IRRIGATION AUSTRALIA

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AUSTRALIAN COUNTRY PAPER

Integrated Approaches to Irrigation Management in the Future

Northern Adelaide Irrigation Scheme
- Estimated Cost: $155.6m
- Completion date: 2024
- Jointly funded with the Australian Government through the National Water Grid Fund and other partners

The project will deliver new water treatment facilities in the Northern Adelaide Plains, and will construct infrastructure to treat, store and distribute recycled irrigation water to local producers.

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1. Introduction

Australia is the driest inhabited continent. Our use of water in irrigation has reaped great rewards in terms of the development of rural industries, the growth of the economy and the modernisation of Australia. Water resource policies since European Settlement were, like those relating to other resources, focused on promoting economic and population growth, and creating jobs.

The formative years of irrigation in Australia were in the 19th Century and the major irrigation developments occurred initially in the Murray-Darling Basin, where the conditions were the most conducive to such development. The late 19th and early 20th centuries saw a dramatic increase in irrigation development both in the Murray Darling Basin and elsewhere as governments attempted to overcome a natural water scarcity. Drought was always of concern.

Australia has now moved well away from the economic/social development thinking, attitudes and actions which underpinned Australia’s use of water since European settlement. It has become clear that this previous approach did not serve Australia well from a sustainability perspective. Over the past 25+ years there has been a dramatic change in the way water is managed, both as a resource and in irrigation. Perhaps the most dramatic of these changes was the 1995 Cap on Diversions in the Murray Darling Basin. Climate Change is also impacting water management policy and use through reduced water availability, greater variability of rainfall and increased periods of drought.

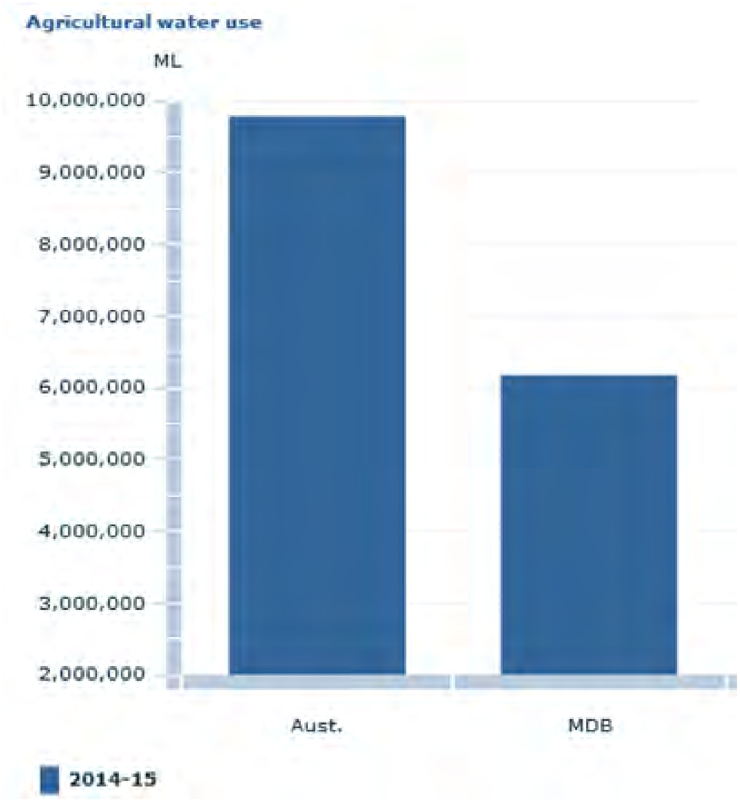
The recognition that the environment is entitled to primary access to water, together with other structural reforms such as the unlinking of water licenses from specific land holdings and the related capacity to trade, has dramatically changed the way water is valued and used in Australia. Government action to redress over-allocation of the water resource, particularly for irrigation, is an important component of Australia's commitment to water reform, the National Water Initiative (NWI).

This Paper provides a brief overview of integration and innovation of irrigation (and water) management in contemporary Australia.

2. Current status of National irrigation sectors

2.1. Statistics on irrigation in Australia

Australia uses about 5% of its total renewable freshwater resources, compared with about 20% for the United States and 43% for Italy (based on 2006 data). Agriculture accounts for over 50% of water consumed in Australia and irrigation accounts for up to 90% of that water use[1]. Irrigation accounts for about 30% of all agricultural product value from about 1% of land use or an average of about 2 million hectares. The majority of this area is surface/gravity irrigated.



2.2. Australian Water Use for Agriculture

Agricultural businesses operate across about half of Australia's total land area. 87% of the land farmed is used for grazing and 31 million hectares are cropped. The gross value of Australian agriculture was AUD$60.8 billion in 2016-17 with crops accounting for AUD$32 billion. The dominant crops, by weight, were sugarcane, wheat, barley, oats and canola. Australia irrigates 2 million hectares of land for cotton, rice, fruit and nut crops, grapevines, pastures and vegetables. The annual farm gate value of produce from irrigation farms is approximately AUD$12 billion, or about 25% of the total agricultural production of the nation. The main irrigation area is in the Murray-Darling Basin (covering parts of South Australia, New South Wales, Queensland and Victoria).

Rainfall varies spatially and temporally across Australia and climate change is exacerbating this variability and generally reducing availability in the main irrigation regions. To maximise

[1] https://soe.environment.gov.au/theme/inland-water/topic/australias-water-resources-and-use

water availability to the sector, Australian has developed a range of water products that reflect the security of supply ranging from general (low) security to high security entitlements. Opportunities to access additional water during high/flood flow events are also made available in some jurisdictions.

Due to the variability of water availability for irrigation, particularly for lower reliability 'general security' irrigation supplies, the area of land irrigated and volumes of water applied via surface irrigation systems reflects the variability of natural rainfall and runoff from year to year.

As an impact of water policy changes, changes in commodity markets, and climate change impacts some industries, such protected cropping (vegetables), various tree crops and broad area crops (cotton) have responded with increased crop areas being planted. Investment in high value perennial cropping has seen considerable redirection of water to new projects, resulting in considerable challenges for policy, social settings and operational adaptation across the MDB system, as water is transferred across the Basin and between industry sectors.

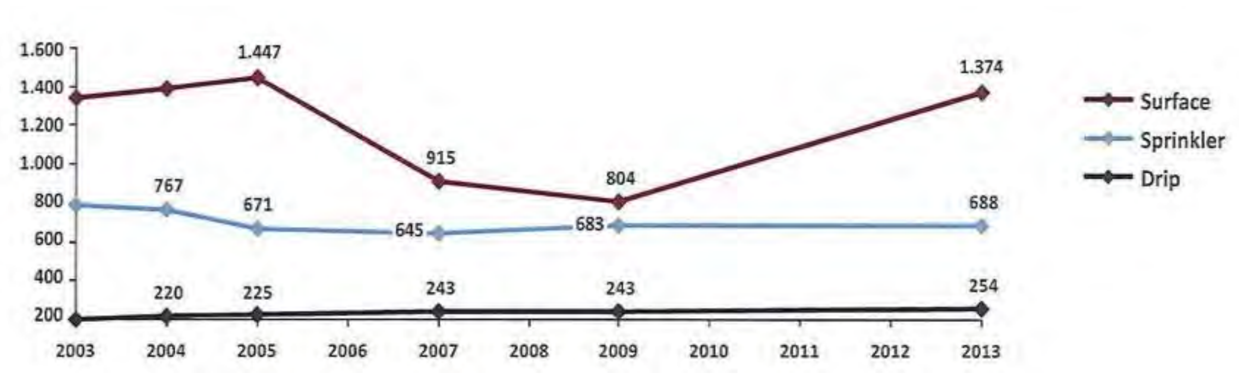
National rainfall was below average with 2019-20 the sixth driest year on record. In that year: -

- 5.7 million megalitres of water was applied to crops and pastures
- 1.5 million hectares of agricultural land was irrigated
- 20,700 farms applied water to their land

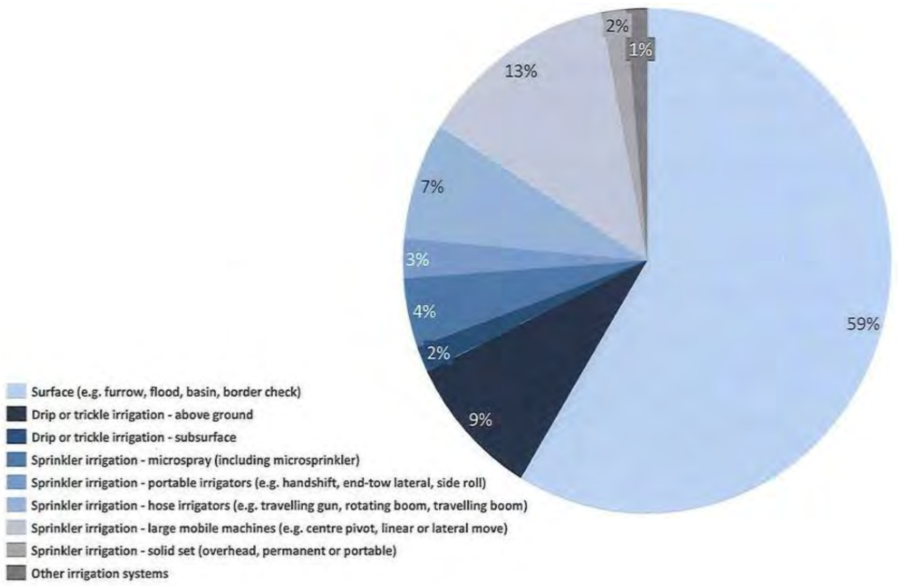
Water application rate for selected crops and pastures[2]

	2018-19 (ML/ha)	2019-20 (ML/ha)
Rice	9.9	12.2
Cotton	7.1	6.9
Sugar cane	4.5	4.7
Fruit and nuts (excluding grapes)	6.2	6.2
Grapevines	4	3.8
Vegetables	4.3	4.1
Pastures and cereals for grazing	2.9	2.7

Irrigation method by area and by water volume percentage



[2] *Source: Australian Bureau of Statistics, Water Use on Australian Farms 2019-20 financial year*



At Section 7 are some Case Studies of various irrigated crops and the innovation of systems (both on-farm and off-farm) that are utilised for these production systems.

3. Future investment in irrigation infrastructure modernisation and management

3.1. Introduction

Sustainability and economic imperatives are driving irrigation infrastructure modernisation and management innovation as operators at farm and system level seek to reduce wastage (seepage, evaporation, operational control, etc) and maximise efficiency and effectiveness of available water supplies. These supplies are reducing due to climate change and the change in priority of water use to include the environment. The broader community is demanding, and there is general agreement, that the environment's demand for water cannot be ignored any longer. To ensure that water becomes available for the environment, in an over-allocated system water sharing/resource plans are being developed to specify how the available water will be shared. Investment in irrigation infrastructure modernisation is, in part, facilitating this re-alignment of water use by reducing losses and redirecting this 'saved water' to the environment. The Australian Government also purchased irrigation entitlements directly from willing sellers/irrigators to reduce the volume of take across the remaining entitlement holders.

3.2. Australian Government Initiatives

Australia faces major challenges in ensuring sustainable water supply in the face of a drying climate and growing demand for water. In response, the Australian Governments, State and National, are adopting new water policy initiatives and legislation reform for all Australians.

In 2007 the Australian Government announced The National Plan for Water Security, a AU$10 billion initiative to address the unsustainable overallocation of water resources particularly in the Murray Darling Basin. This resulted in the development and implementation of the Murray Darling Basin Plan (see Section 4.5). The Plan requires the Australian Government to invest in a range of projects and programs to allow an agreed volume of water use to move from economic uses to environmental uses and for State Governments to amend or develop water sharing plans to achieve agreed sustainable diversion limits in all catchments of the Basin. Without this acceptance of the need to rebalance environmental sustainability with productive demands this investment is less likely to have proceeded at the present rate.

Australia is at the leading edge in its approach to large scale basin-wide water resource management. Through legislation such as the *Water Act 2007* with complementary state legislations and policy reform agendas such as the National Water Initiative, the water reform journey with continue, ensuring best practice water resource management.

As well as direct water purchase from irrigators, Australian Governments are working to improve the efficiency and productivity of irrigation water use and management through a number of funding programs and initiatives.

3.2.1 Current programs and projects

The Australian Government is putting communities and jobs at the heart of the Murray–Darling Basin Plan and water management generally. This focus on communities and jobs allows the Government to invest in water efficiency measures at above the free market value for water. If the objective was solely the return of overallocated water resources to sustainable diversion levels, then it could be argued that it may be more cost effectively achieved by the direct purchase of overallocated water for the environment's use however, with the communities and jobs as a focus, lowest direct cost is not the sole objective.

Direct Purchase of Water Entitlements: The Australian Government purchased water entitlements by tender direct form irrigators. Due to concerns raised by irrigation stakeholders, this program is capped at a maximum recovery of 1500GL.

The Water Efficiency Program was intended to fund urban, industrial, off-farm, on-farm and metering infrastructure projects across the Murray–Darling Basin. Water savings required under the Basin Plan are being achieved from approved projects contributed to 'bridge the gap' to the newly agreed sustainable diversion limits and an additional 450 GL of efficiency measures required under the Basin Plan with neutral or positive social and economic impacts.

The Sustainable Rural Water Use and Infrastructure Program (SRWUIP) is a national program investing in rural water use, management and efficiency, including improved water knowledge and market reform, and water purchase for the environment. It is the key mechanism to 'bridge the gap' to the sustainable diversion limits (SDLs) under the Murray-Darling Basin Plan.

Components of SRWUIP include: -

- The On-Farm Irrigation Efficiency Program (OFIEP) assists irrigators within the southern connected system of the Murray–Darling Basin to modernise their on-farm irrigation infrastructure while returning water savings to the environment.
- The Commonwealth On-Farm Further Irrigation Efficiency (COFFIE) Program is funding infrastructure to make water delivery systems for irrigation even more efficient so that additional water can be recovered for the environment.
- The Private Irrigation Infrastructure Operators Program (PIIOP) in New South Wales (NSW) aims to improve the efficiency and productivity of water use and management of private irrigation networks to deliver water savings for the environment.
- The Private Irrigation Infrastructure Program (PIIP) for South Australia (SA) funds irrigation infrastructure efficiency improvements for Murray–Darling Basin operators in South Australia, with a share of the water savings achieved from those projects being used for environmental water purposes.

3.3. Future Programs

Australian Governments, through direct investment and NWI water policy directions, are pursuing a progressive increase in more efficient systems both on farm and in the publicly and privately controlled systems that harvest and store water in large dams as well as delivery through the rivers systems and the channels and streams. This is mainly through investment in measurement and monitoring to support the distribution of water in accordance with the nation's desire to find the balance between irrigation for productive agriculture and emulating natural flows that support a healthy environment.

The principles behind the Murray Darling Basin Plan are being used to drive many changes across Australia to pursue this balance as part of any new developments or renewal of existing developments. This recognition of the importance of a healthy water system, as a key to our long-term sustainable use of water for human need, has become a critical element of policy, allocation, delivery settings and management decisions, requiring measurement of performance, validation of share arrangements, and the monitoring of impacts and/or improvements.

4. National factors affecting irrigation management, including water policy, institutions, and capacities

4.1. Water Governance

Water governance in Australia is complex and varies in detail from state to state but has the same underlying principles. Additionally, there are some forced commonalities within the Murray Darling Basin. This section deals with the way in which the resource is managed and discusses water licensing, water sharing, water trading, water extraction monitoring, the Murray Darling Basin plan and, last but not least, water pricing.

The Australian Government's Productivity Commission periodically reviews progress of the NWI and recommends changes.

4.2. Water licensing

The use of water in Australia in agricultural production is highly regulated and this has evolved over time. Licenses or access and use rights are required for the extraction and use of water in irrigation, be it from groundwater, surface water, rivers or irrigation supply networks. Structures that allow for this extraction of water generally require licences as well; these works may be for hillside dams, large on-farm storages and their diversion works including pumps, channels and flow control structures.

Initially in Australia, water was allocated to irrigate a specific area (size and location) and hence the irrigation licence was area based and connected to that specific parcel of land. This did not facilitate efficient irrigation as water was taken to irrigate that area, no matter how much water was actually required.

Over time, as water resources became fully allocated, these area allocations were converted to volumetric licences as a step in a drive to increase irrigation efficiency and reduce water use.

Generally, in the past, access to water for irrigation was regulated with water use only occurring on the land to which it was licensed. One of the most significant structural adjustments was the disconnection of land and water enabling the movement of water to higher value uses. The establishment of water markets was key to this water movement. As part of this movement to new areas, there is a need for development permits involving evaluation of environmental, social and economic risks together with management strategies to mitigate any negative impacts.

Water licences also relate to reliability and security of water supply with implications on what types of crops the water is used. High security water (with its almost fixed volume of water) will generally be used on high value perennial crops whereas general security water, where volumes available in an individual year will reflect the general availability of the water resource, will be used on lower value annual crops.

Water Licenses have two parts:

1) A Licensed water access entitlement for up to a defined volumetric amount of water per year
2) An annual allocation applied to the water access entitlement depending on the seasonal availability of water

Both parts can be traded i.e., a License holder can trade their water access entitlement permanently or they can trade the volume of water allocated in a given year (often referred to as a lease).

4.3. Water Sharing

Water sharing is primarily the function of water resource plans. Each water resource plan area has different resources, environmental assets, development and geography and these things all impact the management of water resources in each area and how water is shared across all competing users. They may have different names in different parts of Australia but the objective to equitably share the resource remains common.

In particular, water resource plans are an integral part of implementing the Murray Darling Basin Plan. They set new rules on how much water can be taken from the system, ensuring the sustainable diversion limit is not exceeded over time.[3]

Basin state governments are developing water resource plans. The Murray–Darling Basin Authority is working closely with Basin state governments to ensure water resource plans meet the requirements of the Basin Plan and address the local requirements of water resource management.

Each water resource plan sets out the rules for how water is used at a local or catchment level, including new limits on how much water can be taken from the system, how much water will be made available to the environment, and how water quality standards can be met. Basin state governments are responsible for complying with water resource plans and accounting for water taken from the river system.

Water resource plans outline how each region aims to achieve community, environmental, economic and cultural outcomes and ensure that state water management rules meet the Basin Plan objectives. The plans reflect current arrangements that are working and incorporate new arrangements that strengthen water management at a local level.

Getting the plans right can take time—local communities must have confidence that the plans are robust, high quality and adequately address local needs. Water resource plans will continue to evolve and be adapted over time as new information becomes available and imperative change. They may need to be reaccredited in the future as they are adjusted and improved.

4.4. Water Trading

The disconnection of water to land and the traditional concept of water-rights has allowed water markets and trading to develop. This has allowed water to move from lower value uses to higher value uses and move up and down valleys. There may be, however, a range of constraints, both physical or policy, which may limit the water transfers.

The fundamental reforms that enabled water markets to develop in Australia commenced in the 1980s with the introduction of limited water trading in Victoria and in NSW with the transfer of water between related holdings during the severe drought of the late 1980s. The introduction of the National Competition Policy in the early 1990s facilitated these market developments.

The adoption of nationally agreed water reform packages in 1994 and 2004 facilitated the expansion of water markets across connected valleys and eventually state borders in the Murray-Darling Basin.

[3] https://www.mdba.gov.au/basin-plan-roll-out/water-resource-plans#

Australian water markets are internationally recognised as a water reform success story. A market now boasting an annual turnover of between $1 and $3 billion AUD is allowing water to move to its most economically productive uses. Trading generates economic benefits valued in hundreds of millions of dollars annually.

The States have established water registers to keep track of who owns what and what type of water it is, whether it is leased or permanently traded, and the price paid for the transfer. It is an open market and information on price and availability is generally readily accessed. Water brokers facilitate this trading.

4.4.1 Key features of Australian water markets

The price of water is an important input into an irrigator's business decisions. The ability to sell, lease or buy water in response to the price of water and commodities allows flexibility for water users. This flexibility allowed many businesses to continue operating through the millennium drought as some irrigators stopped irrigating and leased/sold water enabling others to continue or complete crops.

Australian governments have established regulatory frameworks to reduce barriers to water trade. Commonwealth legislation under the Water Act 2007 (Water Act) and the Basin Plan Water Trading Rules sets out high-level principles and requirements to promote water trading in the Murray Darling Basin. Other trading rules that apply at the state or local level, including in water resource plans, operate concurrently with the Basin Plan water trading rules.

The Basin Plan water trading rules are part of a broader package of reforms under the Water Act aimed at improving water market outcomes, including water market and charge rules. The Australian Competition and Consumer Commission is the relevant enforcement agency for the water market and charge rules. The Murray-Darling Basin Authority enforces the Basin Plan Water Trading Rules.

It is important to note that water for critical human needs, such as drinking water for towns, households and stock animals, is protected in water resource plans.

Water needed to sustain agreed environmental values is given statutory recognition. Environmental water holders can participate in water markets as both buyers and sellers/leasers.

4.4.2 How water markets operate in Australia

Access to shared water resources are regulated by states and territories through water access entitlements, and annual water allocations, both of which are also tradable assets.

Trade prices for water are determined by the market and are influenced by supply and demand drivers, such as water availability, climate conditions and demand for different agricultural commodities. Water can be traded on a temporary (annual water allocation) or permanent (water access entitlement) basis.

Water trading rules made under the Water Act confer different rights, responsibilities and obligations to holders of tradeable water rights, infrastructure operators, governments and trade approval authorities. These rules operate together to facilitate the continued development and operation of water markets in Australia. Entitlements of the same class, including environmental water holdings, are subject to the same carryover rules, allocations, restrictions and fees and charges. In order for the market to operate most effectively, there should be minimal restrictions on water trade. The Basin Plan water trading rules provides for a person to trade a water access right generally free of specified conditions and restrictions.

Some may consider that regardless of the size of the market, all water markets offer benefits to irrigators by adding flexibility to business decisions. However, there have been enquiries into effectiveness and efficiency of water market systems, water 'hoarding' and a range of other issues related to water markets in Australia. To further facilitate the efficient operation of this dynamic market, ongoing innovations in the accessibility and transparency of market information are anticipated.

Free and open markets have their distractors, and we may not see the same value in our water as others but Canadian superannuation funds value Australian water with significant purchases of land and water over recent years. May it be that the largest holders of water in Australia are Canadian superannuation funds?

4.4.3 Locations of water markets

Water markets in Australia are dispersed, defined by their hydrological connectivity and operating with varying degrees of maturity.

The most highly developed and active water market is within the regulated southern connected Murray-Darling Basin. The water market in the northern Murray-Darling Basin is characterised by unregulated rivers or rivers regulated by single storages. Outside the Murray-Darling Basin region, new water markets have emerged in Tasmania, Western Australia, Northern Territory and northern Queensland.

The Australian, state and territory governments have made a commitment to adhere to the National Water Initiative principles to enable the emergence of new water markets.

4.5. Water Extraction Monitoring

The old adage that you cannot manage something without measuring is particularly true in the area of water resources. Modern Water policy in Australia places many constraints on how, where, and when water may be used and this is predicated on an understanding of how much water is available to share so to complete the water balance inputs and outputs need to be measured/monitored.

Water extraction monitoring is necessary to allow for ensuring that licensees are only using what they are entitled to, but also that those various licensees pay for the water which they are using.

Initially, it was primarily an issue of ensuring that any water use was paid for as water licenses were primarily area based and so there were no constraints on how much water was used to irrigate that area.

Over time, with the implementation of various water reforms, be they the volumetric conversion of area-based licenses to volumetric allocations or improved resource management, water extraction monitoring has changed to ensure that accurate systems of measurement are being used.

With water resources becoming scarcer, monitoring of use utilises modern technology to ensure that irrigators do not exceed entitlements or times for extraction.

4.6. Cost Recovery and National Water Initiative (NWI)

Prior to the 1994 Council of Australian Governments (COAG) agreement, the various states with irrigation determined their water charges by whatever principles they wished to employ. Full cost recovery, including charges for resource utilisation, was not utilised. In many instances, there was no accounting for the actual resource use and charges basically related to administration and delivery of the resource in both government and non-government irrigation schemes. Sinking funds were not utilised to fund asset refurbishment/replacement.

The 1994 COAG agreement included general principles for pricing, including consumption-based pricing, full-cost recovery and (desirably) the removal of cross-subsidies. In respect of rural water supply, the agreement provided for a move to full cost-recovery and to achieve positive real rates of return on the written-down replacement costs of assets in rural water. The various states agreed to aim to implement this new pricing regime by 2001.

Further advancing these goals, the 2004 National Water Initiative (NWI) required that the parties:

- Promote economically efficient and sustainable use of water resources, water infrastructure assets, and government resources.
- Ensure sufficient revenue streams to allow efficient delivery of the required services.
- Facilitate the efficient functioning of water markets, and
- Give effect to the principles of user-pays and achieve pricing transparency in respect of water storage and delivery in irrigation systems and cost recovery for water planning and management and for asset refurbishment/replacement.

The agreement specifically provided for consumption-based pricing, coupled with full cost recovery for water services, to ensure business viability and avoid monopoly rents, including (where feasible and practicable) the recovery of environmental externalities.

It requires:

- Full cost recovery (save some small community services/obligations) with:
  - lower bound pricing;
  - a move towards upper bound pricing, where practicable; and
  - public reporting of subsidies where full cost recovery is unlikely to be achieved in the long term.
- Recovery of water planning and management costs, through:
  - identification of costs associated with water planning and management; and
  - identification of the proportion of those costs that can be attributed to water access entitlement holders.
- Future investment in water infrastructure to be assessed as economically viable and ecologically sustainable prior to investment occurring.
- Annual independent, public report benchmarking of pricing and service quality for rural water delivery agencies; and
- An independent pricing regulator together with regular review and public reporting.

The approaches taken by Queensland, New South Wales, South Australia and Victoria may be different, but all comply with the NWI principles. In NSW the Independent Pricing and Regulatory Tribunal (IPART) is accredited by the ACCC under the Commonwealth Government's Water Charge (Infrastructure) Rules 2010 (WCIR) to set bulk water prices for WaterNSW within the Murray-Darling Basin (MDB) and sets maximum prices that WaterNSW can charge for its monopoly bulk water services in rural areas. IPART is required to conduct the price review in accordance with the requirements set out in the WCIR for valleys in the MDB. IPART’s review of WaterNSW's prices for coastal valleys is conducted under the IPART Act. In Victoria the Victorian Essential Services Commission (ESC) is responsible for the economic regulation including regulating prices and service standards – of the Victorian water sector, including both urban and rural water services.

The implementation of these principles in the various states has had different timeframes and hence stages of completion, particularly due to the political sensitivities associated with increasing water charges. In many instances, States have adopted price paths, typically for five-year periods, to incrementally move towards full-cost recovery prices.

It has long been acknowledged that increasing water prices is not of itself a sufficient policy response to promote efficiency in use and delivery. (There are many instances of where increases in water security have resulted in a reduction in efficiency and effectiveness of water use.) The NWI provides for benchmarking of service providers. Annual performance reports for water service providers were compiled by the then National Water Commission as part of a benchmarking exercise.

While the States were slower than originally anticipated in achieving lower bound pricing (the 1994 COAG originally set a target of 2001), this goal has now been realised in the vast majority of government-owned water supply schemes. Where government entities were required to provide water supply services to irrigators at a price that is less than lower bound levels, the balance was paid by government as a transparent community service obligation (CSO) payment.

In Victoria and elsewhere, water access entitlements (i.e., an irrigator's right to a share of the seasonally available water resource) and delivery rights (a right to a share of the capacity of a distribution system) have been unbundled. Consequently, irrigators in Victorian owned supply schemes and other private irrigation infrastructure operator schemes hold both a water access entitlement and an infrastructure delivery share. The unbundling process has (necessarily) been applied to the water pricing regime, with different charges attached to each of these two elements. The system allows for greater freedom for an irrigator to sell their water share outside of the scheme's delivery system, while ensuring someone (whoever owns the delivery share) remains liable for the fixed charges associated with the delivery share, thus contributing to continued operation and maintenance of the delivery assets. This approach protects a water supply scheme owner from the risk of lost revenue as a result of water access entitlements being traded out of the scheme and reducing the scheme's revenue (i.e., the issue of stranded assets). It also provides a more cost-reflective approach to addressing the issue of capacity constraints associated with peak delivery periods. In other Australian states, typically an "exit fee" must be paid before any water entitlement can be transferred out of the supply scheme, to protect the revenue and viability of the scheme's operator [4].

4.7. The Murray Darling Basin Plan

The Murray–Darling Basin is the largest and most complex river system in Australia. It covers one million square kilometres of south-eastern Australia, across New South Wales, Queensland, South Australia, Victoria and the Australian Capital Territory.

The Basin encompasses a complex network of people, cultures, environments, industries and organisations with competing interests and so the water needs to be managed carefully for future generations.

The Millennium Drought (1998-2010) was the worst drought in the MDB's recorded history. The irrigation sector was hit hard with critically low levels of water availability and for the first time critical human needs was at risk. The City of Adelaide came perilously close to running out of potable water. Australia acknowledged that, in the national interest, the management of the Murray Darling Basin could no longer be solely the responsibility of the States.

[4] ://www.oecd.org/greengrowth/sustainable-agriculture/49040929.pdf, Seamus Parker, 2010.

National Legislation to address overallocation of the water resource was enacted after the Australian Government reached an accord with each of the Basin states: Queensland, New South Wales, Victoria, South Australia and the Australian Capital Territory. Passage of the legislation required the ceding of some constitutional powers over the management of water from the States to the Australian Government. The Australian Government also committed US $7 billion to resource the necessary adjustments to bring the system back from the brink of collapse.

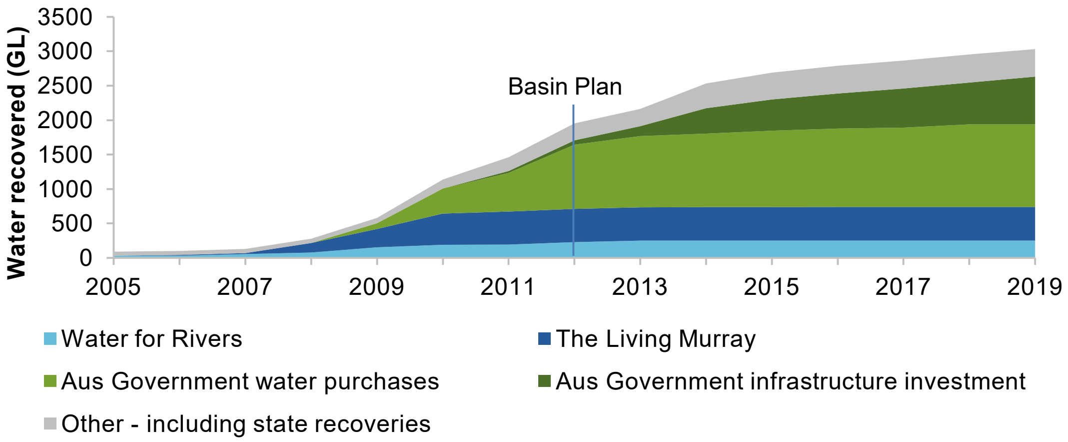
The Murray Darling Basin Plan (The Plan) was adopted in 2012 and is the first basin scale water planning initiative of this size in the world. It is an historic, multijurisdictional agreement about how the water that flows down the nation's longest river system is managed to ensure its long-term health. The Basin Plan sets the amount of water that can be taken from the Basin, while leaving enough for our rivers, lakes and wetlands and the plants and animals that depend on them.

The Basin Plan is being implemented in a partnership between the Murray-Darling Basin Authority, the Australian Government, and the governments of New South Wales, Queensland, South Australia, Victoria and the Australian Capital Territory.

Aspects of the Plan implementation include addressing over allocation of water in the MDB through water access entitlement buybacks, modernisation of irrigation, water efficiency, investing in information and monitoring, new governance for water management and acceleration of the National Water Initiative implementation.

The Plan continues to be controversial, and whilst some timelines have slipped, it has achieved a great deal towards returning the system toward sustainability. The following graph illustrates the water recovery profile)[5].

Held environmental water recovery in the Murray–Darling Basin[a,b]



[a] Volumes recovered to 30 June 2019 in terms of long-term average annual yield. [b] State recoveries include programs such as New South Wales Riverbank and other small recoveries.

[5] https://www.pc.gov.au/inquiries/completed/water-reform-2020/report/water-reform-2020.pdf

4.8. Irrigation Management Transfer

While, in late 1990, there was a global call, being led by the World Bank and FAO, to shift the ownership and management of irrigation systems to farmers, there was already significant diversity in ownership and management of irrigation schemes in Australia. Australia had large state-run government irrigation areas and districts as well as large private irrigation companies and cooperatives as well as a myriad of private schemes of various sizes, in various forms from individual irrigation farms extracting water from rivers under an individual licence or multiple licences to group schemes with one licence and diversion works supplying multiple farms through a common ownership of the supply works. Only some of the largest of the government schemes had associated drainage schemes, often integrated in the supply system for reuse further downstream.

Starting in the late 1980s, government run irrigation schemes started to be privatised, where ownership was transferred to the Water Users Associations/constituent farmers supplied by the scheme or corporatised, where the state still owned the asset, but the Water User Association/farmers become accountable for operation, maintenance and refurbishment of the scheme but were also required to pay a dividend to government.

The Australian Government, together with some state governments, have invested significant funds across the whole irrigation sector to modernise irrigation infrastructure to reduce system and farm level losses to provide for a more sustainable system. Surrender of system and on-farm losses saved by modernisation have generally been returned to the environment to boost environmental flows.

5. Prospective areas for future management:

In May 2019, in response to the Australian Government's Productivity Commission 2017 inquiry on national water reform, the Australian Government agreed to renew the National Water Initiative (NWI) and, in partnership with State and Territory Governments, has commenced the process of policy renewal[6].

The NWI is now seventeen years old and most jurisdictions have largely achieved their 2004 NWI commitments. All, except Western Australia and the Northern Territory, have enacted legislation to create secure, NWI-consistent water access entitlements for consumptive uses. Water planning arrangements have been established for all areas of intensive water use, and environmental sustainability has been supported by formal provisions of water for the environment. Water markets have been created, allowing water to be traded to higher-value uses. Water accounting is generally providing practical, credible and reliable information, however most States and Territories are still in the process of implementing non–urban metering policies.

Adoption of NWI-consistent water planning and entitlement frameworks has created the foundations for efficient and sustainable resource management. Water planning has established transparent processes for deciding how the water in a system is shared between consumptive users (people and businesses) and the environment. Creation of water entitlements, separate from land, has provided clear and secure long-term property rights for both consumptive users and the environment. Together these developments have provided the essential prerequisites for water markets and trading and have established pathways to a more sustainable balance between consumptive and environmental use.

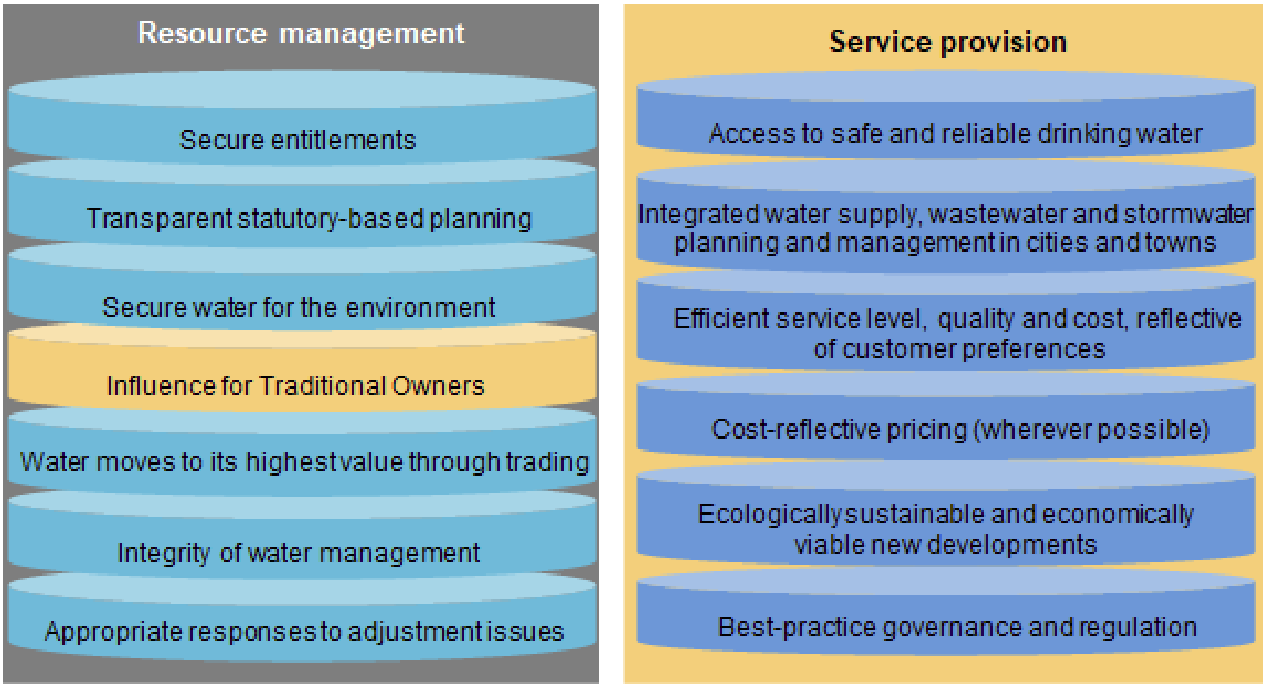
Water entitlements have become a valuable asset — estimates put their value in the southern MDB at more than AUD$26billion. This value, coupled with their legal backing and the development of water markets, means entitlements can now be used as collateral for loans.

Water trading has become a sizeable economic activity. In 2018-19, turnover was estimated at AUD$5.2 billion. Studies of the economic benefits of this activity, although dated, point to substantial value. For example, regional GDP in the southern MDB was estimated to be AUD$4.3 billion higher over the 5 years to 2010-11 than it would have been without trading.

The current NWI has a strong focus on water resource management. But reform in aspects of water service provision (water supply, wastewater and stormwater services) will be equally important to successfully navigate the challenges ahead. A renewed NWI will need to reflect the importance of both sustainable water resource management and effective, equitable and efficient water service provision — a more detailed set of objectives covering both spheres of policy focus is proposed (figure 1).

[6] www.pc.gov.au/inquiries/completed/water-reform-2020/report

Figure 1 **Summary view of suggested new NWI objectives a, b**



a) Yellow colouring represents new objectives. **b)** The Productivity Commission's advice includes additional detail for most of the current NWI water resource management objectives.

Box 1 **Proposed elements of a renewed agreement**

The overall goal and objectives of a renewed NWI should be delivered through the following elements:

Water resource management

1. Water access entitlement and planning frameworks
2. Water trading and markets
3. Environmental management[a]
4. Aboriginal and Torres Strait Islander people's interests in water[b]
5. System integrity[a]

Water services provision

6. Pricing and institutional arrangements
7. Urban water services
8. New infrastructure development[b]

Supporting arrangements

9. Community engagement, and adjustment
10. Knowledge, capacity and capability building

[a] Significantly enhanced element. [b]New element.

6. Way Forward and Recommendations

6.1. Best Practices

Best practice is ever evolving as new knowledge is brought on board; we must continue to seek to implement Best Practice to ensure that the water resources that we have for use in irrigation of food and fibre crops are used in a sustainable manner as climate change impacts and the world's population demands more food.

Just as catchment water sharing plans evolve over time, similarly the Murray Darling Basin Plan is evolving. These Plans are based on knowledge as it is when the Plan is developed, and over time new knowledge becomes available and so the Plans need to evolve.

The MERI Framework is often used in this continuous improvement cycle, where the MERI acronym stands for: -

Monitoring
Evaluation
Reporting
Improvement

Best Practice means: -

- knowing the volume of the available resource and how that volume of the water resource is changing, due to climate change and climate variability
- allocating it equitably across all users in accordance with approved resource/sharing plans
- distributing it efficiently to these users via dams, rivers and streams (both natural and man-made) to the various end-users (the environment, farmers, industry, domestic users, etc) using SCADA and Total Channel Control (TCC) to minimise losses
- applying irrigation water in the most effective and efficient manner to produce 'more crop per drop' and increasingly, more crop *value* per drop
- measuring how much is actually being taken by the various users using accurate measurement systems'
- charging for the volumes used in a way which reflects agreed values, to cover all costs in managing and supplying the resource.

Some examples of Best Practice, at its present state of development, are detailed in Section 7 – Case Studies

6.2. Recommendations

6.2.1 Improved Governance

Australia has moved from a development phase to a management phase in the utilisation of water and this has changed our approach to the resource and how it should be used. Economic and Social development objectives have given way to sustainability and environment protection with these now being paramount as we seek to deliver to future generations an environment which will benefit all, while utilising our water resources in a productive manner.

- The National Water Initiative is the basis for water management in Australia as it seeks to impose improved governance in the use of water across all users. This new approach has enabled substantial value creation as water moves to higher value uses and users are charged for all costs associated with the management and delivery of the resource.
- Water Planning and associated water sharing plans requires that we consider all aspects of the resource and how it is used and who/what has priority. As we plan, we need to consider the impacts of our plans and build in mechanisms which require us to implement, monitor, review and revise to ensure that our plans remain relevant to the times. The continuous improvement cycle needs to be applied to how we deal with water sharing as redressing over-allocation is very costly and politically difficult, so best not to get into that situation.
- We also need to consider what is 'sustainable' and our place in history; it is worthwhile to invest the time and resources upfront to understand the perspectives of everyone who may be affected, even indirectly.
- Integrity is a critical component of Water Markets and Trade. Buyers and sellers need confidence that they are achieving a fair price for the commodity, so openness and transparency are essential. Public registers of transfers play an important part in this. Price is only one aspect that needs consideration as there will be charges that are associated with the water transferred. These changes may relate to access and use with some being variable and others fixed.
- There are many aspects to Water Security and water users, whoever they are, benefit from surety, be it available water volumes, the certainty/reliability of supply, the water price, etc. Aspects of these will be set by the government or the market or irrigation supply infrastructure operators.

6.2.2 Climate Variability and Climate Change

Australia is suffering impacts from Climate Change with the bottom line being less water available and more stochastic weather events. Australia has massive storage capacity with still more being built where opportunities arise but no amount of dams can protect irrigators from unprecedented drought sequences. Some of our large storages have been all but empty at the start of irrigation seasons, as an impact of climate variability, with dramatic impacts of regional communities. Climate Change will make this a more common event.

Our water sharing arrangements/plans need to reflect the increased likelihood of longer and more severe droughts brought about by climate change. They also need to reflect the other side of the weather coin and be able to plan for the flooding rains.

7. Case studies on the various aspects of integrated and innovative irrigation management within Australia

Introduction

Following are a series of brief case studies across various sectors of the Australian irrigation industry. They are a combination of both types of irrigation systems and their management and the technologies that manage them, so they look at both the irrigation system and how it is managed and also the irrigated crop and how it is managed to deliver quality and quantity outcomes.

Many of the irrigation industries in Australia have documented Best Management Practices and these will often be found at industry websites.

These case studies cover irrigation delivery systems at scheme and farm level as well as broad area agricultural cropping and extensive horticulture.

Case Study 1- Trangie Nevertire Private Irrigation Scheme

This modernisation /renewal project involved the transfer/sale of water to the Australian Government in return for funding to totally modernize the irrigation infrastructure of the Trangie-Nevertire Co-operative Ltd both off-farm and on-farm. Channel conveyance losses have reduced from in excess of 50% to 7%. On-farm productivity improved from greater availably of water and installation of “state of the art” farm irrigation systems.

Previous off-farm and on-farm irrigation losses are now being used for environmental benefit.

In May 2010 the Co-operative was granted $115m to modernise its irrigation scheme, in exchange for 29889 ML of water savings transferred from its members to the Australian government for environmental use in the Ramsar-listed Macquarie Marshes.

The Modernisation Project had 5 major elements:

1. Reduction in the earthen channel system from 240 km down to 138 km and retiring 17 members permanently from irrigation.
2. Rebuilding the remaining 138 kms of channel system, lining 108 kms with Firestone EPDM rubber membrane, and installing a complete Rubicon water gate system, all enclosed within electric animal exclusion fencing.
3. Installing a 230 km Stock & Domestic pipeline from the river to all continuing and retiring members’ farms to replace the previous reliance on the channel system.
4. Modernising the remaining members’ on-farm irrigation infrastructure, with 24 linear move or centre pivot irrigators installed, as well as upgraded field layouts, tailwater return systems and storages.
5. Decommissioning the irrigation infrastructure on those retiring members’ farms and reconfiguring them back to a dryland basis including the provision of piped stock and domestic water reticulation.

The inclusion of the automated Rubicon Total Channel Control system has substantially increased the level of service of water delivery to the Members, allowing on time and accurate on-farm water supply and measurement.

The modernisation has led to the farming members now having more water available to them at the farm gate now than pre-project.

The system can now operate to irrigate even in very low allocation years, as losses are stable and predictable whereas pre-modernisation 25% or greater allocations were needed to reduce the wet-up loss to tolerable levels

Photo 1. Lined channel section with Rubicon control gates.

1. The on-farm infrastructure upgrades on the remaining member farms have led to both water savings and yield increases on both summer and winter crops grown. Most of these projects were based around replacing traditional furrow surface irrigation with overhead sprinkler centre pivot and linear move irrigators. Water use on the predominant cotton crop under these machines has reduced by around 1 ML per ha while crop yields have risen by 1-2 bales/ha, leading to Water Use Efficiency increases in the order of 30%.

Case Study 2 – Bankless Channel Surface Irrigation

As irrigators strive to improve irrigation efficiency and effectiveness in a whole farm context they improvise. Flexibility is an important aspect of an irrigation layout and a system which allows for different crops to be grown effectively will be attractive to the irrigator.

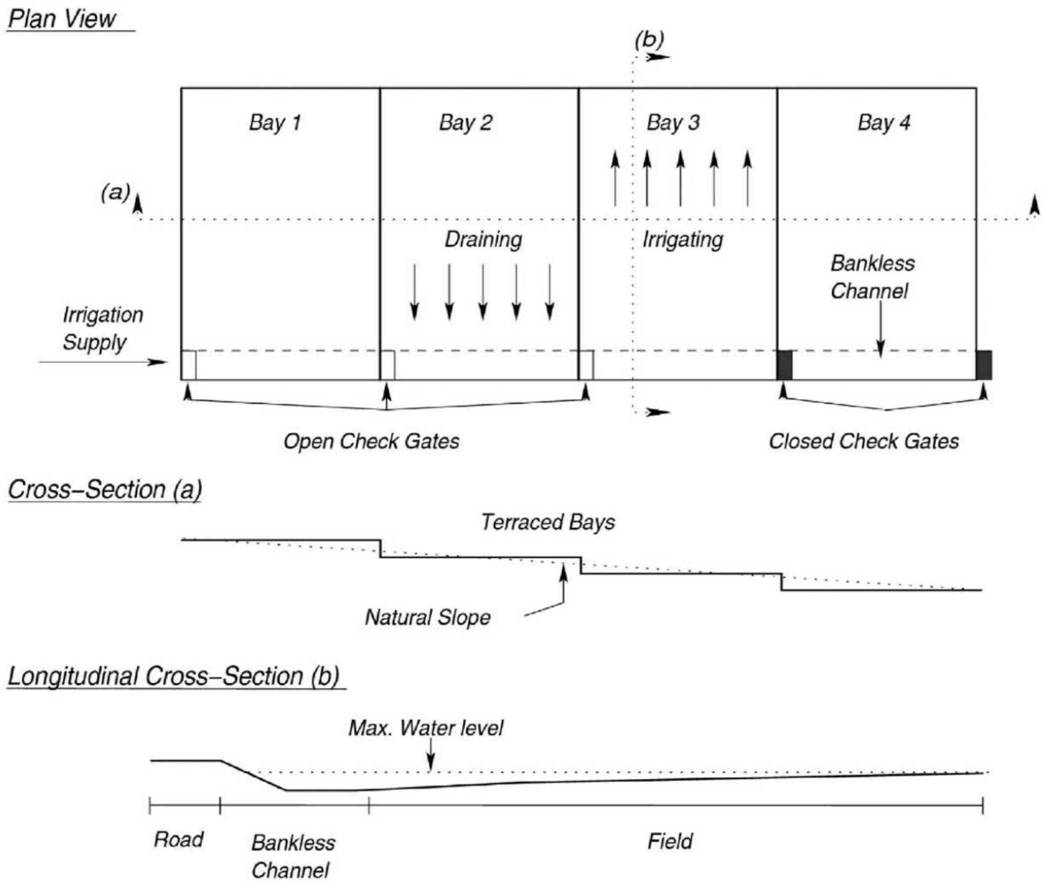
Bankless Channel Irrigation Systems (BCISs) have evolved out of combining basin and furrow irrigation and are a surface irrigation system composed of adjacent, terraced bays with an interconnecting channel constructed such that the rim of the channel is level with the floor of each adjoining bay. The mode of irrigation may be considered as similar to Drain Back Level Basins (DBLBs) where the accumulated surface storage of each upstream bay is used to augment flow to a downstream bay. It is this style of BCIS that has generated considerable interest in Australia, particularly in the Murray Darling Basin, where the system is used to grow a variety of crops and offers considerable labour and machine efficiency savings. Two defining features of BCISs are a positive field slope which rises from the bankless channel, and the hydraulic interaction between adjoining bays during the recession phase of the upstream bay and the advance phase in the downstream bay.

Stage 1 of a cotton and rice modernisation together with an efficient water recirculating system. The 108 hectares in these 2 new paddocks replaced nearly 50 irrigation bays which after development became 10. Internal channels are Bankless so that machinery can drive the full length in a straight line (> 1 kilometre) with great efficiencies cf driving round and round 50 little bays.

The system delivers high water flows along one edge to shallower side delivery which dry out quickly for machinery traffic ability. Permanent 1.8 metre beds have been installed in the bays which are flat with >150mm steps between adjacent bays. This phot shows a 70Ml/day outlet delivering water to the top bay.

Cost has been roughly AUD$2500/ ha but labour and water savings enormous. Have the ability, flexibility to grow Cotton and other crops as a result and no syphons. Water savings are greater than 10 % on every irrigation. Less important with rice but the cotton used 8.5 megalitres per ha to yield 11.2 bales which was above the area yield of 10.8 Water savings occur because the water is on and off very quickly. The cotton was being watered each time with 30 ML/d of water ordered in in plus the drainage from the previous irrigation

Below are plan and cross section views of a BCIS showing flows showing irrigation of third bay in a series of 4 bays. Cross section 'a' shows the terraced bays showing the natural slope, while cross section 'b' shows a longitudinal section of the bay[7].



System description

Two main design approaches are currently being used for BCIS. The conventional form of BCIS consists of a series of terraced bays with a vertical separation of between 0.1to 0.2 m. Bays typically have either a zero or very shallow positive (uphill) field slope of around +0.01% (1:10000). Bays must have no cross-slope and can be configured with beds or flat-planted. All bays are connected by bank less channel (above). However, each bay is irrigated individually by backing-up water behind a closed structure in the channel, causing water to rise and spill into the adjacent bay. Once irrigation is complete for that bay, water is released through the structure, allowing both supply water from the channel and drainage water from the bay to flow into the next bay in the series. This process is repeated until all bays are irrigated. The flow into each bay is augmented by the runoff from the accumulated sur face storage volume in each preceding bay. This creates a higher discharge rate, which means fast advance rates can be achieved.

7

http://www.insidecotton.com/jspui/bitstream/1/555/37/5_4%20Bankless%20Channels%20Cotton%20WATERpak.pdf

Case Study 3 – Irrigation Upgrades in the GMID

The Goulburn-Murray Irrigation District (GMID) is Australia's largest irrigation delivery network and spans 27,000 sq km in Northern Victoria. The modernisation of the GMID network has been Australia's most significant irrigation infrastructure upgrade. In October 2020 the achievement of the project's 429GL per year water savings target was announced by the Australian Government. The modernisation works were described as "one of the most significant infrastructure projects ever undertaken in this country when it comes to delivering water savings and benefits for farmers, communities and the environment."[8]

The GMID's irrigation supply infrastructure services 14,131 gravity irrigators. These farms generate more than $5.9 billion annually and directly support over 10,000 jobs[9] in the district. The irrigated agriculture in the district includes 1,200 dairy farms producing 2 billion litres of milk worth $850 million each year, 400,000 hectares of irrigated broadacre crops worth $395 million, and 28,151 hectares of fruit and vegetables worth $702 million each year.[10]

Prior to the modernisation works, the district diverted 3,000 GL and it was estimated that up to 900GL of water was lost within the GMID distribution network each year.


GMID in 1900s


GMID in 2003

Figure 1 - A comparison of GMID infrastructure in the 1900s and in 2003

Irrigators received water with four-day lead times, and manual system operations made it challenging to provide consistent flows to all farmers, contributing to inefficient irrigation practices on-farm.

Australia's Federal and State Governments increasingly prioritised irrigation efficiency as a means of ensuring sustainable irrigated agriculture and healthy rural communities while returning water to the environment11. From the year 2000, a body of work was undertaken to better understand irrigation losses within the GMID and to identify possible means for reducing these losses and measuring savings.

The baseline distribution network efficiency was first established by a series of real-time measurement and automation demonstration projects in the Central Goulburn District. This work provided, for the first time, accurate real-time 24/7 data at network offtakes, check

[8] minister.awe.gov.au/pitt/media-release/connections-project
[9] https://www.g-mwater.com.au/about
[10] https://www.g-mwater.com.au/downloads/gmw/aboutUs/GMW_at_a_glance_Web.pdf, 2015-2016 data
[11] Victorian Department of Sustainability and Environment

structures, farm supply points and outfall structures. This data was used to identify the causes of water losses within the network.

Data spanning 1989/90 through to 1998/99 was used to determine the physical loss mechanisms within the delivery network. Data assessments concluded that operational spill accounted for up to approximately 45% of all losses, measurement error accounted for approximately 25% of all losses, and the remaining 30% of losses was attributable to seepage and leakage, evaporation, system filling and unauthorized withdrawals of water.[12]

Following this data-informed understanding of system losses, it was possible to consider opportunities for recovery of the unaccounted-for water. Following extensive consultation and economic analysis, the modernisation of the full system was committed to, comprising channel automation to stop outfalls while providing improved delivery service to irrigators, accurate metering, targeted lining or piping of leaky canals (informed by real-time loss measurement data), and network reconfiguration. Rubicon Water's Total Channel Control technology was implemented to automate over 3,000km of canals to create an on-demand, efficient, low energy, automated irrigation system.

Figure 2 - GMID Modernised Infrastructure in 2020

The project completion was announced in October 2020, with the Australian Government confirming that the modernisation of GMID was achieving 429 gigalitres of water savings each year. Under the project's funding agreement these long-term annual water savings are shared between GMID irrigators, Melbourne's water retailers and the environment. In October 2021 it was announced that more than $300 million worth of water made available as a result of the GMID irrigation system upgrades is being handed to irrigators in northern Victoria to keep and use or sell on the open market.[13]

The modernisation of the irrigation system means irrigators have consistent flowrates, supplied by modernised channels and pipelines with improved water efficiency to support high value crops. The project has generated significant opportunity for contractors and local businesses in Northern Victoria and boosted the local economy. Over 800 local jobs have been created annually resulting in an annual increase of the regional GDP of around $170 million[14].

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[12] Source - Improving Water-use Efficiency in Irrigation Conveyance Systems: a Study of Investment Strategies, Marsden Jacob Associates, Land & Water Australia, 2003. Product Number PR030516. Page 8

[13] https://www.abc.net.au/news/rural/2021-10-29/free-water-windfall-for-murray-darling-irrigators/100574964

[14] connectionsproject.com.au/news/landmark-connections-project-delivered

Case Study 4 - Variable Rate Irrigation (VRI) on Centre Pivots[15]

Converting centre pivot irrigators to Variable Rate Irrigations (VRI) provides significant savings in both water and energy for the Pye Group, operating 56 centre pivots in the Mallee region of South Australia, growing carrots, potatoes and onions. Water use has dropped by between 20 and 30 per cent while improving efficiency because the right amount is being applied at the right time where it is needed. The savings also extend to diesel use, which is reduced because pump/engine control is allowing ramping up and down of flow rates to meet demand.

The new improved system allows for intensive management with fields being irrigated every day. Irrigation can be turned off to parts of fields where potatoes have already been dug, representing another water saving. Similarly, after rain, all irrigation can be turned off on heavy soils and affected areas are allowed to dry out. While these savings are significant the biggest benefit is minimising waterlogging and runoff, major contributors to both crop quality and sustainability. With such significant benefits, it is little wonder that the plan is for all pivots eventually to be upgraded and VRI ready.

The crops are grown in sandy soils in a dune and swale landscape. Most of the pivots are situated in paddocks with a combination of high dunes of deep, free-draining sand, and flats and hollows of heavier soils comprising loam or clay or both. This variation in elevation and soil type leads to challenges with irrigation application rates, scheduling and weather events. Crops growing in the lighter, free-draining sands typically require more water than those in the lower, heavy flats, with potential for waterlogged soils and boggy hollows. Irrigating at the same rate across the area results in lost crop because it is too boggy to harvest, and because of poorer quality produce due to waterlogging.

The aim of the Pye Group is to grow quality premium produce, which meant they had to rethink how they irrigated with their centre pivots to ensure optimum quality. Upgrading centre pivots with variable rate irrigation technology has seen water use efficiency improve and energy costs decrease on the Pye Group's Mallee property. While the production system is intensive requiring more ground truthing and crop health monitoring the results in producing premium vegetables speak for themselves.

Due to the soil variability, investigations, prior to upgrading the centre pivots, started with the soils. This investigation started with EM38 (Electromagnetic Induction) mapping which identified conductive (heavier) soils and less conductive (sandier) ones. EM maps were merged with elevation maps to gives a starting point for a prescribed irrigation map. The irrigation map often consisting of five or six zones, with different irrigation rates. Sandy zones have the highest application rate and clayey zones the lowest rates. This irrigation map is then uploaded to the pivot panel.

[15] https://issuu.com/irrigationaustralia/docs/ij_winter_2020

To complement the irrigation plan, plant health is monitored using a fixed-wing drone with a Normalised Difference Vegetation Index (NDVI) camera. The data and imagery are processed in-house and identify plants that are affected by over- or underwatering and other stress-related issues. This allows irrigation requirements to be monitored and application rates tweaked each day using the panel on the centre pivot, a computer or a mobile device.

VRI technology

Upgrading machines with VRI means that application rates can be adjusted along the rig based on monitoring information, providing water savings of between 20 and 30 per cent.

The centre pivots used by Pye Group are manufactured by Lindsay Zimmatic. The VRI uses FieldNET remote irrigation management and scheduling technology, which provides the flexibility to get real-time information and to make changes on the go. The VRI has helped improve water use efficiency by only applying the volume of water needed for each zone.

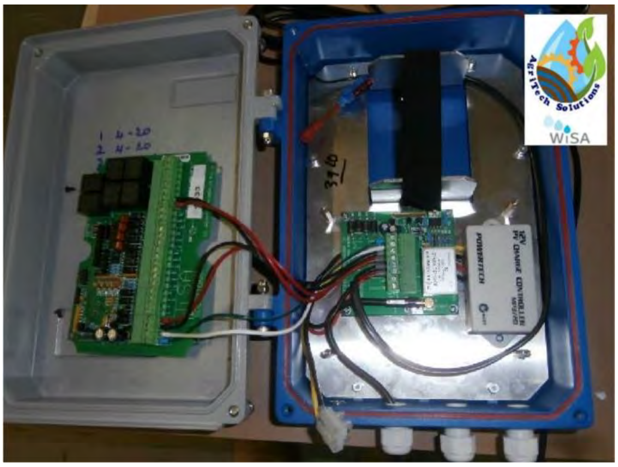
FieldNET system is a web-based program that is used to control, program, monitor and set alerts on each centre pivot. It is a powerful management tool that incorporates a dashboard showing what is happening on pivot panel in real time. The pivot panel can be viewed and programmed from anywhere, and functions such as application rates, dry or wet and VRI on or off can be controlled remotely.

Soils in each area irrigated by centre pivot are mapped using EM38 technology. This is then combined with information about landscape elevation and a map is generated that identifies zones based on soil types. This irrigation map is used to determine variable irrigation rates.

Case Study 5 - Automation of surface irrigation systems in the Burdekin region of Australia

The Burdekin Region in North Queensland Australia is home to significant irrigation-based industries, being the most productive sugarcane growing region in Australia and a thriving fruit and vegetable industry. The district sits between the cities of Townsville and Bowen in the delta of the Burdekin River. The climate is considered dry tropics due to the latitude and the comparatively low annual rainfall of approximately 950mm/year. Despite the low rainfall, the Burdekin Falls Dam (completed in 1987) has a hydrological catchment area of some 13 million hectares and a capacity of 1,860,000 megalitres. In addition to this surface water resource, the Burdekin region also has a substantial groundwater resource available to irrigators.

The traditional sugarcane furrow irrigation systems are on gently sloping fields fed by gated pipe or fluming. The farmer typically irrigates a field in a number of sets for a defined duration. Each time a set is complete the farmer needs to open a valve to allow new furrows to be irrigated before closing the valve of the completed irrigation set to allow new furrows to be irrigated. Most farmers are irrigating several fields and each field typically requires between 15 to 25 irrigations per season. This accounts for a significant time impost on the farmer to undertake these manual tasks.



WiSA field radio used to control field valves (Source: Agritech Solutions)

In recent years the desire to optimise water use efficiency and labour in the region has directed a growing number of farmers to look towards automation of their furrow irrigation systems. Local consultants were engaged to guide growers along the journey of system upgrades towards automation. The consultants worked with farmers to understand their individual fields and farming systems before designing a custom hardware and software solution to provide them with the ability to control their irrigation systems remotely. The system comprises a series of field based linear actuators to open and close valves controlled by a software system connected through field radios.

Linear actuator controlled by radio to open and close valves (Source: Agritech Solutions)

The industry standard crop model (IrrigWeb) is linked to automation controller software to trigger irrigation events based on crop need and further reduce the farmers time in manual data transfer.

Software interface for automation control (Source: Agritech Solutions)

This technology has the potential to provide a step change in the performance of their irrigation systems at a fraction of the capital and ongoing cost of conversion to pressurised irrigation. When the automation systems have been well designed and the irrigation management has been optimised, evidence has shown improvements in a number of irrigation and water use efficiency metrics. Farmers are better able to schedule their irrigations to meet crop demand and limit runoff and deep draining below the crop root zone.

In addition to the significant costs saving associated with labour and pumping electricity, there have been a number of incidental benefits to the farmer and the environment. Reductions in lost nutrients, reduced sediment and pesticide runoff, but importantly an improvement in the quality of life for farmers and their families who are now spending less time irrigating.

Case Study 6 - Select Harvests Almond Irrigation Management Practices:

Water is a key input for almond production that requires between 12 and 15 megalitres per hectare on mature orchards to produce average yields of 3.2 to 4.0 tonnes of almond kernel per hectare and around 6 and 6.5 tonnes of hull and shell per hectare. Select Harvests and the almond industry supports water use efficiency and best farm management practices, so deploys the latest technology to optimise almond production, by growing more almonds for every litre of water applied.

Sweeping of harvest prior to gathering for processing

Soil moisture monitoring transmitter

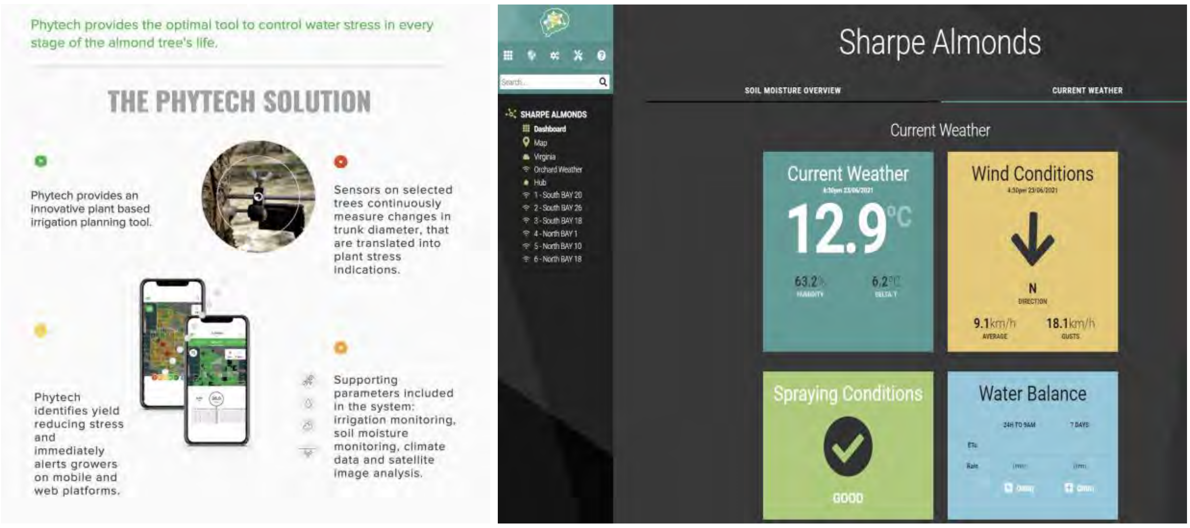
Almond trees have large canopies, leaf mass, growth, and fruit numbers. Within a season the tree is setting/yielding a crop in parallel with establishing fruiting sites/potential yield for next season. Several practices can influence annual yield with the major driving factor being water and its application timing throughout the season (apply the right amount of water at the right time). Likewise, a desired kernel size and quality is also achieved through the optimal volume and timing of irrigation supply and is thus an important contributor to crop value.

Below lists Select Harvests key practices, aimed at supporting average to above average yields year on year, whilst optimising water supply.

1. Compensated drip irrigation, designed considering soil water holding capacities; irrigation block sizes vary from 3ha to15ha depending on variation in soil characteristics across the site
2. System maintenance to optimise operating pressures, water output and water distribution uniformity
3. Maintaining fertiliser inputs in accord with soil and plant tissue analyses, plant demand and crop removal
4. Monitoring and management of pest and disease
5. Tree canopy management to assist in light penetration and maintenance of fruitfulness with the aim to establish a smaller efficient canopy
6. Regular in-field soil inspections through hand augers
7. Continuous logging oil moisture monitoring with capacitance sensors.
8. High resolution remote sensing images by 'CERES' Imaging that assess tree stress and health
9. 'Phytech' to monitor tree stress through sensors measuring changes to trunk growth.
10. Monitor daily weather, forecasts, ETo, calculated crop factors and assist with the minimal amount to irrigate to avoid major stress and achieve tree recovery.

For Select Harvests, making the best-use of water is vital for sustainability, productivity, and cost-efficiency. A key Select almond orchard has demonstrated the success of careful irrigation management and monitoring tree stress with 'Phytech' and other tools to reduce annual applications of irrigation by 1ML/ha across mature plantings. This equated to approximately a 10% water saving for this site, amounting to savings in that season of more than $400/ha (annual cost savings are dependent on the seasonal water and electricity pricing).

Productivity improvements across Select's mature almond orchards have increased in the past few seasons by 15-20% with no additional water applied.



Green Brain and Phytech platforms used to improve productivity

INTERNATIONAL COMMISSION ON IRRIGATION AND DRAINAGE

SYMPOSIUM
24th ICID CONGRESS
06 October, 2022, Adelaide, Australia

Theme: Integrated Approaches to Irrigation Management in the Future

PERFORMANCE OF IRRIGATION INFRASTRUCTURE

INDIA COUNTRY PAPER

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INDIA COUNTRY PAPER:

PERFORMANCE OF IRRIGATION INFRASTRUCTURE

0.0 ABSTRACT

India has an agrarian economy where agriculture still remains the principal source of livelihood for about 54.6 percent of the population (Dept. of Agriculture, Annual Report 2020-21). Agriculture in turn is dependent on rainfall. India receives an annual precipitation of about 3880 Billion Cubic Metres (BCM) and the average water availability is 1999 BCM (Central Water Commission, Reassessment of Water Availability Report 2019). Out of the total water available, the utilizable water resources could be assessed as 1123 BCM (National Commission on Integrated Water Resources Development- NCIWRD Report' 1999) due to topographic constraints, distribution effects, etc. As per the NCIWRD Report, the overall water demand of the country in 2010 was estimated at 710 BCM in a high projection scenario out of which, the water use in irrigation was about 557 BCM (78%). The overall water demand for 2050 is projected to be 1180 BCM which would exceed the total utilizable water resources viz. 1123 BCM. As irrigation takes a major part of the country's water consumption, meticulous steps have to be taken to ensure judicious use of water in irrigation to manage a water crisis in the future. Further, Irrigation projects involve huge capital investment, displacement and resettlement of local community due to submergence, environmental issues, wildlife issues, etc. therefore, it becomes important that these projects perform at their highest level and successfully deliver the benefits that were envisaged at the time of project planning. Government of India has been making dedicated efforts to increase the coverage of net irrigated area in the Country right from the start of Five Year Plans. However, according to the Working Group Report of Ministry of Water Resources (Nov'2011) a significant gap of about 15% has been observed in the Irrigation Potential Created (IPC) and Irrigation Potential Utilized (IPU). Also, the water use efficiency of irrigation projects has been estimated to be about 36% (CWC Report on WUE Studies for 35 Irrigation Projects' 2016). There have been several reasons plaguing the performance of irrigation projects right from the construction stage upto its operation & management necessitating the need for modernization in irrigation infrastructure and practices. The need of the hour is to focus more on demand side management. Irrigation Modernization with special focus on the Participatory Irrigation Modernization and Micro Irrigation (Drip & Sprinkler) is expected to be an effective tool for managing the irrigation demand and thereby lead to sustainable agriculture practices. Any improvement in the water use efficiency in irrigation/ agriculture sector would result into significant savings in terms of volume of water which can then be used to reclaim the lost irrigation potential, bring additional area under irrigation or alternatively can be used in other competing sectors of water use such as domestic water supply, industrial water supply, etc.

Several studies have been undertaken by Central Water Commission (CWC) and Department of Water Resources, River Development & Ganga Rejuvenation (DoWR,RD&GR) to assess the performance of canal irrigation projects in the Country and highlight the issues leading to their sub-optimal performance. This paper is an attempt towards analyzing and identifying the issues plaguing irrigation/ agriculture and the way forward in improving the irrigation performance. This paper also highlights several initiatives taken by Government of India and various State Governments in this regard.

Keywords: Water Use Efficiency, Irrigation Performance Assessment, Remote Sensing techniques, Irrigation Modernization, Micro Irrigation

1.0 INTRODUCTION

The Ultimate Irrigation Potential (UIP) in India through all major, medium and minor irrigation projects (both surface and groundwater) has been assessed as 139.9 Mha (excluding 35 Mha of additional potential that may be created on implementation of Inter Basin Water Transfer (IBWT) proposals as per National Perspective Plan of the Ministry of Jal Shakti). Against this, the irrigation potential created (IPC) in the country is 112 Mha (as on 2015-16) (State of Indian Agriculture, 2015-16) and the gross irrigated area (or irrigation potential utilized) at present is 98.15Mha. Thus there is a significant gap of more than 14 Mha between the IPC and IPU out of which majority share is from Major/ Medium Irrigation (MMI) projects. Working Group Report of Ministry of Water Resources (Nov’2011) identified this IPC-IPU gap as about 15%.

It has been observed that the performance of conventional irrigation projects in India that delivers water to the field of farmers through a system of canal network has not been very satisfactory. Since these projects involve huge capital investment, displacement and resettlement of local community due to submergence, environmental issues, wildlife issues, etc. therefore, it becomes important that these projects perform at their highest level and successfully deliver the benefits that were envisaged at the time of project planning.

There have been several reasons plaguing the performance of irrigation projects right from the construction stage upto its operation& management. Government of India has been making dedicated efforts to increase the coverage of net irrigated area in the Country right from the start of Five Year Plans. It launched Centrally Sponsored Schemes such as Accelerated Irrigation Benefits Programme (AIBP) launched in 1996-97 for financially assisting the States in completing the ongoing MMI projects that are already in advance stage of construction, Command Area Development Programme launched during the Vth Plan (1974-78) with the objective of optimal utilization of Potential created. As a result of these programs and the initiatives by States, the IPC from MMI projects in the Country increased from 9.72Mha in pre-plan period to 46.24 Mha upto XIth Plan (2007-2012). The ultimate irrigation potential of MMI projects in the Country has been estimated as 58.47 Mha. However, the net area being irrigated through canal irrigation remains only 15.669 Mha (2016-17) which is about 23% of the total net irrigated area from all sources. Despite an increase in overall potential creation from MMI projects, its share in total irrigated area has reduced from 40% in 1950-51 to 23% in 2016-17. During the same period, the contribution from Groundwater has increased from 29% to 64% which is a cause of concern due to reducing groundwater levels especially in the Northern & North- Western part of the country. Moreover, contribution of canal irrigation in the total irrigated area has been more or less constant as 15.29 Mha since 1980-81.

2.0 IRRIGATION PERFORMANCE ASSESSMENT

2.1 Water Use Efficiency Studies

Water Use Efficiency can be defined in many different ways, by agriculturists, hydrologists and engineers. However, most common and widely accepted definition of water use efficiency in agriculture/ irrigation sector is the ratio of actual volume of water consumed by crop/plant during evapo-transpiration and the volume extracted or derived from a supply source. Central Water Commission (CWC) has formulated the Guidelines for computing WUE of the irrigation projects.

2.1.1 Water Use Efficiency Studies of 35 MMI projects

CWC in May'2006 had taken up the study of 35 MMI projects from 7 States (Andhra Pradesh, Haryana, Punjab, Rajasthan, Telangana, Uttar Pradesh & Uttarakhand) which had already been completed and were in operation, to make a realistic assessment of water use efficiency of completed MMI projects.

Conveyance Efficiency (W_c)

Conveyance efficiency is a reflector of the losses in the conveyance system. It indicates how well the system is designed and how well the system is managed. The conveyance efficiency of the 35 projects studied showed wide variations ranging from 47% (Narayanapuram Medium Irrigation Project, Andhra Pradesh) to 91% (Vamsadhara Major Irrigation Project, Andhra Pradesh) with weighted average of about 68%. As anticipated, the conveyance efficiencies in lined sections of the canals is found to be higher than the unlined sections. The average conveyance efficiency of lined sections has been computed as 82% in comparison to 73% computed for unlined sections.

The major reasons identified for low Conveyance Efficiency of Irrigation projects apart from non-provision of canal lining are poor or no maintenance of canal and distribution network resulting in growth of weed & vegetation, siltation, damages in lining in case of lined canals, distortion of canal sections due to siltation or collapse of slopes, damaged structures, leakages from gates and shutters, etc.

On-Farm Application Efficiency (W_F)

On Farm Application Efficiency (OFAE) is the percentage of water delivered to the field that is effectively used by the crop for its evapo-transpiration (ET) requirement. OFAE of the 35 projects studied showed wide variations ranging from 27% (Nagal Lift Project, Haryana) to 80% (Matatila Dam Project, Uttar Pradesh) with weighted average efficiency of about 53%. The major reasons identified for low On-farm Application Efficiency of Irrigation projects are non-provision of lining in field channels/water courses, over irrigation due to non-availability of control structures in distribution system, poor management practices, lack of awareness among farmers about efficient irrigation practices and cropping pattern, etc.

Overall Project Efficiency (W_P)

The overall project efficiency (W_P) has been computed by taking the product of Water Conveyance Efficiency (W_C) and On-Farm Application Efficiency (W_F). The overall water use efficiency of the studied projects ranged from 13% (Nagal Lift project, Haryana) to 62% (Koil Sagar project, Telangana) with the group weighted average (in terms of CCA) of the projects at around 36%.The computed overall project efficiencies for 34 projects (out of 35 projects studied) can be represented graphically as in Figure-1and Figure-2.

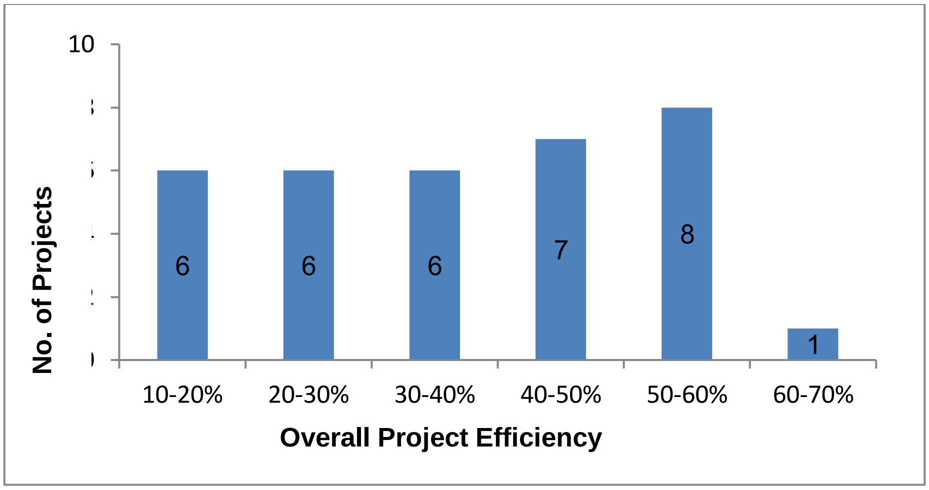

Figure 1. Overall Project Efficiency

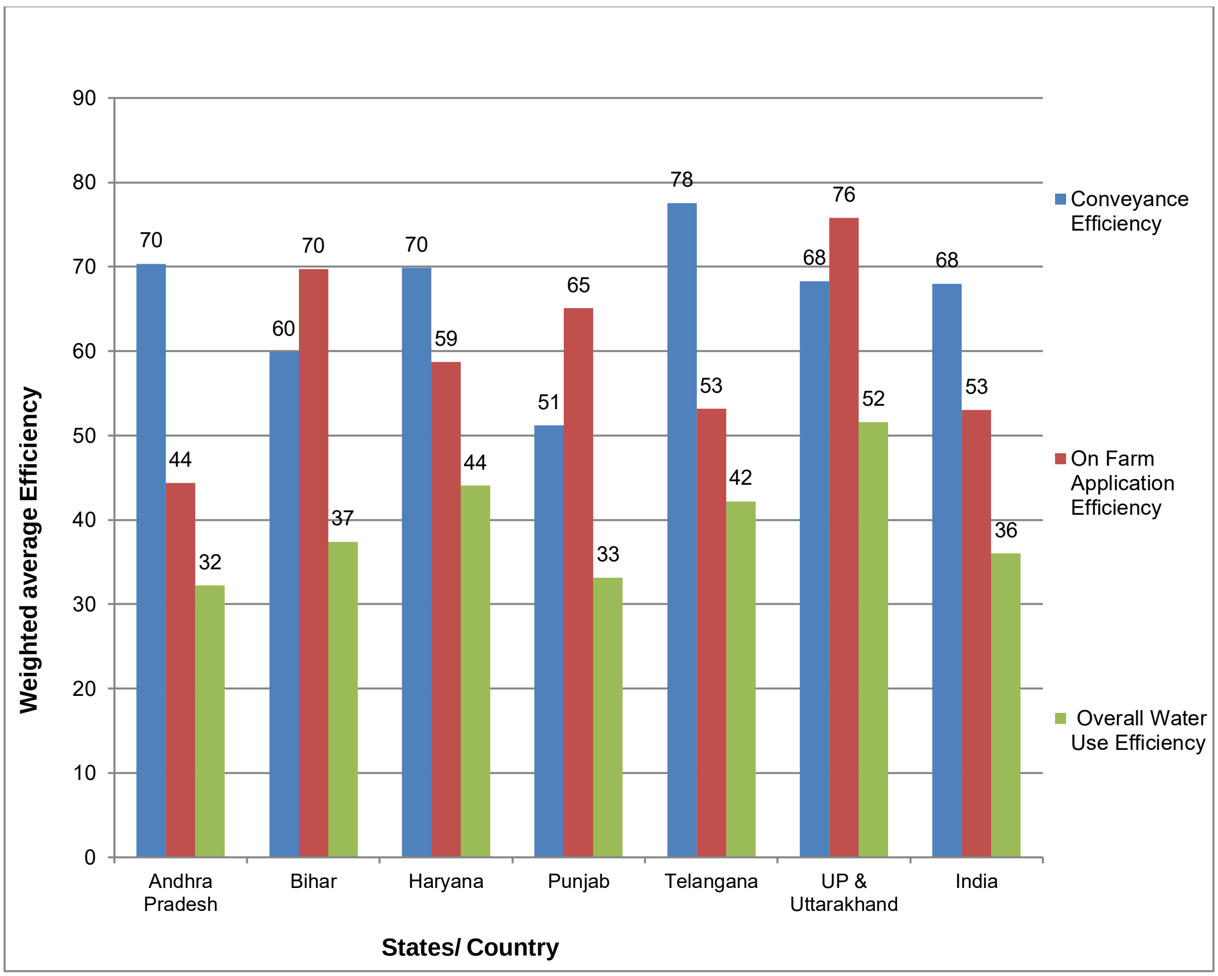

Figure 2. Water Use Efficiency of 35 MMI Projects

2.2 Baseline Studies to assess Water Use Efficiency of MMI projects

National Water Mission (NWM) established under DoWR,RD&GR is one of the eight missions that were identified to meet the challenges of impact of climate change, under the National Action Plan on Climate Change (NAPCC) that was released by the Hon'ble Prime Minister in June'2008. Out of the five goals identified by NWM, one of the major goal is to improve the water use efficiency in all sectors by 20%. Under this goal, Baseline Studies of 22 MMI projects from various parts of the Country have been taken up to evaluate their water use efficiency. Final Reports from these studies are under compilation. However, based on the draft reports prepared for 14 of the projects, the average reservoir efficiency (W_R) has been computed as 87%, average conveyance efficiency (WC) as 74% and average on-farm application efficiency (W_F) as 52%. The average overall water use efficiency for the 14 projects has been studied to be around 34%.

2.3 Overall Irrigation Performance

Assessment of irrigation performance is necessary to determine if the purpose for which the project has been setup is being achieved or not. It is necessary to know if the planned cropping area has received required water supplies at the proper time and the distribution has been equitable, reliable, adequate; if the system components are capable of delivering the required quantity of water, whether each component is being maintained & operated properly, that the canals run as per programme; if the cropping pattern as envisaged at DPR stage (or revised) is being followed and that the yields are appropriate; if investments made by the farmer or by the State are achieving desired rate of returns. Evaluation of irrigation performance helps in identifying the areas with deficiencies so that steps may be taken in time for its improvement. It also helps in improvement of future design of new systems to obtain optimum output from investments.

2.3.1 Evaluation of Irrigation Performance by CWC

CWC's guidelines for Performance Evaluation of irrigation system (August'2002) lays down the procedure for evaluating irrigation performance. The guidelines prescribe certain set of indicators to assess the project performance viz. irrigation performance objectives such as reliable water delivery and its utilization for crop production, indicators for successful water management such as equity, reliability, adequacy, regularity and durability. CWC has carried out the performance evaluation for 28 irrigation projects in the Country by engaging the Water & Land Management Institutes (WALMIs) or other similar institutes of States or renowned technical institutes under overall supervision and guidance of CWC. Some of the major findings from these studies are as listed below:

1. Canal system of most of the projects (in patches) was found to be damaged or silted leading to significant seepage and operational losses in water transit.
2. Lack of proper and timely maintenance of system by the concerned project authorities often due to low budget available for O&M.
3. Inefficient system operation which fails to adjust keeping in view the availability of water and crop water requirements.
4. Lack of flexibility with respect to change in cropping pattern in the event of low water availability.
5. Absence of water measuring structures leading to inequitable supply of water to farmers in the head and tail-end reaches.

6. Excess use of ground water for irrigation due to unreliable and inadequate supply from canal system.
7. No or very low water rates/ irrigation service fee resulting in inadequate funds available for operation & management.
8. Inadequate number of Water User Associations (WUAs) in the project command which can be instrumental in equitable distribution of water as well as for maintenance of water courses, field channels and other agriculture support services.
9. Lack of knowledge among farming community regarding the efficient field water application techniques often leading to using excess waters, chemical fertilizers and pesticides.

2.3.2 Performance Assessment through Remote Sensing

Use of remote sensing techniques for performance assessment has been studied for quite some time now and it has been widely reported and published to be a tool for quick assessment of system performance at expense of relatively far less time and resources in comparison to the conventional system of field survey. In the recent years, Department of Water Resources, RD & GR by engaging different International Agencies has attempted to come up with a protocol for assessment of irrigation performance that is reasonably quick and easy to use in Indian context. These studies are elaborated in further paras.

2.3.2.1 Study by World Bank

The set of indicators adopted by World Bank experts and the Remote Sensing method used to evaluate each of the indicators is as mentioned in Table 1.

Table 1. Performance Indicators Adopted

Long-Term Outcome	Indicators Used	Description	Remote Sensing Method
Equitable and cost-effective access to irrigation water	Equitable Delivery	Estimates the equity in water delivery within the command area at various reaches	Variation of ET- coefficient of variation (CV) for ETa across the space. (Higher the range of variation higher the inequity)
	Reliability of Service	Estimates the sufficiency of water availability for crops' consumption throughout the season	Variation of RET- Coefficient of Variation (CV) of Relative ET. (Higher the range of variation higher the unreliability of water supply)
Productive use of water	Cropping Intensity	No. of crop cycles per agricultural year on the same field	No. of peaks of observed NDVI in a given area
Availability of water within a sustainable hydrological ecosystem	Water Stress-Aridity Index (AI)	Seasonal Aridity Index (AI) measures degree of dryness of the climate at a given location.	Ratio of precipitation to potential evapotranspiration (higher the aridity index, greater the water resources variability which in turn indicates spatial differences in irrigation water requirement)
	Water Shortage	Ability of a system to meet crop water demand - measured as the number of days during the critical growth periods of crops	Relative ET= ratio of Actual ET to Potential ET (Lower the RET, more severe the water shortage in command)

Long-Term Outcome	Indicators Used	Description	Remote Sensing Method
		that crop water demand is met	
	Sustaining Water Balance- Depleted Fraction (DF)	Depleted Fraction (DF) relates the actual evapotranspiration from the area to the sum of all precipitation on this area plus the volume of the irrigation water diverted into the area.	DF= ETa/ Pg+Vd Pg is the gross precipitation over the study area; and Vd is the Volume of diverted water. (higher the ratio the higher the water shortage risk, particularly if the rainfall component in the equation is relatively low)

The above six (06) indictors have been pilot tested on ten MMI projects selected from different agro-climatic regions of India and the results obtained are as mentioned in Table 2.

Table 2. Irrigation Performance of the 10 MMI projects

Sl.	Project Name/ State	Cost-effective and equitable access to irrigation water		Productive Use of Water	Sustained hydrological ecosystem services regime		
		Water consumption uniformity[1]	**Reliability of supply[2]**	**Cropping intensity[3]**	**Water stress (AI)[4]**	**Water shortage[5]**	**Sustained water balance[6]**
1	Shah Nehar Project (HP)	9%	5	2.77	0.67	high	0.39
2	Eastern Ganga Canal (UP)	11%	16	2.94	0.63	low	0.52
3	Boradikarai (Assam)	25%	29	2.93	1.72	low	0.25
4	Upper Kolab (Odisha)	15%	25	1.51	0.93	low	0.32
5	Karjan (Gujarat)	16%	5	2.53	0.32	high	-
6	Upper Bari Doab Canal (Punjab)	10%	52	2.63	0.48	low	0.72
7	Mahi Bajaj Sagar (Rajasthan)	10%	0	2.39	0.39	very high	0.40
8	Priyadarshini Jurala (Telangana)	24%	4	1.95	0.27	high	0.57
9	Upper Wardha (Maharashtra)	18%	7	2.23	0.53	high	0.49
10	Upper Wainganga (MP)	9%	9	2.34	0.59	high	0.45

[1]Refers to Coefficient of Variation (CV) in ET in a crop growing season – higher CV higher diversity of water delivery.

[2]Refers to the number of days RET is above 0.75 during the critical phases of crop growth – lower numbers mean crop water requirements are rarely met.

[3]Number of cropping cycles in an agriculture year –low = 1 to 2;medium> 2; and high is >= 3 per year or crop year.

[4]Aridity Index (AI) defined as rainfall divided by Potential ET.

[5]Refers to the ability of a system to meet water demand of crops.

[6]Refers to Depleted Fraction variable defined as areal ET divided by the sum of precipitation and diverted (delivered) water.

Based on the outcome of the study, following inferences can be drawn regarding the studied 10 projects:

1. Most of the projects depicted high values of CV for ET (=>10%) representing low levels of uniformity in water distribution.
2. Most of the projects did not even have 10 days of reliable water supply.
3. Cropping intensity in almost all the projects was found to be more than 2 which indicate multiple cropping cycles in an agriculture year.
4. In 6 of the projects there was an issue of water shortage which means inadequate water was made available to the fields in comparison to their water requirements.

2.3.2.2 Study under India- European Union Water Partnership (IEWP)

The study under IEWP adopted four (04) indicators viz. (i) Irrigated and Cropped Areas; (ii) Equity/ uniformity; (iii) Adequacy; and (iv) Reliability that are widely used in irrigation performance and have also been described in the above discussed study by World Bank. These indicators have been tested on the three pilot projects and the results obtained are as mentioned in Table 3.

Table 3. Irrigation Performance of 3 Pilot Projects

Project Name/ State	% Command Area cropped/ irrigated (Rabi + Kharif)	Uniformity[1]	Adequacy[2]	Reliability[3]
Gollavagu (Telangana)	115%	0.15	0.80	0.07
Lower Panzara (Maharashtra)	123%	0.37	0.65	0.24
Mahuar (Madhya Pradesh)	134%	0.15	0.84	0.31

[1]Uniformity-Values below 0.10 point to good performance

[2]Adequacy-Values above 0.70 regarded as good performance

[3]Reliability-Values less than 0.10 point to good performance

Based on the outcome of the study, following inferences can be drawn regarding the identified 3 pilot projects:

1. Cropping/ Irrigation intensity for the projects varied from 1.15 to 1.34 which can be categorized as low for the command of an irrigation project.

2. The uniformity/equity performance is low for all the three projects, indicating an uneven distribution of irrigation water over the command area possibly canal tail-ends not receiving water.
3. The seasonal adequacy of the irrigated area is near or above 0.70 indicating fairly adequate amount of water being made available for the crop water requirement.
4. The values of reliability indicator are high suggesting that there are monthly fluctuations in the water supply thus rendering the system unreliable.

3.0 ISSUES IDENTIFIED FROM THE PERFORMANCE ASSESSMENT

Based on the results/ outcome of various studies undertaken so far, as described in above sections, the following major issues regarding irrigation systems could be identified:

1. The average overall Water Use Efficiency of irrigation projects under study has been only 36%. This needs to be significantly improved to meet the future anticipated food & water requirements.
2. Performance of irrigation project deteriorates over time due to lack of proper and timely maintenance of the system. It is a vicious cycle that starts with inadequate maintenance, resulting in poor service that causes limited willingness to pay the water charges by users. This leads to insufficient maintenance funds available for the project which further reduces the operational efficiency of the system.
3. There are significant seepage losses in the conveyance systems primarily from the unlined sections of the canal or from the damaged sections of the lined canal. Also, the vegetation growth in such sections further reduces the conveyance efficiency.
4. There are issues regarding uniformity, adequacy and reliability of water supply from irrigation projects mainly due to inefficient operation of canal system, absence of discharge measuring structures, etc.
5. There is lack of knowledge and awareness among farming community regarding the efficient water application practices, irrigation techniques, cropping pattern based on water availability, etc.

4.0 WAY FORWARD

Given the dilapidated condition of irrigation infrastructure, as also proven by various studies described above, there is an eminent need to focus on the rehabilitation/ modernization of irrigation projects. There can be various possible interventions for modernization of irrigation infrastructure, a few of them categorized into structural and non-structural interventions as following:

4.1 Structural Interventions

1. Lining of the canal system or relining the damaged lined section to reduce seepage losses, reduces vegetation growth and speed up water delivery.
2. Use of Under Ground Pipeline (UGPL) or Piped Distribution Network (PDN) to reduce the conveyance losses and also to avoid the land acquisition issues during the project implementation.
3. Supervisory Control and Data Acquisition (SCADA) system to provide real time data on water levels, gate openings and discharges at key control points in the irrigation system. It improves distribution efficiency since the water supply is remotely controlled to match the demand.

4. Canal top solar power generation to reduce the evaporation losses from the canal, save cost of land for setting up solar plant and help in meeting power demand of the State/ project.
5. Installation of measuring structures (weirs, flumes) at critical points in the canal distribution network to measure the discharge and thus improve the distribution uniformity.
6. Use of micro irrigation techniques such as drip, sprinkler in place of conventional flood irrigation to improve On-Farm Application Efficiency.

4.2 Non-structural Interventions

1. Adopting participatory irrigation management (PIM) practices by setting up Water Users Associations (WUAs) in the command area and transferring the control of irrigation system below the Government controlled outlets to the WUAs. Equitable distribution of irrigation water as well as maintenance of infrastructure can be effectively managed by the concerned WUAs.
2. Improved system of collection of Irrigation Service Fee (ISF) which preferably should be based on volumetric use of water by the users. WUAs can also be engaged in the activity of fee collection.
3. Capacity building of farmers by engaging Krishi Vigyan Kendras (KVKs) to improve various aspects of irrigation farming such as use of efficient water application techniques (application timing, application depth), land levelling, cropping pattern in accordance to the water available for irrigation, conjunctive use of surface and ground water, etc.

5.0 INITIATIVES TOWARDS IMPROVING PERFORMANCE OF IRRIGATION PROJECTS

Some of the initiatives taken by the Union Government and various States of India in this regard are as under:

5.1 Extension, Renovation & Modernization (ERM) projects

Government of India has been providing financial assistance to States for implementing the Major/ Medium ERM projects under its AIBP scheme and now under Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)-AIBP (since 2016). The MMI projects that are facing the issues of lost irrigation potential due to system deficiencies and have been completed/ commissioned atleast 10 years earlier are considered under the ERM projects for improving their performance. These ERM projects are required to either i) implement micro irrigation in atleast 10% of command area; or ii) have enacted Participatory Irrigation Management (PIM) legislation and active working of Water User Associations (WUAs) to maintain the system and collection of water cess; or iii) have envisaged creation of new potential along with restoration of lost potential; or iv) have CAD works completed or taken up and likely to be completed. A fine example of ERM project being implemented as part of prioritized 99 irrigation projects under PMKSY-AIBP is Narayanpur Left Bank Canal (NLBC), Karnataka which also involves implementation of SCADA based canal automation.

Supervisory Control and Data Acquisition (SCADA)- Automation in NLBC

The distribution network under Narayanpur Left Bank Canal (NLBC) since being in operation for about 3 decades, had developed certain deficiencies resulting in lost irrigation potential to an extent of about 105 th.ha. out of the 450 th.ha. of total project command. Also, absence of proper drainage had resulted in water logging and subsequent salinity and alkalinity in the command area to an extent of 37,580 ha. In order to restore the irrigation water supply in the affected command area, the ERM of NLBC project was included under AIBP in Year 2014-15.

Along with the works carried out which targeted desilting/ lining of canal systems, renovation/ strengthening of canal embankment/ canal structures/ gates, etc., significant achievement has been made by the project in implementation of SCADA based canal automation. Some of the benefits achieved from the canal automation are as under:

- The suffering command area of about 10,520 ha under main canal network has been restored.
- First time in the history of NLBC, water could be delivered to the suffering tail end users in an area of about 5,000 ha of Hunasagi Branch Canal (HBC).
- Increased Water Use Efficiency in the network resulting in increased irrigated area.
- Equitable and efficient water distribution in the project command.
- Reduction in water loss & increased crop productivity.
- Water Auditing & Accounting, Online water demand, billing & revenue generation, better service to the water users
- Automatic control of the canal network in the absence of operators.

5.2 Command Area Development and Water Management (CADWM) Works

The Command Area Development and Water Management (CADWM) programme is a component of the PMKSY scheme of Government of India with main focus on the completion of command area development (CAD) works under the 99 identified prioritized projects. The structural interventions proposed under the scheme give thrust on formation of lined field channels, underground pipelines and micro irrigation. The non-structural interventions focus on Participatory Irrigation Management and formation of Water User Associations (WUAs) with the motive of handing over the complete water management activities to the WUAs. The CADWM works covering CCA of 1.50 Mha out of the targeted 4.50 Mha has been completed during 2016-17 to 2020-21 with an expenditure of more than Rs. 5,300 crores (~700 Million USD). Further, 8,890 WUAs have been formed for water management in these projects. On completion, it is expected to result into proper last mile connectivity and significant reduction in the wastage of water during on-farm application, thereby increasing the water use efficiency of the project and the overall irrigation performance.

5.3 Use of Underground Pipelines in Prioritized Projects under PMKSY-AIBP

Use of underground pressurized pipe systems in place of field channels obviates long and costly land acquisition process and reduces evaporation losses which help in increasing water use efficiency. Detailed guidelines on design and use of Piped Irrigation Network were issued by DoWR,RD&GR and Central Water Commission during 2017. Twenty six prioritized projects under PMKSY-AIBP are reported to have planned/utilized piped distribution extensively to cover a total length of 64,137.30 km. In these projects, total area of land acquisition avoided is 12.8 Thousand ha with a direct cost saving of more than Rs. 2,300 crore (~300 Million USD). Other prioritized projects and States are being encouraged to utilize UGPL systems wherever feasible.

5.4 Micro Irrigation

The irrigation by flooding has been the traditional and widely practiced technique in India which leads to an exorbitantly high amount of water being used for crop production. The Micro Irrigation techniques in the form of Drip or Sprinkler results into the on-farm application efficiency upto 90-95%.The Micro Irrigation potential of the country is estimated to be about 69.5 Mha out of which only 12.54 Mha could be achieved so far. Thus, there is a huge potential to be tapped under micro irrigation. The Government of India through its flagship scheme Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) – Per Drop More Crop component has been providing subsidy to the farmers for installing the Drips/ Sprinklers in their farms. Some of the efforts for promoting Micro Irrigation in the Country are discussed below.

5.4.1 Micro Irrigation under Per Drop More Crop (PDMC)

A target of covering 10 Mha agricultural land under Micro Irrigation was kept over the period of 5 years under PDMC component of PMKSY launched in 2015-16. During 2019-20, the Sectoral Group of Secretaries has recommended for covering additional 9.8 Mha under micro irrigation during the five-year period from 2019-20 to 2023-24. The Central and State share for providing micro irrigation equipment to small and marginal farmers is about 55%. The rest of the cost is to be borne by farmers. However, State Governments provide subsidies for most of the cost to be borne by the farmers. Further, Micro Irrigation Fund (MIF) has been established for providing funding by States for such top up. To keep the borrowing under MIF attractive for the State Governments, NABARD shall lend at 3% lower interest rate than the corresponding cost of funds mobilized by NABARD from the market which shall be paid to NABARD by Government of India. During 2015-16 to 2020-21, an area of 5.37 Mha has been brought under MI by providing Central Assistance of Rs. 13,728 crore (~1.80 Billion USD).

5.4.2 Micro Irrigation in Narmada Canal Project

The Narmada Canal Project in the State of Rajasthan is the first project of India to have mandatory pressurized sprinkler irrigation systems. By implementation of micro irrigation in the project command, following benefits have been accrued:

1. Increase in command area from 135 Th. ha with 54% of intensity of irrigation to 246 Th. ha with 61% intensity of irrigation with the same quantity of water available.
2. Number of villages benefitted by irrigation increased from 89 to 233.
3. Number of villages benefitted by drinking water increased from 124 to 1541
4. Income from food production has increased from Rs.534 crore (~71.50 Million USD) to Rs. 1,480 crore (~198.2 Million USD) viz. 177% rise from the year 2013-14.

5.5 Support for Irrigation Modernization Programme (SIMP)

DoWR,RD&GR with technical assistance from Asian Development Bank (ADB) has taken up a new initiative ‘Support for Irrigation Modernization Programme’ (SIMP). The SIMP proposes application of national and international best practices for modernizing Major & Medium Irrigation (MMI) projects in India to improve water use efficiency and crop water productivity. Under the recently concluded Phase-1 of SIMP, 4 MMI projects in the Country have been identified as first batch of projects for preparation of Irrigation Modernization Plans (IMPs). The entire process including the preparation of IMPs, Detailed Project Report (DPRs), detailed designs and final implementation/ project execution is expected to be completed by Phase- 4.

5.6 Other Interventions by Central/ State Governments

1. Government of India proposes to establish a National Bureau of Water Use Efficiency (NBWUE) which will have the overall responsibility of improving water use efficiency across various sectors, namely irrigation, drinking water supply, power generation, industries, cities and all other areas where water is used.
2. DoWR,RD&GR launched the ‘Sahi Fasal’ campaign during Nov’2019 to nudge farmers in the water stressed areas to grow crops which are not water intensive and to use the water more efficiently in such a way that overall food security of the Country is not affected.
3. To reduce the area under paddy cultivation or water intensive crops, the State Government of Haryana launched “Mera Pani Meri Virasat” translated as “My Water, My Heritage”

scheme during 2020. It aimed at replacement of Paddy by Maize, Cotton, Bajra, Pulses, Oilseeds, Horticulture crops in 2,00,000 acres (about 81,000 ha.). The State Government is providing Rs. 7,000 per acre (~230 USD per hectare) to support and incentivize the farmers for making a shift from paddy cultivation to alternate crops. The alternate crops are procured by the government on a Minimum Support Price (MSP).

4. The Government of Madhya Pradesh in the past decade has taken major initiatives in irrigation sector such as emphasis on pre-irrigation maintenance, rehabilitation of old irrigation assets, encouraging pressurized piped distribution system coupled with sprinkler and drip irrigation in upcoming projects, focus on improved management with target setting and continuous measurement and monitoring of system performance through conventional as well as web-based tools. This has resulted into 33% increase in IPC, 272% increase in IPU and 311% increase in food production from 2009-10 to 2016-17 in the State.
5. To address the issue of huge energy consumption (freely available to farmers) for groundwater extraction to meet the irrigation requirement in the State of Punjab (energy-groundwater-agriculture nexus), the State Government launched "Pani Bachao Paise Kamao" programme translated as "Save Water, Earn Money" in June'2018. The programme targets the crisis situation in groundwater depletion and the high power subsidy burden by offering incentives to the farmers to save electricity and water.

6.0 CONCLUSION

From the above discussion, it is seen that judicious use of water in irrigation is of utmost importance for India to be self-sufficient in meeting the food grain requirement of the future. To improve the water use efficiency by 20% as one of the major goals of National Water Mission, it is imperative to assess the various factors that impact water use efficiency and make efforts to contain the shortcomings in all these factors. As accurate determination of water use efficiency highly depends on a sound measurement system in place at every stage of the water distribution, assessment of irrigation performance using various remote sensing techniques provides a quick and holistic evaluation of the irrigation projects. Through various initiatives taken by Central / State Governments along with various agencies it is possible to identify the areas in a project where more efforts need to be concentrated to improve project performance. This facilitates the State Governments to identify existing projects where ERM needs to be carried out. ERM projects have significantly improved the project performance with various example highlighted above.

Micro irrigation is emerging as a strong tool to replace flood irrigation for reducing wastage of water in agriculture. With the increasing popularity of micro irrigation, crops like paddy and sugarcane which were traditionally flood irrigated are now being irrigated by micro irrigation techniques in various drought-prone States.

In addition to the on-going efforts by Government of India discussed in the paper, it is important that modern techniques for improving the performance of irrigation infrastructure are explored. Improving the irrigation performance is vital for India in the present day as supply-side solutions are limited. Judicious demand-side management of water would not only reduce the stress on the existing infrastructure but also help in sustaining the water demand under the availability level while at the same time, lead to increase in agricultural productivity. This goes a long way in bringing about a socio-economic transformation of the region which in turn, contributes to the individual's as well as nation's economic growth.

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IRRIGATION MANAGEMENT REFORMS IN IRAN: LESSONS LEARNED FROM 30 YEARS' EXPERIENCE AND ISSUES FOR THE FUTURE

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ABSTRACT

Irrigation development in Iran has been started since 1961. From 1961 up to now, about 2.5 million hectares modern irrigation networks have been constructed, but are not performed very well. From 1991 Irrigation Management Reforms (IMRs) have been initiated in Iran. It was evidenced; the results of IMRs would be obtained through long-term program and its process. The final results and sustainability of achieved outputs have more dependency on the level of active participation of local communities and governmental body in the process and their trusts to natural and inherent of participation. In this context the active participation in the process follows the assurance of the empowering and institutional capacity building for the construction of further Participation Irrigation Management (PIM). In fact, the new built capacities are the main sources for the principle evolutions and reforms. In this article, through rapid diagnosis (RD), IMRs' constraints have been reviewed and lesson learned obtained from 30 years experiences in Iran. RD indicates that abilities and technical skills of local communities have no priority as a pre-requirements of PIM, but PIM has a high dependency on awareness of the executive team to this approach and their skills to conducting participatory methodology, transparency of national policies and strategies for IMRs, plans for principals evolution on community attitude to new approach, their managing abilities, their trusts to local government, etc. Based on this experience, adaptation of IMT/PIM plan with farmers' perceptions is the key element of success and defined practical bylaws to conduct in actual situation as well. Execution of IMT/PIM in national level needs holistic plan for enhancing the institutional capacities (including: GOs, NGOs, private sectors and local communities) at all level and local managerial empowerments. In this case, empowered local authorities and communities can conduct the management of Irrigation networks, according to the national and local policies through reform process.

However, over the three categories of intensive efforts, a number of policy adjustments on modern Irrigation networks' management have been carried out in Iran. Such efforts are devolving the responsibility of irrigation management to users, but with inapplicable legislations for transferring the authorities. In addition, lack of cconsensus within

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managers, key staffs and related specialists on clear IMT/PIM process were main constraints on IMT/PIM process within the past 30 year's efforts. Last year, the ministry of Energy as a responsible of water recourses management strategy, has an enhanced organizational revolution and focused on local good governance in each watershed borders. This organizational revolution is a one of the started points for decentralisation and transfer of water resource management to the local communities and its formal organization. This paper describes the efforts, constraints, lessons learned and issues for the future.

Key words: Management reforms, strategies, IMT/ PIM, Iran.

INTRODUCTION

We have passed more than half a century efforts on solution of social and management constraints of Irrigation system through irrigation management transfer (IMT) and participatory irrigation management (PIM). Now it is clear to us that farmer participation on Irrigation operation and maintenance is a part of solution of weak performance of the irrigation systems in the world.

Recent researches focusing on reforms of institutions made clear to us that; there are more constraints, which have not had solution in short-term reforms. There fore, proper capacity building in local community and local government for irrigation management transfer requires a long-term plan.

Now the question is: how could be ensured about the sustainability of the reformed irrigation management through transferring the responsibility for O&M to the users, without transferring the sufficient authority and proper capacity building in local level? Of course, in this situation there is no guarantee to increase water efficiency and to improve system performance.

Today in Iran, the government face the challenges of optimizing allocation and utilization of the limited water resources for food production, and rural livelihoods. However, the lack of farmers' participation in the rural affairs was known as one of the reasons for the failure of the irrigation management improvement and development.

Transfer of irrigation management from the government to local level constituent (both in public and private sector) and forming irrigation participatory management, which are involved in organizing the operational and maintenance of irrigation network and administrative as well, needs a long-term program which must be implemented through well defined plan and managed participatory monitoring and evaluation program. Irrigation management reforms, if not implemented well, can lead to further constraints rather than improving irrigation performance (Kendy, et. al. 2003). From 1960s, many practices have been done on participation as one of key element of irrigation improvement, but the paradigm of such an approach could not have been understood as well, and caused a failure to achieve intended result. The First model based on public participation in the 1980s and 1990s were developed (Burkey, 1993; Chambers, 1997; Khanal, 2003). This reform happened through local management by users' organizations, referred to water users' association (Vermillion & Sagardoy, 1999; Meinzen-Dick et al., 2002). IMT is the full or partial transfer of responsibility and authority for the governance, management and financing of irrigation systems from the government to water users' associations. At present, WUAs progressively take over responsibilities and the role of government & irrigation agencies. (Vermillion, 2003; Peter, 2004).

Irrigation development in Iran has been started since 1961, from 1961 up to now, more than 2.5 million hectares modern irrigation networks have been constructed in Iran, but are not yet performed very well. There fore, the system of irrigation networks could not fully provide acceptable water efficiency and productivity. Under three groups of intensive efforts, a number of policy adjustments on water resources have been performed. Further to this, Irrigation management reforms (IMRs) attempts have also been carried out on modern Irrigation networks of Iran.

In this context, various policies, law, regulation and bylaws were approved by the government of Iran through congress, aimed at improving efficiency of water use and its productivity. Such policies are devolving the responsibility of irrigation management to users, without clear legislations for transferring the authorities. In addition, lack of cconsensus within managers, key staffs and related specialists on clear IMT/PIM process were main constraints on IMT/PIM process in Iran.

This paper describes the past three decades of Iranian experience on IMRs and the issues from these exercises, and also reviews the results of IMT/PIM on some pilots of Irrigation networks in Iran.

A SUMMERY OF TRADITIONAL MANAGEMENT REVOLUTIONS ON IRRIGATED AGRICULTURE IN IRAN

Iran is situated in the Middle East region of the South Western Asia and is located between 25° and 40° in the North, 44° and 63° in the East. The climatic conditions are arid and semi-arid, and about two-thirds of the country receives less than 250 mm of precipitation per year. It means that optimised use of water resources is very important in this country.

Regarding water management capacity, Iranian rural communities have a history of accumulated knowledge and experiences. Many years ago, there were no water resource management legislations, but non-written bylaws were accepted by the local communities. Hence, there were enough reasons for farmers to adapt themselves to such bylaws for proper management and efficient water use. In other words, there was no recurrent dilemma between the adaptations of farmers to the local bylaws and social context versus the implementation of the necessary managerial changes imposed by local elders or leaders.

In the other hand, under accepted definitions of local land attribution and water distribution, they had traditional water control and measurement structures. It should be noted here that, there was no considerable conflict or struggle in water distribution and Irrigation systems' maintenance. The farmers could manage their own traditional irrigation system even in water shortage during draught years.

The land reformation in 1962 changed the local social structures of water management and disturbed the traditional cooperation and social cohesion gradually. Governmental organizations and the relevant agencies (GOs) became the active external players in the economical and social life of the villages. Local community became passive in decision-making on main part of their daily activities. Therefore, the gradual weakening of traditional cooperation started in the rural area.

From that time, the government has developed dam construction and Irrigation networks as fast as possible. Development of water resources was an advantage but increased the financial burden on the government. Through this phenomenon, the gap between the authorities responsible for water resource management and the local communities were asked. Further to such planning and development revolutions in water resource management, which emphasized the “top-down” approach, the entire management on irrigation networks tackled to the government, with very limited involvement of the farmers.

Last year, the ministry of Energy as a responsible of water recourses management strategy, has an enhanced organizational revolution, focused on local good governances in each watershed borders. This organizational revolution is a one of the started points for decentralisation and transfer of water resource management to the local communities and its formal organization.

Today the agricultural development could be seen in this country. Out of 37 million hectares of potential area for agriculture, 7.8 million hectares is under irrigation. For this command area, more than 85 billion cubic meters of available water is consumed (more than 70% of supplied water is used for irrigation). It means the efficiency of Irrigation water is not acceptable. This also is the other effect of that phenomenon.

The limited budget for construction, the conflicts between social perceptions and the designed schemes are the main constraints on operation and maintenances on such modern irrigation networks. Hence, continuous increasing financial burden led to inabilities of government to fully provide the operation and maintenance costs and development as well. Moreover, inappropriate management of irrigation has contributed to environmental problems, operational and maintenance constraints caused the social problems and physical deterioration.

Within the two past decades, the migration of rural population to the capital and urbanization has increased the domestic demand for water, which has put enormous pressure on the agriculture sector to reduce its consumption of water. Consequently, the concept of participation became the most important pre-condition for the development plans. However, the farmers’ participation in irrigation management, were not possible, with having understood that the government should take the full authorities for developing of irrigation networks.

From three past decades (1990), Iran initiated the first 5-year plan for the economical, social and cultural development (5YDP). During the two past decades Government also initiated the exercise of management reforms in the modern irrigation systems. This paper describes those management reforms’ exercises on Irrigation networks and water resource development as well.

IRRIGATION MANAGEMENT REFORMS IN IRAN

In early 1990, the first 5-year plan for the economical, social and cultural development (5YDP) is initiated. The general trend of the 5YDP was toward privatization. Irrigation networks development was a part of this plan, but more focused on budget sharing.

According to 5YDP policy, farmers had to pay the majority of Irrigation networks' construction costs.

Strategies of Irrigation Management reforms were not clear and the government was not succeeding in budget sharing policy for irrigation development. In addition, highly bureaucracies' constraints and inadequate maintenance of irrigation systems, led government to divert most of its roles to the private sector. In this context, four groups of events could be classified as follow:

1- PRIVATISATION ON OPERATION OF MODERN IRRIGATION SYSTEMS

In 1991, the government of Iran sought to provide more independence of operation and maintenance practices from public sector, in the management of the irrigation networks, and decided to establish a new private company - Operation and Maintenance (O&M) of Irrigation Networks Company (OMIC) - as an autonomous body under the Ministry of Energy (MOE). In this year a multilateral agreement signed by Jihad-Agriculture Ministry (JAM), Ministry of Energy, Management and Planning Organization (MPO). With the establishment of OMIC, the operation, maintenance and administration of the Irrigation network (INet) should have been transferred to local communities gradually. Each OMIC had concession of performing O&M in each INet.

The New Irrigation management policy enacted in 1991 rationalizes O&M responsibility, which is assigned to three administrative levels (Central / Province/local) with the designation of responsibility. OMIC establishment could be the origin to the Irrigation Management Transfer (IMT) program in Iran.

In early 1992, about 20 OMICs were established to perform following tasks:

- Improving the quality of Operation and Maintenance of Irrigation Networks;
- Increasing water use efficiency;
- Improving the efficiency of water fee collection;
- Reforming irrigation agency structure and reducing the number of employees;
- Improving the water users' structure, and promoting the Irrigation management systematically;
- Enhancing the collaboration and communication between water users and related public sectors;
- Developing the Participatory Irrigation Management.

At the beginning, the ownership of OMICs should be shared between water users (51%) and governmental organizations (49% for JAM & MOE). In reality, this kind of shared stocks was not applicable (e.g. deteriorated Irrigation network and reluctance of the farmers to tackle). Actually, 100% of ownership was shared between GOs.

Although in most of the INet, the quality of O&M and communications improved, government body became bigger and water users' management structures got weaker. In addition, most of the initial objectives were forgotten.

In fact, it could be said: there were acceptable incentives to transfer of responsibilities in the related GOs, but there were no sufficient incentives in local communities, unclear bylaws for transferring the needs' authorities to the water users, insufficient capacities in the local communities, improper structures to perform such responsibilities. Hence, according to this policy water users couldn't initiate and play their own real roles on O&M and administrative affairs as well. Looking for solution on above-mentioned constraints made an extra force to the OMICs to perform the following policies.

2- SUPPORTIVE LAWS AND INTENSIVE POLICIES FOR OPTIMIZED USE OF AGRICULTURAL WATER

The backgrounds of these policies were as following:

- Based on note 19 from the second 5YDP (1995 to 1999), the government approved the related bylaws. This note emphasizes on Optimised Use of Agricultural Water (OUAW). In code 5 of this bylaw, the provincial part of JAM is responsible for establishment of water users' formal groups.
- Increasing the constraints of financial burden, limited employees, budget, insufficient equipments etc. in the Irrigation networks under OMICs management.
- Article 107 from the third 5YDP (2000 to 2004), and Article 17 from the fourth 5YDP (2005 to 2009) emphasize on participation of landowners and water users groups in soil and water resources management.
- Article 35 under chapter five from Agriculture and Natural resources Engineering Authority (ANEA) law (NGO).

Based on the above-mentioned supportive laws and intensive regulations, water users groups should be organized by the provincial parts of JAM with the participation of provincial parts of MOE and Ministry of Cooperation (MOC). In this regard, the Water Users Groups (WUG) as a formal type of Community Based Organization (CBO), but in the form of Cooperatives agency (WUC), presented in the Iranian water resource management literature for the first time in the 1996.

According to code 5 optimised use of agricultural water's law, the JAM should organize the WUG within the maximum two years and introduce the representative of each WUG to the OMIC for each intake of secondary canal, as the water-master who is responsible for water distribution among each tertiary unit water users.

In these intensive regulations and bylaws, main conflicts between two organizations (JAM & MOE) were as follows:

JAM had no formal department or section with defined budget for these kinds of responsibilities. In fact, such constraints were daily problems to MOE, but the responsibilities were on the other side (JAM). There were no defined communications or relations between JAM and WUGs in this regard. In reality, most of the agreements had no guarantee to be performed by JAM or other related GOs. There are many examples in this regard; the first exercise in Ghazvin Irrigation network, which has happened between 1997 and 2002, is a good example.

Qazvin Irrigation Network (QINet), with 50,000 hectares area under cultivation, is located in the northwest of Tehran. Due to above-mentioned atmosphere (article five and constraints in OMIC management), the first IMT exercise is started by OMIC under high supervisory of MOE (at the capital) and on the basis of Consulting Engineering Plan (CEP) in 1997.

Although from the beginning of the Irrigation network operation, farmers had their own managerial structure to distribute water among one another, but for solution of some constraints on O&M, Irrigation management reforms should be performed. According to CEP, the secondary unit L2 selected as a pilot. 12 WUCs and one Federation were constituted within the two years efforts. These WUCs and its Federation have survived only for three years.

The results of Rapid Diagnosis (RD) on IMT in QINet, by Iranian PIM working group (IRPIM) in 2002, are as follows:

A) Main constraints

- lack of consensus within managers, key staffs and related specialists on IMT/PIM process.
- Lack of clarity and unwell defined shared responsibilities to the majorities of the farmers;
- Transfer of responsibility to the WUCs with insufficient authorities;
- Financial Burden on WUCs with undefined budget sources;
- Insufficient capacity of WUCs to carry out such transferred responsibilities;
- Poor legality to carry out the responsibilities;
- Related local governments left the WUCs, just after establishment without any co-ordination among them;

Finally, the majority of water users, which have to play the main roles, had no sufficient incentives.

B) Lessons learned

- In transitional period of time, more expenses will result to the farmers to carry out the new responsibilities, looking for the solutions of such constraints should be paid before WUCs' constitution;
- After the WUCs were constituted, the local GOs (JAM&MOC) should pay continuous attentions to WUCs with respect to authorized them;
- WUCs should be supported (not as a charity, not as a subsidy, but as a real means of participatory) and strengthened for a transitional time segment, while it is necessary;
- IMT has its own defined process, which should be experienced.

In this regard, the local department of JAM was not interested in WUCs' constitution. Particularly, they had different model in their hands (Rural producers Cooperative = RPC) and trying the new model was not interested to them (e.g. Novin Dez RPC in Khozestan province, Mahidasht RPC in Tehran province).

In fact, such intensive regulations couldn't have any positive impact (except Lesson learned) and acceptable performance until 1999.

Due to suggestion of MOE, In order to find the solutions of above-mentioned constraints, the OUAW bylaw's committee at two levels (capital and provinces) was established in 1999. This committee includes the representatives of MOE, JAM and MOC.

The committee conducted several meetings and had several outputs. The first bylaw for instruction of WUCs was the most important one. This bylaw was approved by MOC and was ordered to Provinces to establish the WUCs as fast as possible.

According to this bylaw, many WUCs were established, but most of them never succeeded. The main constraints were lack of sufficient incentives, lack of defined position for WUCs on decision-making and WUCs' institutional weakness to play their roles.

In beside of WUCs, the RPC also couldn't find own institutional capacity to perform OUAW law and plays basic roles in 1990 decade. Gillan experience is a good example in this regard.

In early 2002, the OUAW bylaw's committee suggested to Gillan's OMIC transfers a part of O&M responsibilities (e.g. fee collection) to Rural Consumers Cooperatives (RCC) and RPC. Negative impacts were their performance within the five years.

In some Irrigation networks, establishment of the WUCs was not on their plans. Those OMICs choose the different strategy and performed the improved traditional management. Varamin Irrigation network experience was a good example in the late 1990, in this regard.

From the beginning of the Varamin Irrigation network (VINet) operation, farmers had their own management model. In this model, the representatives of WUGs in each secondary unit were responsible for operation and maintenance of lower part of main canals with developed cooperation. During the drought years and water shortage such cooperation enhanced. According to article five from OUAW's bylaw, such cooperation enhanced up to villages (includes several secondary units) and participation grew up faster. At the moment, Secondary units CW and CNZ covers 14 and 50 villages respectively and 300 representatives have been reduced to 150 representatives.

The results of Rapid Diagnosis (RD) on IMT in VINet, which has been done by Iranian PIM working group (IRPIM) in 2003, are as follows:

A) Main constraints

- Lack of legal recognition of WUGs by provincial and local government.

B) Lesson learned

- Adaptation of IMT plan with farmers' perceptions is the key element of success. In this case, it could be thought about farmers' financial supports to the IMT.
- In some irrigation networks, without any external force on WUC' constitution, capacity and power of the WUGs have been enhanced for the management reforms. Those reforms were compatible to the administrative legislations and social conditions with less constraint.

However, in VINet, WUGs could delegate the responsibility for the O&M of secondary units to main canal, depending on their abilities and willingness to participate in each of them. Given the positive experience and clear benefits of good water management practices seen over the past years, the OMIC and the WUGs are prepared and ready for whatever the new legal arrangements will bring (e.g. WUCs), and hopefully the outcome will lead to a further improvements to the objectives of OUAW.

In addition, there are many examples in this regard, which have been related to Iranian civilization on water management. For example; from the beginning of operation of Mojen Irrigation network, the WUGs have equipped themselves for management of Irrigation network. It means, they had never thought about sharing responsibilities with external players. They developed their indigenous knowledge and improved their institutional capacities. In early 1960, they constituted the MOjen Agricultural and Irrigation Ltd to better management of Irrigation system. At the moment, they perform all related duty of O&M and administrative affairs as well, without any governmental support and intervention.

With regard to Article 107 from the third 5YDP (2000 to 2005), landowners and water users groups' participation on soil and water resources management became highlighted again. Preparing a bylaw for this article, the OUAW bylaw's committee conducted several meeting and the first draft of participatory plan was its output in 1992, but it wan't approved by MPO. However, with holding those meetings it had some more positive impact on decision- makers in MOE and JAM.

In addition, In the third 5YDP Article 35 under chapter five from Agriculture and Natural resources Engineering Authority (ANEA) law (NGO), more attention was paid on soci-economical formal structured farmers' business groups and marketing.

According to Article 35, JAM had a mission for maximum 6 months to provide the constitution of agricultural activities. In the introductory draft, WUA has a position at the core of all different agricultural constitutions. At the moment, this model for agricultural constitutions activities is under the test in Gazvin Irrigation Network.

As a summery of this chapter of efforts, it could be said that there were a lot of efforts on agricultural constitutions and valuable lessons learned came up from such efforts, but the strategies haven't been approved yet. Most of the articles in the third and the fourth 5YDP, not yet officially implemented since the required bylaws have not been prepared giving important constitutional discrepancies regarding agricultural water use and management. Additionally, a set of reforms on the National Water Law and natural resources are waiting for approval by Congress.

3- SUPPORTIVE LAWS FOR FINANCIAL SUPPORT (NATIONAL & INTERNATIONAL)

In the first 5YDP (1990-1994), budgets' sharing was one of the strict requirements for construction of irrigation networks. Funds for construction of tertiary units must be shared among farmers. However the policies were in transition and some costs were still being covered by government funds. Under those regulations, the primary financial responsibility for irrigation construction of the main and secondary canals and infrastructures for the scheme rests with the central government.

According to the first 5YDP, country's development should have increasing rate. There were not enough budgets for such development. Using financial supports was necessary and loan from internal and external banks was a part of the first 5YDP policies.

Although, when we talk about IMT, we refer to management of O&M and administrative in constructed systems under the GOs' management, so budgets' sharing for construction of irrigation networks has a different story. But this story has influences on IMT in IRAN. Supportive laws and Financial Supports are described at below:

- National supportive laws for irrigation development

Before the second 5YDP, there was an agreement between the government side and agricultural bank about special loan (credit) for soil and water development with low interest rate. Note 3 was one of the yearly budget's law for this purpose (e.g. using loan for traditional canal lining). These agreements have been improved from the second to the fourth 5YDP as following:

In note 26 from the yearly budget's law (1994-95), farmers were responsible to provide 75% budget of irrigation networks construction.

Note 76 from the second 5YDP (1995-99) with improved the government's share up to 30%. Article 106 from the third 5YDP (2000-2004) and article 17 from the fourth 5YDP (2005-2009) extended credit's facilities from the past decade.

Individual farmers have used these financial facilities from 1994. Beside of individual farmers, constitutional arrangement was required in some main and secondary canals. Three types of arrangements carried out in this regard are as the following:

- Under responsibility of Villages' Islamic Council (VIC) such required arrangements for collecting shared budget were approved (in most of the developed irrigation canal).
- New Short-term constitution, including Sar-Abbyaran (traditional canal operators) or/and communities' leader was established for such required arrangements (e.g. Karaj irrigation network).
- New permanent WUCs or RPC were established (e.g. Sufie-chai network). 17 WUCs have been established before 1995 in East-Azarbaiejan province.

Most of designed canal construction and objectives (the above three categories) were fulfilled, but with regard to development of PIM, some constraints could be recognised as follows:

- Lack of clear legal position for WUCs in decision- making on water resource management;
- Improper GOs' constitutions for administrative and technical support of WUCs;
- Lack of clear strategies for enhancing the WUCs' capacities and empowering.

The IRPIM surveys indicate that uncompleted process of PIM's development is the main causes for most of the constraints.

- International financial support for Irrigation improvement

Irrigation improvement project was a joint project between government of Iran and World Bank (WB). This project was on MOE Irrigation program in 1991, but one of the main conditions to gain the WB financial support was to understand about legal position of WUGs in the Irrigation systems. The project has been approved and started in four irrigation networks; (Moghan; (MINet), Behbahan; (BINet), Tajan; and Zarriene-rud), in 2000.

Improvement of MINet and BINet has been performed and Tajan is under construction.

The project performance was good in physical improvements (MINet and BINet), but not so good in Irrigation Management Improvement (IMI).

In Moghan, According to intensive study and field works, the secondary canal DC6 selected as a better condition for IMT pilot. In coordination of local government (MOE and JAM), more efforts performed and Pishro's WUC was constituted for IMT on 1000-hectare command area in late 2001. WUC received enough technical and financial support from local government sectors (JAM and MOE), but such supports never could sustain the Pishro's WUC.

The results of Rapid Diagnosis (RD) on IMT in MINet, which has been done by Iranian PIM working group (IRPIM) in 2003, are as follows:

A) Main constraints

- There was no incentive for IMT in both side (local governments and communities);
- In the local government and communities' points of view, the physical improvement objectives were well defined, but the IMT not;
- There was no agreement in order to indicate the shared responsibilities.

B) Lessons learned

In Moghan, the close coordination between local authorities, technical and financial supports to the WUC had a picture of the successful story, but this cooperation was not sustained for a long time. In the short time (a few months), the conflict between cooperative board and the members put an end on another IMT exercise. This exercise indicates; if there is not any common incentive between GOs and water users with regard to IMT, IMT will not be successful.

4- Organizational revolution

Last year, the ministry of Energy as a responsible of water recourses management strategy, has an enhanced organizational revolution and focused on local good governance in each watershed borders. This organizational revolution is a one of the started points for decentralization and transfer of water resource management to the local communities and its formal organization**.** We will hear more successful events on local water resources management.

SUMMERY OF IRRIGATION MANAGEMENT REFORMS IN IRAN

A) Constraints

- Transfer of responsibility to the WUCs with insufficient authorities;
- Insufficient capacity of WUCs to carry out such transferred responsibilities;
- Unclearness and unwell defined shared responsibilities to the majorities of the farmers;
- Lack of defined common incentives between GOs and water users with regard to IMT;
- Lack of clear legal position for WUCs in decision- making on water resource management;
- Lack of practical bylaws, which could be conducted in actual situation.

B) Lessons learned

- In transitional time segment, more expenses will result to the farmers to carry out the new responsibilities, looking for the solutions of such constraints should be paid before WUCs' constitution;
- Adaptation of IMT plan with farmers' perceptions is the key element of success. In this case, it could be thought about farmers' financial supports to the IMT;
- IMT out of PIM and its whole process has no meaning in the reality. It means the WUCs' constitution is one of the tools for PIM, but is not PIM's objective;
- In IMT/PIM process, if there is not any defined common incentive between GOs and water users, IMT/PIM will not be successful.

C) Conclusion

- IMT is a part of water resource management reforms in Iran.
- Four parallel efforts have been conducted for IMT/ PIM in Iran and have more positive impacts on front line of decision-makers' attitude and have more lessons learned for future plan;

- Past two-decade experiences have a few positive impacts on local communities;
- There are four classified constituents in the PIM process (by author). These constituents are as follows:
  - Participatory Diagnosis;
  - Participatory planning and implementing;
  - Up scaling and out scaling;
  - Participatory Monitoring and evaluation.

Only a part of the second one has been taken into the considerations by the IMT/PIM executive teams in Iran.

- There is more institutional capacity for IMT in private sectors (OMICs & RPCs & RCCs), but need institutional revision;
- Now a days, decision-makers pay more attention to upgrade IMT/PIM in the GOs body and the private sectors;
- IRNCID has been the main scientific entity for IMT/PIM in Iran (through establishment of IRNPIM working group, publications, conferences, workshops, fieldworks reports, written and verbal communication, and meeting with front line of decision-makers, NGOs, CBOs and individual farmers etc.).

ISSUES FOR THE FUTURE

Execution of PIM in national level needs holistic plan for enhancing the institutional capacities (including: GOs, NGOs, private sectors and local communities) at all levels and local managerial empowerments. In this regard, we need more investments.

Carrying out the PIM process, as well as, combining the traditional and modern form of participatory management needs special knowledge and specific skills. Due to insufficient professional experts and lack of proper methodology adaptable to different social-physical characteristics of Irrigation networks, conducting any plan of PIM in Iran needs a mid-term program in some pilots. Let's say 10 pilots for 10 different social- physical characteristics to test the methodology development.

Such mid-term pilots test could help us develop the methodology compatible to Iran conditions, out-scaling and up-scaling through participatory monitoring and evaluation (PME) for long-term plan.

With this suggestion, the opportunities will be provided for: Increasing the common incentives and trusts between stakeholders; enhancing required capacities; time left for learning by doings and training of trainers for long-term program; sufficient times for clear definition and designing the accepted plan of PIM (objectives, strategies, levels, how? where? Whom? etc.). Of course, in reality, awareness and continuous communication between different stakeholders (related GOs and local communities) could be enhanced through Participatory Monitoring and Evaluation in the short-term plan as well.

Finally, the last efforts are institutional evolution within the three main stakeholders' organizations (including: GOs, NGOs, private sectors and local communities), focused on local water governance.

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INTERNATIONAL COMMISSION ON IRRIGATION AND DRAINAGE

24th ICID Congress

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SYMPOSIUM

Theme: Integrated Approaches to Irrigation Management in the Future

Iraq Country Paper

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1.0 Introduction

Iraq is located in western Asia, bordered to the north by Turkey, to the east by Iran, to the southeast by Kuwait, to the south by Saudi Arabia, to the southwest by Jordan, and to the west by Syria, between latitudes 29° and 38° North and longitudes 39° and 49° East. It's total area is (437,072) km2. Iraq takes its water from the Tigris and Euphrates rivers. Both rivers originate in the Armenian mountains of Turkey and are fed by melting of winter snows. The Tigris River flows for a distance of 1415 km inside Iraqi territory and 1160 km from the Euphrates before they meet near Qurna to form Shatt al-Arab River.

2.0 Current status of National irrigation sector

Irrigation water is used in summer for rice, corn, dates, vegetables and fruits crops grown in central and southern Iraq, and in winter for wheat and barley crops. The arable area is (28) million donum, and the area that can be irrigated is (12.75) million donum. The areas cultivated with irrigation for the winter season (except Kurdistan region) for the years (2017, 2018, 2019 and 2020), amounted to (5,399), (4,652), (5,962), (7,415) million donum, respectively. In summer season, they amounted to (1,445), (613),(2,161) (2,142) million donum for the above years. The rainfed cultivated areas (except for the Kurdistan region) amounted to (1,762, 1,815, 1,888, 2,141) million dunum for above years. The Ministry of Water Resources seeks to involve local farmers in the management of irrigation operations by encouraging the establishment of water user associations, which its number at the present time are 179 associations, with a work area estimated at 1.424 million donum. The Ministry of Water Resources also seeks to switch from an open irrigation system to a closed irrigation system, by delivering water from the source to the irrigated fields through pipes, because of its great importance in controlling water distributions, reducing abuses of water quotas, increasing donum yields, as well as increasing the efficiency of transferring water from source to the agricultural units.

3.0 Future investment in irrigation infrastructure modernization and management

There is no current tendency at the Ministry of Water Resources to use investment in modernizing or managing irrigation infrastructure because this will burden the Iraqi farmers, but there is a tendency to manage the irrigation infrastructure in partnership with the stakeholders of the farmers, according to the instructions No. (1) of 2014 for the water user associations to organize this relationship. This step is one of the most important steps of institutional reform in the irrigation sector modernization program in Iraq in order to achieve justice, efficiency and reliability in the operation and maintenance of the system.

4.0 National factors affecting irrigation management, including water policy, institutions, and capacities

The national factors that affect irrigation management depend on set of laws that have been enacted since the establishment of the modern Iraqi government at the beginning of the twentieth century, which regulate water policy, institutions and capacities such as setting water quotas, water distribution and supervision, leasing and organizing agricultural lands, maintenance of irrigation and drainage networks, and drilling wells, water resource conservation and environmental protection and improvement systems. This set of laws is included in the (Irrigation and Water Resources Legislation Set / Laws and Regulations for the year 2013) and work is underway to update it at the present time until 2021.

5.0 Prospective areas for future management and Recommendations

The main outputs that emerged from the strategic study of water resources and lands in Iraq (2015-2035), which Iraq adopted to draw up its water policy until 2035, are the inevitable areas for the future management of water resources for the next fifteen years as a result of the steady decline in water revenues, which recommended the following:

Water security: obtaining natural resources, obtaining good resources, rehabilitating, rehabilitating dams, improving natural resources, rehabilitating, rehabilitating, treating rivers, reducing leakage, preparing water and raising its efficiency.

Food security: The study recommended the cultivation of agricultural crops that suit the natural conditions of all regions of the country, as it has been divided into eight agro-climatic regions to help approve the appropriate agricultural practices for each region and determine the crop type for it. It also recommended expanding the use of pressurized irrigation systems (sprinkler and drip irrigation).) In addition to using closed irrigation pipe systems and taking the necessary measures to gradually raise the efficiency of irrigation.

Energy Security: The study recommended the establishment of new dams inside Iraq for the purpose of generating hydroelectric power during the fifteen years.

Environmental security: The study recommended working in two directions to ensure environmental security, the first of which is Iraq's endeavor to conclude agreements with upstream countries to achieve agreements that guarantee the quality of water reaching Iraq's borders in shared rivers. The second is represented by taking necessary actions to improve the environment inside Iraq through the separation of untreated sewage water and drainage water from fresh water resources by expanding the capacity of sewage treatment, linking the drainage network to the public main drain or evaporation lakes, establishing green belts, and reviving the marshes. The study also recommended preserve the discharges of Tigris River in specific quantities to ensure that the salt tide does not reach Shatt al-Arab region from the Gulf.

Investment Strategies: The strategic study determined the total sums needed to be allocated to implement the mentioned plan for the next fifteen years and distributed over their respective sectors.

24th ICID Congress

(October 3 - 10, 2022 in Adelaide, Australia)

Theme: Integrated Approaches to Irrigation and Drainage Management in the Future

(Country Report)

1. Introduction

About 70% of Japan's land area is mountainous or hilly, while plains cover 25% of the land area and farmland 13.5% of the land area. In addition, Japan is a long and narrow island nation with a series of mountain ranges in the 2-3,000-meter range in the center of the islands. The rivers are short, and their gradients are quite steep, so rainwater runs off to the sea in a short time.

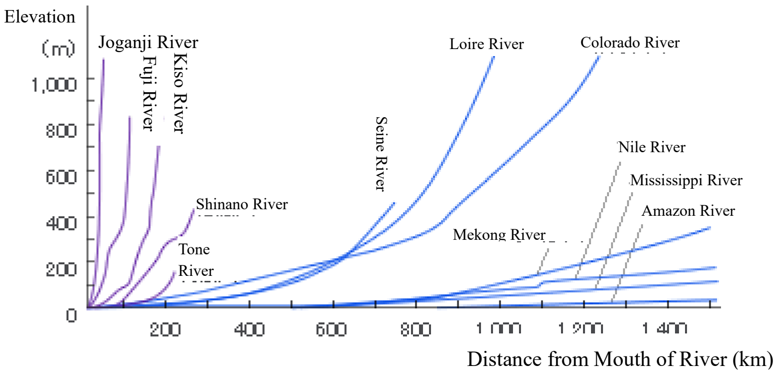


Fig.1 Longitudinal Sections of Rivers

Japan belongs to the Asian monsoon region and receives about twice as much rainfall per year as the world average, but rainfall is concentrated during the rainy and typhoon seasons, and there may be long stretches of time with almost no rain in the summer. Due to such natural conditions, rainfall alone is insufficient to supply water for rice paddies, and so for more than 2,000 years, Japan has been cultivating paddy rice with utilizing river water or reservoirs, and therefore developing irrigation facilities such as irrigation and drainage canals.

At present, about 7,600 large-scale core facilities such as dams, water intake weirs, and irrigation and drainage pump stations have been installed to supply irrigation water for about 2.9 million hectares of farmland, or two-thirds of the nation's 4.37 million hectares (in 2020), and to protect the farmland and surrounding areas, including urban areas, from flood damage. There are 400,000 km of irrigation and drainage canals, including 50,000 km of core canals, which is equivalent to ten times the circumference of the earth.

In Japan, a consensus-building system based on a sense of community has been formed in each village through a long history of rice cultivation, and a water management order has been established with the village as the basic unit for irrigation and drainage management. Since the Meiji era (beginning in 1868), the legal status of water management organizations has been gradually established alongside the development of various legal systems related to irrigation and drainage projects. Mergers of water management organizations have been promoted along with irrigation development projects for the integration of small-scale irrigation and drainage facilities in the modern era. Currently, irrigation and drainage management in Japan is carried out by groups of benefitting farmers, called Land Improvement Districts (LIDs), for each water use system.

As industrialization and urbanization have progressed, the percentage of farmers has declined even in rural areas, and farmland is being converted to other uses, making it difficult to maintain and manage irrigation and drainage facilities. Furthermore, as the birthrate and population decline, and as the number of farmers is expected to decrease further in the future, there is a risk that the conservation and management of local resources such as farmland and agricultural water will not be sufficiently carried out. In addition, irrigation and drainage facilities are aging, and there is growing pressure to preserve and upgrade them. Furthermore, Japan has been experiencing a number of large-scale natural disasters, such as earthquakes and floods, and the amount of damage to agriculture, forestry, and fisheries is on the rise.

Under such circumstances for agriculture and rural communities, in order to develop agriculture in a sustainable manner, it is necessary to make agriculture a growth industry, improve productivity, and increase income from agriculture and in rural communities, while taking advantage of the characteristics of each region. It is also necessary to revitalize rural areas by raising incomes, creating employment opportunities, and improving infrastructure for daily life so that diverse peoples can continue to live in rural areas. Furthermore, as natural disasters are expected to become more frequent and severe in the future, it is necessary to improve the resilience and strengthen the sustainability of infrastructure that sustains agricultural production and rural life.

In addition to these efforts, it is necessary to strengthen the farmer-led Japanese water management system, maintain and improve the conservation of the land and harmony with the environment, and contribute to the sustainable development of agriculture and the revitalization of rural areas.

2. Current Status of the Irrigation and Drainage Sector in Japan

2.1. Land Improvement Projects (LIPs)

The construction and maintenance of irrigation and drainage facilities is carried out in accordance with the Land Improvement Act (LIA) (1949). In principle, LIPs under the

LIA must be implemented with the initiative and application of farmers and the consent of at least two-thirds of the beneficiary farmers in the implementation area. The project implementing bodies for LIPs are the national government, prefectures, and organizations (LIDs, unions of LIDs municipalities, agricultural cooperatives, etc.), and the implementing body is determined in consideration of the scale of the project, technical difficulty, etc. Project costs are borne by the national government, prefectures, municipalities, and benefitting farmers as appropriate in accordance with the type and scale of project.

2.2. Land Improvement Districts (LIDs)

An LID is an organization of farmers stipulated in the LIA that implements LIPs and is established with the approval of the prefectural governor. Since the enactment of the LIA, water management organizations based on traditional villages and organizations based on old laws have been given legal status as LIDs alongside the implementation of LIPs, and now there are 4,325 LIDs with an area of 2,481,000 hectares and 3,460,000 members.

An LID shall establish its articles of incorporation and appoint directors (five or more) and auditors (two or more) as officers. The term of office for officers is four years, and they are elected by the members of the LID. General assemblies are established as the voting bodies for LIDs, and a general assembly of representatives may be held in place of a general assembly for LIDs with more than 200 members.

An LID may levy and collect money, labor, etc. from its members in order to cover the expenses of its projects. The management and operation of LIDs are under the supervision of the prefectural governor, and regular inspections are carried out.

2.3. The Japanese Water Management System

As for the management of the facilities developed by LIPs, in cases where the facilities are developed by organization-managed LIPs, the implementation bodies, such as the LID, shall manage the facilities. Additionally, in many cases operations are entrusted to an LID even if the facility is developed under a state-run or prefectural LIP and the prefecture or municipality is responsible for maintenance and management of the facility. For this reason, core irrigation and drainage facilities such as dams, water intake weirs, irrigation and drainage pump stations, and main irrigation and drainage canals are also in effect managed by the LIDs. Furthermore, among the facilities developed by the national government, those facilities that are large-scale, highly public, and require special technical considerations for their management are, as an exception, under the direct management of the national government.

Water management methods of the LIDs include the operation of gates in main canals and irrigation and drainage pump stations by the LIDs themselves and water management in terminal canals by subordinate organizations, such as villages and water utilization associations, and water is distributed to rice paddies according to a rotation plan. The costs for the operation and maintenance of the facilities are collected as a levy based on the area of farmland and other factors. Safety inspections, grass cutting, and soil raising for canals are often carried out in the form of the provision of labor by farmers and non-farmers in the village concerned.

Japan's agriculture and rural areas not only provide a stable supply of food, but also have the following core multifaceted functions in terms of land and environmental conservation.

① Groundwater Recharge: Much of the rainwater temporarily stored in rice paddies percolates underground and recharges the groundwater, which is then used for urban water supplies in downstream areas.

② Flood Prevention: Floods are controlled by temporarily storing rainwater using rice paddy levees.

③ Biodiversity: Continuously managed farmlands, canals, reservoirs, and woodlands form a secondary nature, and rich ecosystems are preserved.

④ Formation of a Beautiful Landscape: The crops growing in the fields, the houses of farmers, and the surrounding waterfront and woodlands all come together to form a beautiful rural landscape.

⑤ Inheritance of Tradition and Culture: Many of the traditional events and festivals originate in rice farming and have been handed down for many years in countryside.

3. Future Investment in the Modernization and Management of Irrigation Facilities

The asset value, based on reconstruction costs, of the 7,600 dams, intake weirs and other large-scale core irrigation and drainage facilities and the 50,000 km of core irrigation and drainage canals is about 20 trillion yen. However, many of these facilities are aging, and 80% of the irrigation and drainage pump stations and 40% of the irrigation and drainage canals have exceeded their standard service life.

On the other hand, Japan is experiencing a declining birthrate, an aging society, and a declining population, which has led to a decrease in the number of farmers and a decline in the functioning of rural communities.

In addition, large-scale disasters are becoming more frequent and severe, and there is a need to make the land more resilient through disaster prevention and mitigation measures.

The Basic Plan for Food, Agriculture and Rural Areas based on the Food, Agriculture and Rural Areas Basic Act aims to improve the food self-sufficiency rate and establish food security through the combination of industrial policies to promote the growth of agriculture and food industries and regional policies to promote the maintenance and enhancement of the multifunctionality of agriculture, while enhancing the sustainability of food, agriculture, and agricultural communities.

Furthermore, the Ministry of Agriculture, Forestry and Fisheries has formulated the "Strategy for Sustainable Food Systems, MeaDRI" (2021) to strengthen the response to SDGs and global warming and will promote innovations, such as in carbon neutrality, to reduce environmental burden in the medium to long term.

For the development of irrigation and drainage facilities and farmland, the goals and projects for development are set in the long-term plan for land improvement for a period of five years in accordance with the Land Improvement Act, and development is currently being implemented in a planned manner.

It is necessary to, in this way, carry out the systematic renewal and development of irrigation and drainage facilities based on the long-term plan for land improvement, while responding to policy issues and changes in social, economic, and natural conditions.

4. Factors Influencing the Management of Irrigation and Drainage Facilities, Including Water Policy, Organization, and Capacity

4.1. Aging of Irrigation and Drainage Facilities

With the aging of core irrigation and drainage facilities, it is necessary to extend the service life of these facilities and reduce their lifecycle costs by systematically and efficiently repairing and rehabilitating them through facility inspections, functional diagnoses, and monitoring while utilizing robots, such as drones, and ICT.

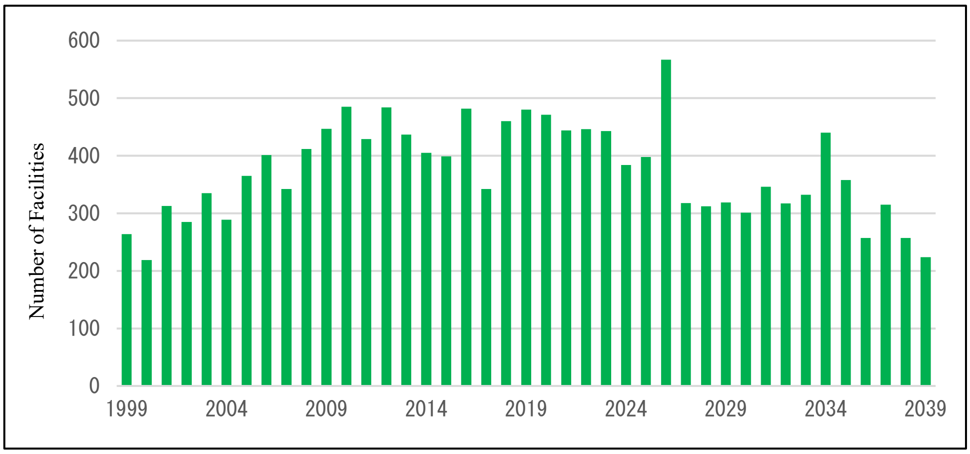


Fig.2 Number of Core Agricultural Water Utilization Facilities Exceeding Their Service Life (as of March 2019)

4.2. Decline in the Number of Farmers Due to a Declining Birthrate, an Aging Society, and a Declining Population

The number of core agricultural workers in 2020 will be 1,361,000, a decrease of 1,039,000 (43.3%) from 2000. Similarly, Japanese society has continued to age, with the percentage of people aged 65 and over increasing to 69.7% and the average age of the population reaching 67.8 years.

Table1 Number of Core Agricultural Workers

Item	2000	2010	2020
Number of Core Agricultural Workers (Thousands)	2,400	2,051	1,361
Number of Persons Aged 65 and Over (Thousands) (%)	1,228 (51.2)	1,253 (61.1)	949 (69.7)
Number of Persons Aged 75 and Over (Thousands) (%)	306 (12.7)	589 (28.7)	432 (31.7)
Average Age (Years)	62.2	66.1	67.8

4.3. Increasing Frequency and Severity of Large-Scale Natural Disasters

In recent years, large-scale natural disasters have become more frequent and more severe. In particular, in 2018 the agriculture, forestry, and fishing industries suffered extensive damage totaling 628.2 billion yen nationwide, making it the year with the greatest agriculture, forestry, and fisheries-related damage when one excludes 2011, the year of the Great East Japan Earthquake.

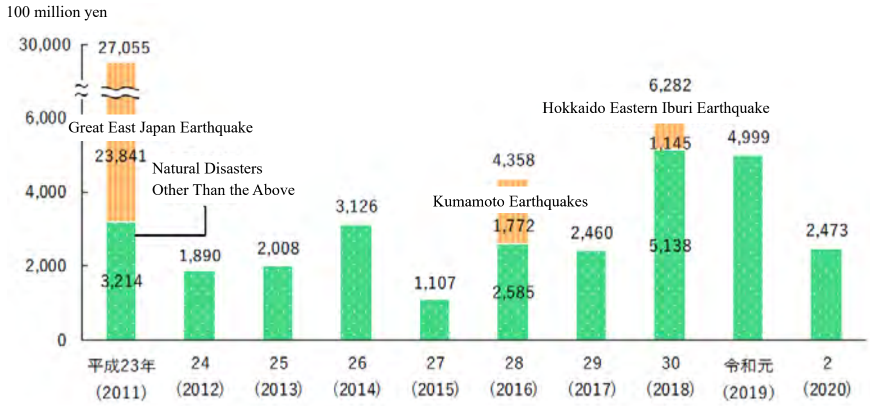


Fig.3 Agriculture, Forestry, and Fisheries Damage from Natural Disasters (2011-2020)

5. Prospects for Irrigation and Drainage Facilities Management in the Future

5.1. Responding to a Declining Birthrate, an Aging Society, and a Declining Population

5.1.1. Advanced Water Management for Smart Agriculture

As the population declines in Japan, there are concerns about the decline in industrial competitiveness and the vitality of local communities, the government has proposed "Society 5.0," a sophisticated fusion of cyberspace and physical space. Society 5.0 will connect all people and things and share various knowledge and information through the IoT and aims to overcome the issues that modern society is facing, such as a declining birthrate, an aging society, and the depopulation of rural areas through AI and automation technologies. In the agricultural sector as well, there are expectations for “smart agriculture” to be a new form of agriculture that utilizes advanced technologies such as robots, AI, and IoT to improve productivity and solve labor shortages. In response to these changes, it is necessary to promote the advanced management of irrigation and drainage facilities, such as in labor-saving water management at the terminal field level through the introduction of automatic water supplies and drainage taps, the automation of water distribution operations in main and branch canal networks using IoT, and daily inspections of facilities, functional diagnoses, and monitoring of facilities with reduced labor requirements through the use of drones and ICT.

In addition, in order to turn agriculture into a growth industry and to improve the income from agriculture for rural communities, farmland is being accumulated into larger plots to reduce production costs and rice paddies are being converted to enable multi-crop farming for the introduction of highly profitable crops. In order to realize such a shift in farming systems and an expansion of scale, it is necessary to improve the flexibility of water use at the field level, and a shift to demand-driven water management systems through pipelines and the use of ICT is required.

5.1.2. Strengthening Rural Community Functions and Demonstrating the Multifunctionality of Agriculture

The management of terminal irrigation and drainage facilities has been carried out by rural communities and water utilization associations, which are subordinate organizations of the LIDs, but the aging of society, the decline in population, and the increase in the number of non-farmers have led to a decline in the functions of rural communities, which may hinder the management of terminal facilities. Therefore, it is necessary to maintain and enhance the multifunctionality of agriculture, which is manifested through the continuance of agriculture, while maintaining and enhancing rural community functions.

In order to cope with this situation, direct payments are provided for conservation and management activities for farmland and terminal facilities, environmental conservation activities in rural areas, and life-extension activities such as the repair of terminal facilities, all of which are carried out by rural communities. In addition, the revision of the Land Improvement Act has allowed non-farmers to be involved in the maintenance and management of agricultural drainage facilities.

Irrigation canals in particular not only supply water for agriculture but also perform a variety of functions such as creating spaces for water-lovers and ecosystem conservation spaces and supplying water for firefighting and snow removal. It is desirable to gain the understanding and cooperation of local residents and others concerning the management of irrigation facilities through the recognition and active use of these functions.

In addition, rural areas have diverse value such as in their beautiful scenery, diverse ecosystems, and culture and traditional events related to agriculture, which attracts urban residents and creates a flow of people returning to the countryside. Rediscovering the diverse value in rural areas and revitalizing rural communities is also important for the sound management of terminal irrigation and drainage facilities. As part of these efforts, it is also necessary to utilize the World Heritage Irrigation Structures scheme, disseminate information on the historical and cultural value of irrigation and drainage facilities, and tie this to the revitalization of rural areas.

5.2. Making the Land More Resilient

5.2.1. Strengthening the Functions of Drainage Facilities

In recent years, large-scale natural disasters have become more frequent and more severe. In particular, rainfall patterns are changing, and the number of rainfall events with an extremely high intensity per unit time is increasing.

In Japan, low-lying areas in the lower reaches of major rivers have been developed as rice paddy farming areas, and with the economic development after World War II, urban areas have formed and expanded in these areas. For this reason, drainage facilities that have been developed for agricultural use also play an important role in protecting these urban areas from flood damage. In order to protect farmland and urban areas in watersheds from increasingly severe rainfall disasters, it is necessary to strengthen the functions of drainage pump stations and drainage canals along with the systematic renewal of facilities.

5.2.2. Utilizing the Rainwater Storage Function of Rice Paddies

In addition, in recent years, a "rice paddy dam" initiative has been implemented to effectively use the rainwater storage capacity of rice paddies by installing weirs and drainage outlets to control runoff in order to control the rapid rise of rivers and water levels during heavy rains and reduce the risk of flooding in downstream areas.

5.2.3. Efforts to Strengthen the Flood Control Function of Agricultural Dams

Efforts to change the operation of agricultural dams in order to contribute to flood control in watersheds have also been initiated. Efforts have begun to lower the water level of agricultural dams in advance when heavy rains are expected and to use these pockets as flood control capacity.

5.2.4. Conservation and Management of Agricultural Reservoirs

In recent years, due to increasingly severe rainfall disasters, there have been cases where small and medium-sized agricultural reservoirs have collapsed, causing damage to urban areas in downstream areas. Agricultural reservoirs have been constructed in various parts of the country since ancient times as rice paddy agriculture spread, and it is said that there are about 154,000 reservoirs nationwide. However, there are still a considerable number of facilities that are not properly managed, such as those that have become decrepit, those with uncertain construction dates and unclear rights, and those that have fallen into disuse and disrepair due to the conversion of agricultural land. Some of these reservoirs have houses and other structures downstream that could be severely damaged if they were to collapse.

In order to improve this situation, the “Act on the Management and Conservation of

Agricultural Reservoirs" was enacted (2019) with the aim of securing water for agriculture by properly identifying information on agricultural reservoirs and taking necessary measures for their proper management and conservation, protecting the lives and properties of the people from floods and other disasters caused by the collapse of agricultural reservoirs, and thereby contributing to the sustainable development of agriculture and the conservation of the land. Disaster prevention measures are currently being implemented based on a selection of target agricultural reservoirs.

In addition, the "Act on Special Measures for the Promotion of Disaster Prevention Work for Disaster Prevention Priority Agricultural Reservoirs" (2020) has been enacted, with the act requiring the central government to establish basic guidelines and prefectures to formulate promotion plans, as well as requiring the intensive and systematic implementation of deterioration assessments, earthquake and heavy rainfall resistance assessments, and disaster prevention work for reservoirs.

5.2.5. Earthquake Resistance Measures for Core Irrigation and Drainage Facilities

About 30% of the nation's core irrigation and drainage facilities are located within the estimated damage range of a major earthquake along the Nankai Trough, which is expected to occur with a probability of about 70% within the next 30 years. Therefore, it is necessary to systematically implement earthquake resistance measures for irrigation and drainage facilities in preparation for the occurrence of a Nankai Trough earthquake or an earthquake directly below the Tokyo metropolitan area.

5.3. Global Warming Countermeasures

The "Strategy for Sustainable Food Systems, MeaDRI" (2021) has been formulated in order to strengthen the response to SDGs and global warming, and this strategy is set to promote innovations, such as in carbon neutrality, to reduce environmental burden in the medium to long term.

The strategy sets 2050 as the target year and is set to sequentially promote the social implementation (by 2030) of technologies that are already being developed, the development of innovative technologies and production systems (by 2040), and the social implementation of developed technologies (by 2050). In the irrigation sector, the strategy aims to introduce renewable energy sources, such as small-scale hydroelectric power generation, in order to achieve carbon neutrality by 2050.

Most of the irrigation and drainage systems in Japan irrigate agricultural land by utilizing the potential energy of the country's abundant rainfall, which is twice the annual average for the world, as it flows down naturally from watersheds and through rivers. It is a highly sustainable system with an extremely low environmental impact. The active introduction of small-scale hydroelectric power facilities into this process to generate the equivalent energy needed to operate irrigation and drainage pump stations will greatly contribute to the realization of the strategy’s goals.

At present, 159 of the country’s core irrigation and drainage facilities are equipped with small-scale hydroelectric power generation facilities, which generate enough electricity to meet the annual power consumption of about 74,000 households.

5.4. Contributing to SDGs

Among the 17 SDGs, irrigation and drainage projects contribute to:

① “2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture,” from the perspective of improving adaptive capacity for droughts and floods and ensuring a system for the sustainable production of food

② “6. Ensure availability and sustainable management of water and sanitation for all,” from the perspective of vastly improving water use efficiency and supporting and strengthening the participation of local communities in improving the management of water related sectors

③ “9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation,” from the perspective of developing high quality, reliable, sustainable, and resilient infrastructure

5.5. Information Management

An "Agricultural Water Use Stock Information Database" will be established to centrally manage information on irrigation and drainage facilities developed through national projects and will be used for efficient maintenance and management, the appropriate selection of construction methods, and repairs and renewals, thereby promoting strategic conservation and management.

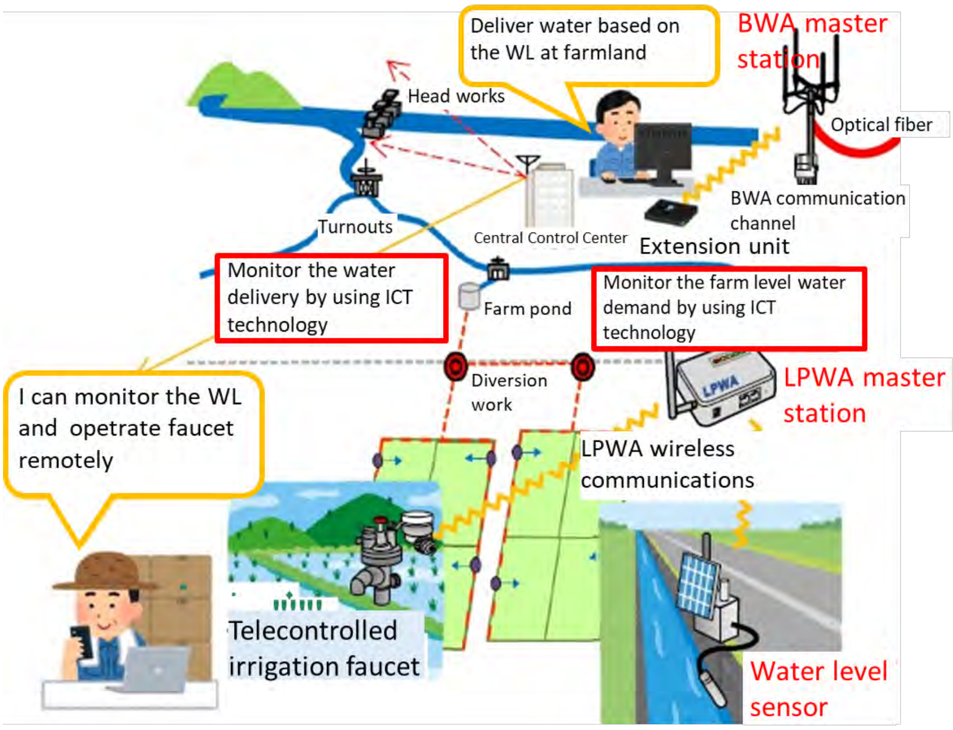
In addition, the Agricultural Data Collaboration Platform (WAGRI), with data linkage, sharing, and provision functions, has been established (2019) in order to create an environment where farmers can use data to increase productivity and improve management, and information on the shape of farmland divisions and the status of irrigation and drainage facility maintenance is also provided. Linking and utilizing such information with meteorological and crop cultivation information is expected to lead to increased productivity, improved quality for agricultural products, and strategic management development among pioneering farmers.

6. Policies and Proposals

6.1. Good Practices

6.1.1. Advanced Water Management for Smart Agriculture (Related to 5.1.1.)

The concept of advanced water management system utilizing ICT is shown as follows.



※ BWA: Broadband Wireless Access
LPWA:Low Power Wide Area

Fig.4 Water Management Using ICT (Concept)

6.1.2. Strengthening Multifunctionality (Related to 5.1.2.)

The Seiwa Resource Conservation Utilization Council (Taki Town, Mie Prefecture) is actively using Taki Town's Tachibai irrigation facilities not only for agriculture but also as a space for water-lovers, as a place for learning, and as water for firefighting.

Fig.5 Utilization as a space for water lovers

Fig.6 Learning about the Tachibai irrigation water: “Waterway research”

Fig.7 Firefighting training using Tachibai Irrigation Water

In Shinjo City (Yamagata Prefecture), irrigation water is passed through the city during heavy snowfalls (January and February) to be used for snow removal.

Fig.8 Snow removal into the canal

Fig.9 Pouring water for snow removal into the canal

The Shirakawa River Midstream Land Improvement District Council (Ozu-machi and Kikuyo-machi, Kumamoto Prefecture) has been working on flooding rotated rice paddies in Ozu-machi and Kikuyo-machi for fixed periods of time in order to recharge the groundwater in downstream areas, and Kumamoto City, which is downstream and benefits from such work, and companies that use the groundwater are providing subsidies for this effort. In addition, agricultural products cultivated in the flooded paddy fields are sold in Kumamoto City under the brand name "Mizu no Megumi" (the bounty of water).

Fig.10 Paddy ridges and rice paddies that contribute to groundwater recharge

6.1.3. **World Heritage Irrigation Structures (Related to 5.1.2.)**

Sayama Pond is the oldest of Japan's World Heritage Irrigation Structures, having been put into service around 616 CE. The total irrigated area is 297 hectares, and there are 1,744 farmers who benefit from the pond. Sayama Pond is part of the Nishiyoke River (Yamato River System) watershed.

Fig.11 Panoramic view of Sayama Pond

Manno Lake is the second oldest of Japan's World Heritage Irrigation Structures, having been put into service in 701 CE. The total irrigated area is 3,003 hectares, and there are 7,452 farmers who benefit from the lake. The lake is part of the Kanakura River (Kanakura River System) and the Doki River (Doki River System) watersheds.

Fig.12 Panoramic view of Manno Lake

6.1.4. **Rice Paddy Dam Initiative (Related to 5.2.2.)**

Niigata Prefecture has many low-lying areas, which have long been subject to flooding and other damage. For this reason, the former village of Kamihayashi (Murakami City) in Niigata Prefecture started a "rice paddy dam" initiative by calling on villages from the downstream areas to the upstream areas. The “rice paddy dam” initiative is expanding more and more by the year, and in fiscal year 2020, about 16,000 hectares of rice paddies in 17 municipalities in Niigata Prefecture were covered by the initiative.

Fig.13 Rice paddies to prevent and reduce flooding

6.1.5. **Small-Scale Hydroelectric Power Generation (Related to 5.3.)**

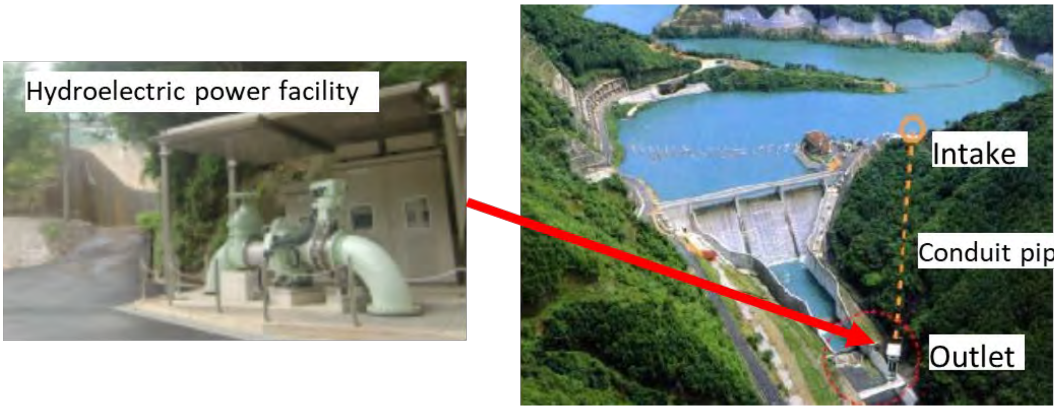


Fig.14 Nanki irrigation district (small-scale hydroelectric power generation at a dam)

Fig.15 Left bank area of the Osaka River (small-scale hydroelectric power generation using the drop of the canal)

6.2. Long-Term Plan for Land Improvement

The following is a summary of the plans outlined in the "Long-Term Plan for Land Improvement (FY 2021-2025)".

6.2.1. **Making Agriculture a Growth Industry by Strengthening Production Infrastructure**

In order to strengthen agricultural competitiveness through the reduction of production costs by accumulating and consolidating farmland for core farmers and promoting smart agriculture, the following measures will be taken: (1) the promotion of infrastructure development such as in large-scale farmland consolidation to accumulate and consolidate farmland for core farmers and to reduce production costs; (2) the promotion of smart agriculture such as by making large plots of rice paddies, adjusting plots and making slopes more gradual for cropland and orchards, autonomous agricultural machinery, ICT water management that can respond to diversified water demands, etc. In addition, in order to strengthen the profitability of production areas through shifting to highly profitable crops and establishing brands for production areas, (3) there will also be a promotion of multi-use rice paddies and the conversion of rice paddies to crop lands, and there will be a shift to highly profitable crops such as vegetables and fruit trees, in addition to the promotion of exports in cooperation with related measures.

6.2.2. Development of Agricultural Communities Where Diverse People Can Continue to Live

In order to secure income and employment opportunities, establish conditions for people to continue to live in rural areas, and create new movements and vitality to support rural communities, the following measures will be taken: (1) the promotion of work reform in rural communities that will realize diverse ways of working through labor saving via the development of facilities, as well as the integrated promotion of infrastructure development and the development of production and sales facilities that take advantage of the characteristics of regions such as the low uplands; (2) the promotion of a return to the countryside and the creation and expansion of related populations through remote work and stays in rural areas by securing the infrastructure for life in rural areas, such as with energy-saving sewerage facilities for rural villages, the strengthening of village roads, and the improvement of the information and communication environment; (3) the strengthening of the organizational management system by involving diverse human resources such as from the LIDs that support agriculture and rural communities.

6.2.3. Making Agriculture and Rural Areas More Resilient

In order to make agriculture and rural areas more resilient by developing drainage facilities and reservoirs to cope with increasingly frequent and severe disasters, and by implementing watershed flood control, the following measures will be taken: (1) assessments of the deterioration of priority agricultural reservoirs for disaster prevention, assessments of earthquake and heavy rainfall resistance, and the intensive and systematic promotion of disaster prevention works; (2) earthquake resistance measures for irrigation and drainage facilities, development and repair of drainage pump stations, the strengthening of the flood control function of existing dams, and the promotion of flood control in watersheds through the use of rice paddies (rice paddy dams). In addition, in order to promote strategic conservation management and flexible water management for irrigation and drainage facilities using new technologies such as ICT, (3) there will be a promotion of development that enables flexible water management and thorough strategic conservation management through the systematic and efficient repair and renewal of facilities that also utilize robots and ICT.

6.3. Proposals

6.3.1. **Support for Agricultural Infrastructure Development in Asia and Africa**

In Asia and Africa, in addition to securing food to feed populations that are continuing to grow, the challenges are to strengthen agricultural competitiveness by reducing production costs and to increase income by improving quality and shifting to highly profitable crops. In addition, several Asian countries are facing rapid aging and declining birthrates in the future, and it is expected that the structure of agriculture and agricultural communities will change along with this. It is believed that Japan's agricultural infrastructure development technologies such as for construction, rehabilitation and maintenance, will be highly applicable and effective in handling these issues. In addition, it is important to give consideration to the introduction of green technology in support. It is believed that this will enable the development of infrastructures that address the issues at hand while also contributing to the resolution of global issues, such as environmental and disaster prevention issues.

6.3.2. **Support for the Sustainable Rural Development**

Across Japan, there are many examples of rural areas that have been developed starting with land improvement projects. In light of these cases, it is necessary to establish a model for rural development that utilizes local resources such as heritage irrigation structures. It is also important to establish a form of infrastructure development for overseas rural areas that provides a package of rural development measures, such as environmentally friendly measures, disaster prevention and mitigation measures, energy conservation, and the utilization of local resources.

6.3.3. **Dissemination of Information on the Sustainability of Rice Paddy Agriculture**

The Strategy for Sustainable Food Systems, MeaDRI, which aims to combine improved productivity and sustainability for the food, agriculture, forestry, and fishing industries through innovation, includes as one of its specific initiatives the development of rice paddy management technology that reduces methane generation. In Japan, research has been conducted on a technique called "mid-summer drainage" for rice paddies, and the results have shown that extending the mid-summer drying period can reduce methane emissions from rice paddies. Japan is expected to take the lead in disseminating the results of these studies and evidence of the multifunctionality of rice paddies at international conferences and other events and to advocate for the sustainability of rice paddy agriculture in the Asian monsoon region. Furthermore, it is believed that Japan will be able to contribute to solving global issues such as global warming.

(End)

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Annex-2

24th ICID Congress

03-10 October 2022, Adelaide, South Australia

SYMPOSIUM

06 October 2022

Theme: Integrated Approaches to Irrigation Management in the Future

Republic of Korea Country Papers

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1.0 Introduction

Natural disasters due to climate change occur worldwide, and the resulting damage is enormous. Korea is no exception to this trend. Because of rapid climate change, changes in precipitation amount, and increases in regional precipitation variation, the possibility of natural disasters such as drought and floods in Korea continues to increase locally every year. The recently released sixth report of the Intergovernmental Panel on Climate Change predicted that catastrophes such as heat waves, droughts, and floods would increase more than expected in the next 10 years.

To limit global warming, which causes climate change, the Republic of Korea declared the 2050 net-zero target (October 28, 2020) and announced a carbon-neutral strategy (Dec. 7, 2020). The Carbon Neutral Framework Act was recently promulgated (Jan. 24, 2021); the Ministry of Agriculture and Food and Rural Affairs established and promoted the 2050 carbon-neutral priority management task in agriculture.

At the same time, significant changes have occurred in the field of agricultural water management. Agricultural water management in Korea has long been empirical and manpower oriented. However, recently, a major shift has been underway toward the so-called integrated water-management policy paradigm.

The Ministry of Environment was given the responsibility of integrated water quantity and water quality management in accordance with the Framework Act on Water Management in 2018 and the Government Organization Act. As the future keystone for agricultural water management, integrated water management began to receive considerable attention, and a number of debates ensued on whether agriculture in fields would be affected by this policy.

From the perspective of the Korea Rural Community Corporation (KRC), which supplies and manages agricultural water stably in response to various disasters such as droughts and floods, it is necessary to understand the contents of the National Water Management Basic Plan, integrated water management policy, and statutory top-level water management plan. It can be seen that mid- to long-term plans for future agricultural water management, new projects, and budget investments can be carried out efficiently and rationally.

By examining the current state of Korea's agricultural water management and the fields that are changing according to the integrated water management policy, we will examine the direction the integrated approach takes in Korea's future agricultural water management.

2.0 Current status of National irrigation sectors

2.1 Current status of agricultural water management system

The total water consumption in Korea is 37.2 billion tons, and the agricultural water consumption is 15.2 billion tons, accounting for 41% of the total; evidently, agricultural water occupies the largest portion of the total water consumption. Accordingly, agricultural water management is important.

<Table 1. Current status of water consumption in Korea>

Division	Usage (100 million tons)	Usage (%)	
		Out of total usage	Domestic·Industrial·Agricultural water
Sum	372	100	
◦ Domestic·Industrial·Rural water	251	67	100
- Domestic water	76	20	30
- Industrial water	23	6	8
- Agricultural water	152	41	62
◦ River maintenance water	121	33	

However, agricultural water management in Korea has long been a manpower-centered and empirical operation. This is because the type of the management system, such as dual management and complex management system, for agricultural water supply and demand is linked to the diversification of supply facilities.

The special characteristics related to the agricultural water management in Korea are as follows:

- It is sensitive to climate change due to the direct use of rainwater.
- It monitors a variety of water sources such as reservoirs, pumping stations, weirs, and supply facilities such as ground water supply and irrigation canals.
- It mostly relies on experienced management by the district manager.
- It is complicated due to regional differences in farming seasons.

Further, despite technological innovation, the agricultural sector is inevitably dependent on labor because of its weak infrastructure. As it is a labor-intensive business, approximately 60% of the maintenance cost is required for labor and expenses.

As mentioned above, agricultural water quantity, water quality, and disaster management are linked to agricultural factors such as food and farmland. In addition, agricultural production infrastructure facilities are managed by dividing them into the jurisdiction of the local government and KRC. Specifically, 58% of the total rice paddy area is managed by the KRC, and 17% of the fields are paddy fields without irrigation facilities.

The KRC is trying to unify agricultural water management to improve the dual management of agricultural water and the quality of water supply services in local government management areas. Currently, ownership and management rights of irrigation facilities of area 200,000 m^3 or more, previously managed by the local government, are transferred to the KRC.

2.2 Current status of agricultural production infrastructure

There are 75,000 agricultural production facilities in total; the limitation with their maintenance is that most of them are small and scattered throughout the country.

Considering area per irrigation facility, 33.2 hectares and 3.5 hectares of irrigation facilities are managed by KRC and local government, respectively, and approximately 50% of the water canals for supplying agricultural water are still installed as earth canals; hence, they are vulnerable to water loss and natural disasters.

<Table 2. Current status of agricultural infrastructure by management entity

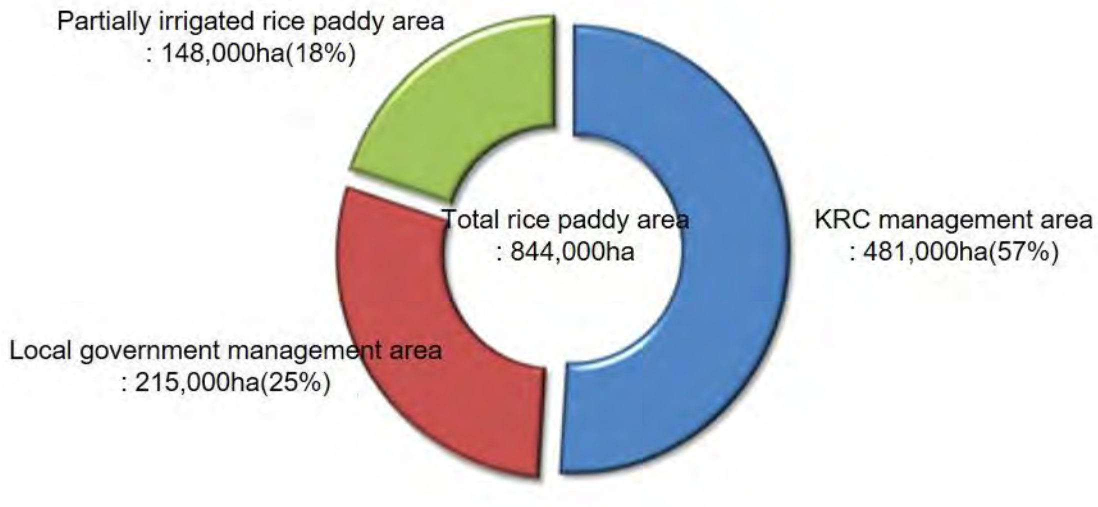
Division	Sum	KRC management	Municipality management
Total	189,888 (100%)	101,452 (100%)	88,436 (100%)
Earth irrigation canal	98,808 (52.0%)	50,657 (49.9%)	48,151 (54.4%)
Structuralization	91,080 (48.0%)	50,795 (50.1%)	40,285 (45.6%)

In addition, 17% (143,000 hectares) of the total paddy area of 830,000 hectares is paddy fields without water treatment facilities, and 62% (520,000 hectares) are paddies equipped with water treatment facilities that do not interfere with the supply of agricultural water even during a 10-year drought. It is vulnerable to local drought responses that occur every year.

Moreover, approximately 60% of the 75,000 irrigation facilities are over 30 years old (96% of the reservoirs), making them vulnerable to natural disasters such as floods due to their age.

Specifically, 108,000 hectares out of 303,000 hectares (36%) of habitually flooded agricultural land are susceptible to flood damage in the event of a heavy rain.

<Figure 1. Status of rice paddy management in Korea >



The foundation of Korea has been established with a water-use system centered on paddy agriculture; however, the infrastructure for the production of field crops is insufficient. Field crop production is a small-scale and multi-item micro industry; therefore, their productivity is weak and they are highly dependent on foreign countries.

* Food self-sufficiency rates (2020) are given as follows: total, 45.8%; rice, 92.8%; wheat, 0.8%; corn, 3.6%; soybean, 30.4; and root and tuber crop, 105.6%.

The demand for field crops has increased owing to the recent oversupply of rice and increased interest in items besides rice; however, only 17% (126,000 hectares) of the total area of 740,000 hectares are equipped to produce such crops.

2.3 Budget Status for Agricultural Water Sector

Here, we look at the budget for the agricultural water sector.

- The budget for agricultural water development has decreased by 7.4% per year for the last 5 years (2016–2020).

* Fields: Rural water development, large-scale agricultural development, drainage improvement, the Saemangeum internal development.

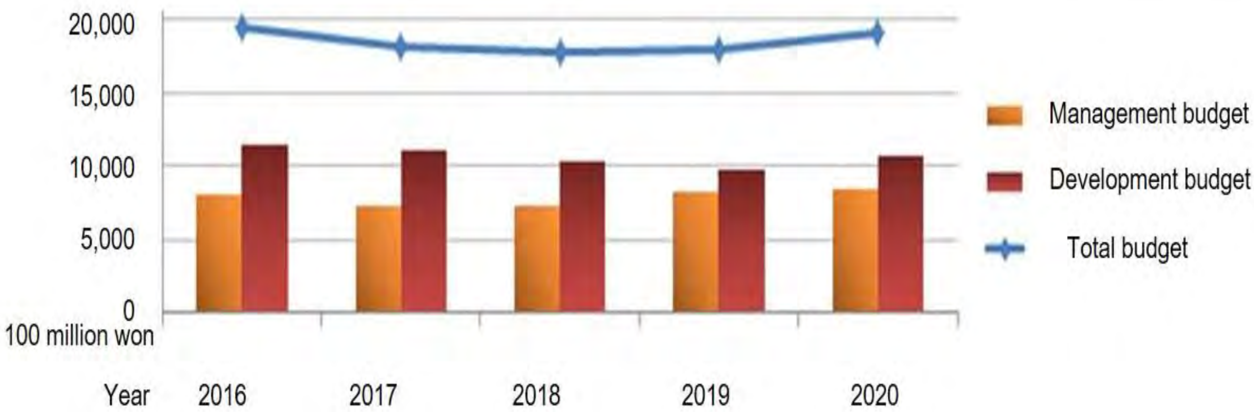
* Budget: decreased by 84.6 billion won, from 1.14 trillion won in 2016 to 1.06 trillion won in 2020.

- The budget for agricultural water management has increased by 4.9% annually for the last 5 years (2016–2020).

* Fields: Maintenance, irrigation facilities, seawall remodeling, and water management.

* Budget: Increased by 39 billion won, from 803.2 billion won in 2016 to 842.2 billion won in 2020.

<Figure 2. Status of rural water development and maintenance budgets by year >



Hence, for agricultural water in Korea, budget investment has shifted from the development of agricultural water use facilities to their repair, reinforcement, and efficient management.

3.0 Future investment in irrigation infrastructure modernization and management

Future investment in the modernization and management of facilities related to agricultural water can be divided and considered as follows:

3.1 Securing safe water function

a) Abundant Agricultural Water Supply

- Conversion of water canal to irrigation canal: convert open canals to irrigation canals step by step and install measuring systems to control water quantity and reduce water shortage.
  * Target: conversion of 22,940 km of water canal to irrigation canal, measurement system installation (10 trillion won, ~2040)
- Raising water capacities: By expanding the size of existing reservoirs, improve disaster preparedness in response to climate change and multi-purpose water supplies, such as environmental water and agricultural water.
  * Target: 54 reservoirs (810 billion won, ~2030)
- Assessment of agricultural water supply: Review the possibility of securing surplus water and operating a drought forecasting warning system.
  * Target: agricultural drought diagnosis in district 73 (3.7 billion won, ~2025) and establishment of a drought warning system in 167 locations (5 billion won, ~2025)

b) Safe flood control field without flood damage
- Expansion of pre-discharge facilities: Install water-level control devices in reservoirs of 200,000 tons or more capacity to strengthen their ability to respond to floods in advance.
  * Target: 681 reservoirs (204.8 billion won, ~2025)
- Comprehensive maintenance of the drainage site: install emergency power and automatic dust removal equipment at the drainage site and establish an unmanned drainage pump operation system to be operated when the disaster risk level is reached.
  * Target: emergency power supply, 658 locations; vibration damper, 547 locations; unmanned operation, 323 locations (1,184.1 billion won, 2030)

c) Safety management of facilities that can withstand major disasters
- Reconstruction of old reservoirs: Completely rebuild old reservoirs, instead of partially repairing them, for fundamental disaster prevention.
  * Target: reservoirs with a total storage capacity of 300,000 tons or 208 reservoirs with a height of 15 m or more (1,459.4 billion won, ~2030)
- Disaster prevention measures: Preemptively prevent disasters by early detection of abnormal signs, such as reservoir collapse and water-leakage warning signals, through the installation of Internet of Things (IoT)-based measuring instruments.
  * Target: 2,637 reservoirs (209.1 billion won, ~2036)
- Expansion of emergency action plan (EAP): expand the EAP established for small, non-statutory reservoirs in locations where their safety is not well studied, for complete disaster prevention.
  * Target: 540 reservoirs with more than 200,000 tons capacity and high-risk dependence (18.9 billion won, ~2025)
- Establishment of an agricultural water management system
- Expansion of smart farms linked to the 4th industry
- Development and management of locally customized water sources

3.2 Enhancing the value of water quality and groundwater resources

a) Securing clean agricultural water and groundwater

- Preventive water quality management: expand water quality measurement automation to advance water quality monitoring and build a real-time detection system for groundwater.

* Target: 1,708 surface water and groundwater quality measurement networks (111.8 billion won, 2030)

- Agricultural discharge water management: Create a healthy water environment through managing water quality throughout the entire process from water supply to water discharge and protecting the water from nonpoint pollution sources.

* Target: water quality improvement and agricultural wastewater management in reservoirs and freshwater lakes (514.8 billion won, ~2036)

- Expansion of groundwater use: install underground dams to solve water shortages in agricultural complexes and secure water for fisheries and aquaculture farms through saltwater surveys.

* Target: 389 business destinations (619.2 billion won, ~2031)

b) Creation of new and renewable energy

- Expand renewable energy business: expand renewable energy business using agricultural infrastructure.

* Target: construction of a 1.4 GW power plant (2,070.8 billion won, ~2025)

3.3 Smart Water Management Technology Innovation

a) Water management technology standardization and big data establishment

- Big data establishment: improve the accuracy of data on beneficiary area, supply amount, and facility status, through a detailed investigation of district boundaries and drainage system and reconstruction of spatial data.

* Target: 481,000 hectares of water supply area, 102,000 km of drainage waterway (47 billion won, ~2023).

- Information provision platform: develop an integrated information system that provides real-time information (using measurement information) on low yield, water quality, and operation of the drainage plant.

* Target: 4,155 locations including reservoirs and drainage stations (10 billion won, ~2023)

- Maintenance Manual: for systematic water management, write a maintenance manual suitable for watershed and regional characteristics and develop an application, instead of using an empirical method.

* Target: establishment of a manual for each district (1, 358 districts), system development, and service start (continued)

b) Intelligent water management function

Demand and supply analysis: quantitatively analyze the actual agricultural water demand and supply by introducing an open canal network analysis to improve water use efficiency.

* Target: 100 locations among reservoirs of 5 million tons or more (2 trillion won, ~2033)

- Establishment of a sluice control system: establish a flood management system by securing the sluice data for each reservoir, measuring the level of downstream rivers, and developing a sluice control decision-making system.

* Target: 24 reservoirs with radial gates (12.3 billion won, ~2025)

- Expanding the base for remote operation: expand the measurement and remote automatic operation of a tele-meter and tele-control system from the plains to the reservoir.

c) Research and development related to water technology

Advancement of disaster response technology: establish a risk management system to respond to climate change and prevent reservoir collapse; develop seismic-performance improvement technology

- Efficiency of water and facility management: develop maintenance-optimization techniques, such as smart water-level control and real-time water level monitoring, to prolong reservoir lifespan

* Target: establishment of self-management system and development of technologies to prolong reservoir lifespan (7.2 billion won, ~2025)

3.4 Water management for everyone

a) Customized water management with stakeholders

- Seasonal water supply: reorganize the management system so that water can be supplied year-round in accordance with the threshing season of crops in paddy field farming, facility horticulture, and field farming.

* Target: facility horticulture, field crops, eco-friendly area of 20,000 hectares (1 trillion won, ~2030).

- Water management governance: Organize an administrative council consisting of various stakeholders who represent the interests of farmers, participate in national water management policies, and collaborate with other water resource managing bodies.

  * Target: Creation and implementation of a water management governing body for each watershed (10.76 billion won, ~2025)

- Water Management Forum: strengthen the operation of the National Assembly and forums for rural water management to support policy research and legislative activities related to agricultural water; organize and operate regional forums for rural water management.

b) Leading Water Management Policy with the Government

Establishment of a comprehensive plan for water in rural areas: establish a plan, for rational use of water in rural areas, that reflects the changed water management standards in the National Basic Water Management Plan, which is the highest plan for water management.

* Target: 511 sites (3 billion won, ~2023) for field investigation, analysis, and planning by area.

- Legislative and institutional reform: suggest and reorganize the legal system to maintain proper water management and manage expenses.

c) Water industry-related employment creation

Expansion of disaster management specialists: prepare measures to increase the vitality of rural areas through efficient management of irrigation facilities and job creation.

- Vitalization of water management promotion: establish a foundation for promoting water conservation and for increasing the income of farmers and anglers by discovering local experts on water management.

4.0 National factors affecting irrigation management, including water policy, institutions, and capacities

4.1 Securing New Agricultural Water in accordance with Changes in Agricultural Policy

In Korea, as per capita rice consumption continues to decrease, a policy to reduce rice production is in progress. While productivity improved due to the expansion of mechanized farming, expansion of water irrigation facilities, variety development, and rice consumption continued to decrease due to changes in eating habits.

* Rice production: (2010) 4,295,000 tons → (2019) 3,868 thousand tons (△ 427)
* Per capita consumption of rice: (2010) 72.8 kg → (2019) 59.2 kg (△ 13.6)

Due to changes in the supply and demand of rice, the area under cultivation of rice continues to decrease. The area under rice cultivation decreased approximately by 103,000 hectares from 833,000 hectares in 2013 to 730,000 hectares in 2019.

In addition, from the above trend, the Korea Rural Economic Research Institute has predicted, using the Korea Agricultural Simulation Model (KASMO), that paddy area of 827,000 hectares in 2020 will decrease to 756,000 hectares in 2030.

<Figure 3. Analysis of the trends of rice field areas in Korea using the KASMO model >

As field agriculture for high-income generation, such as protected cultivation facility agriculture and cultivation of special crops, increases, the cultivation of crops besides rice also increases. With changes in production systems, such as protected cultivation facility agriculture and increased cultivation of field crops, the need for clean water for farming and fishing villages throughout the year increases.

* Field cultivation area: (2015) 202,000 hectares → (2020) 301,000 hectares (increase of 99,000 hectares).
* Productivity of 1 trillion or more: (2006) Rice → (2020) Rice, strawberry, tomato, and watermelon

Finally, the demand for multi-functional and multi-purpose use of agricultural water is increasing, such as using the water for production of growing crops to agricultural, domestic, and industrial use and using environmental resources for environmental maintenance.

4.2 Increased occurrence of disasters due to climate change

Disasters in Korea are similar to disasters worldwide. For the past few years, localized disasters such as torrential rains, typhoons, earthquakes, and droughts have occurred annually.

The status of major disasters in the past is as follows.

- The highest number of typhoons in history (seven times) occurred in 2019 and the longest rainy season (54 days) in history occurred in 2020.

* (2001–2018) average annual typhoon impact 3.2 → (2019) 7 (increased by 218%)
* In 2020, 974 cases of damaged water facilities in rural areas due to heavy rains, amounting to a loss of 51.3 billion won.

- The largest earthquake in Korea struck Gyeongju in 2016 (magnitude 5.8, aftershocks 632 times).Since 2000, there have been seven earthquakes with a magnitude of 5.0 or greater.

* Earthquake frequency: (1978–1999) 19.9 times/year → (2000–2019) 72.4 times/year (increased by 364%)

- According to the meteorological observation in 1973, nationwide drought damage occurs every 5 to 7 years, and the frequency of local droughts has gradually increased.

* Drought frequency: 35 times (0.36 times/year) from 1904 to 2000, 13 times (0.72 times/year) from 2001 to 2018

In addition, owing to the increase in flood volume due to climate change, the required flood control capacity exceeds the capacity designed at the time of construction of facilities, making them vulnerable to natural disasters.

To this end, we intend to secure safety by establishing design standards that reflect the size and regional characteristics of the reservoir, which include determining the probable maximum flood of a fill dam that has a watershed area of 2,500 hectares and storage capacity of 5 million tons or more.

Further, the number of reservoirs that have been in operation for more than 50 years since the construction of agricultural production facilities reached 74.2%.

<Table 3. Construction status by type of agricultural infrastructure >

Division	Sum		Less than 30 years		30–50 years		More than 50 years	
	Number of facilities	%	Number of facilities	%	Number of facilities	%	Number of facilities	%
Total	14,211	100	5,121	36.0	4,299	30.3	4,791	33.7
Reservoir	3,411	100	386	11.3	493	14.5	2,532	74.2
Pumping Drainage station	4,638	100	2,868	61.8	1,386	29.9	384	8.3
Weirs, etc.	6,162	100	1,867	29.8	2,420	44.4	1,875	25.8

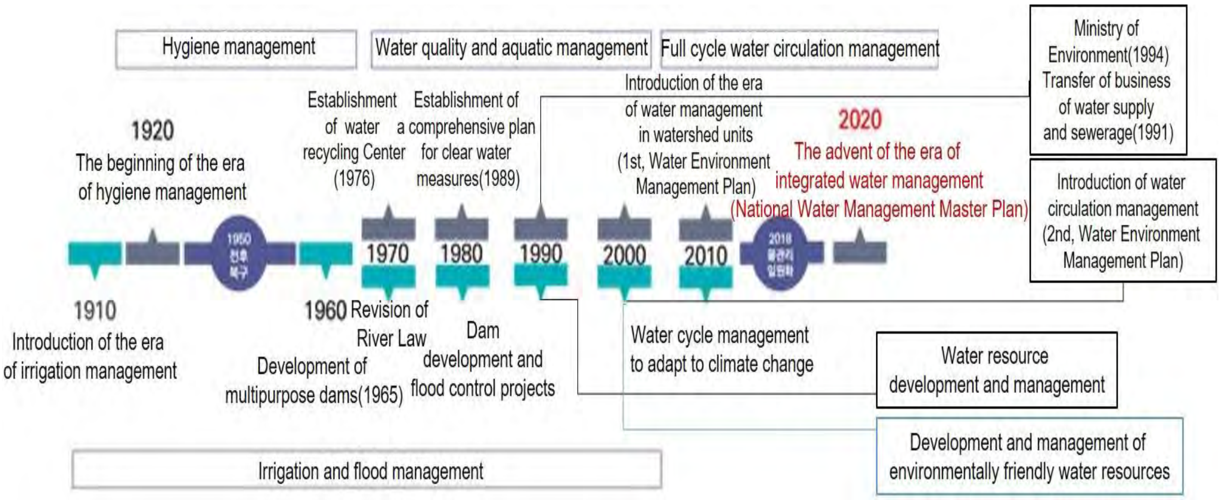
4.3 Demand for a sound agricultural water circulation system in the watershed unit according to integrated water management policy

In Korea, the Ministry of Environment has been promoting the unification of water management since 2018 with the goal of integrating all water supplies, such as those for domestic, industrial, and agricultural uses.

The legal basis for an integrated water management system was laid with three water management laws, enacted and amended between 2018 and 2019: the Government Organization Act, Water Technology Industry Act, and Basic Water Management Act. The Government Organization Act transfers water resources-related tasks from the Ministry of Land, Infrastructure, and Transport to the Ministry of Environment. The Water Technology Industry Act promotes the development of water management technology, water industry, and basic principles of water management to establish a sustainable water management system. The Basic Water Management Act stipulates the principles and the establishment of the National Watershed Management Committee.

Agricultural water (Ministry of Agriculture, Food and Rural Affairs), small rivers and disasters (Ministry of Public Administration and Security), and hydroelectric power generation (Ministry of Commerce, Industry and Energy) were excluded from the unification of water management at the government level. However, agricultural water was included in the integrated water management policy to manage domestic, industrial, agricultural, and environmental water for each basin unit because its water consumption is the highest.

<Figure 4. History of changes in water management policies in Korea >



In particular, the National Water Management Committee under the direct control of the president is a deliberation and decision-making body that consider important matters related to national water management in accordance with the Framework Act on Water Management.

The watershed management committee was installed and given charge of four major rivers, and an era of integrated water management began.

<Table 4. System changes according to integrated water management policy >

<table>
<tr><th colspan="2"></th><th>Domestic water</th><th>Industrial water</th><th>Agricultural water</th><th>Environmental water</th></tr>
<tr><td rowspan="3">Before integrated management</td><td>Ministry in charge</td><td>Ministry of Environment Ministry of Land, Infrastructure and Transport</td><td>Ministry of Environment Ministry of Land, Infrastructure and Transport</td><td>Ministry of Agriculture and Food</td><td>Ministry of Environment Ministry of Land, Infrastructure and Transport</td></tr>
<tr><td>Water usage</td><td>7.6 billion tons (20.4%)</td><td>2.3 billion tons (6.2%)</td><td>15.2 billion tons (40.9%)</td><td>12.1 billion tons (32.5%)</td></tr>
<tr><td>Problem</td><td colspan="4">Low management efficiency due to overlapping projects and budgets due to individual management by each department in charge of water</td></tr>
</table>

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<table>
<tr><td colspan="5">Implementation of government-wide integrated water management policy</td></tr>
<tr><td rowspan="2">Integrated water management in watershed units</td><td>Han River</td><td>Geumgang River</td><td>Yeongsan River·Seomjin River</td><td>Nakdong River</td></tr>
<tr><td>Living·Industrial·Agricultural·Environmental water</td><td>Living·Industrial·Agricultural·Environmental water</td><td>Living·Industrial·Agricultural·Environmental water</td><td>Living·Industrial·Agricultural·Environmental water</td></tr>
</table>

Belonging to the president	National Water Management Committee	Deliberation and resolution of water management policies such as the national master plan for water management and settlement of water disputes between watersheds
	Watershed Management Committee	Deliberation and resolution of water management policies such as watershed unit water management comprehensive plan and water dispute settlement in the watershed
Goal		Achieving a sound water circulation through integrated management of domestic, industrial, agricultural, and environmental water in the watershed unit
Ministry role	(Ministry of Environment) Management of quantity and quality of living and industrial water, etc.	(Ministry of Agriculture and Food) General management of agricultural and rural water

This integrated water management policy aims to promote water demand management in an integrated way at the watershed unit level to increase water use efficiency and maintain equal distribution of living, industrial, rural, and environmental water. The policy, promulgated and enforced in June 2018, also specifies provisions for water demand management.

> Article 15 of the Framework Act on Water Management (Management of Water Demand, etc.)
> ① When the State and local governments intend to establish a plan for the development and supply of water resources, they consider the necessity of appropriately managing water demand through efforts to save water and reduce water loss before establishing the plan.

In addition, an integrated water management policy requires an efficient water supply. The transition from an empirical management of agricultural water to its scientific management for disaster response (irrigation waterway, IoT(Internet of Things) management, etc.) is needed to provide a systematic and efficient water supply.

Based on the analysis of water supply and demand by 2030, the National Basic Plan for Water Management, the most important plan for water management, predicts that 47 tributary rivers supplying rural and fishing villages in 113 districts across the country will have insufficient maintenance. Accordingly, it is necessary to establish a water supply management system using irrigation canals and IoT cutting-edge technology to provide a stable river water ecology and water supply for farming and fishing villages.

Moreover, the paradigm has shifted from quantity-oriented water management to demand-oriented water management, and a gradual change is needed for water management methods through communication and cooperation with consumers.

Through the establishment and expansion of water management governing bodies, such as rural water forums, participation of consumers in water management can be realized.

5.0 Prospective areas for future management

5.1 Establishment of smart agricultural water control and management system

In Korea, the number of old hydraulic facilities is large and safety management of these facilities is required to prepare them for high-intensity natural disasters, such as droughts, floods, and earthquakes. It is necessary to switch to an efficient agricultural water use system in line with changes in the agricultural environment.

a) Real-time safety management of irrigation facilities based on information and communication technology (ICT)

Install more number of measuring devices to secure facility safety and promote real-time monitoring and analysis of danger signals.

- Target: Install a package of measuring devices such as water leakage; displacement; and water level monitors, CCTV, in reservoirs managed by the KRC (3,402 locations)
- Function: to establish a predictive warning system to check safety and respond quickly to danger signals based on big data and artificial intelligence (AI) measurements.
- Implementation: Prioritize 778 small and medium-sized reservoirs of capacity less than 50,000 to 300,000 tons, which were frequently damaged and expanded to other scales in stages.

b) Conversion of water management system in accordance with changes in agricultural environment

It involves the realization of carbon neutrality through intelligent control and management of agricultural water based on supply and usage data and conversion of the water supply system to irrigation canals, to reduce water loss and labor, and to keep paddy water shallow.

Anti-drought capacity: Identify the actual amount of water available through a survey on contents such as soil and other sediments in lakes.

Fact-finding: Investigate and analyze the supply and demand for each water facility and water area based on the digitalization of the waterway system.

- Irrigation canal conversion: Convert water canals close to agricultural lands suffering from significant water loss into an irrigation canal and install an automatic water pipe to establish digital-based intelligent water management.

5.2 Development of a platform for the entire agricultural water cycle

Agricultural water is carbon-neutral and sensitive to climate change. One can overcome work force limitations due to the aging of the field and reduce water consumption by establishing a scientific management system for the entire agricultural water cycle (supply-use-return). Further, one can reduce the labor intensity of manpower-oriented water management through operational automation.

- Direction: development of a digital agricultural water platform capable of collecting, modeling, controlling, and predicting temporal and spatial data for the systematic management of smart agricultural water. Development of an emergency service platform for responding to drought and floods. Development of domestic and international ICT standards.

Development of

- a smart framework technology for the entire cycle of agricultural water.
- an information collection system and data-ization technology for all phases of agricultural water cycle.
- linked open data and automation construction technology for retrieving agricultural water spatial information.
- time-series data collection and analysis process technology for precise management.
- digital twin platform technology for next-generation agricultural water prediction and modeling.
- a technology for predicting agricultural water demand based on digital and machine learning.
- a sensor system technology for measuring soil moisture and evapotranspiration using image analysis.
- self-learning and smart irrigation-waterway control modeling technology fused with an unsteady flow analysis waterway network model.
- carbon neutrality and reduction rate modeling technology based on agricultural water.
- AI-based customized packaging water supply control automation technology.
- image and digital farmland flooding detection and control management system with a flood analysis model.
- generative adversarial network based regression model for self-learning and digital control panel technology.
- self-learning automatic water supply and automatic control management technology.
- unmanned monitoring and mobile small robot technology for agricultural waterways.
- real-time meteorological disaster-linked emergency situation recognition technology.
- drought prediction technology based on integrated digital twins.
- digital twin-based smart agricultural waterway platform and all-in-one integrated control technology.
- AI reservoir completion and system safety management technology.

5.3 Agricultural-Water Governance

The efficient management of agricultural water and its promotion must be prioritized for the conversion to the integrated watershed management (domestic, industrial, agricultural, and environmental water) system according to the implementation of the integrated water management policy and sound water circulation.

Participant: academia and experts (including those in other fields), local farmers, public corporations, local governments, and the media. Establish roles for each participant and specific plans for pilot policy formulations and supervising water conservation.

Roles: clearly articulate roles and prepare a management system to monitor responsibilities and role fulfillment among stakeholders involved in administration.

<Table 5. The role of participants in water conservation>

Division	Academics and Professionals	Farmer (field operation)	KRC	Local government	Media
Common	· Participation in governance, water management debates and administrative operations				
By institution	· Administrative Operations · Conducting discussions and meetings on water management · Analysis of the effectiveness of participatory water management	· Implementation of the administrative measures.	· Agricultural water supply management	· Administrative support	· Publicity of issues and operating results

6.0 Way Forward and Recommendations

6.1 Suggested direction for integrated management

a) Reorganizing the administrative system is necessary to implement integrated watershed management. There may be alternatives, such as establishing a water management or watershed management departments and reestablishing the status of the National Water Management Committee. In particular, agricultural water management must be prioritized, the response function to water disasters such as floods and droughts must be strengthened, and the water resource business promotion and water-environment regulation functions must be separated.

b) Reinforce the quantitative monitoring system of the entire water management cycle (supply-use-return) for scientific implementation of water management and for identifying the current status of water circulation in watershed and substances such as pollutants and untreated sewage in real time; it is necessary to establish and expand the integrated watershed management system through strengthening monitoring.

c) Storage facilities, such as small-scale dams and riverside reservoirs, should be expanded for each watershed to secure various types of waters, such as environmental and ecological water to maintain a healthy aquatic ecosystem and agricultural water for stable food production and to prevent flood damage.

d) It is necessary to upgrade water and sewage facilities (underground, compact, distributed, and linked types) and expand new facilities that can actively respond to the new risks of this era. It is also necessary to expand the budget for the maintenance of water management facilities including agricultural water.

e) The water industry should be promoted and diversified by cultivating highly talented individuals in water management who can keep up on the development of AI, ICT, and rapid urbanization. AI-based smart technologies and digital twins should be actively utilized.

6.2 The Path of Agricultural Water in Integrated Water Management

a) Preparation of legal and institutional reform plan: the scope of agricultural water supply should be expanded for multifunctional and multipurpose water use while reorganizing the water management unit for rural areas into basin units. In addition, the system should be reorganized to establish a periodic plan for the Rural Water Use Rationalization Plan and Rural Maintenance Act to prepare a water management system that consider quantity, water quality, aquatic ecology, and water circulation and focuses on production infrastructure maintenance in rural areas.

b) Establishment of a sustainable smart rural water management system: securing stable rural water through a project is necessary to increase the efficiency of agricultural water use; these projects include construction of irrigation canals, evaluation of agricultural water supply, quantitative analysis of regional demand and supply, and upgradation of water management technology. In addition, it is necessary to standardize the basic data for water management and to convert them to big data through a detailed investigation of the beneficiary area and drainage system.

c) Water quality improvement for agricultural and fishing villages to strengthen the safety of agricultural and fishery products: It is important to strengthen the safety of agricultural and fishery products through an ICT-based preventive water quality management system. It is necessary to promote projects to enhance this effect.

d) Reinforcement of the disaster preparedness capability of hydraulic facilities: We must move toward safe flood control without flood damage by expanding pre-discharge facilities, establishing a hydrological control system, expanding disaster prevention measuring instruments, and revising design standards. In addition, it is necessary to respond actively to drought through the establishment and management of the entire drought cycle response and groundwater utilization systems. Lastly, it is necessary to strengthen the safety management of agricultural reservoirs through modernization of irrigation facilities, such as the reconstruction of old reservoirs, expansion of targets for (precision) safety diagnosis, and reinforcement of seismic performance.

e) Establishment of farmer participatory water management governance: It is important to strengthen organic linkages with farmers through governance structures and operations, where various water-related stakeholders can gather to share opinions and communicate with each other.

f) Improvement of amenities and rural environments in rural areas: To improve the agricultural environment, efforts should be made to improve public value by expanding agricultural environment projects and to reduce carbon-zero greenhouse gases by analyzing the possibility of reducing greenhouse gases in agricultural social overhead capital projects.

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COUNTRY PAPER: THE STATE OF IRRIGATION IN SOUTH AFRICA

Theme: Integrated approaches to irrigation management in future

24th ICID Congress, October 3 -10, 2022 in Adelaide, Australia

Authors: - Ms. PN Mjadu, SANCID Member
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1. INTRODUCTION

1.1 South Africa is located at the southern tip of the African continent and is bordered by Botswana and Zimbabwe to the north, Mozambique and Swaziland to the northeast and east, the Indian Ocean to the southeast and south, the Atlantic Ocean to the southwest and west and Namibia to the northwest (FAO_Aquastats, 2016).

1.2 South Africa covers an area of 122 million hectares of which approximately 14 million hectares (12%) is cultivated land. Approximately 12% of the country has fertile soil. Most of this is marginal for crop production and less than 3% of South Africa is considered as high-potential land due to the aridity of land, (WWF,2018)

1.3 According to the mid-year report by Statistics South Africa, South Africa's population was estimated to have increased to 59,62 million in 2020 and is expected to continue increasing but at a slower rate than in the past century, with the growth rate going below 1% annually by 2026. Studies indicate that South Africa will have to produce 50% more food by 2050 to meet food demands for a growing population, (WWF, 20190

1.4 South Africa is one of the water-stressed countries in the world with extreme climate, rainfall fluctuations and unevenly distributed water resources. It is ranked as the 30th driest country globally. South Africa's water resources are over allocated, with only a limited amount that can be allocated to agricultural sector.

1.5 The country is predominantly reliant on surface water which accounts for 77% of water supplies, with the remaining portion supplied from groundwater (9%) and return flows (15%) (Mutamba, 2019). The total potential groundwater delivery is estimated at 12 000 million m^3, of which 4 500 million m^3 can be practically retrieved (W&SMP, 2018).

1.6 South Africa has 3 three major rivers, namely the Vaal, Orange and Limpopo River. The total run-off per year from South African rivers is estimated at approximately 51 100 million m^3, but because of variable flow and high evaporation, only 30 000 million m^3 can be practically and economically used

1.7 There are more than 500 government dams with a total capacity of 37 000 million cubic metres. This is equivalent to 15 million Olympic sized swimming pools. They form part of the bulk water supply infrastructure and fall within the administration and management of the Ministry of Water and Sanitation

2. CURRENT STATUS OF NATIONAL IRRIGATION SECTOR

2.1 Irrigation in South Africa started to grow rapidly around early 1900, when there was a growing need for feed production for the export of ostrich feathers considering that irrigation doubles the production compared to that under rainfed. Currently there is 1.3334562 hectares (1.1%) that is actively irrigated and supports 25- 30% of national agricultural production, (WRC, 2018).

2.2 Irrigation has the potential to boost agricultural productivity by 50%, (NEPAD, 2021). This can be achieved by ensuring the efficient use of water for irrigation through efficient irrigation methods, irrigation scheduling, determination soil types, crop selection and ensuring reduction of evaporation

2.3 Currently there is limited additional water for the agriculture sector due to high competition between the users, high evaporation rates and climate change.

2.4 Climate change has the potential to reduce food production and the availability of water, including water for irrigation since it is the first activity to be curtailed when restrictions on water use are imposed. Climate prediction studies indicate that by 2050 annual temperature is expected to increase which translates to more evaporation, less moisture available for crops and increased need for irrigation if carbon emission levels are left uncontrolled. This calls for greater preparedness for the country in ensuring that measures to secure the available water for agriculture are in place since water is the primary input for agricultural production.

2.5 South Africa's agricultural sector including irrigated sector is characterised by both large commercial farming and small subsistence farming. This dualistic production structure consists of two categories of farmers: - the large-scale irrigation farmers (commercial farming) and the small-scale irrigation farmers (smallholder irrigation farming).

- **Large-scale irrigation**

Large scale irrigation refers to the modern, commercial irrigation operations undertaken by an estimated 32 000 commercial farmers in South Africa, of which between 5000 and 7000 produce approximately 80 percent of agricultural output (International Trade, 2021). The large-scale commercial farmers (mostly white farmers) produce for local and export markets (Backeberg and Sanewe, 2010).

South Africa has 49 large irrigation schemes which includes the Vaalharts. Vaalhart is the biggest irrigation scheme in the southern hemisphere, and it is 36000 hectares in extent. Several large schemes were developed during the 1930s when South Africa was affected by severe droughts and an economic depression. Most large irrigation schemes were intended to provide employment and means of sustainable living to impoverished whites who were left destitute by the consequences of the War.

The functions of large irrigation schemes are mostly to ensure an adequate supply and delivery of water to farmers based on their water order requests. They are part of bulk water supply, therefore are managed within the Ministry of Water and Sanitation.

Currently the government of South Africa is in a process of transforming the Irrigation Boards which used to be managed by large scale farmers into Water User Associations (WUAs).

There are 99 WUAs currently. It is expected that the WUAs will incorporate all users in the defined area of jurisdiction, whether they have a formal water entitlement or not. It is believed that this transformation will enable better participation of Historically Disadvantaged Individual (HDIs) in the management of water, (WRC Report TT 204/03).

- **Smallholder irrigation**

Smallholder irrigation refers to the traditional, subsistence irrigation activities undertaken by an estimated 2 million smallholder or household farmers whose majority are black women (WWF-SA, 2017) pa. The small-scale irrigators mainly produce for household consumption.

Smallholder irrigation schemes consist of farm holdings historically located in the former homelands, cultivated by black households, and supplied with water for crop production. In general, each plot holder has a plot of up to 5 ha in extent (Fanadzo 2012). Smallholder irrigation schemes as a whole range from about 30 ha to about 400 ha in size.

There are 302 smallholder irrigation schemes with a combined command area of 47 667 ha in South Africa. The plot-holder population on these schemes totalled 34 158. Rivers were the principal source of water.

A total of 46 114 ha (96.7%) obtained its water from rivers, either pumped directly, diverted by means of weirs, or through dam storage. Groundwater was used on 1 405.5 ha (3.0%), municipal water on 110 ha (0.2%) and spring water on 37.6 ha (0.1%). Water was pumped on 23 111.8 ha (48.5%), gravitated on 16 497.2 ha (34.6%) and on 8 058.5 ha (16.9%) gravity and pumping occurred in combination.

On all existing schemes, the irrigation system was constructed after 1950. Schemes that were constructed before 1950 no longer existed in their original form, but the original canal irrigation systems have been replaced with an overhead system.

Majority of these schemes were developed near the riverbanks and others further away from the river systems are also supplied with water from these rivers. There is a growing demand to improve smallholder farming or informal small-scale farming in South Africa with the introduction of modern technologies.

Modern water distribution technologies such as sprinkle and trickle irrigation are replacing more traditional surface methods. Currently, South Africa has 14% flood irrigation, 30% sprinkler, 21% micro and 27% mechanised irrigation. These modern technologies are often favoured because they assist farmers in saving their water.

Currently there is no track record on how much savings have been achieved through the implementation of efficient irrigation technologies, but it must be noted that the adoption/ implementation is still very low including the installation of measuring structures however a notice to install water measuring devices for water taken for irrigation purposes was issued in 2018.

It is estimated that less than 60% of water abstracted from water resources is correctly placed in the root systems of plants. Approximately 35% of irrigation system losses return to the river systems by overland flow and return seepage. This return water can be nutrient enriched and polluted with herbicides, pesticides and other pollutants that could affect the downstream water quality of rivers and streams.

Irrigation methods, irrigation scheduling, soil type, soil preparation, crop selection and evaporation all have an impact on the efficient use of water for irrigation. They should therefore all be considered in the quest to achieve maximum water use efficiency. Given the threat of drought and climate change and other factors, efficient irrigation systems have become a necessity, especially in the smallholder farming sector where most losses occur (Fanadzo & Ncube, 2018)

Lot of investment has been made into research relating to irrigation and water management. This has led to the development of tools and technologies to improve management of water by the agricultural sector however one biggest challenge faced by the sector is the adoption and use of the developed technologies by the farmers, especially the smallholder farmers.

It is estimated that irrigation is responsible for 90% of the production of high value crops including potatoes, vegetables, and fruits and 25 – 40% of production of industrial crops including sugar cane and cotton. In 2020 Agriculture exported R160 billion worth of fruits and grains to the rest of the world and 30% of that was from irrigated agriculture. About 90% of the country's fruits and wine are produced under irrigation and forms part of the export products which generate foreign exchange for the country.

3. FUTURE INVESTMENTS IN IRRIGATION INFRASTRUCTURE MORDENIZATION

3.1 The National Development Plan 2011 (NDP) indicates that the country needs to expand the areas under irrigation by at least 500 000 hectares for economic development, poverty alleviation and job creation. To address this initiative the following measures were developed: -

- Development of Irrigation Strategy 2015, which outlines necessary intervention measures to enhance water use efficiency in irrigation and identifies potential areas for irrigation development which total to only 34 000 hectares which is far less than the

500 000 hectares proposed by the NDP. It also highlights other alternative water sources to eliminate the need for continuous pumping or water withdrawals. This includes the re-use of treated wate water for irrigation, rainwater harvesting, construction of tower gardens for greywater use, etc. There is currently number of research studies relating to the re-use of treated wastewater undertaken in South Africa, and it seems like a feasible option for the sector in a sense that it can eliminate the need for new water withdrawals- thus minimising the pumping cost, minimise potential negative on the water resources to count a few.

- Development of a Business Plan for the Revitalization of irrigation schemes (irrigation infrastructure) was developed and approved in 2013. Progress to date: The implementation is currently underway, but it is very costly and is a lengthy process considering the procurement process to be followed. It is implemented in phases and depends also environmental factors and budget availability.
- Development of a Business Plan for expansion and establishment of new irrigation schemes

3.2 Supported water/ irrigation related research projects on sustainable use and management (water use efficiency, quality, fitness for use, risk management, etc). The major challenges observed is the lack of adoption and use of the developed technologies by farmers. Currently the government and the Research Institutes are embarking on information dissemination sessions with the farmers to enhance the adoption of water efficient irrigation technology innovations.

3.3 South Africa is investing on is the increasing of water storage through construction of bulk infrastructure. This is done on case-by-case basis for example it in the Eastern part of the country, it was deemed feasible to construct a new dam (Umzimvubu Dam), whereas for the Western part it was decided on raising the dam wall (Clanwilliam Dam) and the canal (Brandvlei). With the completion of dams and associated water resource systems which are already at an advanced planning stages the maximum economically feasible increase of yield from the surface water resources would be reached and therefore unlocks irrigation expansion.

3.4 Currently, South Africa has 14% flood irrigation, 30% sprinkler, 21% micro and 27% mechanised irrigation. Modern water distribution technologies such as sprinkle and trickle irrigation are replacing more traditional surface methods. These modern technologies are often favoured because they assist farmers in saving their water. Water savings by some farmers means that more is available for others or to unlock the much-needed irrigation expansion.

3.5 Currently there is no track record on how much savings have been achieved through the implementation of efficient irrigation technologies, but it must be noted that the adoption/ implementation is still very low including the installation of measuring structures however a notice to install water measuring devices for water taken for irrigation purposes was issued in 2018.

4. NATIONAL FACTORS AFFECTING IRRIGATION MANAGEMENT

4.1 Relevant policy

The Ministry of Water Affairs is the custodian of all water resources, and all water resources are regulated under the National Water Act (Act No 36 of 1998). Agriculture, including irrigation activity is listed as a water user sector and therefore it is also regulated under the National Water Act. There is no Irrigation Policy within the Ministry of Agriculture but a couple of framework documents guiding and complementing the implementation of the National Water Act in relation to agricultural water management exist, including: -

- The Irrigation Strategy of South Africa, 2015
- The National Guidelines for Integrated Management of Agricultural Water Use
- Business Plan for the Revitalization of Irrigation Schemes
- Climate Smart Agriculture Framework
- Conservation of Agricultural Resources Act, Act 43, 1983

4.2 Institutions

In terms of the importance of irrigated agriculture in South Africa it is evident that effective communication coordination and cooperation between various stakeholders including government, research institutions, private sector and the farmers will be required.

- The National Government remains the custodian of natural resources and take responsibility for guiding irrigated agriculture in the country.
- The Provincial Departments of Agriculture will develop Business Plans and Feasibility Reports for irrigation and drainage projects. They will also be responsible for implementation of irrigation and drainage projects. They need to establish the Coordination Committees to support and monitor the implementation of irrigation and irrigation projects

- Research and Tertiary Institutions: These Institutions will conduct research on issues relating to water by the sector. They will provide research information as well as possible enterprise related training to farmers/ water users.
- The Private sector should support irrigation initiatives through the provision of linkages and financial and technical support
- The Public in general, including must participate in farming initiatives and become farmers. South African government is looking at prioritising youth and women.
- All these players must ensure provision of advisory services to the farmers.

5. PROSPECTIVES AREAS FOR FUTURE MANAGENT

South Africa has undertaken the following

- Operationalization of Irrigated area mapping using a Satellite Imagery. This will assist the country to monitor and keep track on areas under irrigation.
- Development of the Site-specific, risk-based Decision Support Tool (DSS) for assessing irrigation water quality. It does not only consider risk but also allows for water quality to be assessed at different levels of sophistication and caters to the evaluation of both the fitness-for-use and the setting of water quality requirements.
- Development of SAPWAT. This is a planning tool/ program for estimating irrigation water requirements of crops.
- Irrigation Scheduling Tools. They assist farmers to understand what's happening underground in the root's zones, when to irrigate and how much water to use. There are easy to use by all farmers. Proper irrigation scheduling can enhance even the yields which is an incentive to farmers.
- Agricultural colleges. We are planning to work with Agricultural Colleges to ensure that these irrigation technologies are integrated and incorporated into their curriculum and be offered to students and to farmers.

6. WAY FORWAD AND RECOMMENDATIONS

- Development and promotion of more efficient irrigation technologies,
- Capacity building of government personnel and farmers on the technical know-how of water and irrigation management. This include but not limited to building skills of operation, repair and maintenance of equipment, record keeping and data collection
- Research and technology innovations, especially around the sustainable use and fitness of alternative water sources, sustainable use of land post mining, and alternative energy sources and water food energy nexus and climate smart agriculture, Decision Support Systems

- Develop strategies that give new entrants (HDIs) access to water, product value-chains, markets, and support from the better resourced players. Government should invest a framework and for a fair collaboration between commercial farmers and black farmers
- Development and promotion of integrated funding for irrigation infrastructure (blended funding)
- Give priority to successful farmers in communal areas, and support industries and areas with high potential to create jobs.
- Support commercialisation of new entrant farmers instead of locking them into small farming enterprises
- Alignment and improvement of regulatory frameworks that may impact on irrigation or water use and management in agriculture.

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Integrated approach to Irrigation management in the future in the Republic of Uzbekistan

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I.Introduction

Uzbekistan is one of the countries in the Aral Sea Basin, bordering four countries in Central Asia. Afghanistan borders the Islamic State for less than 150 km.

Uzbekistan is the most densely populated country in Central Asia with a population of 35 million. According to official figures, Uzbeks make up 80 percent of the population and young people 60 percent.

There are 130 ethnic language groups in Uzbekistan.

The territory of the Republic of Uzbekistan covers 448,000 square kilometers, irrigated land area is 4.3 million hectares.

Most of the territory of Uzbekistan is characterized by a continental, arid climate. The average high temperature in summer is above 40 ° C, and the average minimum temperature in winter is -23 ° C.

As a result of global climate change, the area of glaciers in Central Asia has shrunk by about 30 percent over the past 50-60 years. It is estimated that by 2050, water resources in the Syrdarya basin will decrease by 5%, and in the Amudarya basin - by 15%. Over the past 15 years, per capita water supply in Uzbekistan has decreased from 3,048 cubic meters to 1,589 cubic meters.

At the same time, the population of the republic will reach 39 million by 2030. Their demand for quality water is expected to increase by 18-20%. In addition, in recent years, industry and energy are actively developing, and their demand for water is growing every year.

It ranks 25th out of 164 countries in the ranking of countries suffering from water stress, published by the World Water Resource Institute.

Cooperation with Central Asian countries on the use of transboundary water resources is carried out within the framework of the International Fund for Saving the Aral Sea, the Interstate Water Coordination Commission and bilateral cooperation.

The main agricultural crops are cotton, wheat, orchards and vineyards, and 90 percent of the total agricultural output comes from irrigated land.

The available water resources in Uzbekistan consist mainly of reorganized surface and naturally occurring groundwater and anthropogenic water.

II. Current situation in the water sector of the Republic

The Republic of Uzbekistan is located in the Aral Sea basin, the main sources of water are the Amudarya and Syrdarya rivers, as well as inland rivers and streams and groundwater. The average perennial water volume of all sources in the Aral Sea basin is 116 billion cubic meters, of which 67.4% are formed in the Amudarya basin and 32.6% in the Syrdarya basin.

In particular, the total groundwater reserves amounted to 31.2 billion cubic meters, of which 47.2% falls on the Amudarya basin and 52.8% on the Syrdarya basin. Only 20% of the total water used in Uzbekistan is formed in the country.

Annual water use in Uzbekistan is 51-53 billion cubic meters, including 97.2% from rivers and streams, 1.9% from collector networks and 0.9% from groundwater.

90-91% of the extracted water resources are used in agriculture, 4.5% in public utilities, 1.4% in industry, 1.2% in fisheries, 0.5% in thermal energy and 1% in other sectors of the economy.

Improving the reclamation of irrigated lands, rehabilitation of agricultural lands, rational and prudent use of water resources through the introduction of water-saving technologies, increasing the productivity of irrigated lands are among the priorities of further development of the country.

A strict system of automatic water management and accounting is being introduced for all water users in all main canals and water sources in the country, and a water saving program has been developed and implemented in each system.

A single republican center for accounting, planning and integrated management of all water resources has been established in the country.

In order to ensure a reliable supply of water to all sectors of the economy, including agriculture, as well as to improve the reclamation of lands, the country has established a unique water management system.

In the water management system, 28.4 thousand km of irrigation systems and 54,432 various hydraulic structures, as well as a total volume of 19.4 billion cubic meters. 70 cubic meters of water and flood reservoirs are being used.

Due to the complex relief of irrigated lands, more than 2.0 million hectares of irrigated lands are supplied with water by 1687 pumping stations, which consume 7.5 billion kWh of electricity per year.

A total of 155.2 thousand kilometers of irrigation networks and more than 10,280 pumping units are used by 160 water consumers' associations, farms and clusters.

A total of 12.4 thousand irrigation wells are used for irrigation needs, including 4153 in the water management system. To improve the reclamation of irrigated lands, a total length of 142.9 thousand km, including 106.2 thousand km of open and 36.7 thousand km of closed horizontal collector-drainage network, as well as 172 reclamation pumping stations, 3897 vertical drainage wells are used.

The Ministry of Water Resources is carrying out extensive work in this direction on the widespread introduction of digital technologies in the industry. In particular, the Korean International Cooperation Agency (KOICA) has implemented a "Master Plan and pilot project for integrated water resources management in Uzbekistan based on information and communication technologies."

As a result, the project installed "Smart Water" devices for online monitoring of water resources at 61 water facilities, 15 small meteorological stations and surveillance cameras for visual monitoring of the situation on the ground. A water resources monitoring center has also been set up at the ministry's dispatch center.

The dispatch service of the Ministry has installed servers and auxiliary equipment, monitoring systems for generalization and storage of all data coming from the "Smart Water" devices installed on the ground, an information system that allows you to create and analyze databases and automatically track data on water facilities.

To date, Smart Water, which provides online control of water resources at 2,789 water bodies, Diver, which monitors groundwater levels and their mineralization in 1,727 reclamation monitoring wells, and 374 pumping stations. devices were installed to monitor indicators and control electricity consumption at 1687 pumping stations.
In addition, the management processes of 20 major water facilities are being automated, and advanced Rubicon Water technologies operating in the Australian water management system are being widely introduced into the sector.
In particular, Rubicon is fully automating the management of the Mirishkor and Kamashi canals in Kasbi district of Kashkadarya region.
Our main goal in obtaining high yields from agricultural lands and increasing water efficiency is to ensure food security.
Therefore, we need to ensure that the water infrastructure used in the country is technically sound and guaranteed. Despite some work being done, measures will need to be taken to further improve the water infrastructure.

III. The main problems in water management

Most of the water infrastructure used has been in use for 30-50 years. Sixty percent of the length of the canals is in the soil, and the filtration rate of the water remains high. In addition, 77 percent require the repair and rehabilitation of irrigation systems and canals, and 20 percent require reconstruction. A similar situation can be seen in the canals and drains that are on the balance of the Water Consumers Association, the farms.
The bulk of the tray networks have been in service for more than 30 years, 70 percent of which require reconstruction or replacement.
As a result, the efficiency of irrigation systems and irrigation networks is 0.64, which is a very low figure.
Of the 1,687 pumping stations financed from the state budget, 70% have been in service for 30 years, 20% for 20 years, 6% for more than 10 years, or 94% have already reached the normative service of pumping stations (16-18 years). Of the 2,887 km of high-pressure pipes, 10.3 per cent require replacement in the first place, leaving them with high electricity consumption.
45.3% of irrigated lands in the country are at different levels, of which 31.1% are weak, 12.2% are moderately saline, 2% are highly saline, and 24.4% of the area has a groundwater level of 2 meters or more.
At present, 14.5 thousand kilometers of collector-drainage networks, 93 reclamation pumping stations and 1,530 vertical drainage wells are required to be reconstructed and reconstructed.
Irrigation of agricultural crops in the country is carried out in the traditional way, the preparation for laser leveling of lands remains low.
Until recently, little attention was paid to water-saving technologies. As a result, the volume of water supply per hectare of the complex is 8.10 thousand cubic meters.
Material and technical bases of operating organizations are not provided with sufficient machinery, transport and reclamation equipment. 70% of the funds allocated from the state budget are spent on electricity. As a result of the fact that the system of support and financing of water consumer associations is not organized at the required level, their accounts payable and receivable remain high.

There is a need to improve the Law of the Republic of Uzbekistan "On Water and Water Use" based on the results of reforms in agriculture and water management in recent years, as well as the development of the Water Code of the Republic of Uzbekistan.
Currently, 42% of engineers and personnel working in the water sector have higher education. Improving their skills in the future, educating them to be able to use innovation technology that is entering the water management and to improve their skills every year is needed.
In order to eliminate all the above shortcomings and ensure the stable and loss-free operation of the water system of the Republic, the concept of water management development until 2030 was developed in consultation with the Ministries of Agriculture, Public Utilities, the State Committee for Ecology and Environmental Protection and other government agencies. The concept of development of water resources of the Republic was approved by the Decree of the President of the Republic.

IV. The main goal of water management development until 2030 and its priorities and measures to be taken

The main goal of the Republican Water Management Development Plan until 2030 is to create the necessary conditions to meet the growing needs of the population, sectors of the economy and the environment in water, to ensure reliable and safe operation of water facilities and effective management and rational use of water resources; improving the reclamation of irrigated lands, achieving water security in the face of growing water scarcity and global climate change.
According to the approved Concept, to increase the efficiency of irrigation networks from 0.65 to 0.73 by 2030, for this purpose, the reconstruction of irrigation systems and increase the share of concrete-lined canals, replacement of obsolete pumping units with energy-efficient pumping units, low water supply reduction of irrigated lands and expansion of the introduction of water-saving irrigation technologies to 2.0 million hectares will be implemented; accordingly, the improvement of land reclamation in areas where drip irrigation technologies have been introduced, the reduction of salinity of strong and medium-salinity lands by 284,000 hectares, and the re-use of 150,000 hectares of irrigated lands that have fallen into disuse in agriculture will be implemented;rational use of water resources and water-saving technologies In the framework of the project from the Action Strategy of the Republic of Uzbekistan to the Development Strategy in 2022-2026, 1.6 million hectares of land, including 1.3 million hectares of drip irrigation and 300 thousand hectares of other modern water-saving irrigation technologies which covers 30 percent of the irrigated area, will be put into implementation.
The number of local organizations producing components for water-saving irrigation technologies will increase to 100 and the level of localization will reach 85-90%.
In order to ensure the safety and reliable operation of water facilities, practical work will be carried out on the modernization and restoration of control and measuring equipment and early warning systems at reservoirs and other large facilities by 2030 at 55 facilities.
The rapid introduction of modern information and communication and innovative technologies in water management will be continued, and the management of water resources will be automated.

The scope of research, experimental and design work in the field of water management will be expanded, and the development of scientific and innovative potential, scientific achievements will be introduced.
In the context of water scarcity, the Republic of Uzbekistan currently plays a leading role among Central Asian countries in the introduction of advanced technologies on irrigated lands and the continuous rationalization of water resources.
Integrated water resources management is currently being introduced in all regions of Uzbekistan.
To achieve this goal, the plans for 2030 have identified the following as key areas:

1. Improving the system of forecasting, accounting and database formation of water resources and ensuring transparency;
2. Modernization of water facilities, organization of management of large water facilities on the basis of digital technologies, widespread introduction of modern resource-saving technologies, expansion of foreign investment in the sector and ensuring targeted and efficient use of allocated funds;
3. Ensuring the safety and reliable operation of reservoirs, flood reservoirs and other water facilities;
4. Improving the water resources management system, implementing the introduction of "Smart Water" and similar digital technologies in water use and water consumption accounting;
5. Further expansion and encouragement by the state of the introduction of water-saving irrigation technologies in the cultivation of agricultural crops, the implementation of the direction of attracting foreign investment and grants in this area;
6. Implement effective technologies to improve the reclamation and sustainability of irrigated lands, promote soil fertility, reduce and prevent soil salinity;
7. Implementation of the principles of market economy in water management, including the system of gradual reimbursement of part of the cost of water supply by water consumers, the timely use of funds for quality repair, restoration, introduction of digital technologies and effective management of water resources;
8. Introduce public-private partnerships and outsourcing in water management, provide individual water facilities for use by farmers, clusters and other organizations, and direct the saved funds to the modernization of water facilities and the remuneration and incentives for staff;
9. Implementation of the principles of integrated water resources management, ensuring the guaranteed supply of water to the population and the economy, improving water quality and maintaining the ecological balance of the environment;
10. Development of interstate relations on the use of transboundary water resources, the development and implementation of mutually acceptable mechanisms for the joint management of water resources and programs for the efficient use of water, ensuring a balance between the interests of Central Asian countries;
11. To train qualified personnel for the water industry, to improve the system of staff training, to develop cooperation between education, science and industry, and to introduce scientific achievements into production.

V. Expected results from the work to be done by 2030

As a result of the work to be done by 2030, the following goals will be achieved:

- The legal framework and regulations of water management will be improved.
- The system of state management of water resources will be optimized.
- The efficiency of irrigation systems and irrigation networks will increase from 0.64 to 0.73, modern water-saving irrigation technologies will be introduced in agriculture;
- Modernization of water facilities and the widespread introduction of energy efficient technologies;
- Improved reclamation of irrigated lands;
- Modern information and communication technologies will be introduced in water management;
- Research activities and human resources in the field will be increased;
- The principles of integrated management of all surface, groundwater and return water will be widely introduced;

After the implementation of each of the above measures for the development of water resources until 2030, the results of which will be considered for the future measures for 2040-2050.

In general, the implementation of plans for the development of water resources until 2030, the further development and prosperity of the agricultural and water sectors of the Republic of Uzbekistan, will adequately meet the needs of the population in food products.

ZIMBABWE

ICID Country Profile

Geography

Zimbabwe is a low-income developing country that is land-locked, and is located in southern Africa covering an area of 39.08 million hectares. It shares land borders with Zambia to the north (about 763 km), South Africa to the south (about 230 km), Mozambique to the east (about 1402 km), and Botswana to the west (about 834 km), with a tip of the north-western boundary shared with Namibia as part of a four-country (Zambia, Botswana, Namibia, and Zimbabwe) transport corridor. Zimbabwe is located between 15.5° and 22.5° S latitude, and between 25° and 33.2° E longitude.

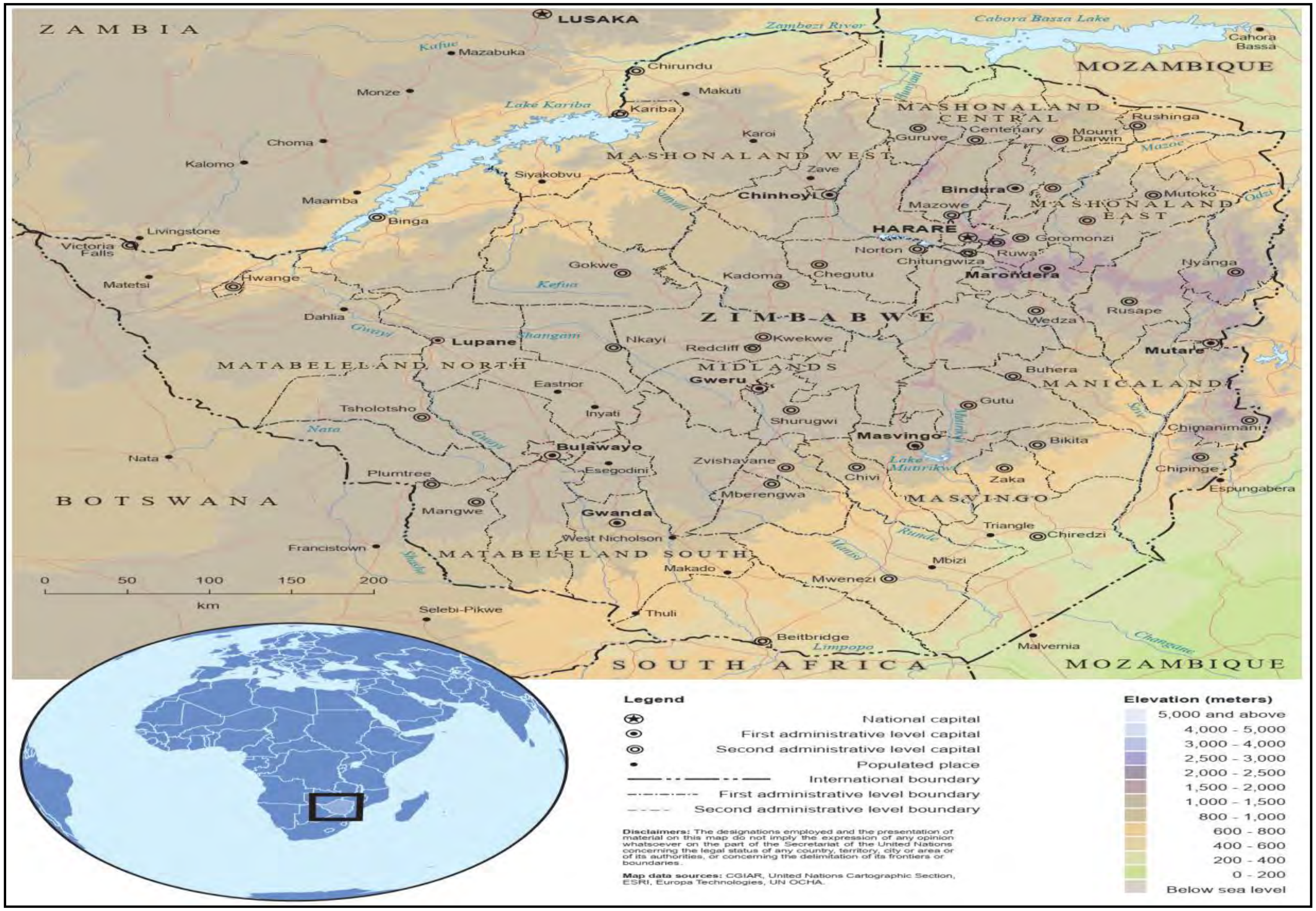


Figure 1: Administrative and relief map of Zimbabwe courtesy of United Nations Office for the Coordination of Humanitarian Affairs, Zimbabwe (UN OCHA, Zimbabwe)

The general elevations of areas across Zimbabwe are presented in the map developed by the United Nations Office for the Coordination of Humanitarian Affairs, Zimbabwe as shown in Figure 1. The highest point in the Zimbabwe is at an elevation of 2 592m in the mountainous region along the eastern border with Mozambique and the peak is called Mount Inyangani. The lowest point is at the confluence of the Save and Runde Rivers at an elevation of 162 m above mean sea level. In general, four major relief regions are recognized in Zimbabwe on the basis of their elevation. These are:

i) the lowveld (< 600 m above mean sea level) includes areas in the Zambezi, Limpopo, and Save river valleys with large contiguous areas for irrigated sugar cane and citrus production;

ii) the middleveld (600-1 200 m), an area with better agricultural soils used for crop production as well as poorer granite-derived soils used for communal land settlement;

iii) the highveld (1 200-2 000 m), a rich mineral deposit region that also forms a watershed area across the middle of the country separating the Zambezi, Save, and Limpopo River basin. It is a central plateau measuring about 650 km long and 30 km wide;

iv) the Eastern Highlands (2 000-2 400 m), a mountainous region used for agro-forestry.

Agriculture occupies a central place in the Zimbabwean economy, contributing 15-18% of Gross Domestic Product (GDP). In addition, it contributes over 40% of national export earnings and 60% of raw materials to agro-industries. Over 70% of the population derives its livelihoods from the agricultural sector. Agriculture-related employment supports a third of the formal labour force. In recognition of the importance of agriculture in economic development, the African Union Commission, through the Maputo Declaration of 2003, encourages member states to spend at least 10% of their National budget towards agriculture.

The diverse agro-climatic conditions enable Zimbabwe to grow a large variety of food and commercial crops. Over 23 types of food and cash crops are grown. The major food crops include maize, sorghum, pearl millet, finger millet, ground nuts, wheat, cow peas, bambara nuts and sweet potatoes. White maize is the main staple food. Cash crops include tobacco, cotton, tea, coffee, sugarcane, soyabean, sunflower and horticultural products. Zimbabwe has a well-developed livestock sector, catering for the needs of both domestic and export markets. The livestock sector comprises beef, dairy, poultry, pigs, goats and sheep.

The Agro-Ecology and Agricultural Potential of Zimbabwe

Zimbabwe has approximately 39 million hectares of land comprising commercial, subsistence and protected lands. Approximately 85% (33.2 million ha) of this land is classified as agricultural land while the remainder 15% is protected lands such as urban settlements, game parks, wildlife estates and forests. Of the agricultural land, 20.6 million ha is currently developed for use with 3.4 million ha (16.5%) being arable whilst 17.2 million ha (83.5%) is pasture or grazing land. An estimated 8.6 million ha are potentially arable while 6.0 million ha are protected lands. Potential for the expansion of arable area exists through the opening of virgin lands for crop production within the 20.6 million.

The Agro-ecological categorization of Zimbabwe

The country is categorised into five agro-ecological regions (I to V) see Map 1. Table 2.1 is a presentation of the distribution of the land use by agro-ecological regions.

Agro-ecological Region I covers less than 2% (705,000 ha) of the country and experiences high rainfall in excess of 1 000 mm and low temperatures which are conducive for such agricultural activities as forestry, fruit, horticulture and intensive livestock production;

Agro-ecological Region II: covers 16% (5,857,000 ha) of the country and receives moderate rainfall (750 – 1 000mm). Agricultural activities suitable for this region include intensive crop and livestock production;

Agro-ecological Region III: covers 7,290,000 ha (17%) and receives annual rainfall of between 500 and 750 mm and is characterized by mid season dry spells and high temperatures. The region is suitable for extensive livestock production with conditions that are marginal for crop production but crops such as maize, tobacco and cotton do well in soils with good moisture retention capacity;

Agro-ecological Region IV: covers 14,770,000ha (38%)are suitable for livestock production since they present great risk for cash crop production due to commonly experienced seasonal droughts. Annual rainfall of below 650mm is received in these two regions making crop production only feasible through growing of drought resistant varieties and or irrigation;

Agro-ecological Region V: covers 10,450,000ha (27%) .

Map 1: Zimbabwe Agro-Ecological Zones

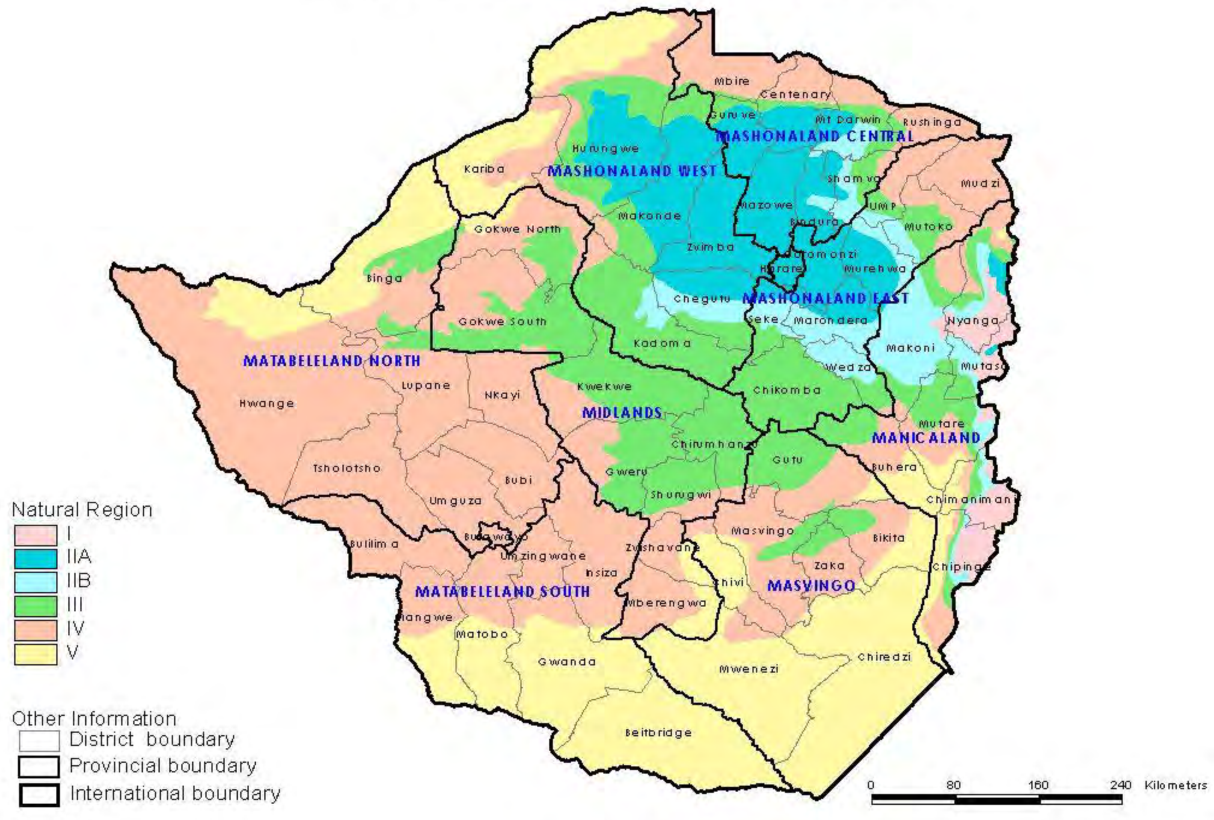


Table 2.2.1: Land Distribution by Agro-ecological Region & Sub-sector (Ha) before FTLRP

Agro-Ecological Region	Farming		Parks & Wildlife	Forests	Total
	Commercial	Subsistence			
1	450 000	135 000	50 000	70 000	705 000
2	4 560 000	1 270 000	25 000	2 000	5 857 000
3	3 780 000	282 000	545 000	145 000	7 290 000
4	4 300 000	734 000	2 510 000	620 000	14 770 000
5	3 750 000	4 790 000	1 840 000	70 000	10 450 000
Total	16 840 000	16 355 000	4 970 000	907 000	39 072 000

Source: Moyo (2006).

From the above analysis, it shows that when considering what used to be commercial farming areas, 27% of land lay in Agro-ecological II, while 26 % lay in Agro-ecological region IV. Land in natural regions III and V was at 22% each while land that fell under Agro-ecological region I was a mere 3%. On the other hand, when considering land that was under the smallholder communal area farming sector, the bulk of the land is found in the marginal agro-ecological regions (45 % Agro-ecological region IV and 29 % Agro-ecological region V). The above analysis clearly depicts the imbalances in the natural land resource base between the two farming sectors that is said to have ignited the infernos land redistribution programme of the last decade in Zimbabwe.

THE AGRARIAN REFORM IN ZIMBABWE.

a. Pre-independence era.

Prior to independence in 1980, the land was dominantly owned by about 4 000 white commercial farmers with the majority of the indigenous blacks owning marginal land.

Table 1 shows the land allocations prior to 1980 and Table 2 shows the land allocations after the land reform programme.

Table 1: Land Allocation Patterns in 1980.

Sector	Area (ha)	Population
Communal	16 400 000	1 100 000
Small Scale Commercial Farming Sector	1 400 000	8 500
Large Scale Commercial Farming Sector	15 500 000	6 700
Total	33 300 000	1 115 200

Source: Land Tenure Policy Document 1998

The large scale sector, constituting 1% of the agricultural population, had access to 47 % of the agricultural land. The communal sector, constituting 98 % of the agricultural population, had access to 49 % of the agricultural land.

b) Post Independence era (The Land reform process)

Since the year 2000, Zimbabwe's farming areas have undergone fundamental transformation under the Land Reform Programme. The resulting farm structure now comprises the following categories of farmers; Communal Area, Old Resettlement, A1, Small Scale Commercial, A2, and Large-scale Commercial farmers. The transformation has markedly increased the number of people with access to land.

The changed farm structure presents a number of challenges and opportunities. There are new and expanded demands for knowledge, given the large number of resettled farmers.

Table 2: Percentage Land Distribution after the land reform programme (1980-2008)

Farm Class	Land Tenure	Farms/Households	Area			
		Numbers	% of Total	(Million ha)	% of total	Farm sizes(ha)
Smallholder	Communal	1,100,000		16,400		13
	Old Resettlement	72,000		3.672		51
	A1	141,656		5.7		40
	Sub total	1,313,656	98	25 722	75.6	20
Small to Medium Scale Commercial	Old SSCS	8,000		1.4		175
	Small A2	14,072		1		71
	Sub total	22,072	1.6	2.38	7.2	109
Large Scale Commercial	Medium-Large A2	1,500		0.9		600
	Black LSCS	1.44		0.9		625
	White LSCS	1,377		1.2		871
	Subtotal	4,317	0.3	3	9	695
Corporate Estate	Company	657		1		1,522
	Church	64		1.041		641
	Parastatal	153		0.6		3.922
	Sub total	874	0.1	1.641	4.9	1.878
Transitional	Unallocated			557	1.7	
Total		1,340,909		33.3	100	

Source: Moyo and Yeros, 2005 (cited in World Bank: 2006), GOZ: 1982, GOZ: 1989, own calculations.

The land acquired has been redistributed under various models that are described below.

THE LAND REFORM PROGRAMME

i) Old Resettlement

Old Resettlement farmers have access to an average of 51 ha hectares and operate as a smallholder farming community.

ii) Model A1

Model A1 refers to farmers who are resettled on group basis, similar to the agrarian set up in the communal areas and Old Resettlement areas. This group is mainly constituted by former communal area farmers. Model A1 farmers operate as smallholder farmers with an average land holding of 5-6 hectares arable, 6ha communal grazing and 1 ha for homestead (13 ha per household).

iii) Model A2

Model A2 farmers refer to those farmers who are settled on an individual basis. These operate on a commercial basis. Model A2 has 14 072 small - medium farmers and 1500 medium to large scale farmers. Farmers in this group, numbering 15 572, have come from different sources, but largely constitute urban and rural elites as well as politicians (Moyo: 2004).

iv) The Large Scale Commercial Farmers (LSCF)

The large scale commercial sector is constituted by individual farm households, private companies, state parastatals and churches. Individual farm households include the remaining commercial farmers and the medium to large scale commercial farmers.

v) The Communal Sector

The communal sector has remained intact and has access to 16.4 million hectares of land. CA farmers are estimated at about 1 100 000, owning on average of 13 ha. The subsector occupies about 49 % of the agricultural land.

vii) Small Scale Commercial Sector

The Small Scale Commercial sector has remained intact and has access to 1.4 million hectares. By 1995, they numbered 8 000, with an average land holding of 175 ha. The subsector owns about 4 % of the agricultural land.

Water resources (including legislation and policies)

Based on average effective annual rainfall and land area, the internal annual renewable surface water resources produced in Zimbabwe are 11.26km^3/yr. The annual renewable groundwater resources are estimated at 6km^3/yr and overlap 5km^3/yr with internal surface water resources resulting in total annual internal renewable water resources of 12.26km^3/yr (FAO, 2005). Accounted flows for external renewable surface waters are 7.74km^3/yr (FAO, 2005) and the sum of the internal and external renewable waters gives total annual renewable water resources (TARWR) of 20km^3/yr. The total annual freshwater resources withdrawal in Zimbabwe is estimated at 4.21km^3/yr or 21.05% of TARWR meaning that Zimbabwe is water-stressed in terms of a water intensity use index greater than 20% (Kumar and Singh, 2005) or per capita water availability of less than 1700m^3/yr (Falkenmark and Widstrand, 1992). The apportionment of freshwater withdrawals is estimated as: agriculture (79%), domestic (14%), and industry (7%). The severity of water stress or scarcity is more pronounced in the low rainfall areas. Wastewater is therefore a water resource of greater importance in the low rainfall areas but has not been incorporated into the river system outline plans as a resource (Thebe, 2012) and it also plays an important environmental role in the high rainfall areas.

Water in Zimbabwe is generally managed through the Water Act [Chapter 20:24] that was enacted in 1998. The management of water is generally the responsibility of the Minister assigned by the President to exercise the functions stated in the Water Act [Chapter 20:24]. The Minister responsible for the administration of the Water Act is the Minister of Lands, Agriculture, Fisheries, Water, and Rural Development. According to Section 6 of the Water Act [Chapter 20:24], the general functions of Minister responsible for water are:

(a) to develop policies to guide the orderly and integrated planning of the optimum development, utilization and protection of the country's water resources in the national interest; and

(b) to ensure the availability of water to all citizens for primary purposes and to meet the needs of aquatic and associated ecosystems particularly when there are competing demands for water; and

(c) to ensure the equitable and efficient allocation of the available water resources in the national interest for the development of the rural, urban, industrial, mining and agricultural sectors.

Paragraph (c) of sub-section 1 of section 6 of the Zimbabwean Water Act generally sets the priorities for water allocation in Zimbabwe as water for primary purposes and municipal supply, water for industry, water for mining and energy, and lastly water for agriculture. Summarized, the Minister responsible for water guides the integrated planning, development, and management of water resources; seeks to achieve water security; and fairly allocates water resources.

Zimbabwean national water policy is primarily based on the IWRM framework based on the Dublin principles and is termed as "Dublin IWRM" by Muller (2015). There is generally no consideration of any other integrated approaches to manage water as envisaged in section 6(1)(a) of the Water Act [Chapter 20:24].

Other relevant pieces of legislation in the management of water include the Zimbabwe National Water Authority Act [Chapter 20:25], the Communal Lands Act, the Environmental Management Agency Act 20: 27], Urban Councils Act [Chapter 29:15], Rural District Councils [Chapter 29:13], Mines and Minerals Act [Chapter 21:05], and the Public Health Act [Chapter 15:17]. The Constitution of the Republic of Zimbabwe further provides for the right to food and water, as well as the right to environmental protection. This shows the high importance of water to food security and societal well-being. An assessment within the national water policy noted the uncoordinated approach to water management represented in the individual pieces of legislation.

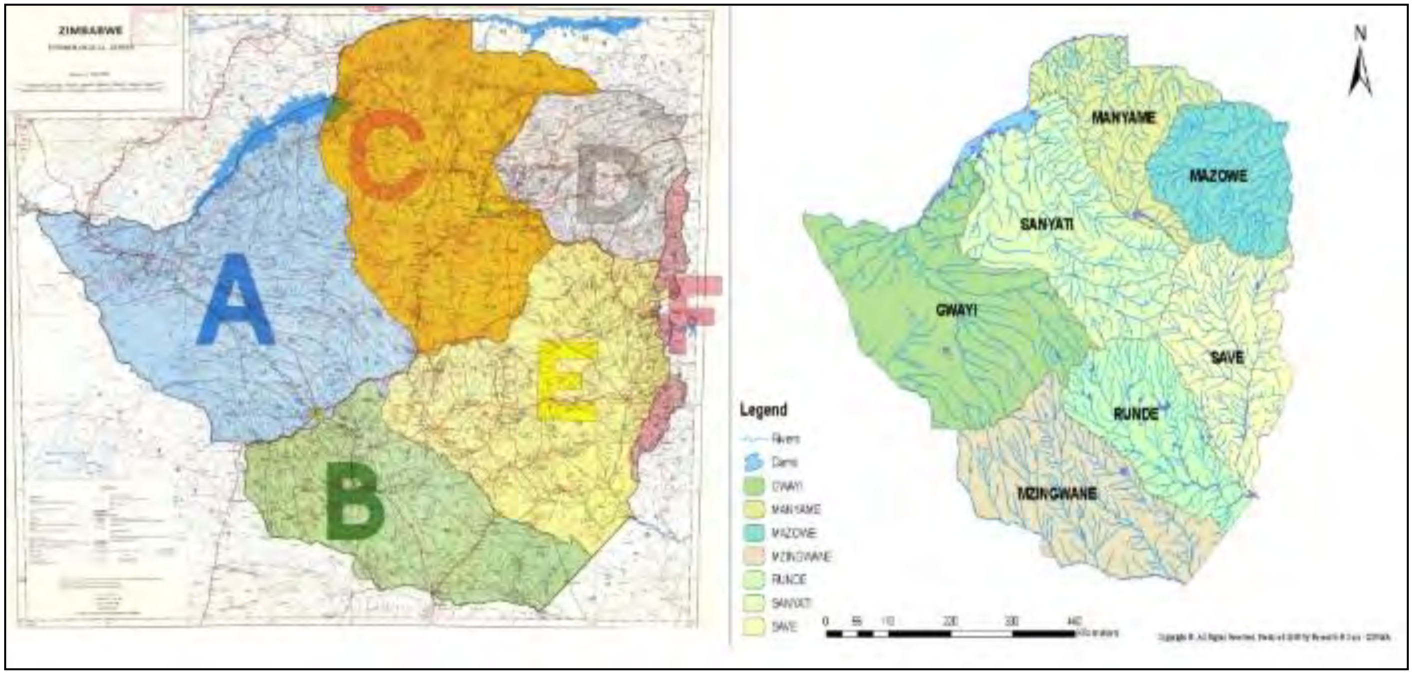


Figure2: Map showing the hydrological zones numbered A – F that were initially used as the unit for water management (courtesy of the Department of the Surveyor General) and the map of the seven catchment areas currently used as the unit for water management (courtesy of the Zimbabwe National Water Authority)

The catchment areas for water management in Zimbabwe drain into international river basins. Gwayi, Sanyati, Manyame, and Mazowe catchments (hydrological zones A, C, and D) drain into the Zambezi river that is managed by an international treaty through the Zambezi Watercourse Commission; Save and Runde catchments (hydrological zones E and F) drain into Save river forming the Pungwe and Buzi international river basins that are co-managed with Mozambique; and

Mzingwane catchment (hydrological zone B) drains into the Limpopo river basin that is managed by an international treaty through the Limpopo Watercourse Commission that has Botswana, South Africa, Zimbabwe, and Mozambique as riparian countries.

The collection of hydrological data started in the 1920s under the Division of Irrigation within the Department of Agriculture. Wurzel (1987) gives a detailed account of hydrology development in Zimbabwe. The hydrology branch of the Agricultural Research Council used to play an important part in the collection of hydrological data until its dissolution in September 1967 and absorption of its functions by the Hydrology Branch of the Ministry of Water Development.

The majority of water resources used for agriculture in Zimbabwe are surface water resources. Zimbabwe has reasonably developed surface water through dam construction. The total storage is about 9 billion m^3 that gives a per capita storage of about 640 m^3. This excludes the storage within the shared Kariba Dam that is used mainly for hydropower generation. Droughts and climate change limit the usability of Kariba Dam for agriculture. There are about 2200 dams in Zimbabwe with approximately 252 large dams. All large dams are owned and controlled by Government as a deliberate policy measure. Private dams are small to medium size and found on individual commercial farms. The groundwater potential is generally low in most areas of Zimbabwe. There are three major trans-boundary aquifers and these are jointly managed with Botswana and Zambia respectively. Groundwater is used mainly for domestic water supplies expect for the major aquifer regions and the alluvial aquifer zones where it is largely used for irrigation.

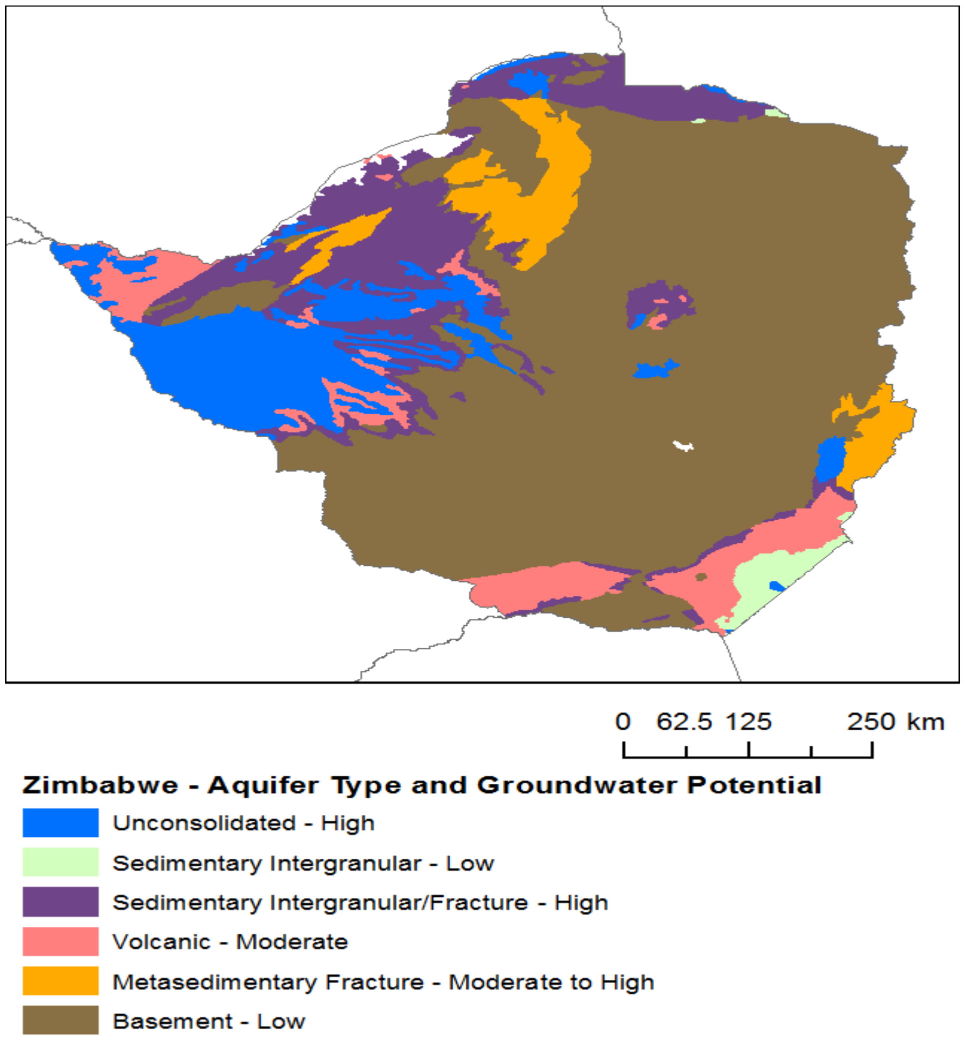


Figure 3: Map showing the groundwater potential across Zimbabwe with the majority of land having low groundwater potential. Map courtesy of UN IGRAC.

Irrigation and drainage

Irrigation in Zimbabwe has been practiced on a small-scale since pre-colonial times. There are traces of an ancient terraced system in Nyanga, Eastern Zimbabwe, with furrows, reservoirs and aqueducts, as well as evidence of historical irrigation in the Limpopo River catchment, and the Lowveld. However, major irrigation infrastructure development commenced with the building of large water storage works such as Mazowe dam during the colonial period. The colonial settlers initially inhabited the Highveld that has the head waters of most rivers and limited irrigation could take place there. Transport networks were also centered on the Highveld making it costly for farmers in the Middleveld to transport their produce to the markets that were on the Highveld. Irrigation development was also in the eastern part of the country where perennial rivers could be found. Irrigation development commence in the south-eastern and southern parts of the country in the 1930s when major dams began to be constructed. Irrigation projects were largely located on private farms. Public-funded schemes were established in the communal lands. Most of the construction in the 1930s to the late 1950s was concentrated on the eastern parts of the country. Public-funded communal irrigation scheme development largely commence in the south western parts of the country from 1960 – 1972. Ingwizi Dam that was to become the largest earthen embankment dam was constructed during this period. Historical accounts on irrigation development by some scholars usually overlook irrigation development in the south-western parts of the country during the period 1960 - 1972. Government continues to invest in public-funded communal irrigation schemes as a measure of drought impact mitigation and improved national food security since independence.

The developed area under irrigation was estimated at 220 000 hectares before the commencement of the land reform programme in 2000 with the bulk of the irrigated areas under private land in commercial farms (about 100 000 hectares) and at sugar estates and other plantations (about 53 000 hectares), with the remainder under public-funded communal irrigation schemes (10 000 hectares) and institutional irrigation schemes or Government agency estates (13 000 hectares). Government briefings point to a currently functional irrigation area of 176 000 hectares. Based on the food production deficit and that Zimbabwe is a net food importer, it is estimated that the area under full and functional irrigation control is in the region of 100 000 hectares of which about 50 000 hectares is in the private sugar estates and other plantations. This means that about 2.4% to 3.7% of Zimbabwe's cultivated area is under irrigation which is within the average for Africa in general. The African Union target is to have at least 7% of cultivated land under irrigation meaning that the irrigated area in Zimbabwe has to be doubled or nearly tripled to meet the development target. The Government estimated in 1930 that the area that could be developed through internal water resources was 250 000 hectares. This estimate was reviewed upwards by the FAO taking into consideration newer methods to estimate crop water requirements and the potential for irrigation development was stated as 300 000 hectares meaning that there is room to double or triple the irrigated area using the internal renewable water resources. Further dam construction would be required.

The area effectively under agricultural land drainage is estimated at 25% of the developed irrigation area. This means that 35 000 hectares is the drained area. Open surface drainage systems are the most widely used. There is limited reuse of agricultural drainage water.

Currently the Government of Zimbabwe is implementing the Accelerated Irrigation Rehabilitation and Development plan which is aimed at achieving vision 2030, through increase areas under irrigation, increasing crop production, ensure food security, employment creation, creation of raw materials for industry and improved economic activities around irrigation schemes. The Accelerated Irrigation, Rehabilitation and Development Plan targets a cumulative 400,000 hectares, by 2030 from the current estimates, comprising rehabilitation of 71,000 hectares, 26 000 smallholder irrigation schemes and 45 000 A1 and A2 and development of 183,000 hectares of new irrigation.

ICID and the Zimbabwe National Committee of ICID

The Zimbabwe National Committee of ICID assumed membership of ICID in 1955. It is one of the longest serving African national committees of ICID. The National Committee was formed under the then Department of Irrigation that later transitioned to the Department of Water Development in 1963. The functions of the national committee were later taken over by the Department of Conservation and Extension in the early 1970s. The Department of Conservation and Extension later transitioned into the Department of AGRITEX that had an irrigation branch off-shooting into the current Department of Irrigation that steers the National Committee among other national stakeholders in the irrigation and drainage sector. These stakeholders include private irrigation and drainage companies represented by the Irrigation Institute of Zimbabwe, Zimbabwe Irrigation Association, Agricultural Dealers and Manufacturers Association; research institutions and universities inclusive of students; farmers' organizations; and non-governmental organizations. The Zimbabwean representative who attended ICID meetings between 1955 and 1962 was James Savory, the Director of Irrigation. His deputy who also succeeded him as Director, Mr. H. Wallis, attended the 1963 ICID Congress and International Executive Council meeting in Tokyo where Zimbabwe's proposal to host the 1964 ICID International Executive Council meeting in Harare was accepted. The 1964 ICID International Executive Council meeting took place in Harare during the month of May and was preceded by a two-day tour of Great Zimbabwe, Kyle Dam (now Lake Mutirikwi), and the Triangle and Hippo Valley sugar estates that are Zimbabwe's largest irrigation schemes. After the meeting the delegates were taken on a tour of the Mazowe irrigation areas, Victoria Falls, Hwange National Park, and Lake Kariba. 31 international delegates attended the ICID International Executive Council meeting in Harare compared to 150 international delegates who attended the ICID Congress and IEC meetings in Tokyo the previous year perhaps due to the long travelling distance from some countries in Asia who usually participated in ICID meetings. The Ministry of Water Development made its representation of Zimbabwe at the 1967 and 1968 ICID International Executive Council meetings before ceding over responsibilities to the Ministry of Agriculture. The Ministry of Water Development placed its focus upon the activities of the International Commission on Large Dams (ICOLD) that has a co-operation agreement with ICID. That co-operation agreement should be implemented at a national level too for more effective collaboration between the respective national committees of ICOLD and ICID.

It is important to note that the greatest water infrastructure achievements in Zimbabwe including the construction of Kariba Dam and Lake Mutirikwi (formerly Kyle Dam) happened during the era when Zimbabwe was a fully fledged member of ICID through the then Department of Irrigation. Several large scale irrigation schemes and major communal irrigation schemes particularly in the southern parts of the country were also built during this period.

The Zimbabwe Committee on Irrigation and Drainage (ZwCID) has responsible activities under Goal D: Enable Cross Disciplinary and Inter-Sectoral Engagement of the ICID Action Plan 2017-2021 to attain the ICID Vision 2030 and is set to contribute to "Build free or low-cost and widely accessible water/irrigation/drainage technical information platform". It is envisaged that ZwCID will make its anticipated full contribution to the realization of ICID Vision 2030.

The Zimbabwe Committee on Irrigation and Drainage (ZwCID) is presently chaired by Engineer Bezzel Chitsungo, following the death of the former Director for Irrigation Development, Dr. Conrade Zawe. The management team holds positions on a voluntary basis and also includes three vice Chairpersons, a Treasurer, a Secretary, and two committee members. The current secretary is Mr Thubelihle Thebe. The current foreign currency shortages in Zimbabwe hinder the uninterrupted payment of annual subscriptions by ZwCID and continuous full membership of ICID. Efforts are underway to secure funding for full revival of ICID memebership. There are presently no representatives of the ZwCID in major ICID work bodies except of ICID- YP in which Eng. Chitsungo was recently nomitated as coordinator. Zimbabwean representatives have not yet been elected to ICID Office Bearer positions.

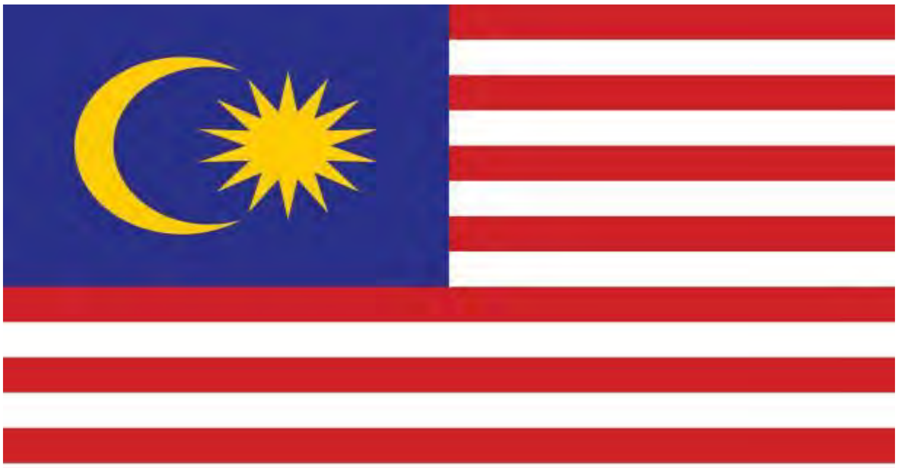
24 th ICID Congress

03-10 October 2022, Adelaide, South Australia

SYMPOSIUM

Theme : Integrated Approaches to Irrigation Management in the Future

MALAYSIA COUNTRY PAPER



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1.0 INTRODUCTION

The agriculture sector plays an important role in Malaysia's economic development – providing rural employment, uplifting rural incomes, and ensuring national food security. About 22 percent of the land in Malaysia is utilized for agriculture.

As early as 1932, irrigation facility was executed by the hydraulic unit of Public Work Department (JKR). Department of Irrigation and Drainage (DID), which previously known as Jabatan Parit dan Tali air (JPT), was establish to fulfill agricultural land development and to serve drainage and irrigation functions.

Jabatan Parit Dan Tali Air
(1932 to 1989)

Jabatan Pengairan Dan Saliran
(1989 to 1992)

The irrigation history in Malaysia can be traced back as the end of the eighteenth century. Starting from Kerian Irrigation scheme in Perak constructed in 1982, there are currently 932 irrigation schemes covering 413700 ha are currently operated throughout Peninsular Malaysia including 20 irrigation schemes in Sabah. These scheme comprising eight granary schemes (210 500 ha), 74 mini-granary (29 500 ha) and 850 non-granary schemes (100 633 ha). The non-granary schemes are scattered all over the country and their sizes vary between 50 ha and 200 ha (Norsida & Sami Ismaila Sadiya, 2009).

Since the formation of the Department of Irrigation and Drainage in 1932, irrigated areas for paddy cultivation have progressively increased. By the year 1960, about 200 000 ha had been developed, the emphasis then being to supplement rainfall for single crop cultivation. During the 1960's and early 1970's, the advent of double cropping of rice cultivation required the development of adequate water resources for the off season crops. During the 1980's, the priority for irrigation took a new dimension with the need to rationalise rice cultivation relevant to production cost and profit considerations (Alam, et.al. 2011). The government evolved a policy to confine irrigation development to the eight large irrigated areas in the country, designated as granary areas totalling 210 500 ha and comprising the irrigated areas of Muda, Kada, Seberang Perai, Trans Perk, Northwest Selangor, Kerian Sungai Manik, Besut and Kemasin-Semerak.

During Malaysia Fifth Plan (1986-90), there were reduction on rice self-sufficiency goal from 80-85 percent of consumption to 60-65 percent of consumption by year 2000, and concentrated public investments in eight "granary" areas covering 220,000 ha. The continuing national decline in rice production shows that even with high subsidies ($220 per ton in 1988), the reduced self-sufficiency targets are not being achieved. Gross paddy production fell from 2.1 million tons in 1979 to 1.6 million tons in 1987 and has fallen further since. Rice consumption fell from 1.34 million tons in 1979 to 1.23 million tons in 1987. In the 1980s, the Government took a bold decision to confine further irrigation development works to the eight major granary areas of the country. Irrigation and drainage facilities were intensified and extended to the tertiary level to improve on-farm water management to enable the cultivation of high yielding varieties of rice. This period also saw the successful introduction of farm mechanization, and the rapid replacement of labour-intensive transplanting to direct seeding methods (Radam & Ismail. 1995). In the 1990s, major efforts were made in the upgrading of infrastructures to support farm mechanization and direct seeding, including improvement to farm roads, field drainage and land levelling. Estate type management for more organized and economic operation as against individual farmer operation was promoted. At the same time, some of the smaller irrigation schemes which are unattractive for rice cultivation are encouraged to diversify into alternative non-paddy crops and aquaculture. The total physical paddy area (covering irrigated and non-irrigated) in Malaysia is about 598,483 ha in 1993. About 322,000 hectares or 48 percent of the total paddy areas in the country are provided with extensive irrigation and drainage facilities while the remaining are rain fed areas. Of the irrigated areas, 290,000 hectares are found in Peninsula Malaysia, 17,000 hectares in Sabah and 15,000 hectares in Sarawak. About 217,000 hectares of the irrigated paddy areas in Peninsular Malaysia have been designated as main granary areas while another 28,000 hectares located all over the country are classified as mini granary areas. The paddy growing area is expected to decline with time as a result of conversion of paddy land for other land use including urbanisation.

2.0 IRRIGATION HISTORY

Malaysia has gone through several distinctive phases which were directly linked to the changing trend of the rice industry in the nation. Rice is said to have been cultivated in Malaysia for the last 2,000 years. The rice areas were generally located in small pockets in the floodplains adjacent to the banks of major rivers. Technically, the irrigation systems were rudimentary with dual-function channels, i.e., irrigation during the growing months and drainage towards the end of the planting season. Water distribution within the rice areas was from plot to plot with irrigation relying largely on rainfall.

In Malaysia, there has been a long history of planting rice under rainfed conditions in pocket areas located along the flood plains of rivers. In the early 1900s, large scale irrigation systems were first introduced, notably in the Kerian Irrigation Scheme and the Wan Mat Saman Scheme. In 1932 the Department of Irrigation and Drainage (DID) was established and together with the Department of Agriculture (DOA), formed the prime movers of organized and systematic irrigation development in the country. These include the development of new areas as well as upgrading of existing schemes. In the 1960s, double cropping was widely introduced to meet the twin objectives of increasing food production and income levels of the rural poor. Water resources development became an important component of irrigation projects with the construction of storage dams, barrages and pumping stations, followed by extensive network of irrigation canals, drains and farm roads.

There were also notable successes of large-scale irrigation systems such as the Wan Mat Saman Scheme in Central Kedah (28,700 ha) and the Kerian Irrigation Scheme in the North Perak (23,400 ha) which had the first irrigation reservoir in the country. Wan Man Saman Canal at one time is the longest canal in Malaysia connecting Sungai Kedah at Alor Star, the Kedah state capital towards the mountainous range of Kedah Peak (Gunung Jerai) where the water source originates. Anak Bukit River is one of the river that flow through Alor Star, behind the Masjid Zahir. It connects between Kedah River and the Wan Mat Saman Canal. The construction of the canal was a “transfer of technology” between the Kingdom of Thailand and Kedah. Dato’ Wan Muhamad Saman invited surveyors from Thailand to help in the construction of the canal after a visit to Bangkok. The construction of the canal was a monumental achievement during its time. When the canal completed in 1895, it is 22miles in length, width of 24 feet and has a depth of 5 feet. It is the longest hand constructed canal in Malaysia and it continues to be in service until today.

Wan Mat Saman Canal

The Wan Mat Saman Canal was under the care of the State of Kedah Drainage and Irrigation Department (DID). When Muda Irrigation Project was developed in the First Malaysia Plan (1966-1970), the canal was incorporated in the design by the Consultant to serve as one of the major trunk drain in the reticulation system. Since then the canal serve as drainage system for paddy cultivation, as well as urban drainage system for small town. The canal was then handed over to Muda Agricultural Development Authority (MADA) for operation and maintenance from the Kedah State DID.

3.0 IRRIGATION ISSUES AND CHALLENGES

Malaysia has a long tradition of support for irrigated rice development, both to retain a degree of self-sufficiency in rice production and to help alleviate poverty among smallholder rice farmers. Currently, irrigation is predominately for paddy cultivation and a minor position for the cultivation of cash crops. Paddy cultivation is mostly carried out by individual farmers working on small plots of about 1 to 1.5 ha. Irrigation facilities for double cropping are mainly focused on the eight main granary schemes and the 74 mini-granary schemes, with an average cropping intensity of 170%. The current irrigation efficiency is around 35 to 45% with water productivity index of about 0.2 kg of rice/m3. The average yield for irrigated rice in 1994 was 3.8 T/ha. In major irrigation schemes the flooding type of irrigation is generally practiced for paddy cultivation where the water depth can be controlled individually by the farmers.

Major irrigation schemes are designed with proper farm roads to cater for farm mechanisation especially for ploughing and harvesting. Most of the irrigation schemes are provided with separate drainage facilities.

i. Irrigation Operational Performance

Irrigation is always associated with proper water resources, mainly from river and rainfall. Although Malaysia is rich in waters, there are certain dry months (May-August) where water can be dropped creating so called “agriculture drought”. Therefore, to ensure continuous water supply, all irrigation schemes operated must be at operational performance. However, some of this irrigation works are below expectations.

ii. Inefficient agricultural water use

Increased competition for water between sectors already affects agriculture in Malaysia and the trend is towards an intensification of the problem due mainly to the rapid growth of the domestic and industrial sectors. Water scarcity and the interdependency between water use sectors are pushing Malaysia to develop integrated water resources management programmes. Water quality and the increased importance of water conservation and protection are also major growing concerns. Agriculture uses about 68% of total water consumption in Malaysia but irrigation efficiency is 50% at best in the larger irrigation schemes and less than 40% in the smaller ones. There is also no recycling of irrigated water. All these factors challenge the sustainability of water resources. The failure to develop adequate operation and maintenance mechanisms to ensure the sustainability of the irrigation schemes (mostly large, public schemes) has led to irrigation management transfer or increased participation of users in the management of the schemes.

4.0 WAY FORWARD

I. Development or improvement of water users’ group (WUG) associations.
II. Improve Irrigation Operational Performance
III. Increase efficiency in agricultural water use.

5.0 CONCLUSION

The challenge to produce more rice with less water, economically and in ways that will be adopted by farmers in a context of reformed agricultural and water policies and integrated water resources management appears formidable yet is vital for the food security of the Region. This will require considerable investments in economic as well as human resources.

A range of options are available for increasing the productivity and efficiency of water in surface irrigated rice ecologies. More radical options departing from traditional systems are also available and may be required. Over the past decades, substantial gains have already been achieved and farmers have demonstrated that, if they are empowered, have the economic incentives and an adequate production tool and irrigation service, they could quickly adopt substantial changes in their water management practices. However, new institutional and technical approaches have had limited impacts in the field.

The most appropriate strategies to adopt will vary over time and space and will have to be designed carefully with the involvement of the farmers but will need to be resolutely forward-looking and perhaps revolutionary. Identifying the policies, management practices and technologies needed at farm, system and basin level will require a multi-disciplinary approach, substantial investments in collection and analysis of new and relevant information and research, as well as constant evaluation of present approaches and practices.

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