# Micro-Irrigation Technologies in India and Africa

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Water is an essential resource for the realization of the United Nations' 2030 Sustainable Development Goals. The increasing global food insecurity, hunger, human population, and uneconomical extraction and use of non-renewable resources require, among other things, a substantial intensification of agricultural production. In this context, there has been a need to adopt irrigation technologies, especially in developing countries where agriculture and its allied sectors employ more than 50% of the total population but account for up to 90% of the total freshwater consumptive use. India and Africa are at the crux of this conundrum, where there is an urgent need to build resilience with the already excessively allotted water resources. Innovative and water-efficient irrigation technologies could be one of the windows of opportunity to overcome water scarcity and enhance food security in these regions.

Keywords: micro-irrigation ; water stress ; water insecurity ; water harvesting

## 1. Micro-Irrigation Technologies

Micro-irrigation is traced as far back as 1917, when it was adopted in Germany, Denmark, New Zealand, and America for the cultivation of greenhouse crops [1]. Shortly after, MI (principally drip irrigation) was accepted as a viable initiative when inexpensive, weather-resistant polyethylene plastics came into full production post-World War II [1]. Indeed, traditional irrigation methods not only waste water but also cause top soil loss through erosion, significantly increasing energy usage, weed growth in farms, and salinity levels in soils [2][3]. Flood irrigation is one of the most widely adopted technologies; however, the efficiency of the water used in this technique is estimated at only 40%; this implies that evaporation or distribution emits 60% of the water [2][4]. Micro-irrigation (MI) technologies include drip, spray, subsurface, bubbler, and sprinkler irrigation. In the classical model of irrigation efficiency, these technologies offer targeted dropping of water to the roots of the crop, drop by drop, through surface or underground distribution networks that reduce conveyance losses, evaporation, runoff, and deep percolation [5][6]. Properly designed and managed MI (drip and sprinkler irrigation) systems have efficiencies between 70% and 90% [7]. This provides an avenue to: (1) save water in irrigated agriculture; (2) increase household income and food and nutritional security; and (3) reduce poverty. Further, they can be automated, which logistically saves time and reduces the quantity of water used. Much inspiration to take up MI worldwide has been due to the potential of the scheme (particularly drip irrigation) to transform the desert nation of Israel into a water surplus-nation [3].

## 2. India's Perspective of Micro-Irrigation Technologies

In India, micro (drip) irrigation technologies arrived in the 1970s from developed countries such as the USA and Israel [1]. Since then, the Government of India and other non-governmental institutions have advocated for MI through the provision of financial, institutional, and technical support systems [3][8][9][10]. At the moment, only Andhra Pradesh, Sikkim, and Karnataka have well over half of their net cultivable land covered by MI [3]. Gujarat, Andhra Pradesh, Maharashtra, Karnataka, and Telangana have at least 85% of their total agricultural land under drip irrigation. Haryana and Rajasthan states have majorly adopted sprinkler irrigation [1][3][11].

The current MI uptake across India is, still low, though, it has grown over the years nationally [5]. For example, in Assam and Odisha, merely 0.72% and 2.46% of the total net sown area are covered under MI [12]. The Indian government launched MI and reaffirmed it as a major breakthrough in 2006. Other later strides, such as the "*National Mission on MI*" and "*National Mission for Sustainable Agriculture,*" had clear missions to promote MI systems [3]. The government subsequently bundled all ongoing irrigation schemes in July 2015 and inaugurated the "*Pradhan Mantri Krishi Sinchai Yojana,*" which sought to improve water use efficiency and conserve water. With its tagline "*har khet ko pani*" for "*assured irrigation to every farm,*" in order to cover the 71.74 million hectares of arable land that were previously anticipated to be unirrigated, the blueprint called for smallholder farmers to get a 55% subsidy to install MI systems [3]. Between 2015 and

2017, an estimated 8.7 million hectares of Indian land were under MI, which is 13% of its full potential [13]. As of 2021, MI coverage has steadily increased to 13.47 million hectares (48% drip and 52% sprinkler) [12].

In India, other private organizations have also supported the MI movement. ConserWater Technologies and Bengaluru-based Fly Bird Innovation constituted a low-cost irrigation system and fertigation irrigation regulators for farmers in their farm fields as per crop requirements to improve crop yields [2][14][15]. Similarly, Gujarat Green Revolution Company Limited also introduced a similar effort for the execution of MI [3]. The Sehgal Foundation, another India-based agricultural development NGO, has promoted MI, mulching, laser leveling, and the use of water absorbents to maintain soil moisture [16]. The use of these water-saving irrigation practices reduces the consumption of water by 25–85%, basis improving farm productivity and minimizing labor costs and pest and diseases incidences. It further educates farmers that efficient use of water is the key to agricultural development. Recently, the RESILIENCE project (http://resilienceindia.org/node/119, accessed on 25 June 2023), in an attempt to address the challenges limiting MI uptake and its increased adoption in India, performed field demonstrations of MI along with other water-saving irrigation practices and capacity building and training programs in four districts in Odisha (Cuttack and Ganjam) and Assam (Golaghat and Sivasagar) [12]. The MI resulted in 20–70% water savings, a substantial (10% to 90%) increase in yields, a two- to four-fold increase in irrigation, and economic water productivity, which prompted some farmers to adopt the MI [12]. This is in agreement with previous authors [17][18], who reiterated that Indian farmers who adopted MI technologies aimed at enhancing their agricultural yields ("*per drop more crop*" mantra) and reducing pressure on groundwater or improving water security.

The salient socioeconomic and institutional factors influencing MI uptake in India include cropping pattern, groundwater access, proportion of capital, education level, socio-economic capacity of the farmers, fragmented landholding, lack of technical know-how to operate and maintain MI equipment, unreliable electricity power for operating MI, and low levels of awareness on the benefits of adopting MI [3][12]. In the context of subsidies (up to 80%) under the *Pradhan Mantri Krishi Sinchai Yojana*, it has been reported that small-scale farmers in some states such as Assam, Rajasthan, and Odisha were still unable to access and afford the subsidy [12][19]. In a recent review, it was concluded that the capital-intensive nature of MI as an intervention is a major hindrance to its adoption. Even with subsidy schemes, the penetration of MI vis-à-vis cultivable area and estimated irrigation potential in India remains low [20] because the decision to adopt MI is influenced by household, farm level, and institutional factors. It should also be noted that adoption of MI may not translate into water conservation unless farmers do not expand the area under irrigation or shift to water-intensive crops, which are more commercially valuable [20].

As women are at the core of Indian agriculture (feminization of agriculture) as well as climate change mitigation and resource conservation management, it is imperative to engage them in activities related to MI uptake. Explorations into the gender dimensions of MI development in India have indicated that few women have adopted MI technologies [8]. In Rajasthan state, for example, Birkenholtz [19] highlighted that female laborers provided a "feminine labour subsidy", which results in productive efficiency gains, thereby lending drip MI infrastructure its durability. Studies conducted globally have come to the conclusion that female farmers can be just as prolific as men if they have equitable access to resources including acreage, technology, mentoring, markets, and sovereignty over their outputs [21]. Taken together, the magnitude of the economic output surplus following the switch from conventional irrigation methods to MI systems, the structure of the use of the conserved water, and the nature and possible number of adopters all determine the influence of MI on the sustainability of groundwater resources [18]. Therefore, a multipronged strategy is required to increase MI adoption in India. For instance, intersectoral convergence of resources to enhance integrated planning and social capital requires interdepartmental and interorganizational coordination among multiple governmental and non-governmental organizations, especially those working on the same scheme [12].

## 3. African Perspective of Micro-Irrigation Technologies

Uptake of MI technologies in Africa is quite lower than in India when compared to surface irrigation [6][22][23][24]. It has the lowest percentage (<1%) of land under MI from global estimates [25], mostly (75%) owned by smallholder farmers [26]. The picture in the West African Sahel is even more worrying as it is on the Sahara Desert's periphery, and past attempts at irrigation development have not yielded much success [27]. To this end, researchers draw on some reports from different parts of Africa, which provide a picture of the adoption of MI technologies across the continent.

### Micro-Irrigation Uptake in North Eastern Africa (Egypt)

The Middle East and North Africa are the worst affected in terms of the physical water deficit globally [28]. Egypt is a North African country with water scarcity problems by virtue of its location in the Sahara Desert (with the Nile River being the only source of fresh water) as well as political turmoil in the region [29][30]. The Egyptian government has thus initiated a

Farm-level Irrigation Modernization Project to upgrade irrigation systems in the northern part of the country. The sole aim of the project is to curtail water consumption through the incorporation of clean (renewable) energy into the agricultural sector [29]. The World Bank outcome brief indicated that the upgrade of irrigation enhanced Egyptian farmers' access to water [31]. The Farm-level Irrigation Modernization Project is a World Bank-funded project that has enabled modernization of agricultural irrigation (replacement of open *marwas* with buried pipes). The modernized *marwa* hydraulic system, combined with systematic rotations and the swapping of diesel supply to electrical pumps, improved water flow by up to 85% compared to the initial 50% before the project. In addition to this, the Egyptian government has, as of August 2019, imposed restrictions on the growth of water-intensive agricultural crops such as rice, sugarcane, and bananas in the Nile basin that are necessary to protect the Nile River's waters [29].

## Micro-Irrigation Uptake in Southern Africa

Drawing another example of an irrigation scheme in Southern Africa (the Chinyanja Triangle), Mango et al. [32][33] reported that the adoption of small-scale MI technologies, soil conservation practices and other water conservation practices, improved water and food security. This can be compared to the situation among most Indian farmers [12][17][18]. The Chinyanja Triangle (CT) is composed of three perceptible ecozones that have plateaus on the northernmost tip, sub-humid escarpments in the middle, and semi-arid Shire, Luangwa, and Zambezi river valleys on the southern end [33]. Geographically, the Tete province of Mozambique, the southern and central areas of Malawi, and the eastern province of Zambia make up CT [34][35].

In the context of water management and irrigated cultivation, the agrarian communities within the CT are dependent on climate-sensitive rain-fed agriculture [36] and therefore highly vulnerable to climatic vagaries [35][37]. Low soil fertility (unproductive agricultural lands), high rates of soil erosion downstream, little agricultural investment, and the pristine environment are under further stress due to input consumption, uncontrolled deforestation, and unsustainable land use practices, endangering the food security and livelihoods of those living in the triangle [35][37].

The choice of MI technologies in the CT is influenced by proximity to irrigation gear and reputable water sources, off-farm employment, and awareness of water and soil conservation practices such as rainwater harvesting [32][33][34][38]. The CT has the potential to become the breadbasket of Southern Africa, and efforts to improve the adoption of MI technologies could, in the long run, improve the food security of this triangle and the region at large. In Southern Africa, MI has been adopted by few women due to limited accessibility to both cultural influences and ecological systems [39].

## Micro-Irrigation Uptake in Eastern Africa

The late 1990s saw the introduction of low-head drip kits MI in Kenya, East Africa. However, it has since been abandoned by most farmers due to cultural factors and an erratic water supply [40]. In East Africa, customized irrigation techniques, including washer pumps, rope pumps, treadle pumps, small motorized pumps, and drip kits, are the most adopted [4][22]. These technologies are challenged by the current land tenure system in the region, restricted access to MI technologies, dependable markets, inadequate extension services, and inadequate infrastructure [4]. For example, the total land under MI in Uganda is less than 1%, out of 3,030,000 irrigated hectares [41]. In Kenya, MI agriculture accounts for only 4% of the total land area [42].

Smaller adoption rates of MI technologies are also evidenced in Rwanda, Ethiopia, Burundi, and Tanzania, where the sole aim of MI is to increase crop yields or reduce food insecurity [43][44]. This is the same scenario reported in India previously [12][17][18]. In Ethiopia, the provision of loans and reduction in ambiguities related to well drilling have influenced farmers to adopt smallholder irrigation packages [45] which is similar to the initiative in India [3]. Where schemes are communal, low levels of community participation, poorly designed irrigation infrastructures, high construction costs, and delayed project completion have hampered the uptake of MI technologies in Ethiopia [46][47]. Specifically, MI is not well established in Ethiopia [48], despite the country's endowment with various water resources and being the "water tower of Africa". Nevertheless, smallholder uptake of drip irrigation technologies has increased in Ethiopia in the past decade [49].

Opportunities for MI expansion and improvement of water security in East Africa exist, with the major ones being rainwater harvesting to enhance water availability and commitment on the side of governments and non-governmental organizations.

Further it calls for donors to boost smallholder MI expansions, as well as exploration of restoring conventional irrigation systems, using low-cost irrigation technology that can be adjusted to local conditions, and using more mobile phones that can be employed to disseminate information [4][47].

### Micro-Irrigation Uptake in Western Africa

In Nigeria, Niger, and Mali, *shaduf* and *delou* systems (a form of water lifting device with simple rope and bucket arrangements) have been used to harness water for human and animal use and consumption and for small-scale irrigation [50]. The first ever MIs in this region were launched in the valley of the Senegal river (Richard Toll irrigation scheme) and the Inner Niger Delta in Mali. Just as in other parts of Africa and India, MI uptake in West Africa is driven by the need to improve soil conservation, crop yields, and family income [51][52][53].

Gendered analyses of MI projects in this region have underscored the limited participation of women in irrigated agriculture. This is particularly explained by the fact that women still have limited access to resources, such as land and water [54]. In Ghana's Upper East Region, for example, irrigation is only possible where a community dam is available. Where there are no dams, men dig deep into riverbeds to access water for irrigation of their small plots near the river. However, women with limited access to land near the rivers and the labor needed to dig the wells are placed at a great disadvantage. They are therefore limited to collecting irrigation water from distant places using buckets or jerrycans [54]. Reviews on the experiences in agricultural water management in West Africa [55][56] showed that there is a need for (a) encouraging irrigation based on the market under a public-private partnership model, (b) adoption of smallholder private irrigation while targeting high-value markets, (c) uptake of small-scale irrigation for the neighborhood markets, administered by the community, and (d) instituting reforms as well as modernizing the available large-scale irrigation projects, better water administration and control, and watershed governance in rain-fed localities. Overall, these findings corroborate the fact that adoption of irrigation technologies should be linked with water harvesting, agroforestry, increased water, soil, and food security, and other conservation initiatives [51][57].

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