M. Chevalier

Title of project and place of implementation:

Knowledge transfer on groundwater detection: An opportunity to guarantee the accessibility to groundwater resources for southern and northern hemisfere of Africa using the last generation NMR tecniques (Nuclear Magnetic Ressonance). Western Kilimanjaro region (Tanzania), Northern Etoscha region (Namibia) and Jendouba region (North-Western of Tunisia).

Dates of implementation of the project:

Commencement date: March 2012

Termination date December 2013

Type of assistance requested:

Type of assistance	Implementation by UNESCO programme sectors, services concerned or field offices	Implementation by the beneficiary **Financial contribution (in US $)**
Specialists and consultants – not including staff costs	❑	
Study grants and fellowships	❑	
Publications, periodicals, documentation, translation, reproduction	❑	
Supplies and equipment (other than vehicles)	**X**	33704,43
Conferences, meetings, translation & interpretation services, participants' travel costs and any other services deemed necessary by common accord (not including those of UNESCO staff members)	❑	
Seminars and training courses	❑	
	Total	Total 33704,43

Contribution from the ~~Member State or~~ INGO in US $: 47378,76

(a) Description of the **project**:

A.0 Main goal

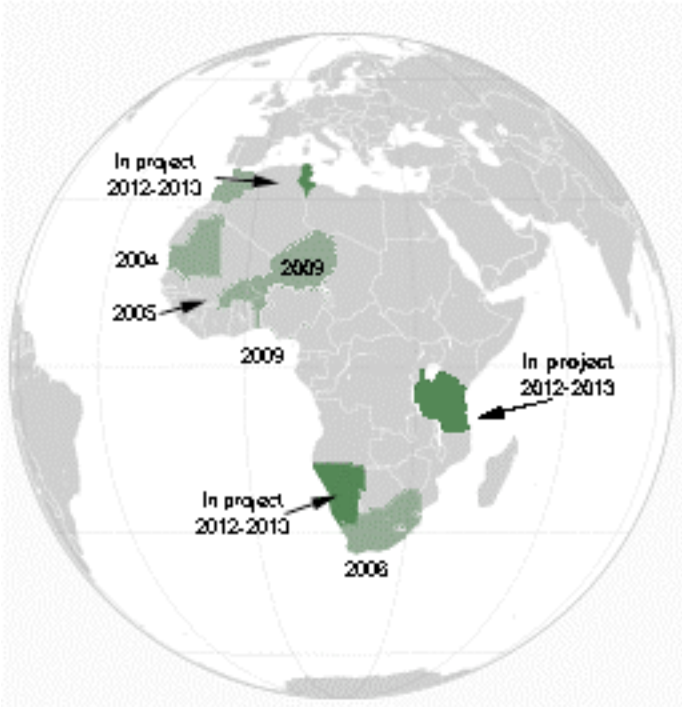
Water accessibility is a limiting factor for the development of a region. In Africa that can be challenged with a better knowledge of groundwater resources. Knowledge transference on groundwater findings to local associations, communities and administration is the aim of that project. Recently a new technology has been developed in Europe and the USA known as "Surface-Nuclear Magnetic Resonance" (SNMR). Few recent experience in central Africa and one at South Africa are known, encouraging us to apply it on distant places of Africa. The SNMR technology works with the Earth's magnetic field, so some particularities happen with side to side from the equator due to differences on the Earth's magnetic gradient. The peculiar geographical position of Africa is important to study the potentials of the SNMR technology in three extreme cases, one on the northern hemisphere (Tunisia), two on the southern hemisphere (Namibia and Tanzania). Comparative study will be done to see the limitations and advantages of that technique in Africa, the ability to optimize costs on water surveying, how SNMR technology can decrease the risk of dry wells drilling and help the decision makers about groundwater resources & policy. For that, local groundawater exploration industry (in Namibia), agriculture (Tanzania) and local groundwater-based agriculture associations and groundwater scientists (in Tunisia) are interested to test in place the SNMR technology to see the possibilities of its implementation. Also Governamental departments related to water resources in Namibia and the agriculture industry in Tunisia are interested to learn about such a novel SNMR technique for groundwater surveying. Once the experiences have been done, a final report will be writen: a practical guideline explaining the possibilities and limitations of SNMR technique in Africa.

A.1 Technology and industry :

Surface nuclear magnetic resonance is a non-invasive groundwater-exploration method that allows a direct determination of the water content and eventually the estimation of discharge. The very first Magnetic Resonance Soundings (MRS) were carried out between 1979 and 1981. Since 1982 the method was already used in the USSR for practical purposes and intensively tested in different geological settings and in different countries. The fall of the Berlin wall in 1990 and the end of the USSR in 1992 provides to the western Europe a brain gain from eastern Europe and the knowledge about MRS was firstly fixed in France by the BRGM (Bureau de Recherches Géologiques et Minières). The joint venture between BRGM and OYO corporation (Japaneese instrumental factory for ground studies) built Iris-Instruments factory on Orléans (France), with the objective to commercialize generic BRGM geophysical devices and develop a commercial version of the MRS device. The arrival of this new geophysical method initiated intensive scientific discussions and exchange of experience. In 1996 a new generation of equipments became commercially available and Iris-Instruments was the only one factory on the world to comercialize MRS devices for groundwater exploration since 2006. On that year the American Vista-Clara Co. introduced the multi-channel surface NMR instrumentation (GeoMRI) and quickly (in 2009) a seccond generation of handly transportable devices (know as GMR) have become commercial from USA. Beside of traditional geophysical meetings these exchanges are occuring through specialized International workshops: Berlin, 1999; Orléans, 2003; Madrid, 2006; Grénoble 2009 and next one will be take in Germany at the end of September 2012. Nowadays the number of MRS users is continually increasing in EU and USA, because the two only factories in the world (Iris-Instruments & Vista-Clara) are on those regions, but for African countries the accessibility to the MRS technique is not easy. This project tries to challenge the dichotomy between developed country and developing countries related to the accessibility to the groundwater tecnologies and to water accessibiilty.

A.2 The MRS technique and experience:

While the efficiency of the MRS applied to groundwater related studies is already proved in developed counties, only few experiences were carried out in Africa: Mauritania, Marocco and Western Sahara (2004), Burkina Faso (2005), South Africa (2006), Niger and Benin (2009). As has been explained before the MRS technique use the natural Earth's magnetic field to energize the free hydrogen atoms in the nature, and in nature, only water and hydrocarbons molecules have such free hydrogen atoms, so in theory if any NMR signal is detected, that would be originated mostly from water (river, lake, reservoir, groundwater). The Magnetic Resonance Sounding (MRS) technique is specially designed to detect groundwater, in which the possible water molecules are energized by pulses of alternating current at the proper frequency (Larmor frequency) transmitted into a loop laid on the ground. The information obtained allows to detect the water content at different depth and the mean pore size, both parameters useful to determine the prospects of a groundwater reservoir BEFORE DRILLING.



During the acquisition the operator, using the PC, monitors the NMR signal curve (the envelop of the proton response, which is an exponentially decaying curve), and the background electromagnetic noise curve stacked in the same conditions as the NMR groundwater signal curve. The theory states that the investigation depth of a measurment varies with the moment of the excitation pulse (product of the intensity of current in the loop at the Larmor frequency by the pulse duration). It is therefore possible to sound the ground, the aim of the MRS technique, with surface NMR measurments. Besides, it can be shown that the decay time constant of the relaxation field is related to the pore size, which potencially permits to distinguish between pore free water and clay bound water.

For interpreting MRS data it is assumed that the underground is stratified at the scale of the loop dimensions. For inverting a set of field data it is first necessary to compute a matrix giving the theoretical response of thin water layers located at various depths. This matrix will take into account the general configuration of the measurements: loop dimension, Earth’s field inclination, ground electrical resistivity, and total moment of pulses. The inversion procedure, which requires noise filtering and regularisation parameters, is performed to solve the water content equivalences, because the same field signal can be obtained with different water contents and aquifer thicknesses. So it is important to know the geology previously.

A.3 MRS versus other geophysical techniques:

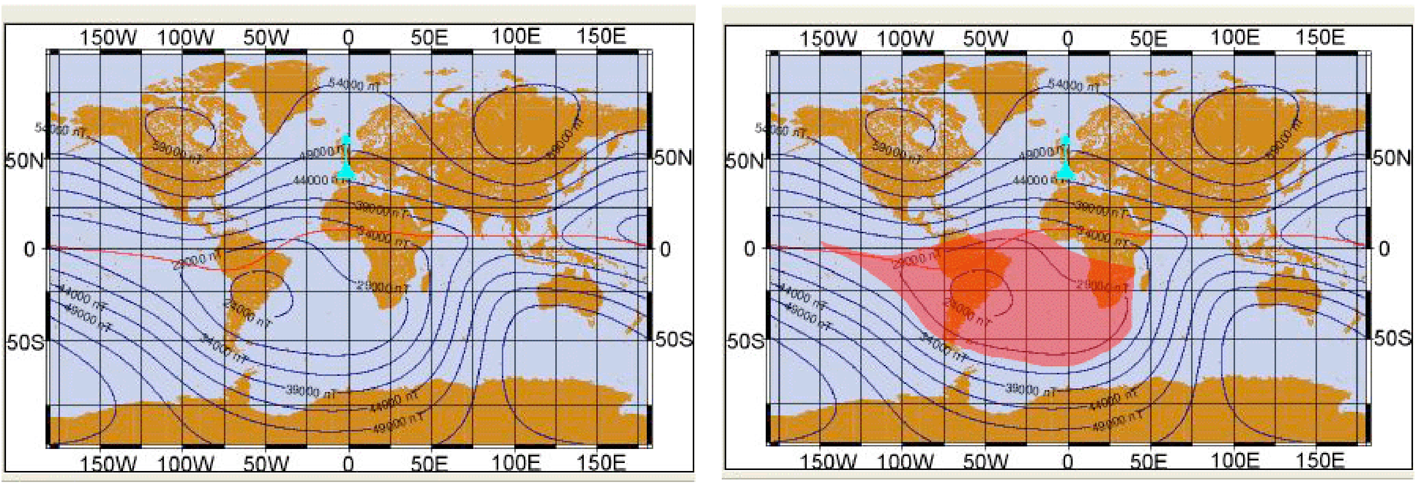
Some traditional methods have more than one century of exprience (electrical resistivity measurements) but they are classified as “indirect methods” because they measure a physical property linked to the probable presence of an aquifer, but can’t detect the aquifer itself. Only in extreme cases related with high contaminated water or brine (salty water) it is possible to detect it. On the other hand, the MRS technique has less than twenty years experience outside the ancient USSR and is classified as a “direct method”, because it detects directly the response of the water (H+ protons) to a electromagnetic exciting pulse. So this method guarantees the existence or not of an aquifer while traditional methods cannot.

The non linearity behaviour between the measured signal and the energizing pulse intensity is a particularity of SNMR physics, so it means that doubling the pulse current does not mean doubling the signal amplitude: instead it increases the depth of investigation for the same Earth’s magnetic field. Nevertheless the signal is linearly related to the water content of the layers, which makes the interpretation quite quick.

In Namibia for example it has been demonstrated that applying only the traditional method a success rate of less than 36% and up to 25% was achieved in the drilling (see next A.5 section of previous knowledge).

A.4 The Earth’s magnetic field and MRS equipments

Two commercial MRS devices are available. A Numis system from Iris-Instruments and a GMR system from Vista-Clara. The Numis system offers now two products, a light Numis Lite device that can survey up to 60 m depth and a heavy MRS device, the Numis Poly which can survey more than 150 m depth. The last one is equivalent to the Vista-Clara’s device, but GMR represents a technological leap. Both systems can be specificaly configurated for places where the Earth’s magnetic field is low (lower than 31,000 nT). In theory the light device, Numis Lite, can operate also in low Earth’s magnetic field by increassing the loop area, then exciting more amounts of water, and consequently an increased signal could be obtained.



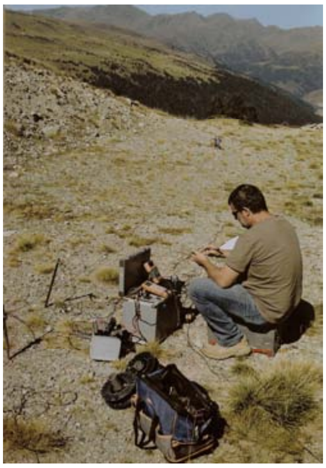
Earth’s magnetic field distribution in nano Tesla (nT), shaded zone corresponds to low magnetic field. Note that all Southern Africa (Namibia included) is charaterized by less than 31,000nT.

A.5 The SNMR hydrogeophysical survey

Two phases are needed for a hydrogeophysical campaign. First, traditional techniques are needed to characterize indirectly the subsurface geology. Usually, the availability of electrical resistivity data of the investigation area is helpful to accomplish the second study phase. In situ Earth's magnetic field and magnetic susceptibility background from surrounding rocks are also highly recommended. Previous electromagnetic noise measurements reduce final loop installation time. Secondly the MRS survey can be done using one of the three commercial instruments. So, the standard equipment we should have the devices listed on Table 1:

Phase 1				Phase 2
Resistivity data	Earth's magnetic field	Magnetic Susceptibility	Electromagnetic noise	MRS
VES	Magnetometer	Susceptibility meter	Reduced MRS antenna	GMR or Numis

Table 1: Devices needed for a full complete hydrogeophysical SNMR survey.



VES device

Proton magnetometer device

Reduced MRS antenna

MRS device (Numis Lite system)

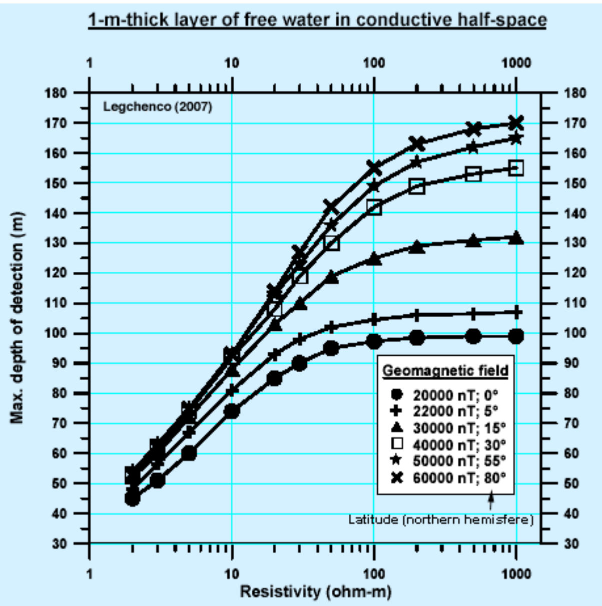
Field basics (Schmidt hammer, GPS, compass, magnetic susceptibilimity meter)

A.6 Specific problems to solve with SNMR

* Trust in science and in scientific methods to detect groundwater.
* Technological knowledge transfer to local groundwater industry, communities and departments.
* The risk of groundwater development without specific studies, the risk of drilling dry wells.
* Accessibility to unknown water supply by local populations.
* Groundwater flow, recharge and discharge.
* Groundwater overexploitation and pedagogy of a renewable resource, the contamination.
* Good practices guideline on groundwater exploration with geophysics.

A.7 Specific problems to test SNMR in Africa

* Which procedure should be taken to investigate in areas with low magnetic Earth's field?
* What will be the depth limitations in different geological contexts and low resistivities (Namibia)?
* How to proceed if magnetic rocks are present (Tanzania)?
* What are the prospects of the MRS technique in improving groundwater supplies to the population and agriculture use in North-western Tunisia?



Tunisia

Tanzania

Namibia

Different teorical SNMR detection depht regarding the Earth's magnetic field and the resistivity in the ground. In Tunisia a maximum of 150 m depth is expectect, while a Tanzania and Namibia 130 m depth or less.

A.8 SNMR pilot study in Africa

The pilot study will integrate all the scatered experiences on SNMR done untill now in Africa by different research groups. That previous experience showed us the technical and metodological problems, the device choice and hardware configuration. That is specialy important in the case of Namibia and Tanzania because the low strength of the Earth's magnetic field hapens, while in Tunisia is rather moderate and the study will be valid for mostly al the Arab Maghreb region.

Tanzania

Tanzania covers an area of approximately 945,000 Km^2, of which the Zanzibar Islands cover 2,400 Km^2, is also among the least urbanized countries in Sub-Saharan Africa with a population of 36 million people. Except for the coastal belt and islands, most of the country is part of the Central African Plateau (1,000-1,500 m.a.s.l) characterized by gently sloping plains, broken by scattered hills and low-lying wetlands. Agriculture remains the largest sector in the economy accounting for about half of GDP (Gross Domestic Product) and exports, and 70% of rural incomes. The area of the SNMR pilot study is close to the border with Kenya (Figure 1), in the Kilimanjaro area of Tanzania and close to Moshi town (890 m.a.s.l.), a small market town with an urban population of 150,000 and rural population of 402,400 and It is the regional capital of the Kilimanjaro region. Ideal Coffee crops constitute the most rewarding local export. The upper parts in the slopes of Mt. Kilimanjaro receive 1200-2000 mm rainfall per year, and the rest of the area receive only about 500 mm per year. There are two distinct rainy seasons, the short one from mid October to December and the long one from mid March to June. It includes the Pangani Basin. The main supplies are from surface water (about 95 percent), and the remaining water is taken from groundwater sources. There is a significant amount of groundwater potential compared to the other basins in the country. Irrigation is the main ground water use, which accounts for 80 percent of the total use. The areas most prospective for Groundwater irrigation include Mtware, Coast, Morogoro, uvuma, Shinyanga, Kilimanjaro, Kagera, Lindi, Mwanza and Mbeya due to the dominance of unconsolidated sand and gravels water bearing formations that permit yields and the existence of suitable soil for agricultural crop cultivation.

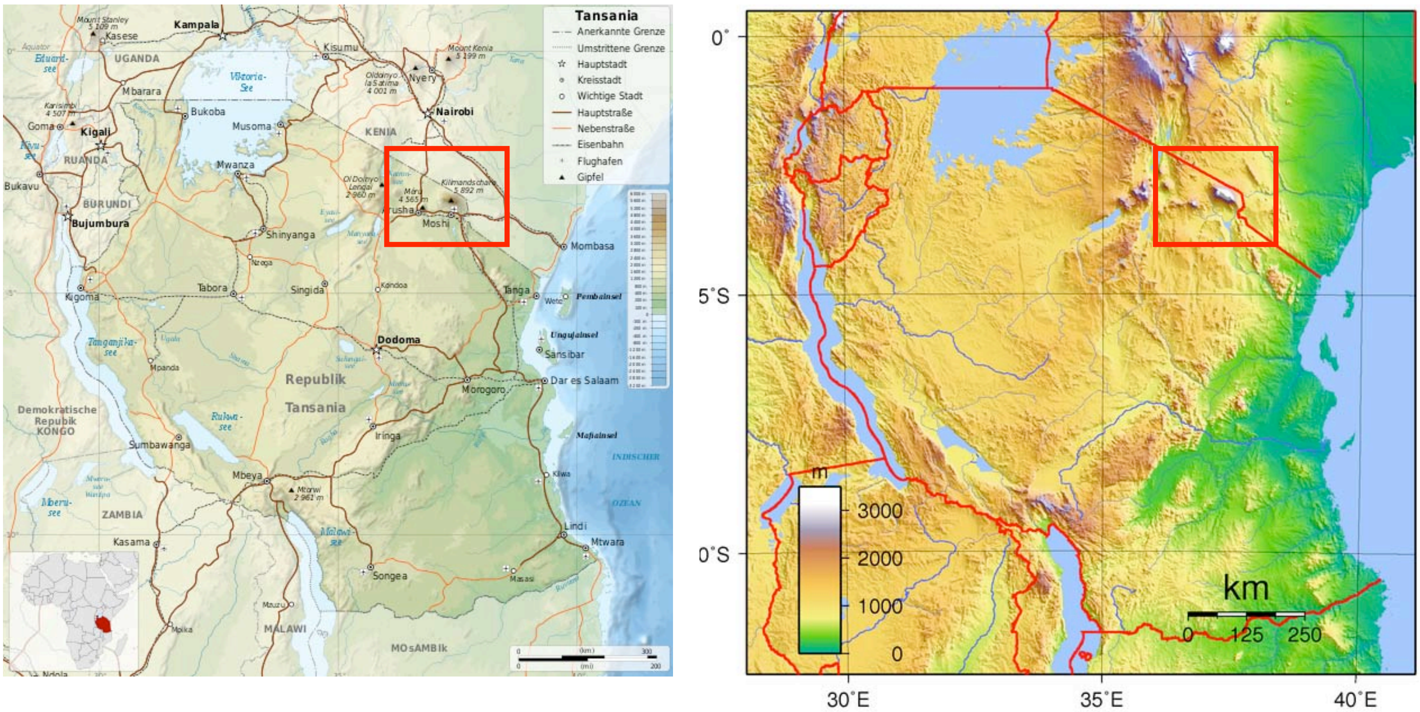


Figure 1: Localisation of the planed SNMR surveying area in Tanzania. The area is close to the Kenia border and on the southern foothill of the Kilimanjaro volcano.

Namibia

With a population of 2.1 million people distributed on thirteen regions (see Figure 2), Namibia has agriculture, herding, tourism and the mining industry. The landscape consists generally of five geographical areas, the Central Plateau, the Namib Desert, the Great Escarpment, the Bushveld and the Kalahari Desert (see Figure 3). The Central Plateau runs from North to South, bordered by the Skeleton Coast to the Northwest, the Namib Desert and its coastal plains to the Southwest, the Orange River to the South, and the Kalahari Desert to the East. Given the presence of the arid Namib Desert, Namibia is the second least densely populated country in the world, after Mongolia. Windhoek, the nation's capital, is located here, as well as most of the arable land. Although arable land accounts for only 1% of Namibia, nearly half of the population is employed in agriculture. The highest point in Namibia (Königstein, 2,606 meters) is in the Central Plateau. The Etoscha pan (Figure 4) is a large endorheic salt pan, forming part of the Kalahari Basin in the North of Namibia, the 120-kilometre-long dry lakebed and its surroundings are protected as Etoscha National Park, one of Namibia's largest wildlife parks. The main SNMR experience will take in the north of Etoscha region, in the Owambo basin and Cuvelai system (Figure 4).

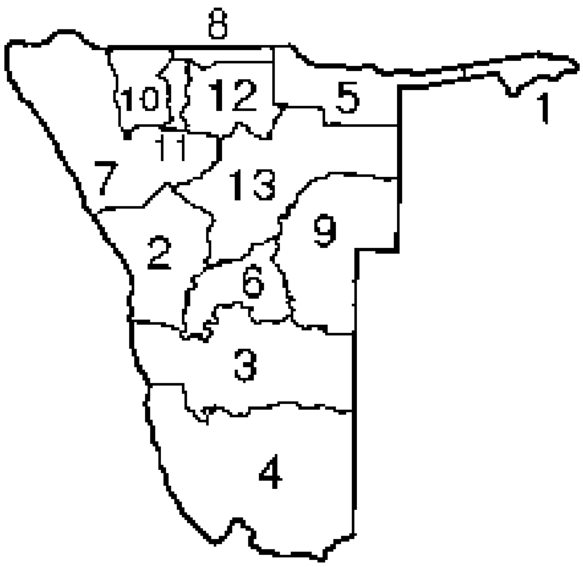


Figure 2 and 3: Cuvelai (1), Erongo (2), Hardap (3), Karas (4), Kavango (5), Khomas (6), Kunene (7), Ohangwena (8), Omaheke (9), Omusati (10), Oshana (11), Oshikoto (12), Otjozondjupa (13). The red square at the north of Namibia and close to the Angola border will be the chosen SNMR surveying area.

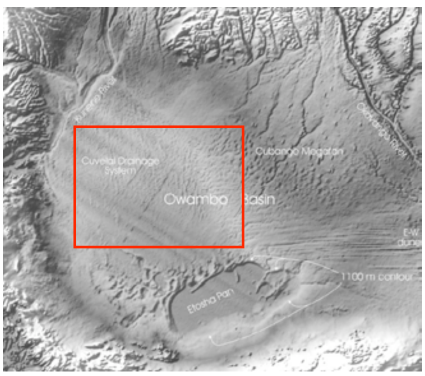


Figura 4: Localisation of the planned SNMR survey zone in Namibia

Tunisia

Tunisia is the Northernmost country in Africa surronded by the Mediterranean Sea to North and East. Its area is almost 165,000 square kilometres with an estimated population of just over 10.4 million. Tunisia is the smallest of the nations situated along the Atlas mountain range. The South of the country is composed of the Sahara desert with much of the remainder consisting of particularly fertile soil and 1,300 kilometres of coastline. The agricultural sector stands for 11.6% of the Gross Domestic Product, industry 25.7%, and services 62.8%. Climate is temperate in the North, with mild rainy winters and hot, dry summers. The terrain is mountainous (Figure 5), which, moving South, gives way to a hot, dry central plain. In the Khroumerie, the northwestern corner of the Tunisian Tell, elevations reach 1,050 metres and snow occurs in winter. The south is semiarid and merges into the desert. Surface water resources (56%) are the most used (90%), while groundwater (44%) can be subdivide in shallow aquifers (< 50 m depth) and are mostly overexploited, deep ones are 80% used.

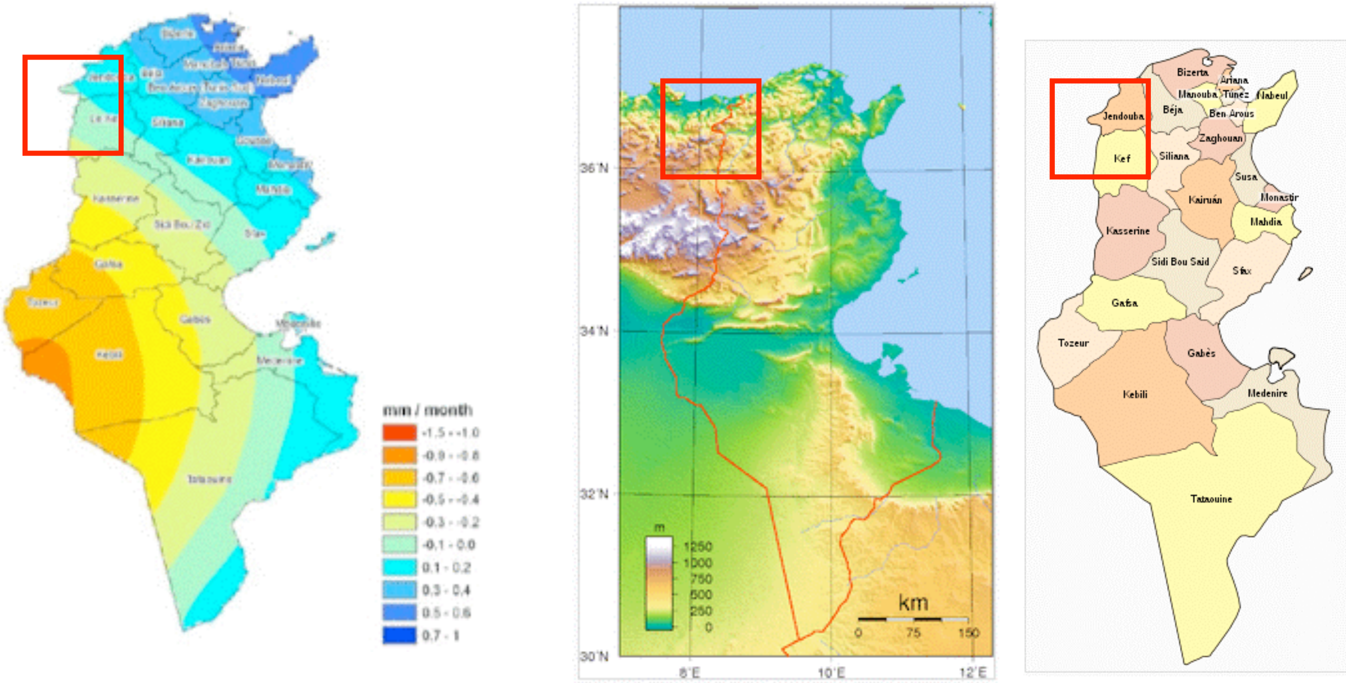


Figure 5: Trend in terrestrial water storage from the 2003-2008 based on GRACE satellite data, where blue areas indicate increases in terrestrial water. Physical and administrative regions of Tunisia and localisation of the surveying area

Figure 6: Jendouba region had 3,102 Km2 and a population of 420,500 persons. The water supply on urban areas is 100% while on rural areas 74%. The 25% of the agriculture surface (170,000 Ha) is irrigated with dammed water and groundwater exploitation. The rural Jendouba have the lowest access to water in all of Tunisia, so the SNMR survey point out in the neediest region of Tunisia

A.9 Previous knowledge on groundwater exploration

Tanzania

Higher agricultural growth is the key requirement to meeting the Millennium Development Goal, and for that the Government of Tanzania, with financial assistance from the World Bank, approved the Agricultural Sector Development Strategy which envisages an agricultural sector that, by 2025, is modernized, commercial, highly productive and profitable, and utilizes natural resources in a sustainable manner. To archive these objectives the District Irrigation Development Fund from the Ministry of Finance invest on complex irrigation infrastructure, including groundwater. Boreholes drilled for domestic water supplies indicate variable yields. Some boreholes in the Dodoma plain have exceptionally high yields of about 460 m^3/h. The average yield of boreholes (excluding Dar es Salaam and dry boreholes) is 11 m^3/h. The average static water level of productive boreholes is about 17 meters and the average total depth 62 meters. The cost for boreholes in Tanzania is about 6,000 USD for hand pumps and 12,000 USD for mechanised systems, drilling is only 50% of the total amount. Nine drainage water basins where established in 1991, being the study area in the Pagani Basin and close to Moshi, capital of Kilimanjaro region. The area is a fertile volcanic area, well fed by streams off the mountain. On the east of the Moshi town the Njoro forest in an area of high groundwater fed by run-off from Mt. Kilimanjaro (5,895 m.a.s.l), the 15% of the aquifers from Tanzania are located in volcanic or igneus rocks (see Figure 7). Most of the aquifers from the Kilimanjaro area are exploited by wells of more than 80 m depth (60%) and 20% between 50-80 m depth (Figure 8). Conclusions from the 2010 International Water Management Institute study to assess groundwater availability across sub-Saharan countries are, in the case of Tanzania, that there are limited information existing on the present state of quantity and quality of groundwater, and before it can be used for large-scale irrigation or other uses, extensive research is needed. Also the majority of people have inadequate understanding of groundwater resources and this has led to inappropriate development of groundwater. In that sense the SNMR survey in Kilimanjaro area will contribute to a better groundwater knowledge and a new method to improve that situation.

Category	Aquifer Type	Main lithologic units	Area (%)
1	Old, Paleogene, Neogene and Quaternary sediments	Alluvial: sand, gravel, silt, mud Lacustrine: sand, sit, limestone, tuff Terresterial: sand, gravel, laterite, silcrete, calcrete; Fluviatile: marine, sand, gravel, silt, limestone	20
2	Volcano-Plutonic/ granite	Black clay soil, yellow altered ash, white pumice and ash breccias, paleosoil with clay and volcanic rocks, alluvial deposits, sand with basalt, weathered basalt,	15
3	Plutonic-Metamorphic/ Gneiss rocks	Marble; quartize, graphitic schist, chlorite, amphibolite, mica and kyanite schist, hornblend biotite and garnet gneiss, acid gneiss, granulite, charnockite, magmatite; mudstone, shale and phylite, arkose, qartize, conglomerate, limestone	65

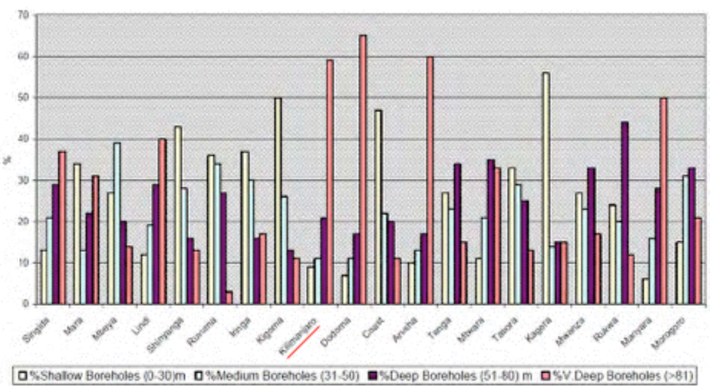


Figure 7 and 8: Surface and aquifer category in Tanzania. Drilling depth of the boreholes in Tanzania from a population of 16,124; only 200 are in the Kilimanjaro area (2010).

Namibia

Regional studies of groundwater (drilling surveys, pumping tests, well loggings,..) and groundwater exploration (*airbone electromagnetic surveys, transient electromagnetic surveys, geoelectrical surveys*) have been carried out since the 70's and several reports have been written on more localised projects aimed at urban and rural water supplies and drought relief.

Geoelectrical Surveys (Vertical Electrical Sounding)

After the completion of some of the drilling. It was demonstrated that there was in fact very little general correlation between the thermal infrared anomalies and geohydrology, whereas a positive correlation was established between all methods and the Landsat. A success rate of less than 25% was achieved in the drilling of the first 9 boreholes.
A correlation between high apparent resistivities and low groundwater potential was established and it was demonstrated that successful boreholes were drilled where profiling gave apparent resistivity values in the range 100 - 310 ohm meters and soundings indicated a deep weathering of bedrock. An overall drilling success rate of 36% (i.e. percentage of boreholes with yields >1 m_3/h) was achieved in the 22 boreholes drilled.

Combined Surface Electro Mangnetic Surveys (TEM) and airbone EM

Three investigation zones were identified areas for that study in 2006. Areas with predominant importance for water supply from groundwater were the Oshivelo area (east of the Etosha Pan). Here the extent of the already known Oshivelo Artesian Aquifer was delineated, the aquifer turned out to be less extensive than expected. The results are important for the future planning of the water supply for the fastest developing area of Namibia, the Cuvelai Basin.

Groundwater studies

A number of boreholes were sited, drilled and tested in order to fill in any gaps in information identified, giving an account of interpretation of results and conclusions. An interpretation of the stratigraphy and regional context was achieved through an examination of several hundred borehole logs and regional topography and drainage patterns. Visual interpretation of satellite imagery was also included.

Water and Environment studies

Those studies covers a baseline Environmental Investigation on the water sector in Namibia and identified appropriate, key indicators for long term monitoring of the health and trends of the Namibia's water environment. It provides extensive background material on environment and water covering the physical and climatic determinants of water gain and loss in Namibia, surface water in its several forms and groundwater in the varied aquifer types found in the country. The study focussed on sustainability of the resource, from environmental, economic and social perspective.

Once the applicability of the SNMR method all thoses previous studied sites are good places to enlarge their groundwater knowledge, because the first phase of the hydrogeophysical survey has been alredy done in Namibia.

Tunisa

In the area of groundwater exploration and monitoring, the limited number of private companies in Tunisia equipped to undertake geophysical prospecting or to drill deep wells militates against a greater involvement of the private sector in these activities.The exploration activities now focus on locations where there is a good potential for finding additional sources of high quality supply but complex geologic structures increase the probability of negative wells explains the paucity of private sector involvement. However, the DGRE (Directorate General of Water Resources), the department in the MOA (Ministry of Agriculture) that is responsible for groundwater exploration and monitoring recognizes this, and is making efforts to provide better incentives for greater private sector participation. Monitoring data are now being made available to a wide range of actors, including the private sector. It has also been identified that, at the present stage, it is far from clear that transferring exploration and development capacities to the private sector can be done without careful preparation. Uncontrolled development of groundwater resources by private companies and individuals is the single largest factor underlying overexploitation. Agricultural research continues to be a public good in the Tunisian context. Private sector involvement is small since its financial and technical capacity is still limited. However, inroads are being made slowly. Several research institutes now contract out research projects to the private sector. Under the Project, strengthening of research committees is envisaged through improved representation of farmers (demand). In the area of extension, the government is keen on exploring the possibility of greater involvement of academics, agro-industry, and other private sector operators. [..] From: Document of The World Bank Report No. 17208-TUN PROJECT APPRAISAL DOCUMENT ON A PROPOSED LOAN IN AN AMOUNT EQUAL TO FRF 246.6 MILLION TO THE REPUBLIC OF TUNISIA FOR A SECOND AGRICULTURAL SECTOR INVESTMENT LOAN (2000).

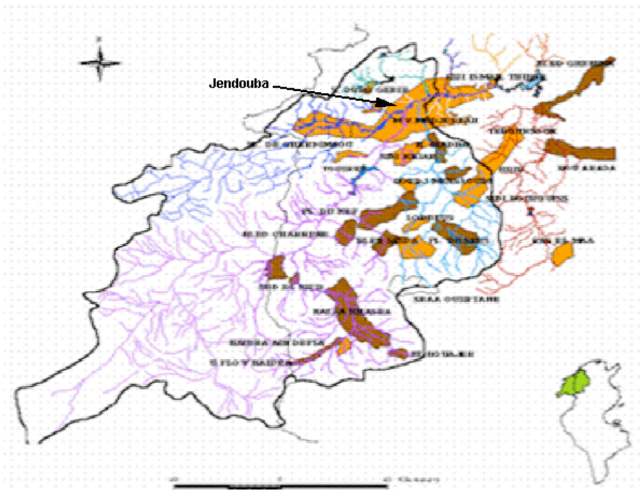


Figure 9: Shallow acquifers in the Northwest zone of Tunisia. According to the whole Tunisia 2000 inventory, the renewable potential of phreatic aquifers is estimated at 736.7 million m3/year. Their net rate of development is 106% from 123 000 phreatic wells. Phreatic water reserves are overexploited at the rate of 104 %.

Groundwater resources

Groundwater is divided into two main components: phreatic and deep. Phreatic aquifers correspond to shallow aquifers just under the ground surface. In Tunisia, phreatic aquifers are located at less than 50 m depth, while deep aquifers have depths between 400 and 500 m. There are also some exceptions of very deep aquifers in the South Region (between 1000 and 2000 m in the CI). The majority of the phreatic aquifer is located in the North (52%) and the center (32%) of
the country. In northwest Tunisia (Jendouba Governorate), the Middle qalley corresponds to an alluvial plain where the Medjerda River receives its main tributaries from the north and the south.
The groundwater salinity gradient, from less than 3 000 ppm on the margins of the plain, increasing towards the centre of the plain, in particular near the cities of Jendouba and Bou Salem, where it can reach over 10 000 ppm.

Water and Environment studies

J. P. Lhomme, R. Mougou and M. Mansour (2009) Potential impact of climate change on durum wheat cropping in Tunisia; *Climate Change;* 96, 4, 549-564 (DOI: 10.1007/s10584-009-9571-9)
The potential effect of climate change on durum wheat in Tunisia is assessed using a simple crop simulation model and a climate projection for the 2071–2100 period, obtained from the Météo-France ARPEGE-Climate atmospheric model run under the IPCC (International Panel on Climate Change) scenario A1B. In the process-oriented crop model, phenology is estimated through thermal time. Water balance is calculated on a daily basis by means of a simple modelling of actual evapotranspiration involving reference evapotranspiration, crop coefficients and some basic soil characteristics. The impact of crop water deficit on yield is accounted for through the linear crop-water production function developed by the FAO (Food and Agriculture Organization of the United Nations). Two stations are chosen to study the climate change effect. They are representative of the main areas where cereals are grown in Tunisia: Jendouba in the northern region and Kairouan in the central region. In the future scenario, temperature systematically increases, whereas precipitation increases or decreases depending on the location and the period of the year. Mean annual precipitation declines in Jendouba and raises in Kairouan. Under climate change, the water conditions needed for sowing occur earlier and cycle lengths are reduced in both locations. Crop water deficit and the corresponding deficit in crop yield happen to be slightly lower in Kairouan; conversely, they become higher in Jendouba.

J. Chahed , A. Hamdane & M. Besbes (2005) Une vision intégrale du bilan hydrique de la Tunisie : Eau Bleue, Eau Verte, Eau virtuelle; 6th International Conference in Paris, France: SHARING A COMMON VISION OF OUR WATER RESOURCES, Proceedings, 93-94
In the integral water vision developed in this paper all kind of water resources are considered: mobilized water "Blue Water", Equivalent-Water of the rain fed agriculture "Green Water" and the Equivalent-Water of the import-export food balance "Virtual Water". In countries where the water resources are limited, this global assessment of water resources, that goes further than the traditional concept of the blue water leads to a better comprehension of the relation between water and the agricultural production and allows to optimize the use of all the water resources. The global assessment of water resources gives a real evaluation of the possibility of the agricultural production. When applied to the Tunisian water balance, this analysis indicates that, the improvement of food security will depend, in the future, on the capacity to manage all the available water in particular by improving the potential of the rain fed agriculture.

The aim of the SNMR pilot survey (this project) is to improve the groundwater exploration overall any geological complexity in Jenouba (and furthermore in Tunis) and change the conclusions of report like the previous one (Raport No. 17208) in the future.

A.9 For whom is destinated the SNMR survey and schendule

Tanzania

Knowledge transference: The public results of the SNMR survey will be given to the « Water supply of Mdawi village, Tanzania » project from SamSamWater Foundation : http://www.samsamwater.com/projectdata.php?projectid=67

Tanzania schendule				
2012	March 1-4	March 5 - 11	Mars 12 - 31	April - June
Geophysical Phase 1				
Geophysical Phase 2		SNMR survey		
interpretation				
Hydrogeopysical raport (SNMR)				SNMR raport

Namibia

Knowledge transference: Presentation and a one week training of the method at the Department of Geohodrylogy (DG), thus the official institutions gets aware of the capabilities and possibilities of MRS via a field test in the north, north of Etoscha, to see how deep and precise the MRS works on cooperation with the DG. The DG should suggest 2 or 3 locations to do some testing).

Project Manager DWA-BGR "Groundwater Investigation in the CEB"

Namibia schendule				
2012	July 4 - 20	July 20 – 31	August 1-5	August 6-12
Geophysical Phases 1 & 2	SNMR			
Interpretation				
Hydrogeopysical raport (SNMR)				SNMR raport

Tunisia

Knowledge transference: Presentation and training on the possibilities of the new MRS technology for groundwater studies for Agencies in Jendouba Governorate:

1. The Agency for the Promotion of Agricultural Investments of Jendouba Governorate, Tunisia, which is responsible on the development all water ressources of the Governorate.

Address: Avenue Khemais El Hajri Immeuble El Ayari, Jendouba, Tunisia 8100.

2. The Agency for the Promotion of Industry and Innovation, Jendouba Governorate, Tunisia, which is responsible on the promotion of innovative technologies related to geophysical prospecting of groundwater in the Governorate of Jendouba.

Address: Avenue Habib Bourguiba, Jendouba, Tunisia 8100.

Tunisia schendule			
2012	Sept. 10- 23	Sept 24-30	October
Geophysical Phases 1 & 2	SNMR		
Interpretation			
Hydrogeopysical raport (SNMR)			SNMR Raport
International SNMR congress in Germany			

A.10 Project monitoring

The project monitoring will be done by the Marcel Chevalier Foundation, given to the local Unesco commission all the results and reports once made following the previous exposed schendules. The last year of the biennial the guideline on groundwater exploration on Africa using SNMR technology and techniques will be writen.

	2012			2013
	March-June	July-August	Sept-Oct	Jan - Dec
Tanzania				
Namibia				
Tunisia				
Guideline				

Is important to note that we shoud start early on the 2012 year because is not possible to work in the raining season between March to May in Tanzania and Namibia. So is for that we plan to go to Tanzania before the rainin season and to Namibia afther. Survey in Tunisia should be done when Universities open to make the knowledge transference to students.

(b) Detailed description of **estimated budget**: The budget must be drawn up in US $ (**provide three pro forma invoices for equipment)**

Two separated items should to be considered, equipment renting and the field work study.

For basics equipment (Resistivimeter and the Magnetic Resonance Device) we look for prices from different geophysical suppliers (NWG, http://www.northwestgeophysics.com/), available in Internet (HG, http://www.heritagegeophysics.com/rental.htm), in Andorra (http://www.igeotest.fr) and also to the two unique manofacurers in the world, Iris-Instruments in Europe (http://www.iris-instruments.com/Rental/rental.html#Anchor-Geophysic-19549) and Vista Clara in USA (http://www.vista-clara.com/index.html). Intercontinental shipping prices should be taken into account, for that a free Internet calculator has been used to provide us an estimative of shipping weight price (http://www.freight-calculator.com/apxocean.asp), being to an aproximate price of $5,83 / Kg. Also an insurance for the equipment should be taken, Iris-Instruments offers daily insurance of about $40 for NMR device and $20 for the resistivimeter.

Rental	Device	Week rate($)	Mobilization($)	Weight (Kg)	Origin	Cargo($)	Quote($)	Surveying	Subtotal ($)	Best Quote
NWG	Resistivity	625	150	102	USA	594,60	2853,21	3	8559,63	8559,63
IRIS	Resistivity	818,4	0	102	EU	594,60	3090,01	3	9270,03	
Igeotest	Resistivity	426,7	0	163	EU	950,20	2951,81	3	8855,43	
HG	Resistivity	800	300	102	USA	594,60	3353,21	3	10059,63	
IRIS	MRS	2508	0	260	EU	1515,66	8575,32	3	25725,95	
HG	MRS	5500	1500	260	USA	1515,66	16059,32	3	48177,95	
Igeotest	MRS	2910,6	462	163	EU	950,20	8381,60	3	25144,81	25144,81
Vista Clara	MRS	5950	1154	535	USA	3118,76	19819,52	3	59458,55	
									Best Total ($)	**33704,43**

For field work study we contact with two Spanish companies that offers resistivity measurments and MRS services. The estimations oscillate between $69000 and $67000 for the Namibian and Tunisian campaign (renting material included at ≈ $10000). That SNMR survey from Andorra costs $47378 for all three field SNMR surveying (without any geophysical renting equipment). All Euro-Dollar conversion has been done at 1,32 rate. So the balance is as follows:

OUTGOINGS		INCOMINGS	
Equipment	$33704,43	UNESCO	$33704,43
Field work and final report	$47378,76	Fundació Marcel Chevalier	$47378,76
TOTAL	$81083,19		$81083,19