

Contribution of GIS to the Mapping and Analysis of Water Boreholes and Their Impacts: A Case Study of the Kemi (Righini), Livulu and Salongo Neighborhoods in Lemba Municipality, Kinshasa, D.R. Congo

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Abstract: In Kinshasa, the limited performance of the public drinking water supply network has led many households to develop independent access to groundwater, particularly through private boreholes. This practice is increasingly observed in the Municipality of Lemba, where rapid urban growth, land parcel fragmentation, and insufficient control of drilling activities have encouraged a dense and poorly regulated distribution of water abstraction points. Such a situation raises important questions regarding groundwater sustainability, aquifer protection, and the environmental consequences of intensive groundwater use in urban areas.

This study applies Geographic Information System (GIS) techniques to locate, map, and analyze the spatial distribution of 203 boreholes identified in selected neighborhoods of Lemba Municipality. The spatial analysis shows a high concentration of boreholes, with observed spacing commonly ranging between 10 and 20 meters, far below the recommended reference distance of 150 meters between abstraction points. This excessive concentration may increase the risk of aquifer interference, groundwater level decline, water quality degradation, anthropogenic contamination, and localized environmental instability.

The results demonstrate the relevance of GIS as a decision-support tool for monitoring groundwater abstraction in rapidly urbanizing areas. They also underline the need for a more structured groundwater management approach based on updated spatial databases, technical regulation of borehole drilling, control of abstraction density, and public awareness. In this context, sustainable groundwater governance in Lemba requires the combined use of hydrogeological knowledge, geomatics tools, and institutional enforcement to ensure long-term water availability while limiting environmental degradation.

Keywords: *Geographic Information Systems (GIS); Groundwater; Boreholes; Drinking Water Supply; Urban Groundwater Management; Overexploitation; Anthropogenic Pollution; Land Subsidence Risk; Kinshasa; Lemba Municipality.*

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I. INTRODUCTION

Kinshasa is facing increasing pressure on its drinking water supply system as a result of sustained demographic growth and rapid urban expansion. With an estimated annual population growth rate of 6.6% and more than 13 million inhabitants, the city's existing water infrastructure is struggling to meet the needs of its population. The limited coverage of the distribution network, together with the aging state of several facilities, contributes to irregular access to safe drinking water and worsens household water insecurity. This situation also has social consequences, particularly for women and children, who are often more directly involved in water collection activities (Bédécarrats et al., 2019; AFD, 2020).

In this context, many households have turned to groundwater as an alternative source of supply. This trend is particularly visible in the Municipality of Lemba, where individual boreholes have multiplied in response to the insufficiency of the public water system. However, the development of these abstraction points is often carried out without adequate technical supervision or regulatory control. In several cases, the spacing between boreholes is reduced to only 10–20 meters, compared with the recommended reference distance of 150 meters. Such dense and poorly regulated groundwater exploitation may disturb local hydrogeological conditions and increase the vulnerability of aquifers to overexploitation, contamination, and environmental degradation.

This study focuses on the contribution of Geographic Information System (GIS) tools to the assessment of borehole distribution and groundwater management challenges in Kinshasa. By mapping the spatial arrangement of boreholes in Lemba Municipality and analyzing the environmental implications of their concentration, the study provides a spatial decision-support framework for urban groundwater governance. The objective is to generate reliable information that can support planning, regulation, and sustainable management of groundwater resources in a rapidly growing urban environment.

II. MATERIALS AND METHODS

The methodology used in this study was based on detailed field investigations combined with the systematic acquisition of georeferenced data. During the fieldwork, the position of each borehole was recorded using a Garmin 64 GPS device and linked to a specific location identification number. The collected coordinates were then integrated into a GIS environment to produce thematic maps and conduct spatial simulations.

This geospatial approach made it possible to examine the distribution pattern of boreholes, highlight areas where abstraction points are highly concentrated, and identify the main issues associated with this spatial densification. GIS tools were therefore used not only for mapping purposes, but also as a decision-support instrument for assessing the possible effects of borehole proliferation on aquifer conditions and anthropogenic contamination risks. The resulting database provides a dynamic and updatable platform that can support decision-makers in groundwater monitoring and management.

III. RESULTS

➤ Study Area Context

The Lemba Municipality, characterized by low-lying terrain in its southern part (Figure 1 and Figure 2), faces significant challenges in terms of drinking water supply. This topography contributes to insufficient hydraulic pressure and the aging condition of water infrastructure, thereby worsening access to water for the local population.

In response to these constraints, the population increasingly relies on groundwater exploitation through boreholes, which are proliferating without strict regulation, exposing the area to significant hydrogeological and environmental risks.

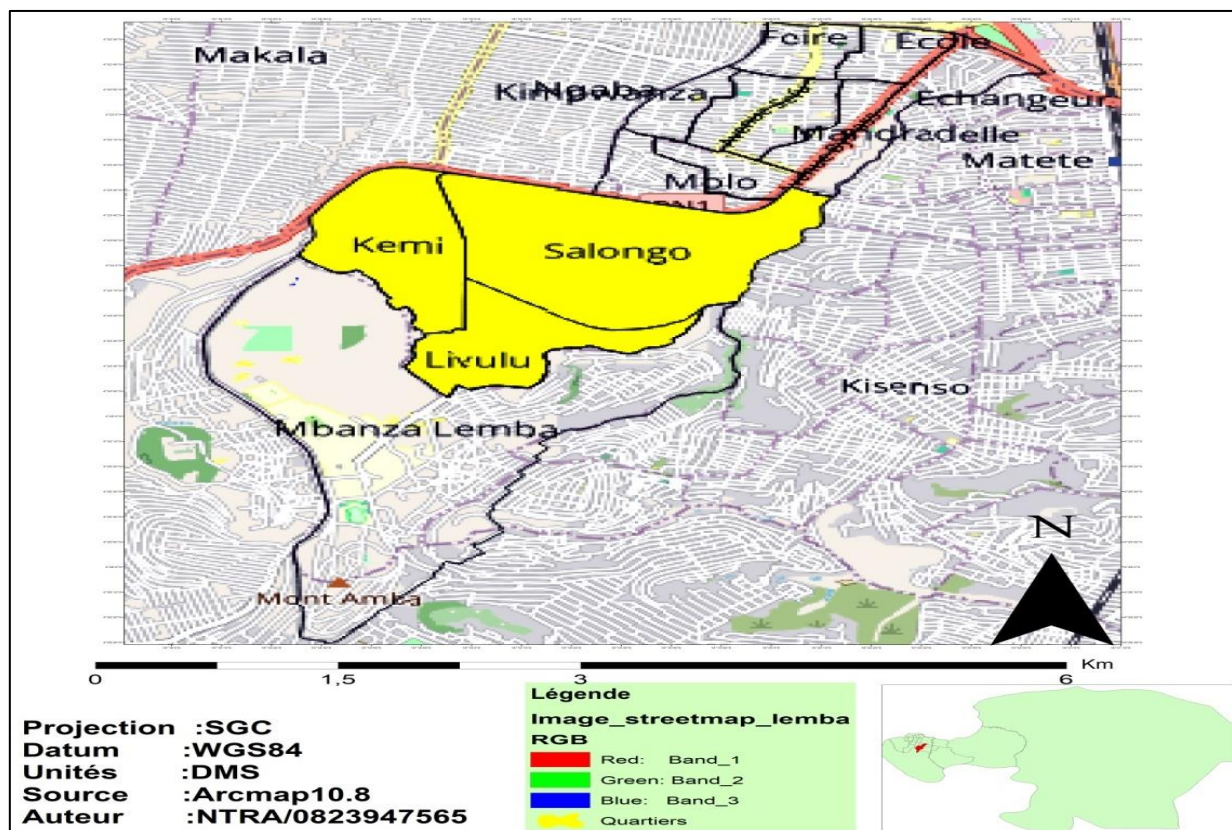


Fig 1 Location Map of the Study Area

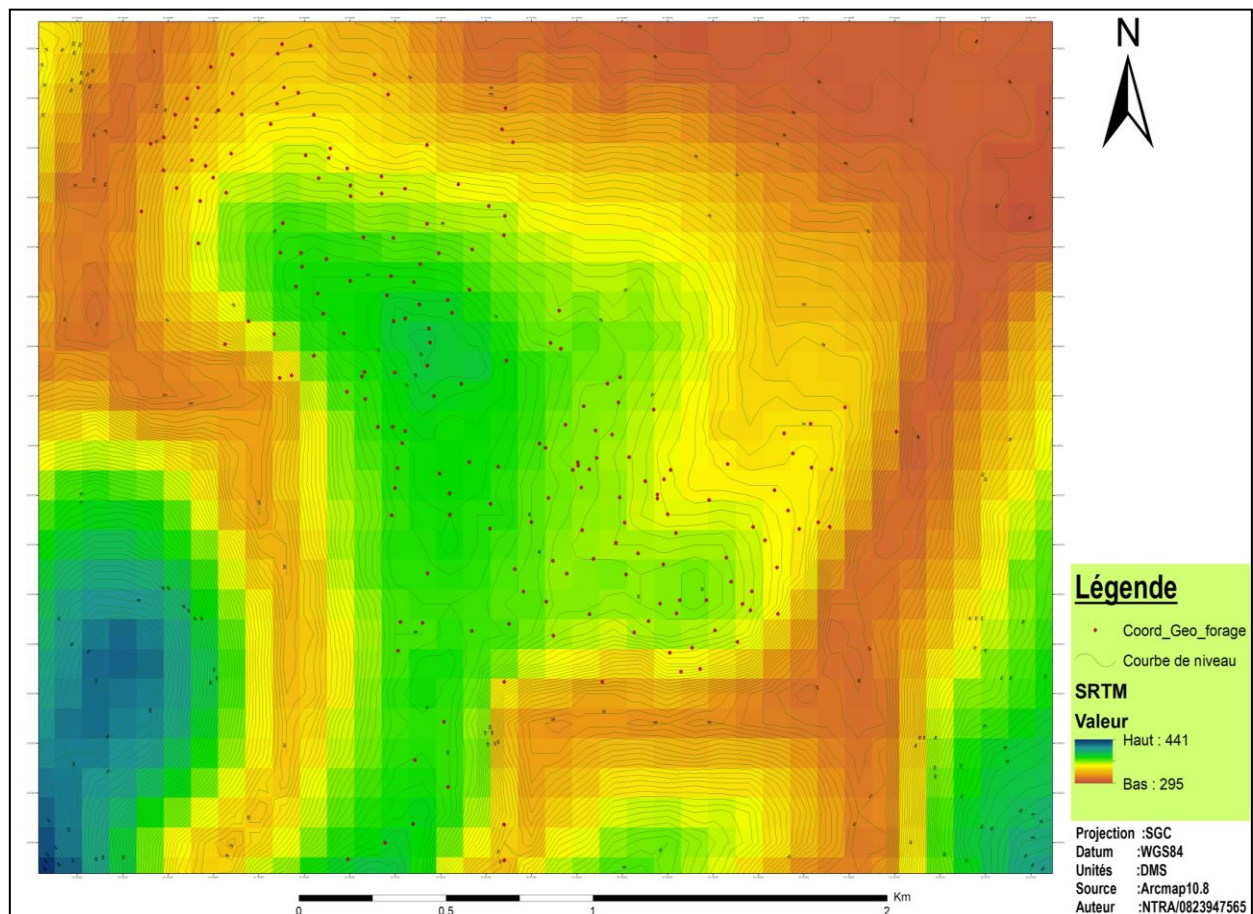


Fig 2 Elevation Map of the Study Area

IV. DISCUSSION

To meet the growing demand for safe drinking water, the population of Lemba relies heavily on groundwater through individual boreholes. However, this reliance becomes problematic when the minimum regulatory distances between water points, set at 150 meters, are not respected.

In the Democratic Republic of the Congo, the absence of harmonized national regulations contributes to this

uncontrolled proliferation. Field observations reveal boreholes spaced sometimes as close as 10 to 20 meters, a direct consequence of land parcel fragmentation—commonly referred to as “gilette”—and the individual desire for autonomous access to water.

This unregulated densification increases the risks of aquifer overexploitation and deterioration of water quality. In this study, data were collected from 203 identified boreholes (Table 1 and Figure 3).

Table 1 Number of Boreholes and Average Spacing between Boreholes by Neighborhood

Neighborhoods	Number of Boreholes	Average Spacing (m)
Kemi (Righini)	84	± 15 m
Salongo	90	± 13 m
Livulu	29	± 18 m

These values indicate that the average distances observed (13 to 18 m) are significantly below the recommended standard of 150 m, confirming the excessive densification of boreholes.

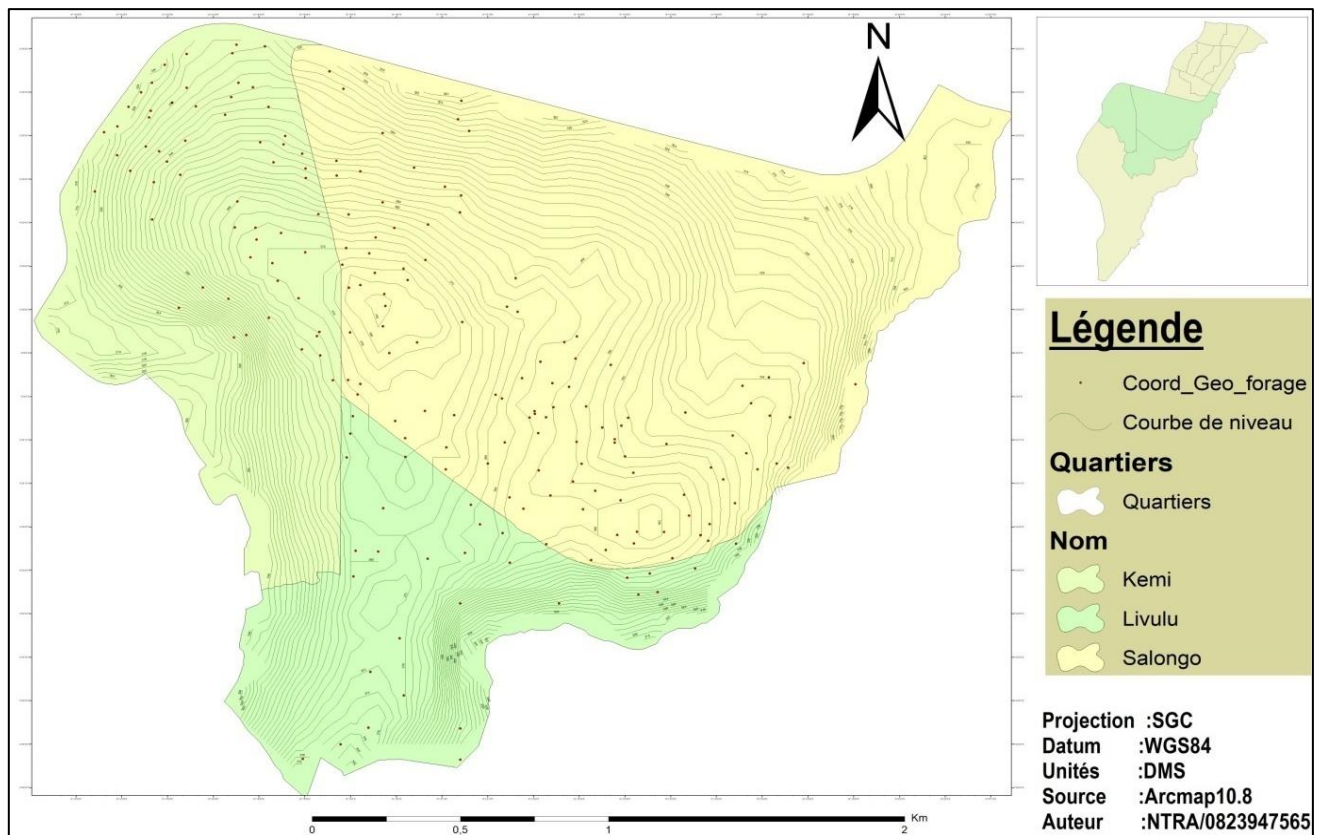


Fig 3 Map of Borehole Sampling Locations

The GIS simulation performed using the buffer function highlighted the overlap of water points (Figure 4), emphasizing the importance of geomatics tools in identifying critical zones and guiding appropriate management policies. This finding is consistent with the European Water

Framework Directive (2008), which states that the quantitative status of groundwater is considered satisfactory when abstractions do not exceed the natural recharge capacity of aquifers.

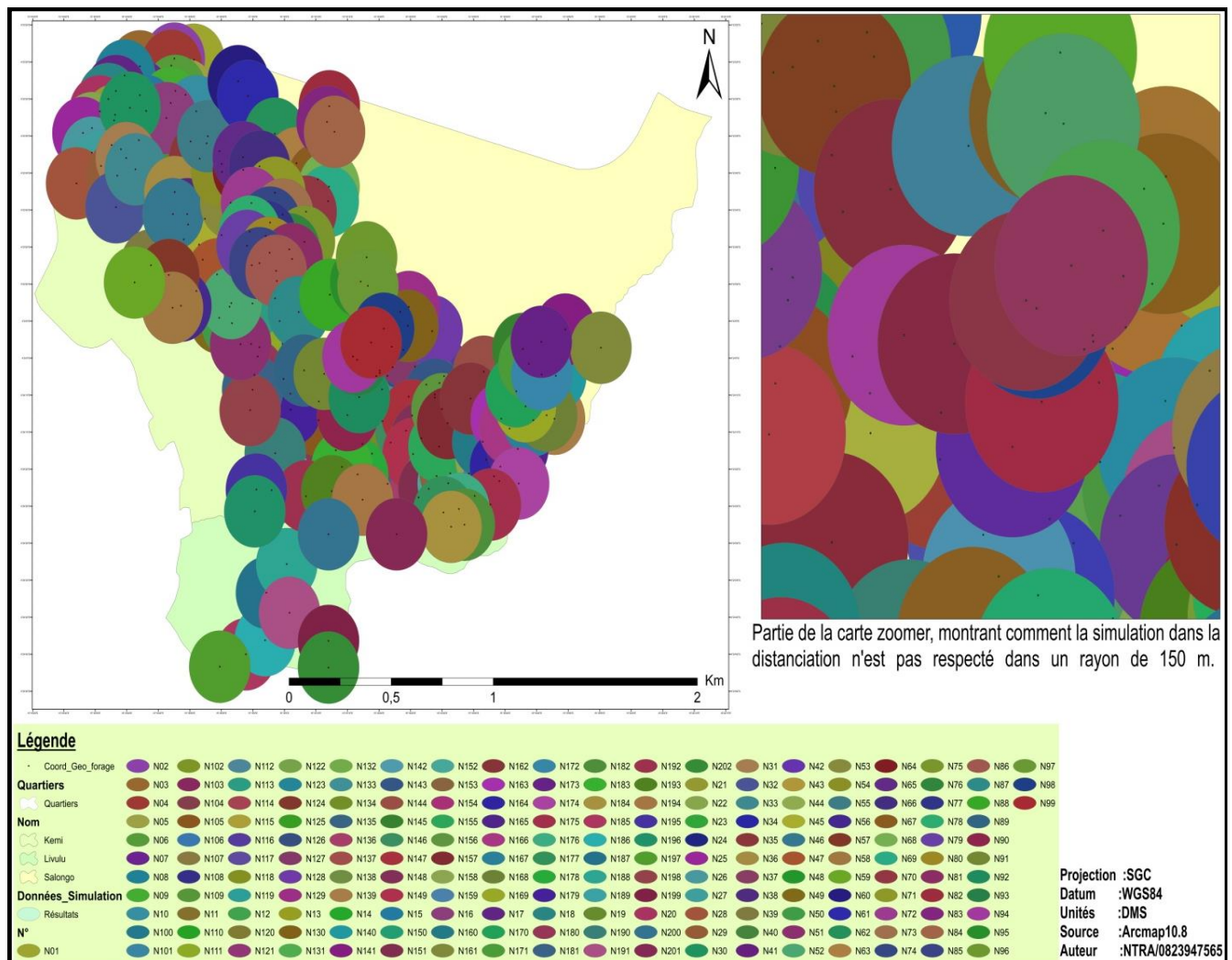


Fig 4Map of Buffer Simulation Highlighting Non-Compliance with Recommended Spacing

➤ Impact on Geological Formations

During drilling operations, the pressure exerted by drilling activities can alter the equilibrium of the geological formations encountered, leading to the accumulation of energy within the host rock that may be released through rupture along pre-existing faults, potentially triggering local seismic events. This dynamic has been observed in several contexts, notably in Quebec (Lord, 2010) and Conakry (Diop, 1990), illustrating the seismic risk associated with the proliferation of boreholes.

➤ Impact on Aquifer Stability

Aquifers, composed of pores and voids saturated with water, maintain a hydrostatic balance that is essential for geological stability. Intensive groundwater pumping disrupts this balance, resulting in several adverse effects:

- *Decline in groundwater level:*

Excessive pumping lowers the groundwater table, making access to water more difficult and costly, and potentially leading to water quality deterioration through the intrusion of pollutants;

- *Deterioration of water quality:*

Overexploitation promotes the upward migration of undesirable substances, thereby compromising water potability;

- *Land subsidence:*

Excessive groundwater extraction causes compaction of porous aquifer materials, resulting in a gradual lowering of the ground surface. This phenomenon, documented in cities across China, Japan, Mexico, and the United States, leads to structural damage to infrastructure (pipelines, roads, and buildings) and increases the risk of flooding. Satellite imagery from NASA and ESA (www.sjra.net) illustrates these major subsidence events, particularly in the San Joaquin Valley in California, where the ground subsided by up to 8.5 meters between 2015 and 2016 (Figure 5).

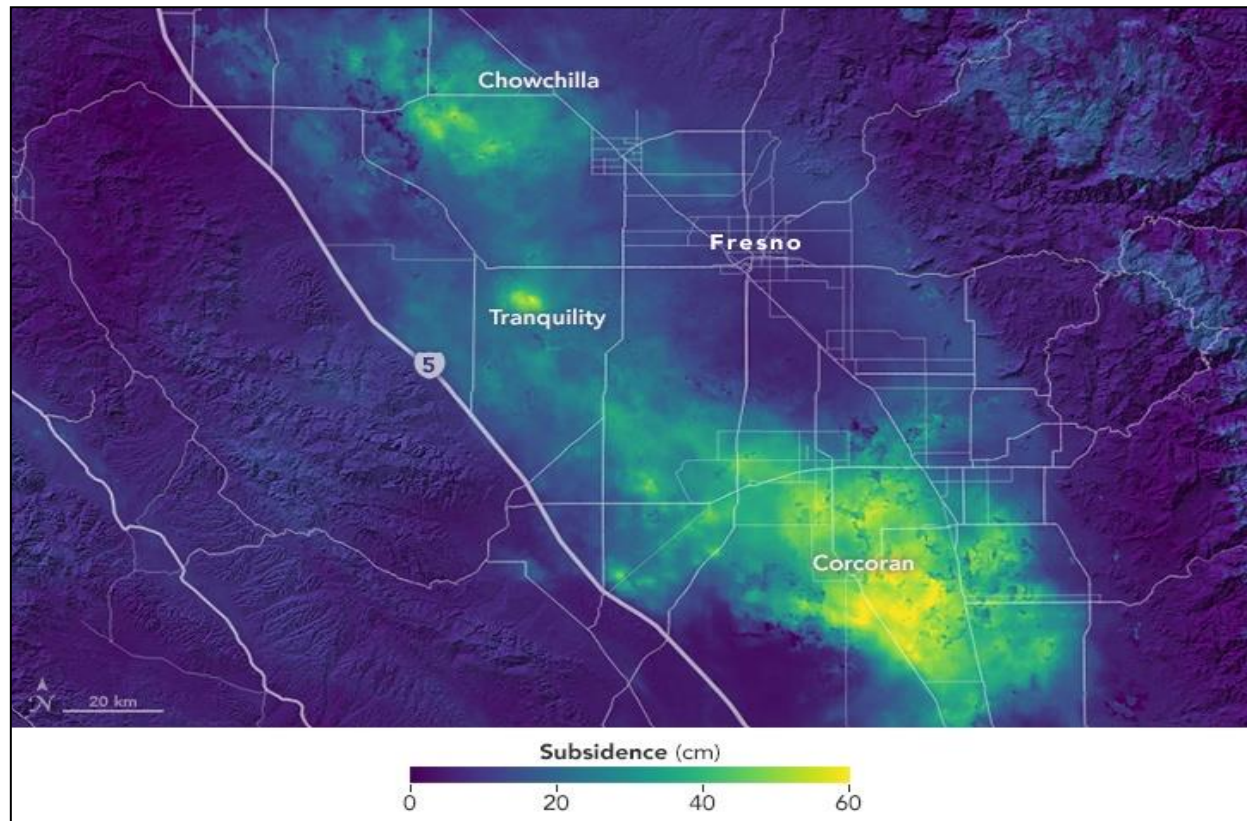


Fig 5 Measured Land Subsidence in Selected Areas of California (cm). Source: NASA (www.sjra.net).

Since the 1920s, excessive groundwater pumping from thousands of wells in the San Joaquin Valley in California has caused land subsidence in certain parts of the valley, or sinkage, of up to 28 feet (8.5 meters).

➤ *Impact Related to Anthropogenic Pollution*

Rapid urbanization, industrial development, and agricultural and mining activities expose aquifers to an increasing risk of pollution. Once contaminated, these underground reservoirs may become unsuitable for use for decades, making rehabilitation measures long, complex, and costly (Ninamou et al., 2021). Delayed awareness of such pollution further aggravates the situation, highlighting the urgency of proactive management.

➤ *Impact on Ecosystems*

Groundwater supplies surface water bodies, springs, and wetlands, constituting a vital component for both aquatic and terrestrial ecosystems. Overexploitation of aquifers leads to a reduction in river baseflow, drying up of springs, and degradation of natural habitats, thereby affecting biodiversity and essential ecosystem services (Ninamou et al., 2021). This degradation also impacts human communities that depend on these resources.

➤ *Impact Related to the Recommended Spacing Standard between Boreholes*

The recommended minimum distance between two boreholes is 150 meters, in order to limit hydrogeological interference and reduce the risk of cross-contamination. This standard is consistent with the principles of the European Water Framework Directive (2000/60/EC), which states that

the quantitative status of groundwater is considered satisfactory when abstractions do not exceed the natural recharge capacity of aquifers.

Furthermore, the WHO Guidelines for Drinking-water Quality (2017), as well as publications from UNESCO (2019) and FAO (2015), emphasize the importance of protecting water abstraction points from anthropogenic contamination, which implies maintaining sufficient spacing between withdrawal points.

In densely populated urban contexts such as Kinshasa, this standard should be considered a minimum threshold and adjusted according to the nature of aquifers and demographic pressure.

V. CONCLUSION

Borehole development and management should be guided by hydrogeological, geological, and environmental considerations. When boreholes are drilled without adequate technical control, they may affect groundwater availability, water quality, and the stability of the surrounding environment. The observations made in selected neighborhoods of Lemba Municipality show that the rapid and poorly regulated increase in boreholes, combined with the non-respect of the recommended 150-meter spacing distance, may expose the area to several risks, including groundwater table decline, contamination of water resources, localized ground instability, and degradation of ecosystems.

Reducing these risks requires a coordinated and sustainable approach to groundwater management. Priority actions should include:

- Controlling the number and spatial distribution of boreholes;
- Enforcing minimum spacing requirements between abstraction points;
- Promoting practices that support natural or artificial aquifer recharge;
- Establishing appropriate groundwater abstraction limits;
- Integrating groundwater protection measures into urban planning and land-use policies.

In this context, Geographic Information System (GIS) tools provide an effective framework for mapping, analyzing, and monitoring borehole distribution. They allow decision-makers to identify critical zones, update groundwater-related information, and base management decisions on spatial evidence. The combination of hydrogeological expertise, geospatial technologies, and effective institutional regulation is therefore essential to ensure the long-term availability of groundwater resources while reducing environmental impacts in rapidly urbanizing areas.

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