QUANTITATIVE GROUNDWATER ZONING OF THE HAOUZ AQUIFER (MOROCCO)

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ABSTRACT

Groundwater zoning is one of the techniques used for groundwater protection. It aims to analyze the quantitative status of the groundwater resources and identify different zones regarding their degree of degradation. The quantitative zoning could be of great interest in areas characterized by water scarcity and increasing pressure on groundwater. It is impulsed by the need to protect groundwater resources against deterioration due to anthropogenic activities. The applied approach herein is hydrogeologically based. To obtain the groundwater quantitative zoning map of the Haouz aquifer (Morocco), four parameters are combined, namely groundwater depth, interannual groundwater decrease, current rate of groundwater decrease and aquifer thickness. The resulting map shows three main zones: one is heavily depleted, the second is overexploited and the third is the less affected zone.

Keywords: Groundwater zoning, overexploitation, semi-arid climate, management

1 INTRODUCTION

Groundwater zoning is one of the techniques used for groundwater protection both in term of quantity and quality (Vsevolozhskii et al., 2003; Neil et al., 2009; Saravanan et al. 2011). If the zoning for groundwater quality protection is widely used in terms of vulnerability maps and wellheads protection areas, the quantitative zoning is less developed. The latter aims to analyze the quantitative status of the groundwater resources and to identify different zones regarding their degree of degradation. The quantitative zoning could be of great interest in areas characterized by water scarcity and increasing pressure on groundwater.

The example of the Haouz basin, one of the most important agricultural regions of Morocco, illustrates these aspects and addresses the problem of the field implementation of specific areas for quantitative protection of the groundwater resources.

2 PRESENTATION OF THE HAOUZ BASIN

The Haouz basin (Fig. 1), with an area of 6000 km^2, contains the most important plain in the Tensift basin. The climate is semi-arid, characterized by low rainfall (~250 mm/year) and high evaporative demand (~1400 mm/year). The plain includes the city of Marrakech with about 1 million inhabitants and receives 2 million tourists per year. It contains important agricultural lands extended over 170000 ha producing mainly olives, citrus fruits and cereals.

The Haouz basin is part of a tectonic depression, filled of siliciclastic deposits (alluvial fans, fluviatile formations, etc.) of Neogene and Quaternary age. These sediments are brought from the High-Atlas Mountains by several rivers crossing the basin from south to north. The groundwater is provided by the unconfined aquifer of the Haouz. The later is heterogeneous because of the variability of the alluvial deposits. The groundwater has generally good quality. The groundwater recharge is supplied by rain and rivers. The frequency of droughts has caused decrease in available surface water, reduction in aquifer's recharge and increase in water withdrawal. The aquifer of the Haouz is currently under heavy exploitation.

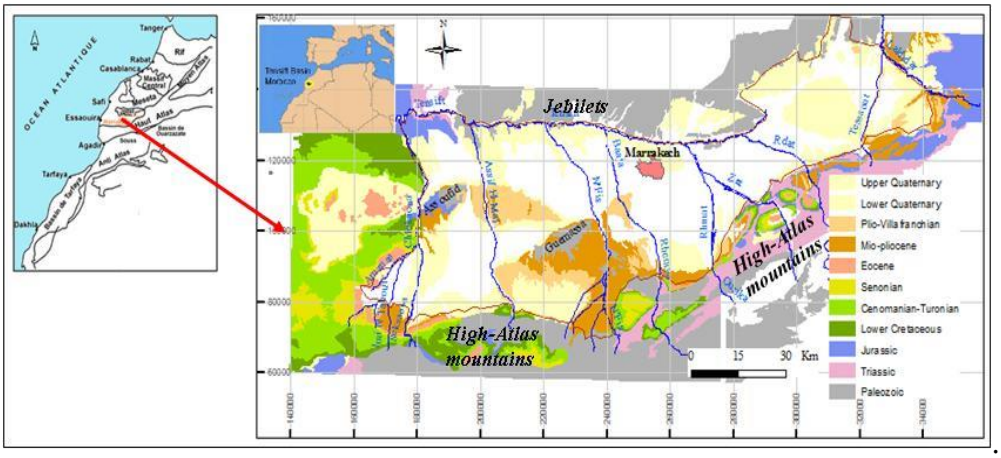

Figure 1. Location and geologic map of the Haouz

3 QUANTITATIVE ZONING OF THE HAOUZ AQUIFER

3.1 Legal framework

In Morocco, the delineation of specific zones where groundwater exploitation must be limited or prohibited is announced in the Article 16 of the Water Law n° 10-95 (adopted in July 1995). The Articles 49 and 50 respectively define the zones of limitation and prohibition of groundwater pumping. The regulation stipulates that:

- "protection zones" where groundwater abstraction has to be limited, should be delineated in areas where the amount of withdrawals begins to affect the groundwater balance. Any abstraction of groundwater in these areas should be subject to prior authorization, whatever the volume to be withdrawn;
- "prohibition zones" should be defined by decree, in areas affected by overexploitation or degradation. Since the date of the publication of the decree, no authorization or concession may be delivered, except for the cases of human or livestock water supply.

3.2 Mapping of criteria used for zoning

The selected criteria used for the groundwater zoning of the Haouz aquifer are:

- Groundwater depth (m): three thresholds were fixed, including the one at 40 m depth fixing the depth at which no drilling authorization is requested (according to the Decree of the Minister of Equipment No. 1556-1502 of 17 October 2002).
- Interannual groundwater decrease (m): it is assessed as the difference between the current statement (represened by the 2008 piezometric map) and the reference statement of 1971 (represened by the 1971 piezometric map).
- Current rate of groundwater decrease (m): it measures the mean annual declining rate of groundwater, recorded by the piezometric monitoring during the last dry period from 1998 to 2008. This parameter point out the areas that are currently very affected by overexploitation.
- Aquifer thickness (m): it gives an indication on the distribution of groundwater reserves. It is calculated from the piezometric map of 2008. The areas with low groundwater thickness could be degraded more rapidly than the ones with high groundwater thickness.

The thematic maps elaborated according to these criteria are presented below (Fig. 2, 3, 4).

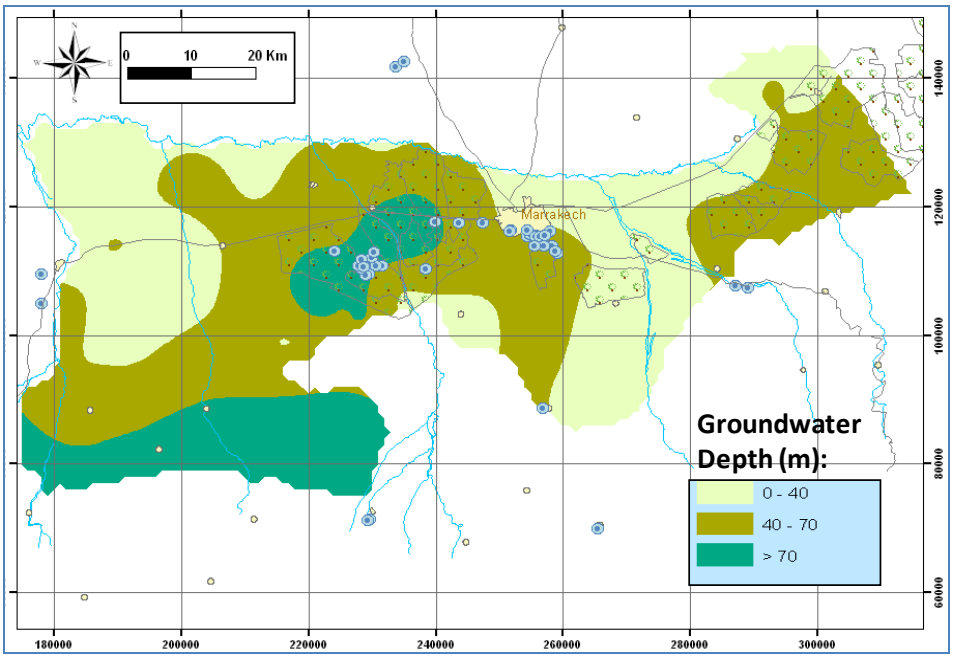

Figure 2. Groundwater depth of the Haouz aquifer, 2008

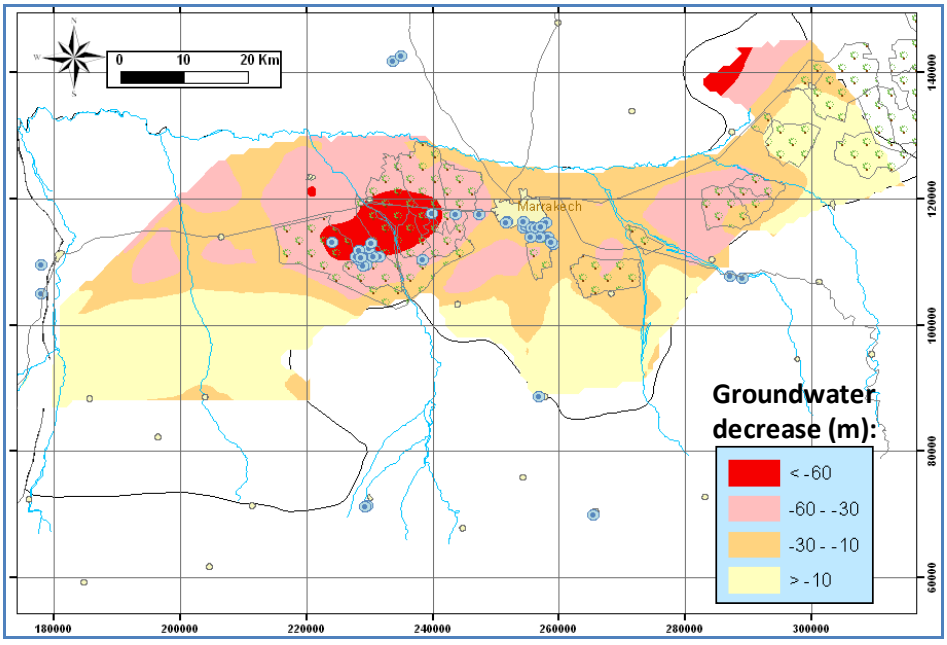

Figure 3. Groundwater decrease between 1971 to 2008

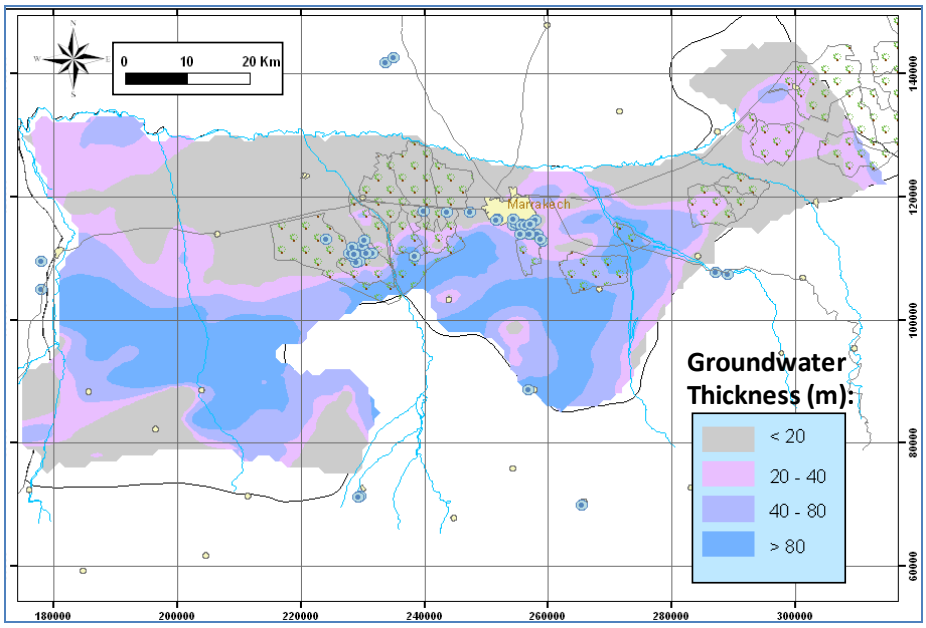

Figure 4. The Haouz aquifer thickness, 2008

4 GROUNDWATER ZONING MAP

A based GIS map is obtained as a result of overlaying the previous thematic maps (Fig. 5).

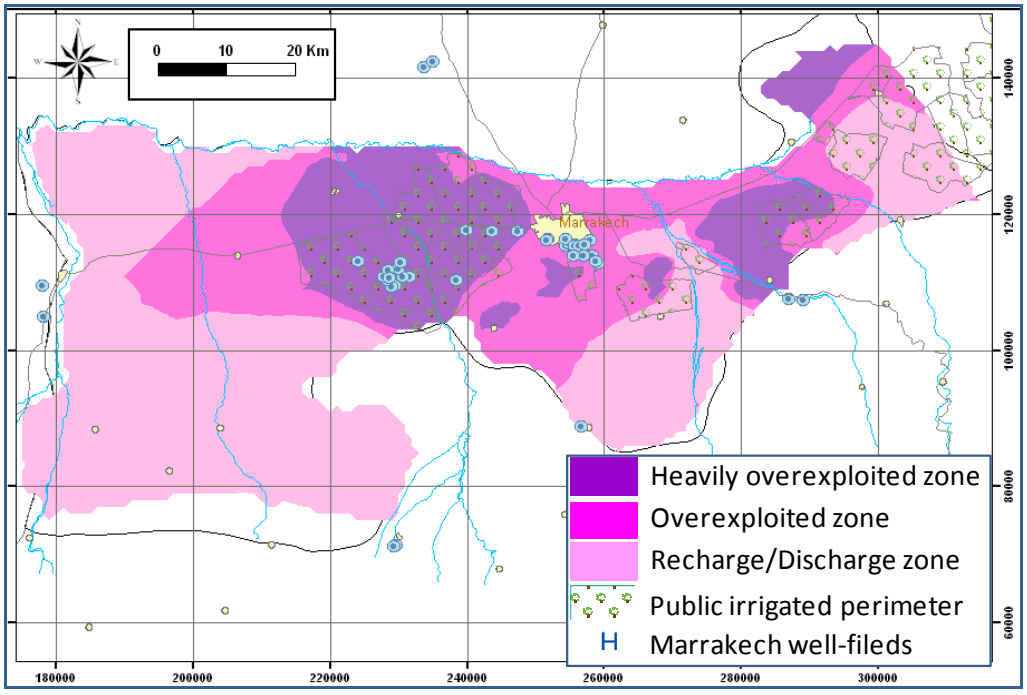

Figure 5. Groundwater zoning map

Three main zones are identified :

i) Heavily depleted zone characterized by:

- groundwater depth is higher than 40m and exceeds 70m in certain sectors ;
- interannual groundwater decrease is excessive (more than 60m);

- current rate of groundwater decrease is alarming, greater than or equal to 2 m/year;
- aquifer thickness is small (less than 20m).

This area could be considered as "prohibition zone". Measures of groundwater resources replenishment should be applied.

ii) Overexploited zone characterised by :

- groundwater depth is generally around 40m ;
- interannual groundwater decrease is high, between 10m to 30m ;
- current rate of groundwater decrease is greater than or equal to 1m/year but do not exceed 2m/year ;
- aquifer thickness varies between 20m and 40m.

In this area, the growing pressure of pumping endangers existing water resources. If we adopt strict groundwater protection rules, this area could be considered as a prohibited area. However, considering the large extension of this zone, this decision should nevertheless take into account the socio-economic interests in the Haouz plain. For instance, the area could be considered as a "protection zone". The groundwater evolution should be controlled as well as the groundwater abstraction.

iii) Zone that is less affected :

- groundwater depth is heterogeneous, from low to high ;
- interannual groundwater decrease is lower than 10m ;
- current rate of groundwater decrease is lower than 1m/year ;
- high aquifer thickness, more than 40m and can exceed 80m in some areas.

However this potentially important area in terms of groundwater resources has in some sectors an annual groundwater declining rate around 1m/year. An increasing pumping activity is being developed within the area, supplying irrigation and also growing tourism activity. This zone contains the aquifer recharge area and should be set under control.

5 PROBLEMS FACING THE FIELD IMPLEMENTATION OF THE GROUNDWATER ZONING

In the Haouz plain, the heavily overexploited zone lies on the public irrigation perimeter of N'Fis which contains a highly developed agricultural infrastructure and well-fileds of Marrakech city. In this zone, it is not question of only prohibiting new pumping but also reducing the existing pumping because of the excessive groundwater depletion. However, the current agricultural activity has not only developed on irrigation by surface water from the dams but also and especially by groundwater. This is due to the frequency of droughts in the last decades and the groundwater is intensely used to palliate the lack of surface water. Indeed, in the plain of the Haouz, groundwater pumping has settled and multiplied for over 40 years. The groundwater presently is exploited by more than 24000 pumping wells, withdrawing around 300-400 106 m^3/year (Fakir et al. 2010).

Prohibiting new pumping or reducing the existing ones in such conditions is very difficult to implement and control within the Haouz plain. The elaborated zoning shows the reality of the groundwater resources status. However, as reported in several studies and experiences, sustainable management of groundwater is more a political than a technical issue (Allan, 2003). One of the main mitigation tracks is to involve farmers in the management of the groundwater in the framework of an Aquifer Contract between groundwater stakeholders (Le Page et al. 2012).

REFERENCES

[1]. Allan, J. A. (2003) Integrated water resources management is more a political than a technical challenge. *Developments in Water Science*, 50, pp. 9–23.

[2]. Fakir, Y., Berjamy, B., Tilborg, H., Huber, M., Wolfer, J., Le Page, M., Abourida, A. (2010) Development of a decision support system for water management in the Haouz-Mejjate plain (Tensift basin – Morocco). *XXXVIIII Congress of the International Association of Hydrogeologists (IAH)*, Krakow, Poland.

[3]. Nel, J., Xu, Y., Batelaan, O., Brendonck, L. (2009) Benefit and Implementation of Groundwater Protection Zoning in South Africa. *Water Resources Management*, 23 (14), pp. 2895-2911, DOI: 10.1007/s11269-009-9415-4

[4]. Saravanan, R., Balamurugan, R., Karthikeyan, M.S., Rajkumar, R., Anuthaman, N.G., Navaneetha Gopalakrishnan, A., (2011) Groundwater modeling and demarcation of groundwater protection zones for Tirupur Basin - A case study. *Journal of Hydro-environment Research* 5, pp. 197-212.

[5]. Vsevolozhskii, V. A., Kochetkova, R. P., Fidelli, I. F., (2003) Principles of Hydrogeological Zoning by the Conditions of Formation and the Distribution of the Natural Resources of Fresh Groundwater. *Water Resources*, 30 (3), pp. 233-245, DOI: 10.1023/A:1023828710692