Case study


©IFAD/Guido Rutten

Programme de développement durable des oasis (PDDO)

Introducing solar-powered pumping in the oases of Mauritania

Background

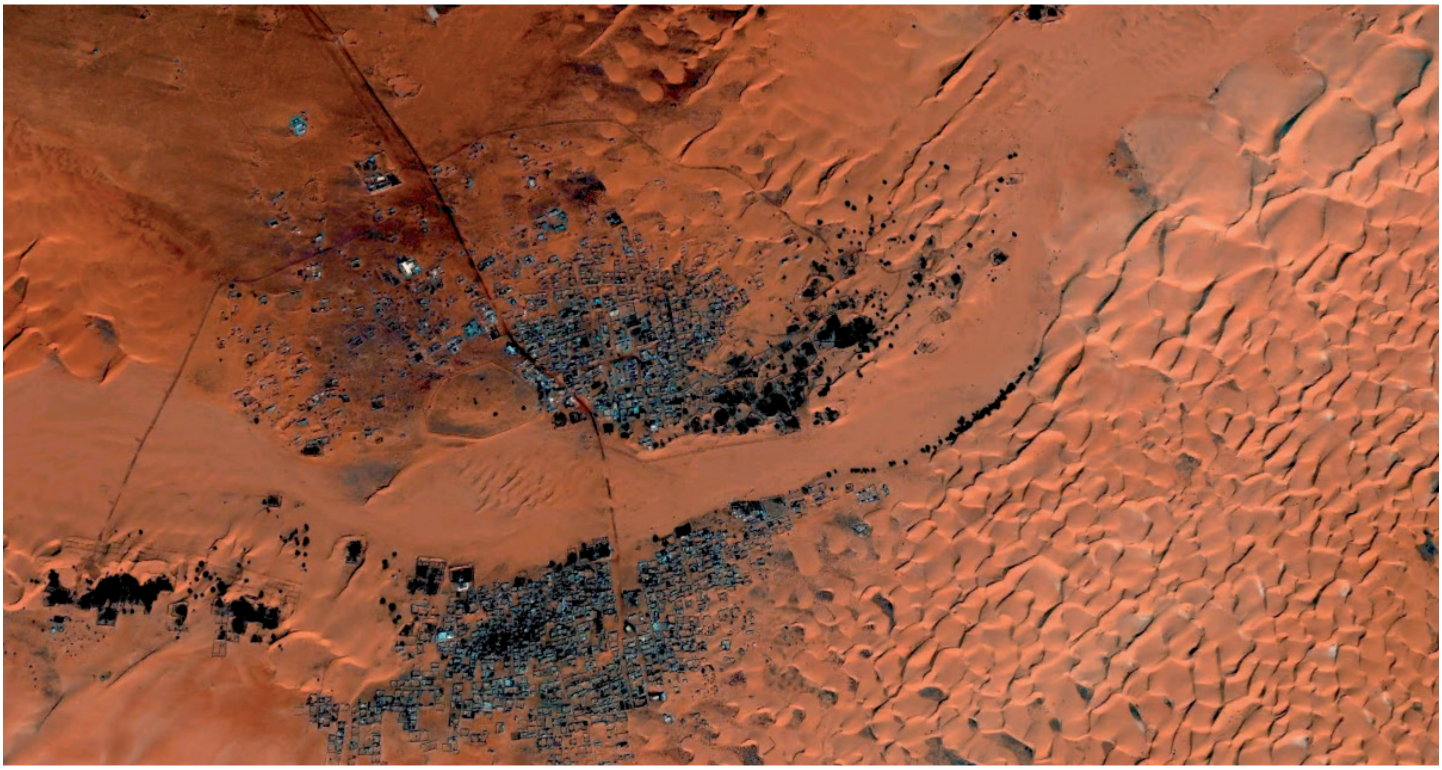
The oases of Mauritania represent a truly unique ecosystem, where the delicate balance between the availability of natural resources and human consumption is key to the livelihoods of the oasis inhabitants. Many of these oases have been inhabited and cultivated for thousands of years, but climatic events and human development in the last decennia have disrupted that balance.

Under the *Programme de Développement des Oasis* (PDDO), the Government of Mauritania, the International Fund for Agricultural Development (IFAD) and the Global Environment Facility (GEF) have introduced and piloted solar-powered water pumping for agricultural use in the oases. The programme's overall objective was to establish a solid base for development, create the conditions under which the people of the oases could overcome poverty, and combat the degradation of their environment. The introduction of solar-powered pumping, a clean technology with the potential of promoting inclusive growth, has played an important role in achieving this objective. As the PDDO has come to an end, this document describes some of the valuable experiences gained and offers a critical review of the impact of this new technology on water sustainability.

The oasis

An oasis is a fertile area in an otherwise arid region, such as a desert, created by a local availability of water. This water source can be a spring, or shallow groundwater along a *wadi* (i.e. a riverbed that fills up with water only during times of rain). The natural availability of water can be further enhanced by human activity (i.e. by capturing water from the riverbed, known as water harvesting) or by using wells to extract groundwater.

IFAD
Investing in rural people



A famous oasis: Chinguitti, a medieval town once flourishing from the trans-Saharan trade route
Source: Google Earth

The availability and efficient use of water are key to agricultural development within these particular ecosystems.

Oases are often home to ancient human settlements; some oases have developed into modern cities. The typical oasis in the Mauritanian desert is a long stretch of small settlement clusters along a wadi that is flooded only a few days per year. One oasis can be more than 10 kilometres in length and usually consists of patchy groups of cultivated perimeters, on average 500 hectares per oasis. A cultivated perimeter is usually small (around 70 per cent have an area of less than 0.5 hectares) and contains on average around 85 date palms (JICA, 2001).

Solar-powered pumping

The oasis water system

In the Saharan ecology of Mauritania, surface water is available only in a few oases. As a result, farmers in oases mostly rely on groundwater for their agricultural production and their livelihoods. The depth of the water table depends on the hydrogeological properties of the subsurface, as well as the recharge it gets from the highly irregular rainfall and the floods that subsequently run through the wadi.

To increase the reliability of groundwater sources for irrigation purposes, the PDDO supported efforts to increase the infiltration of water and the efficiency of irrigation. Infiltration weirs were built across the wadi to slow down the flood waters whenever they came, thus allowing more water to percolate and be stored in the subsurface. Water efficiency improvement measures mostly targeted the distribution of water from the source to each plant, minimizing losses through evaporation.

In some areas, the water table may be only a few meters below the surface, hence palm trees can access water with their roots. In other areas, the water table is deeper, and water lifting is required to make it available to plants. This was traditionally carried out with *shadufs* (i.e. rope-and-bucket systems). Now, with support from the PDDO, farmers in the oases have more powerful and less cumbersome means at their disposition.

Water pumping

The Sahel droughts in the 1970s and 1980s caused water levels to drop, which compelled the farmers to shift from manual water extraction to using diesel motor pumps to extract groundwater from greater depths. At that time, diesel pumps available on the market had a much higher capacity than the traditional methods (i.e. 30 cubic metres per hour for a diesel pump versus 3 cubic metres per hour for a shaduf). Their capacity was also much higher than that required for irrigation (i.e. a farm with 100 palms would require around 15 cubic metres per day). In the absence of good management, this overcapacity often led to overuse and spillage. As a result, water levels in the wells dropped further, and wells were often depleted after only a few hours of pumping.

Against this backdrop of increasingly unsustainable use of natural resources in the oases, the PDDO aimed to rehabilitate land productivity and reduce poverty through targeted sustainable land management investments. One of these investments was the introduction of solar-powered pumping in combination with water storage and improved distribution systems (i.e. cost-effective, clean technologies, offering opportunities for fostering inclusive growth).

Motor pumps left behind as farmers move to more sustainable solar-powered pumping.
©IFAD/Guido Rutten

System set-ups

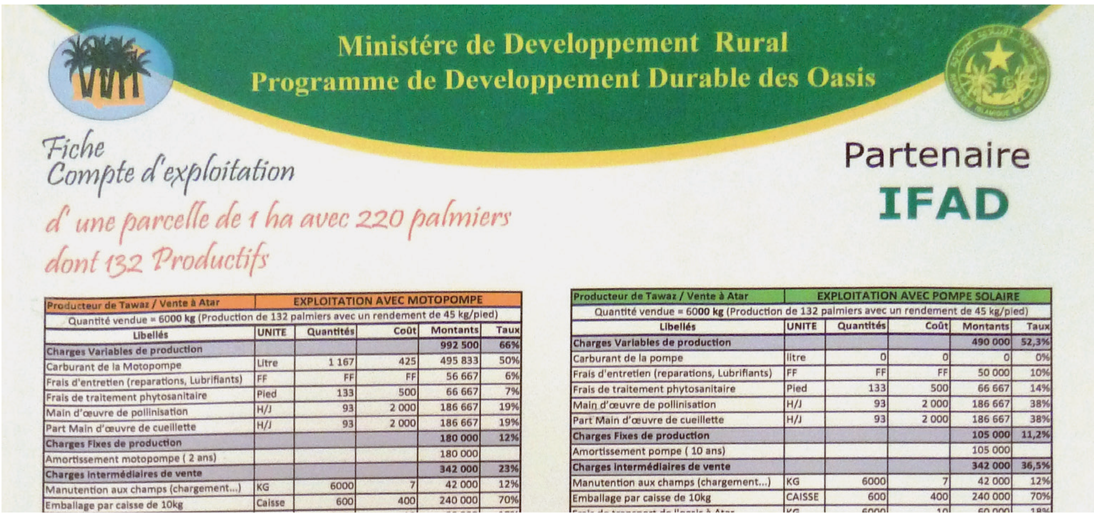
The PDDO experimented with three set-ups, combining different social and technological configurations to identify those that would create the largest impact. All the systems make use of a pump and a reservoir with a capacity of 30 cubic metres, which allows for nighttime irrigation and eliminates the need for batteries. The irrigation systems are used for both palm trees and vegetable gardens.

A water tower feeding a large collective scheme.
©IFAD/Guido Rutten

Table 1
System set-ups

Individual	**People per system: 1** **Pump: 1.2 kW** **max 45 m^3/day** **(~300 palm trees)*** **Solar panels: 6**	In this set-up, a small pump is connected to a collection of six solar panels, feeding a reservoir placed slightly above ground level. With on average nine hours of sun, the pump can deliver up to 45 m^3 of water per day. With such capacity, this system allows market-oriented individual farmers to reach higher production levels.
Small collective	**People per system: 3-5** **Pump: 1.2 kW** **max 45 m^3/day** **(~300 palm trees)*** **Solar panels: 6**	This set-up has the same technical configuration as the individual set-up, but water is distributed among three to five farmers possessing relatively fewer palm trees. This set-up allows for a more inclusive use of the irrigation system, reducing per capita up-front capital costs while sharing benefits. Water distribution is usually done on a rotating schedule – for instance, each farmer is allocated two days of irrigation per week.
Large collective	**People per system: 30** **Pump: 1.8 kW** **max 100 m^3/day** **(~1000 palm trees)*** **Solar panels: 9**	This set-up consists of a more powerful pump and a water tower, connected to a water-saving tube distribution system servicing up to 30 people, with flow meters for each user. This set-up provides economies of scale and more efficient water use, but at the same time requires more advanced management.

*The pumping capacity of the solar pump depends on the depth of the water table (here assumed at 40 metres). The amount of water needed for each palm tree depends on a number of factors, including efficiency of irrigation.



A poster developed by PDDO comparing the costs of motor pumping and solar-powered pumping.
©IFAD/Guido Rutten

Comparing the costs

Solar-powered systems are characterized by higher up-front capital investments but a longer asset lifespan compared to motor pumps. Typically, a motor pump costing US$400 on the local market has a lifespan of two years, while a set composed of a solar-powered pump and panels, altogether costing US$3,200, lasts for 10 years.

The cost trade-off between motor pumping and solar-powered pumping depends on the technical configuration and the fluctuating costs of fuel. Graph 1 compares the yearly costs of a typical motor pump (Chinese brand) with a small solar pump system, both in combination with a surface storage reservoir. For this comparison, the costs and life expectancy are as per Table 2, while the costs of fuel have been estimated at US$1.50 per litre. As the graph shows, the resulting yearly depreciation costs for the solar system are slightly higher than for the motor pump, however, these extra costs are offset by the running costs of fuel.

The economic and financial feasibility of solar-powered pumping was confirmed by a study carried out by the PDDO in 2013, which analyzed combined costs and benefits. This study found that profits were 27 per cent higher for households that used solar-powered pumps to irrigate their palm trees, compared to the profits of those that used motor pumps. For vegetable gardening, especially in the case of carrots, the study found an up to 200 per cent increase in revenue.

On the other hand, the high up-front capital costs of solar-powered pumping are a challenge for poor farmers. For the set-up indicated in Graph 1, it would take six years before the annual costs of motor pumping (annual depreciation, operation cost) surpass those of solar-powered pumping. Yearly costs for adding enhanced irrigation systems (tubes and valves) are substantial. Moreover, farmers

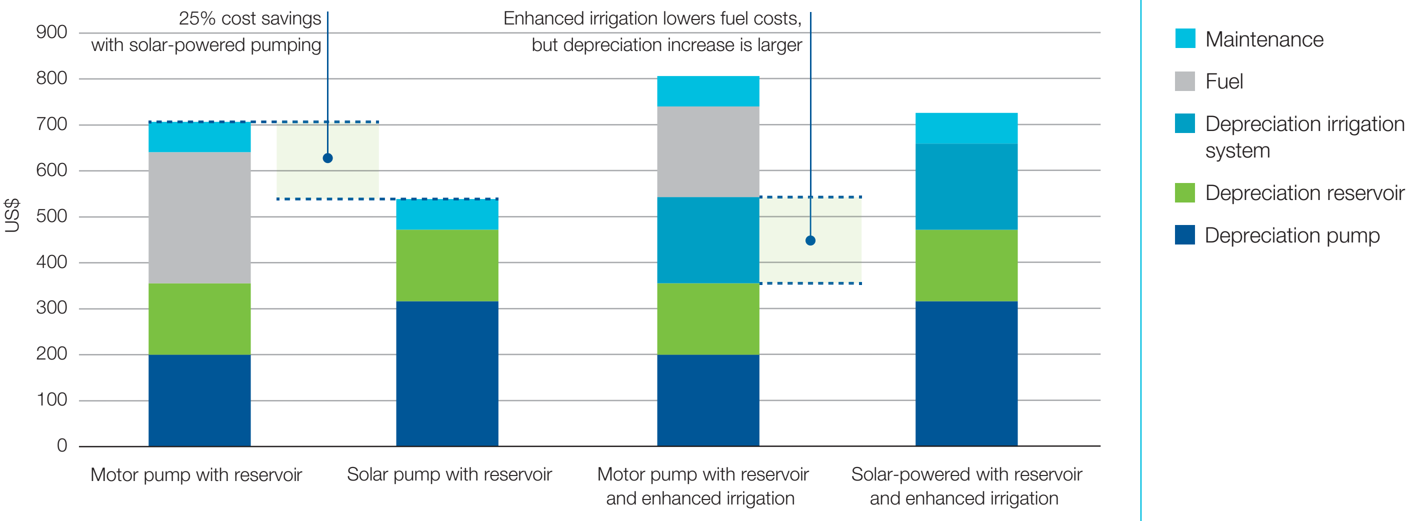
"Thanks to the solar system, I have been able to plant new palm trees, which will start producing in three years. This way, I'm investing in the continuity of my production."

A farmer in the oasis of Chinguitti

Table 2
Comparison of costs of irrigation systems

Asset		Local price	Life expectancy
Motor pump			
Pump	300 m³/day	$300	2 years
Solar pumps			
Small pump 1.2 kW	45 m³/day	$3,200	10 years
Larger pump 1.8 kW	100 m³/day	$4,500	10 years
Solar panel	0.2 kW/each	$200	10 years
Storage			
Surface reservoir	30 m³	$2,300	15 years
Water distribution			
Localized irrigation	per ha	$750	4 years

Graph 1
Total yearly costs for small system (example)



Comparison of yearly costs for motor and solar-powered pumping for a small system, servicing 85 palm trees and 0.1 hectares of vegetable gardens.

have to save money for 10 years in order to be able to renew the solar-powered installation once it reaches the end of its lifespan. For this purpose, farmers would need to have access to credit and savings mechanisms that would support this type of investment.

While the results of this study give an indication of the financial feasibility of solar-powered pumping, further economic and financial analysis could provide more robust evidence. In particular a more thorough assessment could examine the different types of benefits accruing to the farmers, such as the freeing up of time for other productive activities (see chart below) and how these impact on the farmers' livelihoods.

Social and environmental benefits

Savings and income generation
Solar-powered pumping reduces the **costs** of irrigation, while it frees up **time** for farmers to cultivate their land or expand into off-farm activities, thus generating extra income.

Climate change mitigation
Solar-powered pumping significantly reduces greenhouse gas emissions, thus contributing to the mitigation of climate change.

Collective action, inclusive model
The collective configuration of solar-powered pumping has proven a successful method to enhance collective action. Poor farmers group with those having more resources, sharing efforts and reducing individual risks.

Human safety
Over recent years, toxic gasses from diesel pumps in poorly ventilated auxiliary wells have caused many human casualties. With solar-powered pumping, farmers live a safer and healthier life.

Clean soils, quiet mornings
Solar-powered pumping has reduced the diesel spills polluting the oases and the groundwater. Farmers report that their quality of life has also improved, as they are no longer woken up too early in the morning by the deafening noise of motor pumps.

Water saving
The introduction of solar-powered pumping is a good opportunity to save water through more demand-based pumping and the introduction of enhanced water distribution methods (see next page).

Water savings

Solar-powered water pumping offers good opportunities for water saving, as it provides a pumping capacity that is more aligned with the demand for water. Water savings are magnified with the simultaneous introduction of more efficient water distribution systems.

The motor pumps available on the market and used in the oases generally have a higher capacity than that required by individual farmers for cultivation and is five times as high as that of the solar-powered pumps. When motor pumps are used – especially without a reservoir to control water distribution – a lot of water is wasted and wells run dry after only a few hours of pumping. With the lower capacity of solar-powered pumping, farmers have noticed that wells no longer run dry, and thanks to water storage they can easily control the time and quantity of water application to their crops.

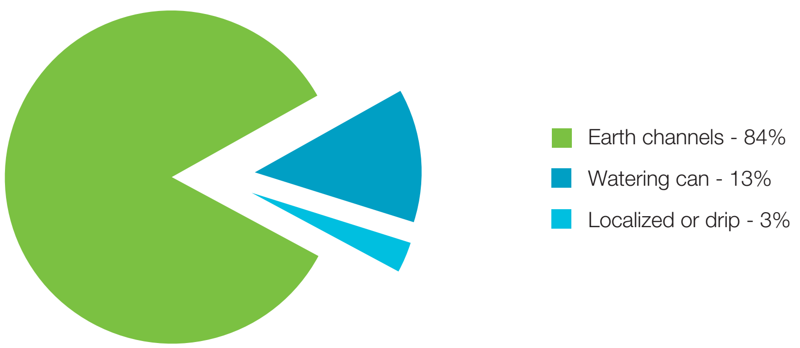
Traditionally, farmers in the oases distribute irrigation water by digging channels. This technique requires no investments in equipment and can be maintained by the farmer. However, it is labour-intensive and results in significant water loss through percolation of the sandy soil and evaporation – as much as 30 per cent, depending on local characteristics.

An important feature of solar-powered pumping is its use in combination with enhanced water distribution techniques, some of which have been implemented by the PDDO. The most common among these is the localized irrigation system, whereby a network of tubes with branches extended to the palm trees is installed. A circle-shaped basin is dug around each palm tree to contain the water it needs, in addition to the water needed by any vegetables cultivated around its base. The branches of the tubing system are closed off with valves to control the flow of water. For vegetable cultivation, even more precise irrigation can be obtained with drip irrigation systems.

Finding the right incentives for the introduction of water-saving technologies remains a key challenge. The installation of such technologies does not always lead to notable cost reduction nor income increase for the farmers, hence the latter might not be motivated to adopt them if, for instance, a pump provides sufficient water for traditional irrigation and expansion of the farm is not feasible. Furthermore, the introduction of these systems requires capacity building. After an initial batch of drip irrigation kits was poorly adopted by the farmers, the PDDO began accompanying the introduction of kits with substantial support from extension services. Through this support, farmers learned how to use the systems correctly, which significantly increased their adoption rate and sustainability.

Initially, to promote water-saving practices, the PDDO required farmers to invest in distribution systems in order to be eligible to receive solar pumps. However, this condition was soon discarded, as it prevented some of the poorer farmers from participating. It was also found that in some locations, improved water distribution systems were less suitable than the traditional ones, as the high salinity of groundwater caused clogging of the tubes.

Graph 2
Current types of water distribution



How to make it work

Successful introduction of green technology needs a solid business case. Through piloting and promotion, the PDDO demonstrated the potential of solar-powered pumping to farmers in the oases. This investment has paid off, as the interest generated among the farmers in adopting the technology has been such that, towards the end of the project, the number of solar-powered pumps in operation doubled through autonomous adoption by farmers – thus validating the business case. The PDDO has also started to demonstrate how this innovation can be pro-poor by promoting collective set-ups of solar-powered pumping.

To enable further scaling-up of this technology, alternative financing mechanisms should be explored. This would allow farmers to overcome the barrier of higher up-front investment costs. In addition, a public-private partnership – with, for instance, the suppliers of solar pumping equipment – could stimulate further inclusive, sustainable growth.

Changing contexts

Transition to sustainable use of natural resources in the oases of Mauritania is key to building an ecosystem that is more resilient to changing contexts. While the overall near-term effects of climate change on the availability of freshwater in Mauritania may be limited (IPCC, 2014), the climate system remains variable and the risk of a major drought is very high.

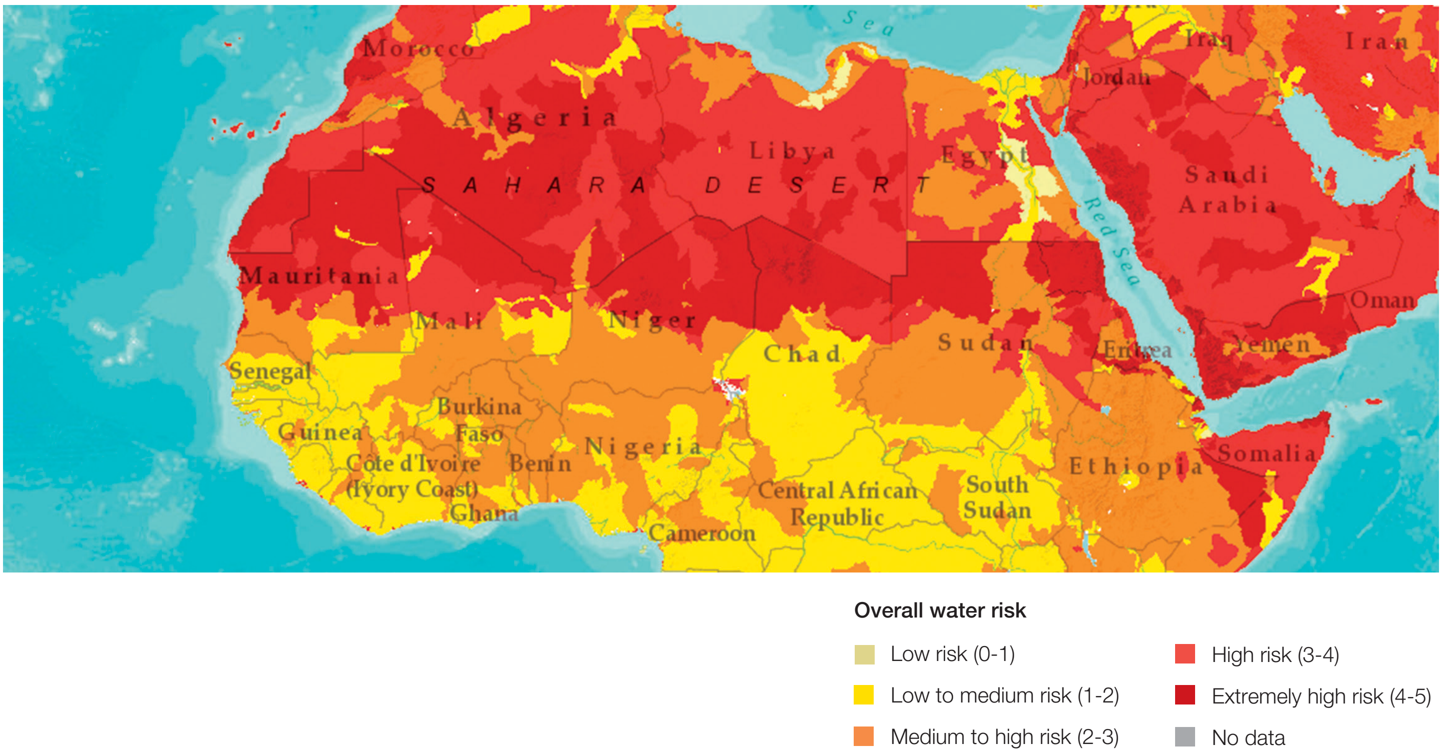
Moreover, the socio-economic context is also changing. Competition with the outside world, in terms of markets and the use of natural resources, will have important effects on the production in the oases. As farmers intensify their production, the pressure on natural resources grows, and their sustainable management becomes more vital than ever.

Investments in improved natural resource management create resilience. If water resources are used more efficiently, then higher water tables would be restored, creating a buffer for times of drought. Yet, while the efficiency of production in terms of water use is important, reinforcement of community-driven water governance mechanisms will be key to long-term sustainability. This governance should include the management of water demand, as well as strong monitoring and evaluation practices.

Competing for water with the city

The oasis of Teyarett is only a few kilometers away from Atar, the capital of the Adrar region, and a large pipeline transports drinking water from Teyarett to Atar. While the proximity of the city and its markets has many advantages for the people of Teyarett, the competition for water resources is now starting to be felt, as water levels are dropping.

Map showing current water risks across Africa.
Source: WRI Aqueduct, wri.org/aqueduct



©IFAD/Guido Rutten

A solar-powered future

The pilot test of solar-powered pumping in the oases of Mauritania has proven to be a success. While it must be acknowledged that solar-powered pumping alone will not solve all of the challenges of sustainable natural resource management in the oases, it is a technological option offering several developmental benefits. Solar-powered pumps have proven to be more cost-efficient and offer significant environmental benefits over the course of their 10-year lifespan. Collective ownership and management of the pumps has significant social benefits, allowing even the poorest among farmers to benefit from technological advancements. Groundwater levels have been stabilized and production has increased. Having witnessed these positive changes, some inhabitants of the oases began adopting the technology using their own means. The PDDO has thus created a significant positive impact, approaching a *critical mass* of interventions.

The challenge for the future is to: support and accelerate the transition to 100 per cent solar-powered, water-efficient and sustainable livelihoods in the oases of Mauritania; to ensure that this transition is inclusive; and to seize all opportunities to further strengthen the resilience of the oases' ecosystem to climate change.

IFAD

International Fund for Agricultural Development
Via Paolo di Dono, 44
00142 Rome, Italy
Tel: +39 06 54591
Fax: +39 06 5043463
E-mail: ifad@ifad.org
water@ifad.org
www.ifad.org
www.ruralpovertyportal.org

ifad-un.blogspot.com
www.facebook.com/ifad
instagram.com/ifadnews
www.twitter.com/ifadnews
www.youtube.com/user/ifadTV

References

JICA (2001). Rapport de l'étude sur le développement des oasis en Mauritanie

PDDO (2013). Evaluation des performances des systèmes d'irrigation et de vulgarisation au niveau de la zone d'intervention du programme de développement durable des oasis (PDDO) en milieu oasien.

WRI Aqueduct. Accessible online at www.wri.org/our-work/project/aqueduct/aqueduct-atlas

July 2015