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Themulti-Levelperspective in Analysis Ofthe Irrigation Innovations in Israel

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ABSTRACT. *The irrigation innovationsin Israel hasprimarily contributed to the great increment in the value of produce grown by local farmers over the last65 years.Israel is a dry-land nation. Lack of water is always a tricky problem,but many innovative ideasgenerated by the people in Israel are capable of providing enough water for a growing population. Using the multi-level perspective (MLP) to analyze the irrigation innovations of this country helps to find the institutions, drivers, policies and changes of local people's values behind the astonishing surge in agricultural productivity.In particular, the three levels of the MLP, namely the niche level, the regime level and the landscape level, are thoroughly analyzed to accommodate the complexity of thekey transition processes of the irrigation innovations in Israel. The innovative irrigation technologies originated in Israel are beneficial to the food security across the globe, but the factors limiting the adoption of these technologies should be considered in advance to avoid the possible failure of the uptake in other countries.*

KEYWORDS: *Israel, Irrigation, Innovation, Transition, Multi-level perspective (mlp), Agriculture*

1. Introduction

The goal of this essay is to identify and explain the key factors which promote the adoption and speed the rate of irrigation innovations in Israel. Like any new technology, the innovative irrigation technologies, such as drip irrigation, have to go through a phase of dissemination. The driving forces of the adoption of the irrigation innovations are, therefore, a key issue. The MLP is a prominent transition framework. The MLP posits that transitions come about through interaction processes within amongst three analyticallevels, namely niches, socio-technical regimes andsocio-technical landscapes(EI, 2019). The essay employs the MLP to analyze thekey transitions of the irrigation innovations in Israel. It is of vital importance to realize the irrigation water need of the farmers who inhabit the drylands. Israel is a relatively small country. Lack of water is always a problem in Israel mainly because the rainy season cannot provide enough water for people to last through the dry season and the water resources are geographically unevenly distributed; however, the great attention paid to education and technology is a big help for the appearance of the irrigation innovations. The necessary irrigation

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innovations originated in Israel can assist farmers in growing more crops. Hence it would be possible to address the challenges of achieving food security globally.

Groundwater is of great importance to agriculture. In many areas of the world, irrigation is the most important water use sector accounting for around 70 percent of the global freshwater withdrawals and 90 percent of consumptive water uses (Siebert et al., 2010). It is estimated that groundwater which is less than 50 years old - the time since groundwater is recharged - accounts for less than 6 percent of all groundwater in uppermost layers of the earth (Gleeson et al., 2016). Agriculture is the economic sector where most water is consumed. Efficient irrigation facilities can largely contribute to food security. Faced with the growing water scarcity, all the nations, especially from dry-land areas, need to consider how to overcome the problems associated with water scarcity and achieve sustainable development of the agricultural sector (Tal, 2016a). Based on the research of the United Nations Development Program, water scarcity affects a significant portion of the population around the world, and it is projected that at least one in four people will suffer recurring water shortages by 2050. Water scarcity and food security are also two themes mentioned in the Sustainable Development Goals (SDGs). The sustainability of the agricultural sector is, therefore, of great importance to food security. The irrigation innovations led by Israel are able to offer some solutions to the problems faced by the countries in the arid and semi-arid areas. Decades of practical experience and extensive research by Israeli scientific communities greatly improve the viability of Israel’s strategies and practices to deal with the problems caused by water shortages and promote the effectiveness of irrigated agriculture in dry areas.

2. The Irrigation Innovations in Israel

Before the appearance of innovative irrigation technologies, less than 20 percent of Israel’s cultivated area was intensively irrigated. It consisted largely of surface irrigation of citrus orchards in the central coastal plain. A substantial number of shallow local wells were then used to supply water through ditches to basins around individual trees (Stanhill et al., 1986). The total irrigated area has substantially increased since the adoption of the irrigation innovations across the country. Almost all the cultivated area is irrigated by sprinklers or drip systems now. The accelerating decline in the rate of water applied per unit irrigated area has been accompanied by the increasing popularity of innovative irrigation systems in agriculture.

Israel faces salient asymmetry of precipitation.Rainfall is also unevenly distributed; southern, hyper-arid regions frequently receive less than 100 mm annually. In the early years of this country, furrow and gravity based flooding systems were normative (Tal, 2016a); however, with the huge immigration into this country and fast population growth, it is crucial to increase the food production to accommodate the burgeoning population. According to the figure below, it is clear

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that the annual rate of population growth of Israel was much higher than that of the world in most years between 1960 and 2017 (Figure 1). The traditional ways of irrigation would make water shortages become even worse; therefore, some measures seeking to streamline and optimize the productivenessand effectiveness of water consumption in the farming activities are of greatimportance considering the substantial volumes of water required for food production (Mancosu et al., 2015).

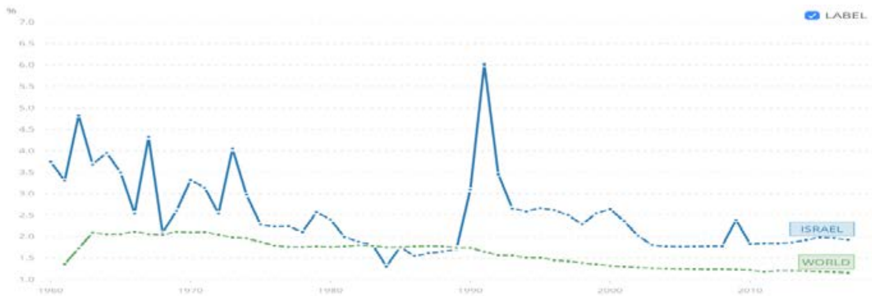

Fig.1 The Comparison of Population Growth between the Average of the World and Israel, 1960-2017 (Annual %)

(Source: The World Bank)

The gap between the demand and the availability of irrigation water almost reached critical levels for many southern areas of Israel at that time.Besides, the water supply of Israel was already very limited. The national water carrier project to bring water southward from northern Galilee constituted about 80 percent of all investment in the country’s water infrastructure (Tal, 2016b). The expansion and intensification of the total irrigated area were able to be achieved largely by the construction of all these projects. However,even the copious additional supply of water provided by the water carriers soon became inadequate for the fast growing needs from the burgeoning population of this country. Therefore, with the help of an impressive agricultural extension service, farmers soon switched to pressure-based sprinklers and gradually to micro-irrigation systems based on drippers, micro-sprinklers and point-based emitters in a large number of new agricultural operations (Tal, 2016a). These designs become the prototypes of the drip irrigation systems which are the key parts of the irrigation innovations of Israel. The government did not discourage these innovative actions carried out by the individuals. Instead, it reinforced technological support for the positive changes in farming practices, thus greatly strengthening innovative systems and fundamentally restructuring existing systems of water consumption.

While more and more people were embracing drip irrigation in agricultural production, failures and difficulties with solutions to chronical water shortage were still severe problems.From the 1950s forward, more and more farmers in Israel started to reuse wastewaterso as to guarantee their land under enough cultivation

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(Tal, 2016a). The application of reusing sewage to the farming land was geared to the needs of the soil and the crop (Hkukelekian, 1957). Again, the government tried to encourage the phenomenon. The Ministry of Health and the Ministry of Agriculture set a series of standards to regulate the reuse of effluents. Besides, the government also put forward a 1956 national master plan that envisaged Israel's farming utilizing 150 million cubic meters of treated wastewater as a source of irrigation (Tal, 2016a). Later, the fundamental dynamic forces driving Israel's water policy started to involve the use of sea water. The water management strategies began to put considerable investment in desalination plants (Tal, 2016b). With the utilization of sewage and desalination plants, it was more than likely that water supply did not solely rely on erratic rain and became more predictable than ever before. The sea could offer this country a seemingly inexhaustible source of water resources for steady food production.

The scientific and business communities also pushed the process into a new stage.Drip irrigation technologies developed fast after its initial introduction in the 1960s. With more technical support from the scientific community, drip irrigation systems become more efficient and durable. Besides, it is a successful leap to use computers to control the systems. Computer controls are beneficial for those irrigation innovations to finally achieve automation and thus can be applied to national farming on a large scale. At the same time, some technological companies were established to ameliorate the irrigation systems and produce drippers, dripper lines, sprinklers and micro-emitters to distribute innovative irrigation technologies to the whole nation and even to other countries. Thesecompaniesenthusiastically participated in innovation trajectories and helped to create a supportive environment for the innovations (Farla et al., 2012).

3. The Key Transitions

By employing the MLP to analyze the socio-technical transitions, it is easy to conceptualize overall dynamic patterns in the irrigation innovations of Israel (Geels, 2011). In the course of a socio-technical transition, new products, services, business models and policies emerge,partly complementing, and partly substituting the existing ones (Farla et al., 2012). The MLP is characterized by niche innovations, existing regimes and exogenous landscapes(Geels et al., 2016).Niches considered in the essay include individuals and personal companies. Regimes refer to the existing science and technology, the government and some big companies. When the landscape level is considered, it refers to the various conditions brought by the environment, Israel's water laws, social values, pricing of water and agricultural export.

For niche innovations, in the 1950s, an engineer named Simcha Blass began to test the drip irrigation idea and invented the world's first dripper device. Later, this person made the first practical surface drip irrigation emitter. in order to break the mold of traditional agriculture, he decided to expand his engineering office and prepare to set up a company which becomes the famous Netafim irrigation company today, trying to enhance the influence of this new technology. Little by little, some

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farmers, although in a very small scale, began to accept this kind of innovative way of irrigation.

At that time, thousands of immigrants crowded the newly independent country, so water shortage was one of the primary issues faced by the farming industry.Addressing the issue was indispensable for Israel to achieve social stability and sustainability. Besides, the estimated boost of the national population growth rate pointed out the inevitable increase of future food demand (Mancosu et al., 2015). Therefore, the farmers in the areas affected by water scarcity began to use the innovative dripirrigation systems to meet the need for enough food and avoid excessive water consumption. They gradually gave up traditional methods of irrigation which were not quite efficient. The introduction of drip irrigation systems could partly mitigate the issues related to water scarcity. The government encouraged the development of the prototype of the irrigation innovations and offered practical help with infrastructure investment.

As for the regime level, it is both influenced by the landscape level and can influence the landscape level in turn. With the development of these innovative technologies, great benefits are seen from them. It is possible to achieve the goal of "less water input but bumper crop output". At the same time, some new technologies began to make the irrigation systems more sophisticated. With the development of the Internet and engineering, computers were introduced to allow real-time operation of the irrigation systems. Soil and plant moisture sensors were also used to provide information about the plants' growth and their environment, allowing automatic operation of the systems whenever needed. The fertilizers were added via the irrigation systems. This process is called fertigation, a combination of fertilization and irrigation. The development of subsurface irrigation systems brought more benefits. They could reduce water loss to evaporation, bringing both a high yield and a high quality.

In the meantime, faced with the combined problems of increasingly acute water shortages and widespread contamination, individuals decided to treat and recycle huge amounts of wastewater. Treated wastewater was also considered as a "new" source of irrigation water by the farmers, and this "new" source could substitute conventional groundwater used for irrigation (Friedler, 2001); however, there was some resistance due to health concerns.The government began to invest on the infrastructure of wastewater treatment plants, and it gave more supportive policies to encourage the development of these innovations. Some measures as imposing more stringent regulations on wastewater treatment had a positive effect on the sustainability of domestic land use.Israel's Ministry of Health facilitated the initial foray into the utilization of sewage and regulated therequired quality of wastewater treatment. A national plan was soon put into action to make 150 million cubic meters of wastewater recycled be a source of irrigation water.Later, the wastewater reuse standards were also promulgated to prevent the anticipated health hazards.

On the landscape level, all these regimesgeneratedgreat changesin social values, making people realize the importance of saving water resources and getting used to the new ways of irrigation. Therefore, the traditional irrigation methodswere largely

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eliminated. Plus, there is a huge increase of food production. Over the past sixty years it has seen a 1600 percent increase in the value of the produce grown by local farmers. Israel produces 92 percent of its own requirements, supplemented by some necessary imports of grains, oil seeds, meat, coffee and sugar. The monetary value of the import is almost offset by the large export of a wide range of agricultural products. Agricultural exports amount to 7 percent of the total export value. Furthermore, Israel's water laws also play a role. They regulate water resources exploitation and allocation, prevention of pollution and water conservation. Also, the implementation of pricing policy of domestic water use resulted in a substantial increase in water prices and a significant reduction in the level of government subsidies. All these steps greatly inhabited the high consumption of valuable water resources and encouraged people to seek to other water-saving methods to decrease their cost.

The broader public could benefit from the improved awareness of saving water and ensuring food security. These transitions would involve disruptions of the status quo and transformational changes in technology, business, policy and infrastructure (Geels, 2018). More and more people gradually realized the great importance of the application of efficient water management strategies. The improvement of irrigation systems and irrigation schemes could lead to a more efficient and sustainable agricultural water management (Mancosu et al., 2015). Furthermore, the effective and efficient input of resources into farming made the agricultural sector in Israel become a highly developed industry. Most of Israel's food was domestically produced, and only a small portion of it was supplemented by imports. Israel gradually becomes a major exporter of fresh produce and a worldleader in agricultural technologies.

Agriculture requires more water than any other activity on this planet. The burgeoning demand for food and thus irrigation water brings about considerable challenges in many countries that are already experiencing water stress. Drip irrigation systems possessgreat potential for enhancing the efficiency of water useand for increasing food production.Food security can,therefore, be guaranteed by allowing agriculture on marginal and dry land and further increasing the cultivated area (Garb and Friedlander, 2014). Drip irrigation's uptake is a complex issue, so it is necessary to figure out the contextual dependence of these technologies and the useful strategies that offer comprehensive understandings of how the technologies travel and evolve. It is not right to only transfer static physical facilities into new contexts without considering whether there are similar local systems for the technologies to be successfully used. In India, asmost of the easily accessible groundwater has been severely depleted,there is plenty of scope for enhancement ofthe efficiency. It is found that the most ideal policy environment for promotion of micro irrigation technologies in targeted areas would be pro-rata pricing of electricity, a method that could bring direct incentives for efficient drip irrigation systems (Kumar, 2012).Therefore, it is important to address these important issues with regard to the factors limiting or enhancing the adoption of drip irrigation systems. The concrete policy action is also needed at different levels to speed up the adoption of drip irrigation in local areas.

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4. Conclusion

Water is becoming an increasingly scarce resource and hindering agricultural development in many developing and developed countries around the world. With the fast population growth of Israel, it is imperative that this country has to increase food production without increasing the demand for water. In the 1950s, the invention of drip irrigation made it possible to improve the efficiency of irrigation water and fully utilize arable fields. Israel even had food surplus for export. In the meantime, in order to increase the water supply, the people started to reuse wastewater for irrigation. By employing the MLP to analyze the irrigation innovations originated in Israel, the initial niche innovations brought by individuals gained support from scientific and business communities and the government. These innovations accumulated enough momentum to change the existing regimes and help to create a better future for the country and even the whole world. These innovative irrigation technologies can be applied to other areas across the world. It is essential to carefully think how to make the drip systems adapt specific local conditions and avoid failed uptake of drip technologies.

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