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Review of Irrigation Practice in Ethiopia, Lessons from Israel

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Abstract

This report tried to address why Ethiopia is suffered from low agricultural production blessed with high potential of irrigation water resource, irrigable land, labor and suitable climate and why Israel is very effective in irrigated agriculture by having very low arable land, water resource, and with adverse climatic condition. What lessons should Ethiopia share from Israel in irrigated agriculture to improve the economic and social development of Ethiopia? Various research papers were reviewed in this paper and it indicated that if Ethiopia want to be effective in irrigation and brings its population in to food security it could take lessons from Israel's long-term struggle and effort on the management of its irrigation water. Ethiopia should have to develop its own solutions to serve the needs of farmers as well those of broader economic development. Ethiopia has an important opportunity in water-led development, but it needs to
address critical challenges in the planning, design, delivery, and maintenance of irrigation systems to capture its full potential. This report showed how Ethiopia can be successful in irrigation so that the people of the country will improve their economy and will be food and water secured country in a short period of time. Hence, Ethiopia should take lessons from Israel in irrigation practice systems viz use of advanced and water saving technology, reuse of waste water and adoption of effective water management practices.

Keywords: Irrigation practice • Water management • Reuse of wastewater • Israel • Ethiopia

Introduction

The total population of Ethiopia is estimated to be nearly 100 million [1]. The annual population growth rate is 2.6 percent and the average population density is 90 population/km². Nowadays the rural-urban migration has been increased leading to a rise of urban population. The urban population is growing rapidly as a result of both populations increase and high rural-urban migration. Most of the population in Ethiopia lives in highland areas, with 85% being rural and dependent on agriculture with a low level of productivity [2-5].

In Ethiopia agriculture is the leading sector accounting about 47.7 percent of the total GDP [6]. The country has sufficient amount of surface and groundwater from the 12 river basins with 122 billion m^3 of surface water and 2.6-2.65 billion m^3 of groundwater. This indicated that there is about 1575 m^3 of physically available water per person per year, a relatively large volume [3,7]. As a result of this ample water resource potential, Ethiopia is said to be the 'water tower of Africa' [8].

However, there is ample water resource and irrigable land, the irrigated land is estimated between the range of 160,000 and 200,000 ha which is less than 5% of the country's irrigable land [8-11]. However, MoA [12] reported about 10-12% of the total irrigable potentials are currently under production using traditional and modern irrigation schemes.

According to Belay and Bewket [13] the estimated irrigable land of Ethiopia varies between 1.5 and 4.3 million hectares (Mha) in average about 3.5 Mha [5,14,15]. Even though there is no evidence, it is believed that irrigation practices were started during very old times with unstipulated commencement period. However, irrigation was not likely a driving force for the initiation of ancient civilization in Ethiopia. Its contribution to the national economy is insignificant as compared to rain-fed agriculture [16]. In most cases, Ethiopian irrigation systems have failed and did not significantly enhance the livelihoods of rural community or cannot bring considerably impact on food security in the country.

As of MOWR [17] report, Ethiopia has an area coverage of 1.13 million km2, of which 99.3 percent is land area and the remaining 0.7 percent is covered with water bodies of lakes. The land is also covered with an arable land (10%), permanent crops (0.65%) and the remaining 89.34% covered with others. The cultivable land area estimates showed a variation between 30 to 70 Mha. Currently, high estimates show that only 15 Mha of land is under cultivation. From the existing cultivated area, only about 4 to 5 percent is irrigated, with existing equipped irrigation schemes covering about 640,000 hectares. This indicated that a substantial portion of cultivated land is not under irrigation [10].

Even though the country has surplus water resource and irrigable land, it is found to be low productive. These low productivities resulted in an imbalance between the population and production leading to the expansions of agricultural land by deforesting and using rangelands. Low productivity resulted many of Ethiopians to be faced under food insecurity for the last four decades. In addition, an increased population brings about continuous land degradation, excessive deforestation, erratic and unreliable rainfall which has brought negative impact on farm households. Furthermore, the recurrent drought occurred with a long-lasting effect on the livelihood of agricultural communities and the whole economy. As a consequence, both severe and chronic hunger and malnutrition occur [18].

On the other hand, Israel is one of the most densely populated countries in the world, which has only 20% arable land of which half of it has to be irrigated. More than half of Israel is arid and/or semi-arid, and the rest of the

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country is dominated by steep hillsides and forests. But Israel not only produces most of its own food, but also exports $1.3 billion worth of agricultural produce annually and $1.2 billion worth of agricultural inputs and technology sold every year.

Israel is an example for the world in optimizing the use of water in general and agriculture in particular. Irrigation water management is a critical issue which will provide food for billions of people in the world. Some countries are using their water resources wisely and others are not effectively and sustainably using their water resources for irrigation. In that context, taking lessons from countries like Israel which could be a role model in water management is important for those countries which are blessed of natural resources but not effective in the utilization and management like Ethiopia which said to be "the water tower of Africa".

About 80% of Israel's water potential lies in the northern part of the country from which 95% are used for irrigation and domestic purposes. So that large amount of water should be transported more than 200 km distance to supply the water demand of the domestic and irrigation. The surface water supply is about 33% and the rest ground water supply is obtained from two major aquifers. About 275 MCM treated water from which 65% treated waste water is currently utilized for irrigation purposes.

Thus, it should be revived to show how we should manage our precious resources in the field of irrigation and water resource management. Their experience is especially relevant to the developing world including Ethiopia [19]. Therefore, this report tried to identify the problems of irrigation systems in Ethiopia by taking lessons about the challenges and success stories of irrigation from Israel. This review tried to answer the following questions from different perspectives.

- Why irrigation couldn't be successful in Ethiopia and why Israeli is successful?
- Is irrigation a bless for other countries and curse for Ethiopia?
- What success stories of irrigation can share for Ethiopians agricultural water management from the other countries?
- Which requirements of successful irrigation lacks in Ethiopia?
- What are the challenges and opportunities of irrigation development Ethiopia?

Review of Literature

Development of irrigation in Ethiopia

Irrigation is provided to supply water to crops and other cultivated plants to increase productivity during dry periods and erratic rainfall conditions to as a supplementary irrigation. Irrigation has been implemented to increase the agricultural productivity and reducing of food insecurity in the nation [10].

Irrigation projects have been classified as small scale, medium scale and large scale based of the extent of the irrigated command area. According to Ministry of water, irrigation and electricity small scale irrigation projects cover an area less than 200 hectares, medium scale covers an area between 200 to 3000 hectares and medium scale covers an area greater than 3000 hectares [14,15,17]. In Ethiopia such like irrigation system classification is common. Hence about 46% of irrigation development is categorized under small scale irrigation project category [15]. Small scale irrigation projects are community based and traditional methods of irrigation. Most of the time medium scale irrigation projects are community based or publicly sponsored, while large scale irrigation projects are commercially or publicly sponsored.

Why Ethiopia is not successful in irrigation and Why Israel is successful?

Opportunities: Ethiopia is endowed of natural resources, as it is known as water tower of Africa; it has great opportunity of irrigating the land resource. Currently Ethiopia plans to increase significantly irrigated land from 640,000 ha to 1.8 million ha, through small-scale, medium scale and large-scale irrigation projects. Some of the irrigation development opportunities in Ethiopia are; emphasis and priorities are given to irrigation in the growth and transformation plan of the country, indigenous knowledge and introduction of promising household water harvesting and micro-irrigation technologies, government's strong political commitment and encouragement to private sector and public enterprises involvement in irrigation development, abundant water resources, climate and land suitability, availability of inexpensive labor, availability of suitable lands for irrigation developments especially at arid areas of the country [9,16,20].

Challenges: Even though there are several opportunities of irrigation development in Ethiopia, there are also challenges. Low water and land productivity have been observed in most of the government initiated and community-managed projects due to multifaceted technical and socio-economic problems. Lack of sense of ownership of the beneficiaries and low operation and maintenance are the common problems in Ethiopian irrigation projects [21]. The main challenges of irrigation in Ethiopia are,

- **Inconsistent delivery of scheme:** most of the time there is significant gap between the design/plan of irrigation project and actual delivery/construction. These are illustrated by the number of irrigation projects and the number of hectares to be irrigated are less than the plans and or the designs of irrigation projects.
- **Low-performance of schemes:** Many schemes currently operate significantly under their design capacity. The research team estimates that scheme performance is on average 30 percent below design, implying a loss of about 230 thousand hectares of irrigated land, leading to only 410,000 ha performing to the expectation
- **Constraints on scale-up of irrigation projects:** Irrigation projects need scale up, but there is a constraint to do so due to inadequate funding, limited private sector participation, and human capacity and labor constraints.
- **Limited project sustainability:** The sustainability of irrigation projects is threatened due to inappropriate water resources development, lack of watershed and environmental management, land degradation caused by soil erosion, and poor drainage practices.

Abiyu and Tebeje [22] stated that inappropriate technology choice, poor land and water management, too small land holding, conflicts over irrigation water utilization, poor marketing access, shortage of improved seed supply and inefficient utilization of resources are the some of the challenges observed in Ethiopian irrigation. Poor awareness of irrigation water management in irrigation scheduling techniques, water saving irrigation technologies, water measurement techniques, operation and maintenance of irrigation facilities, inadequate knowledge on improved and diversified irrigation agronomic practices, scheme based approach rather than area/catchments based approach for the development of SSI Schemes, inadequate baseline data and information on the development of water resources, lack of experience in design, construction and supervision of quality irrigation projects, low productivity of existing irrigation schemes, inadequate community involvement and consultation in scheme planning, construction and implementation of irrigation development, poor economic background of users for irrigation infrastructure development, to access irrigation technologies and agricultural inputs, where the price increment is not affordable to farmers. High rainfall variability and unreliability; significant runoff variability; significant erosion and sediment in the system; no adequate storage, property rights are not clear, conflict between users, limited market access, too small land holding, dependency syndrome, lack of adequate training, capital and research are the constraints on irrigation in Ethiopia [23].

On the other hand, most of Israel's land is covered by arid and semi-arid with saline soil which accounts only 20% of arable land. Currently the country has increased its arable land from 20% to 80% and the farming land and its production has been multiplied by 16 times. The total annual renewable natural sources of fresh water of Israel are below the UN definition of water poverty. The rainfall in Israel has an erratic nature and most of the time it has been expected to get drier [3,22,24].

The success stories of Israel's Irrigation were achieved after a long period hard work and effort on unfavorable land. Based on the world order of irrigated land, Israel irrigated land is ranked as 73th of the world irrigated land order whereas Ethiopia is ranked as 63th. Today, Israel's agricultural sector is a highly developed industry and its importance in Israel's overall economy is high. Agriculture in Israel contributed to just 3% of total exports in 2006, rising to 4.2% (over $2 billion US) of total exports in 2010. Currently, Israel exports more than $2 billion dollars of fruit and vegetables each year. These exports amounted to 18% of agricultural production in 2014. But Ethiopia cannot even provide agricultural products for its population by having huge potential of irrigable land for agricultural production [25,26].

Water is a very critical problem in Israel to address this problem the country consolidates its national water management system policy plan. this plane encompasses planning and construction of elaborate water shortage and distribution system, development of alternative water sources and continual search for innovative water management technologies. The policy plane considers supplying of water according to the demand for agriculture, industrial and human consumption.

The achievement of water resource development in Israel is coordinated by the problems of amount and quality of irrigation water which include among others, increased water scarcity, depletion of water resources, frequent drought technological uncertainty, degradation of water quality and high cost of nonconventional water sources, rapid urbanization and desertification of agricultural land. To overcome all those challenges Israel has recorded remarkable achievement under dynamic and changing world by creating new policy related to future water demand of the country. From these policies issues related to water, food security and agricultural production are among the main policy issues aiming to make the agriculture industry freely competing with industrial and domestic users. Emphasis was given to integrated use of water management of conventional and non-conventional sources, increased water use efficiency, combined with agricultural production. Furthermore, by assuming that peace process would create strong regional commitment to prevent water crisis in the country [25].

Success stories of irrigation from Israel

Knowing the insufficiency of natural water resources and adverse climatic condition of the country, Israel has planned and practiced different technologies to use their scarce resources efficiently and wisely. Some of the different technologies include extensive use of desalination water, reuse of treated sewage for agriculture, computerized early-warning systems for leaks, and computerized drip irrigation and micro sprinklers. As a result, Israel is a world leader in water reuses of water which accounts 86% compared to Australia that accounts only 10%. This days Israel is becoming the water surplus nation by using the above-mentioned technologies. In the year 2016, Israel had five desalination plants, producing more than 600 million cubic meters of water/year. This plant only provides adequate drinking water to supply 1.5 million people. The desalination process involves membrane technology, where saltwater is pushed into membranes containing microscopic pores. The water gets through, while the larger salt molecules are left behind [27].

In addition, Israel has set a template for reusing wastewater for irrigation. It treats 80 per cent of its domestic wastewater, which is recycled for agricultural use and constitutes nearly 50 percent of the total water used for agriculture. Drip irrigation is one of the most effective forms used by farmers in many developed nations to reduce water wastage. Here water is allowed to drip slowly to the roots of many different plants either onto the soil surface or directly on to the roots through a network of pipes and emitters.

Israel also has also been practiced WATER GENERATION: An alternative to desalination is to extract and condense the natural humidity in the air. Watergen, an Israel based company uses humidity in the air to create clean and fresh drinking water. The heart of the Watergen product line is the revolutionary heat-exchange technology. Air is drawn into the Atmospheric Water Generator (AWG), where it is thoroughly cleaned, removing any dust and dirt and leaving only pure air in the system. The clean air is then directed through the heat exchange and cooling process, bringing it to its dew-point – the temperature at which condensation occurs – to create high quality water [27].

Efficient irrigation water management

Irrigation water management needs to be evaluated and characterized, hence the characterization of irrigation water management and service delivery indicators are; the perception of farmers' of the service rendered; the incidence of conflicts between farmers and organizations; the existence/absence of irrigation institutions; the functions of institutions; the institutional achievement to ensure water delivery equity; willingness of the farmers to contribute to the operation and maintenance; and role of women irrigation organizations [28].

Efficient water management has increased agricultural output 12-fold during the past 50 years, while water consumption has remained constant through rigorous maintenance of infrastructure, replenishing of aquifers and the allocation of appropriate quotas and pricing to discourage wasteful consumption.

Israel mainly applies IWRM Principles for sustainable development and use of resources. The following are principles relate to IWRM in Israel: imposition of water extraction levies on the extraction of water from natural sources, seawater desalination, efficient use of wastewater and effluents, brackish water desalination, demand management (conservation and pricing), and impoundment of floodwater along the coastal area [29].

Key principles of water resources management lessons to Ethiopia

Sustainable farming: This is one of the water resources management principles which include farm selection and management, integrated crop management, integrated pest management, Soil protection and yards. Efficient water management has increased agricultural output to fold up during the past 50 years, while water consumption has remained constant through rigorous maintenance of infrastructure, replenishing of aquifers and the allocation of appropriate quotas and pricing to discourage wasteful consumption. Israeli professionals are currently planning rural development projects in Thailand, the Philippines and Brazil. In the Gap region of Turkey, an area half the size of Israel, experts are upgrading the province's agriculture based on more efficient use of water from the Tigris River. Companies stress that agro-technologies must not only be appropriate for a particular region or climate, but local farmers must also be trained to use and maintain the systems they purchase [30].

Economic sustainability: This is the other principle concerning with safety, quality and transparency of the water use throughout the farming production, financial stability, and accountability, innovation, and risk management.

Social sustainability: This ensures working conditions and community engagement.

Environmental sustainability: This is the proper planning of irrigation systems to achieve water reduction, schedule irrigation to reduce water use, properly manage irrigation use, properly measure the irrigation system, prevent and reduce water losses, ensure responsible and efficient use of pesticides and chemicals in the farm, ensure safe pesticide/fertilizer storage, proper water conservation, ensure quality of water is suitable for irrigation,

minimize water point and non-point water sources, seek professional advice in assessing and planning pollution control, conduct water use inventory to manage and optimize water use in farm, minimize impacts on water courses and the environment; develop, implement and manage and monitor a comprehensive water management plan for the whole farm, and focus on specific crops. Though agriculture is the dominant sector, most of Ethiopia's cultivated land is under rain fed agriculture.

In Ethiopia, as dramatic change in rain-dependent farming system, irrigated agriculture was thought to be one of the solutions to enhance food security in the country. Although agriculture is the leading sector, the majority of Ethiopia's cultivated land is under rain fed agriculture. Since its initial promotion, irrigated agriculture in Ethiopia still only comprises a small fraction of total cultivated area; of the 4.3 million hectares that can be irrigated, only 247,470 ha are irrigated. From this irrigated area, 56% are traditional schemes, 19% are small-modern scale schemes and 25% covered by medium to large modern scale schemes [31].

Reuse of waste water

In arid and semi-arid zones of Israel, effluent serves asan important water resource for improving the national and regional water reserves. The combination of severe water shortages, contamination of water resources, densely populated urban areas and highly intensive irrigated agriculture, makes it essential that countries put wastewater treatment and reuse high on its list of national priorities. Treated Wastewater (TWW) is the most readily available water resource and provides a partial solution to the scarcity problem. The main motivation for increased use of WW for irrigation is: Irrigated agriculture serves as the best solution for human health protection and prevention of environment pollution [32].

Facts about wastewater treatment in Israel 2005

In Israel, Wastewater accounts about 500 Million M^3 WW/year, 50% treated to secondary level, 30% treated to tertiary level, 4% discharged via cesspits, 16% inadequately treated, Effluents=450 Million M3/year, 65% of effluents (300 M^3) reclaimed for irrigation, 35% discharged to rivers or sea and By 2010 – Reclaimed Effluents=50% of all water to Agriculture.

The use of recycled water has provided another solution. Out of 1.1 billion cubic meters of water used for agriculture in, 250 million cubic meters were recycled effluents. The Water Commission forecasts that by 2020 two third of all crops will be irrigated with "cleaned" water.

Use of technology

Agriculture in Israel have more severe problem due to lack of water resources. To alleviate such like challenges, Israel has developed innovative technologies of using the available water resources, including highly mechanized, high-input methods and water-saving irrigation systems which have enabled it to become a leader in high-yielding agriculture. Nowadays, agriculture accounts for nearly 60% of the water used, but approximately half of this water constitutes effluents and marginal water.

The use of different technologies including Implementation of pressure irrigation technologies, fundamentally changed traditional agricultural practices, boosting the development of a modern and highly productive agriculture, Drip irrigation and fertigation, agro-techniques that allow the supply of water and nutrients according to the demand of the crop, as well as promoting reuse of treated waste- and marginal water and protection of the environment have contributed to transforming land incapable of being cultivated into productive farmland, and increase the crop yields and reducing water and fertilizers consumption,

Cloud seeding (injecting clouds with iodine to increase the percentage of water that each cloud yields) has proven effective. Exploration (using sophisticated seismological techniques), prevention of pollution, soil conservation and drainage have all maximized water use. Landscaping to redirect floodwaters, computerized calculations to chart routes of runoff water and the strategic placement of trees and crops have also prevented desertification.

In Israel every drop of water counts: The most innovative development in water utilization has been drip irrigation, conceived in Israel some 35 years ago. Today, networks of plastic pipes with small openings for each plant or tree are strategically placed across fields. Via the drippers, controlled amounts of fertilizer can be pumped through the irrigation pipes to the plants – a system known as "fertigation" [27].

Traditionally, drip irrigation has been used in regions where water is scarce, but it has also been effective where rainfall is high because of its precision. For example, experiments in Northern California in "precision" irrigation caused some types of tree to grow three times faster. Fast-growing trees can increase profits for timber growers and at the same time minimize environmental damage by reducing the number of trees that need to be felled [27]. Half a dozen Israeli companies sell plastic piping and a full range of accessories for drip irrigation. Many also specialize in designing customized irrigation systems for gardens, parks, farms and entire regions, installing them and then providing consultation and maintenance. Exports of irrigation equipment totaled almost $300 million.

Other types of irrigation include: Pressure irrigation methods; buried irrigation, which prevents infiltration by tiny roots; spray irrigation, which is suitable for orchards; and sprinklers used for entire fields. Sensors to monitor the moisture level of the soil and check changes in the diameter of the stem or fruit. These systems can be very simple or high-tech. Options range from the basic turn on/off variety with volume clocks, to more sophisticated computerized systems, which include. Other accessories include filter traps to sweep dirt away and low flow drip emitters for soil-less media in greenhouses. Minute or ultra-low-rate (ULR) irrigation methods have been developed to apply water at rates of less than one millimeter per hour [33].

Advanced drip-irrigation systems with smart technology and sensors to help farmers significantly cut down on water users have been developed in Israel. The company is also pioneering a process known as fertigation (fertilization + irrigation), in which sensors are attached to plant roots and the surrounding soil that analyze soil conditions, weather, water, and nutrient levels. After conducting this analysis, the system uses computer algorithms to determine when and how much water, fertilizer, and pest control to deliver to the individual plants for maximum growth. Farmers in the United Kingdom who have been using the system have been able to cut down their water usage by 30% while increasing crop yields by 28% and decreasing pesticide use by 70%. Drip fertigation system has been implemented in 13 countries and used with 70 different types of crops.

Fustigation has led to the development of a new generation of soluble fertilizers for injection into irrigation systems. Basic chemicals such as nitrogen or ammoniac nitrogen with trace elements of iron, quartz, manganese and copper, which enrich the soil and enhance the growth of plants, have been combined to develop soluble fertilizers. Israeli professionals are currently planning rural development projects in Thailand, the Philippines and Brazil. In the Gap region of Turkey, an area half the size of Israel, experts are upgrading the province's agriculture based on more efficient use of water from the Tigris River. The key word in these projects is sustainability. Companies stress that agro-technologies must not only be appropriate for a particular region or climate, but local farmers must also be trained to use and maintain the systems they purchase.

In addition, Israel has focused on the following water management areas to be successful in irrigated agriculture including the following.

Irrigation water use: The agricultural sector consumes about 1200 MCM/ year to irrigate about 200,000 ha. Irrigation water comprises of fresh and marginal water. This quantity has not changed significantly over the last 20 years, despite the significant increase in agricultural production. In future, the total consumption will not be reduced, although the quality of supply will be dramatically reduced.

Irrigation water control: Computers were introduced to allow real-time operation of the irrigation systems, providing precision, reliability and savings in manpower.

Currently, satellite linked valve control was applied to control distant water systems. Soil and plant moisture sensors are also used to provide information on moisture, allowing automatic operation of the system when needed.

Irrigation efficiency: The adoption of, drip, micro-sprinklers and automation has increased the average efficiency to 90% as compared to 64% for furrow irrigation.

As a result, the average requirement of water per unit of land area has decreased from 8,700 m3/ha in 1975 to 5,500 m^3/ha in 1995. At the same time agricultural output has increased twelve times, while total water consumption by the sector has remained constant. Moreover irrigation efficiency is being attempted by regulating water application to each individual plant, using individual moisture sensing emitters. The root volume can be controlled, leading to a shortening of the crop growing cycle.

Conclusion

This report shows how Ethiopia can chart a practical path of initiatives that will allow it to support the scale-up of its irrigated agricultural sector, the growth of its small holder farmers, and the transition of its pastoralist communities to food and water security. So, by taking lessons from Israel Ethiopia can provide food for the world beyond its people if experiences are well undertaken from Israel scientists' and farmers. The success stories of irrigation in Israel and unsuccessfulness of irrigation in Ethiopia is not a matter of blessing and curse. It is not also a problem of land, water, climate or capital and labor, but it is problem of awareness about the effective utilization of irrigation water.

There is no lack of Natural Resource in Ethiopia but the attitude of the people and the government should be changed to technological advancements in agriculture. Ethiopia has an important opportunity in water-led development, but it needs to address critical challenges in the planning, design, delivery, and maintenance of its irrigation systems if it is to capture its full potential. Ethiopia is blessed of has huge cultivable land, water, favorable climate and young labor forces. This means that there are potential opportunities to vastly increase the amount of irrigated land. Even though Ethiopia has abundant land for irrigation only very small amount is being utilized. Given the amount of water available, it is evident that the promotion of water development technologies, especially irrigation can provide an opportunity to improve the productivity of land and labor and increase production volumes.

Although Ethiopia has abundant rainfall and water resources, its agricultural system does not yet fully benefit from the technologies of irrigation. So, lessons should be learned from Israel which became food provided of for the world beyond their nations by adapting themselves with unfavorable climate, low water potential resources, and densely populated areas. Israel's agricultural success is attributed to the close cooperation between farmers, Israel's agro industry, and technological research budget allocation for agriculture. Technological achievements include computer-controlled drip irrigation, computerized early warning systems for leaks, thermal imaging for crop water stress detection, biological pest control and new varieties of fruit and vegetables. Israeli drip and micro-irrigation solutions have rapidly spread worldwide.

The newest models are self-cleaning and maintain uniform flow rate regardless of water quality and pressure. Development of reusable plastic trays to collect dew from there, reducing the water needed by crops or trees by up to 50 percent Israeli irrigation and efficient water management technology has dramatically improved local yields, and could go a long way towards feeding a hungry world. From small-scale irrigation to large-scale schemes – to construct a viable solution. Like many countries before it, Ethiopia will have to develop its own spectrum of solutions to serve the needs of smallholder farmers as well those of broader economic development.

Ethiopia has an important opportunity in water-led development, but it needs to address critical challenges in the planning, design, delivery, and maintenance of its irrigation systems to capture its full potential. Ethiopia can chart a practical path of initiatives that will allow it to support the scale-up of its irrigated agricultural sector, the growth of its small holder farmers, and the transition of its pastoralist communities to food and water security. If successful, irrigation in Ethiopia could represent a cornerstone of the agricultural development of the country, contributing up to ETB 140 billion to the economy and potentially moving up to 6 million households into food security. However, irrigation is not a simple silver bullet: first, it can only work if other components of the agricultural system are also effective (e.g., seeds, extension). Second, all the tools in the toolkit will be required. Irrigation is one means by which agricultural production can be increased to meet the growing demands in Ethiopia. The best alternatives to consider for reliable and sustainable food security development is expanding irrigation system on various scales, through river diversion, constructing micro dams and water harvesting structures.

The Way Forward

- The critical challenges to overcome irrigation development in Ethiopia is to build the capacity to plan, deliver, and maintain at scale the aspirations set out in, significant skills and equipment constraints, as well as limited resources for managing information, planning, and execution.

- Ensure sustainable funding by developing business cases for water schemes at all levels and pursue cost recovery opportunities. Improving scheme performance incorporating applied research on irrigated agriculture such as irrigation schedules in regional research centers, coordinated at federal level and supported by experienced international centers; farmer and DA training through the extension system (e.g., on agricultural water management); and reconfiguring contract management for medium- and large-scale schemes to improve their risk-return profile.

- Scheme sustainability demands an ambitious program for groundwater resource research and regulation, and integrating watershed and environmental management across all irrigation development.

- Due considerations should be given during expansion of irrigation infrastructures. Irrigation can have adverse effects on environment and public health, if it is not properly managed.

- Ethiopia will be able to harness its considerable labor resources for the delivery of a vast system of small-scale irrigation schemes, creating opportunities for employment while extending the reach of its water infrastructure. In the face of such ambition, the complexity of Ethiopia's hydrology and hydrogeology, its limited access to foreign exchange and to international investors, and its need to mobilize the international community to provide the financial resources needed at scale, imply a critical role for effective planning, delivery, and execution.

Conflict of Interest

There is no conflict of interest between authors.

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