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IMPROVING ACCESS AND SUSTAINABILITY

Identification of suitable zones for manual drilling using borehole data, thematic maps and remote sensing

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Manual drilling is a possible option to increase access to safe water with low cost techniques, but it can be applied only where hydrogeological conditions are suitable. To improve the method to produce maps of suitable zones for manual drilling, a research project has been carried out in Senegal and Guinea. The main objective is to elaborate a new method of interpretation of hydrogeological data and integrate indirect environmental information obtained from public data, available all over the world. The final results are more reliable and detailed maps to support manual drilling implementation, as well specific tools and method to process water point data. This paper presents the results obtained in Senegal and suggests some recommendations for future application.

Background

In the last decades there is a raising interest for sustainable techniques to increase access to safe water in those countries where situation is still dramatic. Manual drilling (technique to drill borehole for groundwater exploitation using human or animal power, without mechanised equipment) is one of the options that recently has received attention from international organisation. It was introduced in Senegal in the early 90's. and has been carried out mainly by small private contractors in the South. Between 2010 and 2013 a USAID/PEPAM program trained local drillers and promoted the implementation of hand drilled boreholes in Casamance and Tambacounda (Naugle, 2013).

The application of manual drilling is limited to those areas where hydrogeological conditions are suitable: shallow layers of unconsolidated sediments and water level not too deep. Identifying these areas is important for a correct planning of different programs to promote this technique and increase the professional level of drillers.

The study conducted by UNICEF concerning the identification of suitable zones for manual drilling in Senegal (UNICEF, 2010; Kane et al., 2013) showed that there are regions where this technique could provide a feasible option to increase the rate of access to safe water in rural areas; in particular, the map of suitable zones (Figure 1) shows that there is good potential for manual drilling in the northern coastal strip, along the Valley of river Senegal, in the western side of Fatick region and Casamance. Despite of large areas covered by unconsolidated sandy layers, the main limiting factor for manual drilling implementation in Senegal is the depth of water.

This map represented a basic document for the definition of the following low cost drilling program by USAID and UNICEF. However, this study was produced through the interpretation of small scale thematic maps, water point data not homogeneously distributed (with limited information in central and eastern part of Senegal) and interpretation based on qualitative perception by experts (without a systematic and quantitative method to estimate hydrogeological characteristics of shallow layers). As a result, it is difficult to rely on this map in areas with limited previous information. It is as well problematic to have a semi quantitative estimation of the geometry and hydraulic properties of shallow porous aquifer (target for

manual drilled wells). Furthermore, the following process to downscale this map at a more detailed level is difficult.

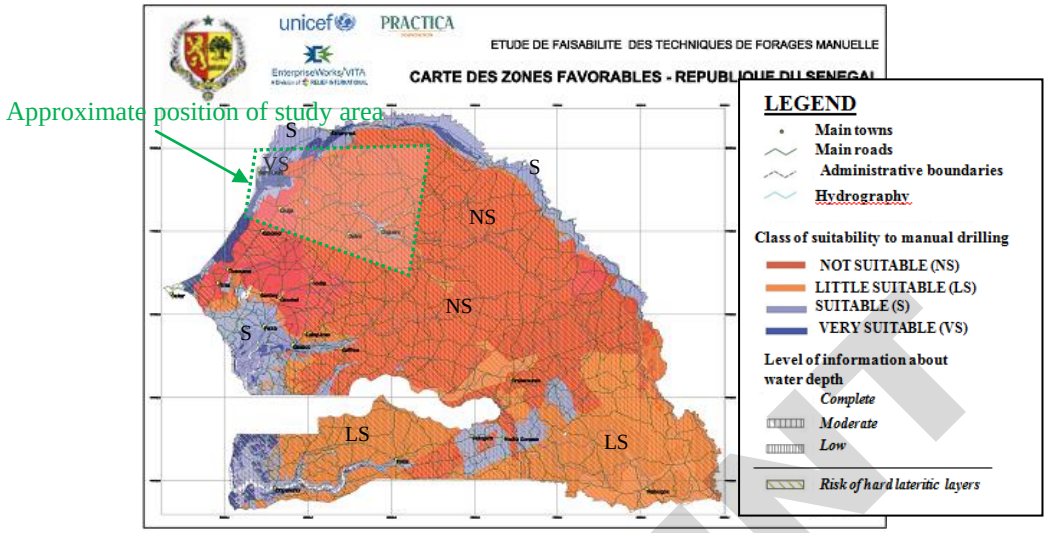

Figure 1 - Map of suitable zones for manual drilling in Senegal

Source: UNICEF, 2010 (modified)

Objective of the research

The research presented in this paper proposes an improved methodology to estimate the shallow hydrogeological context and identify suitable areas for manual drilling, with some innovative aspects:

- it is based on a more structured and quantitative procedure to elaborate existing geological data, especially those coming from water point database and borehole stratigraphic logs
- it is able to integrate other sources of indirect information to fill the gap inwater point data and geological maps in case of discontinuous distribution or not sufficient level of detail.

This research is part of a larger project financed by NERC (National Environment Research Council, UK) in the framework of the program UPGRO (Unlocking the Potential of Groundwater for the Poors), with the collaboration of different partners from Italy, Senegal and Guinea.

The study has been carried out in two different study areas, in Senegal (whose results are presented in this paper) and Guinea

Study area

The Study area in Senegal corresponds to the region of Louga (Figure 2), in Northwestern Senegal. It lies between 14°70' and 16°10' North and 14°27' to 16°50' West, extended for 24874 square km.

The total population is 880482 inhabitants, with an intense migration process to other regions of Senegal or abroad, caused by the difficult rural economy. The rural population is more than 500.000 inhabitants, with a rate of access to safe drinking water of 57% and adequate sanitation for 17%. (source: PEPAM).

The region has an arid climate, with yearly rainfall from 200 to 500 mm, concentrated between June and October. Morphology is mainly flat, with limited undulation formed by sandy dunes. Almost the whole area is covered by quaternary sands and sandy clay overlaying a tertiary sedimentary basement (limestone, marl, sandstone)

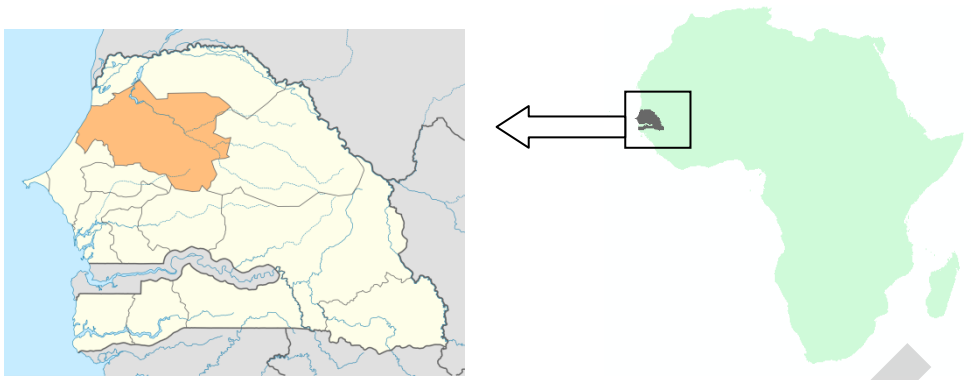

Figure 2 - Location of the study area

Data collection and analysis

The process of data collection and analysis has been carried out through the estimation of hydrogeologic parameters from borehole data, a second step of extraction of indirect environmental indicators from maps and remote sensing, finally a spatialisation of the hydrogeological information of the boreholes using the indirect layers with a multivariate statistics approach. This last step (still to complete) will lead to define suitability and potential for exploitation with manual drilling for the different zones

Hydrogeological parameters obtained from water point data and stratigraphic logs

The basic information concerning water points has been obtained from the national database of DGPRE: (Direction de la Gestion et de Planification des Resources en Eaux). A set of hydrogeological parameters for a sample of almost 200 points have been extracted trough a process of organization, codification and automatic analysis of borehole data (figure 3), using a specific software (TANGAFRIC) designed during the research.

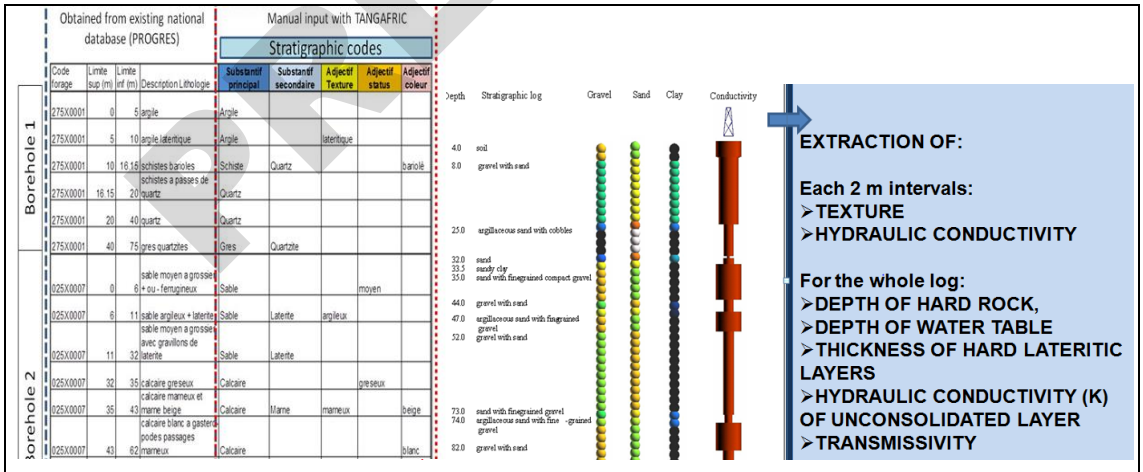

Figure 3 - Codification of borehole logs and extraction of hydrogeological parameters

Extraction of indirect layers of information from thematic maps and remote sensing data

A series of indirect layers of information have been obtained from existing thematic maps and remote sensing data. In details:

- Geology, soil, morphopedology, landuse from existing thematic maps
- Apparent thermal inertia and dynamics of vegetation (fig. 4), from MODIS optical satellite data

- Dynamic of soil moisture, from ASAR radar satellite data
- Morphometric parameters (wetness index, slope, curvature, terrain ruggedness, etc) from ASTER digital elevation model.

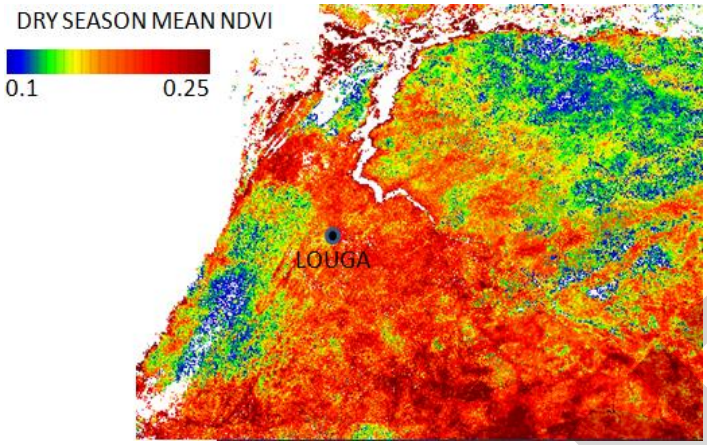

Figure 4 - Mean NDVI Vegetation Index in dry season (2012)

Spatialisation of hydrogeological data and identification of suitable zones for manual drilling

In this final step the relation between hydrogeological parameters and environmental indirect variables have been studied with a multivariate statistical approach. This has allowed to find a reliable combination of variables to predict shallow hydrogeological parameters across the whole study area, and is leading us to identify those zones which are suitable for manual drilling, as well as estimate the feasibility of this technique and the potential for exploitation

Results achieved

At this moment a series of maps (like the example in figure 5) have been produced with the calculation of different hydrogeological parameters at borehole logs position (depth to groundwater, depth to hard rock, average K and average transmissivity in exploitable layers, thickness of laterite) and the estimation of feasibility and potential for manual drilling (figure 6).

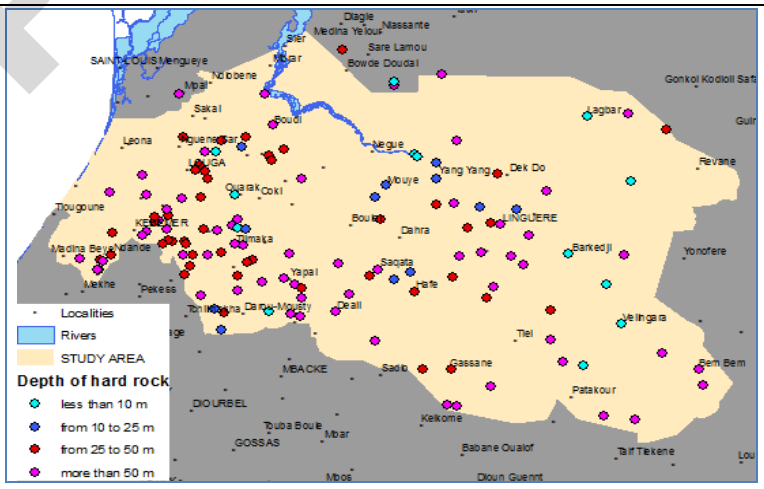

Figure 5. Map of depth of hard rock at borehole position

The multivariate statistical model of interpretation is under validation, and the final complete maps of suitability for manual drilling will be delivered before the end of the project (may 2015).

In the meantime the specific software designed to elaborate borehole logs data has been completed and applied in two different database of codified stratigraphic data in Senegal (approximately 200 logs) and Guinea (170). This tool has been presented to the institutions involved in groundwater management in Senegal.

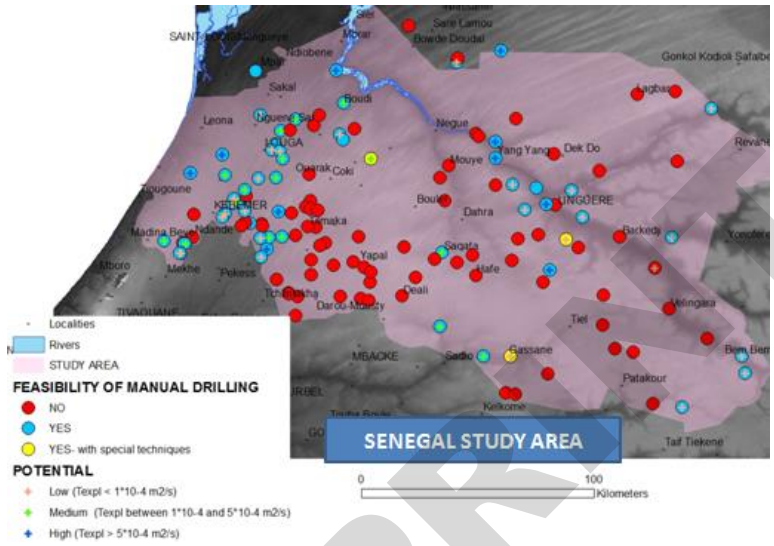

Figure 6 - Feasibility and potential for manual drilling at borehole position

Lessons learnt and conclusion

This study allowed us to carry out a semi-automatic procedure of analysis of stratigraphic information through a well-structured method of organization, codification and processing of existing borehole logs data. This activity has been completed on a sample of 200 borehole logs data of Louga region. However, a large amount of data are available in the whole country (the national database at DGPRE contains a detailed description of 1419 stratigraphic logs, but many more are available on hard copy in the regional branches of the National Water Authority). The extension of the process of data processing using Tangafric to the whole country would provide an important layer of information for the exploitation and management of groundwater. For this reason, DPRGE and UNICEF have shown interest in the application of this tool in other areas of Senegal and a regional workshop to present the results in West Africa is planned in April 2015.

Concerning the application of the proposed method to identify suitable zones for manual drilling through the integration of different layers of information, it is important to underline that all the type of data used in this study are available free of cost from national institutions (database of water points and stratigraphic logs, thematic maps), from international organizations (radar data) or directly donloadable from the web (optical satellite images and digital elevation model). Therefore, the same approach can be extended easily to other regions. This study can be considered a suitable model for shallow hydrogeology interpretation to support the program to promote manual drilling implemented in several countries.

In the next few years manual drilling is expected to spread in several countries. Various international organizations and funding agencies are committed to support this process; for example UNICEF and its partners (PRACTICA, SKAT, RWSN) are running an important technical assistance program to create a high professional manual drilling sector in many countries in Western and Central Africa (Central African Republic, Togo, Mauritania, Mali, Ivory Coast, Guinea, Niger, Nigeria, DRC) funded by DGIS, DFID and other donors.Figure formats.

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