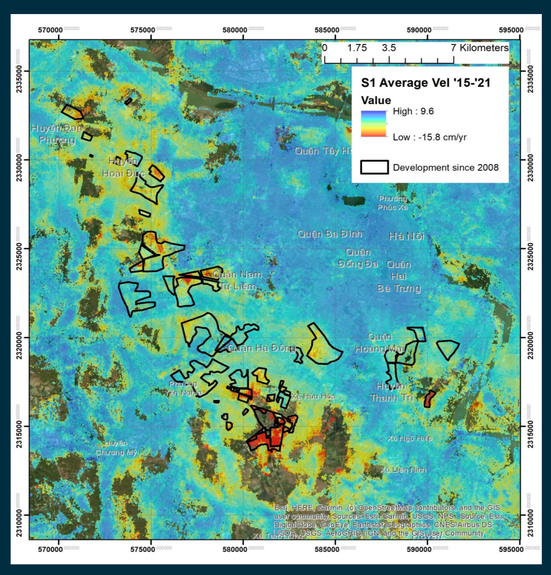
The motion is now not centred on the boreholes as would be expected if abstraction from these were the sole cause of motion.



InSAR time series plotted with changes in groundwater level reveals that both have a similar trend, overall subsidence with an overall decrease in GW level. However, we do not see the detail of the GW level change reflected in the ground motion as we see in other studies.

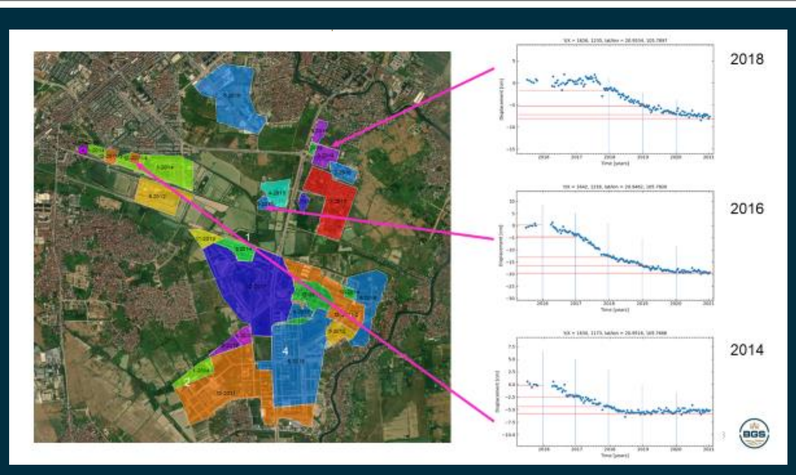
InSAR and Urban Development

Time series of optical imagery reveal how the land is reclaimed from flooded rice paddies to solid ground suitable for building. The progressive dumping of aggregate is clearly evident

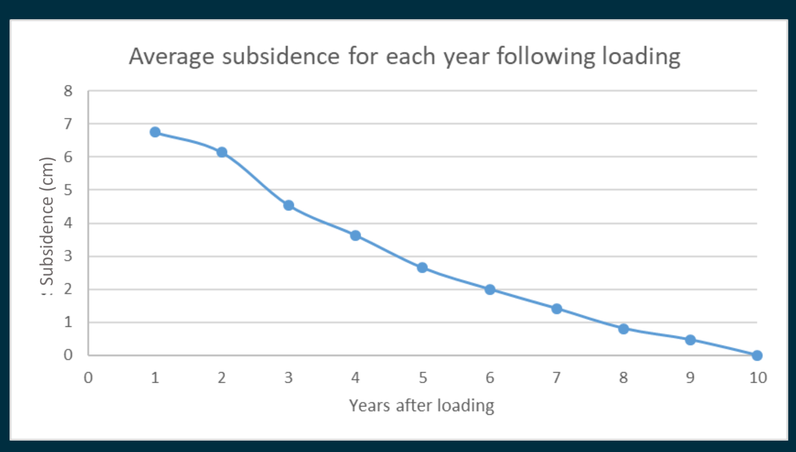


The majority of areas of subsidence correspond with areas of rapid urban development as identified from time series of optical satellite imagery.

Comparison of the InSAR time series with the ground loading history reveals spatial and temporal associations between subsidence and loading. The rate of subsidence rapidly increases as the ground is loaded and the rate declines over time.



We extract areas of development (coloured polygons) and label with year of first development. Average subsidence time series are plotted for each polygon revealing rates of subsidence for each year following loading.



Extracting rates of motion for over 40 polygons identified as areas of rapid development enables the extraction of the average amount of subsidence for each year following loading of the ground.

Initially subsidence is 7cm per year and declines to zero after 10 years

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