

# ICID *news*

MANAGING WATER FOR SUSTAINABLE AGRICULTURE



## MESSAGE FROM THE PRESIDENT

Dear Colleagues and Friends,

Greetings!

Human evolution has been a journey of multi-dimensional innovations over thousands of years. Water and other vital natural resources such as land, air, and minerals made it possible for humans to rapidly populate the earth using selective domestication of plants and animals in different geographies and climatic zones. During human evolution in different parts of the world, freshwater availability served as one of the primary factors for the emergence of human tribes, communities, and civilizations, influencing migration and invasion patterns to resource-rich lands offering better environmental conditions. The base of the entire food chain is the vegetative food and fodder on which the entire fauna ecosystem survives. Food production has been a key survival activity where agricultural water use is the key ingredient. Considering the above, the common phrase "Water is Life" could not be an over-statement.

The major challenge facing irrigated agriculture today is producing more food using less water per unit of output, i.e., increasing water productivity in irrigated and rainfed agriculture. This goal will only be achieved if the appropriate water-saving technologies, management tools, and policies are in place. All those involved in irrigation water management – managers, farmers, workers need to be encouraged and guided, through appropriate policies and incentives, to save water and minimize wastages to mitigate adverse environmental impacts.

Irrigated agriculture is often termed as water guzzler due to the fact that between 1950 and 2000; the world population increased threefold, irrigated area doubled, while water diversions to irrigated agriculture increased sixfold. While the coverage increased, the efficiencies did not keep pace with the increased usage. Consequently, some major river basins approached an advanced level of water depletion. In arid and semi-arid countries, water is already a limiting factor for agricultural production. Climate change is likely to exacerbate the water scarcity situation further. Thus, under a business-as-usual scenario, there may not be enough water to produce the food needed to feed the world in 2050. It is therefore imperative to promote water-saving practices in irrigated agriculture on a large scale. Consequently, many international organizations, national governments, research institutes, farmers' organizations, and private agencies worldwide are focusing their efforts on developing and applying various water-saving measures. Since its inception, ICID, through its WatSave Awards program, has also played an important role in recognizing and promoting water-saving technologies,

management practices, and community-based governance of agricultural water.

A vast range of technologies is available for improved operation, better management, and efficient use of irrigation water, ranging from simple siphon tubes for field water application to sophisticated canal automation and telemetry. Water-saving approaches/practices in irrigated agriculture may be categorized as engineering, agronomical, management, and institutional. The success of these approaches depends on the level of their integration in a given locality or context.

This issue of ICID News is devoted to the four winners of WatSave Awards of 2021, announced recently in Marrakech, Morocco, during the plenary session of the ICID International Executive Council (IEC) meeting. The awardees present a sample of global efforts in the areas of water-saving. The international panel of judges and its chair evaluated all the nominations received and recommended these winners for IEC endorsement. The editorial board of the Irrigation and Drainage Journal of ICID also identifies and recommends the best research paper for each year for showcasing the latest scientific development in the sector. The best paper award is also included in this issue of ICID News. I hope you find the articles on award winners informative and relevant in your area of work.

Wishing You All a Very Happy New Year 2022!

**Prof. Dr. Ragab Ragab**  
President, ICID



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## ICID Awards Excellence in Water Saving - WATSAVE

### Technology Award

## Hybrid Irrigation Method for Water Saving in Irrigated Agriculture

Dr. Abdrabbo Abdel-Azim Abdrabbo Shehata (Egypt)\*

**Area Covered:**  
50,000 ha

**Water Saved:**  
125 MCM/BCM

### Hybrid Irrigation Method

The innovative method provides a hybrid between surface and pressurised irrigation methods to overcome the disadvantages of both methods. The hybrid irrigation method can be defined as the group of application techniques where water is applied and distributed over the soil surface, same as in surface irrigation but one or more of the main components of micro-irrigation or sprinkler irrigation methods is introduced (e.g. mainlines, sub-mainlines, or manifolds). The hybrid irrigation methods enable a significant degree of management and increase application efficiency. Depending on the systems used, the efficiency of this method can be as high as that of sprinkler irrigation systems.

### Hybrid Irrigation Systems

Pressurised irrigation systems are closed conduit systems, whereas surface irrigation systems are open flow systems, so hybrid irrigation systems are semi-closed conduit systems. Therefore, eight irrigation systems could be classified as hybrid irrigation, such as the multiple-inlet irrigation system, multioutlet hybrid irrigation system, Simulated Low Energy Precision Application (Simulated LEPA), low-head bubbler, micro flood, perforated pipes irrigation system, gated pipes irrigation system, and Multiset irrigation system.

### The Multioutlet Hybrid Irrigation System

The multioutlet hybrid irrigation system is a semi-closed conduit system accomplished by flowing water under pressure over the soil surface through outlets as in surface irrigation using the main components of the pressurised irrigation methods (mainlines, sub-

mainlines, and manifolds) without lateral lines and distributors (drippers, bubbles, sprinklers, etc.); each lateral line and its distributors are replaced by an outlet for irrigating a certain plot. The outlets are devices that release water from high-head pipelines into basins, borders, strips, or furrows (i.e., in the multioutlet hybrid irrigation system, the outlets consist of a riser pipe and one or more valves to control the flow). The outlets should release into fields without causing erosion. They may include alfalfa or orchard valves, various types of hydrants, etc.

The multioutlet hybrid irrigation system may achieve high distribution efficiency, equal to that of pressurised irrigation systems, by using the main components of its networks. Also, it may reach a high application efficiency by decreasing advance time. The multioutlet hybrid irrigation system theory and applications will be presented in detail in the following sections.

### Water Saving through the Innovation

The multioutlet hybrid irrigation system maximises the water distribution efficiency to equal the performance of pressurised irrigation systems by using a network of pipelines that decrease water losses by eliminating evaporation, deep percolation, surface run-off, and seepage, as occurs under normal conditions of surface irrigation using earthen ditches. Moreover, application efficiency was modified by delivering water under pressure inside the field plot to minimise advance time, decreasing water losses. The system design also ensures that the depths and discharge variations over the field are relatively uniform. As a result, available soil water in the root zone is also uniform.

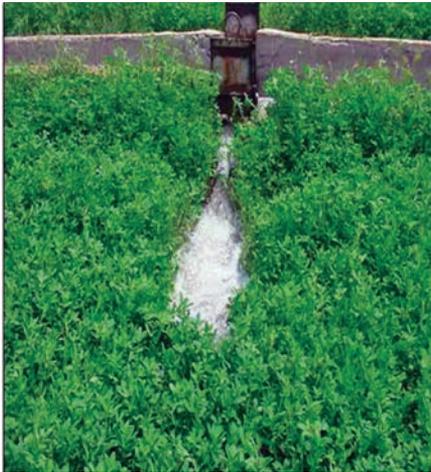
### Implementation of the Innovation

The multioutlet hybrid irrigation system was first developed as an experimental

system in 2005 in Egypt's National Water Research Center. Several studies were conducted to evaluate the potential use of the innovative system for irrigating crops in the Western Nile Delta. The technology was introduced to farmers, producers, decision-makers, and policy planners in Egypt, Mali, South Sudan, Brazil, India, China, Qatar, Jordan, Sri Lanka, and the USA via direct meetings, presentations, farmer field events, workshops etc. throughout national and international organisations. The following two up-scaling models were developed to improve surface irrigation systems and achieve food security in the depressed agricultural and water-scarce areas of Egypt and Mali.

**Model for Up-Scaling in Egypt:** In Egypt, water shortage is the country's central dilemma, and inefficient surface irrigation systems are the predominant systems in the Nile Valley and Delta. Consequently, the Ministry of Water Resources and Irrigation and the Ministry of Agriculture and Land Reclamation adopted the multioutlet hybrid irrigation system to be implemented on a large scale. It was also adopted as the new model for the Irrigation Improvement Project in the West Nile Delta of Egypt, on an area of nearly 504 ha. In addition, some orchard producers have adopted the system for irrigating about 3.8 ha of citrus trees in the East Nile Delta. Moreover, the experimental fields equipped by the multioutlet hybrid irrigation system at the Water Management Research Institute (WMRI) increased from 1.3 ha to 2.6 ha. It is also planned to replace the 6.7 ha of lined ditches with the multioutlet hybrid irrigation system in the experiment stations of WMRI. It is further planned to use the multioutlet hybrid irrigation system model in all ongoing and future irrigation improvement projects.

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**Model for Up-Scaling in Mali and Sub-Saharan Africa:** Mali is one of the poorest countries in the world, with approximately 60% of the population living in poverty and 28% malnourished, as per UN-FAO. Agriculture accounts for a substantial portion of Mali's Gross Domestic Product (GDP) and employs a large section of the country's workforce. Many Malian farmers still use primitive irrigation methods, manual tillage tools, flood irrigation without drainage systems, and unimproved crop varieties to produce their food. As a result, they have dispersed and small cultivated plots (100 m<sup>2</sup>/family), water and soil quality degradation and desertification, insignificant income and extreme poverty, joblessness, food insecurity, and widespread hunger. Thus, another up-scaling model of the multioutlet hybrid



irrigation system was developed and implemented in Mali (Tibibas Project) for irrigating 365 ha as an example for converting from monoculture crop in rain-fed production systems to multi-cropping through an appropriate irrigation system for achieving food security and rural income sustainability in depressed areas of sub-Saharan Africa. The overall goal of this up-scaling model was to establish multi-season agriculture and crop diversification along with achieving increased yield and crop water productivity. Other benefits of this model include water and food security, mitigating extreme poverty, promoting gender equality and empowering women by increasing the cultivated area per woman (by 2500%), improving soil and water quality, controlling malaria, and combating malaria desertification.

The model will also ensure water, environment, livelihoods, and rural income sustainability.

### Scope for Further Expansion of the Innovation

The Hybrid irrigation method and its eight irrigation systems are promising, alternative technologies for marginal farmers to produce their food. The technique and its systems have a range of long-term advantages; therefore, they have scope for significant expansion.

The multioutlet system was adopted and developed by farmers and producers in both developed and developing countries to improve surface irrigation efficiencies, achieve food security, and increase rural income sustainability by increasing cultivated area per woman in sub-Saharan Africa. In Egypt, farmers are moving from using surface irrigation to the multioutlet hybrid irrigation system to irrigate high water consumption crops in the Nile Valley and Delta, such as sugarcane, rice, bananas, etc. Lately, some international organisations have adopted the multioutlet hybrid irrigation system in sub-Saharan Africa to increase the impacts of their food security projects, especially in depressed regions. The multioutlet irrigation system is recently spreading worldwide and adopted by small farmers in many areas of Africa, Asia, the USA, and Latin America for its significant long-term advantages.

## Innovative Water Management Award

### Management: FIRST PPP Irrigation Project in the World (EL GUERDANE Scheme) in South of Morocco

Mr. EL BOUARI Ahmed (Morocco)\*

<b>Area Covered:</b> 10,000 ha	<b>Water Saved:</b> 45 MCM
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#### Innovation Description

Irrigated agriculture is at the heart of Morocco's economic and social development. It plays a crucial role in meeting Morocco's food demands. It also generates more than 75% of the country's agricultural exports, providing jobs for half the rural labour force. However,

irrigation monopolises the country's scarce water resources, accounting for 85% of water usage. With water resources becoming increasingly scarce, Morocco urgently needs to find a better way to manage water for irrigation. Indeed, the irrigation sector in Morocco is confronted with several constraints, mainly because of the limits of the institutional framework that continues to govern the sector. These limits, which mainly concern the Regional Offices

for Agricultural Development (ORMVAs), can be summarised as follows: their statutory framework as public institutions of an administrative nature; their current budgetary framework, which does not establish the principle of separation of public service missions and commercial missions; their dependence on the State's budgetary resources; and the relational framework that establishes a state-to-user relationship in which the farmer positions himself in the State's

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favour rather than as a customer of the water service.

These limits have not allowed the irrigation sector to generate sufficient internal financial resources to guarantee the equipment's sustainability and ensure an efficient water service. Even recurrent expenses of this service continue to be partly covered by budgetary transfers. In this context and since the end of the 1990s, the Department of Agriculture, after a thorough examination of the feasibility of the various possible options: (i) the autonomy of the water service within the ORMVA, (ii) the transfer of management to farmers, and (iii) the delegated management in a private setting, concluded that the option of delegated management in a public-private partnership framework that represents an innovation is appropriate.

The public-private partnership in irrigation consists of interesting private operators in investing and managing irrigation infrastructure in irrigated perimeters under delegated management/concession contracts. The irrigation water service in this perimeter is a public service delegated under the law.

The objective is to improve the technical, economic, and financial conditions of the management of the irrigation water service in these perimeters, in this case:

- ◆ Better Water and energy efficiency;
- ◆ Optimisation of the use of water resources and the costs of operation and maintenance;
- ◆ To achieve sustainable development
- ◆ Improvement of the water service; and
- ◆ The reduction of Government budget transfers for the management of irrigation schemes.

In this innovation, the intervention of the private sector covers the following main tasks:

- ◆ Co-finance irrigation schemes;
- ◆ Design and build irrigation infrastructure;
- ◆ Manage, operate and maintain these infrastructures to ensure water distribution to the farmer, who is the user, in optimal conditions. Of course, the irrigation infrastructure remains public property;

- ◆ Bring expertise and innovation for the modernisation of irrigation;
- ◆ Support the risks related to the irrigation project (construction risks, operation, and maintenance risks, financial risks, commercial risks, etc.);
- ◆ Collect remuneration from the users based on a tariff of the water service validated by the government, etc.

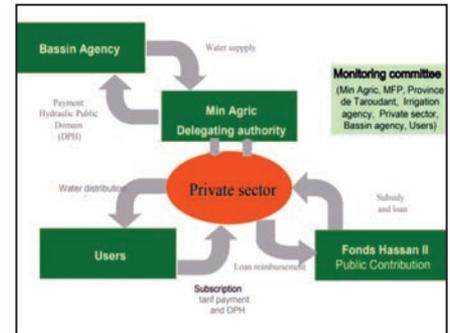
### Water Saving through the Innovation

About 70% of the irrigated areas of the region are fed by groundwater. For twenty years now, the abstraction of irrigation water far exceeds the possibilities of renewal of the water table of Souss. This situation has resulted in an annual reduction of the groundwater of the order of 1.5 to 2 m.

It should be noted that the EL Guerdone perimeter (10,000 ha), the only perimeter currently in delegated operation, has continued since its inception in 2009 to record the best-expected performance in terms of satisfaction of contractual water allocations, the efficiency of distribution, recovery rate, the satisfaction of user complaints and their information in real-time, intervention diligence, quality of maintenance and maintenance.

### Environmental and social impacts:

- ◆ Energy-saving: Reduction of Water pumping costs by more than 50%;
- ◆ Inhibition of the phenomenon of abandonment of farms and
- ◆ safeguarding the wealth of the district;
- ◆ Preservation of around 11,000 jobs in the region;
- ◆ Creation of 40 direct permanent jobs in the region, and between 300 and 400 jobs when the work is carried out (28 months).
- ◆ Preservation of the Souss water table: 65 MCM
- ◆ Water-saving on pumping the water table by mobilising a resource alternative: 45 MCM from the Aoulouz-Mokhtar Soussi dam complex
- ◆ Saving irrigation water: by adopting drip irrigation systems commonly called Goutte à Goutte at the level of farms benefiting from the water service



### Implementation of the Innovation

This innovation brought about the realisation of the Public-Private Partnership project to safeguard the citrus area of El Guerdone in Souss (10,000 ha). A delegated management agreement was signed in 2005 between the Ministry of Agriculture and a private operator (Amensouss company) to co-finance, implement and manage the irrigation infrastructure. Indeed, the construction was completed in July 2009, and management by the delegate started in October 2009 after inauguration by HM King Mohammed VI on October 2, 2010.

### Scope for Further Expansion of the Innovation

For decades attempts have been made to avoid jeopardising the whole effort of the national community in the field of irrigation. The salvation by which the sector must be sustainably improved is reforming the institutional framework governing this service. The content of this reform is summarised in:

- ◆ The adaptation of the texts by repealing the statutory and regulatory provisions of a prescriptive nature.
- ◆ The continuation and consolidation of the policy encourage users to invest in modernising irrigation techniques on the plot (localised irrigation, pivot, improved spraying, etc.).
- ◆ The separation of the management of the irrigation service from the other activities of the ORMVAs.
- ◆ The financing of the extension of irrigation, particularly through the opening of the irrigation sector to private developers in the framework of public-private partnership, was the most appropriate choice of management of the water irrigation service to ensure its durability and quality.

The PPP Irrigation Program was launched in September 2008. To maximise the chances of success of delegated irrigation management, the Department of Agriculture is proceeding with the structuring of each of the PPP projects through in-depth studies. Each project has two critical phases: (i) a feasibility study and definition of strategic partnership options, at all legal, institutional, technical, economic, and financial levels; and (ii) the execution of the call for tenders for the designation of the private delegate and the establishment and signing of the contractual documents (delegated management agreement, specifications, user contracts, public financing agreement, and water supply agreement). The program concerned the following perimeters:

- ◆ The existing irrigation schemes for modernisation and improvement of their management: Loukkos (26,500 ha), Tadla (98,000 ha), Doukkala (95,000 ha), Gharb (117,000 ha), Moulouya (65,400 ha), Haouz (143,000 ha). These projects have been the subject of feasibility studies;
- ◆ New hydro-agricultural development projects (in the feasibility study phase): extension of irrigation in Gharb (113,900 ha) and the Loukkos perimeter (9,700 ha); Dar Khrofa project in Loukkos (21,000 ha); development of newly irrigated areas downstream of the Kaddoussa Dam (5,442 ha); extension of irrigation in the Dakhla zone irrigated

from desalinated Water (5,000 ha) which is in the phase of negotiation;

- ◆ Irrigation safeguard projects in areas with high agricultural production potential: the seawater desalination irrigation project in the Chtouka area in Souss-Massa (15,000 ha); Azemmour - Birjdid coastal zone irrigation project (3,200 ha), which are in the phase of construction and subscription.

The record of the PPP program exceeded all expectations. The structuring studies carried out or in progress have involved 545,000 ha in the existing perimeters, 185,000 ha of new irrigation schemes, and 18,000 ha of conservation irrigation projects.



## Young Professionals Award

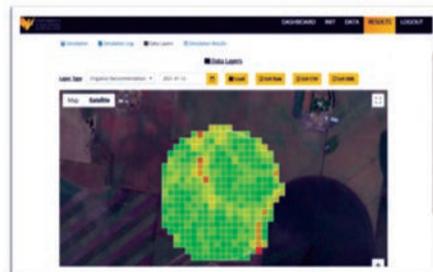
### Automated Site-Specific Irrigation Optimisation Using 'VARIwise'

Dr. Alison McCarthy (Australia)\*

<b>Area Covered:</b> 600 ha	<b>Water Saved:</b> 200 ML = 0.2 MCM
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#### Innovation Description

This innovation is software 'VARIwise' that combines sensing, modelling, optimisation and actuation to determine site-specific irrigation requirements to maximise yield and crop productivity for broad-acre crops. The innovation focuses on identifying irrigation timing and spatially variable depths across fields to best achieve maximum forecasted yield using models. This contrasts with existing commercial automated site-specific irrigation control strategies that are either time-based or are based on variability maps that may not necessarily relate to actual irrigation requirements. In addition, typical strategies developed in other research apply irrigation when the plant has reached a specific stress point if using canopy temperature sensors or soil-water deficit if using soil moisture sensors. These systems do not consider water availability and target seasonal



performance objectives (e.g., maximise yield or water productivity). Therefore, they cannot adapt to different weather conditions or limited water situations. In particular, some crops (e.g., cotton) require stress in early growth stages to produce maximum yield, and simply managing irrigation according to soil moisture deficit does not target optimal yield.

VARIwise has been evaluated on cotton and dairy pasture crops to determine site-specific irrigation requirements with surface and centre pivot irrigation. The system developed involves a novel combination of the following components:

- ◆ Industry-standard crop biophysical models that are automatically parameterised from online and infield data sources of weather, soil properties, and irrigation management information
- ◆ Machine vision cameras to automatically detect growth rates from infield cameras and parameterise the crop biophysical model
- ◆ Optimisation algorithms that iteratively run the parameterised crop model to identify which irrigation day/volume will optimise yield and water productivity

VARIwise produces the best irrigation day in the next three days (if any) and the required irrigation depths. For centre pivot and lateral move irrigation machines with variable-rate irrigation capability, VARIwise automatically generates prescription maps in formats compatible with commercially available panels. The maps can then be approved by the grower, uploaded, and enabled.

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### Water Saving through the Innovation

This innovation improves water productivity by applying irrigation where it is needed, at the right time, specific to the crop's water requirements. For example, Water is saved by the model on cotton crops by recognising the impact of Water on potential yield at all growth stages. This has led to strategies that reduce irrigation depth and apply stress to the plant earlier in the season to encourage root development and flower production, and later in the season, full irrigation occurs to maximise yield. Implementation of this system has led to yield improvements of 4 to 11% and water savings of 12 to 22% for cotton. Water is saved by the model on dairy pasture when updated with the daily growth status from the machine vision system. For dairy pastures, infield cameras and machine vision algorithms have been developed to sense grazing status from pasture growth rates automatically. By updating the grazing status within the crop biophysical model, the resultant strategies reduce irrigation depths immediately after grazing and increase irrigation depth as pasture growth progresses. In contrast, grazing information is typically manually recorded and is not sensed as part of existing soil moisture or satellite monitoring systems. Trials on dairy pasture are currently being conducted to compare the performance of soil moisture sensor-based irrigation against optimisation strategies from VARIwise.

The performance of VARIwise irrigation strategies relies on the ability to predict yield accurately. Trials have been conducted to evaluate the yield prediction performance across 17 cotton sites with varying levels of fruit removal, hail damage, and heat stress. The overall yield prediction accuracies were: 81.2 to 89.8% at a date three months before the harvest; 91.1 to 95.1% two months before the harvest; and 90.5 to 97.5% one month before harvest.

### Implementation of the Innovation

VARIwise will be introduced to the industry through commercialisation opportunities with manufacturers of irrigation hardware or precision agriculture software. This will involve selecting commercial partners and sharing the intellectual property for implementation. Planning for commercialisation has commenced

with the project's funders. An expression of interest process for commercial partners was released in 2020, and the applicant is currently providing support for commercialisation with the respondent. The software would initially be used for centre pivot and lateral move irrigation in the cotton and/or dairy industries. In the Australian cotton industry, there is 61,030 ha of land irrigated by centre pivot or lateral move irrigation machines, and around 287,2000 ha of land developed for surface irrigation, irrigated by about 1,000 irrigation systems that could each utilise one of these units. Australian cotton has an annual export value in New South Wales and Queensland of \$1.3 billion and \$670 million. These two industries will be targeted initially, as they have provided funding for this innovative development and field evaluation (Cotton Research and Development Corporation and Australian Government Department of Agriculture, Water and Environment as part of its Rural R&D for Profit program).

It is expected that the commercial partner would make the VARIwise system available as an add-on to existing variable-rate irrigation hardware. The integration of VARIwise prescription map development capability within the commercial partner existing systems may be phased, with implementation through the following steps: (a) generate VRI map compatible with commercial variable-rate irrigation systems; (b) supply data from on-site weather stations in a required format for VARIwise runs; (c) import variability maps from satellite, soil, or elevation maps; (d) read in data from cameras/grazing sensors; and, (e) purchase a commercial license for the crop biophysical model to link available data to the generation of prescription maps.

### Scope for Further Expansion of the Innovation

There is potential for the VARIwise technology to be expanded across a range of crops and irrigation systems. The software could be transferred to any



crop where the bio-physical soil-plant-atmosphere relationships are available in a model that can be parameterised and can predict yield. Potential crops for technology transfer include vegetables and fruit, contributing \$2.9 billion and \$2.3 billion to the Australian economy, respectively. There is also potential for the control system to be implemented in the grains industry, particularly in the USA, where the irrigable area is 22 million ha. Over half of this area is irrigated with centre pivots and lateral moves that could each utilise one of these systems. In particular, the USA is the world's largest corn producer, with an annual irrigated crop value of \$13 billion and irrigated corn area of about 5,500,000 ha.

The software could also be expanded to plan irrigation between multiple fields. For example, this would involve focussing available irrigation to fields with higher yield potential and then separately implementing optimisation within these fields. There is also potential for sub-components of this innovation to be adopted separately. This will enable phased adoption of irrigation automation technologies. These individual sub-components include the yield prediction software, the machine vision system to detect and record grazing events for pasture automatically, and the automated prescription map development process.

## Farmers Award

## Increasing Wheat Water Productivity in the Wheat-based System in Iran (Case Study: Darab City)

Mr. Gholamreza Ansari (Iran)\*

Area Covered:  
5 haWater Saved:  
3750 m<sup>3</sup>/ha**Innovation Description**

Darab township is located almost in the south of Iran, between 28° 46' and 28° 76' north latitude and 54° 32' and 54° 54' east longitude with an arid climate and an average annual rainfall of 270 mm. Darab is one of the major agricultural zones in Fars province, located between the plains and mountains, where groundwater resources mostly irrigate the arable lands. One of the challenges in this area is the low chemical quality of the water, along with the drop in groundwater levels. The chemical quality of groundwater in this flat is influenced by the salt domes, evaporation rate, and the direction of groundwater, which are the main factors affecting the water quality of the plains. Due to these conditions of Darab city and the 8-years drought situation, agricultural water management is critical. In this regard, since 2018, the plan of increasing the productivity of wheat-based systems with the approach of conservation agriculture and integrated water and soil management has been implemented. The educational research site of the farm with an area of 5 ha is located in Marian village of Darab city.

Localisation principles and implementation of conservation agriculture based on crop management are among the most important innovations of this project. Besides, another goal is to generate knowledge and information to utilise conservation agriculture by expanding cooperation between stakeholders and forming teams with different specialities.

**Water Saving through the Innovation**

Conservation Agriculture (CA) is a sustainable package that alleviates soil erosion and greenhouse gases, enhances soil fertility and productivity, and has many other benefits. Generally, CA is



a triple approach for agriculture that includes maintaining a permanent cover on the soil by crop residuals, practising no-tillage to reduce soil disturbance and dispersion, and using crop rotation to cut off the cycle of pests and improve soil fertility. In other words, CA is an approach to manage agricultural ecosystems that achieve sustainable agriculture by minimising soil disturbance and soil erosion, maintaining crop residues, and diversifying the crops. The primary purpose of conservation agriculture is to increase soil organic matter by preserving crop residue and soil moisture. For soil management, planting and cultivation methods are modified on wide, long, and fixed ridges to reduce machine traffic and minimise soil compaction due to increased soil physical properties. Preservation of at least 30% and at most 50% of crop residue at the surface of the ridges increased soil moisture and soil permeability. Increasing soil organic matter from 1.03 to 1.32% in two growing seasons has improved soil biological properties.

Other measures taken in conservation agriculture include proper and timely management of weeds and reducing competition in water consumption with the main plant, correction of crop rotation and adequate plant density per square meter.

Due to the installation of a water flow volume meter at the field entrance, the amount of water consumed was measured during the growing period. The results showed that due to the change of irrigation system from surface to tape, water consumption has decreased by 30%. In this project, the amount of water used for wheat was 3750 m<sup>3</sup>/ha. The measure of conservation agriculture and integrated water and soil management led to a 25% increase in wheat yield.

**Implementation of the Innovation**

The cultivation program of this educational research site has been developed on a 5-year plan. At the end of each cropping season, to promote conservation agriculture, training classes are held with experts and farmers in the cities of the Fars province. All technical reports of growing, harvesting, and packing have been published in the mass media. Separate lines and plots have been defined to compare different cultivars, machines, disease, and weed management. In these conditions, practical and technical comparison of conservation and traditional cultivation is feasible. Economic analysis and comparison of production costs under conservation cultivation and tillage under the surface and pressurised irrigation conditions have been performed.

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### Scope for Further Expansion of the Innovation

Most governments can apply various methods to use CA principles by farmers. Most methods can be classified into three categories: law and regulations, financial incentives, and farmers' voluntary behaviours. Utilising incentives and laws and regulations are methods that will have short-term effects. But, farmers' voluntary behaviours have long-term and positive impacts on sustainable agriculture, requiring a proper understanding of the farmers' willingness and ability to carry out sustainability activities. The learning transfer means applying the skills, knowledge, and attitudes gained from the training to a workplace in

the direction of sustainability and environmental protection. In other words, learning transfer occurs when farmers apply sustainability skills, attitudes and knowledge learned from training to their farms. Learning transfer is a novel and relevant issue deployed in various fields. The learning transfer system helps recognise how farmers apply the learned skills and principles in farms. This study on this farm is novel because the level of farmers' learning transfer is denoted based on their characteristics.

The most crucial strategy for the development and dissemination of conservation agriculture in the future are:

- ◆ Informing political officials, Executive, research, extension,

and local governments to develop better programs

- ◆ Cooperation of various research and executive departments, manufacturing companies at national, provincial, city and service centers.

A farming activity has a complex structure because it exploits living organisms in an uncertain environment, both bio-pedo-climatic and socio-economic. This extreme complexity has made the modelling of agricultural training difficult because it is unsure whether it will effectively reoccur in the same area and at the same time.



## Best Paper Award

# Effect of a Root-Zone Injection Irrigation Method on Water Productivity and Apple Production in a Semi-Arid Region in North-Western China

Yan-Ping Wang, Lin-Sen Zhang, Yan Mu, Wei-Hong Liu, Fu-Xing Guo and Tian-Ran Chang\*

### Abstract

Within the Chinese Loess Plateau, water resources are scarce, and irrigation efficiency is a challenging issue. Traditional surface drip irrigation (SDI) methods have failed to improve irrigation efficiency and reduce surface evaporation in the region. An easy-to-install and practicable root-zone injection irrigation (RII) method, with a low risk of emitter clogging and which uses subsurface infiltration-promoting apparatuses (SIPA) to deliver water directly to the root zone, was designed and tested in an apple orchard over 3 years in northern Shaanxi, China. In the 0–0.6 m soil layer (where the apple roots are concentrated), the RII method produced consistently higher soil water content than the SDI method over all three growing seasons. The soil water content was consistently higher than 60% of field capacity, thus meeting



the water requirements of fruit-bearing apple trees. In addition, the RII method alleviated soil desiccation, significantly increased apple yields and improved fruit quality compared with the SDI method using the same volume of irrigation water. Both irrigation efficiency and water-use efficiency were improved with the RII method. These results provide a

theoretical basis for the utilisation of the RII irrigation method in apple orchards in semi-arid regions, which may improve water conservation and the sustainability of apple production.

For the full-length paper, please visit: <https://onlinelibrary.wiley.com/doi/full/10.1002/ird.2379>



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