

SAHARA
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OBSERVATORY



OBSERVATOIRE
DU SAHARA
ET DU SAHEL

IULLEMEDEN, TAOUDENI-TANEZROUFT
TRANSBOUNDARY AQUIFER SYSTEM

ATLAS OF WATER RESOURCES



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ACKNOWLEDGEMENTS

This Atlas was published by the Sahara and Sahel Observatory, Tunis, Tunisia.

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For reference purposes, this publication should be referred to as:

OSS (2017). « Atlas of the Water Resources of the Iullemeden, Taoudeni-Tanezrouft Aquifer System Countries - 1st edition » ; Joint and Integrated Water Resources Management of the Iullemeden, Taoudeni-Tanezrouft Aquifer Systems and the Niger River Project (GICRESAIT)

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The GICRESAIT project was coordinated by OSS together with its national partners.

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Iullemeden, Taoudeni-Tanezrouft Transboundary Aquifer Systems: Atlas of Water Resources \OSS.
Imprimeries Réunies, Tunis : 2017 - 48 pages.

ISBN : 978-9938-933-05-5



Foreword

The study on the “Joint and Integrated Water Resources Management of the Iullemeden, Taoudeni-Tanezrouft Aquifer Systems and the Niger River” (GICRESAIT) was funded by the Fonds Français pour l’Environnement Mondial/French Facility for Global Environment (FFEM) and the African Water Facility (AWF) and carried out by the Sahara and Sahel Observatory between 2010 and 2016.

It involved the seven basin-sharing countries (Algeria, Benin, Burkina Faso, Mali, Mauritania, Niger and Nigeria) and contributed to building up knowledge of the aquifer and a regional database that must continue to grow.

We are convinced that after more detailed investigation, the medium term result will be better-defined programmes and better-structured investments to satisfy the water needs of the people and the growth of sustainable agriculture capable of ensuring food security.

The idea of this Atlas arose from the OSS decision to develop its work as an observatory by providing the OSS countries with synthesized data that allowed for a global view of the region. Maps were designed and created based on the GICRESAIT study, national multisectoral studies, and regional and international documentation.

This atlas includes indicators connected to water resources, especially water availability, access to drinking water, sanitation, and vulnerability to climate change and pollution, which we felt were the most pertinent one. How paradoxical that the level of abstraction in a region with a mighty water potential is too slight to meet more than a very small part of the region’s demand for water!

There is still a lot to be done, both in terms of acquiring knowledge and finetuning surveillance and in terms of integrated water resources management that is as sustainable and cost-efficient as possible.

Allow me to express wholeheartedly gratitude to the Fonds Français pour l’Environnement Mondial and the African Water Facility for their unwavering support for OSS. Without them, this Atlas could not have been successfully completed.

Khatim KHERRAZ
Executive Secretary
Sahara and Sahel Observatory



Women at a traditional well in Niger

This Atlas was produced through the GICRESAIT project: « Joint and Integrated Water Resources Management of the Iullemeden, Taoudeni-Tanezrouft Aquifer Systems and the Niger River ».

The joint and integrated management of the region's water resources is a lever of development for the sub-region. The GICRESAIT project, funded by the AWF and FFEM (total amount of 1728 K€) was carried out by OSS from 2010 to 2016, with the participation of the seven GICRESAIT countries (Algeria, Benin, Burkina Faso, Mali, Mauritania, Niger and Nigeria).

The project made it possible to :

- significantly improve the knowledge base of the water resources ;
- identify zones with high groundwater potential ;
- create a regional database ;
- address several themes: hydrogeology, land cover, aquifer recharge, piezometry, vulnerability to climate change, aquifer pollution ;
- provide for the adoption of a Memorandum of Understanding and a road map for the creation of a Consultation Mechanism for the joint management of shared groundwaters.

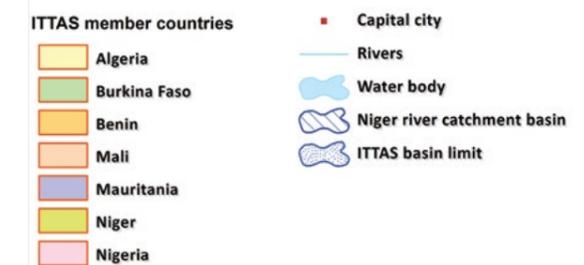
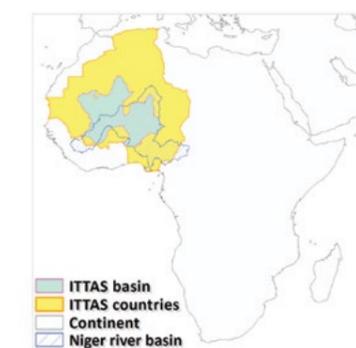
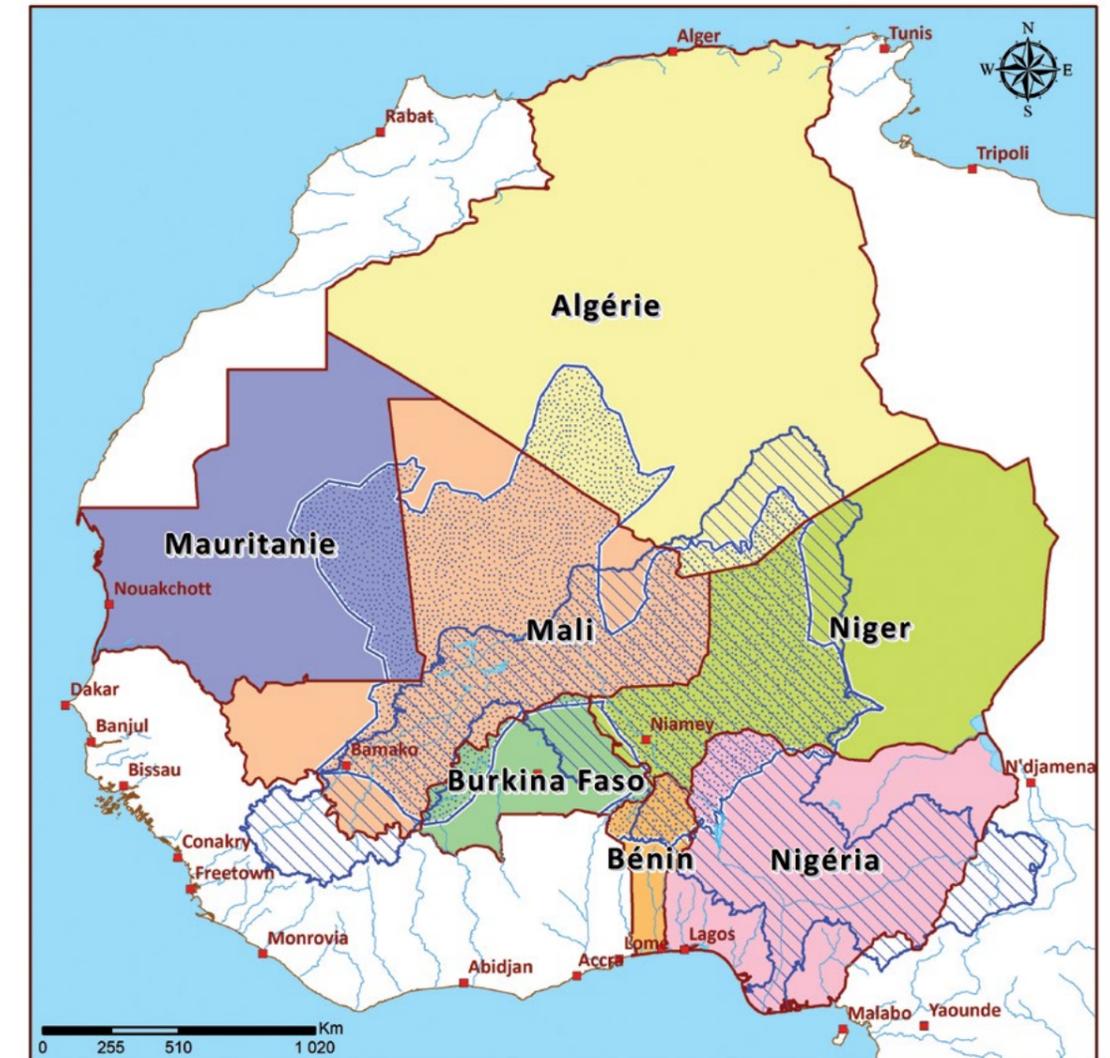
GENERAL CONTEXT

The Iullemeden, Taoudeni-Tanezrouft transboundary basin is shared by Algeria, Benin, Burkina Faso, Mali, Mauritania, Niger, and Nigeria. (Fig.1).

This sector includes parts of North Africa and West Africa and is subdivided into four zones :

- the Sudanian zone with a Guinean climate and annual precipitation over 1200 mm ;
- the Sudano-Sahelian zone with a tropical climate and annual precipitation between 700 and 1200 mm ;
- the Sahelian zone with a Sahelian climate and annual precipitation between 200 and 700 mm ;
- the sub-Saharan zone with a sub-desert climate and annual precipitation between 200 mm to under 50 mm.

Figure 1 GICRESAIT project study area



Developed by : Sahara and Sahel Observatory, 2017

A landscape in Niger showing a road and a large dust cloud. The scene is dominated by a wide, unpaved road that stretches from the foreground into the distance. The road is flanked by dry, reddish-brown earth and sparse, low-lying vegetation. In the background, a massive, dense cloud of dust or sand rises, partially obscuring the sky. The sky is filled with soft, hazy clouds, suggesting an overcast or stormy atmosphere. The overall color palette is warm and earthy, with various shades of brown, orange, and red.

**THE IULLEMEDEN,
TAOUDENI-TANEZROUFT
TRANSBOUNDARY BASIN REGION**

Cloud of dust just before the rains in Baleyara, Niger

GROUNDWATER RESOURCES

The Iullemeden and Taoudeni-Tanezrouft sedimentary basins extend over a total area of approx. 2.5 million km².

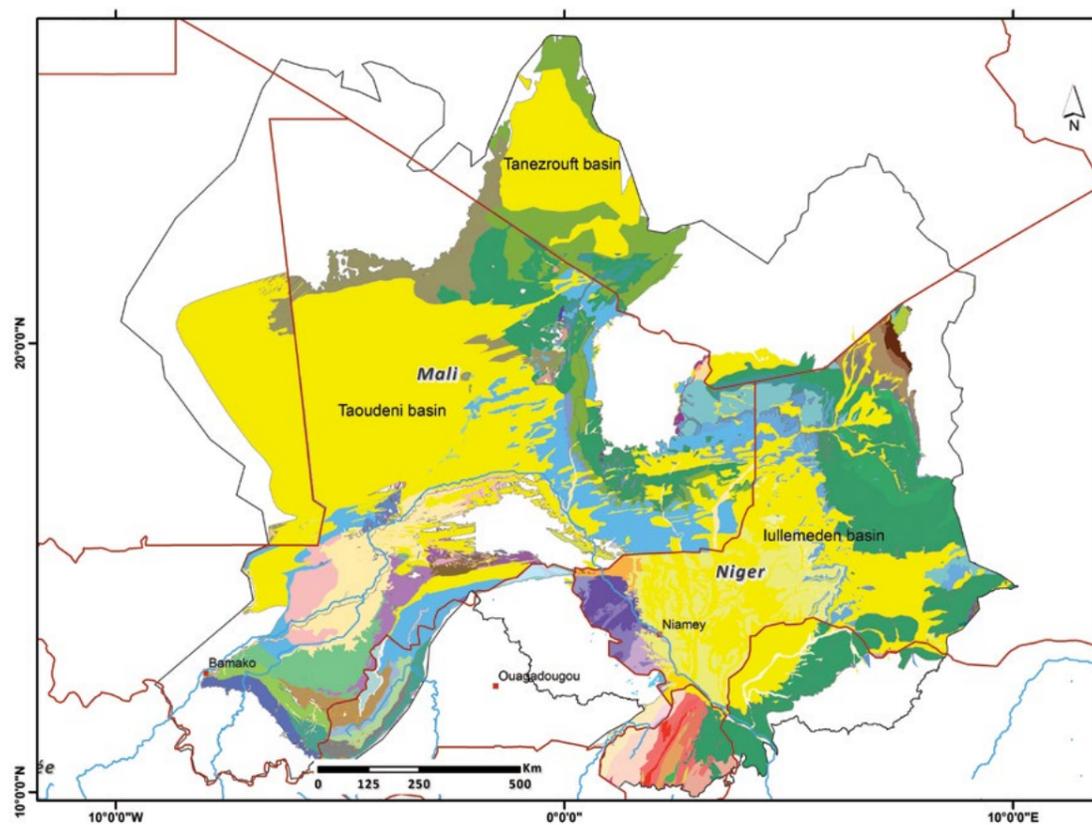
The area is in geological and hydrogeological continuity and together form a single set of several groundwaters located in geological formations dating back to the period between the Palaeozoic to the Quaternary eras (Fig.2).

The groundwater resources included in this Atlas are those of the Continental Intercalary

(CI) dated to the Upper Cretaceous and the Continental Terminal (CT) dated to the period between the Tertiary to the Quaternary eras.

The main watercourse of the Niger River crosses the ITTAS over nearly 2,480 km: 1,700 km are in Mali (forming a flood plain called the Inner Delta), 540 km in Niger, 140 km in Benin (frontier with Niger) and about 100 km in Nigeria (crossing the Sokoto basin).

Figure 2 The Iullemeden, Taoudeni-Tanezrouft aquifer system, 2013



Sedimentary formations located in the basin border region

Developed by : Sahara and Sahel Observatory, 2017

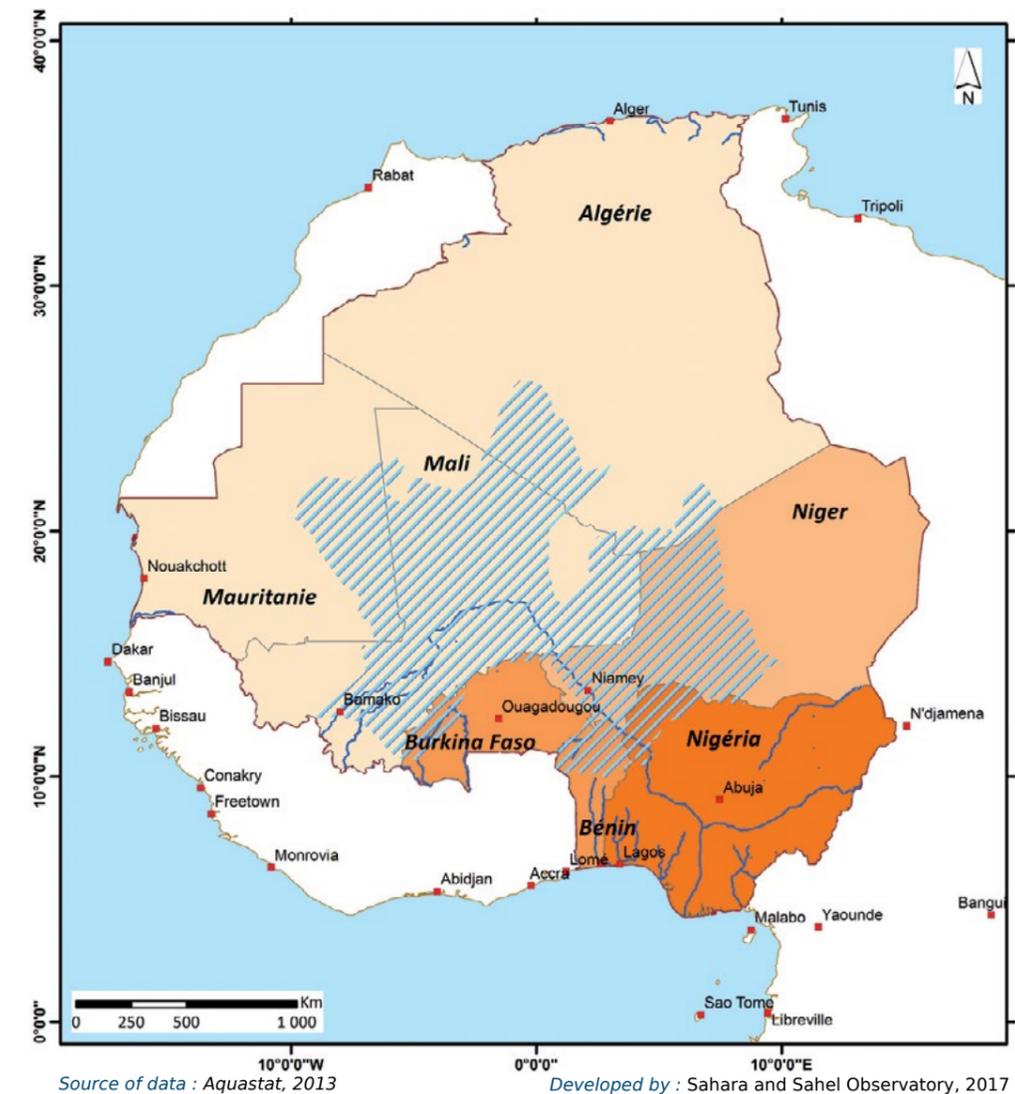
Dark brown: Palaeozoic
Blue and green: Mesozoic
Light brown: Tertiary
Yellow: Quaternary

LAND RESOURCES

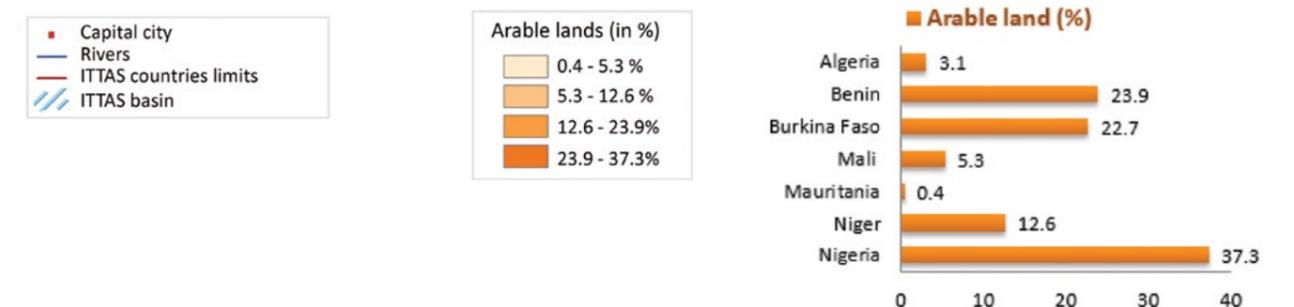
The ITTAS countries have an abundance of agricultural lands. Rainfed cropping is predominant, except in the southern part of Algeria. The potential arable land is estimated

at more than 137 million hectares, (AQUASTAT, 2015) (Fig. 3). The total area presently cultivated is around 46 million hectares (ECA, 2012).

Figure 3 Arable land potential in ITTAS countries, 2013



Arable lands : Expressed as a percentage of the territory, these are land allocated to crop temporary (harvested area twice only being counted once), temporary grasslands to be mown or used as pastures, gardens and land temporary fallow (less than five years).



A wide, calm river flows under a twilight sky. In the foreground, a grassy bank is visible. A person stands on the bank on the left, another person is partially submerged in the water on the right, and a person is seated in a small wooden boat in the middle of the river. The background shows a distant shoreline with trees. The overall mood is serene and quiet.

THE CHALLENGES TO WATER RESOURCES

MOBILIZATION OF RENEWABLE WATER RESOURCES

The comparative analysis of current pressures on renewable water resources shows that current water abstraction in North Africa is close to the overall potential for renewable resources. This makes recourse to fairly renewable, even fossil,

water resources and to non-conventional waters almost inevitable.

On the contrary, water withdrawal in West and East Africa is insignificant compared to the regions' considerable potential of renewable water resources (Table 1).

Table 1 : Current pressures on the renewable water resources in the OSS zone of action

Current pressures on renewable water resources	Africa sub-region		
	North	West	East
Renewable water resources (km ³ /yr)	98	387	273
Current abstractions (km ³ /yr)	92	13	40
Average exploitation index (%)	93	3	15

Source : FAO, Aquastat, 2012-2013

Pressures on groundwaters characterize the exploitation index of the renewable resources. This index has been calculated for the three African sub-regions: North, West and East Africa (Fig.4).

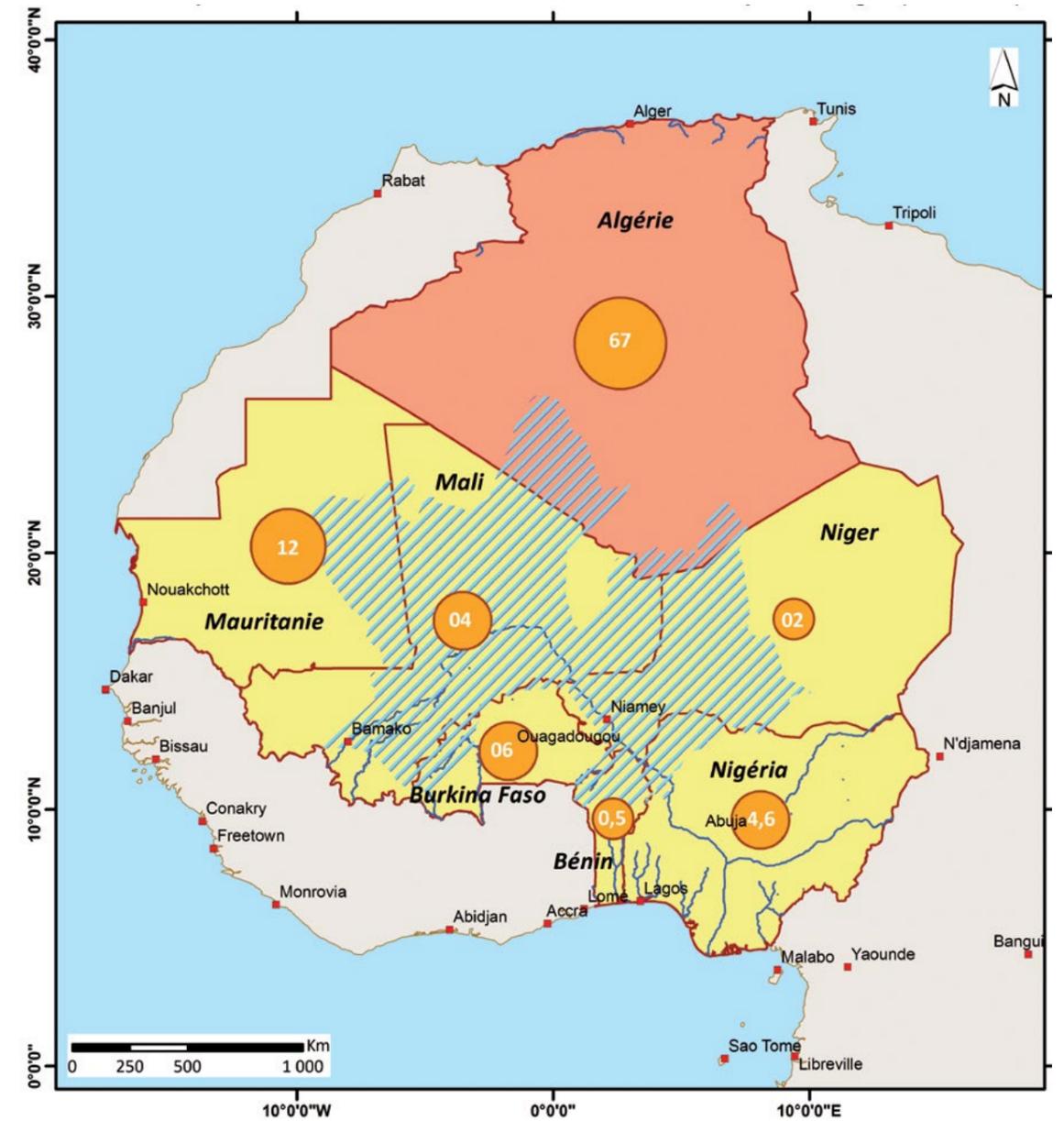
The very low exploitation index for West and East Africa raises the issue of the countries' capacity to access the considerable renewable

resources in these two sub-regions. Actually, the fact that abstraction rates are low in West and East Africa does not mean that the water needs have been satisfied, but rather that there is insufficient access to drinking water. This is true for both the urban and rural populations in these countries.



Artesian well

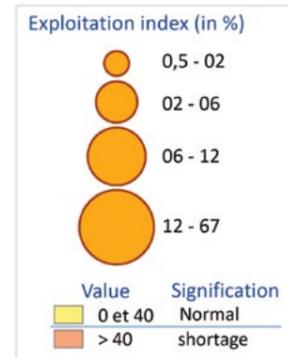
Figure 4 Exploitation index for renewable water resources 2001-2012 (in %)



Source : Aquastat, 2001-2012

Developed by : Sahara and Sahel Observatory, 2017

Exploitation index : Withdrawals of conventional freshwater resources (surface and groundwater) in relation to total renewable resources. This parameter is an indication of the pressure on the renewable resources.



Exploitation index (%)

Algeria	67
Benin	0.5
Burkina Faso	6
Mali	4
Mauritania	12
Niger	2
Nigeria	4.6



A traditional well in Niger

ACCESS TO DRINKING WATER

2015 was a crucial year worldwide and especially for Africa. It marked the final assessment of the fulfilment of the Millennium Development Goals (MDGs), and most notably Goal 7 whose Target 7.C aims to “halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation”.

The 2015 progress report on the MDGs in Africa, published in 2015, highlights that access to drinking water has improved, but essentially in urban areas, and in certain countries there is still a major difference between access to drinking water in the urban and the rural areas.

Access to safe drinking water for the seven ITTAS countries exceeds 80% in the urban area (110 million persons out of 140 million) (Fig.5).

Between 50% and 80% of the rural population has access to safe drinking water, depending

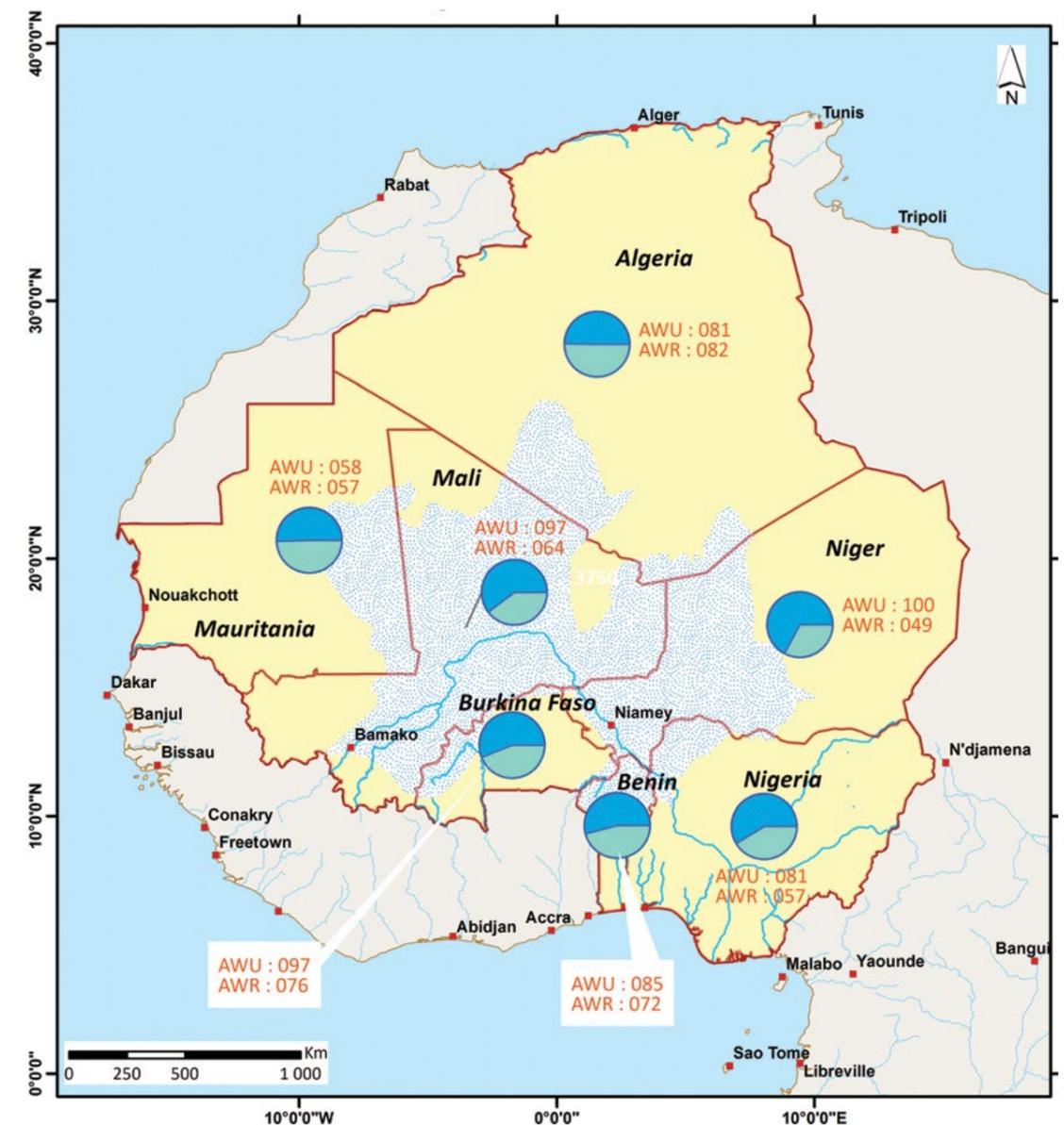
on the country, i.e. between 77 and 125 million persons for the entire basin (Fig.5).

The major challenge is to increase access to safe water in rural areas where the average daily per capita need is approx. 30 liters/day.

Access to safe drinking water is defined on the basis of the proportion of the population that is supplied with or has “reasonable access” to adequate amounts of safe drinking water.

The amount of water required to cover the metabolic, hygienic and domestic needs is estimated at a minimum of 20 liters/day per capita. “Reasonable access” to water means that safe drinking water is available at less than fifteen minutes walking distance, or less than 1000 meters away (Source WHO).

Figure 5 Access to safe drinking water in rural and urban areas (%), 2015



Source: Aquastat, 2015

Developed by : Sahara and Sahel Observatory, 2017

Access to safe water: It is the share of the population that is Served or having reasonable access to a sufficient volume of drinking water. Volume of water needed to cover the metabolic, hygienic and domestic needs is estimated at 20 liters of drinking water per day and per person at least. « Reasonable access» to Water Supplies Drinking Water Available Less than 15 minutes walk or less than 1000 meters (Source: WHO).

	Access to drinking water (%)	
	Urban	Rural
Algeria	81	82
Benin	85	72
Burkina Faso	97	76
Mali	97	64
Mauritania	58	57
Niger	100	49
Nigeria	81	57

■ Capital city
— Rivers
 ITTAS countries limits
 ITTAS basin

● AWU : Access to Water in Urban areas
● AWR : Access to Water in Rural areas

Access to safe water
 Urban area
 Rural area

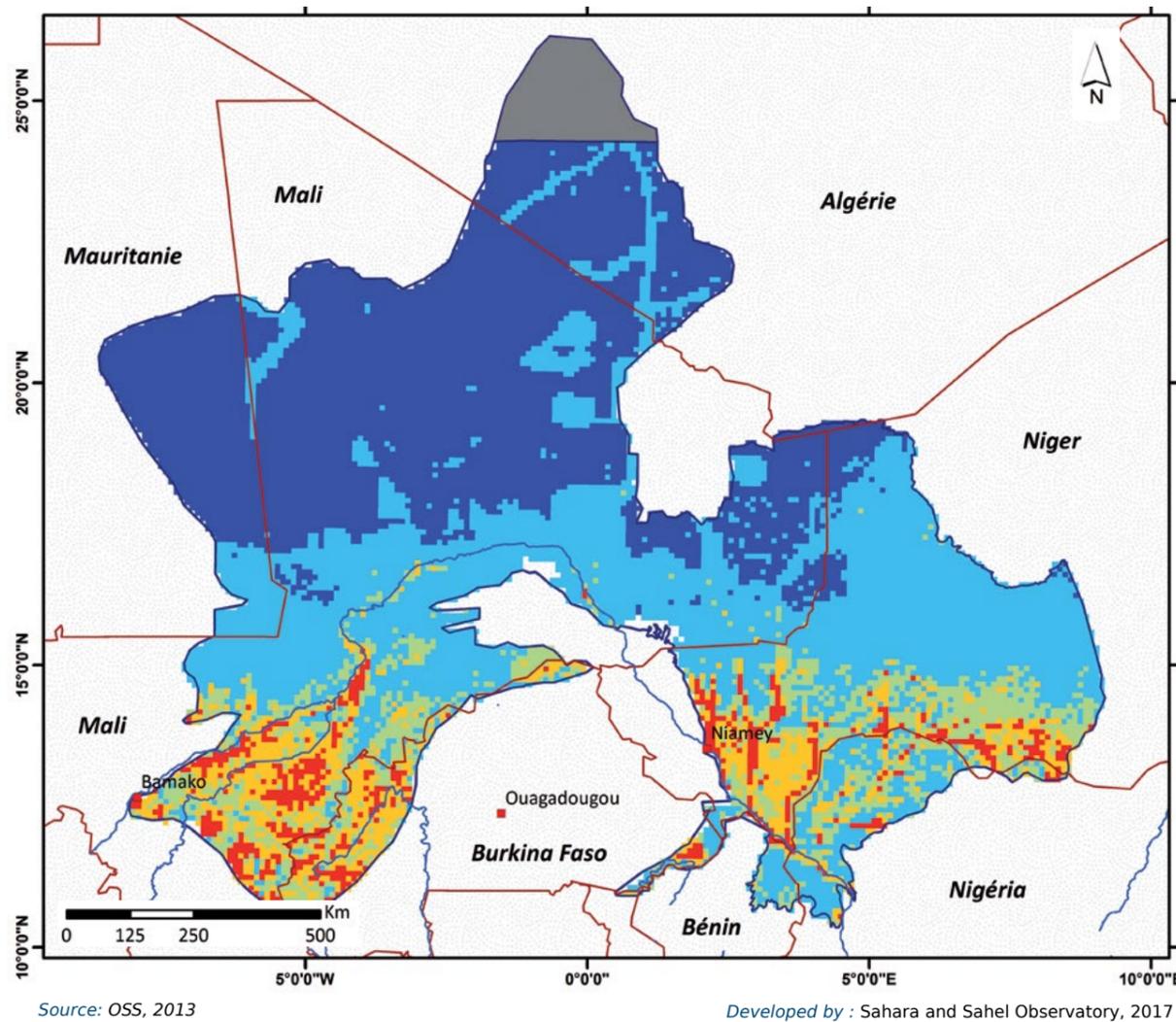
RISK OF GROUNDWATER QUALITY DEGRADATION

The quality of the groundwater resources of the Iullemeden, Taoudeni-Tanezrouft Aquifer System is being jeopardized, mainly by anthropogenic activity such as, industry, mining, and agriculture, especially irrigated agriculture along the Niger River and its Inner Delta, where large quantities

of fertilizers and crop protection products are used.

The greatest risk of groundwater pollution is in the southern, more populated basin area (Fig.6).

Figure 6 Groundwater pollution risk due to human activity, 2013



Vulnerability

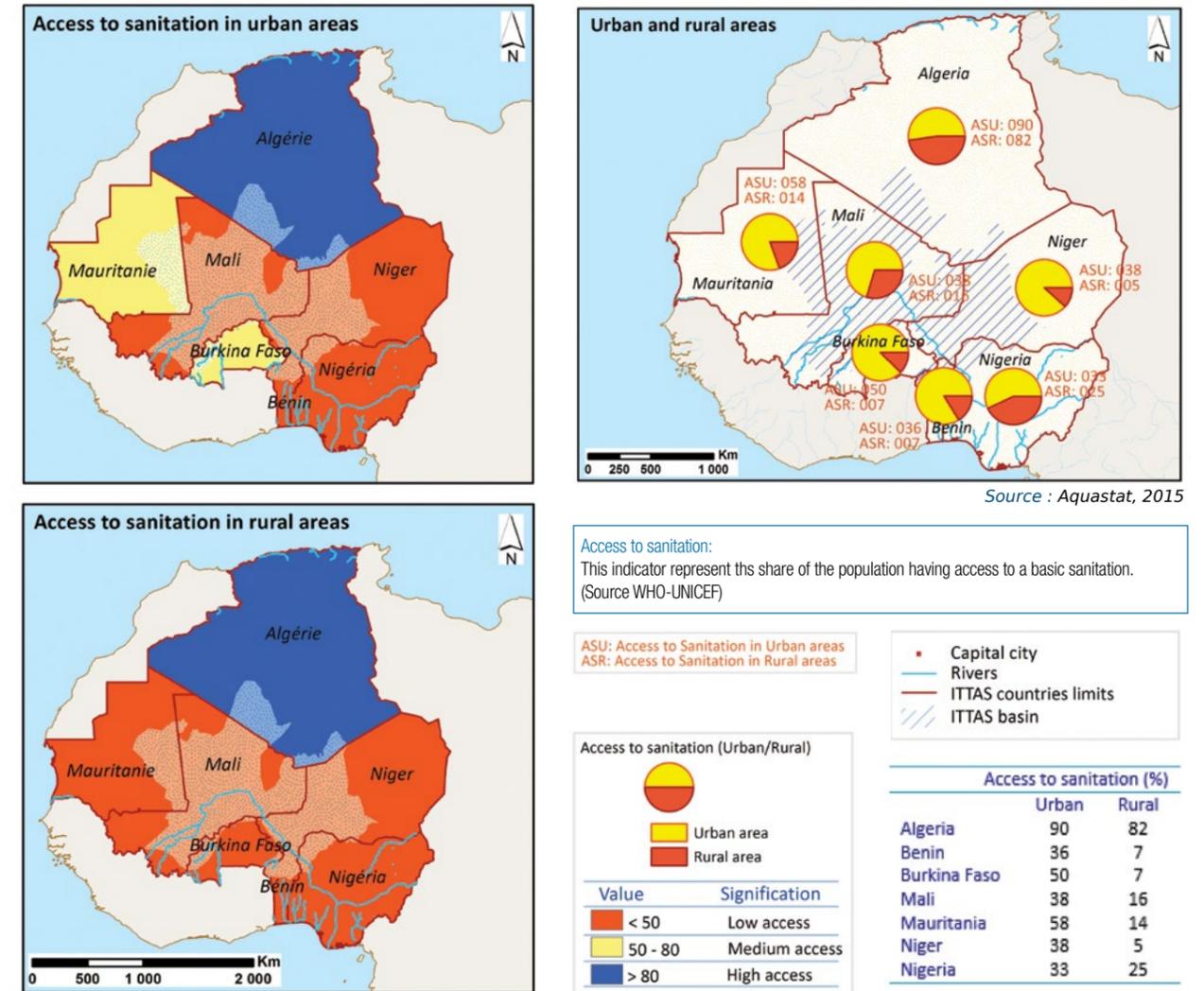
Very low risk	high risk
low risk	very high risk
medium risk	no data

- Capital City
- countries limits
- rivers
- Limit of ITTAS

ACCESS TO SANITATION FACILITIES

Neither the urban nor the rural areas of the seven countries have adequate access to basic sanitation facilities (Fig.7).

Figure 7 Access to a sanitation system in urban and rural areas, at the country level, 2015



Developed by : Sahara and Sahel Observatory, 2017

Given the sub-region's rapid population growth rate (100% increase between now to 2030), access to sanitation will be a major challenge in the next few years. This mainly involves SDG 6.2 : « by 2030, achieve access to adequate and

equitable sanitation and hygiene for all, and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations ».



**GROUNDWATER :
WHICH OPPORTUNITIES ?**

Young boy preparing to draw water from a traditional well in Niger. The length of the wound up rope gives an idea of the depth

Africa has an abundance of transboundary surface and ground water resources. Out of the world's 200 major transboundary river basins and lakes, about 80 are in Africa and include 55 major transboundary basins shared by two or more countries. Out of the world's 608 major transboundary aquifers, 83 are in Africa and are shared by two or more countries.

Several hydrogeological studies conducted on the Iullemeden, Taoudeni-Tanezrouft Aquifer Basin have contributed to the identification of sectors with a high groundwater exploitation potential.



Water-efficient irrigation system in the Sahel

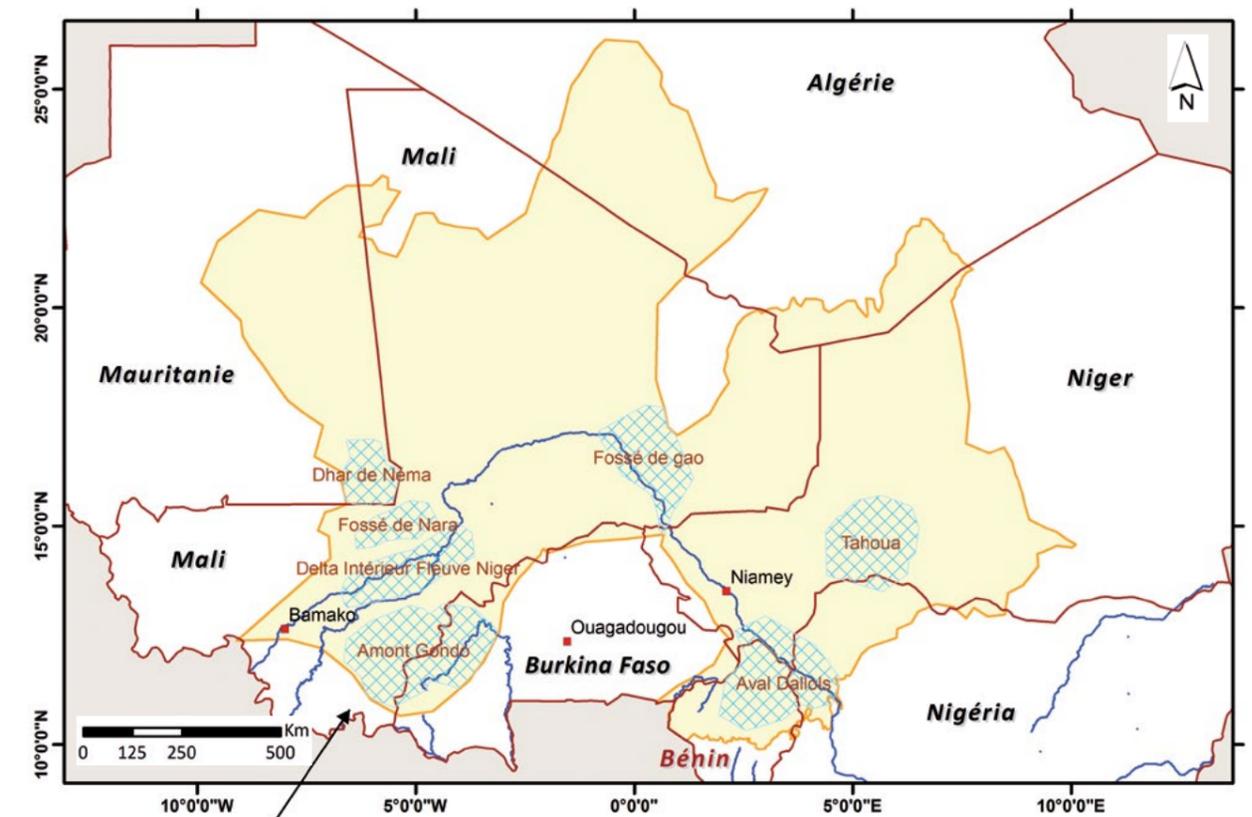
AREAS OF HIGH POTENTIAL

Several phenomena explain the high groundwater potential in certain parts of the basin (OSS, 2017) (Fig.8) :

- ◆ **Either a connection between Ground and Surface waters**, which ensures a regular supply of the basin, even at periods of rainwater deficit due to climate change. These **renewable resources** are located in the following sectors:
 - The Inner Delta of the Niger River in Mali ;
 - The downstream sector of the dallols in Niger and Nigeria ;
 - The Mouhoun basin upstream of the Gondo plain in Burkina Faso ;
 - The Gao Graben in Mali and Niger.

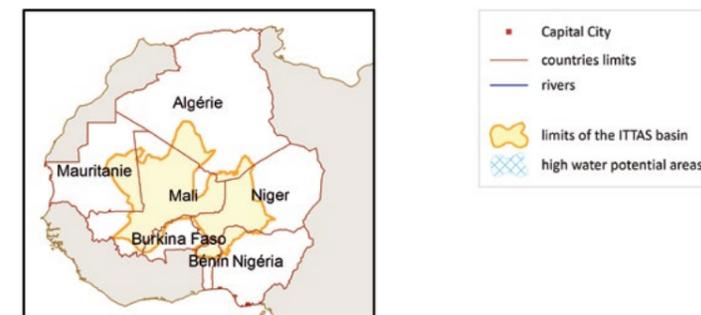
- ◆ **Or the high thickness and permeability of the aquifer formations**, which make it possible to withdraw large volumes of **barely renewable** groundwater from the water catchment infrastructure. This mainly concerns:
 - The Tahoua sector in Niger ;
 - The South Sector of "Dhar de Nema" in Mauritania ;
 - The Nara Graben in Mali.

Figure 8 Areas with identified high groundwater potential, 2013



Source: OSS, 2013

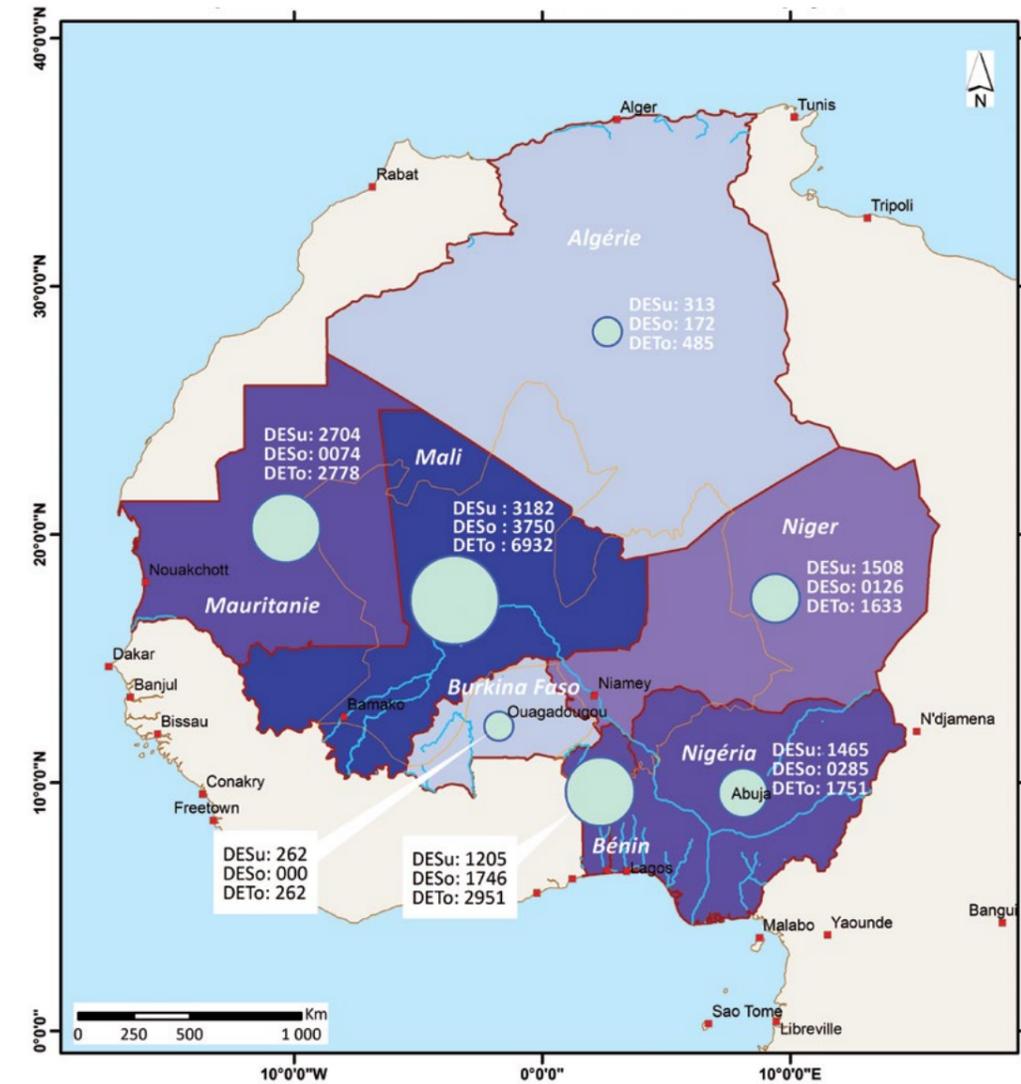
Developed by : Sahara and Sahel Observatory, 2017





Hippopotamus pond in Bala - Satiri, Burkina Faso

Figure 9 Renewable Water Availability (m³/inhab/yr), 2014



Source of data : National multi-sectorial studies : Benin, Burkina Faso, Nigeria, Niger, Mali, 2004 ; Atlas of water resources-Mauritania, 2011 ; Scientific article - DEMMAK A., 2012: Monitoring Evaluation of Water in North Africa, National report ; population data : AQUASTAT, 2014.

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WATER AVAILABILITY

Water availability is an indicator expressed in m³/inhab/yr calculated by dividing average renewable natural freshwater resources by a territory's population at a specific date.

Water availability compared to total renewable resources

Water availability calculations highlight the water shortage in Algeria and Burkina Faso with less than 1000 m³/inhab/yr, and a vulnerable

situation in Niger (Fig.9). The other countries can be considered as enjoying a water security or "comfort" status.

Water availability : Expressed in m³/in hab/year, it is the ratio of average renewable natural water resources of good quality on the population of the territory on a specified date (Source : FAO-Aquastat).

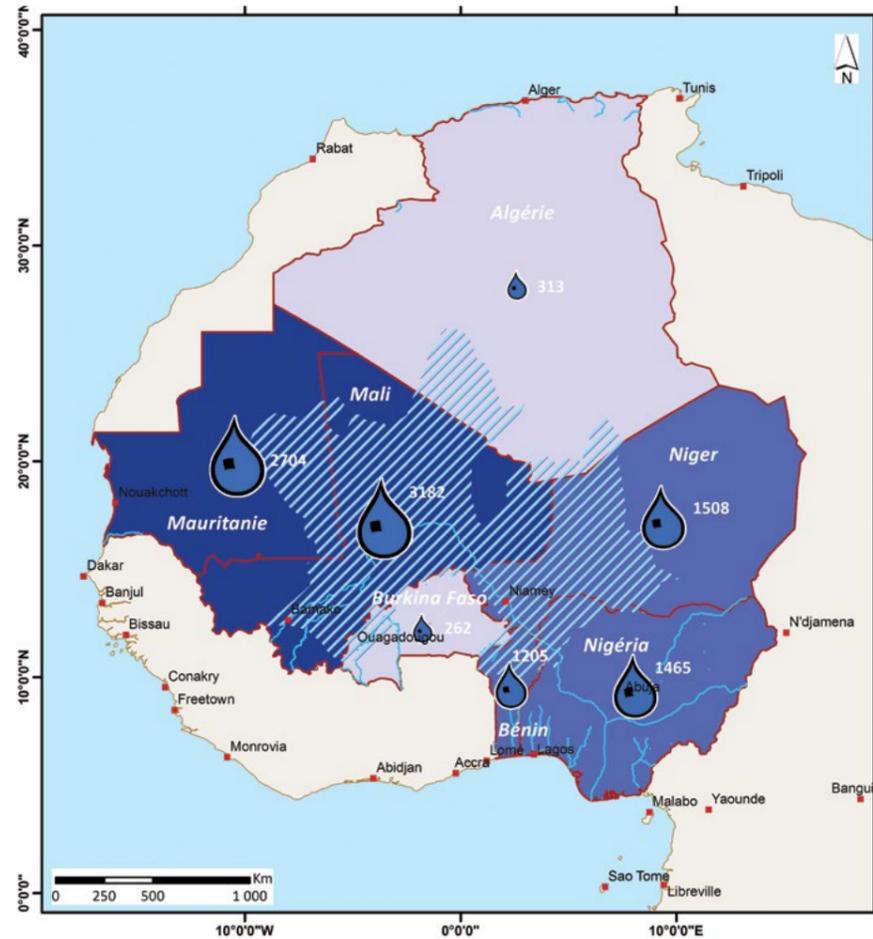


Surface water availability

The map on surface water availability (Fig.10) shows that Mali and Mauritania enjoy water comfort. Despite the important water resources from watershed of the Niger River and Chad

Lake watershed, Niger and Nigeria are both vulnerable. Algeria and Burkina Faso suffer from a water shortage.

Figure 10 Surface Water Availability (m³/inhab/yr), 2014



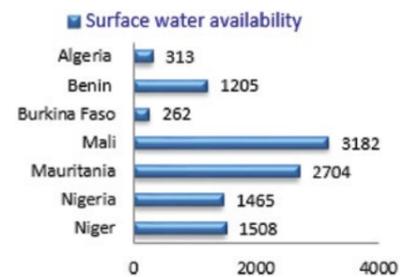
Source of data : National multi-sectorial studies : Benin, Burkina Faso, Nigeria, Niger, Mali, 2004 ; Atlas of water resources-Mauritania,2011 ; Scientific article - DEMMAK A., 2012: Monitoring Evaluation of Water in North Africa, National report ; population data : AQUASTAT, 2014.

Developed by : Sahara and Sahel Observatory, 2017

Water availability : Expressed in m³/in hab/year, it is the ratio of average renewable natural water resources of good quality on the population of the territory on a specified date (Source : FAO-Aquastat).



Water availability (m ³ /inhab/year)	Water situation
< 500	Shortage
500 - 1000	Stress
1000 - 1700	Vulnerability
1700 - 5000	Security
5000 - 10000	Confort
> 10000	Luxury



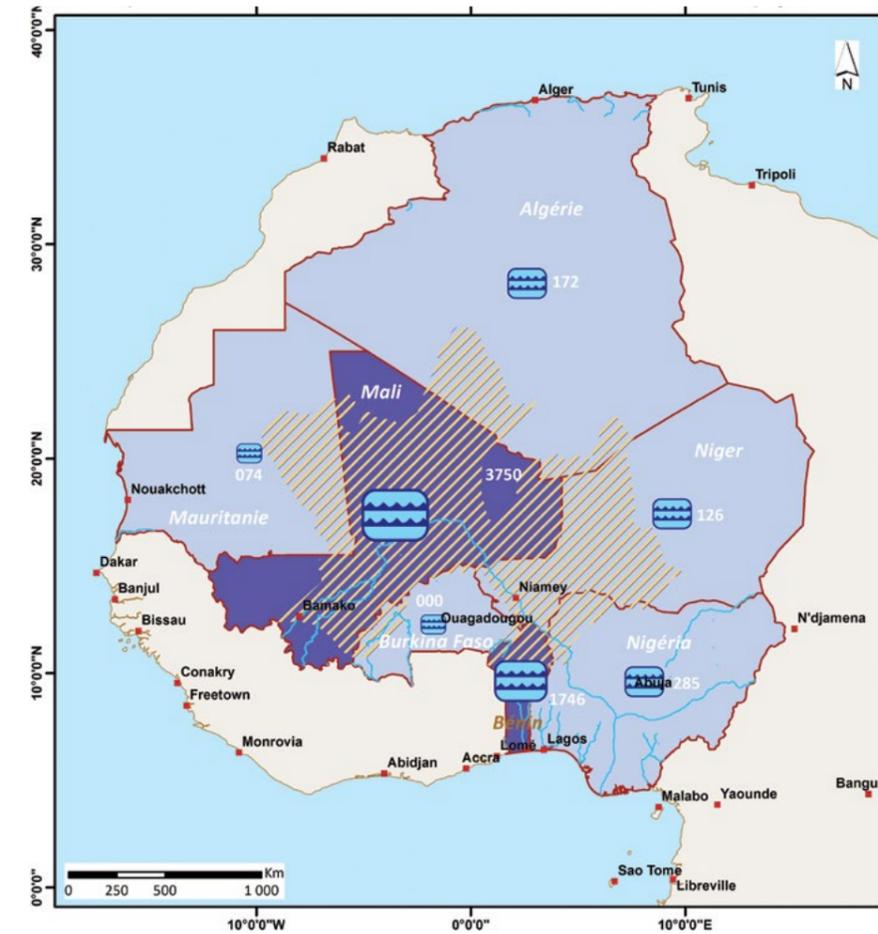
Availability of renewable groundwater resources

Based on this indicator, all of the ITTAS countries, except Benin and Mali, apparently suffer from water stress or water shortage (Fig.11), despite the considerable renewable

groundwater resources of the lullemeden, Taoudeni-Tanezrouft Aquifer System, Chad Lake, and the Senegal-Mauritanian Aquifer System.

Figure 11 Groundwater Availability (m³/inhab/yr), 2014

The water availability indicator does not include fossil groundwaters.



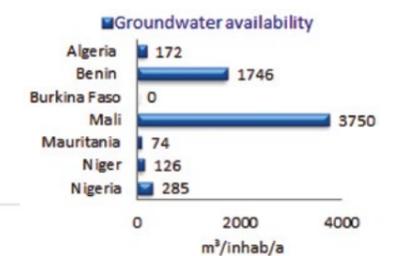
Source of data : National multi-sectorial studies : Benin, Burkina Faso, Nigeria, Niger, Mali, 2004 ; Atlas of water resources-Mauritania,2011 ; Scientific article - DEMMAK A., 2012: Monitoring Evaluation of Water in North Africa, National report ; population data : AQUASTAT, 2014.

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Water availability : Expressed in m³/in hab/year, it is the ratio of average renewable natural water resources of good quality on the population of the territory on a specified date (Source : FAO-Aquastat).



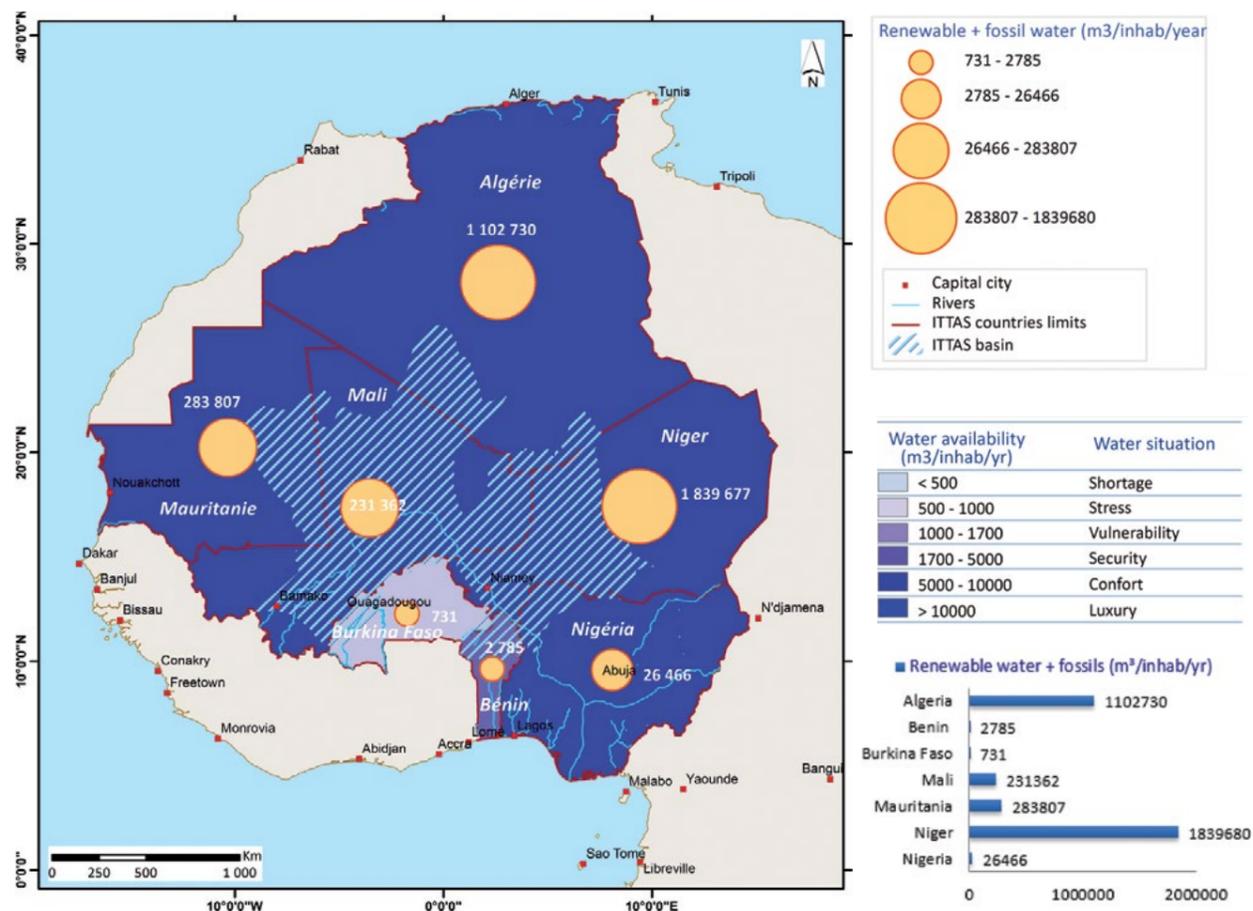
Water availability (m ³ /inhab/year)	Water situation
< 500	Shortage
500 - 1000	Stress
1000 - 1700	Vulnerability
1700 - 5000	Security
5000 - 10000	Confort
> 10000	Luxury



Renewable water and fossil water availability

In terms of fossil water, all the countries, except Benin and Burkina Faso, are considered to be in a water comfort situation (Fig. 12).

Figure 12 Fossil water and renewable water availability (m³/inhab/yr), 2014



Source of data : National multi-sectorial studies : Benin, Burkina Faso, Nigeria, Niger, Mali, 2004 ; Atlas of water resources-Mauritania, 2011 ; Scientific article - DEMMAK A., 2012: Monitoring Evaluation of Water in North Africa, National report ; population data : AQUASTAT, 2014.

Developed by : Sahara and Sahel Observatory, 2017

Water availability : Expressed in m³/in hab/year, it is the ratio of average renewable natural water resources of good quality on the population of the territory on a specified date (Source : FAO-Aquastat).

Barely renewable or fossil water are not well exploited as drinking water because of the high cost of boreholes due to the depth of aquifers, high recurrent expenses, etc.

On the other hand, these resources are often used for agriculture and industrial development, which can cause local environmental and health problems.

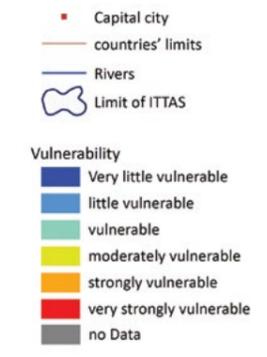
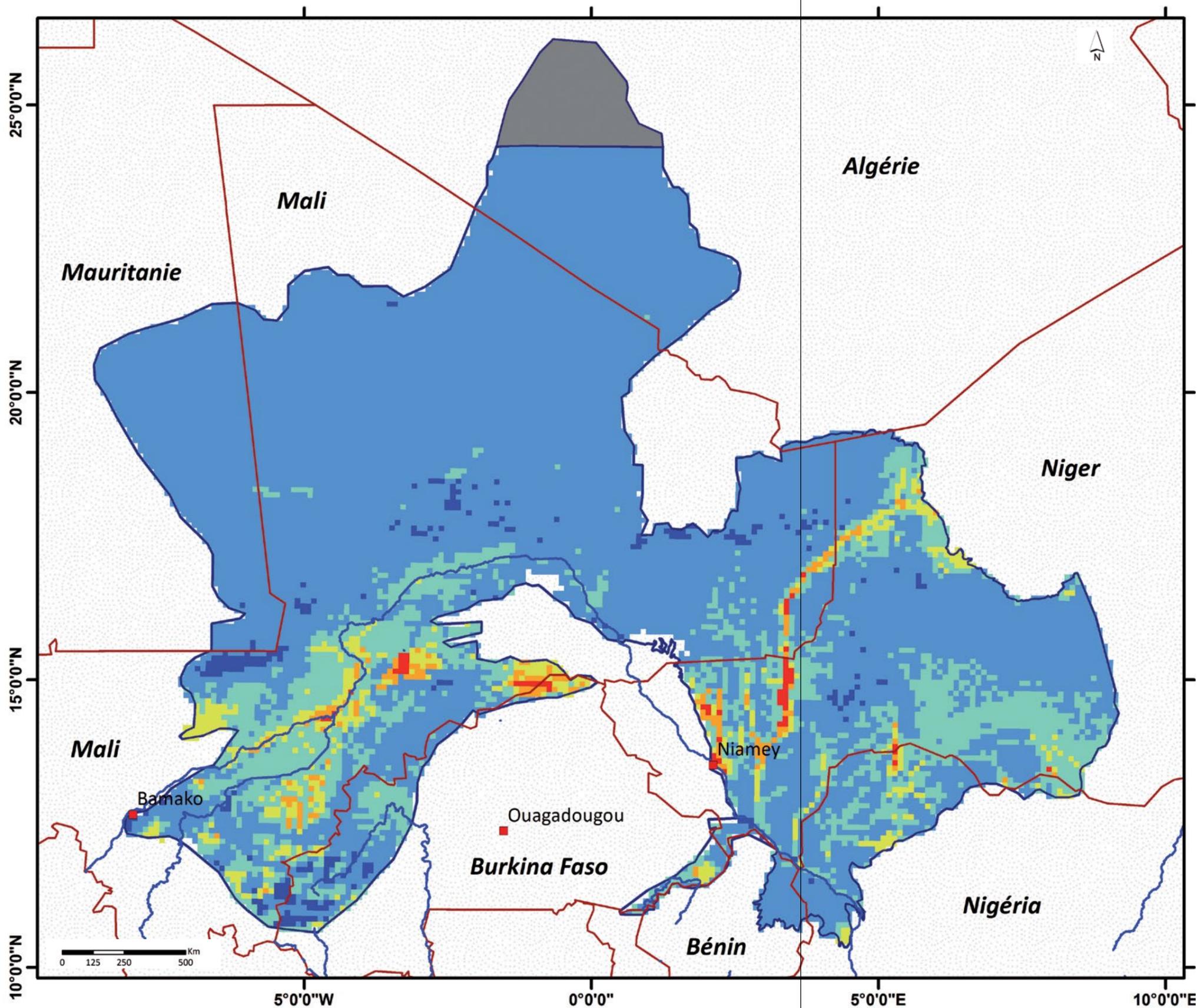
In Algeria, the use of fossil waters essentially for irrigated agriculture leads to overexploitation of Saharan aquifers and environmental degradation (soil salinization, etc).

In Niger, the use of fossil water mainly for Uranium mining activities in the Northern part of Niger, has led to water quality degradation which in turn has impaired human health.



Modern well at Banizoumbou, Niger

Figure 14 Groundwater vulnerability due to climate change, 2013



Source : OSS, 2013

Developed by : Sahara and Sahel Observatory, 2017

Mathematical models were developed, inter alia, to estimate the impact of drought on aquifer recharge, taking into account the increased water demand caused by population growth.

Simulations show that the lowering of water tables due to severe droughts and population growth amount to only a few additional meters compared to normal years.

Simulations have also shown that the recharge from one very rainy year can compensate for several consecutive years of drops in water table levels due to low recharge.

The groundwater resources of the lullemeden, Taoudeni-Tanezrouft Aquifer System are an abundant, but lightly exploited resource that is rather well protected against climate variation, and therefore serves as a "buffer" vis-à-vis the surface waters, and an alternative in case of extreme water shortage.



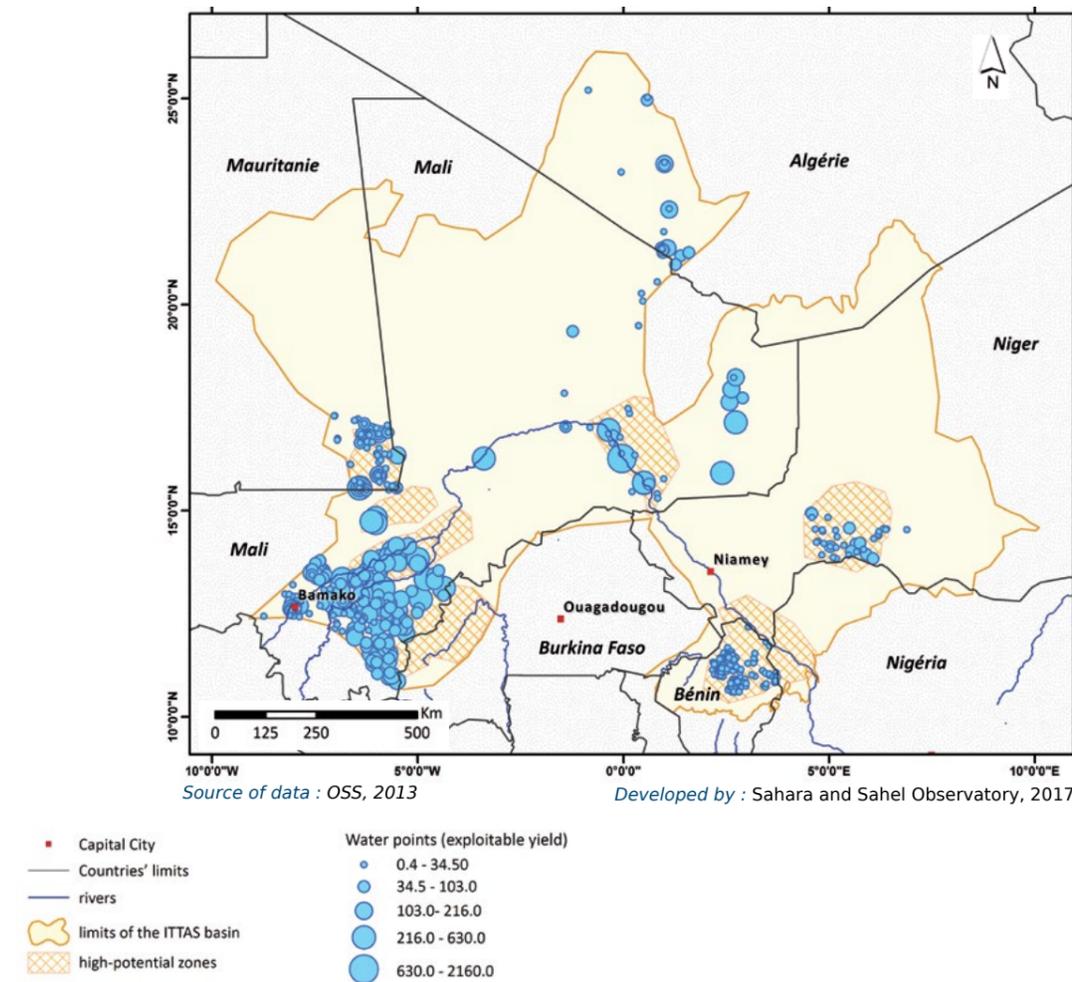
**SUSTAINABLE MANAGEMENT
OF THE REGION'S
WATER RESOURCES**

WATER TRANSFER

The ITTAS aquifer basin has considerable underexploited potential for groundwaters and agriculture yet at the same time certain populations suffer from food and water insecurity due to insufficient access to drinking water. These populations are the first to suffer from the recurrent impacts of climate change. The groundwater resources of these high

potential zones, which represent a vital source of water for the communities around the basin, could also constitute an economically viable source of water for the other populations living far from the outflows of the Niger River. In this situation, water transfers from the high potential zones would be one of the best solutions to the water shortage (Fig. 15).

Figure 15 Exploitable flows (m³/h), 2010



The water points are mainly concentrated in the **high-potential zones**, which confirms their value as a source of drinking water.

Fulfilling the water requirements of communities (mainly rural), agriculture, and industry should be part of a regional master plan for water resources distribution for the whole region. The

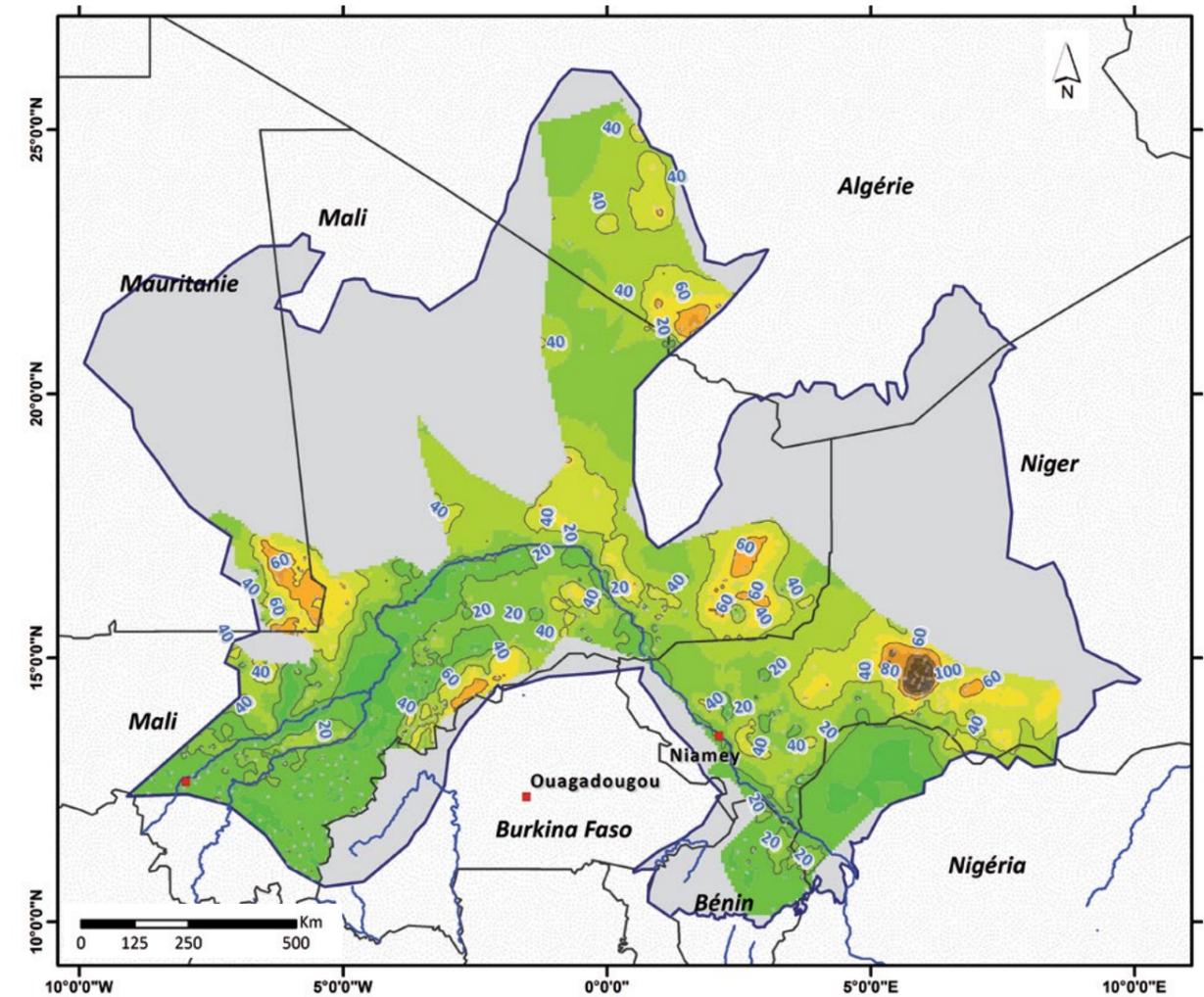
plan should take account of the water transfer issue and the actions set out in the Action Plan for the Development of the Niger Basin Authority.

WATER-ENERGY INTERACTION

The maps of water levels compared to soil levels (Fig. 16) provide useful information for decision-makers and managers in their analyses of costs

and types of energy (thermal, photovoltaic solar, eolian) for supplying drinking water to the people.

Figure 16 Static level of the groundwater with respect to the soil level, 2010



Source: 2010 national data: (focal points, national structures, and national consultants).

Developed by : Sahara and Sahel Observatory, 2017

The lullemeden, Taoudeni-Tanezrouft basin has a considerable solar and wind energy potential (Table 2). In the zones where the aquifer level is not deep, pumping by solar energy is an

efficient way to develop irrigated agriculture during the dry seasons. The drip irrigation technique could also contribute to significantly improving the Basin's agricultural sector.

Table 2 : Solar and wind energy potential

	Sunshine (kWh/m ² /yr)	Wind speed (m/s)
Algeria	2650	2 - 6
Benin	1800 - 2200	3 - 5
Burkina Faso	2000	2 - 5
Mali	1800 - 2550	4,5 - 6,5
Mauritania	2 000 - 2 300	Max 9
Niger	1800 - 2550	Aver 5
Nigeria	800 - 1800	4 - 5



A cloud of dust just before the rains



High waters on the Niger River



Traditional wells



Off-season crops

AFRICAN NATIONS COMMITMENTS

For Africa, and more precisely for the seven countries sharing the lullemeden, Taoudeni-Tanezrouft Aquifer System, challenges are being met with the following commitments:

- ▶ **The Africa Water Vision for 2025** « an Africa where there is an equitable and sustainable use and management of water resources for poverty alleviation, socio-economic development, regional cooperation, and the environment ». African States have committed to addressing the continent's major challenges to sustainable water resources management and to finding solutions to the competing demands for basic water supply, sanitation, food security, economic development and the environment.
- ▶ **Agenda 2063** adopted by the Heads of State and Governments at the 50th anniversary of the African Union on 25 May 2013 in Addis Ababa (Ethiopia). Countries have committed to the road map for the next fifty years in order to accelerate actions in several fields, including natural resources development.
- ▶ **Sustainable Development Goals (SDGs)**. On 25 September 2015 the United Nations adopted a new agenda entitled "Transforming our world: the 2030 Agenda for Sustainable Development". This agenda includes 17 goals divided into 169 targets to be achieved by 2030.
- ▶ **The Paris Climate Agreement** : This agreement entered into force in November 2016 and commits its signatories to mitigate the effects of climate change and implement rigorous adaptation measures. Water is strongly brought up in four priority themes: agriculture, risk management (meteorological and hydrological variability), integrated water resources management, and access to drinking water.

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ABBREVIATIONS AND ACRONYMS

AfDB	African Development Bank
AU	African Union
AWF	African Water Facility
CI	Continental Intercalary
CILSS	Permanent Interstates Committee for Drought Control in the Sahel
COP	Conference of Parties
CT	Continental Terminal
ECA	Economic Commission for Africa
FAO	Food and Agricultural Organization of the United Nations
FFEM	Fonds Français pour l'Environnement Mondial
GHG	Greenhouse Gas
GICRESAIT	Joint and Integrated Water Resources Management of the Iullemeden, Taoudeni-Tanezrouft Aquifer Systems and the Niger River
IAS	Iullemeden, Aquifer-System
IGRAC	International Groundwater Resources Assessments Center
INDCs	Intended Nationally Determined Contributions
ITTAS	Iullemeden, Taoudeni-Tanezrouft Aquifer System
MDGs	Millennium Development Goals
OSS	Sahara and Sahel Observatory
SDGs	Sustainable Development Goals
TAS	Taoudeni/Tanezrouft Aquifer System
UNDP	United Nations Development Programme
UNECA	United Nations Economic Commission for Africa
WHO	World Health Organization



Water efficient irrigation system in the Sahel



Sahara and Sahel Observatory, 2017

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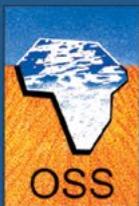
March 2017

This Atlas is meant to be used by decision-makers, development partners and the general public.

The purpose of the Atlas, containing some 30 maps and graphs derived from an OSS regional study on the Iullemeden, Taoudeni-Tanezrouft Aquifer System, is to provide information on the availability and use of water resources in this region of seven countries (Algeria, Benin, Burkina Faso, Mali, Mauritania, Niger, Nigeria).

The Atlas also offers the reader illustrations concerning water and the strategic role it plays in transboundary cooperation, food security, health, and socio-economic development to help cope with global changes.

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ISBN : 978-9938-933-03-1

March 2017

