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SAHEL GROUNDWATER

CATALYZING FARMER-LED IRRIGATION DEVELOPMENT IN THE SAHEL FROM SHALLOW GROUNDWATER

Women farmers manually irrigating nursery trees from an open well in the Sahel. ©CILSS

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CIWA LEARNING NOTES

HIGHLIGHTS

1 **Farmers in the Sahel can tap into the shallow groundwater along rivers and in lowlands to develop irrigation, with limited overexploitation risks.** The potential for shallow groundwater-based irrigation in the Sahel is estimated to be more than 2-to-3 million hectares.

2 **Open wells are expensive in the Sahel, making them unaffordable for most. Farmer-Led Irrigation Development (FLID) projects should therefore promote the use of local well-lining materials** to reduce investment costs and ease access to shallow groundwater sources.

3 **Well construction techniques need to be improved and the technical capacity of well diggers strengthened** to improve the productivity and sustainability of wells. In low permeability terrains, large diameter agro-wells could be an option to increase well productivity.

4 **Solar-based surface pump solutions need to be more accessible in the Sahel** to ease irrigation operations for women and other vulnerable populations while reducing pumping costs, limiting greenhouse gas (GHG) emissions and preventing groundwater overuse.

5 **Barriers that prevent women from accessing improved technologies for groundwater-based irrigation need to be overcome given the critical role they play in agricultural production.** Targeted measures are needed to address deep-seated patriarchal values that exclude women from participating, to create the enabling conditions for women to succeed in their farming projects, and to address technological challenges.

CONTEXT AND POTENTIAL FOR SHALLOW GROUNDWATER-BASED FLID

Groundwater is usually considered shallow when the water table is found less than 8 m deep. This allows its abstraction with an inexpensive surface pump operating by suction.

Regional studies conducted in the six Sahelian countries—Burkina Faso, Chad, Mali, Mauritania, Niger, and Senegal— conclude that there is huge potential to develop shallow groundwater for farmers to take the initiative in irrigation development, tapping into the shallow groundwater with pumping equipment fitted to serve less than one to several hectares, for individuals or a small group of producers. Farmers are typically entrepreneurs targeting new markets and investing their own resources. FLID has high potential to generate profits and internal rates of return (Burney *et al.* 2013; Giordano *et al.* 2012).

The highest potential for shallow groundwater-based irrigation is in the alluvial plains of major rivers (e.g., the Niger, Gambia, Senegal, and Volta rivers systems and tributaries of Lake Chad including the Chari and Logone rivers), in the lowlands, and near major lakes, where conditions are compatible with low-cost drilling and pumping techniques. Although there is considerable uncertainty about their groundwater potential, these areas should be promising. An unpublished World Bank study[1] estimates that in Mali alone there are 900,000 ha available for low-cost groundwater-based irrigation and 260,000 ha in Chad. These are conservative figures that only consider the amount of water that can be sustainably used without affecting groundwater-dependent ecosystems (GDEs) or nearby wells.

> Shallow groundwater-based FLID potential in the Sahel is estimated to be more than 2-to-3 million hectares

Despite its potential, groundwater-based FLID represents only 9 percent of the Sahel's current total irrigated surface of 720,000 ha. Farmers' activities in irrigation development are constrained by a variety of factors, some of which are not related to the water source, including difficult access to markets for crop produce; the unavailability and/or high costs of inputs and labor; the lack of farmer training and support services; land tenure insecurity, which is particularly a barrier for women; and the institutional context. The inclusion of a diversity of women including female-headed households, widows, child brides, and women in polygamous marriages is critical since they play a key role in agricultural production, particularly subsistence farming where they ensure that there is sufficient food in their households.

As the main water collectors, women face challenges in engaging in productive agricultural activities due to their poor access to water. It is therefore important to adopt targeted measures to overcome obstacles that women face. This could include addressing financial and technological obstacles so that women are able to participate on an equal footing at all stages of a project. It could also include providing grants or selecting technologies that women are able to easily use. It is equally important to engage men to secure their buy-in and to enlist them as champions for women's participation.

Other challenges are specific to groundwater-based irrigation and related to constraints with commonly used groundwater-lifting technologies, which include open wells and pumping systems.

WHY NOT DEEP GROUNDWATER FOR FLID?

Groundwater plays a pivotal role in sustaining agriculture and livelihoods in the Sahel, but its development is still rather limited. Groundwater withdrawal is also a rapidly evolving sector that is largely unregulated and unmanaged. Although the legal framework to control groundwater abstraction exists in all six countries, in practice, enforcement is weak, and private boreholes and pumps are installed without a license or monitoring of abstractions.

When the depth[2] of the pumping groundwater level exceeds 8 m, the inexpensive suction pump needs to be replaced by a more costly and complex submersible pump. In the absence of regulation and control for sustainable groundwater management and abstraction, this deep-pumping technology leads to overexploitation and resource-depletion risks.

Adjusting well or borehole production to the available groundwater resource is a well-known challenge, and no efficient approach exists to prevent farmers from using a borehole to its full capacity. When several deep boreholes are tapping the same aquifer and pumping beyond the sustainability of the resource, there is a vicious cycle of continuous lowering of the water table, resulting in users deepening their boreholes and lowering the water table even more. In addition to driving equipment and operational costs to unaffordable levels for most small Sahelian farmers, this leads to a concentration of agriculture under large operations, excluding the poorest women and men.

[1] Mapping irrigated areas and identifying areas suitable for irrigation in Mali and Chad, Practica Foundation for the World Bank

[2] The 8 m limit corresponds to the suction head, i.e., the vertical height from the water level in the well to the pump, plus the head losses in the pipe.

CHALLENGES AND TECHNICAL SOLUTIONS

Although to a lesser extent than in South Asia, in all six Sahelian countries, the demand for wells and boreholes has prompted the development of a local market for manufacturing drilling machines and pumping systems and the provision of drilling services. Nonetheless, farmers report several technical challenges limiting the wider and more equitable use of groundwater.

CHALLENGE: WELL CONSTRUCTION COSTS

The generalized use of concrete rings for lining wells in the Sahel results in total construction costs three-to-five times higher than in South Asia. In Mauritania and Senegal, the cost of lined wells is the highest (from US$250 to US$550/m) and hardly affordable by small-scale farmers, while in other Sahelian countries it is lower (about US$150/m). These costs are higher than in South Asia, where lining in unconsolidated aquifers is done with local materials that are easily accessible, which limits the total cost of wells to less than US$60/m in Bangladesh, India, and Sri Lanka. Moreover, often farmers in the Sahel do not own the land they are cultivating, which discourages them from investing in costly infrastructure.

WAY FORWARD: USE LOCAL LINING MATERIAL AND FACILITATE WOMEN'S LAND OWNERSHIP

On the Indo-Gangetic plain of East India and southern Bangladesh and coastal tracts of southern India, wells dug in clay and sandy strata have traditionally been lined with rings of baked clay to prevent the walls from collapsing. This should be explored in the Sahel. Another option is the use of native stones in both basement and sedimentary terrain. Planning of irrigation projects must consider that because the value of land will likely increase because of the operation, women might then be displaced by male farmers. Facilitating the transfer of land titles to women will require partnering with local authorities and tapping into existing initiatives that seek to address deep-seated cultural barriers that prevent women from owning land. Land leasing is an inferior alternative, as land ownership incentivizes private investments in permanent assets such as wells.

Water well lined with clay rings in India. ©KK Clay Works

Manual drilling operation using auger technique in Niger. ©Kerstin Danert

WHY NOT MANUALLY DRILLED SHALLOW BOREHOLES?

Manual drilling is an alternative to conventional machine drilling or open well construction. Increasingly, the drilling equipment can be found or produced locally, which stimulates the development of small local enterprises. However, although manually drilled shallow boreholes are sometimes 10 times cheaper than open wells at the same depth, their use in irrigation has several shortcomings, notably in crystalline-bedrock aquifers. The main one is the rapid clogging that usually limits boreholes lifespan to less than a few years. Other challenges include design issues that result in low water productivity or sand pumping that damages pumps. When a certain depth is exceeded, submersible pumps are required that involve high investment costs compared to surface motor pumps. With the opportunity to drill and pump deeper, the risk of resource depletion increases significantly. Moreover, manual drilling technologies and submersible pumps exclude women as they are costly, technically complex, and physically intense.

CHALLENGE: LIMITED PRODUCTIVITY OF THE WELLS

Open wells often yield less than a few cubic meters per hour, sometimes not even sufficient to irrigate half or a quarter of a hectare. Common causes include: (i) low productive aquifer type (e.g., low-yield weathered basement and metasedimentary rock aquifers) or limited aquifer saturated thickness and consequent limited available drawdown in the wells and (ii) seasonal flow fluctuations associated with lowering water table.

WAY FOWARD: LARGE DIAMETER WELLS CAN INCREASE THE BUFFER CAPACITY OF WELLS

Large diameter wells (> 3 m) with high storage capacity can overcome the limited productivity of some shallow aquifers. As an example, a standard 0.9 m diameter well stores 0.63 m^3 of water per meter of depth. This volume reaches 28 m^3 of water per meter of depth in a 6 m diameter well, representing a substantial water reservoir if it is allowed to recharge overnight. Large-diameter wells are not yet common in the Sahel, but are widespread in Sri Lanka, where they are known as agro-wells, typically 6 m wide and 6-9 m deep. Dug by hand and unlined when they were first introduced in the late 1980s, these wells are generally located close to the irrigated plot, and water is extracted by small pumps and conveyed to the fields via plastic pipes. Each well irrigates 0.4 ha on average, depending on the crop. These technologies were initially subsidized and underwent testing and evaluation by female and male farmers. Adoption by farmers increased after five-to-10 years, driven mainly by private investments (De Silva *et al.* 2016).

Agro-well in the North-Central Province, Sri Lanka. ©S. De Silva / IWMI

CHALLENGE: WELL CONSTRUCTION AND DEPTH

Well deepening is a common issue for professional well diggers, notably in hard laterite, saprolite, basement, and metasedimentary rock aquifer settings in Burkina Faso, west-southwest Mali, southwest Niger, and southeast Senegal. Depth of the water table may fluctuate around a constant inter-annual level following the natural seasonal cycle of recharge and discharge. With the changing climate, the amplitude of this fluctuation can increase. This, combined with the shallow depth of many wells and boreholes, causes reduced well yields and seasonal drying up that is common to all Sahelian countries. Moreover, power tools, such as jackhammers, are not commonly used for digging hard rock wells, thus limiting the capacity of deepening them.

WAY FORWARD: PROFESSIONAL WELL DIGGERS USING STATE-OF-THE-ART TECHNOLOGIES

Dewatering methods are needed to keep the excavation bottom dry and facilitate well construction and deepening. Dewatering is also used to restore unused or under-utilized wells. In hard rock terrains, the use of a jackhammer eases the task of drilling or deepening a well. In poorly permeable terrains, the productivity of wells can be improved by deepening them with boreholes, which are drilled in the well bottom and can tap deeper productive layers. This method is cheaper than deepening the whole well as it usually does not need installing a casing pipe in the borehole but rather filling it with a gravel pack that is sufficient to stabilize the hole and ensure its productivity. Even if these techniques are profitable, women are likely to be excluded given financial and socio-cultural barriers including lack of access to education and low levels of literacy. As such, targeted actions such as providing training tailored to their education level are needed so women can also derive benefits.

Well digging with a Jackhammer, Mali. @Joerg Boethling / Alamy Stock Photo

CHALLENGE: FINDING INEXPENSIVE PUMPING SOLUTIONS

Small-scale farmers are migrating from manual (treadle, rope, and hand) pumps to motor pumps that are largely available on local markets and an affordable option when the pumping water level is less than 8 m deep—the physical limit for the suction technique (and sometimes up to 12 m if a counter-well is dug to lower the pump intake). Engine repair services are also generally available for these diesel motor pumps. Although these pumps usually cost less than US$170, high operational expenses (often in the range of US$300 to US$600 fuel cost per year) limits their viability for the poorest farmers, especially women.

> “Solar pumps are climate-positive, cost-effective, and a gender-friendly solution for using shallow groundwater”

WAY FORWARD: SOLAR-POWERED PUMPS

The solar pump industry is a growing sector with rapidly evolving technologies. In the Sahel, the supply chain and service provision for these pumps are, surprisingly, still poorly developed. Solar-powered pumps present several benefits such as using clean energy, no risk of fuel shortages, the possibility of diverting electricity for other uses, and low-to-negligible operational costs while the capital cost is still high. Several solar-powered pump options are available for smallholder farmers in the Sahel, notably the Future pumps, the mini-Volanta promoted by Practica Foundation, or the solar pumps installed by the Global Green Growth Institute in Burkina Faso. Future pumps are made in India and available in Burkina Faso, Mali, Niger, and Senegal. They are notably light enough to allow an easy operation by women, as opposed to standard diesel pumps.

Woman operating a Future Pump SP2 for irrigation. ©FuturePump


Field training on solar pumps in West Africa. ©COSTEA

A PATH TO SUSTAINABLE AND EQUITABLE GROUNDWATER-BASED FLID

To stimulate the growth of sustainable and equitable groundwater-based FLID, a systematic and inclusive approach is needed. Technology development should respond to the needs of different groups of farmers (e.g., men, women, youth, elderly, and vulnerable people) and be accompanied by participatory field testing and evaluation and equitable access to training and support services. Women farmers face additional challenges that prevent them from accessing and adopting irrigation technologies that could otherwise ease their work. For instance, women farmers complain about the physical burden of moving heavy pumping equipment and hand-irrigating crops and lack of access to support services and training, especially on solar-powered pumps.

Inclusive programs targeting local service providers, manufacturers, farmer groups, and women's cooperatives and associations could be initiated in synergy with the ongoing Sahel Irrigation Initiative Support Project (SIIP) or equivalent irrigation projects and include the following key actions:

Mapping the shallow groundwater potential for FLID. The knowledge gap about available shallow groundwater needs to be closed as a precondition to promote the mobilization and management of shallow groundwater for FLID.

Strengthening the capacity of professional well diggers. Digging service providers need to be trained in improved well construction techniques such as: (i) dewatering methods, (ii) tools and techniques for digging and deepening wells in hard rocks and sleeving techniques for deepening hand-dug wells in alluvial and unconsolidated sediments, and (iii) local lining materials for well lining.

Learning from Sri Lanka's experience with large diameter wells. Lessons learned in Sri Lanka with large diameter Agro-wells can contribute to improving well productivity and storage in low-yielding aquifers in the Sahel.

Solar-powered pumps are increasingly becoming available and affordable on the local market. Enabling the local production and distribution of proven surface solar pumps will contribute to the scale-up of groundwater-based irrigation. These pumps are also easier for women to handle and maintain, compared to diesel pumps.

Promoting field trainings and demonstrations on the above techniques that accommodate women and other vulnerable populations to build a community of practice that supports participatory technology development, adoption, and learning. The timing and location of the events should fit women's schedules and preferences, or separate training sessions should be organized tailored to the specific needs of women. Participatory approaches that use tools to address women's higher rates of illiteracy and discomfort speaking up at meetings are also useful.

OVERCOMING GENDER BARRIERS

Besides technology-specific constraints, other barriers related to the broader social, institutional, and policy context limit women's ability to access and derive benefits from improved technologies and use of shallow groundwater for irrigation. To create an enabling environment for women's adoption of improved groundwater technologies, key measures include:

Facilitate women's access to financing for irrigation infrastructure and equipment, seeds, inputs, and later for operations, maintenance, repairs, and technical support. This requires setting up a system of subsidies, grants, or loans tailored to women's needs, assistance with loan guarantees, and, if needed, quotas. A subsidies program, covering a substantial portion of the start-up costs would be the most straightforward and effective way forward. Given the levels of poverty in the region, loans, which would require a guarantee, are not recommended and could be a barrier for women who have fewer opportunities to generate income. Effective communication about available financing schemes and the simple application procedures coupled with technical support are key to ensure inclusiveness.

Engage men in women's empowerment. Any intervention to benefit women within a family requires the engagement of men to secure their buy-in by demonstrating the benefits to the whole family. Projects promoting women's empowerment often face male resistance, which can result in gender-based violence because of changing roles and power balances. Women may also face challenges in controlling the financial resources they generate.

Promote women's associations and cooperatives. By working collectively through women's groups, women farmers are better positioned to voice their needs and achieve their objectives. Access to financing, training, and technical support is also generally easier if women are organized in a group. Often women cooperatives may work as self-help groups with a rotating fund that women can access when their turn comes up.

Encourage women to speak up. Where women's groups are not an option, women farmers should be invited to attend, and encouraged to actively participate in, meetings and invited to join village cooperatives. To meaningfully participate in meetings, women need to be empowered to voice their concerns, which may require training in skills such as public speaking while also undertaking capacity building and awareness among men to secure their willingness to listen to, and accept, proposals from women regarding their needs and desires.

Woman standing in a field of crops. ©Darren Baker / Shutterstock

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