Groundwater management in the middle Drâa-River basin (South-Morocco)

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Summary
The increasing number of irrigation pumps enhances the local progressive trend of the groundwater drawdown in the middle Drâa basin. Additionally a complex coaction of evapotranspiration processes, infiltration of high mineralized run-off water, re-infiltration of irrigation water and the intensification of agriculture is responsible for the observed changes in the groundwater quality. This situation leads to the need of alternative strategies for sustainable resource management. Thus differentiated and applicable strategies for water use and the essential input data for groundwater modelling are provided by an interdisciplinary study. Objects of the current research are the hydrogeological setting, the pedological situation and the water consumption for irrigation and domestic use. First results show a negative groundwater balance (Feija area: -1.3 Mm^3/a) and locally increasing salinity.

Résumé
Un nombre croissant des pompages pour l'irrigation renforce la tendance de diminution de la réserve d'eau souterraine dans la bassin versant moyen du Drâa. Additionnelle, un interaction complexe d'evapotranspiration, d'infiltration de l'eau superficielle fortement minéralisée, re-infiltration de l'eau d'irrigation et l'intensification de l'agriculture est responsable pour des changements de la qualité de l'eau souterrain observé. De cette situation, la nécessité des stratégies alternatives pour l'aménagement durable des ressources se dérive. Donc les stratégies différenciés et applicables pour l'usage d'eau et les paramètres intrants essentiels pour la modélisation d'écoulement souterrain sont préparées par une recherche interdisciplinaire. Le contenu de la recherche actuelle sont la situation hydrogéologique, l'état pédologique et la prélèvement pour l'irrigation et l'usage domestique. Premiers résultats montrent une bilan de la nappe négative (bassin de Feija : -1.3 Mm^3/a) et une croissance locale de salinité.

Introduction
This work is part of the IMPETUS project in the framework of the GLOWA program. IMPETUS is a multidisciplinary project for the sustainable management of water resources in West-Africa. The second phase of this project (2003-2006) intends the modelling of the likely changes in water resources and soil degradation up to the year 2020 regarding different scenarios. In this context the groundwater quantity and quality in the Drâa river basin is observed and the local groundwater flow is modelled using MODFLOW.
This study aims to develop options for integrated strategies of the groundwater use on the local and sub-regional scale. It focuses on the influences of the groundwater withdrawal especially for irrigation and hence the problem of increasing salinity in the middle Drâa river basin.

Materials and Methods
An integrated hydrogeological mapping is chosen as the principal approach. This interdisciplinary research provides differentiated and implementable strategies for water use and the essential input data for groundwater modelling.

The hydrogeological setting is investigated by field observations, measurements of hydraulic heads, pumping tests and the analysis of groundwater samples. At the same time the pedological state is surveyed. Additional observations of the withdrawal for irrigation and domestic use are carried out. The climate data and other necessary data are provided by the other working groups of IMPETUS and Moroccan partners.
Further analysis and evaluation are based on maps (groundwater contour maps etc.) generated with a geographical information system.

Results

As typical example for the middle Drâa-River catchment the sub-basin of Zagora is chosen. The geological setting shows a pre-variscian basin structure crossed by faults. The filling of this basin consists of neogenic alluvial and lacustrine sediments (AOUBOUAZZA & MEKNASSI, 1996). The vegetation is dominated by the *Acacia raddiana* steppe in the plains and the *Hammada scoparia* steppe on the pediments and rocky hill sites (FINCKH & STAUDINGER, 2002). Wherever silty deposits occur agriculture takes place which is based on irrigation by pumping wells. The water supply for the city Zagora and other villages is derives from several municipal wells combined with cisterns and numerous private wells. The hydrogeological setting is characterised by sparse rain fall (mean: 63 mm/a) and thus limited pluvial aquifer recharge as well as a rare lateral groundwater afflux (CHAMAYOU, 1966; AOUBOUAZZA & MEKNASSI, 1996; DIRECTION DE LA REGION HYDRAULIQUE D'AGADIR DE SOUSS-MASSA ET DRÂA, 1998). The general trend of the hydraulic heads is declining since 1996. One important feature is the municipal regulated episodic run-off in the Drâa-River.
Quaternary fluvial deposits connected with a sub-layer of palaeozoic weathered shales build the upper aquifer (Fig. 1). The boundary conditions are given by Cambrian and Ordovician quartzites. The hydraulic parameters are varying locally and depending on the occurrence of different geological units. In general this upper aquifer features a mean transmissivity around $3*10^{-4}$ m/s and a mean storage coefficient around $2*10^{-5}$ (AOUBOUAZZA & MEKNASSI, 1996). Current aquifer tests validate this value for the mean transmissivity.

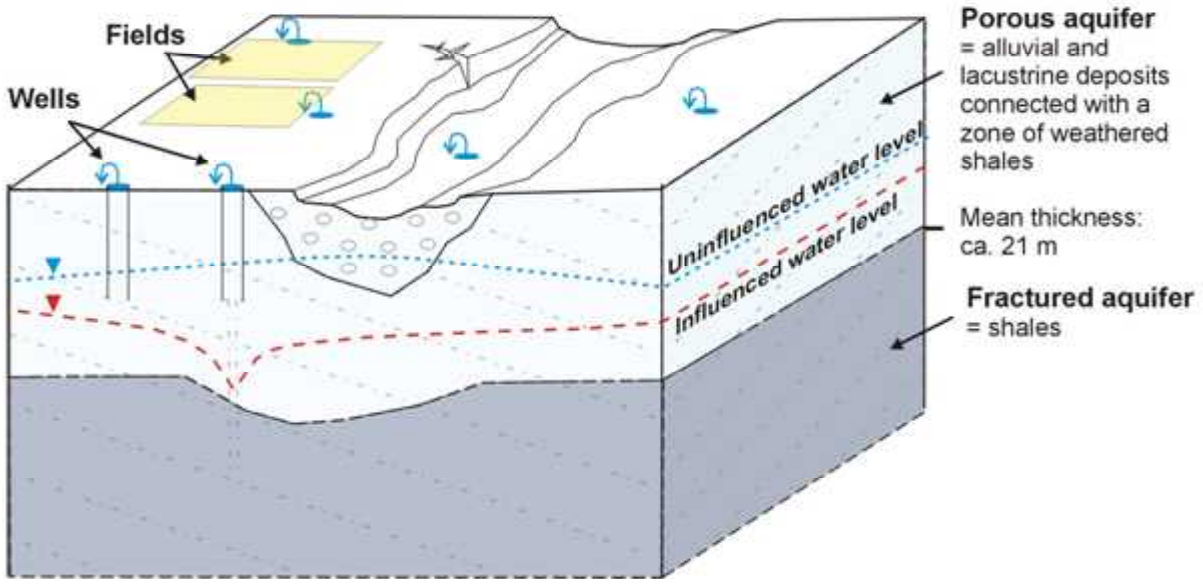

Fig. 1: Simplified hydrogeological conceptual model of the Zagora area.

The groundwater level exhibits a sinking trend since the year 1996 (oral advice: FILALI,

2005). The increasing number of irrigation pumps enhances this local progressive trend of the groundwater drawdown. Current studies in the Feija area assess an overexploitation of the groundwater resources. An estimated groundwater balance neglecting the consumption of the private dug wells displays a negative value (Tab. 1).

Tab. 1: Estimated negative groundwater balance for the Feija area (including data from *AOUBOUAZZA & MEKNASSI, 1996; **ZAINABI & AIT ICHOUL., 1998).

Recharge Mm³/a	
Rain Infiltration*	2.87
Lateral afflux*	0.74
Artificial recharge by irrigation water	0.11
Total	3.72

Discharge Mm³/a	
Evaporation*	0.40
Min. withdrawal by private pumping wells (Q Feija)	3.60
Withdrawal for the water supply of Zagora*	1.00
Total	5.00
Balance Mm³/a	-1.28

Re-Estimation of withdrawal by private pumping wells and artificial recharge by irrigation

Q pumping well	**l/s**	**m³/s**	**m³/h**	**m³/d** (pumping time = 4 h)	**m³/a**
min	4	0.004	14.4	57.6	21,024
max	6	0.006	21.6	86.4	31,536

Q Feija	**m³/a**	**Mm³/a**	**number of pumps in the Feija ****	**artificial recharge** (infiltration coeffincient = 2%*)
min	3,595,104	3.60	171	0.07
max	5,392,656	5.39		0.11

The steady state groundwater flow in the upper aquifer is modelled with MODFLOW. Simulations are calculated in consideration to different climate and withdrawal scenarios.

The hydrochemical characterisation shows different types of groundwater and gives clues of different local influences on groundwater quality. A complex coaction of evapotranspiration processes, infiltration of high mineralized run-off water, re-infiltration of irrigation water and the intensification of agriculture is responsible for the observed salinity of the groundwater (Fig. 2).

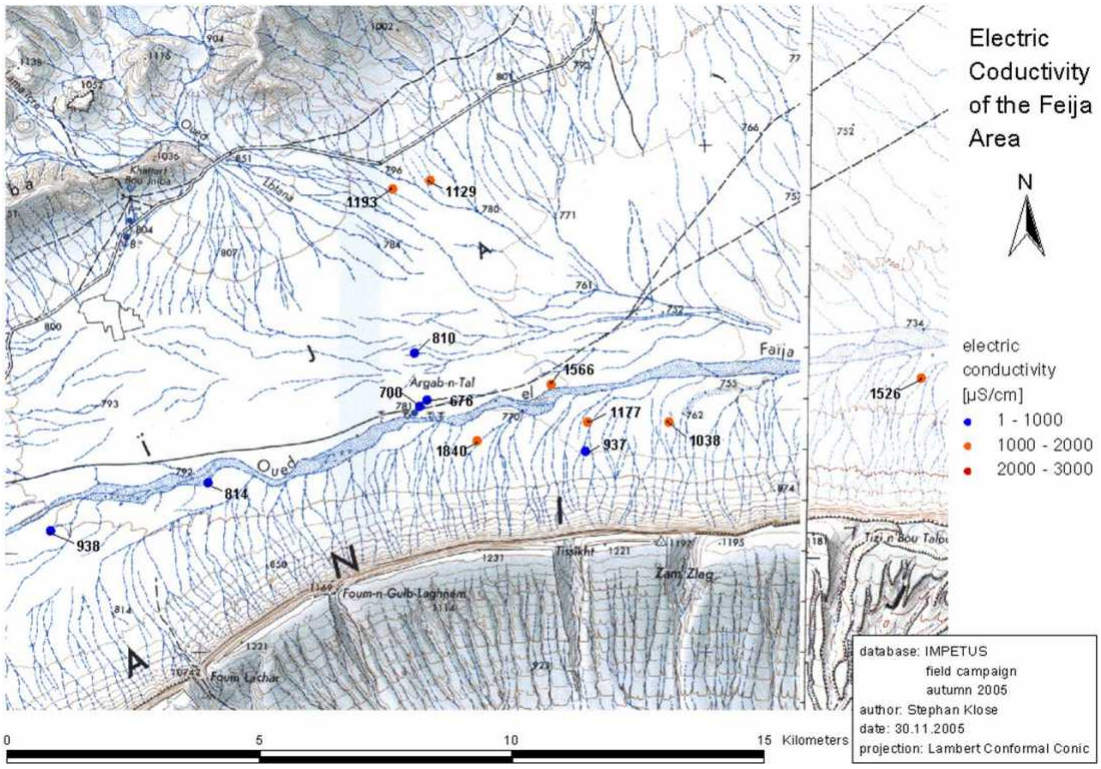

Fig. 2: Distribution of the electric conductivity in the groundwater in the Feija area autumn 2005.

Discussion and conclusion

The complex balances of the groundwater quantity and quality are carried out to support local decision makers and private consumers.

The synoptical interpretation of both the modelling results and the hydrochemical analysis have been used to estimate and discuss possibilities of artificial groundwater recharge and alterative irrigation as well as the need of strategies for groundwater protection.

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