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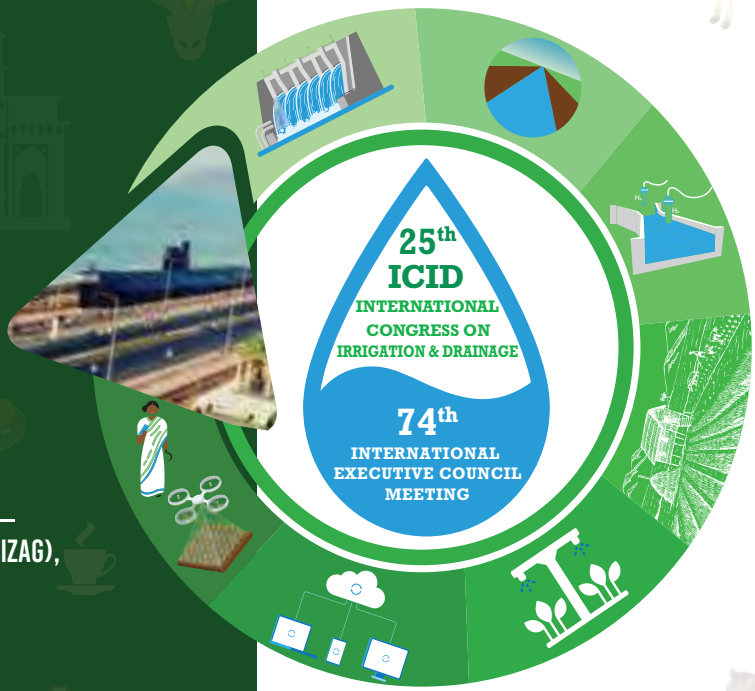

PROCEEDINGS

International Symposium on Pathways and Technologies for Modern Irrigation Services

TACKLING WATER SCARCITY IN AGRICULTURE

LUTTER CONTRE LA PENURIE D'EAU DANS L'AGRICULTURE

INTERNATIONAL COMMISSION ON IRRIGATION AND DRAINAGE
COMMISSION INTERNATIONALE DES IRRIGATIONS ET DU DRAINAGE

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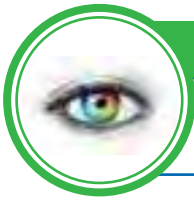
The International Commission on Irrigation and Drainage (ICID), established in 1950 is the leading scientific, technical and not-for-profit Non-Governmental Organization (NGO). The Commission through its network of professionals spread across more than a hundred countries, has facilitated sharing of experiences and transfer of water management technology for over six decades. ICID supports capacity development, stimulates research and innovation and strives to promote policies and programs to enhance sustainable development of irrigated agriculture through a comprehensive water management framework.



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- **E** Encourage Research and Support Development of Tools to Extend Innovation into Field
- **F** Facilitate Capacity Development

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Proceedings

International Symposium on
Pathways and Technologies for Modern Irrigation Services

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Preface

The irrigation and drainage sector (I&D) has a long history of development of schemes to support irrigated agriculture in a wide range of environments and climate settings. Irrigation and drainage have contributed to the development of thriving rural economies and the provision of increasing food security across the world. However, in many locations, the maintenance, operation, and management (MOM) of too many irrigation schemes have led to the rapid decline in the services provided by the system and in accelerated deterioration of the infrastructure. This has resulted in I&D to be characterized by a "build-neglect-rehabilitate" syndrome, where systems are not adequately maintained, and frequent need for additional investments to rehabilitate the infrastructure to an operational level.

Water scarcity and the resulting need for its efficient use is a global challenge. In some countries there are also increasing land use intensification impacts on water quality driven by irrigation. The investment in irrigation systems is considerable. For example, in a modern agricultural context the irrigation system investment behind the farm gate is frequently greater than the water storage and distribution infrastructure. Ensuring that irrigation schemes are designed, installed, managed, and maintained well is essential if production gains, subsequent direct, indirect, and induced economic benefits are to be realised, all whilst managing direct and indirect environmental impacts. It may be expected that in the coming period most of the activities in irrigation will be in the field of modernisation and enhancement of existing schemes. For some schemes revitalisation will be required, before modernisation activities can be undertaken, or such activities may be undertaken in combination. The revitalisation concerns the broader policy and strategy aspects of Governments with respect to actual activities with respect to the modernization of irrigation schemes.

With accelerating changes in the social and economic environment and the impacts of climate change, the build-neglect-rehabilitate cycle is neither a sustainable nor an adequate approach to provide the services essential for sustainable irrigated agriculture. Furthermore, simply rehabilitating existing infrastructure and modes of operations will not provide appropriate services as the requirements of the irrigation systems evolve to meet changing climate and social needs. Despite these socio-economic and environmental drivers there are no internationally accepted standards and associated codes of practice associated with irrigation design, installation, and evaluation.

The ICID Working Group on Modernization and Revitalization has proposed that modernization is defined as the "Process of upgrading infrastructure, operations and management of irrigation systems to sustain the water delivery service requirements of farmers and optimize production and water productivity (ICID, 2016)". Modernization focuses more attention on the needs of farmers as the core objective of irrigation operations and modernization efforts. Irrigation modernization undertakes technical and managerial upgrading (as opposed to mere infrastructure repair or restoration) of irrigation systems combined with institutional reforms, with the objective to improve resource utilization (labour, water, economic, social, and environmental assets) to provide improved water delivery service to farms. Irrigation systems not only include the physical infrastructure for agricultural development, but also include stakeholders' participation as well to holistically improve the irrigation systems for all the beneficiaries.

The international symposium provides a platform for irrigation and drainage professionals and other stakeholders to share their knowledge and experience of approaches to modernization for sustainable agriculture water management. Participants will deliberate on aspects of modernization of irrigation and drainage services, including:

(i) Current status of national irrigation sectors

(ii) Future investment in irrigation infrastructure modernization and management

(iii) National factors affecting irrigation management, including water policy, institutions, and capacities.

(iv) Prospective areas for future management: resource management, supply and demand management, infrastructure management, on-farm water management, climate change adaptation and disaster risk reduction, institutional and policy reforms, data management, technological interventions, capacity development, gender issues, among others specific to local contexts

It is my great pleasure to thank all the authors and members of the Working Group on Modernization and Revitalization for their dedication to preparing the papers that are included in these proceedings. In addition, I express my sincere appreciation and gratitude to Er. Balasaheb Anantrao. Chivate, Director (Technical), and the ICID Central Office for their support in the preparation of these proceedings and the arrangements for the symposium in Vishakhapatnam.

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ICID Guidelines on Modernization

VPH Ian W Makin[1]

Abstract

The ICID Working Group on Modernization and Revitalization of Irrigation and Drainage Services (WG_M&R) was established in 2015 (ICID, 2015) with the objective of leading: (i) a review of current approaches to modernization of these services, and (ii) the development of ICID Guidelines on Modernization. This paper summarizes the key activities of the working group on Modernization and Revitalization of Irrigation and Drainages Services (WG_M&R) and introduces the major output of the group – the ICID Guidelines on Modernization and Revitalization of Irrigation and Drainage Services. The paper presents an overview of the developing Guidelines and proposes future activities to maintain and further develop ICID leadership on the increasingly important issue of ensuring appropriate irrigation and drainage (I&D) services to support agricultural systems in the context of increasing competition for access to water resources and the developing challenges posed by climate change.

Introduction

The irrigation and drainage sector (I&D) has a long history of development of schemes to support irrigated agriculture in a wide range of environments and climate settings. Irrigation and drainage have contributed to the development of thriving rural economies and the provision of increasing food security across the world. However, in many locations, the maintenance, operation, and management (MOM) of too many irrigation schemes have led to the rapid decline in the services provided by the system and in accelerated deterioration of the infrastructure. This has resulted in I&D to be characterized by a "build-neglect-rehabilitate" syndrome, where systems are not adequately maintained, and frequent need for additional investments to rehabilitate the infrastructure to an operational level. Irrigation needs to be revitalized and modernized to meet the challenges of agriculture in the 21st century.

Public and private sector investment in irrigated agriculture is considerable and diverse. For example in the modern agricultural context, investment in irrigation behind the farm gate is frequently greater than for the water storage and distribution infrastructure required to deliver water to the farm. Ensuring that irrigation schemes are designed, developed, managed, and maintained efficiently and effectively is essential to ensure the gains in agricultural productivity and benefits to farmers and communities of the direct, indirect, and induced economic benefits are fully realized. In parallel, irrigation is increasingly faced with managing direct and indirect environmental impacts and the maintenance of a range of ecosystem services.

This paper summarizes the key activities of the working group on Modernization and Revitalization of Irrigation and Drainages Services (WG_M&R) and introduces the major output of the group – the ICID Guidelines on Modernization and Revitalization of Irrigation and Drainage Services.

ICID Working Group Modernization and Revitalization of Irrigation and Drainage Services

To explore the current and developing state of knowledge on irrigation and drainage services, the ICID established a new working group WG_M&R in 2014. at 66th IEC meeting in Montpelier, France (ICID, 2015). The objectives established for the working group were to investigate, analyse, disseminate information on new developments and to formulate recommendations with respect to:

(i) Planning and preparation for modernization and revitalization of irrigation schemes;

(ii) Interaction between modernization, revitalization and required operation and maintenance;

(iii) Cost sharing for modernization, revitalization and required operation and maintenance; Institutional and organizational framework required for modernization, revitalization and operation and maintenance;

[1] Chair - Working Group on Modernization and Revitalization of Irrigation Schemes (WG-M&R)

(iv) Methods and techniques of lining of conveyance and distribution canals;

(v) Canal control systems with respect to their automation, using internet, mobile communication and remote monitoring in canal operation;

(vi) Modification to improve communication, operational capacities and flexibility in operation and maintenance of systems; and

(vii) Standardization and codes of practice in irrigation systems.

To address the broad canvas of issues presented to the WG_M&R in its mandate, the WG adopted a working definition of modernization, drawing from work developed by the International Water Management Institute (IWMI) in collaboration with the Asian Development Bank (ADB) and Lahmeyer (consultants) under the More Food- Less water project (ADB 2011). This definition is designed to encourage a stronger focus, throughout the design, implementation, and operational phases of an irrigation modernization program, on the needs of farmers that utilize the services provided by the irrigation system.

Modernization is the process of upgrading infrastructure, operations, maintenance, and management of irrigation systems to sustain water delivery services required farmers and optimize production and water productivity

This definition distinguishes modernization and revitalization investments from the, historically more prevalent, investments in rehabilitation of irrigation schemes which tended to give a higher emphasis on reconstruction and upgrading of infrastructure and lesser focus on improving services to farmers. The definition encapsulates concepts that distinguish “modernization” of irrigation services from “rehabilitation” of irrigation systems which are expanded as:

(i) “process” reflecting the need that modernization of systems should be a continuous exercise to enable incorporation of future changes in the irrigation system and service requirements of the farmers. Ideally the process will align with existing government development and budgetary timeframes and systems;

(ii) “upgrading” means improving beyond what is existing; not replacing or rehabilitating. It means applying design best practices to infrastructure to optimize operation requirements and maximize system performance and efficiencies;

(iii) “infrastructure” means all physical assets related to the irrigation system, including headworks, conveyance systems, drainage systems, monitoring systems, communication systems, farm and access road networks, operation buildings etc.;

(iv) “operations, maintenance and management” means all human resources and management processes responsible for managing, operating and maintaining the irrigation system including ground and surface water management, and the associated physical infrastructure;

(v) “irrigation system” encapsulates all physical and non-physical components that contribute to convert water and nutrients into food and fibre. This includes the infrastructure, water resources, agency staff, farmers, services providers, supply and market chains required to enable farmers conduct a viable enterprise, whether for subsistence or in active engagement with external markets;

(vi) “sustain” means that the irrigation system will continue to deliver a defined level of performance after upgrading. This includes managing the water resources to: (i) account for reallocations to other users, (ii) prevent adverse depletion of land and water resources, and (iii) enhance resilience to climate variability and adverse impacts anticipated from climate change. It also means ensuring that all costs relating to management, operation, maintenance, and asset depreciation of the system are affordable and are fully covered through either government, user (farmer), or private sector financing;

(vii) “water delivery service requirements of the farmers” means ensuring reliable, adequate and flexible supply of water as agreed with farmers allowing them to maximize water and agricultural productivity. This requires farmers to be involved in planning, design and operation of the irrigation system, and in routine water management decisions;

(viii) "optimize production and water productivity" means farmers must endeavour, and be supported through technology transfer and extension services, to optimize the productivity of their land with the available water.

In this definition, modernization is not limited to the introduction of modern hardware and/or software techniques but involves fundamental transformation of the way in which the business of irrigated agriculture is done. In most cases, modernization of irrigation infrastructure and services will be a more relevant and cost-effective investment than rehabilitation, or restoration, of the original infrastructure – although a more complex undertaking often involving multiple stakeholders and agencies than previous approaches.

To explore the experience of the ICID membership with modernization the WG_M&R have organized workshops and presentations at each of the ICID annual conferences since 2015, except for the disrupted events during the COVID pandemic (2020, 2021). The titles of cases studies presented are given in **Annex 1**, and which are available on the ICID website, ICID 2023).

What should Modernization Achieve?

Whether implemented by individual or groups of farmers, national irrigation agencies, and/or bilateral or multilateral funding institutions, any investment in irrigation modernization must establish clear objectives that are recognized and accepted by all the key stakeholders. As noted above, modernization of irrigation services can be distinguished from irrigation rehabilitation by the adoption of a broader canvas of interventions which encompass more than rehabilitating damaged or inadequately maintained infrastructure or the introduction of modern technologies such as remote monitoring and control systems.

Irrigated agriculture is, in many cases, the largest user and consumer of water resources in a river basin. However, these resources are increasingly contested by urbanization, industrialisation, and climate change. In addition, increasing recognition of the environmental and cultural value of environmental services that are also dependent on these resources mean that all users must be responsible and productive users of the water allocated to their sector, this includes irrigated agriculture.

Irrigated agriculture is central to rural employment and food security in many of the ICID member countries; however, the sector is often considered to be underperforming despite the substantial investments. Improving the productivity and efficiency of water use in irrigated agriculture will involve (i) investing in modern irrigation infrastructure, (ii) adopting enabling policies that correctly price the opportunity cost of water, and (iii) strengthening institutions for more efficient and sustainable water management.

The WG_M&R recommends that, in the general case, the objective of a modernization program for irrigation and/or drainage systems should be to establish the necessary infrastructure, control and management systems to provide for the sustainable water delivery services required farmers to optimize agricultural production and water productivity**.** However, sustainable does not imply that the services are unchanging, but rather a water delivery service that evolves with the requirements of the local agricultural systems within the water resources environment in which the irrigation services are embedded. A modern irrigation service provider will implement management and control systems that enable increasingly flexible water delivery (and in some cases, drainage) services that are responsive to evolving farming and wider community needs.

ICID Guidelines on Modernization of Irrigation and Drainage Services

The WG_M&R was tasked with identifying case studies and developing guidelines on modernization of irrigation and drainage services for use by the irrigation profession. In response workshops, symposia, and meetings of WG members have been organized over the period since it first met in Montpelier in 2015 (ICID2015). The members of the WG_M&R (Annex 2) have each contributed their knowledge and thoughts about important aspects of modernization of I&D services and have contributed to development of the initial draft of the proposed ICID Guidelines. The following sections provide an overview of the contents of the version 1 of guidelines that are expected to be available on the ICID website from early 2024.

The publication will include a short preface by invited sector specialists. This is followed by an Executive summary that provides an overview of the key findings and recommendations from the WG_M&R, including Key Messages and Action points for professionals involved in the implementation of modernization and revitalization strategies.

Introduction - Modernization and revitalization of services is not only about infrastructure and is unlikely to be a one-shot exercise (Burt,2011). Systems are dynamic, modernized systems must be able to evolve in a changing operational environment. These changes may be caused by changes in the agricultural systems served, developing social expectations, changing national and international economic situations, emerging changes in water resource, and climate changes.

While rehabilitating or modernizing infrastructure and strengthening institutions might be central components of a modernization process, it is the vision, drive, and leadership of those managing the process that make it work (Dankova, R et al. 2022).

Modernization and revitalization of irrigation and drainage services

Definition of Modernization – As set out above, modernization is a process that will be an on-going 3exercise of improvement and upgrading of the irrigation and drainage systems to provide the services required by farmers and the wider community.

Applicability of different M&R strategies – water management for agricultural production is implemented in a wide variety of settings from arid to humid climates, different farming systems and scales, and across a wide variety of cultural and institutional settings. It is therefore obvious that a single approach to modernization will not be always appropriate in every location and time. Clearly a “One size” does not fit all situations, it may be that a revitalization of the organization may be required before modernization. It must be recognized that, in most cases, modernization will not be a one-shot activity but must involve a process over time.

Definition of Institutions and Governance arrangements – At each stage of the modernization process, it is essential to understand the system specific current, and potential, institutional and governance arrangements. A careful stakeholder analysis is essential to identify the roles and responsibilities, constraints, and opportunities that each group of stakeholders represent to achieve sustainable advances in water services for the agricultural system. A change management program may well be required to support the transformation of the institutions involved in the systems.

Definition of performance measures - Improvement of the functions and measures to avoid deterioration of irrigation and drainage facilities are generally included in modernization programs. Performance measurements apply to be applied to both renewal projects and individual facility evaluations. Five evaluation criteria from the Project Cycle Management (PCM) method are recommended based on the Overseas Economic Cooperation Fund (OECF) Development Assistance Committee (DAC) processes. These are also used in the overseas development assistance in Japan. The criteria are: (a) Relevance, (b) Effectiveness, (c) Efficiency, (d) Impacts, and (e) Sustainability. Specific definitions of performance measurement and evaluation criteria are proposed in consideration of the characteristics of the irrigation and drainage projects.

Diagnostic approaches to design of interventions - The FAO MASCOTTE diagnostic tools are recommended for work leading to the design of investments in irrigation systems to enable greater uniformity in the assessment of system conditions and selection of strategies to upgrade services. In addition to the assessment of the condition and performance infrastructure and management systems using MASCOTTE, the performance of the agricultural system served by the irrigation system should be assessed by remote sensing to identify where opportunities exist to improve performance, at field, farm, tertiary or main distribution systems. To complement the MASCOTTE approach, Steely and Makin (2023) have proposed a diagnostic framework to guide the assessment of the requirement for interventions with a focus on the impacts on water users. (Figure 1)

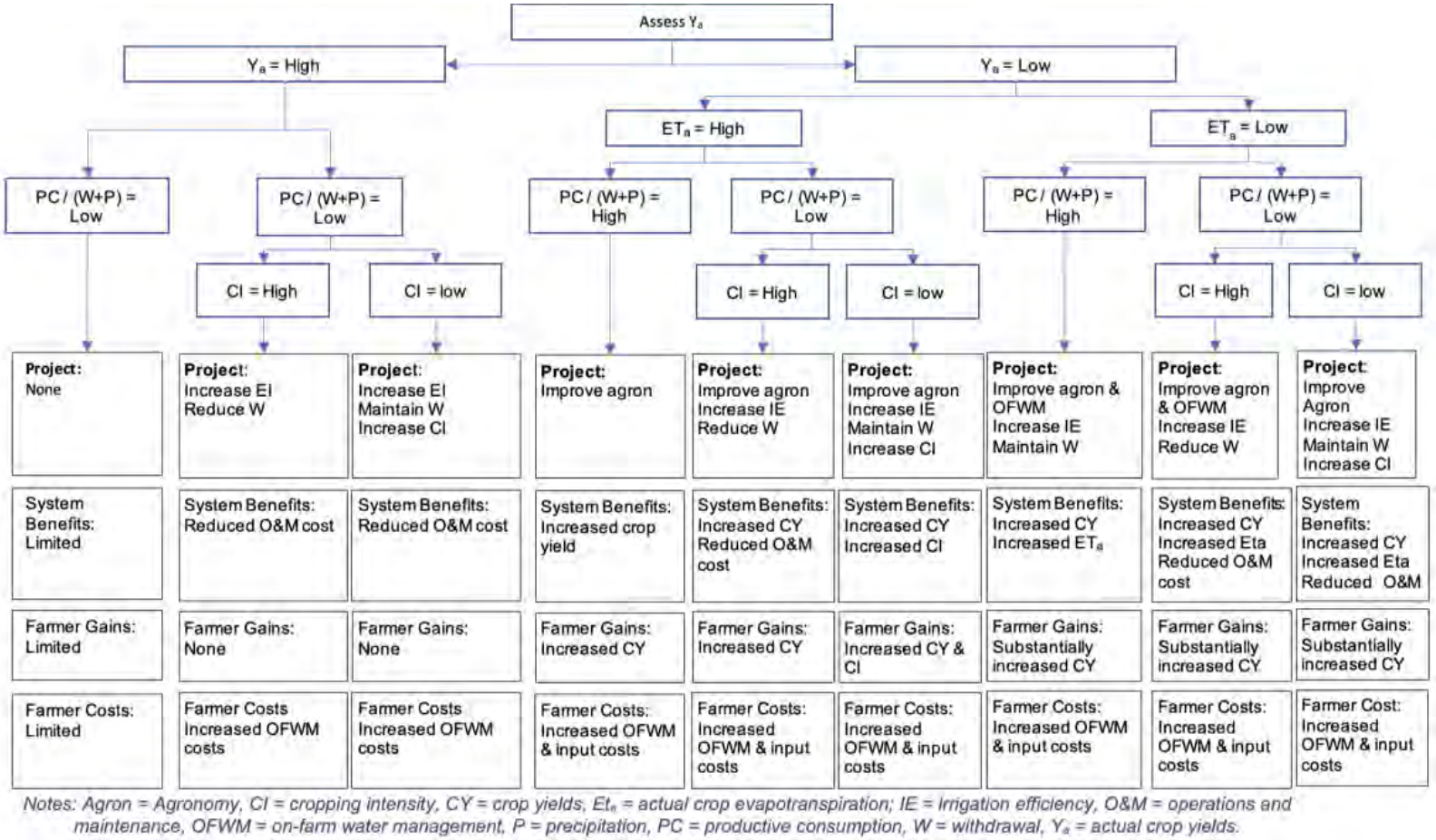

Figure 1. Irrigation system crop water productivity performance assessment and diagnosis framework

Approaches to selection of modernization interventions – While focussing on the objective of providing water users with a responsive service, investments in I&D modernization must also provide value for money and show an economic return for the investors. This is true whether the investment is by individual farmers, irrigation estates, government agencies or the bilateral and multilateral development organizations. The guidelines will include recommended approaches to evaluating alternate modernization investments to assist the investors choose which interventions to prioritize.

Irrigation and drainage services – getting relevant stakeholders involved.

This section presents guidelines and recommendations on getting the relevant stakeholders involved and achieving effective stakeholder engagement in an irrigation modernization project, addressing:

- who are the stakeholders and their roles and responsibilities
- the need to involve stakeholders
- stakeholder engagement plan
- stakeholder engagement challenges, considerations, and guidelines
- summary and key recommendations

There are many stakeholders involved in any irrigation modernization project. The stakeholders will vary depending on the country/location of the project, but will generally include; (i) Funding Agency(ies), (ii) Project Implementing Agency, (iii) Other Government Agencies, (iv) Individual Farmers, (v) Farmer-Led Organizations (WUAs, etc.), and (vi) Other Stakeholders.

The development of human capital and the capacity to effectively operate, manage and maintain irrigation infrastructure is central to successful irrigation scheme modernization.

With multiple stakeholders involved (as above), and differing roles and responsibilities of each stakeholder group in the overall OM&M of the irrigation scheme, it is essential to involve the stakeholders in the project to have any chance of success. Stakeholders need to be involved in both project planning and implementation. A top-down approach where all decisions are made by the Government entities has not produced desired results in the past and cannot be expected to in the future. Therefore, early, and effective stakeholder involvement in each stage of the modernization process is critical to the success of the initiative. Stakeholders can make or break the success of any irrigation project, depending on whether they make a positive contribution to the project, or choose to block the progress of the project.

Modernizing irrigation and drainage systems for service delivery

This section discusses the important considerations when designing modernization and revitalization interventions.

Services - The services to be provided by an irrigation and drainage project often extend beyond the obvious services of water delivery and removal to support irrigated agriculture. As noted elsewhere, irrigated agricultural systems operate within the wider context of basin water resources and the constraints imposed by other water users within the same resource system. Therefore, in addition to the I&D services, the design and implementation of irrigation modernization investments must, increasingly, also consider the unexpected positive and negative impacts on the other systems affected. The analytical framework provided by the ecosystem services concept may be used to evaluate the services provided by an irrigation and drainage system and its modernization and revitalization. Ecosystem services is defined as the direct and indirect contributions of ecosystems to human well-being. The concept 'ecosystem goods and services' include four categories of ecosystem services (TEEB, 2010): (i) Provisioning Services are ecosystem services that describe the material outputs from ecosystems. They include food, water and other resources, (ii) Regulating Services are the services that ecosystems provide by acting as regulators e.g., regulating the quality of air and soil or by providing flood and disease control, (iii) Habitat or Supporting Services underpin almost all other services. Ecosystems provide living spaces for plants or animals; they also maintain a diversity of different breeds of plants and animals, and (iv) Cultural Services include the non-material benefits people obtain from contact with ecosystems. They include aesthetic, spiritual, and psychological benefits. The role of I&D

systems in increasing the resilience of communities to climate extremes (droughts and floods) is becoming more important and interventions to modernize I&D systems should be designed considering these needs.

Infrastructure – Concerns over increasing water scarcity and the reported inefficiencies of large-scale surface irrigation schemes encourage governments to modernise their systems and farming practices. In many countries, change is primarily infrastructure-led, with little attention to irrigation management, and the much-needed strengthening of human and institutional capacity, discussed below. However, although modernization does involve greater focus on what may be considered the "softer" interventions, investment in infrastructure and new technologies also play an important role in the development of irrigation systems to meet ever changing circumstances. In addition to the more traditional upgrading and repair of open surface canal systems, there is increasing interest in the adoption of piped distribution systems. Such pipe irrigation systems offer opportunities to reduce seepage, operational losses, and energy requirements, provide an on-demand level of service to farmers within design and operational limitations, and enable farmers to diversify cropping, increase yields and control fertilizer applications. An increasing choice of hardware and software for water distribution, monitoring and control is available, both for canal and pipe systems. Planners and stakeholders face difficult decisions on how best to modernize older canal systems, and whether pipes should be adopted as part of their modernization. The guidelines provide a summary of the opportunities and choices available, and some of the mistakes that should be avoided. It also reflects on the paradigm shift in operation and maintenance that occurs with adoption of pipes.

Capacity development for modernization - In 2004 FAO highlighted a consensus among policymakers in the developing world that a lack of capacity was constraining development in irrigated agriculture. This was not a new issue; training for people was recognised but was usually considered more as a bolt-on to the more important mainstream activity of infrastructure development (FAO, 2004) Governments and donor agencies have not helped as they are often more willing to invest in 'hard' infrastructure rather than 'soft' capacity development, which is much less visible and more difficult to measure success. Yet paradoxically, we all know that people, their knowledge and skills, and effective organisations are essential to make technologies work. Bolger (2000) identifies four levels of capacity development, summarized in Figure 2, and described below.

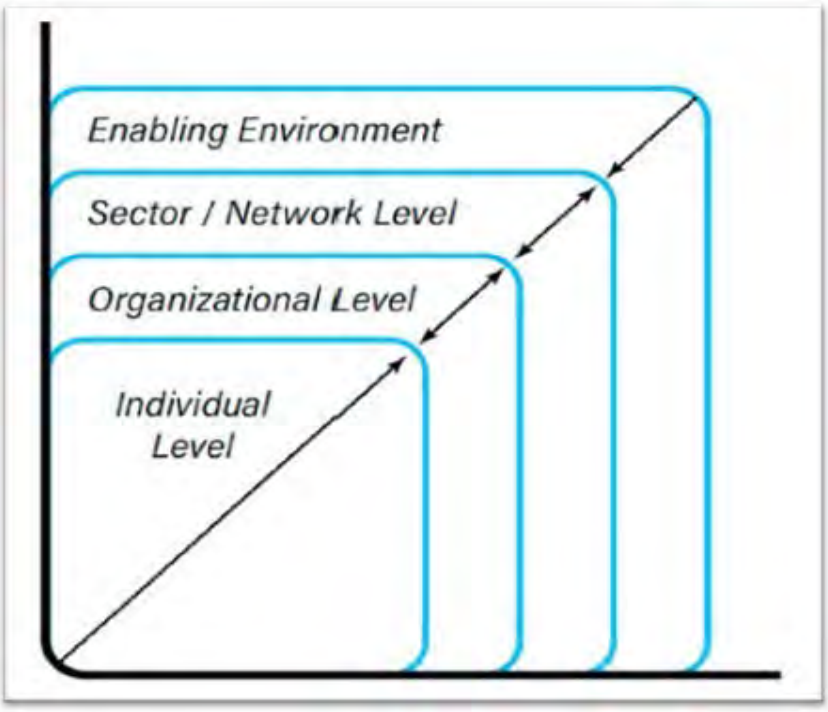

Figure 2. Four levels of capacity development

(i) **Individuals -** This is the most concrete and familiar part of capacity development and includes educating and training various stakeholders, farmers, and local professionals.

(ii) **Organisational level: -** This refers to the wide range of organisations involved in irrigation such as water user organisations, research groups, government extension agencies, private companies that share common objectives such as improved livelihoods at a farming level or improved water management or increased agricultural productivity at a national level. The capacity of an organisation is embedded in the ability of its individuals to work together within established rules and values and to interact with other organisations.

(iii) **Sector level: -** Highlights that irrigation is part of the larger picture of IWRM and reflects the increasing awareness of the need for policies that integrate all aspects of water development and not just irrigation.

(iv) **Enabling environment: -** This represents the broad national and international context within which irrigated agriculture can develop. It has immense influence over what happens at the lower levels. It is concerned with policy at the highest levels in government, the socio-economic conditions that enable or discourage irrigation development and the legal framework that provides farmers with security of tenure for land and water and the power to seek legal redress when contracts are broken.

The levels are linked. Organisations of water users are shaped as much by society (laws, regulations) as by individuals (skills, leadership, relationships). However, the levels provide a structure that allows capacity development to be examined and analysed and they provide possible entry points for support and technical cooperation, leading to transformational changes required in the management and operation of modernized irrigation and drainage services.

Change management – An effective modernization program will frequently involve multiple stakeholders, both individuals and institutions, having to change how they operate and the roles and responsibilities their operations involve. Change is an uncomfortable process for everyone involved with individuals often worried that change will leave them behind or perhaps make their role redundant. This can generate considerable resistance to the implementation of the changes required. Therefore, it is essential that throughout the implementation of a modernization project the process is designed within the context of a change management program. The change management program depends on the multiple stakeholders involved having a clear vision of what the modernization process is aiming to achieve, ideally involving the stakeholders defining the objectives through extensive communication of the challenges being addressed and the options available. Careful discussions are required with the stakeholder groups to finalize the project objectives. Change management is a process, not a destination, Balasco (1990). Change does not end; it is the process of continual improvement, supported by capacity development and investments in upgrading systems and infrastructure.

Sustaining modernized I&D services.

At many locations, the inadequate investment in maintenance, operation, and management (MOM) of too many irrigation schemes has led to the rapid decline in the services provided by the systems and in accelerated deterioration of the infrastructure. The investments in modernization of I&D services are intended to enable transformational change of how I&D is operated and maintained.

Asset management – asset management was defined by Burton et al (2003) as "*A structured and auditable process for planning, implementing and monitoring investment in the maintenance of built infrastructure to provide users with a sustainable and defined level of service*". Asset management has a major role to play in the irrigation sector as its underlying purpose is to identify the funding requirements to maintain an irrigation system in a functioning condition. At present, in irrigation systems in many developing countries, there is little or no objective and systematic assessment of the condition and performance of irrigation assets, and little or no assessment of the real costs of sustaining these assets, or the value of the agricultural production lost because of poorly maintained systems. Burton (2014) calculated that the cumulative value of production lost over 30 years of decline due to inadequate maintenance of the 50,145ha system was 35 times that of the amount required for adequate levels of maintenance.

The starting point is asset management planning (AMP) which identifies asset stock (canals, drains, structures, roads, buildings, etc.) and quantifies its condition and performance. From the assessment of the asset condition and level of performance estimates can be made of the investment required to either:

(i) maintain the existing asset condition and system performance, or enhance or extend asset condition and system performance;

(ii) Asset management planning defines the level of service to be provided, in terms of water rates, levels and availability;

(iii) quantifies the ability of the water users to pay for the specified service;

(iv) identifies the condition and performance of the assets (canal, drains, structures, roads, etc.) and

(v) quantifies the investment and expenditure required to maintain, improve or extend the assets in order to satisfy the specified levels of service.

An important application of asset management is in the process of transferring the management, operation and maintenance of irrigation and drainage systems to Water Users Associations, or designated 3rd party operating agencies, Burton, 2013. Applying asset management procedures at the transfer stage can have important benefits, including identification and audit of all infrastructure assets; identification of water users' desired level of service; identification of the cost of maintaining the system over time commensurate with the agreed level of service provision; understanding by the water users of the relationship between infrastructure condition and system performance; and understanding by water users and the irrigation service provider of the relationship between fee payment and service provision.

While AM is necessary it may not prove sufficient to ensure sustained maintenance, without adequate incentives, for the WUA or other operators, commensurate with: (i) management (O&M) responsibilities and costs, under participatory irrigation management and transfer (PIM/IMT or private sector management) programs, and (ii) irrigation service fee (ISF) payments to recover agency O&M costs. This necessitates WUA participation in irrigation system management (if not directly in O&M), requiring joint agency and WUA: (i) informed inclusive consensus, regarding system operation arrangements (water delivery schedules to support farmers' preferred cropping patterns etc.), (ii) implementation of the agreed arrangements, (iii) monitoring and iterative performance assessment and diagnosis of their implementation, and (iv) their successive refinement over several years.

Financing sustainable service delivery – a recurrent theme in studies of irrigation performance and declining condition of irrigation and drainage assets is the frequent inability of system managers to secure funding to enable adequate maintenance, operations and management of the water services expected by users. A failure to deliver the expected water services reduces water users' ability and willingness to pay service fees where these are levied, often leading to further declines in service levels. This leads to declining cost recovery and eventual need for rehabilitation investments – the "build-neglect-rehabilitate" process mentioned earlier.

To break out of this declining circle, it is recommended that system managers and water users agree a specified, or *desired,* level of service to be provided by the modernized I&D system. The ability to deliver the desired level of service will primarily depend on:

1. The type of irrigation infrastructure provided.
2. The performance of the infrastructure.
3. The capability of the O&M management.

The level of service that the farmers request or require must be discussed with them to establish exactly what they require, and to make them aware of the cost implications and their commitments, chief amongst which will be a commitment to pay the irrigation service fee.

Once the level of service is agreed, the farmers and irrigation agency will sign a service delivery agreement.

Figure 2 illustrates the relationship between the service provider and the water user, with the former providing the service for which the latter pays. The details of this relationship are detailed in the specifications of what service will be provided (quantity of water, timing, reliability, etc.) and the conditions (including the service fees) for provision of that service. To provide this level of service, control and measurement are required, together with management, and water delivery schedules shown in Figure 3.

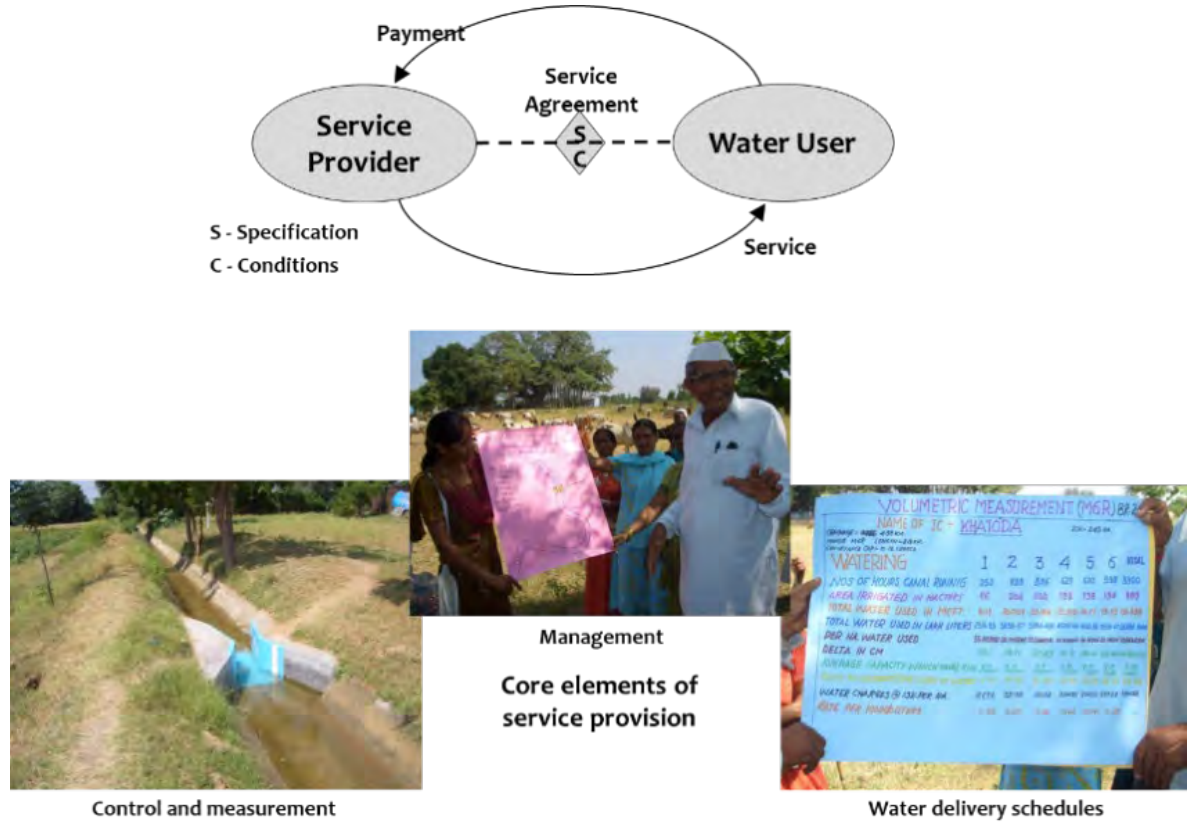

Figure 3. Key components of service delivery (Source: After Huppert and Urban,1998; Burton, 2020)

Responding to changing needs - Irrigation development is aimed at achieving a set of defined objectives, which may include food production, income generation, acceleration of rural development, poverty alleviation, improved nutrition, and economic growth, among others. Irrigation systems are planned and designed based on the development agenda and policy of the government, water governance and management setup, design values and standards, and observed hydroclimatic conditions. They are constructed and equipped with concurrent irrigation technology that can be operated according to the water distribution and delivery targets. Changes in the original irrigation objectives, design consideration, and physical components will have an implication on the operation, management, and irrigation system performance. Similarly, changes in the physical components and operations can determine how well the objectives are achieved.

Changes in irrigation objectives and technology may be due to changes internal to the irrigation scheme such farmers' preference of cropping pattern or crop mix, reduced irrigation service area due to land conversion, and new management setup

More often, changes in irrigation objectives and technology are triggered by external factors such as changes in the climate, land use in the river basin, water source flow regimes, water rights, water allocation laws/policy, and increasing water demand for other uses. Climate change and deforestation have been associated with less predictable weather pattern, floods, sediment-laden flows, highly variable river flows, and drought. These effects of climate and land use changes represent new constraints and are not among the original design considerations and assumptions of older irrigations systems. The increasing water demand for cities and municipal uses, which are accorded highest

priority in water allocation by most societies, and the growing recognition of water rights of the environment have decreased the water share agriculture. Upgrading of irrigation infrastructures, development of supplemental water sources, and managing irrigation demands have become imperative to circumvent the adverse effects of these changes on irrigation sector.

Stakeholders roles and responsibilities – Modernization investments may have a number of objectives, including some or all of: (i) generating employment, (ii) supporting emerging farmers, (iii) increasing crop yields, (iv) maximising economic gains from soils, water, infrastructure resources, etc., (v) poverty alleviation, (vi) providing food security, (vii) modernizing irrigation infrastructure, and (viii) political influence. These objectives are often open to interpretation and are therefore dangerous if left undefined as different people will understand them differently. If all stakeholders are assumed to have common goals can result in one- or another-party seeing outcomes of the investments as a failure. It is also impossible to plan coherently without crystal clear objectives which are agreed across the community of stakeholders. Clear objectives must be defined and maintained as visible reference points to guide all proposals and decision-making. Not only are modernization objectives sometimes vague, but on closer consideration they are often in conflict with each other. In some case you can only achieve one at the expense of another requiring clear decisions about which to prioritize.

The national and provincial policy environment is clearly an important starting point in revitalization. National policy requires that irrigation schemes are planned to deliver positive economic returns (in keeping with national economic targets) and cover their own operational costs, which may require initial support through 'sunrise' funding packages and ultimately phasing out of subsidies. These require the leadership of the modernization process to integrate the concerns and capacities of a broad range of stakeholders in the activities of the investment plan.

Important stakeholders in most countries will include: (i) Department of Agriculture at National and sub-national levels, (ii) Water Resource management agencies and river basin managers, (iii) local government agencies and municipal councils, (iv) farmers, estate managers, irrigation system operators and management, (v) private sector operators, including agricultural suppliers, markets, and processors; and (vi) public utilities, such as energy suppliers. Each of these groups of stakeholders have specific, and often overlapping interests and roles that are more beneficial when appropriately coordinated and aligned.

Capacity development for sustainability - Investment projects designed to modernize irrigation systems to provide cost-effective, flexible, and responsive irrigation services to farming communities should include capacity development for the system managers and operators, as well as for the leaders and members of water user organizations. The scale, complexity and financial value[2] of irrigation system operations merits far greater investments than are currently made to ensure that managers and operators are equipped to provide effective management of the systems. Drawing on the considerable business and corporate sector experience available in change management processes there is an urgent need to change the way business is done and develop a renewed cadre of leaders and irrigation professionals able to bring best practices into the management of irrigation and drainage services. These capacity development investments should continue beyond the timeframe of an investment program to upgrade infrastructure etc.

ICID recommendations on Modernization and Revitalization of I&D services

What can ICID members do to enhance I&D services – The ICID membership represent an important cross-section of the irrigation and drainage profession. The ICID and its members can play a leading role in promoting and facilitating investment in the modernization of I&D services to support food security and the mitigation of the impacts of climate change on communities across the globe. The leadership may include:

- Promoting best practices: ICID can promote best practices in irrigation modernization, such as adopting water-efficient technologies, promoting sustainable irrigation practices, and increasing the use of renewable energy in irrigation. This can be done through advocacy, knowledge sharing, and capacity building.

[2] *An irrigation system of, say, 10,000 ha, producing two crops of rice at 5 t/ha produces about US$42 million per year of paddy rice at the farm gate*

- Providing technical expertise: ICID has a wealth of technical expertise in irrigation and drainage, including designing and operating irrigation systems. This expertise can be shared with countries and organizations looking to modernize their irrigation schemes.

- Facilitating international cooperation: ICID can facilitate international cooperation on irrigation modernization by creating a platform for knowledge sharing and collaboration among countries and organizations. This can be done through conferences, workshops, and technical exchanges.

- Advocating for investment: ICID can advocate for investment in irrigation modernization by highlighting the benefits of efficient and sustainable irrigation systems, such as increased food security, reduced poverty, and improved environmental sustainability.

How will ICID help members and other stakeholders – The mandate of the WG_M&R concludes during the Congress in 2023. However, in the process of restructuring ICID Working Groups, the ICID may wish to consider how to continue the development and dissemination of knowledge on experiences with modernization of I&D services in member countries by tasking a new working group with further development of the ICID Guidelines on Modernization and Revitalization of Irrigation Services.

What next? - The ICID Guidelines on Modernization and Revitalization of Irrigation Services draws together examples of approaches to the M&R from a range of ICID member countries. While the experience presented offers a broad overview of the current state of practice and aspirations in a variety of settings, the Guidelines are not considered to be comprehensive or final. Rather the Guidelines are intended to establish a framework of key areas that any organization investing in the modernization of I&D services should take into the design and implementation of the investment and program of work. The Guidelines are intended to be a "living document" that will be updated and expanded as further case studies are developed and the outcomes of different approaches are evaluated by ICID working groups and authors of papers at ICID events.

Conclusion

It is important that users of the guidelines appreciate the nature of the guides – each present one or more examples of approaches to different aspects of a modernization program. Each guide is not intended as a "cookbook" to be followed precisely but rather provides guidance on areas or issues to be considered and evaluated as locally appropriate solutions are developed. Critically, the combination of interventions that are proposed for implementation must be communicated, discussed, and agreed with the farming community that will depend on the success of those interventions for their future livelihood before final commitment to the investment required. In many cases, for a modernization program to succeed, the interventions will include substantial investment in capacity development for the system operators and the irrigators that will use the upgraded infrastructure, technology, and management processes. Such capacity development programs will, likely, need to continue for a longer period than required for the infrastructure development.

Acknowledgements

This paper is developed from the contributions to the draft Guidelines on Modernization of Irrigation and Drainage Services by the members of the Working Group on Modernization and Revitalization of Irrigation and Drainage Services (**Annex 2**).

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Annex 1

Case studies and presentations – Working Group Modernization and Revitalization

Thailand 2016

- Modernization and Rehabilitation of Irrigation in Indonesia. (Soekrasno S, Adang Saf Ahmad, Bistok Simanjuntak, Eko Subekti, M. Adrie Azhari

Mexico 2017

- Irrigation Modernization and Revitalization in Korea (Kwang Sik Yoon) -ppt
- A case study of Jiamakou Yellow River Diversion Project Shanxi Province, China (Dr. Dong Bin) -ppt
- Modernization and Revitalization of Irrigation in Pakistan- A case study of Sindh (Fateh Muhammad Marri) docx
- REHABILITATION AND REVITALIZATION OF IRRIGATION SCHEMES IN NIGERIA: Lessons from Bakolori Irrigation Scheme (Engr. Muhammad Sani Bala) docs and ppt
- Case study of irrigation modernization in Northern Victoria, (Hugh Turral and Mark Wood) docx

Canada – 2018

- Modernization & Revitalization a case study of Japan (Shinji?) ppt
- Irrigation modernization with IoT and cloud-top computing: case study in Taiwan (Chih-Hung Tan, Ph.D.) ppt
- Canal Automation for Irrigation Delivery Systems (Dr Brian Wahlin) - ppt
- Modernization of the San Luis Canal Company in Central California (Charles M. Burt. P.E., Ph.D., D.WRE. Presented by Brian Wahlin, P.E., Ph.D., D.WRE) ppt
- Tertiary Infrastructure Development in the Muda Area (National Key Economic Area [NKEA] – Entry Point Project [EPP]10) (Malaysia – ned to confirm author) ppt

2019 Bali, Indonesia

- International Workshop on Modernizing Irrigation Services for Water, Food, and Nutrition Security
- Process of Irrigation Modernization of Indonesia, Case: Serayu and Wadaslintang Irrigation Schemes, Indonesia
- Using smart water operation center for better water management in Thailand
- ICT, IoT, and Big DATA Application for Irrigation facilities management
- Practical evaluation of ICT smart automated sluice gate for paddy fields from the aspect of an additional function of ponding water temperature control
- Innovative Initiatives in Water Stressed Area by Effective Monitoring of Canal Operations
- Re-Visiting the Rap Evaluation for Irrigation Modernization - Concept and Application for Small-Scale Irrigation
- Automatic Subsurface Irrigation and Drainage using Sheet-pipe typed Mole Drain
- A Case Study on Conversion of Canal Based Irrigation Network System to Pressurized Pipe Based Network System Integrated with Solar Plant in The State of Uttar Pradesh, India
- Subsurface water level control system “FOEAS” and its diffusion

2020 & 2021 – no case studies presented

- COVID pandemic caused cancellation of events.

2022 Australia – International Workshop

- A readiness assessment of Indonesian pilot project modernization. Case study Kedungputri, a premium irrigation area, Central Java. – (Vicky Ariyanti , Corri Eriza, and Kuji Murtiningrum)
- Assessment of modernization needs for the Philippine National Irrigation Systems to Support High Value Crop Production – (Mona Liza F. Delos Reyes)
- Not presented => Modernization of East Fork Irrigation District – A Case Study Hood River, Oregon, USA – (Brett Golden, Julie Oshea, Preston Brown, Kristen Allgood = contact Brian Wahlin)
- Not presented => ESTABLISHMENT OF DIGITAL TERRAIN MODEL OF AN IMPOUNDING RESERVOIR WITH ECHO-SOUNDER AND DRONE (Joongu Lee , Moonsuk Lee , Kangwon Choi and Hyunsu Kim)

NOT PRESENTED → INNOVATIVE LIFT IRRIGATION SCHEME FOR FOOD SECURITY AND AGRICULTURAL SUSTAINABILITY (DR. SHIVAJI SANGLE, MS. SHIVANI SANGLE)

- Modernizing a pressurised pipeline supply system for high value agriculture in Asia. (Rob Rendell)
- BERNAM RIVER WATER BALANCE MANAGEMENT SYSTEM, MALAYSIA. A Case Study on Paddy Irrigation Efficiency at the Pasir Panjang Irrigation Block of the Barat Laut Selangor Irrigation Scheme (BLSIS), Bernam River Basin, Malaysia (Dato' Ir Hanapi Mohamad Noor, Ir Yong Siew Fang)
- Towards enhanced capacity of farmers and institutions in irrigation and drainage as key contributors to sustainable food production and poverty alleviation in the Philippines (Mona Liza F. Delos Reyes and Bart Schultz)
- Not presented – Monitoring and detection of soil elements for the sustainable management of irrigation of agricultural resistance by an intelligent system (Loubna BOUHACHLAF, Jamal MABROUKI, Ahmed Elshaikh, and Souad EL HAJJAJI)
- Curse Or Blessing! Are Smallholder Irrigation Schemes Doomed To Succeed? (Eng Bezzel Chitsungo) – presented but no paper received
- Developing effective institutions for irrigation services, including capacity building of different stakeholders, a case of Zimbabwe (Eng Bezzel Chitsungo) – presented but no paper received
- Modernization of Irrigation through Piped Irrigation Systems in India. Alok Sikka, Kuhelika Ghosh, Faiz Alam (IWMI, India)
- Presentation by Rubicon on Canal Automation by Ravi Varun.

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Annex 2

Members of the ICID Working Group on Modernization and Revitalization of Irrigation and Drainage Services

Members	Member from (Year)
VPH Ian Makin, Chairman (UK)	2015
Dr. Dong Bin, Vice Chairman (China)	2015
Engr. Muhammad Sani Bala, Secretary (Nigeria)	2015
Mr. Mehrzad Ehsani (Iran)	2015
Ir. Eko Subekti (Indonesia)	2015
Dr. Kwang-Sik Yoon (South Korea)	2015
Mr. Mohd Yazid bin Abdullah (Malaysia)	2015
Dr. Brian T. Wahlin (USA)	2015
Mr. Usman-e-Ghani (Pakistan)	2016
Dr. Ali Omran Ali (Iraq)	2016
Dr. Sanjay Belsare (India)	2017
Mr. Jan Potgieter (South Africa)	2018
Prof. Dr. Tarek Ahmed El-Samman (Egypt)	2018
Dr. Chih-Hung Tan (Chinese Taipei Committee)	2018
Dr. Shinji Fukuda (Japan)	2018
Omid Moridnejaad – Young Professional (Iran)	2018
Ms. Mona Liza Delos Reyes (Philippines)	2019
Engr. Reyne B. Ugay (Philippines)	2019
Dr. Toshihiko Kuno (Japan)	2020
Mrs. Zaineb Mohammed Akram (Iraq)	2020
Dr. Mohsen Barahimi (Iran)	2020
Mr. Dinesh Bhatt (Nepal)	2020
Prof. Sunil D. Gorantiwar (India)	2021
Dr. Neelam Patel (India)	2021
Dr. YaLong Li (China)	2021
Dr. SHI Yuan (China)	2021
Dr. Di Wu (China)	2021
Dr. Usman Khalid Awan (Pakistan)	2022
Dr. Macdex Mutema (South Africa)	2022
Dr. Hwa-Lung Yu (Chinese Taipei Committee)	2022
Secretary General, ICID	
Permanent observers	
Mr. Alan Kendall Clark (UK)	2015
FAO Representative	2015
World Bank representative (Dr. Petra Schmitter)	2021
IWMI representative (Dr. Alok Sikka)	2021

Contributors: (i) Dr Martin Burton, Consultant, UK, (ii) Mr Melvyn Kay, Consultant, UK, (iii) Mr Lance Core, ADB, and (iv) Beau Freeman and Mike Chegwin, Laymeyer Consultants.

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ASRWG TECHNICAL REPORT ON IRRIGATION AND DRAINAGE FOR ASIAN FOOD SECURITY[1]

1. Introduction

Australia comprises a land area of about 7.7 million square kilometres; this is about five per cent of the world's land mass. Australia is the planet's sixth largest country after Russia, Canada, China, the United States of America, and Brazil.

It is also the only one of the largest six nations that is surrounded by water and does not share any land borders or river systems with another country. Australia is the smallest and oldest of the world's continents; it is also the lowest, the flattest (apart from the eastern divide, land slopes are often around 1:10,000 to 1:5,000) and apart from Antarctica, is the driest. Nearly 20 per cent of Australia's land mass is classified as desert.

The highest point on the Australian mainland is Mount Kosciuszko, at 2228 metres above sea level. The lowest point is the dry bed of Lake Eyre, South Australia, which is 15 metres below sea level.

Rivers are one of the most important natural features of the Australian environment. There are many different types of rivers in Australia, with their character, dependent ecosystems, and unique flora and fauna determined by local and regional climate and geomorphology. Rivers in northern Australia are characterised by flooding from monsoonal rains in the summer and may be dry for the remainder of the year; the arid interior receives sporadic, heavy rainfall from tropical cyclones, resulting in spectacular and widespread flooding, while the southern parts of Australia receive more uniform rainfall in a temperate climate, often influenced by Southern Ocean weather systems.

Rivers sustain environmentally important billabongs (oxbow lakes), large floodplains, and lakes and estuaries, the nurseries of bountiful fisheries. Rivers are the home of Australia's iconic River Red Gums and coolabah trees, with the low relief landscapes often resulting in wide floodplains critical to a wide array of animals and plants.

The spiritual role of rivers in Dreamtime stories of First Nations peoples is also very important. Rivers were the pathways for European explorers and subsequent colonists, and our largest rivers became important corridors of trade. Few Australian towns are far from a river, with many of them on a floodplain.

While Australians have a strong affinity for rivers and streams, many of Australia's distinctive and important rivers are severely degraded. Australian rivers are under increasing pressure from over-extraction of water for a wide range of purposes from town water supply to irrigation and heavy industry, pollution, catchment modification and river regulation. Similar to many other parts of the world, all Australian rivers flowing through regions with intensive agriculture are degraded to some degree by human activity.

2. Population

The population of Australia in (2019) was about 25 million people with 85% of these living within 50 km of the coasts. Population density ranges from above 10,000 people per square km to less than 0.2 persons per square km in the arid centre. Human habitation of the Australian continent is estimated to have begun around 65,000 to 70,000 years ago, with the migration of people by land bridges and short sea-crossings from what is now Southeast Asia. Australian First Nations culture is one of the oldest continual cultures on earth.

3. Climate and Rainfall

Climatic zones range from tropical rainforests, deserts, and cool temperature forests to snow covered mountains (winter). Australia is the driest inhabited continent in the world; rainfall is extremely variable, and droughts are common. Australia is a relatively arid continent, with 80 per cent of the land receiving less than 600 millimetres of rainfall per year, and half receiving less than 300 millimetres of rainfall per year. The majority of Australia's land mass is therefore semi-arid to desert lands. Temperatures and evaporation are seasonally high across much of the country, average annual evaporation exceeds average annual rainfall in many regions, and substantial areas of fertile soils are uncommon.

As well as having a low average annual rainfall, rainfall across Australia is also variable. The rainfall pattern is generally concentric around the extensive arid core of the continent, with seasonal rainfall intensity high in the tropics and some coastal areas.

[1] Irrigation Australia – Committee for Irrigation and Drainage

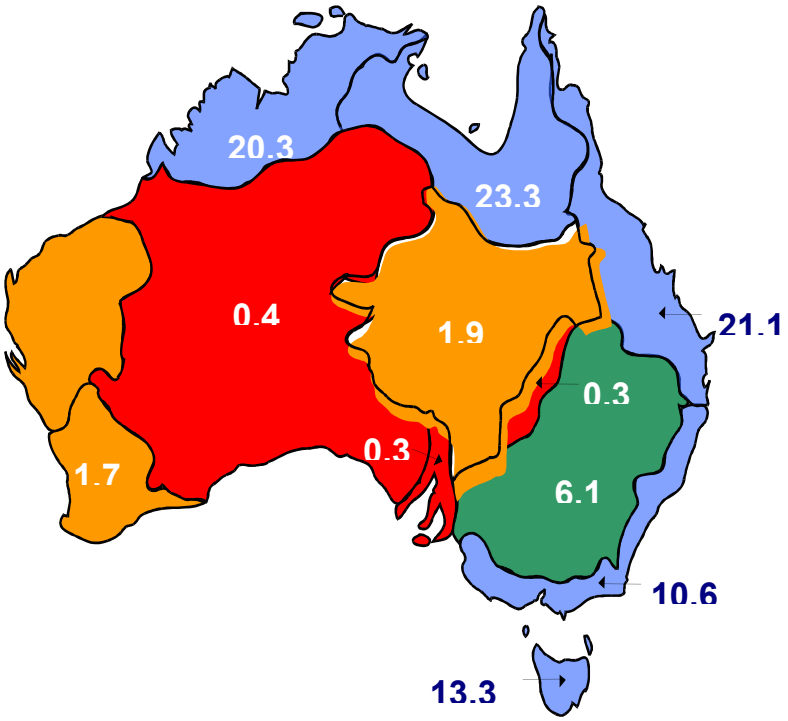

Figure 1: Distribution of Australian Rainfall Run-Off

About 65% of run-off occurs in the North and only about 6% of run-off occurs in the Murray-Darling Basin, which produces over 40% of our food, (green area in Figure 1.). Importantly, much of the rainfall that occurs in northern Australian is concentrated during a 3–4-month monsoonal season in the Australian summer (December to March) and is relatively dry for the remainder of the year. Northern Australia also has the lowest population density and is the least developed region.

4. Area Under Agriculture, Irrigation and Drainage

Agricultural businesses, the majority of which are family-owned operations, operate across about half of Australia's total land area with 87% of the land farmed used for grazing and 31 million hectares are cropped.
In 2021–22 Australia agricultural, fisheries and forestry exports reached an estimated record of AUD$76 billion. Key crop results for 2021-22 include $13.1 billion for wheat (up 33% from 2020-21), $6.0 billion for canola (up 105%), and $4.4 billion for barley (up 17%), reflecting highly favourable seasonal conditions in the previous 12 months (ABS, 2022).

The dominant crops, by weight, were sugarcane, wheat, barley, oats, and canola. Australia irrigates 2 million hectares of land for cotton, rice, fruit crops, grapevines, pastures, and vegetables. Notably, Australia exports about 70% of its agriculture production annually and is therefore highly food secure, while food imports account for around 11% of consumption by value (DAFF, 2023).

The main irrigation area in Australia is the Murray-Darling Basin, covering parts of South Australia, New South Wales, Queensland, and Victoria. Water required for irrigation is stored in reservoirs in the upper reaches of the main streams and rivers and is released to downstream irrigators and for environmental watering purposes. Smaller but regionally significant irrigation areas also occur in mainly coastal areas of Queensland, and in south-west Western Australia.

The formative years of irrigation in Australia were in the 19th Century and the major irrigation developments occurred initially in the Murray-Darling Basin. In New South Wales, 500,000 ha of pastures, and 200,000 ha of rice and cotton are flood irrigated. In Victoria, 500,000 ha of pastures are flood irrigated. Major channel systems divert water from the river systems to the irrigation districts. In South Australia, Victoria, and New South Wales, over

100,000 ha of high value horticultural crops (citrus, grapes, stone fruit, almonds, and vegetables) are sprinkler or drip irrigated. South Australia also irrigated 60,000 ha of pastures. In other states, a similar range of crops are produced. Queensland also irrigates 140,000 ha of sugarcane. Many inland areas of Australia have been developed only through the irrigation industry.

Access to irrigation water is controlled by state governments with the amount available to any irrigator, or the area that may be irrigated, regulated by agreed Water Sharing Plans. These Water Sharing Plans generally define a specific catchment or aquifer, describe the key hydrological, landscape, environmental and socioeconomic factors that the Plan applies to, and sets out rules for all forms of water use including town water supplies, irrigation and provisions for the environment. In most cases, water take from a river or aquifer requires a specified water license or entitlement which has a legal basis as defined in the Water Plan. Water entitlements under most Water Sharing Plans in Australia form the basis of water market arrangements and can be traded, sold, divided, and mortgaged within the rules specified in the plan.

Significant private irrigators do exist, but most regional water supply infrastructure, particularly large dams, and distribution infrastructure is owned, constructed, maintained, and operated by state government agencies. For example, two of the largest irrigation districts in the southern hemisphere (Murray Irrigation and Murrumbidgee Irrigation schemes) are privately owned and operated and occur in the Murray Darling Basin, but both take water from government-owned and operated dams upstream. By contrast, the role of the Federal government in the Murray Darling Basin is in coordinating water management across state borders and setting overall goals for water management at Basin and national scale, plus for environmental water outcomes and setting overall water quality standards.

Irrigation technology continues to evolve both at the system and farm level. Significant investment by industry, and state and federal governments in the past 20 years has seen dramatic improvements in water use efficiency in systems by reducing conveyance losses (operational, seepage and evaporation) and on-farm by adoption of ‘state of the art’ micro, spray, and surface irrigation systems. The largest of these federal government investments was termed the ‘Sustainable Rural Water Use and Infrastructure Program – SRWUIP’ which funded extensive irrigation research, development, and infrastructure upgrades nationally but with a focus on the Murray Darling Basin. The more extensive private and public irrigation infrastructure operators have made use of SRWUIP funding to modernise their irrigation infrastructure. Under this modernisation, thousands of old manually operated structures have been replaced with automated gates, leaky channels have been replaced by lined channels and pipelines and old-style Dethridge wheel outlets have been replaced with modern accurate farm outlets. Many of these automated systems are so controlled that farmers can order water and see it being delivered to their farm offtake via computer and utilizing mobile phones applications.

Common irrigation systems in Australia are given in Figure 2.

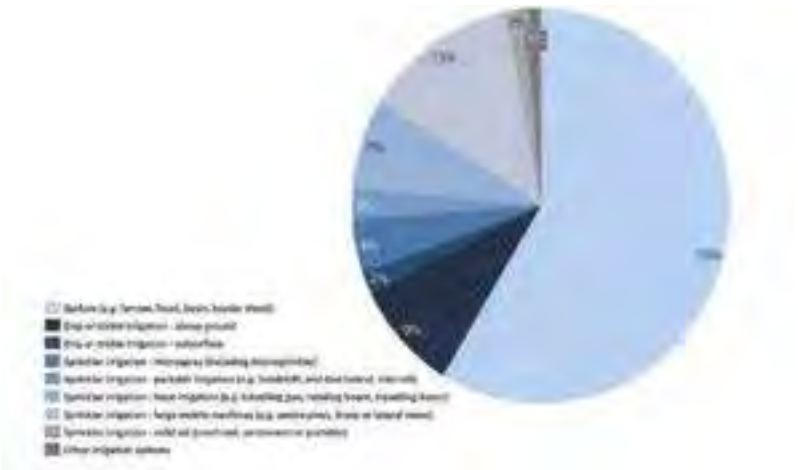

Figure 2: Irrigation Technology Types in Australia

5. Role of Water Resources Management

Total consumptive use (i.e., take of water from all sources including surface and groundwater) of water in Australia in 2016-17 was 16,287 gigalitres (16.28 km^3).

Of this amount, 10,233 gigalitres was extracted and used by the agriculture sector; 1,483 gigalitres was used by the water supply services industry; a further 2,662 gigalitres by all other industries; and 1,909 gigalitres by households. In 2020-21 across Australia, 5.7 million megalitres were applied to crops (73% of all water applied): 1.3 million megalitres for cotton (up 249%) 1.1 million megalitres for fruit and nuts (up 5%) 795,400 megalitres for sugar cane (down 10%). The preceding numbers reflect total water extractions, often through metered diversions from rivers and aquifers, and do not include water that returns to rivers and streams from irrigation, industry and towns.

Australia's average water consumption is 432 litres per capita per day.

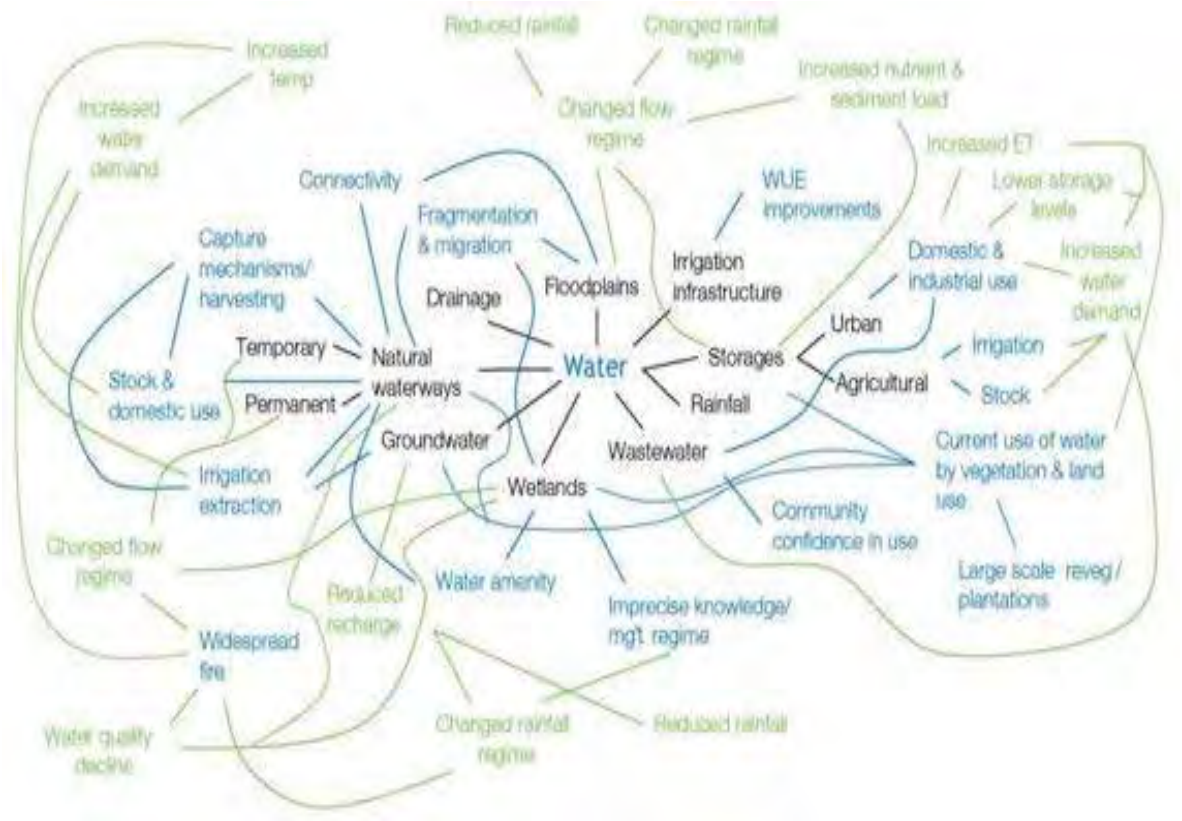

Figure 3: Water is a Complex Business in Australia, and elsewhere!

Before the 1970s, property rights to irrigation water resided largely with state governments. Since the 1970s, there has been a transfer of property rights from state governments to either individual irrigators, collectives of irrigators such as cooperatives or farmer-owned companies, or government-owned irrigation business enterprises that have taken over ownership and management of much of the distribution infrastructure.

Overall water governance and policy settings in Australia has for some decades been operating under the Council of Australian Governments [2] (COAG) water reform framework (now National Cabinet; see: https://federation.gov.au/national-cabinet). This nationally agreed framework requires each state and territory jurisdiction to develop a comprehensive system of sustainable water allocations (including formal water sharing plans and environmental water allocations) and legally secure water entitlements. Commencing in 1994 the Australian and Murray-Darling Basin state governments agreed to implement a cap on diversions as part of the Murray-Darling Basin Agreement, based on 1993-94 levels of utilisation. Prior to this in 2003, COAG agreed to refresh its 1994 water reform agenda by developing a new national water policy, termed the 'National Water Initiative'. Among other things, the Initiative set out desired reforms for best practice pricing and institutional arrangements. This included: Promoting the economically efficient and sustainable use of water; Giving effect to

[2] The Council of Australian Governments (COAG) is the primary intergovernmental forum in Australia. Comprising the federal government, the governments of the six states and two mainland territories and the Australian Local Government Association, it manages governmental relations within Australia's federal system within the scope of matters of national importance.

the principles of user-pays; Achieving pricing transparency; and facilitating the efficient functioning of water markets. The Commonwealth Water Act 2007 was passed in 2007-2008 and Murray–Darling Basin Authority was created as one of the key measures of the National Plan for Water Security (See: AWP, 2016).

Since 2004, The National Water Initiative has encouraged state and Territory governments to implement state laws and policies that provide for:

- More secure water entitlements, including for the environment
- Improved water planning including sharing
- Improved water markets
- Improved water pricing reflecting user pays and market-based trading
- Improved water accounting based on nationally consistent hydrological data sets
  As part of the agreement to implement the National Water Initiative, the Commonwealth government agreed to commit AUD $2 billion over seven years to fund state and regional priority water infrastructure projects. Significant additional funding exceeding AUD$12 billion was subsequently provided under various programs from about 2006, mostly for the upgrading of irrigation schemes across the country and the Murray-Darling Basin in particular.

6. Intercessions for Food Security

Interventions were required since the Millennium Drought that impacted south-east Australia from 1998 to about 2008, combined with extensive extractions in the last decades of twentieth Century, resulted in almost complete collapse of the water allocation across the Murray Darling Basin. For example, this can be seen in a history of allocations against entitlements in the Murrumbidgee river valley, a major tributary system of the Murray Valley and the centre of significant irrigation areas, as shown in Figure 4.
The Australian Government's national response to drought and other water challenges was the *Water for the Future* initiative – 2008, a strategic programme over 12 years with emphasis on:

- Taking action on climate change
- Using water wisely
- Securing water supplies
- Healthy rivers and waterways

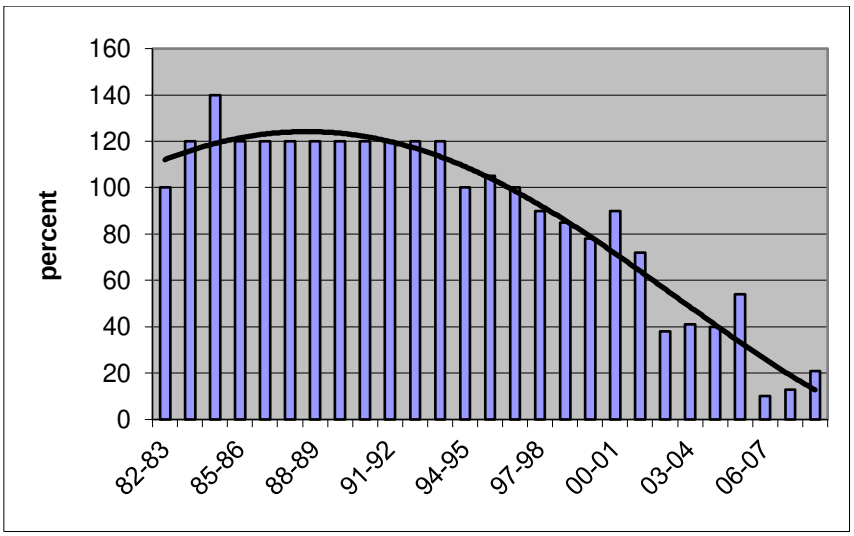

Figure 4: Decline in Water Allocation in Murrumbidgee river valley. The histograms are water in storages and the black line is volumetric allocations, in %, against nominal water entitlements.

The 2008 Water for the Future initiative committed over $10 Billion over 10 years to support, among other things, the 'Sustainable Rural Water Use and Infrastructure Program' (SWRUIP). Other elements of the integrated funding package included:

- Restoring the balance in the Basin (water entitlement purchasing)
- National urban water and desalination plan
- Water smart Australia
- Driving reform in the Basin (DEWHA and ACCC)
- Improving water information (BOM)
- National water security plan for cities and towns
- National rainwater and greywater initiatives
- Raising national water standards (NWC)
- Living Murray initiative
- Great Artesian Basin
- Northern Australian Futures

Of the $10 Billion, the SRWUIP had a budget of more than $6 Billion which was mainly invested in rural water use efficiencies, focussing in particular on improvements to irrigation system modernization and efficiency (both on and off-farm), but also including improved water information and market reforms.

7. Role of Research and Development

Australia has a proud history of government and industry co-investing in commodity based irrigated cropping industry Research and Development. These Research and Development Corporations (such as cotton, dairy, sugarcane, etc) have, at times, been complemented by Cooperative Research Centres (CRCs) focussing on these irrigated commodities or production systems. These RDCs and CRCs primarily combine with government agencies and universities, as well as private entities to deliver industry-based research, development, and extension.
There are 15 Rural Research and Development Corporations (RDCs) covering the main agricultural industries. The RDCs bring industry and researchers together to share funding and develop strategic directions that provide the sector with innovative and productive tools to compete in global markets.

The RDC partnership model between industry and government has been a vital element in the success of Australia's research, development, and extension (RD&E) effort. R&D has helped Australian agriculture double its productivity over the past 25 years.

In 2017-18, the 15 RDCs invested approximately $750 million in RD&E to improve the profitability and sustainability of rural industries and communities. This funding is a combination of levies on production paid by producers, and contributions from government, paid by taxpayers.

The largest evaluation of Australian rural research and investment ever undertaken found that investment directed by rural RDCs benefits both the sector and the wider Australian community. A research report released in December 2008, showed that from a group of randomly selected RDC projects, every RDC dollar invested gave a return to the community of $11. The return shows that the RDC model of co-investment is a very efficient mechanism for achieving solid results[3].

8. Progress in Reducing Food Insecurity

The COVID-19 pandemic has taken Australia and the world by surprise. Coming after severe drought conditions in eastern Australia in the first decade of this century, concerns have been raised about Australian food security. These concerns are understandable but misplaced. Despite temporary shortages of some food items in supermarkets caused by an unexpected surge in demand, Australia does not have a food security problem.

[3] https://www.frdc.com.au/rural-research-and-development-corporations

Food security refers to the physical availability of food, and to whether people have the resources and opportunity to gain reliable access to it.

The 1996 World Food Summit defined food security as the situation "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO 1996).

More technically, the four pillars of food security are availability, access, utilization, and stability of supply (FAO 2006).

Australia ranks among the most food secure nations in the world, alongside Canada, Germany, and France (EIU 2020). Australia is a high-income country, ranking 12th in the world for per capita income, and the vast majority of Australians can purchase basic foodstuffs that provide adequate nutrition. Australians benefit from being able to choose from an enormous and growing number of food products sourced from all over the world at affordable prices (Martin and Laborde 2018) and can access diverse and high-quality foods regardless of seasonal conditions or changes in world prices. Australia is in the top 10 countries in the world for affordability and availability and have the world's equal lowest level of undernourishment (FAO 2019).

Australia also plays a part in the food security of other countries. International trade – including Australian food exports – supports food security in other countries through providing physical access to food, lowering prices, and making food more economically accessible. Australia also contributes to food security in other countries through agricultural research, development assistance, and the transfer of Australian agronomic knowledge and expertise (D'Occhio 2011)[4].

To help ensure that irrigated production is efficient and productive the Australian Government implemented a wide range of programs which, *inter alia*, funded projects such as:

- Planning, investigation, and project design
- Works on irrigation systems **off farm** – modernization and rationalisation
- Works **on farm** to improve water use efficiency
- Works to improve ecological health and restore nature flows
- Water saving municipal projects – e/g/ storm water and wastewater harvesting and re-use

Upgrading irrigation systems off farm:

- Fixing / replacing inefficient supply systems
- Lining channels, replacing channels with pipes
- Improving water delivery standards for timing and volume
- Metering to meet modern standards
- Reconfiguring and rationalising channel systems and farm off-takes
- Decommissioning channels and providing alternate stock and domestic supply

On Farm investments:

- Improving on farm storage and tail water reticulation system
- Installing pipes and risers for individual irrigated fields and furrows
- Installing pressurized drip irrigation systems and centre pivot irrigation as an alternative to flood irrigation
- Moisture deficit management and increased precision delivery

[4] https://www.agriculture.gov.au/abares/products/insights/australian-food-security-and-COVID-19

The projects were delivered by a range of:

- State government departments (water, infrastructure, and environment)
- Irrigation infrastructure operators
- Irrigation industry associations
- Industry commodity bodies (e.g., rice growers, tomato growers …)
- Individual irrigators
- Catchment managers (resource management) authorities
- Local government
- Water utilities
- Science agencies

While many countries have implemented large scale irrigation improvement programs, the major programs and expenditures on improving irrigation efficiencies in the Murray Darling Basin occurred though the Millenium drought, followed by widespread floods in 2001/12. Many measures of whether these investments resulted in long term improvements were tested by project managers, buy one key overall measure was whether the value of irrigated agriculture declined, was static or increased during the droughts and following floods. Pleasingly, as can be seen in Figure 5 it was observed that there was indeed a decoupling of the total water extracted for irrigation and the value of agriculture production during the worst of the drought, reflecting the use of significantly more efficient irrigation systems and the skills of farmers in the main irrigation areas.

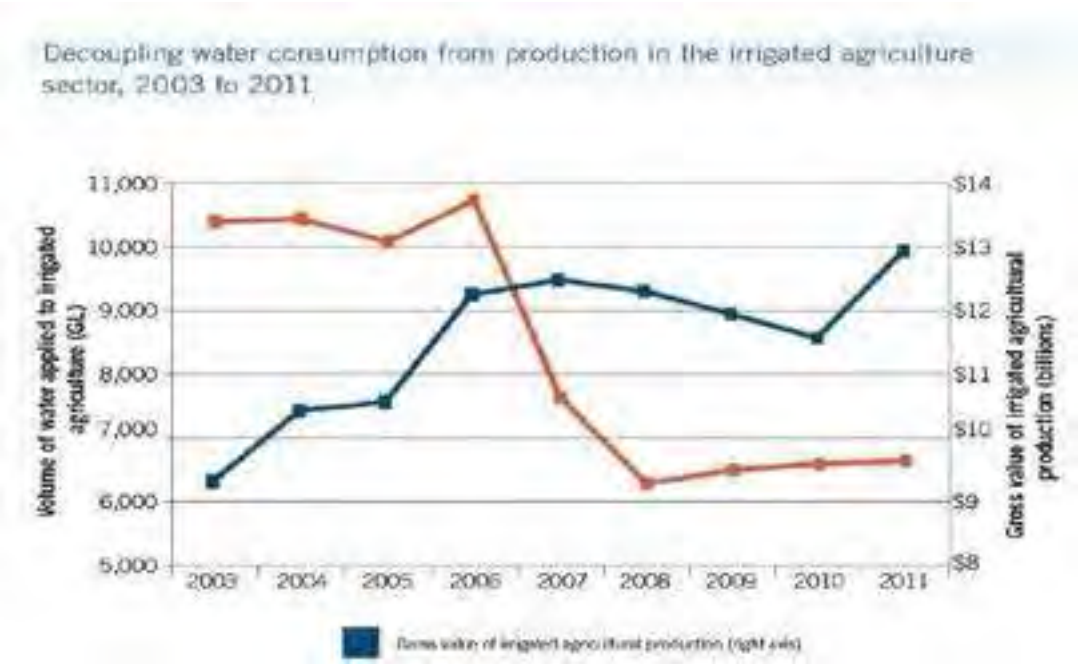

Figure 5: Reduction of water used in irrigation and increase in the value of agricultural production between years 2003 and 2011.

9. Way Forward: Country Strategy for Food Security

Key conclusions and lessons learnt in Australia's Murray Darling Basin have provided the base for the Country Strategy for food security, namely:

- Modernising irrigation systems alone is not enough: it must be done in parallel with other reforms such as better monitoring of water availability and quality, water trading, secure water entitlements, education, technology improvements, etc.
- It takes a lot of time. Farm and rural communities often need to work major changes through at their pace, not arbitrary government pace.
- It takes bipartisan political support, through multiple electoral cycles.
- It takes money, sufficient that most stakeholders understand that they will be better off at the end of the reforms.

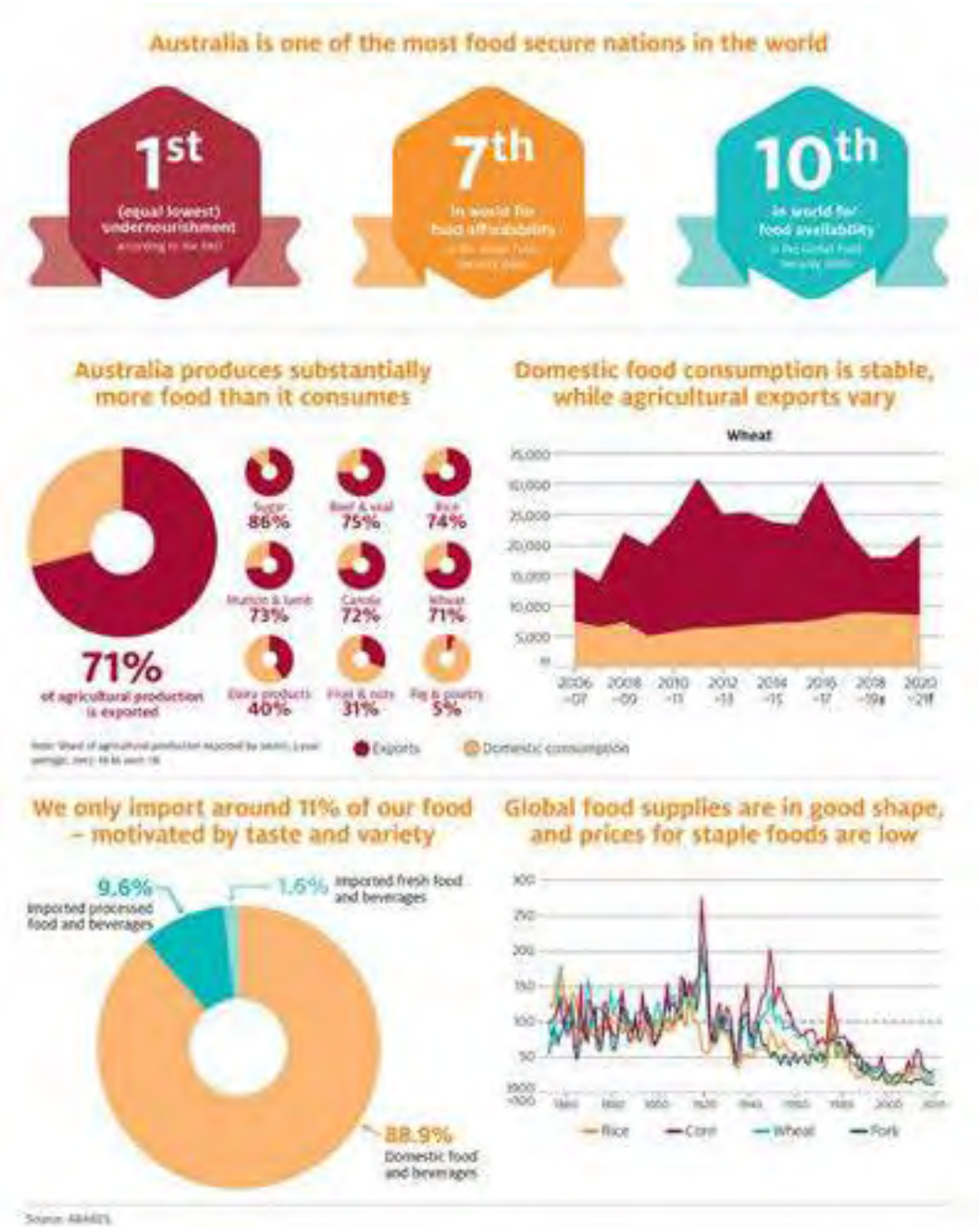

Figure 6: Food Security in Australia

In addition, we have both learnt and observed that:

- Peaceful sharing of scarce water resources is a key consideration – a key aim is to have very little litigation and community level conflict involved!
- Use of irrigation modernisation along with efficient use of water markets to achieve local social benefits such as schools, medical services, energy, telecommunications, etc.
- Maintained agriculture productivity and value while ensuring environmental integrity is a key consideration for most Australians, particularly city-based citizens
- Long term planning for uncertainty, undertaken for and by irrigators, is critical for a wide range of reasons but including investment security and social cohesion
- Irrigation modernisation is a solid basis for adapting to climate change
- Increased the overall value of the irrigator asset base – both for water entitlement holders and farm communities, leads to improved socioeconomic indicators in rural communities.

Some key information related to the food security in Australia are given in Figure 6 as above.

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PATHWAYS AND TECHNOLOGIES FOR MODERN IRRIGATION SERVICES COUNTRY PAPER BURKINA FASO – WEST AFRICA

Dr, Keita, Amadou)[1], Dr, Dial, Niang[1]; Yira, Yacouba[2] Ouango, François[3]; Coulibaly, Siaka[4]; and Schultz, Bart[5]

1. Introduction

A firm will of the ICID to encourage the realization of modern irrigation systems, efficient in the use of water, resolutely turned towards the enrichment of the rural world is the main justification of this study. Modernization here means the integration of new technologies available in the proposed production systems aimed at meeting the current and future needs of farmers. Modernization also means using the most up-to-date methods and means to improve not only production infrastructure, but also that of storage, processing, marketing and the human institutions that allow them to be created and managed.

2. Overview of national irrigation and drainage services

2.1 Governmental institution in charge of irrigation and drainage services

At national level, the Ministry of Agriculture, Animals and Fishery Resources (MARAH) is responsible for the whole agricultural, pastoral and fishery sectors development (MARAH, 2023). The MARAH acts on those sectors by means of a certain number of General Directorates. Among those directorates, one is particularly accountable for irrigation and drainage development and modernization The General Directorate of Agropastoral and Irrigation Development (DGADI). As stipulated in the ministerial decree N°2023/MARAH/CAB of 24/05/2023, the DGADI is placed under the administrative supervision of the General Secretariat of the Ministry. Its mission is to design, coordinate and monitor the implementation of strategies for hydro-agricultural, pastoral and fisheries development, irrigation development and sustainable land management. As such, it is responsible for:

1. promote the development and rehabilitation of irrigated lands, lowlands, pastoral areas and fisheries infrastructure;
2. to ensure that environmental and social impact studies and notices are considered in all projects and programs for hydro-agricultural, pastoral and fisheries development, irrigation and sustainable land management;
3. develop legislation, regulations and standards in the field of hydro-agricultural, pastoral and fisheries development, irrigation and sustainable land management;
4. to ensure that standards are considered in the construction of infrastructure and hydro-agricultural, pastoral and fisheries facilities
5. to implement the strategy of pastoral hydraulics in concert with the competent ministries;
6. to carry out any research and development study in terms of hydro-agricultural, pastoral and halieutic development, irrigation and sustainable land management;
7. to promote research and development in hydro-agricultural, pastoral and fisheries development, irrigation and sustainable land management;
8. to ensure the monitoring-control of the quality of hydro-agricultural, pastoral and halieutic developments and of sustainable land management;
9. to provide support and advice to local authorities and State departments in the planning, construction and maintenance of hydro-agricultural, pastoral and fisheries facilities, sustainable land management facilities and maintenance of works;

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10. ensure the monitoring and supervision of studies and construction works, maintenance and rehabilitation of hydro-agricultural, pastoral and fisheries facilities and sustainable land management;
11. promote public-private partnership in irrigation, sustainable land management and development of facilities;
12. ensure the effective and efficient management of agropastoral development;
13. to ensure the development of agropastoral developments;
14. monitor agricultural production and irrigated pastoral resources;
15. promote innovation in irrigation and sustainable land management;
16. to promote the use of innovative techniques and technologies for irrigation and sustainable land management;
17. promote the construction of small water mobilization structures for small-scale irrigation, in particular boulis, runoff collection basins, weirs and boreholes;
18. promote actions for the conservation, recovery and restoration of degraded agricultural and pastoral land;
19. promote agroecology in sustainable land management actions;
20. ensure participatory planning and programming of activities in the field of hydro-agricultural, pastoral and fisheries development, irrigation and sustainable land management;
21. to capitalize information from projects and programs, NGOs, associations and private promoters in terms of hydro-agricultural, pastoral and fisheries development, irrigation and sustainable land management;
22. contribute to the protection of watersheds and water bodies offering irrigation opportunities;
23. contributing to the formulation and monitoring of the implementation of projects and programs for hydro-agricultural, pastoral and fisheries development, irrigation and sustainable land management;
24. to contribute to the establishment and animation of an information system and the monitoring of good practices in terms of hydro-agricultural, pastoral and fisheries development, irrigation and sustainable land management,
25. contribute to the promotion of private investment (agro-investors) in the field of hydro-agricultural, pastoral and fisheries development, irrigation and sustainable land management;
26. contribute to the development and implementation of national strategies for hydro-agricultural, pastoral and fisheries development, irrigation, and sustainable land management;
27. to carry out any other related task entrusted within the regulatory framework.

The DGADI addresses development projects and programs under its management through 4 Directorates and 7 supporting services The supporting services deliver soft activities such as finance, human resource, monitoring and evaluation etc. The 4 directorates are directly under the supervision of the General Director of the DGADI, who is however helped by 5 Technical Support Officers (CAT) who have the same rank than the Department Heads. The CATs are nominated by the Minister of MARAH after proposal by the General Director of DGADI. Each of the 4 directorates is managed by a Director, having well defined activities in charge, which are defined in the decree N°2023/MARAH/CAB of 24/05/2023.

The essential mission of the Directorate can be perceived in their very denominations. Each of the directorate implements its mission through 2 or 3 technical departments. At the whole DGADI, there are 9 technical departments, each of which is managed by a Head of Department (or Head of Service). Among the 4 directorates, 2 are especially in charge of hydroagricultural and irrigation development: the Directorate of Hydroagricultural Development (DAH) and the one of irrigation development (DDI). Both departments are responsible for irrigation technology research, innovation and pathways for modernization and dissemination. Their activities, with some overlapping discussed later with the issue of redundancy.

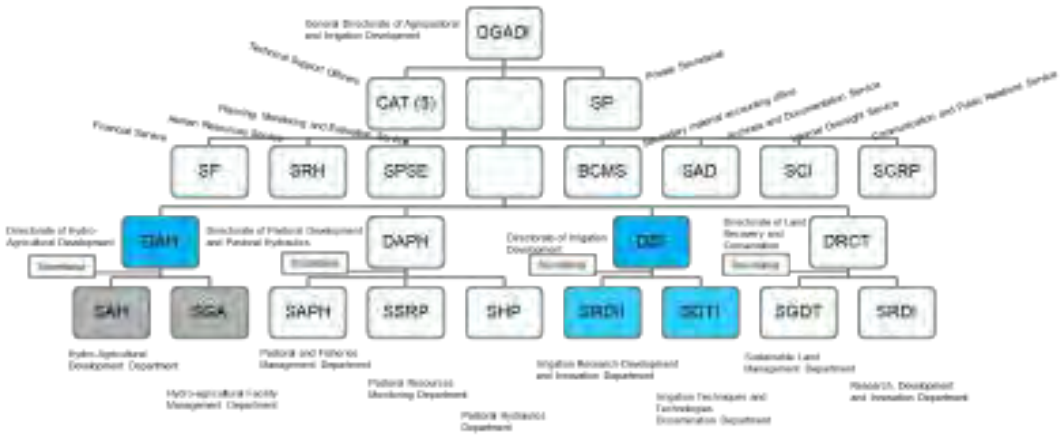

Figure 1: Flowchart of the General Directorate of Agropastoral and Irrigation Development (DGADI)

2.2 National Committee for Irrigation and Drainage – CNID-B

The National Committee for Irrigation and Drainage of Burkina (CNID-B) – an active member of ARID and ICID – was created in 1999 in Ouagadougou. Its main objectives are in line with those of ARID (Regional Association for Irrigation and Drainage) and ICID, with the following main activities: i) Irrigation Technical Days; ii) Training of members and other irrigation stakeholders; iii) Support to the Ministry of Agriculture, Animal and Fishery Resources in the expertise of development study; iv) Participation in the ARID activities of the ICID national units 5. Organization of study tours for members.

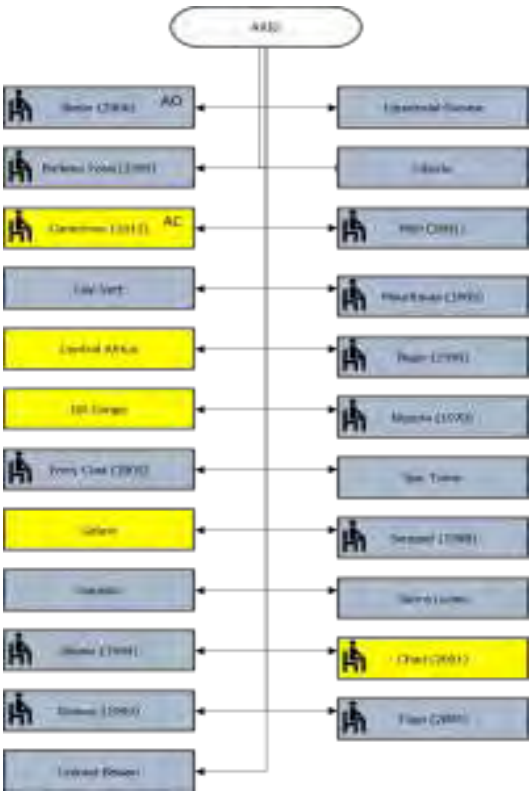

Figure 2: ARID and the 13 countries with member associations (situation in 2016)

Since its creation in 1999 (**Error! Reference source not found.**), the National Committee for Irrigation and D rainage of Burkina Faso (CNID-B), organizes the Irrigation Technical Days every two years. These technical days have treated several technical aspects of irrigation: irrigation techniques and technologies, implementation of infrastructure (design and construction), development and exploitation of irrigated schemes, reflection on environmental aspects, etc. In prelude to the recent Irrigation Technical Days held in 16-17 February 2023, a special capacity building session was held with the theme Sustainable development: "Localized irrigation and microsprinkler moved by photovoltaic solar energy". A firm will of the CNID-B to encourage the realization of modern irrigation systems, efficient in the use of water, resolutely turned towards the enrichment of the rural world while being driven by a zero-carbon technology was the main justification of this training. The following was written in the Terms of Reference of this training session: "Modernity […] means the integration of new technologies available in the proposed production systems aimed at meeting the current and future needs of farmers." Therefore, CNID-B is expected to continue playing a key role in modernization of irrigation services.

In yellow are the countries of Central Africa (CA), and in blue those of West Africa (WA). The icon of the seated man indicates that a National Committee for Irrigation and Drainage (NCID) has been set up, with an indication of the dates of creation. No icon means there is no NCID, although a national association of rural development and irrigation engineers may exist.

2.3 Other Institutions

Several other institutions dealing with irrigation development and modernization. These institutions can be classed in 3 categories: i) Non-Governmental Organizations (NGOs), ii) research and capacity building organizations and iii) private sector operating in irrigation equipment and agribusiness. According to the Permanent Secretariat of NGOs, there are more than 277 local NGOs and more than 65 international NGOs operating in various sectors in Burkina Faso (SPONG, 2022). Not all of them are involved in irrigation development. These NGO's are either created by native nationals, or a local emanation of international NGOs. Currently, many funding to support rural development are introduced through NGOs although their impact on rural development have been criticized (Keita et al., 2022), even though many governmental institutions are struggling to succeed in irrigation and rural development (Lim and Kim, 2020). Among research and capacity building organizations dealing with irrigations, there are mainly the International Institute for Water and Environmental Engineering (2iE) through many research and development projects (2iE, 2023) and the Institute of Environment and Agricultural Research (INERA) which, in reality, has only a marginal involvement in irrigation (Traoré and Traoré, 2014). Many other capacity buildings exist in the country (IDR, 2019; MARAH, 2018),but most of them are essentially operating in agronomy and agriculture. Finally, private sector is represented by many enterprises like Emergence Ingénierie, AC3E, BETICO, Quincaillerie AgroForestière, IrriFaso…(Goafricaonline, 2023). These enterprises are active in design, logistics and irrigation system infrastructure construction.

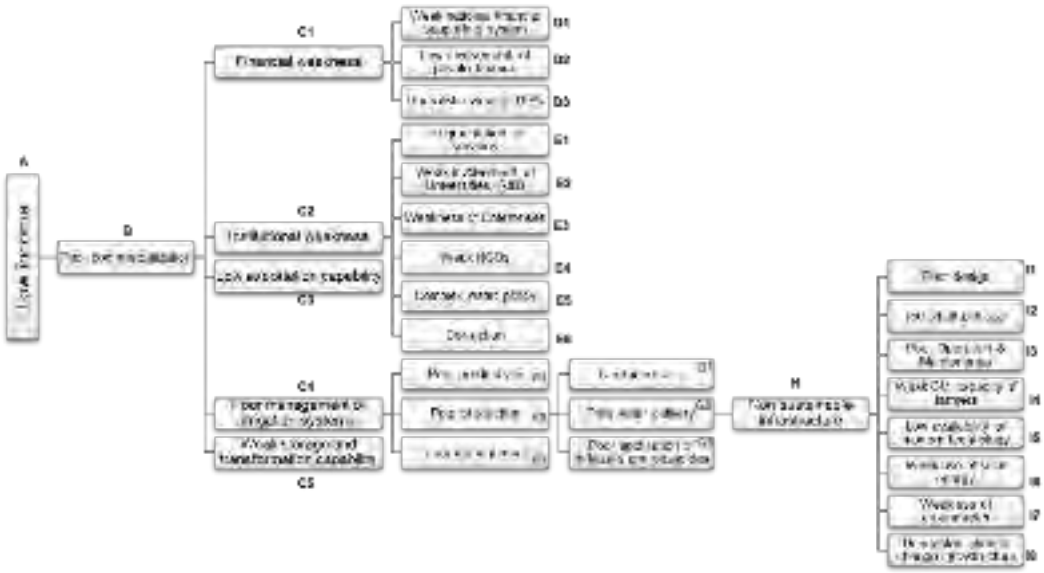

Figure 3: Conceptual flowchart of rural farmers low income from deep causes (at the right) to the most visible effect (on the left)

3. Assessment of modernization and revitalization requirements

3.1 Identifying modernization areas

Within the irrigation system framework, modernization concept has considerably evolved in recent years, toward more accuracy. In a general meaning, something has been modernized when it "was designed or made based on or using the newest information, methods, or technology [in order to] meet present styles of needs" (Merriam Webster, 2008). Previously, for the International Irrigation and Drainage Commission (ICID), "modernization is the "process of upgrading infrastructure, operations and management of irrigation systems to sustain the water delivery service requirements of farmers and optimize production and water productivity. However, experiences from all around world testify that "modernization" only applied to irrigation infrastructure has led to no or little impact on rural poor farmers' incomes.

Therefore, the ICID updated its definition: modernization focuses more attention on the needs of farmers as the core objective of irrigation operations and modernization efforts. Crop production from farmplot to its effective commercialization that makes significant income for farmers is a complex process, on which several factors such as institutions and financial systems play a key role.

Before any action is proposed, it is useful to clearly identify "what" modernization actions must operate on. For this purpose, a cause-effect tentative flowchart was elaborated and shown on Figure 3. Several researchers (Coulibaly, 2019) consider that for any modernization and innovation of economic factors of production – such as irrigation systems – to be successful, there must be insurance that involved stakeholders income will improve as the outcome of the process. Therefore, factors identified in the modernization process extend from farm level (boxes I1 to I7 on the right) to the main outcome (box A on the left). To change the "low income" outcome to a positive one – "high income for farmers" – modernization actions will have to deal consistently with all the intermediate factors. For a given country, not all factors will exist, nor have the same impact. In the case of Burkina Faso, some of the following factors are examined as a sample of potential objects that need modernization:

- "I" factors: poor design (I1), too small plot size (I2), poor maintenance (I3), low use of solar energy (I6), weak use of groundwater (I7)
- "F" factors: fragmentation of services (E1), low involvement of universities and R&D (E2), weak NGOs (E4);
- "D" factors: unrealistic view of TPFs (D3);
- "C" factors: weak storage and transportation capability (C5).

3.2 Irrigation system classification

In order to describe the real conditions of irrigation and drainage infrastructure in Burkina Faso and propose modernization or revitalization actions, several typologies of the infrastructure were undertaken. One of the first typologies resulted from a study of ARID funded by the French government (ARID, 2004). This study built upon national classifications of the 4 states of Burkina Faso, Mali, Mauritania, Niger and Senegal to yield 9 types, based mainly on organizational and institutional criteria (Figure 4). The basic hypothesis was that the i) the financial capability, ii) the management skills and iii) the type of stakeholders were the major explanatory factors for the characteristics and performance of irrigated systems. The ARID study proposed 3 basic and 4 secondary criteria of typology. The 3 basic ones were i) the degree of water control, ii) the origin of investment and iii) the irrigation system management mode. The 4 secondary criteria were: i) the size of the irrigation system, ii) the cropping pattern, iii) the water extraction technology and iv) the water distribution method. These secondary criteria were used to defined subtypes obtained from the 3 basic criteria.

Although the ARID typology covered all the types of irrigation systems in Sahelian countries of West Africa with stress on institutional and management issues, another typology – named the Permanent Interstate Committee for Drought Control in the Sahel (CILSS) typology – was elaborated some fifteen years later (CILSS, 2017).

Worth of interest, the working document produced by the latter does not even mention the ARID's typology. Nevertheless, the CILSS typology was one of the major outputs of the Sahel Irrigation Initiative (2iS) – a joint initiative of six Sahelian countries, coordinated by CILSS, supported by the regional economic communities (ECOWAS, UEMOA) – sponsored by the World Bank. The 2iS followed the Dakar Forum on Irrigation in the Sahel held in October 2013. The Forum concluded with the adoption of a Declaration by the Governments of the 6 states of Senegal, Mauritania, Mali, Burkina Faso, Niger and Chad (the new incomer) and their partners.

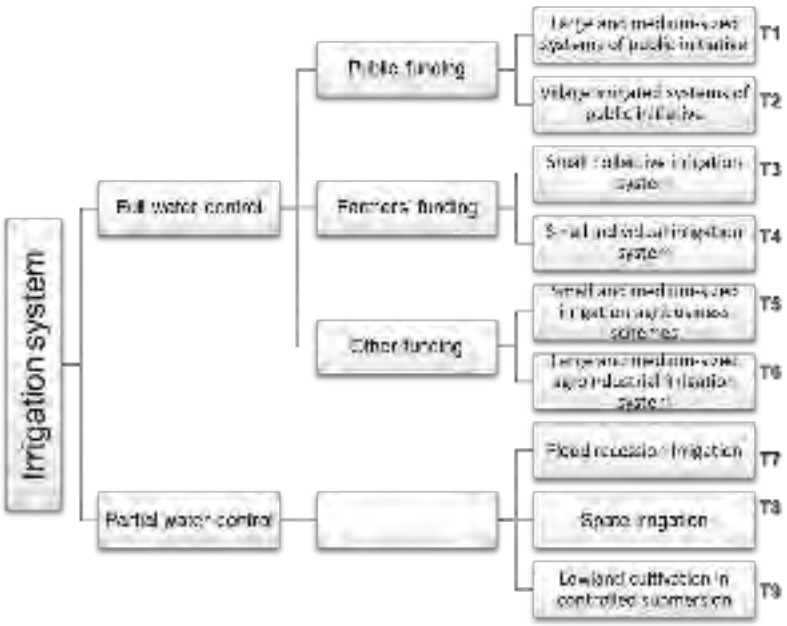

Figure 4:ARID irrigation system typology 9 types (T1 to T9) for West Africa

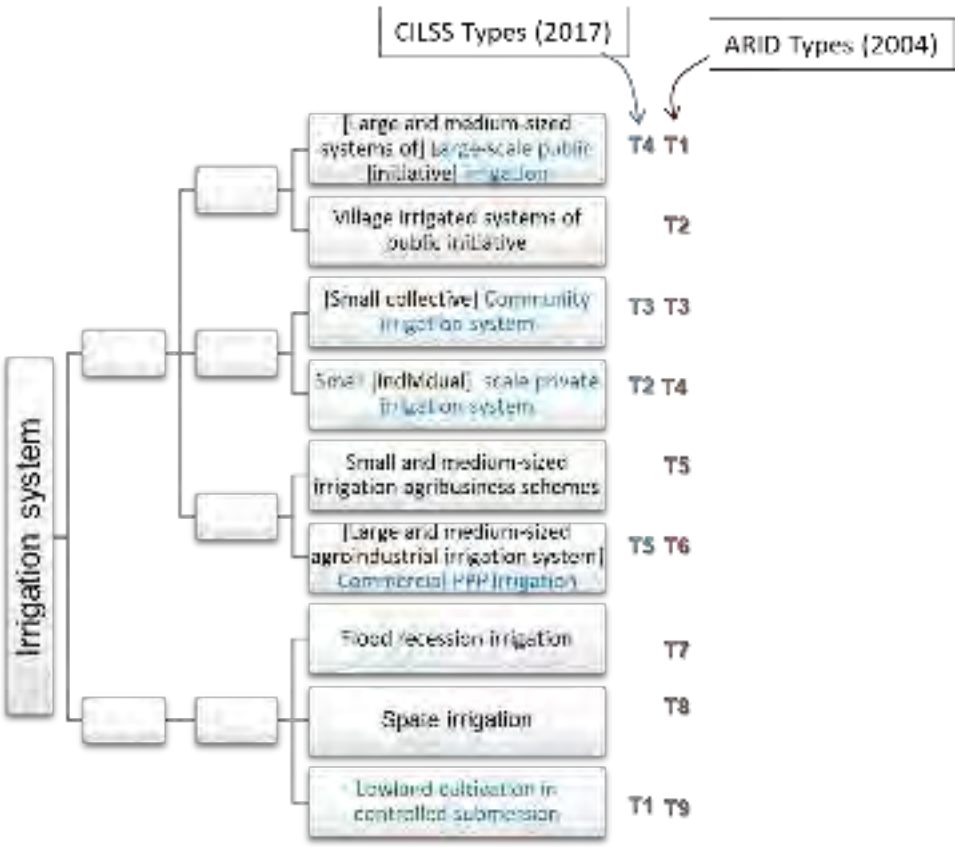

Figure 5: Comparing CILSS (5 types in blue) and ARID irrigation system typologies

While the classification criteria were not clearly defined (empty boxes in (Figure 5), the CILSS study – drawing from the types of irrigation systems found in the 6 Sahelian countries – proposed for adoption a classification truncated of previous ARID types T2 (village irrigation), T5 (small and medium-sized irrigation agribusiness), T7 (flood recession irrigation) and T8 (spate irrigation). The resulting typology numbered 5 types of irrigation systems: Lowland cultivation in controlled submersion (T1), small-scale private irrigation (T2), community irrigation systems (T3), large-scale public irrigation (T4) and commercial PP irrigation (T5). Discussing the pros and cons of each typology would be beyond the scope of the current paper aimed to focus on modernization of irrigation services. However, from **Figure 4**Figure 4 and Figure 5 it appears that the ARID typology was more detailed – without redundancy – compared with the CILSS's, and thus had the potential for helping in accurate modernization actions. Nevertheless, for obvious financial partner power and political system backing, the CILSS classification has been already adopted by many, including researchers (Bassolo Cyrille et al., 2022).

4. National factors affecting irrigation and drainage services, including water policy, institutions, and human resource capacities

4.1 Poor design, maintenance and farmplot size (factors I1, I2, I3)

Many investigations have pointed out the poor conditions of irrigation systems in Burkina Faso. For example, Baki (2022) applied a multiple correspondence analysis (MCA) to 4070 irrigation systems built between 1950 and 2020 and classified them according to the CILSS typology (T1 to T5). The results showed that the irrigation systems of less than 100 ha, which were funded by the government or organizations (associations, NGOs) and managed by local communities – type T3 in both ARID and CILSS classifications – are the least functional ones and in bad condition. The study does not provide the reasons for such specific deterioration. After investigating on 10 community irrigation systems sized each one 1.0 ha and fed by well groundwater (type T3), Keita (2022) reached the conclusion that i) water availability was not ensured in any of the systems, ii) Water distribution was also found far from the expected areas, iii) farmplot sizes were inconsistent, iv) despite the tremendous publicity and enthusiasm, it seems that the small farmers in the Sahelian zones were not yet ready to adopt drip irrigation technologies.

Apart from the type T3, other irrigation systems are subject to deterioration. The type T1 (lowland irrigation) is the most frequent in Burkina Faso. Sill, in comparison to other irrigation systems, these facilities are the ones found most frequently "less functional" and "imperfect" constructions. This kind of irrigation system uses compacted embankments as basic structures to partially control the water flows. Therefore, it is methodically intentional that the system should be renovated following each rainy season harvesting campaign (Bassolo Cyrille et al., 2022). Modernization actions would be most suitable for type T1 infrastructure.

4.2 Weak use of solar energy (factor I6)

In many new agricultural development projects proposed for funding in Burkina Faso, so-called "nature-based solutions (NBS)" ignore – deliberately or not – solar energy often considered "expensive" or even non-NBS. NBS are considered by many to be traditional agricultural methods which in the past have proven to be very unproductive, unable to fight famine in large areas of Africa. These methods, often based on human energy, are so painful that they compromise for an indefinite period the hope of many rural families to break the ruthless yoke of poverty. Moreover, while it is brandished by many development aid partners, the effect of traditional farming methods in terms of climate mitigation is often overestimated. Conversely, the use of solar photovoltaic as a substitute for fossils and human energy has the potential to reduce not only greenhouse gas emissions, but also the hardship of work while improving the efficiency of use of water and the living conditions of rural populations. This training encourages the use of solar energy as a source of energy.

4.3 Weak use of groundwater for irrigation (factor I7)

Despite its unfavorable situation as regards with water resources, Burkina Faso has deployed a tremendous effort to use those resources for development. The country has very limited water, being crossed by only 3 temporary rivers: the Mouhoun, the Nakambe, and the Nazinon. This situation has led to building more than 2500 small earthen dams for, at the beginning, the population needs, and later for irrigation. Unfortunately, 95% of Burkina Faso territory built upon the deep West African Precambrian crystalline rock composed of granite. Ghana, Côte d'Ivoire, Guinea — Conakry, Sierra Leone and Liberia have also respectively 98%, 96%, 82%, 74% and 100% of their territory subsoil built in the basement granite (CIEH, 1987). However, at the opposite of Burkina Faso, these countries have much more surface water resources. Aquifers of basement rock are discontinuous, deep, located in rock fractures and difficult to locate even with geophysical prospecting equipment (CIEH, 1987; Savadogo et

al., 1997). In the Centre East Region of Burkina Faso, for example, there is no permanent surface water. In important cities like Tenkodogo, Bittou and Cinkanssé, but even more in rural areas, the populations rely on groundwater for domestic needs. For various reasons, it is rarer to observe its use for irrigation, except for very small farm plots often fewer than 100 m2 (Keita et al., 2022). Three fundamental reasons are often invoked to explain this situation: i) the difficulty to locate groundwater in basement rock where it is only located in rock fractures, ii) the lack of competence of drilling companies and iii) the much higher exigences – when compared with drinking water expectations – of irrigation in terms of flow rates, water head and dynamic head of the boreholes. Modernization is therefore a real need in this area.

4.4 Fragmentation of services, low involvement, and capabilities of institutions (factors F)

"Fragmentation" in irrigation services bears unnecessary potential for counter-performance. Fragmentation may originate from weak synergy, a lack of trust among workers, a weak knowledge of the planned operations, insufficient adequation between policy and stakeholders' strategies (Coulibaly, 2019). It is considered as a systemic weakness of institutions. Fragmentation – instead of bringing complementarity for effectiveness – often leads to useless infighting with three mutually exclusive major consequences. The first is the "functional discrepancy" that occurs when planned activities in an institution won't materialize into mutual strengthening of the co-workers. For example, workers in two departments of the same Directorate waste energy, focus and time in competing against one another (Bugalia et al., 2020; Nilsson and Moodysson, 2015). The second consequence is the "institutional mismatch" that refers to conditions in which non-suitable employees are recruited by an institution. The third possible consequence "Negative Lock-in" that prevents changes to occur either in the institution or in the targeted field of operation.

Intentional fragmentation has been used by states to weaken institutions. For example, some states, in order to counter the threat of a coup, created institutional redundancy, severely limiting interbranch communications, and basing promotions on loyalty rather than merit (Brown et al., 2016). Consequently, the fighting effectiveness of these armed forces is degraded, and the marginal return on military investment is greatly reduced. The same may occur with civil institution dealing with rural development and irrigation.

Modernization and introduction of innovation cannot effectively take place within an institutional framework built upon fragmentation and redundancy. A close look at the flowchart of the General Directorate of Agropastoral and Irrigation Development (DGADI) in Figure 1 and at the missions of the 2 departments of the Directorate of Irrigation Development (DDI) in reveals some redundancies that a modernization action will need to tackle. In this table, 23 activities are assigned to the Irrigation Research-Development and Innovation Department (SRDII) and 28 to the Irrigation Techniques and Technologies Dissemination Department (SDTI). Redundancies are identified by alphanumeric symbols such as (1x) with SRDII. For example (1x) refers to "develop reference documents on irrigation techniques and technologies and ensure their application" with SRDII, and "to ensure that standards are considered in the construction of irrigation infrastructure and equipment" are pointing to the same activity. It does not appear that Research Development and Dissemination departments have both to take care of the "application of standards". One department can set up a standard while the other one disseminates them. Such redundancies can also be noticed for (2x) ["to ensure that environmental and social impact studies and notices are considered in irrigation projects and programmes], or for (4x) ["to monitor the performance of irrigation equipment and technologies"]. The DDI will gain in efficiency by revitalizing through removing fragmentation. When doing so, one will bear in mind that necessary activities like meetings, reporting is necessary in all services and hence are not redundancy.

Low involvement of institutions such as universities, engineering schools, research, and development institute in real-word irrigation modernization actions is also worth of notice. It has led to negative consequence. In developing countries like Burkina Faso, it is not surprising to find a critical mass of scientists produced by the education sector but who does not participate - at least for certain sectors - in the research effort and development, and therefore modernization (Coulibaly, 2019). There is a certain policy incoherence in the fact that graduates are produced while efforts are limited to stimulate their demand by the research and development structures and the business sectors. Something even more difficult to bear, this phenomenon lasts for more than 60 years Burkina Faso (and other African countries) gained their independence. The modernization of irrigation and drainage should be based on a national technological policy aimed at achieving this incentive. This policy should be based on an integrated framework whose overall consistency has been matured to avoid major disappointment.

Indeed, in the years 1999, in Sourou (Burkina Faso) and particularly on the irrigation systems (ARID type T1) of Niassan Di, Débé and Gouran, there was an attempt to settle private agribusiness farmers. Family farmers or small farmers were the most numerous and so was the total area allocated to them. This was also the case of their contribution to the food production of these localities. Notwithstanding, agribusinessmen, even in smaller numbers, were not the less fortunate. Certain advantages placed them individually above the small farmers. This

was about the minimum area to be irrigated (10 ha) against 0.12 to 3 ha for the latter. Land laws also facilitated their enterprise. But, in practice, agribusiness production was not available or accessible. Also, there was still the problem of sustainability and food variability, whereas agribusiness was supposed to solve it (Zongo, 2014).

It emerges from the investigations made by Zongo (2014) that the relationship between agribusiness, land and food security in the localities of Niassan, Di, Débé and Gouran was not an achieved objective. Agribusiness had been taken away from its primary mission entrusted to it by that of the State, which was primarily food security. This has hampered the policy of industrialization and industrial transformation of agribusiness agricultural products because of the sale in their raw state. Clearly, a well-designed policy with the involvement of universities and engineering schools could have preserved from such an issue.

Table 1: Side by side view of SRDII and SDTI missions within DDI

Mission of Irrigation Research-Development and Innovation Department (SRDII)	Mission of Irrigation Techniques and Technologies Dissemination Department (SDTI)
1. develop reference documents on irrigation techniques and technologies and ensure their application (1x); 2. to ensure that environmental and social impact studies and notices are considered in irrigation projects and programmes (2x); 3. to monitor the performance of irrigation equipment and technologies; (4x) 4. to ensure the development of irrigation techniques and technologies; 5. to promote partnership with research institutions, universities, schools and training centres; 6. to promote research, development and innovation in the field of irrigation (5x); 7. to promote private investment in the field of irrigation(3x); 8. capitalize on information from projects, programs, NGOs, associations and private promoters in the field of irrigation (6x); 9. to contribute to the follow-up of studies and works for the construction of water mobilization works for agricultural use (market gardening wells, boreholes, drinking water collection basins, etc.); 10. to contribute to the promotion of the use of innovative irrigation techniques and technologies (7x); 11. to contribute to the support-advice to local authorities and dismemberments of the State in the planning, construction, maintenance and maintenance of small water collection works for agricultural use and irrigation equipment (8x); 12. contribute to the protection of water bodies offering irrigation opportunities; 13. to contribute to the development and management of irrigation infrastructure; (9x) 14. to contribute to the capacity building of stakeholders in irrigation techniques and technologies; 15. to contribute to the animation of irrigation	1. to ensure that standards are considered in the construction of irrigation infrastructure and equipment (1x); 2. to ensure that environmental and social impact studies and notices are considered in irrigation projects and programmes (2x); 3. to ensure the harmonization of interventions in the field of irrigation; 4. to ensure the monitoring, supervision and control of studies and works for the realization of water mobilization works for agricultural use (market gardening wells, boreholes, runoff water collection basins, impluvium, catchment basins) and market vegetable irrigation systems; 5. to promote the construction of small water mobilization works for small-scale irrigation (market gardening wells, boreholes, impluvium, catchment basins, etc.); 6. to promote private investment in the field of irrigation (3x); 7. to promote innovation in the field of irrigation (5x); 8. promote the use of innovative irrigation techniques and technologies; (7x) 9. to ensure the dissemination of innovative and efficient techniques and technologies in irrigation (7x); 10. to strengthen the capacities of irrigation stakeholders in terms of irrigation techniques and technologies; 11. to provide advisory support to local authorities and State divisions for the development of irrigation (8x);; 12. to capitalize on information from projects, programs, NGOs, associations and private promoters in the field of irrigation (6x); 13. contribute to the organization of the launch of the dry season agro-pastoral campaign; 14. to contribute to the monitoring of the dry season agro-pastoral campaign, 15. contribute to the planning and participatory programming of activities in the field of irrigation; 16. to contribute to the promotion of private investment (agro-investors) in the field of irrigation; (3x) 17. contribute to knowledge management in the field of irrigation 11x); 18. to contribute to the animation of frameworks for the promotion of irrigation (10x);

Mission of Irrigation Research-Development and Innovation Department (SRDII)	Mission of Irrigation Techniques and Technologies Dissemination Department (SDTI)
promotion frameworks (10x); 16. to contribute to the management of knowledge in the field of irrigation (11x); 17. to contribute to the consideration of standards in the construction of irrigation infrastructure and equipment;(1x) 18. to contribute to the development and management of irrigation infrastructure; (9x) 19. to contribute to the formulation and monitoring of the implementation of irrigation development projects and programmes (12x); 20. contribute to the development and implementation of national irrigation strategies (13x), 21. to contribute to the establishment and animation of an information system and the monitoring of good practices in irrigation (14x); 22. to prepare the periodic reports within its competence (14x); 23. to carry out any other related tasks entrusted within the regulatory framework.	19. contribute to the development and management of irrigation infrastructure;(9x) 20. contribute to the protection of water bodies offering irrigation opportunities; 21. contribute to the development and implementation of national irrigation strategies (13x); 22. to contribute to the development of reference documents on irrigation techniques and technologies and to ensure their application; (1x) 23. to contribute to the formulation and monitoring of the implementation of irrigation development projects and programmes (12x); 24. to contribute to the establishment and animation of an information system and the monitoring of good practices in irrigation (14x); 25. contribute to the monitoring of the performance of irrigation equipment and technologies; (4x) 26. to contribute to the development and management of irrigation infrastructure;(9x) 27. to prepare the periodic reports within its competence (14x); 28. 28) to carry out any other related tasks entrusted within the regulatory framework.

5. Priority issues for modernization of irrigation and drainage services

From the discussions done in the previous sections, it appears that for Burkina Faso, modern irrigation services will have in priority to deal with:

At infrastructure levels:

- Poor design, small farmplot size and maintenance issues with irrigation systems of types T1 (Lowland
- Cultivation in controlled submersion) and T3 (Community irrigation system) in CILSS classification
- Weak use of solar energy
- Weak use of groundwater
- At institutional level:
- fragmentation of services, low involvement and capability of institutions

6. Conclusions and Recommendations

Modernization of irrigation services needs to be an integrated approach, based on a logical pathway flowchart. Such a flowchart was proposed in the case of Burkina Faso. It built clear cause-effect links between conditions and institutions from the infrastructure to the final output that is the low income of poor rural farmers, passing through institutional difficulties that hamper rural development. The approach used infrastructure typology to specify the type of action to undertake. For each modernization difficulty a (set of) solutions were proposed.

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CHINA COUNTRY PAPER: PATHWAYS AND TECHNOLOGIES FOR MODERN IRRIGATION SERVICE

1. Introduction

As the major provider of China's agricultural production, large-and-medium-sized irrigation schemes are the pillars of food security and rural economic and social development. Chinese government has always attached great importance to the construction and development of irrigation schemes. Since 1998, the state has been heavily investing in the modernization and revitalization of large-scale irrigation schemes, with the purposes of saving water, controlling risk factors, improve capacity, and solving the leakage problems of major canals.

Thanks to these measures, the efficiency and profitability of irrigation water have been upgraded, and the comprehensive agricultural production capacity boosted greatly. However, due to low construction standard, long service duration, changing water and soil conditions, and exacerbating supply-demand conflicts, some irrigation schemes still face severe capacity constraints in terms of infrastructure, water use management, and sustainable development, and are unlikely to meet the demand of rural revitalization, national food security, and agricultural modernization.

Following the water governance guideline of prioritizing water conservation, balancing development with spatial distribution of water resources, practicing systematic governance and achieving government-market synergy, the Chinese government has set the goals of raising agricultural water use efficiency, improving the availability and accessibility of water supply service, and enhancing the production capacity of key agricultural products. To reach these goals, it has launched the campaign of modernizing and revitalizing major irrigation and drainage infrastructure. For instance, in areas with suitable water and soil conditions and the potential for land reclamation, the potential of irrigation projects have been fully tapped and irrigated areas have been recovered and enlarged properly.

In the process of irrigation scheme construction and modernization, modern technologies and advanced management approaches have been introduced and applied, to set up a construction, operation and maintenance system incorporating adequate infrastructure, efficient water use, scientific management, and healthy eco-system. This provides firm support and guarantee to the broader causes of food security, poverty alleviation, and rural modernization and revitalization.

2. Overview of national irrigation and drainage services

Over the years, China has established 7,330 large-and-medium-sized irrigation schemes and more than 22 million small ones, expanding the effective irrigated area to over 69.13 million ha and the drainage area to 21.67 million ha. As such, an irrigation and drainage infrastructure network incorporating large, medium, and small irrigation schemes has been completed. For large irrigation schemes, 60% of canals, 30% of structures on the canals, and 70% of drainage ditches are yet to be rehabilitated; only 65% of the major structures are in good condition. For medium schemes, 34% of headworks, 45% of major canal networks, 44% of structures on the canals, and 65% of the major drainage ditches need rehabilitation and water-saving upgrading. Meanwhile, 65% of large and medium schemes have secured financial resources for staff salary and repair and maintenance.

In the recent years, China's annual agricultural water diversions have stabilized at 364 billion m^3, and the net consumption is between 205 billion m^3 and 207 billion m^3. From 2000 to 2021, 116.96 billion m^3 of water was saved annually in the agricultural sector, and the annual grain output was 684 million tons.

Of all the water saved, 37.55 billion m^3 was contributed by the reduction of net water consumption per unit of grain production (or higher crop water use efficiency), which means the reduction of agricultural water consumption by 66.11 billion m^3 each year; 50.84 billion m^3 of water was saved thanks to irrigation scheme rehabilitation, of which 56.53% could be attributed to agronomic water saving measures, and 43.47% to engineering measures.

3. Assessment of modernization and revitalization requirements

Through its Implementation Program of Major Agricultural Water Saving and Water Supply Projects during the 14th-Five-Year-Plan Period, China has issued a clear mandate to achieve digitalized, web-oriented and smart irrigation scheme management and water regulation. In 2022, the Ministry of Water Resources explicitly called for the building of modernized digital irrigation schemes.

Digitally twinned irrigation scheme is a new type of infrastructure that takes the physical irrigation scheme as the unit, spatial and temporal data as the base, digital model as the core, and water-sector-related knowledge as the driving force. It carries out digital mapping, intelligent simulation, and forward-looking preview of all the physical elements and construction and operation of irrigation schemes. Through synchronous simulation and operation, interaction between the virtual and real worlds, iteration, and optimization, it could achieve real-time monitoring of the physical irrigation scheme, identify its problems, and optimize its regulation.

To build a digitally twinned irrigation scheme, four aspects of work must be carried out.

First, build information infrastructure, mainly including three-dimensional sensing system, automatic control system, and support system, to provide basic support and guarantee of computing capacity for data collection, transmission, storage, analysis, and application, and the operation and management of irrigation schemes.

Second, set up the platform of digital twinning, mainly the repositories of data, model, and knowledge. The database could serve as the calculation basis for the latter two, while the latter two could provide algorithms for typical applications. The repository of data is composed of basic data, monitoring data, management data, geological and spatial data, and externally shared data; the repository of model has hydraulic models, intelligent identification models, and visualization models; the repository of knowledge covers expertise and operational rules based on years of operation and management.

Third, establish a demand-oriented application platform that caters for the following needs: sensing and forecasting of water supply and demand, water resources allocation and water supply regulation, flood and drought disaster prevention, project management, automatic control, water measuring and water fee collection, public services, and the overall mapping of the irrigation scheme.

Fourth, enhance cyber security and the operation and maintenance systems, with the focus laid on organization and management, security technologies, safe operation, supervision and monitoring, data security, O&M, and standards and norms.

4. National factors affecting irrigation and drainage services, including water policy, institutions, and human resource capacities

First, further standardize and codify the management of irrigation schemes. Regarding organizational management, priority has been given to the establishment of a high-skill talent team, and mechanisms of monitoring and assessment and incentive and disincentive schemes have been set up. As to safety management, responsible administrative agencies have been designated, the accountability system of safe production has been adopted, the trainings and drills of flood prevention and control have been regularized, and safe production standards have been set up for management agencies of irrigation and drainage projects. In the aspect of engineering management, daily management, patrol, repair and maintenance have been institutionalized and standardized, responsibilities have been clearly divided and delegated, the repair and maintenance of engineering facilities have been enhanced, grassroots stations have been upgraded and auxiliary facilities set up. For water use and supply management, water resources have been taken as the hard constraint for the reclamation of arable land and agricultural production, a water use and supply management system has been set up by licensing water withdrawal, capping total withdrawal, and applying quota management, under which water use and water fee collection have been standardized, and precision water measurement has been realized through the establishment of tiered water measurement system. As to digitalization, innovative service models have been introduced based on the actual needs of irrigation schemes to further integrate their business architectures with modern information technologies. Financially, financial and asset management has been standardized, staff salary and welfare have been guaranteed, and sustainable development has been

pursued by fully tapping into land and water resources, diversifying business models, and hence improving profitability.

Second, undertake the agricultural water pricing reform. Regarding support measures, multiple systems have been created and applied, targeting licensing irrigation water withdrawal, capping total withdrawal, imposing withdrawal quotas, introducing agricultural water rights allocation, buying back saved irrigation water, exploring water right trading among industries and water users, and providing services such as water right certification and trading, information release, and service consultation. For the improvement of the water pricing mechanism, through adjustments made with proper frequency and scale, prices have been increased to cover the full cost or at least the cost of O&M. A variety of cost-sharing and subsidy models have been explored, so as to set up two separate systems of subsidy and price increase, and to motivate water saving without adding to the burden on farmers; a quota system has been set up for agricultural water use, under which water use outside the quota is priced in a tiered way, and different prices are charged for water used for different purposes such as food crop irrigation, cash crop irrigation, and aquaculture and livestock production. As to improving the investment mechanism for water saving projects, fundings for precision agricultural water saving subsidy and rewards have been secured through various channels, and the effectiveness and sustainability of relevant investment have been enhanced; social capital has been mobilized to participate in the construction and O&M of agricultural water-saving projects. For irrigation scheme rehabilitation, funds are raised through trading of water rights and newly added quota of arable land.

5. Priority issues for modernization of irrigation and drainage services

i. Persist in reform and innovation. As requested by the principle of first establishing the regulatory regime, and then constructing the project, reform the O&M mechanisms of irrigation schemes, and foster innovations in areas such as water saving theories, institutions, technologies, and practices. Based on the National Guidance on Implementing Institutional Reform of Water Conservancy Project Management, further define the responsibilities, rights and obligations of governments, irrigation scheme management agencies, and water user associations according to the tasks they undertake, including preventing and mitigating drought disasters, serving agricultural production, protecting environment and ecology, and safeguarding national food security, and gradually set up a sound operation system through rationalizing the regulatory frameworks and providing sound policy packages.

ii. Enhance the efforts in collecting water fees and securing financial resources for staff salary and repair and maintenance, and to improve the funding mechanism for the O&M of irrigation projects. Set up reasonable standards for government funding and make dynamic and case-specific adjustment according to national policies, irrigation scheme characteristics, and the financial status of local governments; meanwhile, strive to fully guarantee the staff salary funding and water fee collection in at least 90% of irrigation schemes. Optimize the central government's subsidy policy for the O&M of public welfare water conservancy projects in central and western China and other regions that have just eliminated poverty. Fully implement the subsidy policies for the O&M of irrigation and drainage projects.

iii. Adopt the market-oriented approach and further unleash the drive, ingenuity, and talent of potential advocates of agricultural water saving. Combine water saving with agricultural modernization and foster the development of water user associations, farmers' cooperatives, family farms, and leading enterprises, so as to exploit the economies of scale and intensification of crop production on the land of irrigation schemes, and to motivate and capacitate potential beneficiaries and relevant market players for the construction and management of agricultural water-saving projects. Encourage the participation of social capital in the project construction and O&M, carry out contract management for agricultural water saving, introduce advanced technologies, and adopt the mode of water saving service provider. Tighten the oversight and regulation of the water-saving material and equipment market.

iv. Separate repair and maintenance from O&M. Institutionally stop the imbalanced resource allocation between project construction and management, set up rules, standards, and requirements for the separation of repair and maintenance from O&M, adopt quantitative management and appraisal system for project management and maintenance, and clarify the division of responsibilities, so that the investment in repair and maintenance could generate greater benefits, and the project service life could be extended. Introduce various practices of separating repair and maintenance from O&M. For instance, the government could purchase

property management services from professional teams and nurture and regulate the repair and maintenance market.

v. Carry out the delimitation of water conservancy projects and confer them land tenure. The Ministry of Water Resources will enhance communication with other Ministries of natural resources, housing and urban-rural development, transportation, and forestry, and the local governments of irrigation schemes, so as to have the implementation plan drafted for delimiting the management and protection of irrigation schemes according to comprehensive surveys and extensive research. After conducting the delimitation, local water authorities and local governments (above county level) should coordinate with local natural resources authorities to set up boundary markers, confer land tenure and issue relevant certificates. During the 14th-Five-Year-Plan Period, irrigation schemes with clear boundaries and ownerships should confirm their land tenure and obtain relevant documents.

vi. Enhance the management of irrigation water by village collectives, agricultural business entities, and water user associations. Water user associations should enhance capacity building, clarify responsibilities and functions, improve staff quality and stability, and standardize operation. They should also improve the maintenance and management of on-farm engineering facilities, sign water supply contracts with water users, distribute and allocate irrigation water in a fair and proper manner, collect and pay water fees, settle water use disputes between water users, and promote the application of water-saving irrigation technologies

6. Conclusions and recommendations

i. Future modernization plans

First, stress the importance of designing at the top level and overall planning, and formulate national and regional development planning for irrigation scheme modernization. At the national level, extensive research and discussions should be conducted to identify the goals, content, framework, assessment system, and key information on project construction standards of irrigation scheme modernization, so that overarching guidelines could be formulated. Locally, management agencies of irrigation schemes should also make modernization plans (including locating all the measurement and control sites to be equipped with sensing and control facilities, designing in advance the overall structure of the operational platform and other software systems, and taking into consideration future demands for adding functional modules, improving data storage capacity, computing capacity,, and unifying interfaces), and implement them step by step according to levels of priority and funding availability. As a major target of China's investment in infrastructure, irrigation scheme modernization should be first carried out in grain production bases and ecologically vulnerable areas. In addition, it should suit with China's conditions and meet the needs of agricultural modernization. A modernized irrigation scheme should be water saving, eco-friendly, efficient, smart, and innovative.

Second, speed up the construction of national agricultural water network, an important component and capillaries of the national water network. Under this framework, efforts should be made to boost the capacity of water resources allocation, regulation and storage, to change the imbalanced spatial and temporal distribution of land and water resources, to alleviate the tension between food production and water shortage in the North China Plain, Fen-Wei Plain, Hetao Plain, Hexi Corridor, and the plain in the west of Liaoning and east of Inner Mongolia, to properly exploit backup farmland resources and unconventional water resources, and to construct new irrigation schemes. In addition, the rehabilitation and modernization of large-and-medium-sized irrigation schemes should be pushed forward to boost irrigation water use efficiency and crop water use efficiency for better food production capacity. To guarantee water accessibility and agricultural sector's resilience to droughts, small-scale water cellars, pools, dams, pumping stations, and canals need to be constructed and the water supply capacity of small water sources need to be restored. Water-saving technologies need to be applied to build a water efficient agricultural sector. The timing and water use of irrigation need to be set properly and O&M needs to be further refined so as to achieve precise allocation of water resources.

ii. Recommendations

Irrigation scheme modernization is not limited to modern irrigation systems or simple automatization and informatization. It is a process in which engineering facilities, management approaches, and innovation capacity are all updated to produce the results of water saving,

high efficiency, healthy ecology, and high-quality development. Therefore, to realize the modernization and quality development of irrigation schemes, various measures have to be adopted. For instance, the innovation capacity needs to be improved to make the engine of modernization even more powerful. The researches on modernization standards and assessment system need to be strengthened. The technical services of irrigation schemes need to be innovated and upgraded, pilot experimentation projects for modern technologies need to be set up, and the extension of irrigation and drainage technologies need to be commercialized. In the context of climate change, the monitoring and data collection of agricultural water saving and water use efficiency need to be enhanced, for which useful practices include integrating major irrigation experimentation stations of typical areas into the national system of major field observation and research stations, improving the national network of irrigation and drainage experimentation and water use monitoring, and promoting data sharing to provide scientific basis for the planning and design of irrigation scheme modernization. A long-term support system needs to be established for the technological innovation of modern irrigation schemes, and pilot demonstration projects need to be set up.

IRRIGATION MODERNISATION IN INDONESIA 2023

Ariyanti, Vicky

ABSTRACT

FAO defines irrigation modernisation as a process of technical and managerial upgrading of irrigation schemes combined with institutional reforms. ICID defines the modernisation of irrigation as the process of improving an existing project to meet new project criteria. Indonesia's status for modernisation irrigation has not been reported as the efforts do not simultaneously take form based on the Circular Letter on irrigation modernisation in 2019. Although the efforts have started since the 1990s, more prioritisation on modernisation efforts is in place since 2019. This paper highlights the updated status of Indonesia based on the five pillars and 45 steps of modernisation in irrigation.

The case studies are highlighted Kedungputri, Wadaslintang, and Rentang with histories of modernisation efforts. The findings show that currently, the average score for modernisation is at 20.94 out of 45 steps or ranging around 46%. It is promising progress for Indonesia, which is still undergoing modernisation efforts in the upcoming years.

Keywords: modernisation, country status, premium irrigation

1. Introduction

Of the global cropped area, about 17% of the total land area, only about 40% is irrigated (FAO 2022). Water development in irrigation is critical for the world's food security. Currently, some 8 billion people depend on agriculture for food and livelihood (FAO, 2002). Irrigation stabilised food production and enabled crop diversity. Even today, worldwide irrigation still makes up about 80% of water demand. Therefore, irrigation need system-based management incorporating all the assets within the irrigation scheme. Poor irrigation management has resulted in build-up sedimentation, water logging, and further damage.

Modernisation in irrigation varied on the scale and condition of each country. The FAO describes it as “a process of technical and managerial upgrading of irrigation schemes combined with institutional reforms if required, to improve resource utilisation and water delivery service to farms” (Facon and Renault, 1999). Indonesia just started the initiative of modernising its irrigation in the 1990s, but real action with technical guidelines began after 2019 with the existence of the Circular Letter of the Director General of Water Resource. The condition of modernisation on irrigation in Indonesia is described in the following sections.

2. Overview of National irrigation and drainage services

Indonesia has estimated that 2.5 million paddy fields have been converted to other land use in the last 20 years, without replacement and more evident water shortages during the dry season (Kustiani and Scott, 2014). Moreover, our biggest threat is deferred-maintenance, ageing infrastructure, and a lack of rehabilitation of irrigation assets caused primarily by a lack of adequate funding. These conditions create severe constraints on performance resulting in low productivity, which threaten the sustainability of irrigation systems.

The country is in a strategic position located on the equator with a tropical climate, 12 hours of daylight sunshine or around 2,500 hours annually (Climatemps, 2019) mild average temperature of 27.4°C, relative humidity of 78.7% correlating to rainfall in the Monsoon or rainy season between December to May (Table 1). This condition supports all year-round cropping patterns.The archipelago country is also blessed with 60% of surface water potential running on rivers, with a total area of 5,193,150 km2 including the sea, but only 1,904,569 km2 of land (United Nations, 2005). The 5,700 rivers that are managed within 133 official river basin territories, referred to as Wilayah Sungai (WS) (Ariyanti, 2020).

The archipelago is also home of 127 volcanoes (MEMR, 2011), which benefits the fertile condition of the lands for cultivating all kinds of crops. Mainly the land is used to plant rice as the main staple of the people, also combined with corn, cassava in lower regions. Higher regions are used to cultivate vegetables, chillies, tobacco, coffee, tea, even pine trees and rubber trees.

Based on the circular letter on modernisation in irrigation, there are seven irrigation areas prioritised in 2019 as pilots to be modernised in seven river basin organisations (RBOs). These systems are prioritised for premium irrigation have reservoirs in the upstream, namely:

Figure 1. Map of irrigation area in Indonesia (Bappenas, 2023)

Table 1. Indonesia Rainfall Annual

Islands	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	DEP	OCT	NOV	DEC	Annual
Sumatera	146	122	160	169	132	96	92	92	114	146	200	188	1,656
Java	199	189	165	132	73	43	30	19	22	55	132	184	1,244
Bali Nusa Tenggara	177	167	124	68	29	17	11	9	11	31	80	141	866
Kalimantan	162	140	162	162	148	116	92	70	78	112	168	181	1,593
Sulawesi	146	133	141	141	127	115	83	47	47	56	96	142	1,275
Maluku/Papua	149	147	156	149	137	135	118	106	111	104	113	150	1,575
Indonesia	**156**	**141**	**157**	**153**	**129**	**107**	**90**	**77**	**86**	**106**	**140**	**170**	**1,521**

Source: JICA Project Team

1. Cisadane at Ciliwung Cisadane RBO;
2. Wadaslintang at Serayu Opak RBO;
3. Mrican at Brantas RBO;
4. Rentang at Cimanuk Cisanggarung RBO;
5. Saddang at Pompengan Jeneberang RBO;
6. Way Sekampung at Mesuji Sekampung RBO; and
7. Komering at Sumatera VIII RBO.

It also states that 2024 onwards Indonesia will add more modernisation efforts for in irrigation areas all over the main islands of the Indonesian archipelago: Sumatra, Jawa, Kalimantan, Bali, Sulawesi, Nusa Tenggara, Maluku, and Papua, according to budget availability.

The letter also highlighted irrigation management as five pillars including water availability, infrastructure, irrigation O&M, Institutions and human capital. Each of the pillars consists of steps adding up to a total of 45 steps.

Pillar no.1 improves water security and availability in five steps: (1) harmonisation of upstream and downstream relations, (2) maintaining environmental sustainability, (3) watersheds and irrigation channels, (4) water allocation, water supply and storage, and (5) additional water supply.

Pillar no. 2 rehabilitation and upgrading of infrastructure in eight steps: (6) dam, reservoir, situ, long storage, dam, (7) main building (dam, free intake, and others), (8) measuring toll building, (9) carrier and exhaust km and stakes hm, (10) building, (11) OP support facilities, (12) complementary buildings, and (13) tertiary level infrastructure.

Pillar no. 3 improvement of the irrigation management system in 18 steps: (14) irrigation operational system (IT based), (15) water needs, (16) allocation and distribution of water and periodic assessment, (17) water loss, (18) assessment period and watergate operation (real-time), (19) improvements of 12 operation forms and 10 maintenance forms, (20) water allocation, (21) water productivity, (22) monitoring water management implemented as an irrigation service agreement (ISA), (23) water flow control system, (24) water delivery system, (25) water usage (with data logger), (26) drainage, (27) O&M facilities, (28) IT-based O&M, (29) water management at tertiary canals, (30) financing system, and (31) participation

Pillar no.4 strengthens irrigation management institutions in eight steps: (32) irrigation commission, (33) the modern irrigation management Unit (UPIM), (34) the Irrigation Counseling Task Force which is part of UPIM, (35) The mobile special maintenance task force (SPKM) is part of UPIM, (36) Knowledge Management Center task force which is part of UPIM, (37) Irrigation Security Task Force (SPI) which is part of UPIM, (38) Water User Associations (I/G/P3A), and (39) Central Irrigation Modernization Team

Pillar no. 5 strengthens human resources in six steps: (40) status and position, (41) education, training and certification, (42) completion of non-PNS management system, (43) career planning, (44) incentive/remuneration system, and (45) WUAs empowerment.

The Indonesia Country Paper presents the current status of irrigation modernization through case studies of three selected schemes against the 45 steps of irrigation modernization described above.

3. Methodology

The paper uses qualitative comparative analysis (Rihoux, 2006) for Indonesia with in-depth case studies of three irrigation systems of Kedungputri, Wadaslintang, and Rentang. Primary data used were in-depth observations from 2015 to 2023 within the RBOs, interviews with informants representing each level of irrigation system managers, site visits, and documentation. As for secondary data, we use plans, documentation, and reports. Comparative case studies are used to compare between national, provincial, and municipal levels. This method of analysis helps investigate contemporary in-depth phenomena within their real-life context and compares the conditions between the different cases (Riboux, 2006, Yin, 2018). The analysis uses the five pillars of irrigation modernisation and the 45 steps entailed. Each of the steps is given a value based on the implemented condition, 0 for no activity, 0.33 for low activities, 0.66 for progressing activities, and 1 for the complete stage. Detailed data are available for only the three case study irrigation areas; however, these are considered representative of the status of modernization in Indonesia.

4. Assessment of Modernization and Revitalization Requirements

The assessment is done in two steps: (a) Developing a tool to assess the readiness of irrigation schemes to proceed to the irrigation modern index (RPIMI). (b) The implementation of RPIMI in selected typology irrigation systems as pilot irrigation schemes. The RPIMI is used to measure the readiness of irrigation schemes to implement modernisation. The RPIMI is developed based on five pillars as a simple way but accurate enough as an assessment tool, but it has a different method (Table 2a) than the 45 steps mentioned above in determining the readiness of modernisation. The survey is done by applying rapid assessment to 16 schemes (Table 2b).

In addition to the seven prioritised irrigation areas, in the circular letter, the RPIMI survey has been conducted at Bondoyudo, Batang Anai, Colo, Serayu, Cikeusik, Kedungputri, Pamukkulu, Talang, Jurang Batu areas. The seven prioritised areas form the Bappenas target for modernised irrigation of 19.6%.Detailed data for Wadaslintang, Kedungputri, and Rentang, areas are collected on the status of the 45 steps for each irrigation area.

Table 2a Methods of RPIMI (Arif, et al, 2019)

No	Indicator	Allocated point	Category	Weighted point	Point
1	2	3	4	5	6=3x5
1.	Water availability	15	Good Fair Poor	> 80 50 up to 80 < 50	
2.	Irrigation Infrastructure	30	Good Fair Poor	> 80 50 up to 80 < 50	
3.	System Management	20	Good Fair Poor	> 80 50 up to 80 < 50	
4.	Institution	20	Good Fair Poor	> 80 50 up to 80 < 50	
5.	Human Resources	15	Good Fair Poor	> 80 50 up to 80 < 50	
	Total	100		Total point	

Table 2b Results of RPIMI (Arif, et al, 2019)

No	Irrigation scheme	area (ha)	Survey year	RPMI Total Score
1	DI Wadaslintang	31.133	2014	77,6
2	**DI Bondoyudo**	**11.784**	2014	**81,5**
3	**DI Batang Anai**		2014	**63,2**
4	DI Rentang	87.840	2015	66,9
5	**DI Jatiluhur**	240.000	2015	68
6	DI Sadang	60.300	2015	**68,7**
7	**DI Colo**	26.234	2016	**69**
8	**DI Mrican**	31.272	2016	**77,9**
9	DI Komering	62.536	2017	**66**
10	DI Sekampung	55.373	2017	**78**
11	DI Serayu	20.795,60	2017	**85,8**
12	DI Cikeusik	6.899	2018	**66,3**
13	DI Kedung Putri	4.341	2018	**68,8**
14	DI Pamukkuhu	6.256	2018	**67,86**
15	DI Talang	8.844	2018	**67,3**
16	DI Jurang Batu	3.500	2018	**62,4**

5. Priority Issues for Modernization of Irrigation and Drainage Services

Prioritization among the five pillars is based on funding availability. The Government of Indonesia (GoI) utilises loans from the ADB and World Bank to support the implementation of modern irrigation. Pillars 1 and 2 are hard components, while pillars 3 to 5 are soft components. The ADB uses Integrated Participatory Development and Management of Irrigation Program (IPDMIP) and puts more attention on soft components, while the World Bank's Dam Operational Improvement and Safety Project (DOISP) and Strategic Irrigation Modernization and Urgent Rehabilitation Project (SIMURP), also a combination of GoI funding with JICA for Rentang Irrigation Modernisation Project (RIMP) focuses more on the hard components on pillar no.1 improves water security and availability and no.2 rehabilitation and upgrading of infrastructure. However, the emphasis of pillar no.3 improvement of the irrigation management system, with added IT highlights the difference between non-modernised and modernised irrigation.

Although other pillars also need to be addressed, especially the human resources in pillar no.4 strengthen irrigation management institutions, and no. 5 strengthens human resources. Based on the case studies selected for in-depth analysis, we present the condition of three irrigation areas under modernisation efforts, which also is called premium irrigation areas downstream of a dam: Kedungputri (4,341 Ha), and Wadaslintang (31,584 Ha) under the Serayu Opak RBO, and Rentang (87,840 Ha) under the Cimanuk Cisanggarung RBO.

5.1 Kedungputri

The Kedungputri irrigation area (4,341 Ha) is located in Purworejo regency, it is located downstream of the under-construction Bener Dam (Figure 1), which is currently at 26.17% (Serayu Opak RBO, 2023), with the tunnel finished, while the quarry material is still under land acquisition process. Pillar no. 1 is handled by providing reliable water availability with the Bener Dam construction. The funding for this dam is using national funding from the Government of Indonesia through the Ministry of Public Works and Housing, Directorate General of Water Resources, Serayu Opak RBO since 2018 (Figure 2). It will have approximately 92 million cubic metres (MCM) of storage with a 169 m concrete-faced rockfill dam, the highest in Indonesia.

Figure 2. Bener Dam Progress July 2023 (Serayu Opak RBO, 2023)

The Kedungputri irrigation area will become a part of the services area supplied by the dam, in addition to irrigated areas such as Boro, Penungkulan, Jrakah-Kragilan, Kalisemo, and more covering up to 15,500 Ha (Figure 3). The SIMURP funding for Kedungputri (Figure 3 Left) started in 2020 from the World Bank is used to modernise pillars no. 2 and no. 3 by the Serayu Opak RBO.

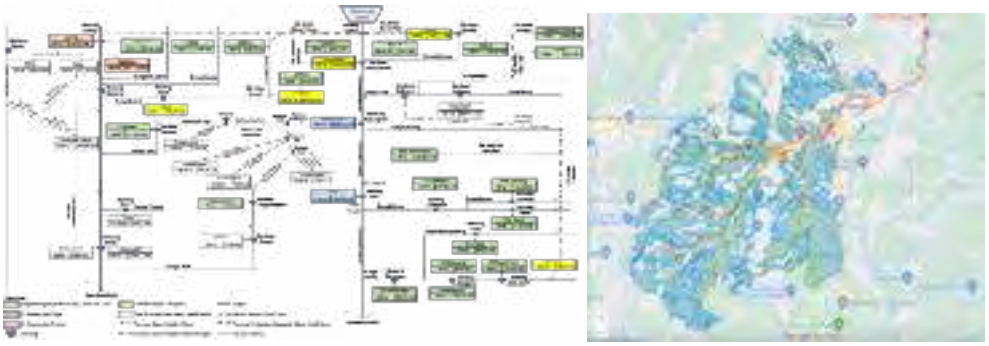

Figure 3. Left: Bener Irrigated Area, Right: Kedungputri Irrigation Area (Serayu Opak RBO, 2022)

Pillar no.2 is implemented by upgrading and rehabilitating the canals with concrete lining including refurbishment of metering infrastructures. This rehabilitation will add functions of more precise water allocation and reduce water loss. The effort is also added with mechanical electrical gates for faster reaction during flood and drought (Figure 4).

Figure 4. Left: Kedungputri Canals, Right: ME Gates at Weir (Serayu Opak RBO, 2023)

The annual water allocation plan (RAAT) for the Bogowonto River Basin is published each year, but the global cropping pattern (RTTG) is legalised once every five years by the Regent of Purworejo. The implementation of the annual cropping pattern is adapted with the rehabilitation conditions throughout 2020 to 2023 with the irrigation commission's approval. The monitoring of water allocation, the irrigation service agreement for this location has been updated in 2023 to cover those areas rehabilitated during 2021-2022. Moreover, the SCADA system contributes to pillar no.3 for real-time water allocation (Figure 5 right), which will be in place in September 2023.

Figure 5. Left: ISA signing, Right: SCADA System (Serayu Opak RBO, 2023)

It also shows collaboration between the RBO of the Ministry of Public Works and Housing, Directorate General of Water Resources with the Ministry of Internal Affairs, Directorate General of Regional Development for the development of pillar 4 and pillar 5. The coordination for pillar no.4 is done through technical assistance (TPM) with the water user associations/federations and irrigation commission revitalisations (Figure 6 left). As for pillar no.5, currently, the irrigation management unit has just started to shape, the existing institution namely the UPT Purworejo with a knowledge transfer process from the RBO, especially for the hybrid of SCADA with manual water allocation (Figure 6 right).

Figure 6. Left: WUA/Fs with irrigation commission and Right: Knowledge Transfer (Serayu Opak RBO, 2023)

5.2 Wadaslintang

The Wadaslintang irrigation area (31,584 Ha) is located downstream of Wadaslintang Dam with a storage capacity of 445 MCM). The dam was constructed from 1982 to 1988 and consisted of inundated areas in two regencies, Wonosobo and Kebumen. However, the irrigation area spans between Kebumen in the west and Purworejo in the east. The condition of the dam needs some refurbishment, especially for the safety inspection standard. Hence, the World funded the DOISP, which implemented pillar no.1 of the modernisation of irrigation. The refurbishment of the dam includes hydro-mechanical works, adding slide control points, construction of two check dams upstream, improvement of bridges plus ring roads, and zoning of the area. The operation curve of Wadaslintang is updated each year (Figure 7), with emergency response plans updated once every five years.

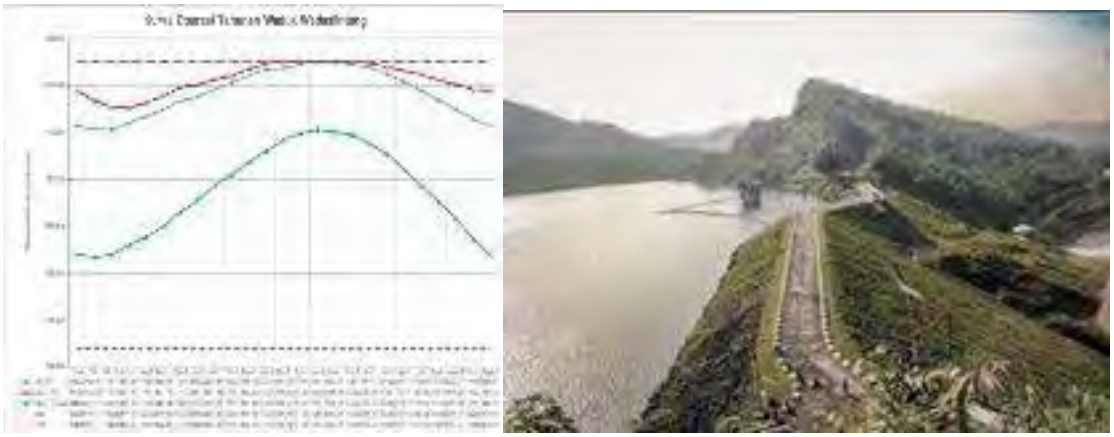

Figure 7. Left: Operation Curve and Right: Wadaslintang Dam (Serayu Opak RBO, 2023)

Meanwhile, for pillar no.2, the rehabilitation of canals and irrigation infrastructures was through two funding sources, namely IPDMIP from ADB for the Wadaslintang Bedegolan Subsystem and SIMURP from WB for the West Wadaslintang Subsystem (Figure 8). Similar approaches were used for canal rehabilitations, like concrete lining for canals, and adding mechanical gates within the subsystems.

Figure 8. Up: Bedegolan Subsystem and Down: Subsystem (Serayu Opak RBO, 2023)

As for pillar no.3, water allocation (RAAT) is published annually for the Wadaslintang System, which consists of the Wawar and Luluk Ulo River Basins. Meanwhile, the cropping patterns (RTTG) were legalised annually for Kebumen and five yearly for Purworejo. The implementation of SCADA will only be in the Bedegolan Subsystem (Figure 9 right), the case study is the representation of the whole system. It also invites the ISA to be drafted for this condition as of the end of 2023.

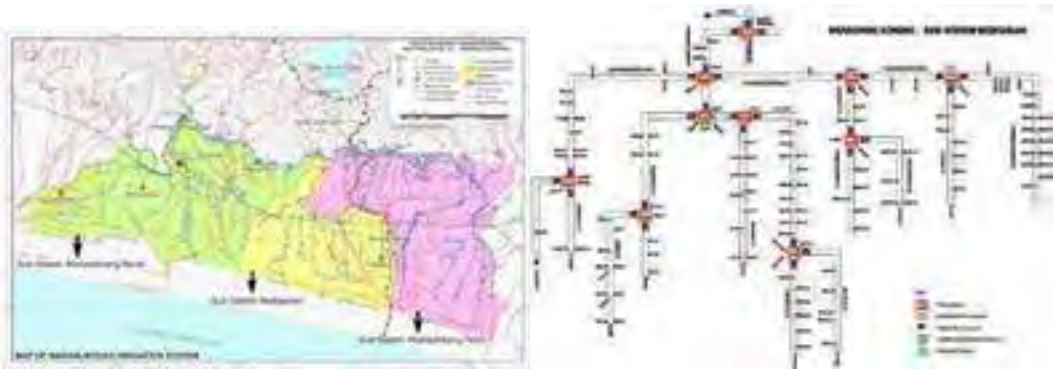

Figure 9. Left: Wadaslintang System and Right: SCADA for Bedegolan (Serayu Opak RBO, 2023)

For pillars no.4 and 5, WUAs/Fs and irrigation commissions for the area are established. They merely needed a boost for revitalisation in their activities (Figure 10). Additional strength for this condition is the starting of a modern irrigation management unit (UPIM) which will be established by the end of 2023. However, not much is done for human resources management and career development for the time being. Once the UPIM is established a range of certifications, career opportunities, and knowledge development is prepared for the new unit.

Figure 10. Revitalisation of WUAs/Fs in Wadaslintang (Serayu Opak RBO, 2023)

5.3 Rentang

The Rentang irrigation area (87,840 Ha) is located downstream of Jatigede Dam (979 MCM). The dam was built between 2008 to 2017, which highlighted the supply of irrigation water in Cirebon, Majalengka, and Indramayu Regencies. The operation curve (Figure 11 left) states the water allocation service annually.

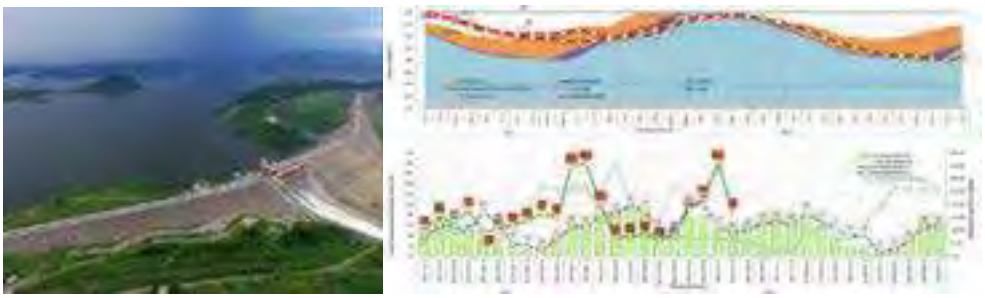

Figure 11. Left: Jatigede Operation Curve and Right: Condition of Jatigede Dam
(Cimanuk Cisanggarung RBO, 2023)

Pillar no.2 consists of the construction and rehabilitation of canals. The Right Rentang subsystem was carried out from 2015 until 2018 with GoI funding, while the design activities for the Left Subsystem were carried out from 2015 to 2016 with funding through the Participatory Irrigation Rehabilitation and Improved Management Project or PIRIMP. Furthermore, in 2020, follow-up irrigation modernization activities are called the Rentang Irrigation Modernization Project (RIMP) and carried out with a funding scheme from the Japan International Cooperation Agency (JICA IP-573) with an effective implementation date from 25th July 2017 to 2026. The RIMP's objective is to increase the production of rice and other crops in the Cimanuk watershed by modernising, rehabilitating and improving the Operation and Maintenance of the irrigation system.

Figure 12. Modernisation of Rentang Irrigation System (Cimanuk Cisanggarung RBO, 2020)

For pillar no.3 water allocation was established using manual and documents of annual water allocation plan (RAAT) and global cropping pattern (RTTG), but not yet IT based. The efforts to upgrade using IT start in 2023, but currently no data is published.

Meanwhile, the improvement of pillar no.4 was following the existing capabilities and needs of farmers through a participatory approach. Empowerment of WUAs emphasised function, active in carrying out their duties and responsibilities, activities that benefit members, and members' contributions, including dues. As of August 2022, outreach has been carried out to 495 P3A candidates and there have been 33 P3As that have been formed. The Irrigation Commissions for Rentang are in the West Java Province, spanning three regencies. Issues that emerged during the coordination were the presence of WUAs in the management of Rentang irrigation and the issue of funding for operations and maintenance activities. The Rentang irrigation is under the central authority, with the assistance of the operation and maintenance by the West Java Province PSDA Office and Municipal Public Works Agencies. Thus, the existence of a UPI or irrigation management unit is needed, although currently not yet labelled with modernisation.

Figure 13. WUAs and Irrigation Commission (Cimanuk Cisanggarung RBO, 2020)

As for pillar no.5, not many activities have been implemented for career development or transfer of knowledge, but the activity carried out is water-efficient rice cultivation using the system of Rice Intensification "SRI" method, in which the system only uses less water than the conventional rice cropping system than farmers usually do. It is hoped that with optimal use of water and adapted to each plant phase, the productivity of irrigation water will increase, and water availability is guaranteed.

Figure 14. SRI Demonstration plot (Cimanuk Cisanggarung RBO, 2020)

5.4 Comparisons

The findings show that currently, the average score for modernisation is at 20.94 out of 45 steps or ranging around 46%, summarized in Table 3 which highlights the continued focus on hardware aspects of modernization (Pillars 1 & 2)

Table 3. Summary of Modernisation Efforts based on the 45 steps and five pillars data for 3 case studies

Irrigation Areas	Pillars					Scheme Status
	1	2	3	4	5	
Kedungputri	52.8%	33.0%	14.7%	11.0%	14.7%	46.3%
Rentang	53.0%	33.1%	14.7%	11.0%	14.7%	44.8%
Wadaslintang	59.4%	37.1%	16.5%	12.4%	16.5%	48.5%
Average Status	55.1%	34.4%	15.3%	11.5%	15.3%	46.5%

Table 4 presents the detailed comparison of progress. Most of the 45 steps were touched, but the progress is still developing. The values in each of the steps are given based on the proofs presented earlier.

Table 4. Comparisons of Modernisation Efforts in Indonesia

Pillars	Steps	Kedungputri	Wadaslintang	Rentang
Pillar 1 : improves water security and availability	1	0,33	0,33	0,33
	2	0,66	0,66	0,33
	3	0,66	0,66	1
	4	0,66	0,66	0,66
	5	0,33	0,66	0,33
Pilar 2: Rehabilitation and upgrading of infrastructure	6	0,33	1	1
	7	1	0,66	1
	8	0,66	0,66	0,66
	9	0,66	0,66	0,66
	10	0,66	0,66	0,66
	11	0,33	0,33	0,33
	12	0,33	0,33	0,33
	13	0,66	0,33	0,33
Pilar 3: Improvement of the irrigation management system	14	0	0,33	0
	15	0,66	0,66	0,66
	16	0,66	0,66	0,66
	17	0,66	0,66	0,66
	18	0,66	0,33	0,66

Pillars	Steps	Kedungputri	Wadaslintang	Rentang
	19	0,33	0,33	0,33
	20	0,66	0,33	0,66
	21	0,33	0,33	0,66
	22	1	0,66	0
	23	0,66	0,33	0,33
	24	0,66	0,33	0,33
	25	0,33	0,66	0
	26	0,33	0,33	0,66
	27	0,66	1	0,66
	28	0,33	0,66	0,33
	29	0,33	0,33	0,33
	30	0,33	0,33	0
	31	0,33	0,66	0,66
Pilar 4: Strengthening for irrigation management institutions	32	1	1	1
	33	0,33	0,66	0,33
	34	0	0	0
	35	0	0	0
	36	0	0	0
	37	0	0	0
	38	1	0,66	1
	39	0,33	0,33	0,33
Pilar 5: Strengthens human resources	40	0,33	0,33	0,33
	41	0	0,33	0,33
	42	0,33	0,33	0,33
	43	0,33	0,66	0,33
	44	0,33	0,33	0,33
	45	0,66	0,66	0,66
	Total	20,83	21,81	20,18

6. National Factors Affecting Irrigation and Drainage Services

In Indonesia, irrigation assets management is done based on the local governance with autonomy with Law no.23/2014 (GoI, 2014), especially with regards to the authority for irrigation development and management between national, provincial or regional, and municipal governments. Under this Law, the Minister of Public Works and Housing (MPWH) Regulation PUPR No.23/PRT/M/2015 (MPWH, 2015a) on irrigation assets management is established.

Clause no.3 (1) defined the assets for both surface and groundwater irrigation, (2) which has special arrangements on other assets owned by the state. It considers all activities on irrigation assets management in clause no.4, namely (a) inventory, (b) planning, (c) implementation, (d) evaluation, and (e) updating the inventory. Also, it is based on Regulation PUPR No. 12/PRT/M/2015 (MPWH, 2015b) about Exploitation and maintenance of the Irrigation Network, where it consists of a systematic and structured management process on planning maintenance and financing to support the level of services and sustainable use of water for irrigation and irrigation network users efficiently (Amrizal, et al, 2017).

Based on the current regulations of Irrigation Assets Management (PAI) has a multilevel governance setup (Hooghe and Marks, 2003, Gupta and Pahl-Wostl, 2017) for irrigation in Indonesia as follows:

1. The irrigation area of more than 3,000 ha belongs to the national authority, which is covered under the RBOs, which are the subsidiaries of the Ministry of Public Works and Housing, Directorate General of Water Resources.
2. For an area between 1,000 to 3,000 ha falls under the regional or provincial authority or most commonly under the Provincial or Regional Public Works Agency.
3. For irrigation areas less than 1,000 ha are managed by the Municipal Public Works Agency.

This condition perpetuates the pre-existing multilevel governance between the national, regional, and municipal levels. However, it does not present the water user associations (WUAs) level of governance, which exists in all tertiary canal governance. This level is mostly done through self-governance (Ostrom, 1993, Pham, et al., 2019) of the WUAs, which functions effectively on a day-to-day basis. This claim is in line with the findings of earlier research in Indonesia on irrigation self-governance (Ariyanti, 2022), which proved the existence of such setups work in Indonesia. The current setup also divided the main irrigation systems, namely the primary and secondary canals under the earlier mentioned agencies up to the tertiary intake, while tertiary and quarterly, even smaller canals are operated and maintained by the farmers under the Water User Associations (WUAs).

7. Conclusions and Recommendations

7.1 Future modernisation plans

Based on the findings in this study, irrigation modernisation in Indonesia represented by three cases shows promising progress with a mean modernisation steps of 46% with following interventions from 2015 to 2023. The current percentage for modernisation shows the need of funding support from all kinds of alternatives, either from loan, national, and local government funding. As of current condition, Indonesia has not considered funding from public-private partnership for irrigation, which is also another possibility to be considered. Of the five pillars, the current plans still focus on the hard components of pillar no.1 and 2, but without efforts on pillar no.3, 4, and 5 it will hamper the modernisation. Therefore, more attention needs to be given to the soft components, especially using GoI funding for sustainability.

7.2 Recommendations

The examples provided in this paper highlighted that each irrigation system had experiences of modernisation, and the RBO knowledge can spread to other locations within Indonesia. The multilevel governance framework helps understand the situation, and how the prioritisation of funding is allocated to infrastructures or human resources. Updating efforts for modernisation needed commitments from all irrigation managers, not only at the national level but also at regional and municipal levels. Therefore, the modernisation efforts for irrigation in Indonesia still have a prospect to be developed within the coming years.

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PATHWAYS AND TECHNOLOGIES FOR MODERN IRRIGATION SERVICES; IRAN COUNTRY PAPER

Mehrzad Ehsani[1]

1.0 INTRODUCTION

I.R. IRAN with 8.8 million hectare irrigated area is the 5th country in the world relevant to the irrigated lands which comprise about 90 percent of the annual agricultural products. Over 20 percent of Iran active labour power in the agricultural sector illustrates the great farmers' capacity in production and employment.

Irrigation and drainage systems in Iran were traditionally established and funded by The farmers themselves up to several decades ago. Such kind of managerial structure maximized the usage of hardware possibilities of the networks and water resources. traditional Irrigation networks mostly covered ordinary-sized areas with a few stockholders. This kind of system still exists in some parts of Iran.

During the recent decades, establishment of modern irrigation networks with simultaneous social reforms has deranged the traditional irrigation management in Iran. Application of traditional methods was improper for running such networks. Therefore, various dependable structures to the government for management, operation and maintenance of such networks appeared.

Having been developed and modernized during the recent years, also, the adjustment of the laws and regulations of the water sector has caused that management framework of irrigation networks were gradually improved so that the public sector role started to decrease as much as possible. In general, in addition to the management framework, equipping with modern tools for measuring water flow and applying applicant tools such as geographic information system and databases has led to the improvement of water distribution and management.

2.0 OVERVIEW OF NATIONAL IRRIGATION AND DRAINAGE SERVICES

Iran Ministry of Energy and affiliated authorities play the main role in water management. In fact, the study and implementation of projects on water supply and transfer, irrigation and drainage networks, dam stability and safety, river and bank engineering, flood control, artificial recharge and hydropower generation, as well as directing and supervising the operation of the related installations and structures done by Iran Water Resources Management Authority. But those are not the only stakeholder influence on water resources. Iran Ministry of Jihad-e-Agriculture involve in water management at the farm level, and improving irrigation method, as well as, financial support to provide facilitates for developing agriculture.

Iran had about 8.8 million ha irrigated land, which represents a little more than a half of the irrigation potential (15 million hectares) that was estimated considering optimum storage and water use. In recent years, irrigation efficiency estimated at around 45 percent on average at national level.

About 55 percent of that area is irrigated by groundwater, the rest is irrigated with surface water sources and treated wastewater. Surface irrigation is the main irrigation technology used in Iran, covering 67 percent of the area equipped for irrigation. Localized and sprinkler irrigation covered 1,600,000 ha (55%) and 1,300,000 ha (45 %) in 2022 respectively, compared to only 0.6 percent each in 1993 (Ministry of Jihad-e-Agriculture, 2022). Almost all pressurized irrigation systems are manufactured in the country. The water in the surface irrigation schemes arrives through a combination of gravity and water lifting systems. Most of the dams constructed in Iran are for irrigation purposes with main and secondary canals built downstream, covering a total area of 1.98 million ha in 2022 and which are called modern systems. The rest of the irrigated areas have traditional canals built by farmers that in many cases have to be rebuilt every year. Small schemes (< 10 ha) cover 50 percent of the total equipped area for irrigation, medium size schemes (10–50 ha) 40 percent and large schemes (>50 ha) 10 percent. Among the holdings practicing irrigation, the average irrigated area is 2.9 ha.

Irrigation schemes in I.R. Iran are classified into 4 categories as follows: (1) Modern Irrigation Networks; (2) Semi-modern Irrigation Networks; (3) Traditional Irrigation Networks; (4) The other irrigation ones.

1. Modern Irrigation Networks: These systems have secured water supply through a reservoir dam, rivers

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with sufficient basic discharge and intake structures such as diversion dams, or pumping stations with primary and secondary concrete lined canals. According to Iran Water Resources Management Company (IWRMCo) data, in May 2023, there were 132 modern irrigation and drainage systems covering 1.98 million hectares.

2. Semi-modern Irrigation Networks: These systems have either water diversion structures on the rivers with secured basic discharge and equipped with a water conveyance main canal or they are supplied by a series of traditional channels in tail reach of the reservoir dam. As opposed to modern irrigation systems these do not have reservoir dams or secondary concrete lined canals. The country has about 500 of this type of systems covering 600 000 hectares of land.
3. Traditional Irrigation Networks: They are usually within limits of cities, villages, and fields. Water is taken from rivers, water spreadings or pondages through traditional canal intakes.
4. Other irrigation Networks These include agricultural areas belonging to agro-industries, cooperatives. They include small and large areas independently irrigated by well, Qanats or springs. These areas generally don't use the dams' regulated water; however, there may be some exceptions.

By far the most important harvested irrigated crop is wheat (almost 30 percent of the total harvested irrigated area), followed by fodder (10 percent), vegetables (6.3 percent), rice (6.3 percent), barley (7.3 percent) and vegetables (6.5 percent). Wheat is also the most important rainfed crop.

Irrigation areas are approximately equal to the rain-fed areas; however, most of the production comes from areas under irrigation. Between 2017-2021, about 91 percent of Iran agricultural products were grown by irrigated farming (figure 1). Crops yields on irrigated land, are generally 2–3 times higher than rainfed land.

Having the objective of optimum usage of Iranian water resources and food security, the Iranian government is determined to develop irrigation systems by emphasizing on developing controlled irrigation methods such as pressurized irrigation, green house.

According to the performed studies, there is the possibility of developing pressurized irrigation for about 4 million hectares in the country. Hence, the Iranian government is committed to pay about 60-85% of total investment and to support the rest with free-interest loans for investment of pressurized irrigation to persuade the farmers to extensively use such methods.

3.0 ASSESSMENT OF MODERNIZATION AND REVITALIZATION REQUIREMENTS

Having established modern irrigation and drainage networks in IRAN, government assumed direct management of such systems. The main problem of governmental structure is lack of dynamism, self-activity and organizational flexibility. With the passage of time, it is proved that governmental management is not economically justified as well as it is inefficient for running professional and technical units. Major structural government problems in management of Irrigation and drainage in Iran are classified as follows:

3.1 Low Productivity

The available evidences reveal that the productivity of public sector labour power, responsibilities, machinery, and technical means is lower than that of the private sector ones because of structural organization and its dominant relationship. The performances of organizations managed by the public sector, especially in technical units, have not been at the standard level economically.

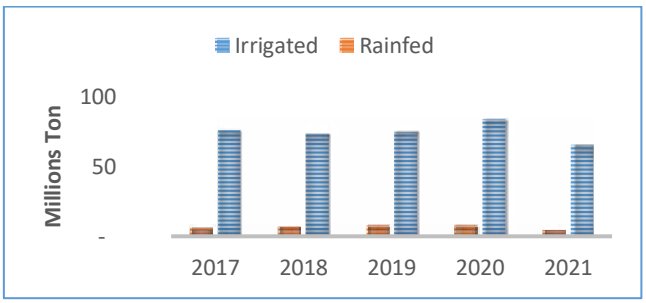

Figure 1. Irrigated and rain-fed annual crops production in Iran
Source: Ministry of Jihad-e-Agriculture, 2023

3.2 Limitation of Employing and Maintaining Efficient Personnel

As the efficient, professional and technical personnel demand higher salaries and remunerations, the public sector can't afford such payments easily because salaries & wages are limited by the rules and regulations. With the passage of time, such personnel may become indifferent, their capabilities may not flourish or they may be absorbed by the private sector, so the services shall be done by the less experienced personnel which can result in more loss of capital investment and further depreciation.

3.3 Lack of Incentives

According to law, the public sector management system can't easily dismiss or retire the surplus labour power, and the employees are aware of it without being anxious about receiving their salaries on time, so they are not encouraged for further productivity and efficiency.

3.4 Slow Decision-making

The hierarchical system of the public sector management does not let the managers make decisions quickly enough specially to solve the problems of water users and urgent affairs which may result in unsatisfaction of the beneficiaries and losses of time, energy and money. It takes a lot of time to receive permissions through a lengthy process to initiate the required affaires, especially in case of goods and services need for financial decisions.

3.5 Lack of Enough Motive to Balance Costs and Benefits

The public sector is not required to balance its costs and revenues because the current budget especially salaries and wages are financed by the government; however, the private sector cannot afford payments that exceed revenues.

3.6 Overstaffing

As it is common in most of the public sector management structures, the number of laymen especially increases in simple services annually. Besides, if their present personnel cannot increase their expertise as required they may also be considered as overmanned laymen who decrease the system's efficiency and productivity.
In spite of several disadvantages of public sector structures in operation and maintenance of Irrigation systems, there are positive points in public sectors which are as the follow:

1. As the public sector is supported legally, judicially and politically, the execution of government ratifications as well as legal tariffs are easier, and the water user's resistance is less against them.
2. In systems with public sector management, the government protects the installations, plants, works and structures against violators and aggressors;
3. In systems with public sector management, accessibility to the government authorities is easier to solve certain problems;
4. The public sector benefits from various governmental facilities and exemptions to fulfill the needs;
5. The public sector management and its employees can use welfare facilities of the affiliated organizations without incurring any investment to establish and maintain such facilities.
6. Water users and operators esteem further legitimacy for the public sector than the private sector because they consider the private sector as investor with specific interests in certain regions.

4.0 National Factors Affecting Irrigation and Drainage Services, Including Water Policy, Institutions, and Human Resource Capacities

Iran Vision 2025 is the document that guides the social and economic development of the country in the long term. Therefore, the current and future endeavours on research, credit, economy and industrial programs shall follow the rationale of these national aspirations. The long term development strategies for Iran’s water resources was prepared by a group of experts in agriculture and water resources management and approved by the government in 2003. The strategy includes specific targets to achieve in regards to water productivity increase, groundwater management and agricultural water share, as follow. Most importantly, it envisages that agricultural

water consumption in Iran should fall from present 92% to 87% in 20 years. Moreover, agricultural water efficiency per cubic meter should be doubled from the present condition within 20 years. This could be achieved by increasing irrigation productivity and allocating water to the products with higher economic values, "Water allocation priorities shall be considered for potable water, sanitation, industry, orchards and farming purposes" and "Incentives should be provided to the private and cooperatives sector to invest capital in water supply, irrigation and drainage systems, soil and water projects" (FAO, 2009).

In addition to vision 2025, other important policy and strategy documents regarding water, agriculture sector include; Fair water distribution law (1982); Nationalization of water resources act (1968); Law for protection of the natural parks, protected areas, and sensitive areas (1975); Law on economic, cultural, and societal development (1989); The law of the fourth economic, social and cultural development plan (2005-2009); The Law of the fifth economic, social and cultural development plan (2010–2015); General policies on principle 44 of the codified law (2008); Law of promotion of investment in water project in Iran (2002); and Law of crop water price fixation (1990).

4.1 Water Ownership

According to Iran's National Constitution, water in any form and at any place shall be at the disposal of the government for it to utilize in accordance with the public interest. In other words, all water is of public interest and under responsibility of government.

4.2 Water Resources Administration

Iran Ministry of Energy and affiliated authorities play the main role in water management. But those are not the only stakeholder of water resources. Iran Ministry of Jihad-e-Agriculture involve in water management at the farm level, and improving irrigation method, as well as financial support to facilitate developing agriculture. It can be said, it is the second important stakeholder in water sector after Ministry of Energy. Provincial governances are also contributing in the development of water supply and investment in industry and agriculture, as they have enough influence on different provincial entities. On the other hand, High Water Council, headed by the President of Iran act as the Policy making body on water supply, distribution, and consumption, as well as coordination of governmental bodies (Alasti S., 2013).

4.3 Obligation for Obtaining Water Use License

Public water authorities shall issue optimum water use license for the agricultural water users according to the criteria declared in the law. There are several reasons why water users are required to register their water use with the Water authorities. Most important are to manage and control water resources for planning and development, to protect water resources against over-use, damage and impacts, and to ensure fair allocation of water among users. Permits are controlled, and not issued if the taking of more water in a given area would adversely affect existing users or the environment (Alasti S., 2013).

Based on Iranian water sector law, the use of water resources requires obtaining water use License (Alasti S., 2013). A committee should be defined for this objective and shall study the quantity of existing water, percentage of cultivable land, place of use, branch, quality of use, customs prevailing in the locality and other factors in accordance with a by-law which shall be prepared by the concerned ministry and Agriculture on the basis of essential information acquired and permits shall be issued according to this committee's recommendation. No one is allowed to use water for any other purposes than what has been mentioned in the permit, nor is the permit transferable to others. A water use License is applicable solely to the piece of land for which it has been issued, unless the government in the region decides otherwise and/or the licensed use of the water is determined to be non-beneficial or uneconomical. The water resources authorities are permitted to proportionately decrease water delivery ceiling mentioned in the issued license during drought years as required. Discharge rate and deliverable water volume shall be reviewed according to the irrigation efficiency and crop pattern (Fair water distribution law, 1982).

4.4 Water Losses Penalties

Water delivery to the water users more than specific volume of water fixed in the water licenses is not permitted according to context of water law and regulations. Therefore, water agencies shall deliver the required water to the water users within the same limit of water license. If water authorities distinguish that a water user does not have the required conditions for applying optimum water use pattern, water delivery to the limit of 25% above the measure for up to two years is possible. In this case, water fee for the extra 10% of fixed pattern shall be one and half time as much as the official fee. However, within the limits of 10% to the ceiling of 25%, the water fee shall be three times as much as the planned fee to be calculated and collected, considering the extra water use and the

kind of the irrigation system. Still, article 7 of law titled "Law of Crop Water Price Fixation" (Parliament of Iran, 1990) states: Water uses in excess of real cultivation needs (rational/advisable use) will be charged extra prices. Those extra prices would be implemented according to specific condition of region and will be up to 1.5 times more than normal water price in that region.

4.5 Water Saving Encouragement

On the other hand, the users who can reduce water consumption by adopting various methods of water saving and management shall benefit from advantages as follows; (a) Some decrease in the water fee per water saving ratio according to the water use license and permits; (b) Facilities in receiving input subsidies and agricultural machinery; and (c) Crop intensity permit in the planned areas for water intake proportionately with water saving in water uses. Subsidies for water charges and supervision charges will be will be provided for farmers whose yields are higher than average.

4.6 Water Charging

Pricing policies play an important role in water demand management and its optimal allocation. Having to pay for irrigation water encourages water-saving behaviour thus can be efficient tool for self-controlling and promoting water conservation (Perry, C. J. 2001). The policy and regulative framework for water tariffs is different in every country. Determining proper water price leads to optimal allocation of water especially in agricultural consumptions. So, improvement of water demand and supply management could be achieved using price policies. Fair water distribution law (1982) insist that water tariff in municipal, agriculture, industry and other use should be determined according to quantity and quality of consumption. Also, in the case of adjusted water systems all variable costs include management, maintenance and depreciations should be including in water tariff considering social-economic conditions of each region (Law for fair water distribution, 1982). Also, long-run development strategy of Iran's water resource and Fourth Iran's development Plan, economic and social program insist on economic valuation of water and calculating supply costs.

Current prices policy for agricultural water depends on crops, source of water supply (surface or groundwater), and area to be irrigated. Agricultural surface-water rate for the water users who follow up the optimum water use pattern in the planned areas of modern, mixed, or traditional systems, shall be calculated according to fixed crop water rate law. In Iran's agricultural sector, the current price of irrigation water is derived from the value of the crops to which it is applied. For surface water resources, for traditional networks, semi-modern irrigation networks and modern irrigation networks, water rates are one, two and three percent of the value of the crops respectively (Nikouei A., Ward Frank A. 2011). Hence, this method needs information on prices of outputs in each province. Its advantage is that it does not require measurement of individual's water consumption which is very expensive or even impossible in many regions.

Based on the 1982 law, water pumping from groundwater resources was in accordance with the crop water requirement and proposed cropping pattern in each region. In this case, water price for groundwater resources had been determined as 0.25-1.0 percent of the commercial value of crop yield. Unfortunately, by Parliament law in 2004 the water price for groundwater withdrawal became free of charge. The removal of charges for groundwater use has resulted in a predictable increase in over-exploitation of groundwater resources.

4.7 Modernization of Irrigation Methods

Iranian major policy objectives and strategies that govern the agricultural sector are achieving self-sufficiency (especially for wheat) in strategic products and improving food security, providing financial and technical support to farmers in order to modernize irrigation methods, applying plant varieties better adapted to the different regions of the country, increasing productivity and improving water consumption patterns in the agriculture sector. Adoption of sprinkler and drip irrigation methods is being encouraged to minimize losses in water application in field. Having the objective of optimum use of the country's water resources and improving water productivity, the Iranian government is determined to develop controlled irrigation methods such as pressurized irrigation, green houses and conveyance in pipes instead of open canals. Since the installation costs are high for these systems, the government has committed to pay about 60-85% of total investment and to support the balance through lowinterest loans for investment in pressurized irrigation to provide an incentive for farmers to use such techniques (Ehsani M., Khaledi H. 2012).

4.8 Reconsideration in Water Allocation

Negative balance between withdrawal and recharge of ground water aquifers in most of plains is one of main challenges in Iran. The long-term development strategies for Iran's water resources were prepared by the

government in 2003 which issued a special statement on protection of ground water. In this case surface water resources consumption should increase from the present rate of 46% to 55% in 20 years to compensate for decreased groundwater withdrawal.

The recent law is relevant to reconsideration of water allocation approved by Iran Parliament in 2011 in order to immediately stop excessive ground water withdrawal and enable recovery of water tables. Negative balance between withdrawal and recharge of ground water aquifers in most of plains is one of main challenges in Iran. To fulfil to this goal the Ministry of Energy is obliged to; (a) implement structural and non-structural projects throughout the plains of the country, (b) implement activities related to protection of water resources, preventing illegal withdrawal of ground water resources, (c) implementing the water management system of the country at national, provincial and basin levels so that at the end of the 5th Five Year Plan the negative trend of ground water table recovers by 25% as compared to the start of the fifth Five Year Plan (12.5% by controlling surface waters and other 12.5% by watershed management and groundwater aquifers management) (Iran 5th Five Year Plan, 2011).

So, in order to increase agricultural water productivity, the Ministry of Energy intends to adopt new measures to regulate water allocation by issuing licenses of water utilizations for all farmers that have water rights, using water permits and developing a volumetric approach to the provision of water supply to water user associations. This may reduce current water use by at least 1% per year. The amount of saved water will be used to develop new agricultural lands or for other uses through the application of modern irrigation methods.

4.9 Volumetric Water Delivery to Users

An orderly system of distributing water must be in place through some existing and respected regulatory framework for allocating water among farmers, as well as rules and procedures defining rights and responsibilities, priorities in case of shortage or excess supplies for both sides. To optimize agricultural water use and increasing water productivity, the Iran Government intends to adopt new measures to regulate water allocation by developing a volumetric approach to water utilizations for all farmers and water user associations. A bylaw on agricultural water usage optimization regulation approved by Iran Government in 1996, as well as, Iran 5th Five Year Plan approved by Parliament in 2011 insisted on mentioned above policy. According to volumetric water delivery approaches water agencies shall deliver the required water to the water users of each zone according to the optimum water use based on regional cropping pattern. Volumetric water delivery point of the irrigation systems shall be the priming point of the planned areas and the point water user associations receive water. For fulfilling volumetric water delivery, water agencies shall take action in establishing irrigation stream gauging systems and by using proper equipment with water users' budget. In case if it was distinguished that the installed equipment for measuring water delivering is broken or defected so that intake water current is not properly determined, they firstly give notice to the relevant water users association or its formal representative to remedy the defects. If water users do not remedy the defects in time, or repeat violation of law, the water organization's officials shall take actions to stop water delivery (Bylaw on agricultural water usage optimization regulation approved by Iran Government, 1996).

Figure 2. Installation of ultrasonic water measurement in canal irrigate

4.10 Smart Meter for Groundwater Usage

Groundwater is one of the most important water resources of Iran. About 55 percent of irrigated lands relying on groundwater, the rest is irrigated with surface water sources and treated wastewater. Utilization of the underground water resources through the drilling of any type of well anywhere in the country should be carried out with the permission of public water authorities. Unfortunately, over-pumping is the main cause for ground water shortage and sharp decrease of water table in arid and semi-arid regions of Iran. Effective management systems for monitoring and management of ground water resources is top priority of Iran Government according to recent policies and strategies. Iran Supreme Water Council approved a statement on ground water protection in 2015.

According to laws and regulations mentioned above Iran public water authorities shall equip all the deep and semi-deep water-wells with volumetric control systems. Installation and maintenance costs of such equipment shall be paid by the water-well license owners. To use advantage of technology to fulfil systematic control and monitoring of groundwater abstraction in Iran the relevant ministries determined to apply controls called smart energy and water meter. The meter measures and record consumed energy and relevant parameter. This also capable of measuring and storing the amount of water withdrawal, water flow and other quantitative parameters required by public water authorities. The meter indicates water credit, validity and start and expiry date. It is also collect data of water wells and transfer to control center via telecommunication infrastructure (Ehsani M., Khaledi H. 2011). This strategy is strongly under progress, and it is expected that all wells will be equipped with smart water device during the five year work plan.

4.11 Preventing land fragmentation

Land fragmentation is a major threat to efficient production system due to the fact that continuous subdivision of irrigated area would lead to small sized land holdings that may be hard to economically operate. Preventing land fragmentation in necessary to improve technical efficiency, increase water productivity and enhance utilization of water and land. In this respect a law was passed in 2007 by which the minimum acceptable area of farmers would be 4-10 hectares for irrigated agriculture and 10-25 hectares in rainfed farms. In order to support landowners to join small holdings above the determined limits, the government would provide special financial and technical privileges and the required infrastructure for consolidation of agricultural lands, overcoming the excessive fragmentation of farmlands. The government committed to pay the insurance fees of such farmers' products for at most 5 years after the land integration has taken place (Law for Preventing land fragmentation, 2007). So by Five-Year National Economic, Social and Cultural Development Plan law (2011-2016) financial support through allocation of credits facilities, administered values, interest subsidy and banking commission for development of job opportunities for rural and tribal households with priority given to local methods and strengthening integrated management through partnership with legal associations for preventing land fragmentation and integration of small land holders.

4.11 Investment for Irrigation Projects

In Iran, the investment and construction works are implemented in most of the water supply and irrigation networks under the government programs. There is an attempt to move towards facilitating cooperative and private sectors to invest in the project for water supply and construction of irrigation networks, hereby the relevant ministries authorized to entrust according to conditions mentioned in the law of promotion of investment in water project in Iran 2002. This law allocates all the exploitable water to the investor, except for water rights which already exist. In addition, all lands potentially irrigated by the new facilities will be transferred to the investors at the price of undeveloped land, and in case the investor is unable to use all the water, the government is bound to buy surplus water at agreed prices (Law for promotion of investment in water project in Iran, 2002).

In addition to speed up investment for developing irrigation schemes, improvement of water management by institutional reform through involvement of private sector capital investment. It is believed the private sector management is more economic and more efficient compared to governmental bodies (Ul Hassan, M.; Qureshi, A. S.; Heydari, N. 2007). It is expected the private sector apply new materials, technologies and techniques to upgrade the structures of irrigation systems and improve water management. The investing works include reinforcing and upgrading water storages, upgrading canals and control structures, replacing and reinforcing dilapidated structures, upgrading pumping systems, lining canals, upgrading on-farm irrigation systems, applying information and automation technologies to operate and control irrigation systems, reforming management institutions and establishing water user associations. By facilitating the mentioned law, five irrigation schemes works are under construction by private sector organizations (General Policies on Principle 44 of the Codified Law, Started in 2008, unlimited).

5.0 PRIORITY ISSUES FOR MODERNIZATION OF I&D SERVICES:

A huge public budget has been invested in Iran during the last thirty years in order to improve irrigation services and increase water productivity. Investigations have shown that the current situation of irrigation and drainage networks is far from the ideal and needs reform in management, operation, and maintenance. Improving performance of irrigation systems needs proper diagnosis of the problems and a systematic approach towards modernization. An optimal operation of the infrastructures needs continuous supervision, applying new technology and techniques and also providing the required funds to implement programs, which are proposed. Existing physical development attitude in irrigation is one of the major challenges and in most cases; the social conditions and traditional operation systems are ignored. Consequently, the developed systems have some weaknesses, which cause problems in optimal operation of irrigation networks. These lead to failure in achieving expected goals of the ideal performance. Therefore, the infrastructure of operation, maintenance and management should be diagnosed in order to improve the current situation.

Technical, Managerial and policies programs, as well as investment on water resources and irrigation infrastructures in addition with training and education of farmers and field engineers towards water saving in agriculture and enhancing water productivity resulted in positive impacts on better management of limited fresh water in irrigation. Modernization planning for irrigation networks are divided into three phases based on technical, managerial and social plans. The recommendations set according to three categories as follows:

Technical Plan:

- Automation of systems to new technology for controlling and measurement of water flows.
- Professional training of operators to better operation of system.
- Mapping of sensitivity of offtakes and cross regulators for providing well services to users.
- Re-built hydraulic water measurement structures for volumetric delivering water to users.
- Lining of unlined canals in the rural area.

Managerial Plan:

- Applying rapid performance assessment of Irrigation System.
- Routine Maintenance of structure base on the scheduled program.
- Preventive maintenance of Irrigation System.
- Volumetric delivery of water to farmers.
- Recovery of water charge to MOM Cost.
- Evaluation of various cost elements of current operation techniques and services for controlling annual budget to improve the investment.
- Financial management in order to reduce the costs and make the system more productive.

Figure 3. Training program on application of MASSCOTE methodology on Dez irrigation network in Ira

Social Plan:

- Training and education of farmers and field engineers.
- Considering of farmers benefits and gives enough information to them to decide crop pattern by marketing needs.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Future modernization plans

According to the article 10 of "Iran Long term development strategy for water resources management", the structure of Iran water management must be improved considering decentralization while implementing and operating projects, increasing peoples and local organizations' participation role and integrated consideration in water cycle, regarding basins as natural units of water management and provincial units for operation and water user's participation observing the laws and regulations.

In achieving the Iran Water Master Plan goals several immediate, mid-term and long-term recommendations were proposed for managerial, operational and institutional improvement in this document. It was recommended to prepare a management information system for collecting and analyzing all information about operation and maintenance of the system to accelerate and optimize our decision making process based on this system.

Concerning the strategic policy adopted by government to involve WUAs in irrigation management, as well as expansion of private commitments in economic activities, the Ministry of Energy and the Ministry of Jihad-e-Agriculture have jointly stressed on realizing participatory approaches via local WUAs in irrigation schemes. Mentioned ministries developed a comprehensive guideline for transferring management and ownership of the irrigation networks to water users (composed of 7 chapters, 37 articles and 20 clauses) and which is going to be submitted to the government after approval by relevant commission. The guidelines recommend grade-specific WUAs for taking over management and ownership responsibilities of irrigation networks, small dams, water bodies, pumping stations, etc. There are key authorities and functions foreseen for water users' organizations as follow:

1. Leading, programming, organizing, operating maintaining, monitoring and evaluation of all affairs linked to irrigation and drainage systems;
2. Provision of financial resources, human forces and needed machinery and tools;
3. Setting synergy at internal divisions and effective liaison with external institutions;
4. Setting the cost of services received from upper systems or authorities;
5. Determining the irrigation fees based on current costs for management, maintenance and their rational disbursement;
6. Constitution of "dispute settlement council" and processing with conflicts or violations committed in the systems;
7. Issuing "Water Fee" for member users (water share bearers/water consumers) for fair and rational allocation of water resources; and
8. Taking advantage of MOE and MOJA training centers for extension and promotion of knowledge and skill favoring members and stakeholders.

This guideline obligates Ministry of Jihad-e-Agriculture to create enabling platform for smooth transfer of management and ownership of the irrigation networks to WUAs, and organizing qualified users' groups based on profound studies and surveys. Moreover, relevant ministry shall commit itself towards WUAs preparation, upon local specifications, and develop an integrated plan for empowerment of WUAs capacities over a 6 year schedule. The idea may incorporate inter-alia the following points:

1. Identification of short-term/long-term objectives and outputs;
2. Determination of responsibilities/authorities for water users, public and private stakeholders;
3. Formulation of all process suggested in action plan;
4. Development of required indicators for measuring impacts and achievements;
5. Setting a prompt participatory monitoring and evaluation plan;

6. Preparing a systematic supportive plan for better sustainability of WUAs; and
7. Estimating the required costs and fund.

6.2 Recommendations

By studying the trend of structural changes in the management of operation and maintenance of Iran irrigation and drainage systems, we find that the system management structure has proportionally increased with development and modernization of irrigation and drainage systems. The first kind of management structure had a lot of problems; however, after gradual improvement of the condition, new kinds of management structures appeared to solve the relevant problems of the systems.

The management structure of irrigation and drainage systems operation maintenance has been improving with the objectives of well maintaining hydro-works, fair water distribution and increasing productivity. After the accomplishment of the latest kind of management structure that is WUAs, it is expected that most of the previous problems will be gradually solved.

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PATHWAYS AND TECHNOLOGIES FOR MODERN IRRIGATION SERVICES – JAPAN'S COUNTRY REPORT

1. Introduction

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

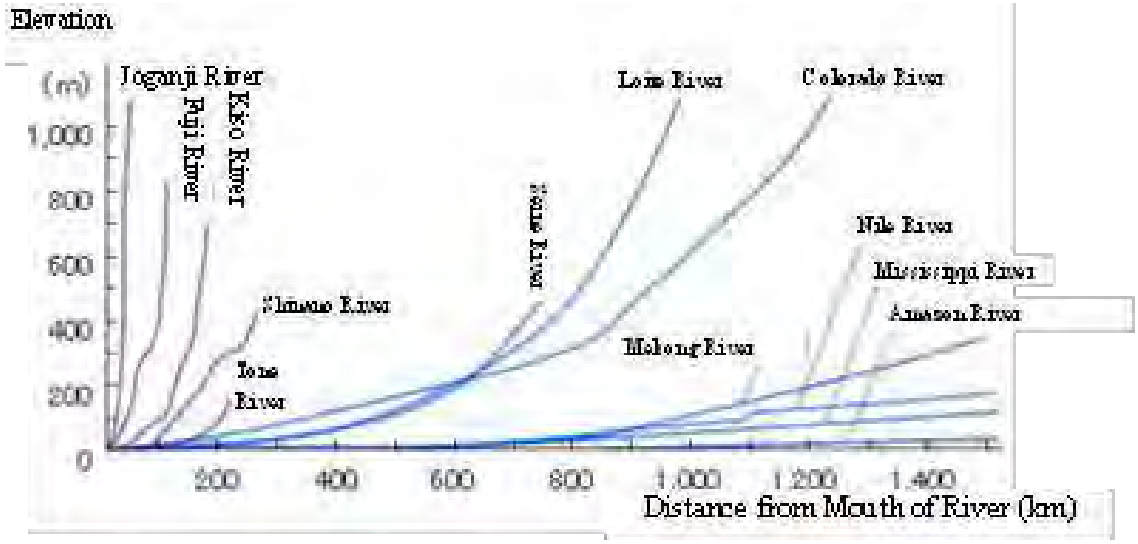

Figure 1. Longitudinal Sections of Rivers distance from Mouth of River (km)

Japan belongs to the Asian monsoon region and receives about twice as much rainfall per year as the world average, but the 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 7,700 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 4.33 million hectares (in 2022), 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 community-based consensus-building system has been formed in each village over a long history of rice cultivation, and a water management has also been carried out with villages as a basic unit. 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 farmers, called Land Improvement Districts (LIDs), for each water use system.

2. Overview of National irrigation and drainage services

2.1. Land Improvement Projects (LIPs)

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 farmers' initiative and application with the consent of at least two-thirds of the beneficiary farmers in each project area. The project implementing bodies for LIPs are the national government, prefectures, and organizations (LIDs, unions of LIDs municipalities, agricultural cooperatives, etc.), which is determined in consideration of a scale of projects, technical difficulty, etc. Project costs are borne by the national government, prefectures, municipalities, and beneficiary farmers in accordance with types and a scale of projects.

2.2. Land Improvement Districts (LIDs)

An LID is an organization of farmers stipulated in the LIA and is established with the approval of prefectural governors. Since the LIA came into effect, water management organizations based on traditional villages and organizations based on old laws have been given legal status as an LID alongside the implementation of LIPs, and now there are 4,203 LIDs (2021) with an area of 2,481,000 hectares and 3,430,000 members.

2.3. The Japanese Water Management System

In general, LIDs shall manage irrigation and drainage facilities developed by LIPs, such as reservoirs, head works, pump stations, main irrigation/drainage canals, etc., apart from large-scale and highly public facilities developed by the national government, which require special technical considerations for their management and are directly managed by the national government.

LIDs' water management methods include operation of gates in main canals, irrigation, and drainage pump stations, etc., as well as water management in terminal canals by subordinate organizations, such as villages and water utilization associations, and water is distributed to farmlands based on a rotation schedule. The costs for the operation and maintenance of the facilities are collected as a levy based on the size of farmlands and other factors. Safety inspections, weeding, and canal cleaning are often carried out by farmers and non-farmers in the village.

3. Assessment of modernization and revitalization requirements

3.1. Aging of Irrigation and Drainage Facilities

The asset value, based on reconstruction costs, of the 7,700 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 (about 150 billion USD). 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 lifetime. With the aging of core irrigation and drainage facilities, it is necessary to extend their lifetime 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.

3.2. Decline in the Number of Farmers, an Aging Society, and a Declining Population

The number of core agricultural workers in 2020 was 1,363,000, a decrease of 1,037,000 (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 old.

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

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

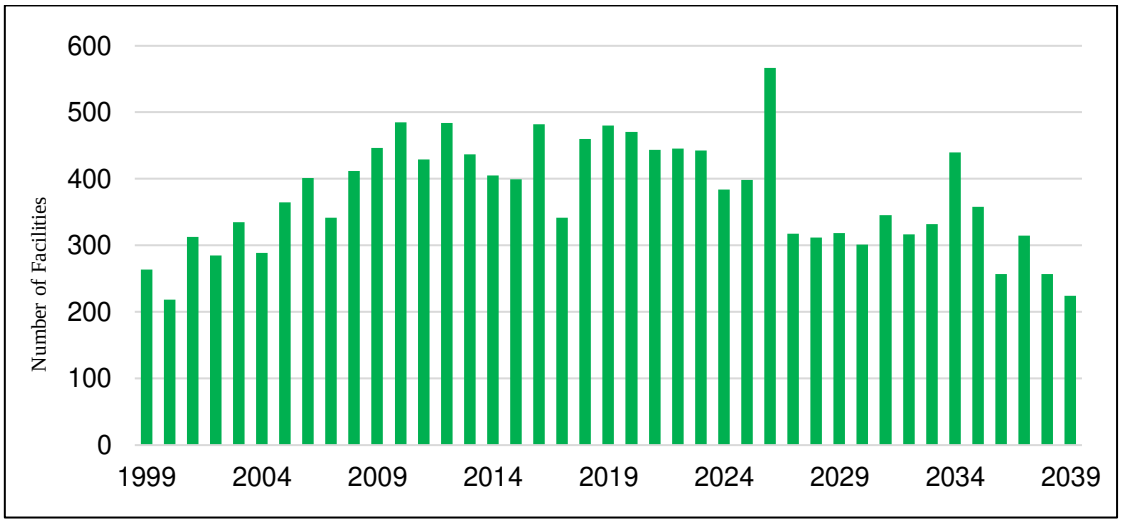

Fig.2. Number of Core Agricultural Water Utilization Facilities Exceeding Their Lifetime (as of March 2019)

Table1 Number of Core Agricultural Workers

Item	2000	2010	2020
Number of Core Agricultural Workers (Thousands)	2,400	2,054	1,363
Number of Persons Aged 65 and Over (Thousands) (%)	1,228 (51.2)	1,262 (61.4)	949 (69.6)
Number of Persons Aged 75 and Over (Thousands) (%)	306 (12.7)	595 (29.0)	432 (31.7)
Average Age (Years)	62.2	66.1	67.8

4. National factors affecting irrigation and drainage services, including water policy, institutions and human resource capacities

4.1. The Basic Plan for Food, Agriculture and Rural Areas

The Basic Plan for Food, Agriculture and Rural Areas based on the Basic Law on Food, Agriculture and Rural Areas aims to improve food self-sufficiency ratio 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 rural areas.

4.2. Strategy for Sustainable Food Systems, MIDORI

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

The strategy sets 2050 as the target year and sequentially promotes the social implementation of technologies that are already being developed (by 2030), 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.

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

4.3. Long-term Plan for Land Improvement

For the development of irrigation and drainage facilities and farmlands, 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. Currently, development is being implemented in a well-planned manner. The goals and projects under the current Plan (2021 – 2025) are shown as below.

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

In order to strengthen agricultural competitiveness by reducing production costs, the following measures will be taken: (1) promotion of infrastructure development such as farm enlargements and farm consolidation for core farmers, (2) promotion of smart agriculture, such as the use of automated agricultural machinery and ICT water management that can respond to diversified water demands, etc. by making large plots of rice paddies adjusting plots' shape, and making slopes more gradual for cropland and orchards, In addition, in order to strengthen the profitability through shifting to highly profitable crops and establishing brands for production areas, the following measure will be also taken: (3) upgrading to multipurposed paddy fields and conversion of rice paddies to crop lands, a shift from rice to highly profitable crops such as vegetables and fruits, in addition to promotion of exports in coordination with related measures.

4.3.2. *Development of Rural Areas 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 areas, the following measures will be taken: (1) promotion of work reform in rural areas 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 development of production and sales facilities that take advantage of the characteristics of regions such as hilly and mountainous areas, (2) 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 energy-saving sewerage facilities in rural villages, strengthening of village roads, and improvement of the information and communication environment, (3) strengthening of organizational management systems by involving diverse human resources such as LIDs that support agriculture and rural areas

4.3.3. *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 basin-wide flood control, the following measures will be taken: (1) assessments of deterioration, earthquake and heavy rainfall resistance of prioritized agricultural reservoirs for disaster prevention, 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, strengthening of the flood control function of existing dams, and 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, the following measure will be also taken: (3) promotion of development that enables flexible water management and strategic conservation management through the systematic and efficient repair and renewal of facilities with robots and ICT.

4.4. Contributing to SDGs

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

1. SDG 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture," from the perspective of improving adaptive capacity for floods and droughts and ensuring a system for the sustainable food production system
2. SDG 6. Ensure availability and sustainable management of water and sanitation for all," from the perspective of improving water use efficiency dramatically and supporting and strengthening participation of local communities in improving management skills in the water related sectors
3. SDG 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation," from the perspective of high quality, reliable, sustainable, and resilient infrastructure development

5. Priority issues for modernization of irrigation and drainage services

5.1. Responding to 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 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, share various knowledge and information through the IoT, and aims to solve issues that modern society is facing, such as a declining birthrate, an aging society, and depopulation of rural areas through AI and automation technologies. In the agricultural sector, "smart agriculture" is also expected 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 advanced management of irrigation and drainage facilities under the labor-saving water management at the field level by introducing automatic water supply and drainage taps, the automated water distribution operations in main and branch canal networks with IoT, and daily inspections of facilities, functional diagnoses, and monitoring with reduced labor requirements through the use of drones and ICT.

In addition, in order to turn agriculture into a growth industry and improve the income from agriculture in rural areas, farm enlargement to reduce production costs and multi-use rice paddies and conversion of rice paddies to crop lands for the introduction of highly profitable crops is promoted. In order to realize such a shift in farming systems and an expansion of scale, it is necessary to improve 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*

Japan's agriculture and rural areas not only provide a stable supply of food, but also have the following core multifunctionalities 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 eventually 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: Crops growing in the fields, houses of farmers, and the surrounding waterfront and woodlands 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.

The management of terminal irrigation and drainage facilities has been carried out by rural communities and water user associations, which are subordinate organizations of LIDs, but an aging society, a decline in population, and an 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 will be displayed through maintaining agriculture, while maintaining and enhancing rural community functions.

In order to cope with this situation, direct payments are introduced for conservation and management activities for farmland and terminal facilities, environmental conservation activities in rural areas, and life-extension works such as repair of terminal facilities, all of which are carried out by farmers and rural communities.

In particular, irrigation canals not only supply water for agriculture but also perform a variety of functions such as water parks, ecosystem conservation, water for firefighting, and snow removal. It is desired that local residents understand and cooperate to manage irrigation facilities through the recognition and active use of these functions.

In addition, rural areas have diverse values such as beautiful scenery, diverse ecosystems, and cultural and traditional events related to agriculture, which attracts urban residents and creates a flow of people returning to the countryside. Rediscovering these diverse values and attractiveness in rural areas and revitalizing rural communities are also important for the sound management of terminal irrigation and drainage facilities. As part of these efforts, it is necessary to utilize the World Heritage Irrigation Structures(WHIS) scheme, in which 47 irrigation schemes are approved in Japan, disseminate information on the historical and cultural values of irrigation and drainage facilities, and lead to 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 severe. In particular, rainfall patterns are changing, and the number of rainfall events with an extremely high intensity rainfall per unit time is increasing.

In Japan, low-lying areas in the major river basins have been developed as rice paddy areas. However, with the economic development after the 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 damages. 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 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. This initiative will control runoff and the rapid rise of water levels in a river during heavy rains, which will 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 been started. The purpose of this initiative is to lower the water level of agricultural dams in advance when heavy rains are expected to use the space for flood control capacity.

5.2.4.

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 take 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. Countermeasures for Global Warming

Most of the irrigation and drainage systems in Japan irrigate agricultural lands by utilizing the potential energy of the country's abundant rainfall, which is about twice the annual average of the world, since 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 goals of the "Strategy for Sustainable Food Systems, MIDORI", which aims at strengthening the response to SDGs and global warming and promoting innovations, such as carbon neutrality, to reduce environmental burden in the medium to long term.

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.

6. Conclusions and recommendations

In addition to the issues of declining population, shrinking domestic market and aging and declining number of farmers, agriculture and rural communities in Japan are now at a big turning point with emerging risk to food security caused by a change in global food supply and demand situation.

Irrigation and drainage facilities are also facing deterioration in their functions, shrinking in institutional capacity for operation and maintenance, frequent and intensified natural disasters caused by climate change.

Under such circumstances, in order to maintain an appropriate level of functions of irrigation and drainage facilities, the government of Japan will facilitate the following efforts:

1. To promote the advanced water management in irrigation and drainage through the use of advanced technologies such as robots, AI, which will realize remote and automated on-farm water management through the introduction of automatic water supplies and drainage taps, water distribution system in main and branch canal networks connecting to the end point operation with IoT,
2. To strengthen the rural community functions and enhance the multifunctionality of agriculture,
3. To enhance national land resilience by improving the function of drainage facilities and providing earthquake resistance measures to the core irrigation and drainage facilities, and
4. To introduce facilities to generate renewable energies into the irrigation systems such as small-scale hydroelectric power facilities in irrigation canals and reservoirs.

Japan will contribute to realization of global water and food security through these activities.

COUNTRY PAPER ON CURRENT STATE AND FUTURE PATHWAYS FOR MODERN IRRIGATION SERVICE IN NEPAL[1]

ABSTRACT

This country paper entitled "Current state and future pathways for Modern Irrigation Service in Nepal" presents brief analysis of the current state of irrigation development in Nepal, along with the challenges and requirements for modernization. It also explores the national factors that affect irrigation and drainage services, including water policy, institutions, and human resource capacities. The paper concludes by highlighting priority issues for the modernization of irrigation and drainage services and outlining future plans.

The growth in population demands increased food production in future. Improving and managing agricultural water for irrigation is crucial for improving food production and ensuring national food security. The current need for enhancing irrigation services across the world is vital given the limitation in the availability of land, water for further expansion.

Irrigation in Nepal is considered as a major factor for enhancing agriculture growth. From traditional Farmers managed irrigation systems (FMIS) to the modern-day large irrigation systems, the irrigation sector in Nepal has evolved through different phases. The historical evolution of irrigation development and the policy shift from the past to the present are discussed, followed by an assessment of the current state of irrigation development in Nepal. It also delves into the implications of federal governance on the irrigation sector.

The assessment of modernization and revitalization requirements focuses on four key aspects. Firstly, it examines the management, operation, and maintenance practices of irrigation systems. Secondly, it highlights the challenges posed by shrinking financing and investment in the sector. Thirdly, the evolving socio-economic and environmental landscape is explored, emphasizing its impact on irrigation. Lastly, the constraints in human resources capacity and technology adoption are discussed.

National factors that directly affect irrigation and drainage services, including water policies, inter-sectoral practices, institutions, human resources capacities, water availability, and financing priorities are thoroughly analyzed. The paper based on the current state and possible future pathways proposes priority issues for the modernization of irrigation and drainage services, namely enhancing management, operation, and maintenance practices, securing finance and international cooperation, investing in research and development, capacity building, knowledge transfer, collaboration, and undertaking institutional and policy reforms.

In conclusion, the abstract provides an overview of future modernization plans for national irrigation and drainage services in Nepal. The paper emphasizes the need for concerted efforts in addressing the identified priority issues and implementing necessary reforms to ensure sustainable and efficient irrigation systems in the country.

Keywords: FMIS**,** mom practice, modernization, water policy, institutions, financing.

1. Introduction

Over the past five decades, irrigation has played a significant role in global agricultural production and food security, contributing to approximately 40% of the world's food production while utilizing less than 20% of its land area. As the world's population is projected to exceed 9 billion people by 2050, the demand for food is expected to rise significantly. To meet this demand, global food production needs to increase by 70%, with developing countries requiring a 100% increase (Alexandratos and Bruinsma, 2012). With limited availability and increasing pressures on resources such as water, land, and energy, the development of efficient and sustainable irrigation and drainage systems, which play a vital role in bolstering water security and attaining food security is inevitable. Furthermore, there is a demand for increased investments, mechanisms for sharing knowledge and experiences, exchange of best practices, and technology transfer in the field of agriculture water management.

Agriculture in Nepal is in a low development stage with lower productivity and competitiveness, limited adoption of technology and high share of cereal crops. Though some of the sub-sectors such as fisheries, dairy products and tea show some positive prospects, the overall agriculture sector remains at the subsistence stage with few signs

[1] Nepal National Committee on Irrigation and Drainage (NENCID)

of commercialization. The increasing trend of outmigration within and out of the country, high rates of labor transfer from agriculture sector to non-agricultural sector, lower profit and limited adoption of commercial agriculture has added further challenges to coping with the increasing population pressure on food and nutrition demand. Despite these challenges, the Government has increased its effort for commercialization of agricultural products and increasing support to farmers through capacity building, subsidy policies and further support to develop input infrastructure such as irrigation.

ADS (2015) has targeted to convert the nation with positive trade deficit in agriculture sector by 2035 through its vision component of self-reliant, sustainable, competitive, inclusive growth, livelihood and food and nutrition. In this context, irrigation is anticipated to be a major contributor to achieving these targets with the long-term plan of developing 80% of the irrigable area with year-round irrigation facilities. In a country where more than two thirds of the population are involved in the agriculture sector and contribute nearly one-quarter of the total GDP, the role of irrigation development cannot be underestimated.

The development of irrigation doesn't only mean expanding the access to irrigation but also ensuring the reliability and year-round irrigation availability. Irrigation in Nepal is prioritized as a sector that can assist in the country's need for poverty alleviation, managing regional imbalances, and ensuring food security among others.

Despite abundant water resources in the nation, expanding and improving the existing irrigation system is still necessary to cover all the irrigable land under irrigation facilities. The irrigation development in Nepal has two phases related to Farmers Managed Irrigation System (FMIS) and Agency Managed Irrigation System (AMIS). Historically, with the increase in the agriculture practice and existing community harmony in the ancient time, farmers started developing their own irrigation systems with their own traditional operational and maintenance techniques and were considered as Farmers Managed Irrigation System (FMIS).

These systems have temporary diversion structures and low conveyance efficiency but are traditionally governed through social norms and collective decision (Pradhan and Belbase, 2018). It is believed that more than 16,700 FMIS were developed, operated, and managed by farmers themselves within the Country (Pradhan, 2000).

Government direct investment was first initiated after the construction of Chandra Nahar (canal) and this kind of system is considered as Agency Managed Irrigation System (AMIS). AMIS in Nepal are either Government operated or jointly operated by Government and Water Users Association. The resource mobilization of the Water Users Association is mostly dependent on Irrigation Service Fee (ISF).

2. Overview of National irrigation and drainage services

2.1 Land, Water Resources and Population in Nepal

The sustainable transformation, growth, and management of Nepal's overall socio-economic, political, and environmental structure rely on three principal components: land, water, and people. By recognizing the interconnectedness of land, water, and people, Nepal can ensure the long-term availability and equitable distribution of water resources, fostering socio-economic development and environmental sustainability.

Population: Nepal has experienced a remarkable shift in its population dynamics over the past decade. Between 2011 and 2021, the population decreased by a total of 2.67 million (CBS, 2021), presenting both challenges and opportunities for the country's development trajectory. This demographic transition, coupled with Nepal's abundant water resources, highlights the need for strategic planning to balance the interplay between land, water, and a changing population. Total population according to the recent census in 2021 was 29.6 million while in 2022, it is reported as 30.547 million.

Water resources: Nepal's total water resources potential is estimated as 225 Billion-Cubic-Meters (BCM) per year (WECS, 2005) and. Groundwater contributes 8.8 BCM in total (Shrestha et al., 2018). The uneven distribution of water resources with space (i.e., with demand centers) and time (i.e., limited availability at the time of need); (Nepal et al., 2021) constraining the year-round irrigation facilities.

The average annual per capita water availability is calculated to be 7,366 cubic meters per year. Koshi in the east, Gandaki at the central and Karnali and Mahakali in the west are the major river basins of Nepal as shown in Fig. 2.

Land resources: Nepal has a total land area of 147,181 km^2. Over 44% of the total area is covered by forest as shown in Fig. 1(b). Agricultural area comprises of about 24% (3.57 million ha). According to the Irrigation Master Plan, 2019, about 70% of the agricultural land (2.5 million ha) is classified as suitable for irrigation. The per capita land availability in Nepal is: (i) total lands 0.49 ha; (ii) agricultural land 0.112ha; and (iii) irrigable lands 0.084ha (2022 CBS data). About 1.53million ha of land currently has irrigation facilities.

a)

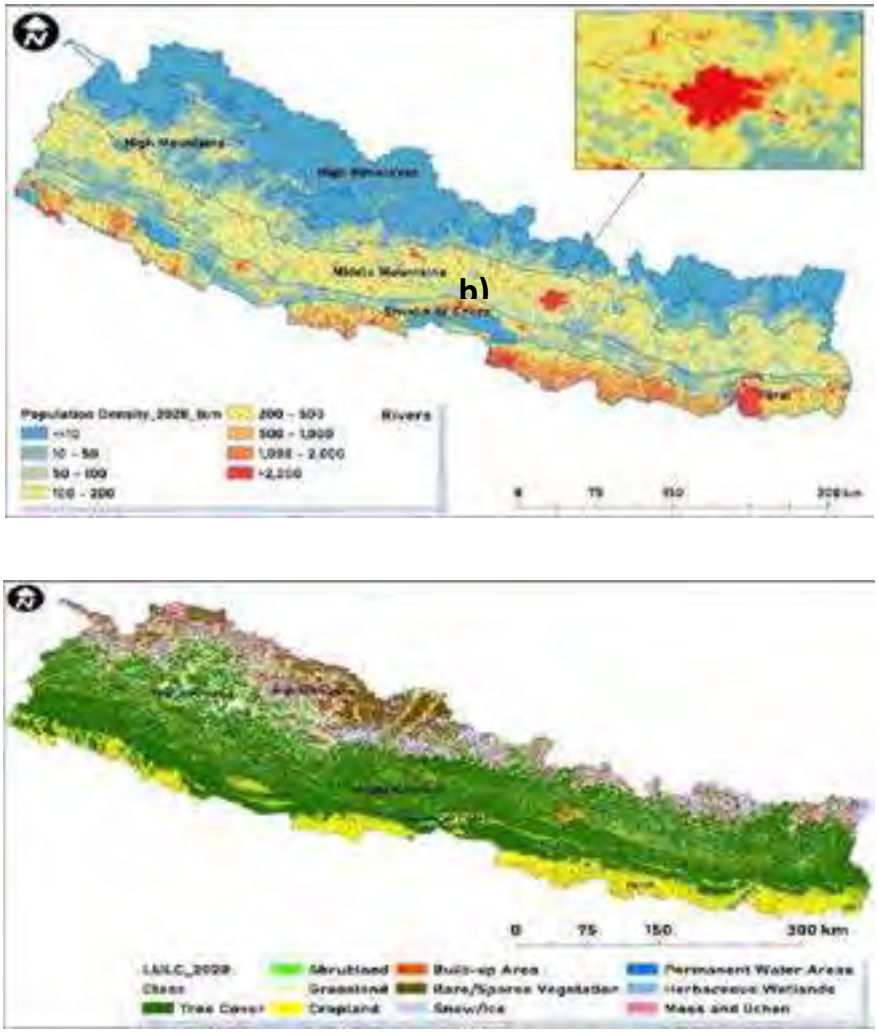

Figure 1. (a) Population density (www.worldpop.org) and (b) Landuse distribution of Nepal for the year 2020 (Zanaga et. Al. 2021)

Figure 2. River networks map of Nepal derived from SRTM90m DEM
(each color representing a river basin)

2.2 Historical Evolution of Irrigation development in Nepal

The current state of Nepal's irrigation sector is the result of multiple phases of development over time. For years, farmers and local communities have driven the irrigation sector through the development of small-scale systems with local knowledge and experience. This longstanding tradition has led to the emergence of numerous Farmer-Managed Irrigation Systems (FMIS) across the country. These systems have evolved their unique sets of regulations, customs, and operational procedures for efficient management (Pradhan, 2000).

Government intervention in irrigation system began after the construction of Chandra Nahar in 1928, Photo 1. Figure 3 depicts different phases of irrigation development in Nepal. Before the beginning of planned development initiatives, irrigation developed through communal efforts. Through the intensive development phase to integrated development phase, irrigation sector transformed from infrastructural approach to a more holistic and management approach when different programs with specific targets were launched (Poudel, 2003). At present the focus is on managing the spatio-temporal water variability by emphasizing inter-basin water transfer projects, groundwater projects, and basin management and multi-utility of available water approaches, etc.

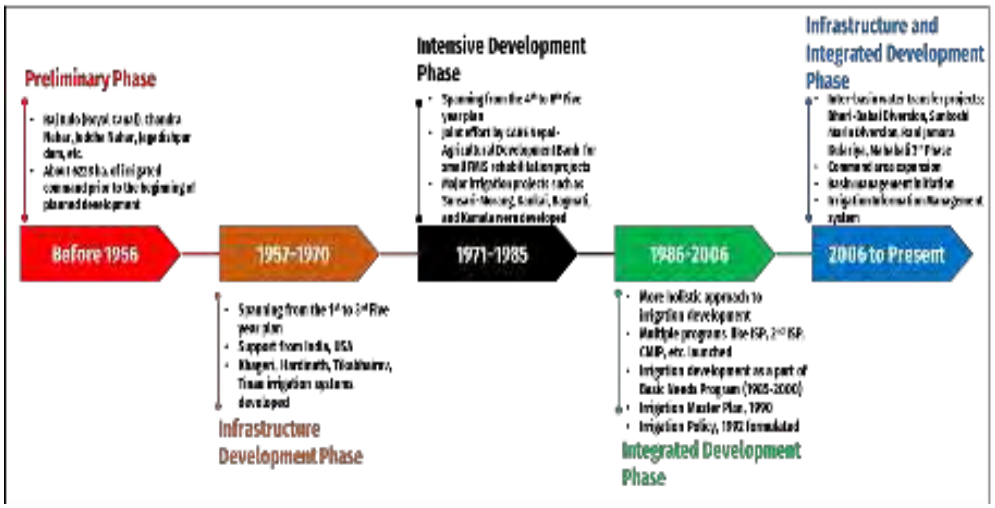

Figure 3. Evolution of irrigation development in Nepal (modified after Poudel, 2003)

2.3 Policy shifts from past to present.

The irrigation and water resources planning and development in Nepal during the past thirty years and beyond have been driven by the objective of alleviating poverty and promoting socio-economic progress. To achieve this objective, several policy documents, including the Irrigation Master Plan (1990), the National Water Resources Strategy (2002), the National Water Plan (2005), the Irrigation Policy, and different Periodic plan have guided irrigation development and planning in Nepal. Irrigation related targets and approaches were set by these documents. The evaluation of the accomplishments and effectiveness of these targets and approaches has been relatively limited.

The IWRM principle was one of the approaches prioritized for the development of water resources including irrigation. However, the implementation of this approach has been limited and challenging due to multiple factors related to governance, institutional arrangements, socio-economy, human resources capacity, etc. (Karki and Acharya, 2023). Building upon the successful implementation of the FMIS nationwide as well as global trends of public involvement, Nepal has embraced and continues to employ the principles of Participatory Irrigation Management (PIM) and Irrigation Management Transfer (IMT) in the management of irrigation systems. Increasing farmer's ownership, minimizing financial and managerial burden on government agencies, improving collection of irrigation service fee as well as embracing the global trends of handover to WUAs, joint management approaches were introduced in completed irrigation systems.

Irrigation Master plan (IMP), 2019 was drafted to guide irrigation development for the next 25 years. IMP, 2019 has emphasized intensification of existing systems, development of new systems, inter-basin and multipurpose projects and groundwater development among others. Similarly, the new water resources policy, 2020 that aligns with the new constitution and federal governance system has also been enforced that prioritizes integrated, multipurpose and coordinated planning and development of water resources in Nepal.

2.4 Current state of Irrigation development in Nepal

The total land area benefiting from irrigation services throughout the country is estimated to be around 1.53 million hectares in which, two third by surface and one third by groundwater system (DWRI, 2022). The Terai plains food basket of country with large size irrigable areas are served by large-scale agency managed irrigation systems, whereas medium and small-scale systems are primarily concentrated in the mid-hills and a few in high mountain regions, as depicted in Figure 4. Around 16,000 FMIS, which are self-sustainable, provide irrigation facilities for over 50% of the irrigated land. However, a significant number of these FMIS are not recorded in the official statistics by the government. Despite the increase in the coverage of irrigated command areas, the irrigation system in Nepal faces a shortage of available water.

It is estimated that only approximately one-third of the command areas receive year-round irrigation services due to the mismatch between the available land, demand, and supply of water in both space and time. To address this challenge, DWRI is emphasizing the development of inter-basin water transfer projects and multipurpose projects, which are being implemented as national pride initiatives. Examples of such projects include the Bheri-Babai Diversion Project in Western Nepal and the Sunkoshi-Marin Diversion Project, among others. In addition to this, the future policy and planning for irrigation facilities extension and coverage could be the conjunctive use of water (surface and groundwater). Water efficient non-conventional irrigation methods, including sprinkler, drip, plastic ponds, and small storage reservoirs, are utilized alongside traditional surface and groundwater systems within the framework of the Non-conventional Irrigation Technology Project (NITP).

These alternative systems are especially valuable for small-scale farmers in marginalized lands of hilly areas and foothills of Chure where water sources are scarce. The NITP to date covers an estimated area of over 6,000 hectares of land. The implementation of NITP sub-projects is currently carried out by the division offices of the provinces. In recent years, improved electricity access and solar-powered batteries has facilitated the adoption of lift irrigation systems by both the Department of Water Resources and Irrigation (DWRI) and the provinces.

Irrigation programs and projects that prioritize improved water management, community involvement, and climate resilience are underway. Notable projects include the Irrigation and Water Management Project (IWRMP), Community Managed Irrigated Agriculture Sector Project (CMIASP), and Irrigation System Improvement Project (ISIP), among others. These initiatives receive funding from various development partners such as the Asian Development Bank, World Bank, and Kuwait Fund for International Development, supplemented by government funds.

The current state of irrigation development in Nepal is characterized by various challenges and limitations that affect the efficiency and effectiveness of the irrigation systems. Outdated infrastructure poses a significant challenge, as many canals, water storage facilities, and distribution networks need modernization and maintenance. Inadequate water storage capacity further exacerbates the issue, as the availability of water during dry periods becomes a major constraint. Inefficient water management practices also contribute to suboptimal irrigation outcomes, leading to water wastage and reduced agricultural productivity

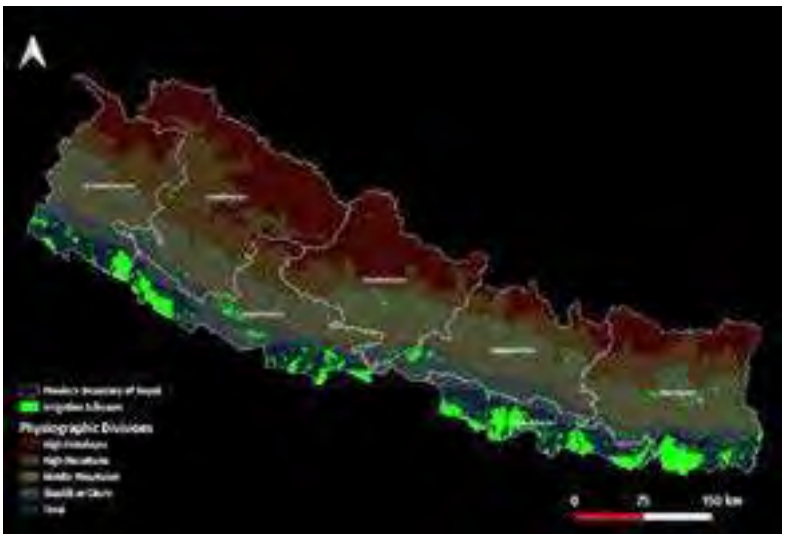

Figure 4. Distribution of irrigation schemes across provinces & physiographic zones of Nepal.

Photo 1: Chandra Canal Irrigation system completed in 1928 embarked the modern irrigation development in Nepal.

Maintenance, operation, and management (MoM) present ongoing challenges, requiring concerted efforts to streamline and enhance these practices. Insufficient funding and investment in irrigation projects pose obstacles to the development and maintenance of irrigation infrastructure. Socio-economic and policy challenges, including issues related to land ownership, water rights, and governance, further impede the progress of irrigation development.

Following the implementation of the new constitution, young and experienced human resources working under the Department of Water Resources and Irrigation (DWRI) were reassigned and integrated into the provincial government. Consequently, this has resulted in a scarcity of human resources at the national level for the implementation of DWRI plans and programs. Technological challenges also exist, with the lack of a comprehensive database on irrigation hindering effective planning, management, and evaluation of irrigation systems. Additionally, while irrigation plays a vital role in increasing agricultural productivity, factors such as access to fertilizers, seeds, and other inputs also impact overall agricultural performance. Another concern is the erosion of indigenous knowledge, which has traditionally played a crucial role in the success of irrigation systems and water management practices. This knowledge is at risk of being lost due to factors such as the generation gap, changing development regimes, globalization, technological advancements, and the growth of the service sector. Preserving and blending indigenous knowledge with modern irrigation practices is essential for sustainable and context-specific solutions.

Addressing these challenges and limitations requires comprehensive efforts, including capacity building, improved water storage capacity, efficient water management practices, adequate investment, policy reforms, technological advancements, and the preservation of indigenous knowledge.

2.5 Irrigation sector under federal governance

Following the implementation of a federal system of governance in the country, the responsibilities and control over the irrigation sector have been divided among the three levels of government: federal, provincial, and local. According to the constitution of Nepal, the federal government is entrusted with overseeing large-scale irrigation projects, while medium-scale projects are the responsibility of provincial governments. Small-scale irrigation systems are managed by local levels. The current Irrigation Policy of Nepal recognizes and assigns an active role to local levels in terms of planning, maintenance, and management of small irrigation systems. However, due to limited institutional and technical capacity, local levels have struggled to effectively fulfill this role.

The provincial level of the irrigation and water resources sector is overseen by the Water Resources and Irrigation Division within the provincial ministry. This division is responsible for various tasks such as planning, budget allocation, and implementation of plans and programs, and project appraisal at district level.

The Department of Water Resources and Irrigation (DWRI), Nepal, along with its project and field offices, is primarily responsible for managing large-scale and mega projects of national significance. This includes national-scale programs related to surface and groundwater irrigation, inter-basin water transfer projects, and large-scale river training projects.

The specific scope of work for each level of government—federal, provincial, and local—is defined in the "Guidelines related to development programs and project classification and distribution under the responsibility of Union, state, and local levels, 2019." These guidelines provide detailed instructions on the responsibilities and distribution of projects among the different levels of government.

Table 1. Classification of irrigation responsibility among federal, provincial and local government

Government Level	Terai	Hills	Mountains
Federal	>5,000ha	>100ha	>50ha
Provincial	200-5,000ha	50-100ha	25-50ha
Local	Maintenance, Rehabilitation and Management of small-scale projects		

The National Water Resources Policy, 2020 aligns with the fundamental principles of the constitution of Nepal by highlighting the significance of collaboration and coordination among the federal, provincial, and local levels of government. This policy emphasizes the imperative of the sustainable development, utilization, and management of water resources in the country. However, due to the relatively early stage of the implementation of federal governance in Nepal, the irrigation sector is yet to completely adjust to this transformed landscape.

3. Assessment of modernization and revitalization requirements

To gain insights into the irrigation modernization and revitalization requirements, a comprehensive assessment covering aspects like Infrastructure evaluation, Water availability and demand, Technology and automation, Farmer engagement and capacity building, Policy and institutional framework, Funding and investment opportunities would be needed. Such assessment can serve as a foundation for developing implementation plans, technological interventions, strategies, policies, and investment plans to enhance irrigation efficiency, water management, and agricultural productivity in the country. Some key aspects that are relevant to the context of Nepal have been discussed here.

3.1 Maintenance, Operation and Management (MOM) practices

The sustainability of any irrigation system relies on effective operation, maintenance and management practices. Maintenance, Operation and Management (MOM) play a crucial role in the functioning of irrigation systems and are vital for achieving the ultimate goal of efficient irrigation services. Despite substantial investments in the development and expansion of irrigation infrastructure over the years, the performance of numerous irrigation and drainage systems falls significantly short of their potential.

Criticism of irrigation worldwide stems from various issues, including inefficient water use, inadequate system performance, and the depletion of groundwater resources, among other concerns. One key contributing factor to this situation is the absence of well-planned MOM practices. 'More crops per drop' is the essence of MOM practice. MOM forms an integral part of the project development and implementation cycle. However, MOM activities are frequently overlooked in Nepal, where more focus is placed on construction and development aspects.

Several attempts have been made in the past to enhance the performance of these systems. However, the end results have not been satisfactory. Though there are several reasons associated with their dismal performance, the lack of institutional capacity in undertaking appropriate MOM of these systems is one such reason. The review of this situation demanded the development of comprehensive guidelines for undertaking the MOM of existing irrigation systems. Under the present scenario of poor performance of some of the large irrigation systems, DWRI has prepared a MOM guideline with an aim of supporting and enhancing the current practice on maintaining, operating, and managing the existing irrigation service for improving their efficiency.

The MOM guideline covers the documentation and digitization of irrigation infrastructures, preparation of asset management plan, preparation, and implementation of canal operation plan, and ensuring the sustainability of system through the active participation of Water Users Association (WUA). The scope of MOM guideline also covers capacity development of WUA, resource mobilization through them with effective ISF collection mechanism.

3.2 Shrinking Financing and Investment

There is a global trend indicating a decline in investment within the irrigation sector, which is expected to continue in the future for several reasons. According to the Food and Agriculture Organization (FAO), during the period from 1960 to 1990, the irrigation sector received the highest share of development investments, accounting for 7% of the World Bank lending, surpassing any other individual sector. However, in the 1990s and 2000s, this percentage dropped significantly to less than 2.5%. Furthermore, investment priorities have shifted over the years, moving away from the development of new irrigation systems and towards the management, rehabilitation, and modernization of existing systems. The evaluation of irrigation financing should go beyond the sole consideration of the amount of money invested. Instead, it should be assessed based on the priority given to specific programs and the envisioned direction for future investments. Over the years, the allocation of the annual budget for the irrigation sector in Nepal has remained stagnant, with no significant increase.

Additionally, a significant portion of the budget allocated to the irrigation sector is primarily focused on developing new inter-basin water transfer projects, while projects aimed at modernizing and upgrading existing systems receive the least priority in terms of budget allocation. As the scope for expanding and developing new systems becomes restricted due to limited financial resources and competition from other sectors of development, it becomes crucial to modernize the current systems to achieve maximum efficiency and output per unit investment. In addition, financing in capacity building, research initiatives, and international collaboration is equally important.

3.3 Evolving Socio-economic and Environmental Landscape

The evolving socio-economic and environmental landscape in Nepal, including the growth of the service sector, shrinking agricultural land, diversified occupations, declining agricultural workforce, generational gap in traditional water management practices, migration, climate change impacts, all underscore the importance of modernizing and revitalizing irrigation services to ensure sustainable water management and agricultural productivity in the country.

Nepal has experienced significant growth in its service sector, which has led to a decline in the adoption of agriculture as a primary occupation. As more people move away from agriculture, there is a need to update and improve irrigation practices to ensure efficient water management and sustainability in the sector. Due to various factors such as population growth, urbanization, and land degradation, the availability of agricultural land in Nepal has been decreasing. This limited land availability puts additional pressure on the remaining agricultural areas, making it crucial to enhance irrigation services for maximum productivity.

The younger generation in Nepal is increasingly engaging in non-agricultural occupations, resulting in a decline in the agricultural workforce. Therefore, there is a need for promoting agricultural development as it will help engage youths and hence generate employment opportunities and control the movement of youths to other sectors in lack of opportunities to make a living. Traditional water management and irrigation practices in Nepal may not be effectively transferred to the younger generation due to the changing occupational preferences and lifestyle patterns. Bridging this generational gap through modernization of irrigation services becomes essential to maintain sustainable water management practices. With the evolving socio-economic landscape, communities in Nepal are becoming more reliant on government agencies for the provision of irrigation services.

This emphasizes the need for modernization and revitalization of these services to meet the increasing demands and ensure effective water resource management. Migration from rural to urban areas and haphazard development activities pose challenges to sustainable irrigation practices. As populations shift and development occurs, there is a need to modernize and revitalize irrigation services to adapt to these changing circumstances and mitigate potential negative impacts. Climate change has led to increased variability in rainfall patterns and an increased risk of natural disasters such as landslides. These factors directly affect water availability and irrigation systems. Modernization and revitalization of irrigation services can help build resilience to climate change impacts and mitigate the risks associated with natural disasters.

3.4 Constraints in Human Resources Capacity and Technology Adoption

When it comes to modernizing irrigation systems in Nepal, there are several constraints related to human resources capacity and technology adoption that need to be considered. The initial investment required for infrastructure upgrades and technology acquisition can be high, making it challenging for farmers and irrigation organizations to afford these advancements. Inadequate infrastructure, such as unreliable electricity supply, lack of proper drainage systems, and limited road connectivity, can hinder the adoption and effective operation of modern irrigation technologies.

Insufficient emphasis on research and development, collaboration, and capacity building has been observed in the context of irrigation and drainage services. An example that highlights this issue is the Nepal's government recent decision to merge the Water Resources Research and Development Centre (WRRDC) within Water and Energy Commission Secretariat (WECS), Nepal. Capacity building initiatives have also been given limited priority, leading to a gap in the skills and knowledge of professionals involved in irrigation and drainage services. Inadequate training programs and educational opportunities have hindered the development of human resources required to effectively manage and operate modern irrigation systems. In the process of modernization, it is crucial to consider both the technical and managerial aspects of a system. Hence, when building the capacity of human resources, the focus should not be solely on technical skills but also on developing managerial and planning skills. The human resources capacity in the irrigation sector is deficient in terms of effectively generating innovative ideas and implementing plans and programs that align with the national goals of the sector.

Across the irrigation sector in Nepal, there is a notable absence of accurate databases, baseline information, and an integrated irrigation and agriculture information management system. Furthermore, initiatives such as system digitization and automation have not been implemented even on a pilot basis. This situation underscores the urgent need to modernize and revitalize the system, both to improve current performance and to facilitate effective planning for the future. The adoption of modern technologies in the irrigation sector is essential to align with the global technological shift in contemporary irrigation practices and to achieve the United Nations sustainable development goals related to water and irrigation.

4. National factors affecting irrigation and drainage services, including water policy, institutions, and human resources capacities.

4.1 Water and inter-sectoral practices and policies

The irrigation sector in Nepal has complex interconnections with various socio-economic and environmental sectors, including agriculture, communities, forests, land, and infrastructure, among others. However, the problem lies in the isolated approach adopted during policy formulation, which often excludes multiple stakeholders and, most importantly, the farmer who are the end users. As a result, policies frequently become redundant or conflict with other sectoral policies. Furthermore, the periodic evaluation of policies is rarely conducted.

While the concept of Integrated Water Resources Management (IWRM) principle was incorporated into the water resources strategy in 2002 and emphasized in the current water resources policy, it is important to acknowledge that the IWRM principles, despite their appeal, cannot be effectively put into practice without their application to specific river basins. Furthermore, the establishment of River Basin Agencies responsible for formulating Master Plans is essential for the principles of IWRM to be fully implemented in both theory and practice. The effectiveness of water policies in promoting sustainable and efficient irrigation and drainage services is crucial. Water related acts in Nepal are quite old and do not reflect the current scenario. Clear policies are required to address water allocation, water rights, pricing mechanisms, water conservation, and environmental protection. The National Water Resources Policy, 2020 has attempted to address this issue but relevant acts, regulations and guidelines needs to be enforced in order to achieve the policy objectives. Effective coordination and integration of water-related policies across different sectors, such as agriculture, environment, and water resources, is essential for effective water management and ensuring the sustainability of irrigation and drainage services which is often lacking in Nepal and ultimately affects the smooth implementation of irrigation development projects and plans. Engaging stakeholders in the policy development process can foster ownership and increase support for implementation. Administrative hurdles are imposed by policies, acts, and regulations pertaining to forests, environmental assessment, riverbed materials, public procurement, and other related areas. These hurdles have a cascading effect throughout the various stages of irrigation system planning and development. Consequently, the introduction of new programs and projects, as well as the timely completion of existing projects, face significant obstacles. In many instances, these challenges are so severe that projects and programs ultimately have to be abandoned or cancelled.

Another factor that hinders the implementation of policies and planning related to irrigation and water resources is the establishment of overly ambitious and impractical targets that exceed the available resources and financial capacity. The pursuit of unrealistic goals can impede progress and lead to ineffective utilization of resources, ultimately hindering the successful implementation of irrigation and water resource plans.

4.2 Institutions and human resources capacity

A well-defined institutional framework includes establishing appropriate authorities, regulatory bodies, and water user associations to ensure efficient water allocation, infrastructure management, and conflict resolution. Following the introduction of the federal system in Nepal, the previously integrated structure of the entire irrigation

sector has become fragmented and has yet to stabilize. Considering the country's federal system of governance, there is a need to restructure the institutional framework to enable the implementation of irrigation and water resources development based on the principles of Integrated Water Resources Management (IWRM). Effective coordination and collaboration among different institutions involved in water resources management, agriculture, and infrastructure development are essential to ensure coherent and integrated approaches to irrigation and drainage services. The absence of an appropriate institutional framework and adequate capacity development for the Nepalese bureaucracy hampers the seamless planning and development of irrigation and water resources projects.

Building a skilled workforce with expertise in irrigation and drainage management is crucial. Strengthening the capacity of institutions involves providing training programs, technical assistance, and knowledge-sharing platforms to enhance the skills and knowledge of professionals working in these institutions. However, the professionals involved in irrigation sector have to take the burden of administrative works which impedes the development of expertise. Promoting knowledge exchange and sharing best practices among professionals, researchers, and practitioners in the irrigation sector is essential. This can be achieved through training programs, workshops, and partnerships with research institutions. Strengthening the capacity of farmers in adopting modern irrigation practices, water-efficient technologies, and sustainable farming techniques by providing training, extension services, and access to information can enhance farmers' ability to manage irrigation systems effectively.

4.3 Water availability

Nepal boasts a per capita water availability of over 7,000m^3, surpassing the global average. However, the actual per capita water consumption is only around 400-500m^3 annually, representing a mere 4-5% of the available water. The predominant use of freshwater in Nepal, accounting for over 95% of withdrawals, is for agricultural purposes. Despite the abundant water resources, their significance remains limited unless efficient and timely delivery to farmers' fields is ensured. The availability and seasonal variability of water are often cited as major constraints in providing irrigation services consistently throughout the year. Irrigation systems constructed along large to medium-sized rivers in the Terai plains face challenges due to reduced river flow, making it difficult to cover the potential command area. Likewise, the FMIS relying on small-sized streams are particularly affected by temporal variations in streamflow. Consequently, farmers often have to rely on rainfall to meet the water requirements for planting paddy crops, which constitute approximately 50% of total area of agricultural crops. Any delays or untimely onset of the monsoon can significantly impact crop production and, in turn, the national economy.

Conversely, during the monsoon season from June to September, Nepal experiences significant damage to irrigation infrastructure, ranging from small to large scales, throughout the country. This leads to substantial expenses for reconstruction and maintenance. Infrastructure damage is more severe in the FMIS located in the hills and mountains of Nepal due to factors such as high-gradient streams, fragile geology, and steep topography. In summary, the water availability in Nepal can be characterized as a paradox of "too little, too much." The water cycle is being disrupted by climate change impacts and haphazard development activities, leading to the drying of water sources. To address this challenge, there is an urgent need for the implementation of climate-resilient irrigation practices which include adopting strategies such as conjunctive use of surface and groundwater, inter-basin water transfer projects, multipurpose projects, reservoir systems, water-saving techniques, small storage ponds, and non-conventional irrigation projects.

4.4 Financing priorities

The financing priorities in Nepal's irrigation sector have undergone significant changes in recent years, with a shift towards modernizing and rehabilitating existing schemes to enhance their efficiency and performance. However, this has resulted in a drastic reduction in financing for irrigation overall. To promote growth in the sector, investments are needed in human resources capacity building, research and development, technology, infrastructure, and policy frameworks. Without adequate investment and financing mechanisms, even well-designed plans and programs may not be effectively implemented.

In the current budget allocation, the Ministry of Agriculture receives approximately 3.4% of the national annual budget for the year 2023/2024, while the Ministry of Energy, Water Resources, and Irrigation (MoEWRI) sector receives around 5%, with a dominant proportion going towards the energy sector. The trend of investment priorities in Nepal has favored physical infrastructure such as roads and bridges in recent years, considering the state of road networks in the country. However, there has been increased attention towards multipurpose projects on water resources and inter-basin water transfer projects which is also reflected in the recent draft of the Irrigation Master plan.

Despite the importance of irrigation, the budget allocated to the sector remains relatively small compared to the actual demand in the field. Moreover, there have been instances where projects and programs have failed to yield desired results despite substantial investments. Proper preparation, future assessment, and evaluation of investment effectiveness are crucial for the sustainability of programs and plans. The inadequate financing of the irrigation sector by the government and other agencies can be attributed to several factors, including the sector's low level of performance, uncertainties, and relatively lower output. Irrigation projects often exhibit lower economic rates of return and longer timeframes for returns compared to sectors such as hydropower and services.

Nepal's increasing imports have contributed to trade deficits, and while the government aims to reduce imports of food and other products, investment levels in irrigation, agriculture, and fertilizers have not been adequately aligned with this goal. Financing agriculture water needs requires robust water and agriculture policies that create an enabling environment for investment and ensure long-term sustainability. It is essential to ensure that the policy environment supports sustainable progress and does not generate future water challenges.

The Department of Water Resources and Irrigation (DWRI) should focus more on exploring various avenues for investment and financing. This necessitates high-level officials in the irrigation sector to contemplate innovative ideas that align with future trends and address existing challenges. International partners such as the Asian Development Bank (ADB), World Bank, Japan International Cooperation Agency (JICA), etc., should be engaged by gradually improving governance, policies, institutions, and human resources capacity. However, overreliance on these donor agencies may impede the country's self-sufficiency and independence in the long run.

5. Priority issues for modernization of I & D services

We can focus on issues that will support, enhance, and improve modern irrigation services to meet future challenges.

5.1 Enhancing MOM Practices

The foremost priority in irrigated agriculture is to enhance the efficiency of existing irrigation systems, thereby realizing the objective of achieving more crop yield with less water usage. In line with this priority issue, the Government has initiated various programs and projects. One such initiative is the launch of MOM guidelines, which aims to streamline and ensure consistency in MOM practices. Given that MOM practices involve multiple stakeholders, including policy makers, engineers, project managers, farmers, and Water Users' communities, it is essential to establish a robust coordination mechanism to facilitate effective MOM implementation. Efficiency, sustainability and return from irrigation development relies on how well the system is managed, operated, and maintained.

Recognizing the significance of both static and continuous data and information regarding irrigation systems for planning, operation, and performance evaluation, the Irrigation Management Division (IMD) of DWRI is currently developing a Nepal Irrigation Management Information System (NIMIS). The lack of proper and consistent database has impacted irrigation system management, planning and project and policy evaluation The NIMIS aims to centralize and manage the vast amount of data related to irrigation systems, facilitating improved decision-making, and enhancing the overall effectiveness of irrigation system management. In the longer run, it is aimed to provide real-time data and information on water availability, distribution, and usage, enabling better Decision Support System and efficient MOM practices.

Embracing technological advancements is imperative for the modernization of irrigation systems and the improvement of MOM practices. In this context, precise measurement of water flow and usage plays a vital role in effective water management. This can be achieved through the utilization of upgraded water measurement techniques, sensors, and other relevant tools.

The implementation of automated systems and the adoption of efficient irrigation practices contribute to the optimization of water distribution, minimization of losses, and enhancement of overall system performance. Additionally, efficient water accounting, auditing, automation, and digitalization are indispensable elements within MOM practices, ensuring optimal management and operation of irrigation systems. Farmers and communities can greatly benefit from the implementation of user-friendly and readily adoptable technologies, which facilitate effective management of irrigation systems. It is crucial to prioritize the involvement of communities and water users as key stakeholders when integrating these technologies into irrigation systems. By considering their perspectives and incorporating their needs, the successful implementation of technological solutions can be ensured, resulting in improved irrigation practices and enhanced outcomes for all stakeholders involved.

5.2 Securing Finance and International cooperation in Irrigation

The effective execution of plans, policies, and programs is contingent upon the availability of secure funding, among other contributing factors, as mentioned in preceding sections. Securing finance and international cooperation play a pivotal role in advancing Nepal's irrigation sector, alongside improved policies. Responsible investment is crucial for driving economic and agricultural development while ensuring sustainable water use and preserving environmental flows. In Nepal, funding for irrigation and drainage services relies on government allocations, donor support, and community contributions. The share of community contributions is decreasing every year and there is increasing dependency on the Government. However, to ensure the long-term viability of irrigation service improvements and water management initiatives, sustainable funding mechanisms and attracting investment are imperative. It is worth noting that securing international funding for these improvements incurs associated expenses. Ensuring quality of services and engaging farmers through MOM will contribute to increase the community contributions.

International cooperation and support hold significant importance in strengthening Nepal's irrigation sector. Several development partners including Asian Development Bank (ADB), World Bank, Kuwait Fund, International Development Association (IDA), Japan International Cooperation Agency (JICA), etc. have been actively involved in irrigation and water resources development of Nepal.

Collaborative efforts can encompass various areas, including knowledge exchange, capacity-building programs, and financial assistance. By engaging in knowledge sharing, Nepal can benefit from the experiences and best practices of other countries, enhancing its irrigation practices and management. Capacity-building programs can further empower local stakeholders, enabling them to effectively implement and sustain irrigation improvements. Additionally, financial assistance from international partners can contribute to the implementation of large-scale projects, infrastructure development, and technological advancements in the irrigation sector.

Regional cooperation is also vital for transboundary water management, sharing best practices, and resolving water-related conflicts. By fostering collaboration with neighboring countries and regional organizations, Nepal can address shared challenges and develop mutually beneficial solutions. This cooperation can facilitate the exchange of expertise, promote efficient water resource utilization, and establish mechanisms for resolving potential conflicts over water usage. By actively engaging in regional cooperation, Nepal can strengthen its irrigation sector and contribute to sustainable water management efforts in the broader context.

5.3 Research and development, capacity building and collaboration

Promoting collaboration among multiple institutions, academia, industry, and international organizations is crucial in the realms of research and development, capacity building, and knowledge transfer within the irrigation sector. By fostering collaboration, there is an opportunity to enhance capacity building efforts, facilitate technology transfer, and foster knowledge sharing among stakeholders. Emphasizing research in the irrigation sector becomes paramount to drive innovation, address existing challenges, and explore new avenues for sustainable water management and agricultural practices. Moreover, investing in capacity building programs for engineers, managers, and policymakers would ensure a skilled workforce capable of implementing effective irrigation strategies. Additionally, integrating Indigenous Knowledge with modern technology presents a unique opportunity to blend traditional wisdom with contemporary advancements, harnessing the best of both worlds to achieve optimal results in irrigation practices and water management.

The adverse effects of climate change and unregulated development activities are disrupting the natural water cycle, leading to the depletion of water sources. This situation highlights the urgent need for climate-resilient irrigation systems in countries like Nepal, which are highly vulnerable to the impacts of climate change. By incorporating climate resilience into irrigation practices, strategies can be developed to mitigate the risks associated with changing climatic conditions. This includes implementing measures such as efficient water storage and distribution systems, water conservation techniques, and adaptive irrigation management approaches. By prioritizing climate-resilient irrigation, Nepal can ensure the sustainability of its water resources, enhance agricultural productivity, and safeguard against the challenges posed by an increasingly uncertain climate.

DWRI is actively engaged in the implementation of various projects aimed at addressing the challenges posed by climate uncertainty. These include inter-basin water transfer projects, integrated Dang valley irrigation projects, initiatives focusing on the conjunctive use of groundwater in the Terai region, and projects centered on the management of the Rupa Lake watershed, among others. These projects, either directly or indirectly, contribute to mitigating the risks associated with climate uncertainty. By improving water availability, enhancing irrigation infrastructure, and promoting sustainable water management practices, DWRI's efforts help to build resilience and adaptability in the face of climate change.

5.4 Institutional and policy reforms

To effectively address the changing socio-economic and demographic dynamics, new system of governance, global trends, and country-specific needs, it is imperative that policies and institutional frameworks are updated accordingly. In the present context, the Water Resource Strategy of 2002 and the Water Resource Plan of 2005 here is a need to evaluate the progress and achievements of the targets set by these policy documents to gauge their effectiveness and identify areas for improvement. Where these have become outdated and no longer fully applicable the policy documents need to be revisited and updated to align with the current system of governance, institutional structure, and evolving water resource management practices. At the same time, the draft IMP, 2019 needs to be revisited and finalized as quickly as possible.

The process of policy formulation should shift away from isolated decision-making and instead embrace a more inclusive approach that involves diverse stakeholders. Nepal is currently in the process of drafting a new irrigation policy, alongside the review of a new Irrigation Master plan. These policy documents will play a crucial role in guiding Nepal's future approach to irrigation development and management. It is essential to subject these policies to critical analysis, which should involve a thorough examination of past policies, consideration of global trends, evaluation of achievements, and extensive stakeholder dialogue. Importantly, the needs and perspectives of farmers and communities must be given due importance throughout this process. By incorporating a wide range of perspectives and engaging stakeholders at various levels, the resulting policies and institutional frameworks can better serve the dynamic challenges and opportunities of the present context.

The existing Irrigation Master Plan of 1990, which guided the irrigation sector policy and programs for the past three decades, was formulated under different circumstances when competition for water use was limited and the socio-economic structure was distinct. The development of new policies, such as the IMP, 2019 and the upcoming Irrigation Policy, should take into account various factors to address the changing future scenario. Effective policies must prioritize collaboration and coordination among the three tiers of government, sustainable irrigation practices, incorporate climate resilience, enhance water-use efficiency, encourage modernization and technological advancements, and promote water-saving practices. These efforts can contribute to not only address immediate challenges but also facilitate long-term sustainability and resilience in the irrigation sector.

6. Conclusions

6.1 Future modernization plans

Embracing modernization pathways is imperative for ensuring the sustainability, self-sufficiency, and competitiveness of Nepal's irrigation sector. There are no viable alternatives when it comes to transforming the sector to meet the evolving needs and challenges of the present times.
The modernization pathways to be pursued in Nepal's irrigation sector will be influenced by global trends in irrigation and agriculture, projected socio-economic landscapes, climate change impacts, institutional capacity, and other pertinent factors. It is essential to consider these factors to determine the most suitable approaches for modernizing irrigation practices to meet the evolving needs and challenges of the sector.

Demand Side Management:

Efficient water management practices will be emphasized, focusing on optimizing water use and reducing wastage through techniques like precision irrigation, water-efficient technologies, and improved irrigation scheduling. Encouraging farmers to adopt water-saving practices and promoting water-efficient crops will also be crucial. The MOM guideline and its implementation arrangement will also be a strong tool to managing the demand.

Upgrading and Modernizing Infrastructure:

Existing irrigation infrastructure will be upgraded and modernized to enhance its efficiency, performance, and capacity. This may involve strengthening the intake structure especially in FMIS systems, rehabilitating irrigation canals, improving water storage facilities, upgrading pumping systems, and adopting smart irrigation technologies for better water distribution and control.

Climate Change Adaptation and Disaster Risk Reduction:

Given the increasing vulnerability to climate change impacts, future modernization plans will prioritize incorporating climate change adaptation and disaster risk reduction measures in irrigation systems and agricultural practices. This may include designing infrastructure to withstand extreme weather events, implementing early warning systems, crop insurances, promoting resilient agricultural practices, water-storage, and groundwater recharge among others.

Database Management and Analysis:

Effective database management and analysis will be essential for informed decision-making and evidence-based planning. Future modernization plans will emphasize developing robust data collection systems, establishing comprehensive databases on water resources and irrigation, and utilizing data analytics for efficient resource allocation and monitoring. Digitization of existing inventories, preparation of asset management plan in online platform, monitoring of system performance and information dissemination through the centralize control room will be the immediate future prospect to be carried out by the irrigation institution in Nepal.

Appropriate Technological Interventions:

Integrating appropriate technological interventions will play a key role in future modernization efforts. This may involve deploying remote sensing and satellite technologies for accurate monitoring of water resources, using automated irrigation systems, and adopting advanced agricultural practices like precision farming and hydroponics.

International and National Collaboration:

Collaboration with international partners, organizations, and donors will be crucial for accessing technical expertise, financial resources, and knowledge exchange. Strengthening partnerships with entities like the Asian Development Bank, World Bank, and other relevant institutions will support the implementation of modernization plans and ensure sustainable development in the irrigation sector.

Capacity Development:

Enhancing the capacity of stakeholders involved in irrigation management will be a priority. This includes providing training programs, workshops, and technical assistance to farmers, irrigation professionals, and policymakers. Building institutional capacity for effective governance, management, and maintenance of irrigation systems will also be essential.

Inclusive Irrigation Management and GESI Issues:

Future modernization plans will prioritize inclusive irrigation management, addressing gender, equity, and social inclusion (GESI) issues. Ensuring equal access to irrigation resources, promoting women's participation in decision-making processes, and addressing social disparities will be integral to achieve sustainable and equitable irrigation development.

By incorporating these elements into future modernization plans, Nepal can pave the way for a sustainable, resilient, and efficient irrigation sector that contributes to agricultural productivity, food security, and rural livelihood improvement.

In conclusion, the analysis of the national irrigation and drainage services in Nepal highlights several key areas that require attention and modernization. To address the challenges and enhance the efficiency and effectiveness of irrigation development, the following recommendations are proposed:

- Reforms in water-related policies, institutions, and governance structures are necessary to create an enabling environment for modernization in irrigation. This includes reviewing and updating water sector policies, strengthening institutional frameworks, and promoting transparent and participatory decision-making processes. Additionally, fostering coordination and cooperation among government agencies, local communities, and stakeholders will support integrated water resources management and sustainable irrigation development.
- There is a critical need to improve the operation, maintenance, and management practices in the irrigation sector. This involves establishing proper monitoring systems, regular maintenance schedules, and effective water allocation mechanisms. Strengthening the capacity of irrigation institutions and providing training to irrigation staff will be essential to ensure efficient and sustainable irrigation service delivery.
- To overcome the shrinking financing and investment opportunities in the irrigation sector, it is crucial to explore diverse funding sources and establish partnerships with international organizations and donor agencies. Collaborating with entities such as the Asian Development Bank, World Bank, and other relevant nations and institutions will help leverage financial resources and technical expertise to support irrigation modernization efforts.
- Investing in research and development activities specific to the irrigation sector will foster innovation, technological advancements, and knowledge transfer. Emphasizing capacity building programs for farmers, irrigation professionals, and policymakers will enhance their skills and understanding of modern irrigation practices.

Based on these recommendations, future modernization plans should prioritize the improvement of operation, maintenance, and management practices; secure financing and international cooperation; invest in research and development; capacity building; knowledge transfer; increase collaboration; and implement institutional and policy reforms. By addressing these priority areas, Nepal can achieve sustainable and efficient irrigation services that contribute to agricultural productivity, water resource management, and overall socio-economic development.

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COUNTRY REPORT ON PATHWAYS AND TECHNOLOGIES FOR MODERN IRRIGATION SERVICES IN NIGERIA[1]

1. Introduction

Irrigation practice by the larger irrigators in Nigeria is just a few miles away from the rudimentary systems and in dire need of modernization. For example, the manual bucket or shaduff irrigation method may no longer be a common practice in Nigeria, but surface irrigation system where water is lifted or diverted from source and allowed to run by gravity over the earth surface for some considerable distance to where it is applied is very commonly practiced. In this process, much water is lost in conveyance and much energy or time is dispensed to convey water. Moreover, the farmers, though very passionate and committed to irrigated agriculture, as it is their lifeline in many instances, are in the quagmire of operating with aged, inadequate, and deteriorating infrastructure amidst low technical capacity and low crop water productivity.

Modernization of irrigation and drainage is considered as a "process of upgrading infrastructure, operations and management of irrigation systems to sustain the water delivery service requirements of farmers and optimize production and water productivity"[2] Modernization in this context, focuses more on the farmer than infrastructure development and repairs. It gives priority to the needs of farmers vis-à-vis technical and managerial upgrading of irrigation systems combined with institutional reforms, with the objective to improve resource utilization. Irrigation resources in this context consider labour, water, socioeconomic and the ecosystem as assets which should be maximized to provide improved water delivery service to farms.

Irrigation systems are also seen to include stakeholders' participation (beside physical infrastructure), to holistically improve the system for all the beneficiaries. Modernizing irrigation therefore will require that all aspects of irrigation and drainage services from reservoir and canal operation to farm management are considered from planning to operational stages. This makes it a holistic assessment that will entail improvement of resource mobilization, use of water saving techniques, upgraded management practices, policies, institutional and financing mechanisms, with a resultant effect in agricultural, social, environmental, and economic benefits for both farmers and the wider community of water users.

This paper elucidates pathways and technologies to achieving such modernization of irrigation in the Nigeria context. The paper attempt to:

(a) review the history of irrigation and drainage services in Nigeria;

(b) assess the modernization and revitalization requirements;

(c) trace some factors affecting irrigation and drainage services; and

(d) prioritize issues for modernization of irrigation and drainage services in the country.

2.0 Overview of National Irrigation and Drainage Development and Management

The history of irrigation development and practice in Nigeria has been traced by Yahaya (2002) to the years where farmers manually drew water from shallow wells and rivers along the flood plains to wet their cropped field during the dry season. According to Olubode-Awosola and Idowu (2004), modern and formal irrigation began to gain prominence in Nigeria after the 1973-1975 droughts, especially in the northern part of Nigeria. In response to that drought, the State and Federal government began the development of dams and irrigation schemes. The outcomes were the development of schemes like the Bakolori Dam, Tiga Dam, Challawa Dam, Goronyo Dam, the Bakolori Irrigation Scheme, Middle Rima Irrigation Scheme, and Kano River Irrigation Scheme, just to mention a few.

The advancement of formal irrigation practices in Nigeria was facilitated by the creation of the two River Basin Development Authorities (RBDA) in 1973 and nine additional ones in 1976, with the following information as detailed in the table below:

[1] Nigeria National Committee on Irrigation and Drainage (Nincid)

[2] Source: https://www.icid.org/prsnt_iif_2016_ian_makin.pdf: Approaches to improving irrigation performance and water use

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S/N	RBDA	Year of creation	Area of the basin (KM^2)	Currecnt irrigation cropped area (HA)	Source of water
1	Upper Niger RBDA	1976	154,600	4,488.5	Dam
2	Lower Niger RBDA	1994		1,593	Dam
3	Upper Benue RBDA	1976	156,500	9,687	Dam
4	Lower Benue RBDA	1976	74,500	6,097	Dam
5	Chad BDA	1973	178,500	365	Dam
6	Hadejia Jama'are RBDA	1976		16,288	Dam
7	Benin-Owena RBDA	1976	99,900	245	Dam
8	Ogun Oshun RBDA	1976		1,662	Dam
9	Sokoto Rima RBDA	1973	135,100	12,593	Dam
10	Cross River BDA	1976	57,400	317	River/Under ground Water
11	Niger Delta RBDA	1976	53,900	549	River/Under ground Water
12	Anambra-Imo RBDA	1976		4,939.5	Dam

Source: Compendium of irrigation in Nigeria by Federal Ministry of Water Resources, 2020

Note: The current irrigation cropped area comprises of both the public and private irrigation schemes (public consists of schemes owned and managed by both Federal and State Governments)

The RBDAs have the mandate to carry out development of irrigation infrastructures in their respective agro-ecological zones, to promote irrigated agriculture in order to achieve food security, socio-economic and rural development. The RBDAs have been leading the frontier of development of irrigation infrastructures and expansion of irrigatable lands in Nigeria, with very significant progress despite limited economy and other anthropogenic and social challenges. Some of the recent laudable achievements of some of the RBDA include the establishment of integrated agricultural system (mixed farming) Songhai Farms Initiative in most of the RBDA where most of the arable and horticultural crops cultivated in the farm are under micro- irrigation system and are integrated with livestock, poultry, fishery. piggery, and biogas generation. Some of the RBDAs like the Benin-Owena has installed 20 ha drip irrigation system and another 1,280 ha Centre Pivot Sprinkler irrigation scheme in Obayantor, Benin City (as Demonstration Farms to showcase zero waste Songhai Farms in Porto Novo in Republic of Benin).

Generally, Nigeria's RBDAs have made some impact in irrigation development, agricultural support, rural electrification, water resource management, environmental conservation, and socio-economic impact. Their activities have increased agricultural output, brought power to rural areas, reduced flood hazards, protected natural ecosystems, and contributed to poverty reduction and overall socioeconomic development. However, continual improvements in governance, stakeholders' participation, and climate change adaptation are still required for sustainable water resource management.

Irrigation development and practices in Nigeria has also been boosted by the massive development of the floodplains and low/wetlands which are spread across the country under the World bank funded National Fadama (flood plain) Development Programmes (I, II & III) between the 1992 and 2019. Through the activities of the Agricultural Development Programmes (ADPs) in all the Federated Units (States and Local Government Areas), about 600,000 hectares of lowlands, valley bottoms, floodplains are being cultivated annually during the dry season (between October and May) across the country.

2.1 Irrigation and Drainage Resources in Nigeria

A compendium of irrigation resources of Nigeria compiled by the Department of Irrigation and Drainage (DI&D) of Federal Ministry of Water Resource (FWMR, 2018) shows that there are over 300 irrigation schemes across the six (6) geo-political zones of Nigeria, some of which are yet to be harnessed for irrigation. An analysis of the

status of the schemes indicates that about 44 % of these schemes are relatively completed, 40.6% are undergoing development, 12% have been abandoned, and 3.4 % are undefined. Furthermore, 76% of the 323 schemes are owned by the Federal and State Governments, thus classified as public irrigation schemes. 13% are owned by cooperatives, 4% are privately owned, while the remaining 7% have different combinations of owners. Most of these schemes are surface irrigation-based and where the water sources are at higher elevations with respect to the irrigation fields, water flows by gravity through natural or constructed canals to deliver water to the fields. Where the irrigated fields are at higher elevation, water is either lifted using fossil-fuel powered pumps of various power rating to irrigate fields. These infrastructures are assets for Nigeria to grow more food and cash crops under irrigation to feed the growing population. The current status of these facilities could provide vast opportunities for further development and modernization of the irrigation and drainage sector.

2.2 Challenges Facing Irrigation and Drainage in Nigeria

The National Irrigation Policy and Strategy (2015) document prepared by the Federal Ministry of Water Resources (FMWR) with the technical support of the Food and Agriculture Organization (FAO) chronicled the challenges facing irrigation and drainage in Nigeria. The document admits the following with respect to the condition of operation and maintenance in irrigation schemes:

(a) The RBDAs and States oversee operation and management of public irrigation, while a part of farmer groups, especially the Water Users Associations in the scheme has been supporting the maintenance of irrigation facilities.

(b) The irrigation infrastructures are dilapidated in most of the irrigation schemes with many pumps in need of repair/replacement and conveyance structures damaged or deteriorated, weed infested and silted up.

(c) Reasons adduced for the increasing deterioration of the schemes include inadequate management capacity, the surface system of irrigation largely practiced which is predominantly gravity-based with very low irrigation efficiency, and the systems operating at low level capacity and low cropping intensities; failures of irrigation pumps due to lack of maintenance leading to breakdown, absence of spare parts at local level; repair/replacement of pumps and high cost of fossil fuel to run these pumps;

(d) Where sprinklers irrigations were installed, farmers were not able to adapt to the use of the system.

(e) Inadequate water delivery to secondary and tertiary canals because water is carried through the cross regulators and the manual sluice gate type. Lack of records of actual flows into the fields because the measuring gauges to determine water depth for measurement are missing or unreadable where they exist.

(f) The Water Users Associations (WUAs) rarely exist in most of the schemes, and where they do, they are neither effective nor active.

(g) The perception of farmers is that the water charge paid should cover the maintenance, thus farmer's motivation to participate or collaborate is low in the maintenance work on scheme.

(h) Recovery of costs are low because the charges are meager. The inadequate pricing is responsible for the cycle of poor services leading to lack of willingness to pay by the user.

(i) In schemes where water is lifted and pumped to the field, most of the irrigation pumps purchased in the 1980s are now obsolete and spare parts no longer available.

(j) Most field production equipment and machinery such as tractors, combined rice harvesters, and rice mills are not being operated due to low maintenance.

(k) There are very few maintenance personnel working on schemes. Repair workshops at all RBDAs were run down, and poorly equipped and staffed. Spare parts were rarely stocked, and records not kept.

Others include:

(a) Policy deficit

(b) Infrastructural deficit

(c) Human resources capacity

(d) Insecurity

(e) Socio-cultural inhibitions

Although these challenges were highlighted almost a decade ago and efforts are being made to address them by relevant stakeholders, the challenges remain daunting. A paradigm shift toward holistic modernization of these irrigation systems may help to accelerate the outputs of measures being taken to address these challenges.

2.3 *Recent efforts in Improving Irrigation Infrastructure in Nigeria: Intervention through Transforming Irrigation Management in Nigeria (TRIMING) Project*

Nigeria is endowed with substantial irrigation potentials. Unfortunately, after 40 years of formal irrigation practice, the area equipped with irrigation infrastructure was less than 300,000 hectares in 2012. However, tremendous effort is being made to change the narrative.

The Federal Ministry of Water Resources (FMWR) formulated *a roadmap for irrigation and drainage development tagged "National Irrigation Programme (2016 – 2030)"*. In this roadmap, plans have been made to develop about 500,000 ha and create an enabling environment for private sector and state governments to develop an additional 1,000,000 ha of irrigation land and associated infrastructure by 2030. An analysis of the report of the achievements of Federal Ministry of Water Resources between 2016 and 2022 shows that the Ministry has completed the development and rehabilitation of a total of 6,784 ha irrigation projects in Sabke, Shagari, Sepeteri, and Ejule-Ojebe, Middle Rima and Gari Irrigation Projects; drained and reclaimed a total of 480 ha of land in Manu Akwa and Obinda communities, supplied and installed 1000 tube wells in selected RBDAs, and supply and installed Centre Pivot Irrigation System over 2880 ha in selected RBDAs.

Between 2014 and 2022, irrigation and drainage practices in Nigeria received a big boost with the joint World Bank and Federal Government of Nigeria funded *Transforming Irrigation Management in Nigeria (TRIMING) Project.* The TRIMING Project activities were in two hydrological Areas (HA1 and HA 8 which are the Niger North and the Chad Basin as pilot schemes. The Project has four components dealing with (i) dams, (ii) Irrigation, (iii) agricultural input/value chain, and (iv) institutional reforms.

This project has continued to positively advance modernization of irrigation in Nigeria. With respect to modernizing irrigation and drainage infrastructure, the TRIMING Project has completed the rehabilitation irrigation canals in 7105 ha of Bakolori Irrigation Scheme (BIS), 14,444 ha of Kano River Irrigation Scheme (KRIS) and 5,759 ha of Hadejia Valley Irrigation Scheme (HVIS). While the Department of Irrigation and Drainage equally completed and handed over Gari Irrigation Project at Kano and Jigawa States to farmers, totaling 1,930ha in April, 2023. The Project has also cleared aquatic weeds, dredged and reshaped river channels for a total 95.7 km along different riverbanks amongst which are Burum Gana River, Gasowa channels, old Hadejia River, Kafin Hausa River. These were done to mitigate flooding of irrigation schemes and allow water to flow downstream of the river course. Flood prevention dykes were built at Marke, Alluwari, Gishinawo and Saleri in Hadejia-Jama'are River Basin.

The TRIMING Project also procured and installed 36 units of Automatic Hydrological equipment for monitoring river flows in selected hydrological areas of Nigeria to facilitate irrigation and drainage development, 13 units of Meteorological stations with 6 units of receiver stations installed in the Hydrological Areas for weather data collection. Dam safety remedial works were carried out in the dams in Zobe, Bakolori, Tiga, Challawa, Ruwan-Kanya, and Goronyo. River Training Works were carried out in Rima and Keta communities and flood protection dyke were built in Falalia and Takakumi Sectors of Middle Rima River Valley Irrigation Project (MRVIS).

Beside physical infrastructures, the TRIMING Project has carried out capacity development activities in different aspects of irrigation and drainage development in Nigeria. Among stakeholders who have been trained both within and outside the country include farmers, organized farmer groups, group and community leaders, extension agents, staff of the RBDA, FMWR, Federal Ministry of Agriculture and Rural Development (FMARD) along with other related line Ministries. According to the Project self-appraisal in 2022, a total of about 903,535 direct project beneficiaries (DPB) have been reached through development and or rehabilitation of about 27,299ha across all schemes. About 47% of the DPBs are females. About 46,000 farmers have been trained in scheme operation and maintenance (O & M) in BIS & MRVIS. A further 52,000 farmers have been trained in O & M in KRIS & HVIS. The training covers all key areas of O & M in about 30 training modules.

Furthermore, the Department of Irrigation and Drainage in collaboration with the RBDAs organized training workshops for Women/Gender Participation in WUAs towards maintaining acceptable water quality and hygiene for irrigated agriculture held at Gari, Kano River, Hadejia Valley and Middle Ogun Irrigation Schemes in year 2022. At Gari Irrigation Scheme 182 beneficiaries' farmers participated, while at Kano River, Hadejia Valley and Middle Ogun Irrigation Schemes, participation was 131, 100, and 142 respectively. The training created awareness on the need to maintain good quality of water bodies as well as environmental preservation and hygiene to prevent contamination of crops being cultivated in irrigated agriculture.

In addition to the above, FMWR is working on the establishment of the Nigerian Standards for Irrigation Water Quality. The collaborating Departments are Irrigation & Drainage and Water Quality Control & Sanitation of the Federal Ministry of Water Resources in conjunction with the Standards Organization of Nigeria (SON).

Drafts of the document have been worked on by relevant Committees and professional bodies. Currently, the document is being processed by the Standards Organization of Nigeria (SON) and thereafter it shall be presented in the stakeholders' meeting involving representatives of the 36 States (sub-nationals) of the Country including Federal Capital Territory for their final input before completion of the Standards processes and subsequent implementation of the approved Standard.

3.0 Assessment of modernization and revitalization requirements

Irrigation in Nigeria has been faced with underdeveloped infrastructure, low technical capacity, poor management on the part of the system managers and system users, corruption and deliberate abuse of infrastructures, inconsistent and unstable policies, and inappropriate legal framework over the years under different administrations. The success of an irrigation scheme, apart from the provision of irrigation infrastructures, very much depends on the technical knowledge of the operators, the technical capacity and socio behavior of the systems users, the resources for O&M of the irrigation infrastructures, and the willingness to take responsibility for sustainability of the system. These were assumed to be government responsibility in time past, and government agencies who were engrossed with the tasks recorded very little success.

Modernization and revitalization of irrigation in Nigeria will require the creation of enabling environment in form of policy framework, facilitation of availability of appropriate technology, and enhancing farmers' awareness and their inclusion in the decision-making process have been identified as key to enhancing irrigation development in Nigeria (Adelodun and Choi, 2018). These issues have been captured in National Water Resource Master Plan, the Irrigation and Drainage Policy and Strategy, National Irrigation Programme 2016-2030, and other policy documents, and are now being addressed by relevant agencies, especially in the Federal Ministry of Water Resources. There is an on-going effort to form, strengthen and train Water Users Associations for active irrigation schemes across the country.

The Irrigation and Drainage Department of FMWR in collaboration with the Nigeria National Committee on Irrigation and Drainage (NINCID) and the RBDA, in the last three years, have sustained the drive to establish Water Users Associations (WUA) and strengthen existing ones in all federal-managed irrigation schemes. They have organized workshops, field visits, hands-on field demonstrations on field water management, operations and maintenance of irrigation infrastructures, and innovative technologies for irrigation water management. The WUA are being legally mandated to maintain the irrigation infrastructures in their respective scheme at secondary and tertiary levels.

Implementing modern technologies and sustainable practices will be essential for the successful expansion of irrigation coverage in the country. Adoption of the practice of water efficient irrigation systems like sprinkler and drip irrigation should become prominent in irrigation schemes in Nigeria.

Improved water management methods, such as equitable distribution, efficient price systems, and effective water rights, are also necessary for long-term water use. Water conservation and the implementation of efficient storage and management measures will contribute to the long-term sustainability of Nigeria's water resources and irrigation development.

There is also the National Water Resources Bill, which seeks to promote the efficient management and utilization of the country's water resources. Unfortunately, this bill has continued to suffer setbacks in the passage by the national parliament; possibly due to mistrust by the political class and inadequate advocacy by the populace.

The National Water Resources Master Plan (2013) (NWRMP) is a comprehensive plan for the development and management of Nigeria's water resources, including irrigation. The purpose and objective of irrigation as stated in the document is as follows:

(i) Increase agricultural productivity in Nigeria by expanding the area of land under irrigation by taken into account water policies in the National Long-Term Plan of 1992.

(ii) Promote food security in Nigeria by enhancing access to water for irrigation; leading to increased crop production, reduction of crop losses due to water shortages, and stabilization food prices.

(iii) Enhance rural development in Nigeria by improving access to water for irrigation, provision of employment opportunities for rural communities, increase income levels, and promote economic growth in rural areas.

(iv) Improve water use efficiency in irrigation by promoting the use of irrigation techniques, with reduced water wastage.

(v) Promote sustainable agriculture in Nigeria by encouraging the adoption of environmentally friendly agricultural practices by providing a reliable source of water for crops.

Although these policies and strategies are well crafted, what remains a challenge is the implementation to the letters of the document. Lack of political will, unwholesome meddlesome interlopers, and political differences between interest groups at federal and state levels may frustrate the implementation of well-intended policy.

4.0 Priority issues for modernization of I&D services:

In Nigeria, the priority issues for modernization of irrigation and drainage are well captured in the NIDPS (2015). The National Irrigation and Drainage Policy and Strategy seeks to institutionalize Integrated Water Resource Management (IWRM) by coordinating the management of water, land and other resources for irrigation and drainage. This is aimed at increasing agricultural productivity, improving food security, and promoting sustainable use of water resources. The policy was designed to address the following key areas: low agricultural productivity, low income and return from investment; low capacity for regulation, coordination, operation and provision of support services; low inclusiveness of users of land and water resources; inappropriate funding mechanism and low private sector participation; low capacity for research and development, low accessibility to improved technologies to support irrigation development and sustain growth; and low capacity for data generation and information, management and use.

The strategy thrusts were clustered to address the primary purpose of the policy for improving performance of irrigation services. This includes closing production gaps in irrigation and drainage development by rehabilitating the existing public schemes, effecting a transition from public funded schemes to commercially viable irrigation; combining all public sector irrigation under accountable community-centred corporate service providers; transforming RBDAs to River Basin Organizations; enhanced enabling environment by introduction of progressive enabling legislation on land and water; in collaboration with FMARD, upgrade of research and service facilities to provide high quality advisory services to farmers (FAO, 2015).

Other issues of priority include:

(i) Human capacity development; by investing in training, education, and skill development, Nigeria can build a competent and knowledgeable workforce for the irrigation sector. Developing technical expertise and empowering farmers, engineers, and irrigation practitioners will enhance the efficient operation, maintenance, and management of irrigation systems.

(ii) availability of efficient (water saving) irrigation tools; efficient irrigation tools offer a solution to irrigation challenges. These tools, designed for water-saving purposes, optimize water usage, reduce wastage, and increase overall irrigation efficiency.

(iii) Energy-saving means of lifting water for irrigation provide a solution to irrigation challenges. Utilizing energy-efficient technologies, such as solar-powered pumps or gravity-fed systems, reduces the energy consumption associated with water lifting.

(iv) Smart agricultural practices. These practices leverage technology, data, and precision farming techniques to optimize water usage, enhance irrigation efficiency, and improve overall agricultural productivity. By adopting smart agricultural practices, such as sensor-based irrigation, remote monitoring, and data-driven decision-making, Nigeria can address water scarcity, reduce water wastage, and promote sustainable irrigation systems.

(v) Research in irrigation is received very little attention in Nigeria. To advance the frontiers of irrigation in Nigeria, fit-for-purpose research options should be given top priority, these research outcomes from the various research institutes and universities, could make irrigation deliver optimally to ensure food security for our growing population.

5.0 Conclusions and Recommendations

The irrigation system in Nigeria faces significant challenges as described in this paper, including insufficient infrastructure, inadequate human capacity, and socio-cultural inhibitions. These obstacles hinder the optimal utilization of water resources and limit agricultural productivity. However, potential solutions exist to overcome these challenges. By investing in the expansion and modernization of irrigation infrastructure, promoting human capacity development, addressing socio-cultural inhibitions, and adopting efficient irrigation tools and practices, Nigeria can transform its irrigation system. This transformation would lead to increased agricultural productivity, improved water management, and enhanced rural development. It is imperative to prioritize these actions and work towards a sustainable and efficient irrigation system to ensure food security, economic growth, and improved livelihoods in the country.

6 Future modernization plans

Emphasis will be on the following:

(a) Good governance, capacity building for effective and efficient resources utilization, to enhance services and improve viability. It will entail:

(i) assessing and identifying the present capacity gaps in the different irrigation schemes and develop plans for capacity development activities;

(ii) developing service-oriented public institutions to respond more efficiently to the needs of irrigation sub-sector and developing improved employment packages for critical mass of staff in irrigation agencies.

(iii) Promote closer collaboration among all stakeholders (most especially the Federal Government, State Governments, Local Government Authorities and Communities) in discharging their mandates to support irrigation Subsector as well as streamline institutions for irrigation development and practices.

(iv) Provide capacity for cost-effective, demand-driven irrigation support services.

(v) Developing the required human resource capacities especially of vulnerable groups (Women, aged and youths, physically challenged).

(b) Responsive funding mechanisms based on effective stakeholder participation and rapid irrigation growth. This may involve the following:

(i) Develop incentive mechanisms and technical capacity that would encourage host communities, Local and State Governments to pool resources to establish irrigation systems and participate in their effective management.

(ii) Lease projects with only dams and headworks in place to private investors with a clear win-win financial and economic plan to complete the irrigation infrastructure and put the scheme into use.

(iii) Promote greater and harmonious engagement among the diverse MDAs with mandate on irrigation and drainage to pool resources, eliminate duplication and wastages.

(iv) Solicit support for increased budgetary allocation for the development, operation, maintenance, and management (OMM) of public irrigation.

(c) Improve collaboration for generation of, accessibility to, and uptake of research findings and innovations

(i) Promote in-field water management tools and techniques that minimize water application losses and increase irrigation efficiency using farmers participatory field demonstrations.

(ii) Conduct on-farm training events for water users on techniques and tools for effective water management at secondary and tertiary levels in irrigation schemes.

(iii) Develop training manuals on improved water management techniques and train irrigation supervisors as trainers of farmers.

(iv) Mobilize and train cadres of young farmers on modern irrigation techniques to serve as vanguard of effective water management in irrigation schemes.

(v) Convene, annually, national stakeholder consultation with research institutions, and donor agencies to review progress in modernization and to chart ways forward in sustainable agricultural water management in Nigeria.

Recommendations

The future plans should be diligently pursued and executed by the Irrigation and Drainage Department of the Federal Ministry of Water Resource to effect modernization and revitalization irrigation and drainage in Nigeria.

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INTERNATIONAL SYMPOSIUM ON THEME: PATHWAYS AND TECHNOLOGIES FOR MODERN IRRIGATION SERVICES

"Irrigation Solution" Approach Promoted by The Sahel Irrigation Initiative Regional Support Project (SIIP): One of The Keys to Improve Investments in Irrigation in The Sahel and West Africa

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1.0 Introduction

Agricultural water management is increasingly crucial for improved agricultural performance despite erratic rainfalls. West African particularly Sahel countries (Burkina Faso, Chad, Mali, Mauritiana, Niger, Senegal) enjoy relatively abundant water resources. Current agricultural withdrawals for irrigation represent less than 6% of total renewable water resources, and groundwater withdrawals are estimated to be about 6% of total annual recharge. Further, irrigated lands represent less than 5 percent of agricultural lands in the Sahel. The availability of vast tracks of land suitable for agriculture along the major perennial rivers, in inland valley and oued / wadi areas as well as the presence of shallow groundwater in large parts of the Sahel are additional opportunities for the Sahel. Moreover, the Sahel benefits from favorable ecological conditions for the production of high-yielding rice varieties and vegetables. Such agricultural products are in high demand on increasingly interconnected subregional markets and can help sustain the creation of well-paying jobs and livelihoods.

In these Sahel countries, there is a wide range of irrigation investment opportunities ranging from low-cost individual equipment to large-scale public developments with a variety of medium-sized community irrigation systems or district irrigation systems, private sector between these two extremes. Previous studies have demonstrated the productivity, profitability, and livelihood impacts of each of these different types of irrigation systems in the Sahel. But these studies also point to challenges that can be addressed using lessons learned from analyzing the successful execution of current and past investments in a holistic approach.

We need a new approach based on key transformative measures to unlock the potential of irrigation.

This holistic approach called "irrigation solution" is proven in the field with the realization of sustainable investments models. "Irrigation solution" approach is iterative. It capitalizes on existing methods and best practices. It is reviewed and improved during the implementation of investments according to lessons learned and other experiences and reinjects innovations and practical solutions according to problems identified. This process should lead to a range of "irrigation solutions" adapted to the different types of irrigation systems, to improve current and future investments. The ambition is to create a ripple effect and scale up in the Sahel and West Africa.

2.0 Overview of National irrigation and drainage services

Irrigation infrastructures in West Africa, particularly in the Sahel (Burkina Faso, Chad, Mali, Mauritiana, Niger, Senegal), are usually very costly and the performance is often low, as demonstrated by the fact that only around 60 percent of the land area equipped for irrigation is actually irrigated. Across the Sahel, crop yields in irrigation schemes remain below potential, a significant number of systems (particularly of type 4) are gradually abandoned due to lack of maintenance by farmers or irrigation agencies. This is explained by both "direct" and "meta" factors. Direct factors include: (a) insufficient engagement of local populations in decision-making processes; (b) inadequate consideration of commercial viability; (c) errors in technical design; (d) poor construction quality; (e) absence of a transparent irrigated land allocation process; (f) limited access to finance; (g) unclear responsibilities for scheme operation and maintenance (O&M); and (h) poor coordination between stakeholders. Meta-factors refer to the fact that, even when some guidelines or best practices to lead to quality infrastructure exist, they are often known by a limited number of practitioners; and efforts to apply them in practice are not sustained; lessons are rarely drawn from failures and turned into actionable, effective, replicable methodologies and solutions that can be applied at scale. Similarly, capitalization and dissemination of successes remains the exception.

3.0 Assessment of modernization and revitalization requirements

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Addressing these constraints requires, first, political momentum for reform to allow the necessary institutional changes to take place, and second, the capacity for scaling up interventions to improve economic efficiency across the value chains. The 'Dakar Declaration' on irrigation, adopted by the six Sahelian countries (Burkina Faso, Mali, Mauritania, Niger, Senegal and Chad) that gathered at the High-Level Forum on Irrigation in the Sahel (October 31, 2013), under the Permanent Interstate Committee for Drought Control in the Sahel (CILSS in French) leadership, recognizes the need to address both of these aspects. The Dakar Declaration calls for a renewed effort to scale up irrigation development and improve irrigation sector performance in the six Sahel countries to contribute to regional food security within natural resource limits. These six Sahel countries jointly engaged in the World Bank financed Regional Sahel Irrigation Initiative Project (SIIP) together with the coordinating regional institution CILSS in order to enhance stakeholders' capacity to develop and manage irrigation and to increase irrigated area using a regional "irrigation solutions" approach in participating countries in the Sahel.

4.0 National factors affecting irrigation and drainage services, including water policy, institutions, and human resource capacities.

An irrigation solution is the set of activities which, when carried out, leads to successful irrigated agriculture. Implementing an irrigation solution means establishing the following four conditions of success: (i) a sound organizational structure with a clear delineation of the roles and responsibilities of the different actors including all aspects; (ii) a robust technical irrigation system with proper O&M; (iii) a well-established and reliable financing system for both investment and O&M; and (iv) farmers with the right practical skills as a result of appropriate training given to them. These four dimensions can be fully functional and maintained only in a transparent, stable, and incentivizing institutional framework for agriculture, water, and land management. Identifying these four dimensions is by itself not new. Solutions are solutions if they can be replicable and adaptable. Hence, in effect, solutions are: (a) a "suite" of rules, tools, methods, institutional arrangements, decision-making processes, technologies, norms that can and need to be adapted to the local context; (b) the actual application in the field of the latter by those involved in irrigation development operations.

Solutions are context-specific and can be informed by good (and bad) practices and successful innovations from other similar areas. They need to be adapted to the constraints and potentialities with regard to water resources availability and variability, land tenure systems, socioeconomic and cultural context, market demand, and consumer behavior. Careful planning taking into account market and natural resources boundaries at the appropriate scale has to support the development of solutions in any given area. Feedback mechanisms from M&E activities are fundamental for this planning.

Irrigation solutions are at the heart of SIIP's project development objective. SIIP's main outcome is a set of solutions for the irrigation system typologies above, based on emerging best practices identified in the participating countries and on lessons learned from past failures and constraints; expansion of the area under irrigation; and improved performance and sustainability of these investments. To achieve this, SIIP finances efficient and reliable irrigation solutions for the revitalization / modernization and management of existing irrigation schemes and development of new schemes in selected project intervention areas.

5.0 Priority issues for modernization of I&D service

5.1 Need to consider the diversity of irrigated systems to adapt irrigation solution.

There is a wide range of hydro-agricultural developments including lowland development, large-scale public and private schemes, small-scale individual irrigation, and village irrigation. This diversity is a regional asset that should be preserved and used to develop Sahelian solutions to agricultural water control. As part of SIIP, five types of irrigation are defined adapted in Sahel context the objective is to promote successful experiences and take into account all types of irrigated systems in order to best respond to producers' needs and to the opportunities presented by the regions.

These systems, however, are not independent elements; they can be developed jointly in a given territory so as to make the most of the opportunities offered by this territory. For example, developed lowlands help to better secure the main production in the rainy season. They also improve groundwater recharge and thus develop individual small-scale irrigation which is highly profitable in the dry season.

Table 1. Different types of irrigation

Type 1:	lowland (bas-fonds) with partial water control and flood recession schemes
Type 2:	Individual small-holder irrigation
Type 3:	Community based irrigation solutions improvement process, with focus on irrigation technologies including solar pumping and on marketing strategies for equipment suppliers
Types 4:	Large-scale public irrigation schemes, usually supplied from large rivers regulated by dams, involving a combination of pump stations, gated structures, large canal and drainage systems, service roads, and a complex governance structure using user organizations.
Type 5:	Medium- to large-scale irrigation schemes, with same technical features as for Type 4, involving a partnership between the Government, a private party, and the communities surrounding the scheme for the development and management of the irrigation system.

Source: Work of the Task Force irrigation, 2015

Small-scale irrigation solutions (types 1 to 3) can be scaled up by increasing the number of schemes and generating very significant economic benefits.

There are also small-scale private or collective irrigation solutions (type 2 or 3) that can be developed within large-scale public schemes (type 4). The objective is to improve water resource development through the joint use of surface water brought by channels and groundwater mobilized through shallow boreholes recharged via surplus water from surface irrigation. This beginning of reuse of irrigation water, which is a driver of crop intensification and diversification, can be observed in the dry season in schemes such as Office du Niger in Mali. It may experience difficulties in collective irrigation management and other water management problems such as waterlogging due to lack of drainage. This highlights the importance of finding institutional solutions for joint management of surface water, groundwater and drainage water resources.

Positive experiences exist for all these systems. However, they are not or rarely generalized. The objective of SIIP is to level upwards the performance of the various irrigated systems. It also seeks to better adjust investment choices by taking into account the possibilities of combining the systems, in order to optimize the development of natural and human resources, and to maximize the return on investment for both the State and the private sector (producers and sectors' stakeholders).

5.2 Efficient and fair management of irrigated land: one of the keystones of performance: one of the principles of the solution approach

An action matrix on irrigated land has been developed to assist public action in public and private irrigation operations, on existing or new developments. Focused on consultation, it has three dimensions: (i) a good overall framing of hydro-agricultural development projects, (ii) management of the local social and land context of the hydro-agricultural development project, (iii) land tenure applicable to the parcel plan of the hydroagricultural development project. This work has shown that the improvement of the land framework is promoted by management at a local level but as part of a national policy. The Action Matrix is an essential instrument for assisting the States in processing applications, which have become frequent in recent years in some Sahelian countries, for the allocation of large areas of irrigable land, by foreign entities and thus avoiding the granting of discretionary "land rights" and "related water rights" but whose practical enforcement proves impossible.

Table 2. Existing innovations for land tenure systems that secure farms.

Innovation/practice	Actions/mechanisms	Country of reference
Adaptation of land rights to the socio-economic context and the types of	Operating license with renovated specifications Emphyteutic lease for PAPs owning lands.	Niger

Innovation/practice	Actions/mechanisms	Country of reference
plot holders on the irrigated areas	Title deed for PAPs with pre-emptive right of the project on sale. Emphyteutic lease for allottees after an approval period of 3 years.	Burkina Faso
	Farming Permit (PEA) of unlimited duration and transmittable, for farmers who have demonstrated their dynamism under the Annual Farming Contract (CAE)	Mali
	Authorization to use related to the unlimited duration of development	Senegal
A system of gradual sanctions for non-payment of water fees	Non-payment of water fees does not imply immediate eviction. The sanction mechanism is gradual: warning for late payment (Article 48), fine for one-year delay in payment (Article 49), eviction in case of proven refusal to pay the fee (Article 50).	Burkina Faso
Promote meeting between local land institutions and the hydraulic bureaucracy	The consultations help to partially align local institutions with those of the scheme. Lineages have formed an Economic Interest Grouping so that the management of the plots allocated to the groupings reflects that of the lineages, but also to ensure that the allocated lands correspond to those of the lineages on which the scheme has been established	Senegal
Supervision of agro-industrial projects	Local communities turned away investors following consultations on the Ngallenka scheme (440ha).	Senegal
	The Bagré Growth Pole supervises investment projects. If they are selected by the management agency, they are awarded a temporary 3-year lease, followed by a longterm lease contract if development has occurred. The water fee is higher for agro-industrial projects than for smallholders.	Burkina Faso

Source: The Task Force's Land Report, July 2015

5.3 A mechanism to ensure farmers' commitment and contribution to irrigation investment: essential for ownership.

The main objective of this mechanism at part of SIIP, is to ensure that the investment bearer (individual promoter, farmers organisation, community, public administration, etc.) is the contracting authority and in capacity (Social engineering and training to strengthen their capacities to the needs) to get actively involved in the recruitment and monitoring of design offices, companies, monitoring execution, managing operations. This is one of the best ways to involve and empower beneficiaries in the efficient and sustainable implementation of irrigation investments.

To do this, the SIIP has defined a participatory and inclusive process for planning and implementing irrigation investments, putting the producer at the heart of this process. the producer participates in the selection and validation of investment choices, in the award of contracts and organizes the development of the investment. An investment financing agreement is signed between the producer and the project.

5.4 Reference costs established for economically viable irrigation schemes.

It has been observed that the unit costs of irrigation projects in the Sahel region are higher than any global average. The economic and financial profitability of the Investments is called into question because of this aspect and therefore the viability of the investment is difficult to prove. In this context, the selection of the most adequate irrigation technology, with a viable solution, is essential. In order to guide the choice of investments, reference investment costs have been defined and agreed.

Table 3: Average investment costs by type of irrigation systems and by country

Cost (USD/ha)	Senegal	Niger	Burkina Faso	Mali	Mauritania	Tchad
Type 1	4,350	6,574	6,648	5,500	2,864	7,194
Type 2	7,250	7,433	19,373	9,000	-	9,956
Type 3	4,198	5,902	15,423	11,568	6,320	9,000
Type 4	-	8,541	-	-	-	-

Source: SIIP régional team 2021

5.5 *Establishment of a quality assurance mechanism for irrigation infrastructure and equipment*

The quality assurance mechanism in place is:

(a) a guide for drafting quality ToRs for design studies and for works control missions are drawn up, validated at regional level, and made available to the countries.

(b) The adequate methodological supports (quality criteria) for the quality review of the studies, the proactive monitoring of the quality of the works and the monitoring of the upkeep and maintenance of the instructors and irrigation equipment are provided by CILSS to country actors.

(c) Technical guidelines and operational manuals for the implementation of type 2 investments (small individual private irrigation) with consideration of solar pumping, are developed with the support of CILSS and adapted to the context of each country with a view to facilitate the scaling up of type 2 investments which are currently arousing great enthusiasm among promoters.

(d) The quality review of complex technical studies at the regional level (CILSS) before their validation

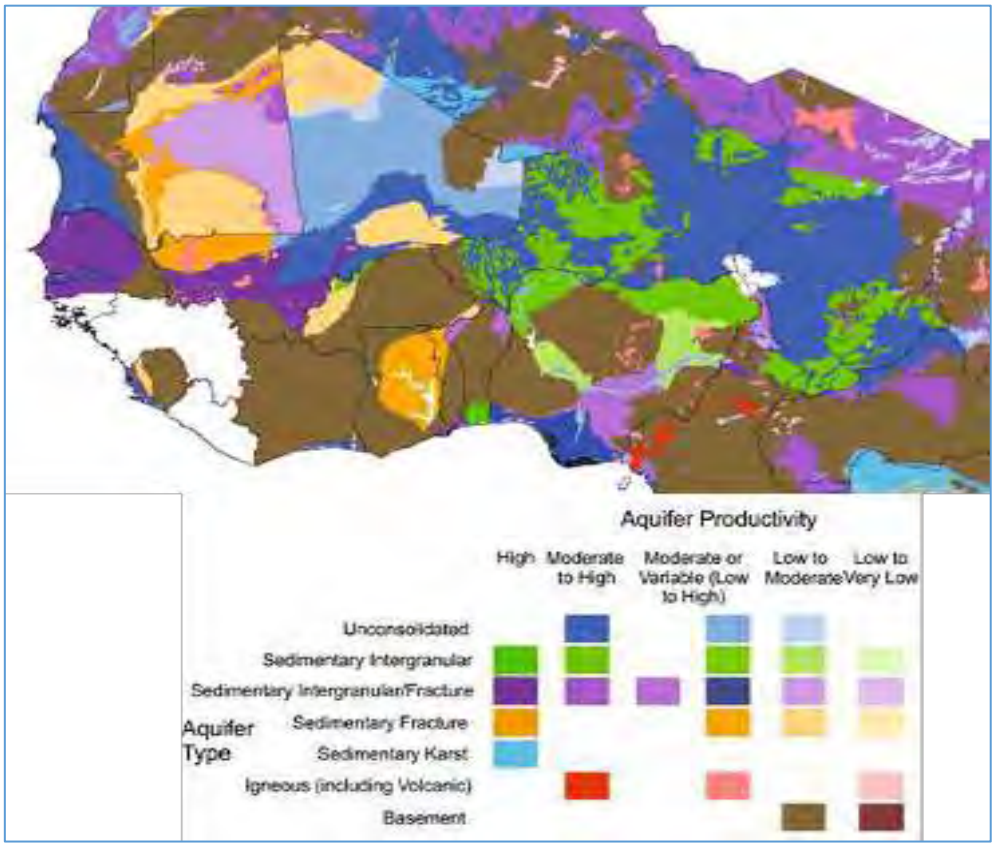

Figure 1: Mapping of potential areas for Individual small-holder irrigation (Type 2) in the SIIP countries

6.0 Conclusions and Recommendations

The Sahel countries have a lot of their economic, agro-ecological, and social characteristics in common and present extensive potential for economies of scale and knowledge transfers. However, a coordination mechanism is imperative to activate and sustain economies of scale and knowledge transfers and surmount political barriers. Such a role is played by the CILSS, which is implementing the regional activities of the project. The project institutionalizes the solutions commonly developed by the six countries to ensure the capitalization of knowledge gained and to guarantee the sustainability of the approach beyond the project life.
In essence the project's regional dimension helps:

1. build the knowledge base and facilitate cross learning at regional level,
2. attract/facilitate participation of the private sector to innovate and provide services at regional level,
3. facilitate introduction of new technologies/innovations at lower cost (e.g. ICT, solar technology etc.),
4. facilitate adoption of regional policies.
5. provide regional information including thematic maps as the map (Figure 1).

The regional dimension can be strengthened further by clarifying what regional services are needed to implement this vision and how the project help establish these services. It needs to show that developing these services at regional level will be more effective than a national level approach.

So, we need a regional approach for economies of scale and irrigation solutions transfers between countries.

REHABILITATION AND MODERNIZATION OF IRRIGATION INFRASTRUCTURES IN SOMALIA

Bashir Ahmed Maow[1], Mohamed Mohamud Abdi[2]

ABSTRACT

According to World Bank, 62% of the population of Sub-Saharan African population depends on agriculture for their livelihoods. Therefore, improving Agriculture is the best way to improve food security. Except for a few pockets of semi-humid terrain, Somalia is mostly arid or semi-arid, and relies heavily on irrigated agriculture to sustain its population. Rainfall occurs in two of the four seasons, with yearly amounts ranging from less than 100 mm at the northern shore to more than 600 mm in some tiny hilly areas. Rainwater management and conservation, both for home and agricultural purposes, could help to ease water shortages, but they must be developed methodically. Irrigated agricultural development started in Somalia in 1920, but significant opportunities for crop production exist under irrigation along the Shabelle and Jubba valleys. However, over 20 years of civil war, the majority of these schemes have collapsed. Unfortunately, dams, barrages and other irrigation infrastructure are in a state of disrepair, either due to direct damage or indirect damage. River embankments are eroded, and barrages, pump sluice gates and canal systems have some degree of sedimentation and vegetation growth which reduce the canals' hydraulic sections.

There is a lot of potential for both rivers to be used for irrigation. If the pre-war irrigation infrastructure was restored, it is estimated that up to 265,000 hectares of land might be irrigated in these two basins. To increase the productivity of the country, the government needs to play a major role in agricultural production by developing irrigation infrastructures, establishing effective policies, adopting the barriers to production, helping farmers with capital, and providing training with the technology.

Key Words: Rehabilitation, Modernization, Irrigation Infrastructure, Somalia.

INTRODUCTION

The rapid population growth will mean a rise in global food demand for at least another 40 years. To feed the world's growing population, which is expected to reach 9.6 billion people by 2050, without causing immense harm to the environment and hunger, society needs to increase agricultural productivity (Jin & Huffman, 2016; Mbara, 2007). According to (Elias, Nohmi, Yasunobu, & Ishida, 2013) 62% of the population of Sub-Saharan African population depends on agriculture for their livelihoods, Therefore, improving Agriculture through effective rehabilitation and modernization of irrigation infrastructure is the best way to improve food security (Abdu-Raheem & Worth, 2011).

Water scarcity is a mounting challenge in many parts of the planet resulting from a growing demand from different sources including agriculture, industry, hydroelectricity generation, and a rising population (Wuebbles, Fahey, & Hibbard, 2017). Given the challenges climate change is expected to pose on smallholder agriculture, irrigation has been identified as an important adaptation strategy to increase agricultural productivity and reduce poverty (Hussein, 2017). However, the potential for bringing additional land under irrigation is limited (FAO, 2012). Consequently, a key strategy is to focus on improving water management efficiency in agriculture. According to (Kassie, Zikhali, Pender, & Köhlin, 2010) as in many other Sub-Saharan Countries, agriculture is the most important sector in Horn of Africa to sustain development and reduce poverty. Nevertheless, lack of adequate farm management practices, low level of modern inputs usage, the depletion of soil organic matter and soil erosion, highly rain fed based farming, and limited irrigation infrastructure are the major obstacles to sustaining Horn of Africa agricultural production.

Agriculture was second only to livestock as Somalia's foreign exchange earner before the civil war began in early 1991 (Abukar, 2004; SO, 2010). Except for a few pockets of semi-humid terrain, Somalia is mostly arid or semi-arid, and relies heavily on irrigated agriculture to sustain its population. Rainfall occurs in two of the four seasons, with yearly amounts ranging from less than 100 mm at the northern shore to more than 600 mm in some tiny hilly areas. Rainwater management and conservation, both for home and agricultural purposes, could help to ease water shortages, but they must be developed methodically. Irrigated agricultural development started in Somalia

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in 1920. Significant opportunities for crop production exist under irrigation along the Shabelle and Jubba valleys (SO, 2010).

The FAO estimates that only about 3 million hectares of land—about 5 percent of the total—is cultivable. Of this total, almost 2.3 million hectares produces or could produce crops under rainfed conditions, and almost 700,000 hectares could produce crops under pump or recession-controlled irrigation, mainly along the two main rivers, the Shabelle and the Jubba. Only 110,800 hectares are currently irrigated, which is less than half the 222,950 hectares under irrigation just before the civil war and only about 15 percent of the total potential irrigable land (EU 2010; SWALIM and FAO 2014). Almost two-thirds of cultivable land (rainfed and irrigated) is in the southern parts of the country.

As the two rivers supply the Somalia's rice bowl and support important economic areas in southern Somalia, several agricultural development projects have been implemented based on the water resources of the two rivers. As the Jubba River is extensively used for irrigation, projects that were implemented or planned on the Jubba River include: Jubba Sugar Project (JSP), often known as Mareerey, irrigating sugarcane near Jilib; Mugaambo Rice Irrigation Project near Jamame, using run-of-the-river via canal; Fanole Dam Project, multipurpose dam development for irrigation, hydropower generation and flood mitigation, located near Jilib; and Arare Banana Irrigation Project, Jamame. Bardere Dam Project (BDP), which is the largest ever planned but unimplemented water project will be discussed below. Water infrastructures that have been set up for irrigation were also destroyed during the civil war.

To increase the productivity of the country, the government needs to play a major role in agricultural production by developing irrigation infrastructures, establishing effective policies, removing the barriers to production, helping farmers with capital, and providing training with the technology. This Paper will present the rehabilitation and modernization works that's ongoing in Somalia to elevate poverty and enhance food security.

IRRIGATION IN SOMALIA

Irrigated agricultural development started in Somalia in 1920. The scale of irrigation development increased rapidly thereafter and by 1980 some 60,000 ha had been developed in Jowhar and Balad districts, located in the Middle Shabelle region. Between 1980 and 1990, irrigated areas benefited from a well-established network of canals and drains, allowing a consistent supply of water that supplemented the scarce and unreliable rains, with abundant surface and underground waters from the Shabelle and Jubba Rivers. Irrigation systems were originally based on a limited number of gated gravity-fed river sluice gates, feeding main canals designed in such a way as to have enough head to command the fields through secondary canals and, further down, smaller tertiary canals to individual farms' sluice gates. However, over 20 years of civil war, the majority of these schemes have collapsed (IGAD, 2019). The existing irrigation infrastructures were rehabilitated and improved through expansion of irrigated areas for improved accessibility.

Before the civil war began in 1991, nine barrages on the Shabelle River and one dam on the Jubba River for river control with irrigation canals were built to irrigate 222,950 hectares of land. There is also a lot of potential for both rivers to be used for irrigation. If the pre-war irrigation infrastructure was restored, it is estimated that up to 265,000 hectares of land might be irrigated in these two basins. Unfortunately, barrages, canals and other irrigation infrastructure are in a state of disrepair, either due to direct damage or indirect damage.

The ongoing conflict, associated with the absence of dependable land-use management systems and water resource management institutions, has led to reports of severe degradation of land and water resources. After the outbreak of war, agricultural production fell by about 50%, largely due to a reduction in cultivated area, and the abandonment of irrigation schemes and collapse of irrigation infrastructure (Mbara, 2007). Effective water and land management are both essential to ongoing relief and rehabilitation efforts primarily the Jubba and Shabelle rivers (Houghton-Carr, Print, Fry, Gadain, & Muchiri, 2011).

CURRENT STATUS OF NATIONAL IRRIGATION SECTOR IN SOMALIA

Since the collapse of the government in 1991, violence has characterized Somalia in the past three decades. The collapse of the central government has hindered the functionality of the private sector, particularly in the areas of trade, commerce, transport, remittance and infrastructure services (FAO, 2011). The growth of the agriculture sector has, however, been pulled backward by insufficient investment capital, trained manpower and absence of a relevant legal and regulatory framework to enforce rules and regulations, common standards and quality control. Somalia's economy traditionally depends on the exploitation of natural resources, mainly livestock and agriculture. Drought and floods have severely affected income generation capacity of the majority of Somalis. Years of conflict have resulted in a protracted and complex emergency, eroded livelihoods and increased vulnerability to food insecurity.

In the agricultural sector, the vulnerability of households was considerably increased as the household asset base has become depleted during the years of conflict and civil unrest. The arable land represents 1.67 per cent, while permanent crops account for 0.04 per cent and the other land represents up to 98.29 per cent. It was estimated that, before the civil war, some 1,815,000 hectares of land were being cultivated with reasonable success. The areas under rain fed agriculture accounted to 1,445,000 ha and 250,000 ha under irrigated conditions. Irrigated land now accounts for 200,000 hectares, and practically, all of it is in Middle and Lower Shebelle and Lower Jubba regions.

There is much lower and inconsistent surface water availability in the agricultural heartlands of southern Somalia where most the irrigated farming is located. This is largely a result of the dilapidated state of the pre-war irrigation and flood control infrastructure and minimal rehabilitation efforts, which all make irrigation of crops increasingly unreliable. The pre-war large scale flood control and irrigation schemes, consisting of barrages, canals, and other infrastructure in the middle and lower reaches of the Jubba and Shabelle rivers have long fallen into disrepair. The cumulative silting of the riverbed over the past three decades has also resulted in rivers easily breaking banks in rainy seasons, often causing extensive floods resulting in crop losses and displacement. This also makes rural roads impassable and thus makes transport and marketing of harvest from unaffected areas difficult or impossible.

The irrigation canal system consisting of primary, secondary, and tertiary canals, in which barrages or weirs control the flow of water, have mostly become unmanageable. Furthermore, pumping stations that supplied water through the canal systems in areas where irrigation by gravity is not feasible have long been either looted or ceased to function due to lack of maintenance. The lack of planning and regulation in irrigation often leads to inefficient water use, increased salinization, and water logging.

REHABILITATION AND MODERNIZATION OF IRRIGATION INFRASTRUCTURES IN SOMALIA

The scarcity of water impacts at the household and community level, in health outcomes, as well as in the economy. Water is especially important in the traditional livestock and agriculture sectors and is often the source of conflict. An early priority of Somalia's National Development Plan (NDP9) 2020-2024, therefore, is the creation of a Water Management Master Plan. In this regard, mobilization of resources for large-scale investments in watershed management and infrastructure to mitigate the impact of extreme cycles of rainfall, floods and drought will be critical for the resilience of Somali livelihoods dependent on livestock. On the other hand, rehabilitation of the pre-war irrigation and flood control infrastructure in southern Somalia is required to improve supply of surface water availability to agriculture (MoPIED, 2020).

Somalia has a long history of irrigated agriculture on the alluvial plains of the Jubba and Shabelle Rivers. According to pre-war statistics, crop production accounted for just over 20% of the foreign exchange. 150,000ha of land were spate irrigated and around 50,000ha under full control irrigation schemes in the Jubba-Shabelle basin (Basnyat, 2009). Since the early 1990s much of the irrigation infrastructure has deteriorated. Civil war, combined with El Nino floods in 1997/98, have led to the total collapse of all large irrigation schemes and agricultural exports are now almost zero.

After long period of civil unrest, Somalia is now regaining its peace, and development in different sectors is ongoing. Food security is one of the key problems in Somalia and is caused by accumulated factors such as lack of security, infrastructure deterioration, civil conflicts and lack of financial power.

In recent years, the Federal Ministry of Agriculture and Irrigation (FMOAI) of Somalia, in partnership with the international partners, has been working towards rebuilding the lost institutional function in order to provide basic regulatory services and stimulate economic growth in the sector. In that regard, different projects in the government and international development institutions are working on a way to revive the lost infrastructure in agriculture sector such as irrigation canals, flood control infrastructures, river embankments, barrages and agriculture markets.

Recently, Ministry of agriculture and irrigation assessed 57 different canals in three states across the country to understand the status of the canals and structures related to be rehabilitated. Assessed canals are in agriculture reach areas of the countries where thousands of people will be benefiting if the canals are rehabilitated and different lands will be cultivated. The assessed canals are in the Southwest state and Hirshabelle States on the Shabelle river and Jubbaland State of Jubba River, Figure 1. After the canals are rehabilitated, its estimated that 15,073 farmers will be benefiting and 23,159.5 ha will be irrigated, Figure 2. This shows a huge boost in farming, alleviation of poverty and enhancement of food security.

In the meantime, different projects in across the country is also ongoing to rehabilitate the irrigation canals. The building resilience in Middle Shabelle (BRiMS) project also rehabilitated 72 canals across the highly agriculture

reach region of Middle Shabelle where a major part of agriculture products in the country is produced. The rehabilitated canals will be serving approximately 20,976 ha of farms in Middle Shabelle region.

The project is intended to enhance production, productivity and thereby the livelihoods and food security of smallholder producers primarily by rehabilitating and improving irrigation canals while strengthening the capacity of Irrigation committees that manage the irrigation infrastructures. Rehabilitating the pre-war irrigation and flood control infrastructure will improve supply of surface water availability, reduce the inefficiency of water use and improve irrigation techniques to reduce soil salinization and water logging. All these canals were rehabilitated with the mindset of "Build back better" which indicates renovating the canals and the related infrastructures in a modern way.

Figure 1 Assessed canal areas through SCRP (Somalia Crisis Recovery) Project

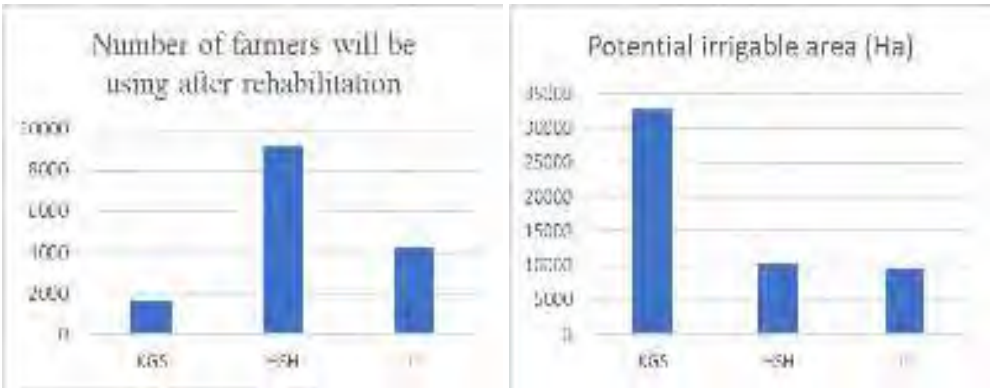

Figure 2 Expected outcome of rehabilitation projects in Koonfur Galbeed Somalia (Southwest State of Somalia), Hirshabelle state and Jubbaland State.

PROSPECTIVE AREAS FOR FUTURE MANAGEMENT OF IRRIGATION SECTOR IN SOMALIA

The irrigation sector in Somalia has been facing significant challenges due to decades of conflict and instability, recurrent droughts, and insufficient investment. The lack of proper maintenance and investment has resulted in a deterioration of irrigation infrastructure and poor water management practices, exacerbating the impacts of droughts and limiting agricultural production. Inadequate water management has also led to land degradation and soil erosion, reducing the arable land available for farming. Despite the challenges, managing irrigation effectively is crucial for achieving higher agricultural productivity and enhancing food security in Somalia. To achieve this

future management of irrigation sector in Somalia needs has to be done in different perspectives including resource management, supply and demand management, infrastructure management, institutional and policy reforms, and technological interventions.

Due to the country's limited water resources and reliance on two perennial rivers that originate in Ethiopia, appropriate water resource management is critical for effective irrigation management. The issues confronting Somalia's irrigation industry, such as deterioration of irrigation infrastructure, inadequate water management practices, and recurring droughts, underline the need for sustainable water resource management. Effective water resource management may assist guarantee that water is allocated equally across diverse sectors, particularly agriculture, and decrease the possibility of water resource disputes. It can also assist in saving water supplies and lessening the effects of droughts on agricultural productivity, benefiting food security and farming communities' lives.

The absence of adequate irrigation infrastructure in Somalia, as well as weak institutional and regulatory frameworks in the irrigation sector, and the limited application of modern technology, underline the urgent need for infrastructure management, institutional and policy reforms, and technical interventions. Improvement and modernizing of irrigation infrastructure, including the building of new irrigation schemes and renovation of existing ones, may greatly increase the supply and distribution of water for agricultural uses. Furthermore, institutional and policy changes can aid in the establishment of regulatory frameworks and the improvement of governance practices, guaranteeing equitable and sustainable water resource management for all stakeholders. Adoption of modern technology can also assist enhance water usage efficiency and decrease water waste.

CONCLUSION

Over the past three decades, Somalia has witnessed a decline in crop production and a reduction in their contribution to GDP, both in terms of export earnings and domestic consumption. The reasons for this decline are numerous, including long-standing civil conflict resulting in insecurity and displacement of rural populations, dilapidated irrigation infrastructure due to the collapse of state-run maintenance services, and the effects of droughts and floods linked to climate change. To address these challenges, irrigation infrastructure has become a subject of substantial policy attention and investment in Somalia, as well as in many other developing countries. However, achieving higher growth will require the acceleration of structural reforms, enhanced provision of basic services, and improved resilience of the agriculture sector.

Given that agriculture is the main source of economic activity in Somalia, the federal government, with the help of international institutions, is working to revive old infrastructures through rehabilitation and modernization, particularly in the irrigation sector. While rehabilitating irrigation infrastructure is an important step towards food security, it is not the only solution. Therefore, the projects are also focused on establishing markets for the farmers, training them with the latest technologies, and subsidizing them with agricultural inputs. These measures will help increase agricultural productivity, improve the livelihoods of farmers, and enhance food security in the country.

The rehabilitation and modernization of irrigation infrastructure in Somalia has been ongoing for some time, but there is still a long way to go. The government and international institutions need to continue investing in infrastructure to ensure that irrigation systems are properly maintained and improved to meet the growing demands of the agriculture sector. Additionally, there is a need to strengthen governance frameworks and regulatory systems to ensure sustainable water resource management. This will require the engagement of all stakeholders, including the private sector, civil society, and local communities. Moreover, the government needs to provide basic services such as education, health, and road infrastructure, to support the development of the agriculture sector and enhance the resilience of farming communities to climate change and other shocks. By implementing these measures, Somalia can achieve sustainable agricultural production, enhance food security, and improve the livelihoods of its people.

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COUNTRY PAPER - NATIONAL IRRIGATION AND DRAINAGE SERVICES- SRI LANKA

Kalana Denuwan[1] and Chandra Padmini[2]

1.0 Introduction

Sri Lanka is known as the pearl of the Indian Ocean without water scarcity. There are ample water resources, including the 103 river basins and 14,000 artificial reservoirs with water channel networks. Annual rainfall is 800 mm to 5000mm, and four seasonal rainfall patterns. Due to the bimodal pattern and climate change, the rainfall pattern has changed, and water scarcity has been identified in some areas of the country. To overcome the water scarcity, water reservoirs were developed mainly in dry zone areas to cultivate paddy. Historically, the King and the village headman controlled this irrigation system. At present, mainly four government institutes govern the water resources in Sri Lanka. Those institutes are the Department of Irrigation (DI), Mahaweli Authority of Sri Lanka (MASL), National Water Supply and Drainage Board (NWSDB), and the Water Resources Board (WRB). However, 41 institutions and 52 legislations cover all the water sector requirements in Sri Lanka (S. S. K. Chandrasekara *et al.,* (2021).

2.0 Overview of National Irrigation and drainage services

2.1 Department of Irrigation (DOI),

The Department of Irrigation is the central government agency responsible for planning, developing, operating, and maintaining irrigation infrastructure in Sri Lanka. Its primary objectives include the construction and management of reservoirs, canals, tanks, and other irrigation structures, as well as promoting sustainable water use and agricultural development

2.2 Mahaweli Authority of Sri Lanka (MASL)

The Mahaweli Authority was established in 1979 by the Act of Parliament to oversee the all Mahaweli development projects, maintain the irrigation network, enhance production of agriculture and post settlement process. The Water Management Panel (WMP) of MASL manages the water resources of the Mahaweli project. The WMP is also responsible for the overall cultivation program.

2.3 National Water Supply and Drainage Board (NWSDB)

The NWSDB is responsible for the provision of clean water for domestic, industrial, and agricultural purposes, as well as the management of wastewater and drainage systems. While its primary focus is on water supply and sanitation, it also collaborates with irrigation authorities to ensure proper water management and usage

2.4 Water Resources Board (WRB)

Water Resources Board (WRB) was established in 1966 by the parliament act no, 29 of 1964 and its vision is “Adequate access to clean and safe water for all. Accordingly, their main servicers are hydrogeological services, Regulatory operations, Drilling and Tube well constructions, Central groundwater information and water quality analysis. By using new technologies and management tools they conserve and advice to sustainable use of water resources of the country.

2.5 Department of Agrarian Development (DAD)

The Department of Agrarian Development plays a crucial role in supporting the agriculture sector and ensuring the sustainable use of water resources. The department aims to enhance food security, increase rural incomes, and contribute to the country’s overall economic development by implementing effective irrigation systems, promoting agricultural best practices, and supporting farmers.

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3.0 Assessment of Modernization and revitalization requirements

Due to the country's urbanization, drinking water demand is increasing and releasing water pollutants also increasing. Due to the effects of climate change, water scarcity is an issue in certain regions, for drinking water. Sri Lankans suffer from many water-borne diseases due to a lack of safe drinking water. Different sources of drinking water are pipe-borne water (49.2%), protected wells (36.4%), unprotected wells (4.4%), river or reservoirs (5.4%), tube wells (3.2%), and rainwater harvesting (1%) (Fan, 2015). Accordingly, the country needs to change the policies of the supply of water for human use, agriculture, and electricity generation. Modernization can be adopted to improve the water sector in the country.

3.1 Enhancing the physical infrastructure of irrigation and drainage systems can involve rehabilitating and expanding existing canals, reservoirs, and dams. Upgrading infrastructure can improve water storage, delivery, and drainage capacities to provide safe filtered drinking water to all nations. Presently in the Northern region people use filtered drinking water very low prices with the assistance of provincial government.

3.2 Implementing modern technologies such as remote sensing, IoT (Internet of Things), and data analytics can optimize water usage and improve operational efficiency. Automated monitoring systems can help detect leaks, measure water levels, and control water flow remotely.

3.3 Promoting efficient irrigation techniques, such as drip irrigation and precision agriculture, can reduce water wastage and improve water-use efficiency. Educating farmers about water-saving practices and providing incentives for adopting sustainable agricultural methods can also contribute to water conservation efforts.

3.4 Water pollution is a significant concern in Sri Lanka, mainly due to inadequate wastewater treatment, agricultural runoff, and industrial discharges. Strengthening water quality monitoring systems, promoting sustainable agricultural practices, and enforcing regulations on industrial pollution are necessary steps. Investment in wastewater treatment facilities and public awareness campaigns on the importance of preserving water quality are also essential

4.0 National factors affecting irrigation and drainage services, including water policy, institutions, and human resource capacities

In Sri Lanka several factors affect irrigation and drainage services; including the lack of proper water policy, water losses throughout the system, improper system operations, and poor maintenance of structures, inefficient practices of irrigation, dis-integration of system components and lack of government intervention as major issues to achieve sustainable use of water in the case of irrigation (Sirimewan et al, 2019, Chandrasekara et al, 2020).

4.1 The water policy of a country determines the allocation, management, and use of water resources, including irrigation and drainage services. Effective water policies promote sustainable water use, prioritize efficient irrigation practices, and ensure equitable distribution of water among different users. Clear and transparent policies can foster investment, innovation, and long-term planning in irrigation and drainage infrastructure.

4.2 The presence of strong and capable institutions is essential for the successful delivery of irrigation and drainage services. Effective institutions provide oversight, regulation, and coordination among different stakeholders involved in water management.

4.3 Human Resource Capacities: Adequate human resources, both in terms of numbers and skills, are critical for the efficient operation and maintenance of irrigation and drainage systems. Trained personnel, such as engineers, technicians, and agronomists, are needed to design, construct, operate, and manage irrigation infrastructure effectively. Investing in education, training, and professional development programs can enhance the technical expertise and management capabilities of the workforce involved in irrigation and drainage services.

4.4 Sufficient financial resources are necessary to develop, maintain, and upgrade irrigation and drainage infrastructure. Governments should allocate adequate budgets to support the construction, operation, and maintenance of these systems. Additionally, mechanisms such as cost recovery through user fees or water pricing can ensure the sustainable financing of irrigation and drainage services. Access to affordable credit and financial incentives can also encourage farmers to invest in water-saving technologies and efficient irrigation practices.

4.5 The adoption of modern technologies can greatly improve the efficiency and productivity of irrigation and drainage services. Advancements in precision irrigation systems, sensor-based monitoring, automation, and remote sensing can help optimize water use, reduce wastage, and enhance crop yields. Governments should promote research and development, provide technical assistance, and facilitate the dissemination of innovative technologies among farmers and water managers.

4.6 Stakeholder Participation and Awareness: Involving stakeholders, including farmers, local communities, and civil society organizations, in decision-making processes can enhance the acceptance and effectiveness of irrigation and drainage services. Public awareness campaigns, training programs, and participatory approaches can help build a sense of ownership, foster responsible water use practices, and promote sustainable behavior among water users.

5.0 Priority issues for modernization of Irrigation and drainage services:

There are several priority issues to consider. Here are some key areas that organizations often focus on infrastructure development and Human resource development:

5.1 Modernizing Irrigation & Drainage services often requires upgrading existing infrastructure. This may involve rehabilitating or replacing aging irrigation and drainage networks, including canals, pipes, pumps, and storage facilities. Upgrading infrastructure can improve water distribution, reduce losses, and to provide safe drinking water.

5.2 Incorporating automation and remote monitoring technologies can significantly improve the efficiency of Irrigation & Drainage services. Remote sensors, telemetry systems, and Internet of Things (IoT) devices can provide real-time data on soil moisture levels, weather conditions, and water flow, allowing for more precise and timely decision-making.

5.3 With changing climate patterns, modernization efforts must address the impact of climate change on water availability and demand. This includes developing resilient infrastructure, implementing adaptive water management strategies, and integrating climate data and forecasting models into Irrigation & Drainage planning.

5.4 Capacity development on sustainable healthy water usage to policy makers, officials and all stakeholders through international and national training and awareness programs.

By addressing these priority issues, the modernization of Irrigation & Drainage services can lead to more sustainable water management, improved agricultural productivity, and better adaptation to the challenges posed by a changing climate

6.0 Conclusions and Recommendations

6.1 Future modernization plans

Upgrading or expanding existing infrastructure such as water purification, pipe lines, canals, reservoir capacities, spillway capacities and water storage facilities to enhance water supply and distribution efficiency. Introducing advanced technologies like sensors, remote monitoring systems, and automation to optimize water usage, detect leaks, and manage irrigation systems more effectively. Infrastructure Upgrades: Upgrading or expanding existing infrastructure such as canals, reservoirs, and water storage facilities to enhance water supply and distribution efficiency and investing in research and development initiatives to explore innovative solutions for water management.

Human resource development on sustainable healthy water usage to all stakeholders through international and national training programs.

6.2 Recommendations

Development of Effective water policies to promote sustainable water use, prioritize efficient irrigation practices, and ensure equitable distribution of water among different users. The presence of strong and capable institutions is essential for the successful delivery of irrigation and drainage services. Effective institutions provide oversight, regulation, and coordination among different stakeholders involved in water management.

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COUNTRY PAPERS – ZIMBABWE ON THE THEME: PATHWAYS AND TECHNOLOGIES FOR MODERN IRRIGATION SERVICES

Thubelihle A. Thebe[1]

1.0 Introduction

Zimbabwe is a land-locked country of 39.08 million hectares located in Southern Africa with an estimated population of 15.1 million people (ZimStat, 2023). The average annual population growth rate in Zimbabwe is in the range 1.5% - 2%. Zimbabwe largely has a sub-tropical climate with one rainy summer season, from November to March, a cool to cold winter season from April to mid-August and the hottest and driest spring period from mid-August to mid-November. Average annual rainfall ranges from over 1,000 mm in the Eastern Highlands on the Eastern border of Zimbabwe to around 300-400 mm in the lower-lying areas in the South. The national average annual rainfall is 657 mm, varying with location as shown in Figure 1. Only 37 percent of the country receives adequate rainfall for agriculture (FAO, 2005). Food production has not kept up with population growth and 35.5% of Zimbabweans face severe food insecurity according to estimates by the Food and Agriculture Organization (FAO, 2021) and is also affected by the inter-annual and intra-annual variability of rainfall that causes Zimbabwe to face what is termed a difficult hydrology (Grey and Sadoff, 2007). This difficult hydrology causes cyclic economic shocks in Zimbabwe (AfDB 2019). Irrigation and drainage services are therefore recognized as a pathway to climate resilient agricultural production to ease the economic shocks caused by the country's rainfall variability and difficult hydrology.

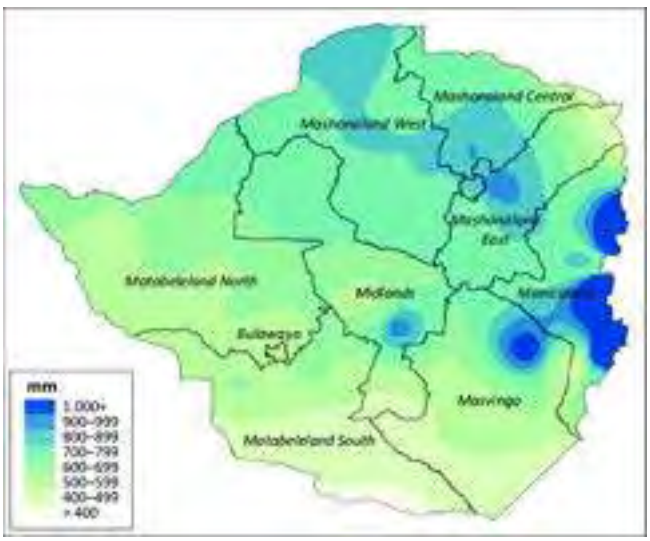

Figure 1: Zimbabwe average annual rainfall for the period 1980-2010 (Source: Meteorological Services Department)

Based on average annual rainfall and land area, the internal annual renewable surface water resources produced in Zimbabwe are 11.26km^3/yr. The net annual renewable groundwater resources are estimated at 1km^3/yr 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. 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 severity of water stress or scarcity is more pronounced in the low rainfall areas. The apportionment of freshwater withdrawals from surface water storages is estimated as: agriculture (79%), domestic (14%), and industry (7%) (AfDB, 2020).

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2.0 Overview of National irrigation and drainage services

2.1 Historical overview

Informal traditional irrigation methods existed in pre-colonial Zimbabwe particularly in the Eastern Highlands at Nyanga where furrow irrigation was practised on terraces. Informal cultivation on wetlands was also prevalent during the pre-colonial period. These traditional irrigation schemes failed by the late 19th century due to various reasons and were largely farmer-led. Formal irrigation development commenced during the colonial period in the early 20th century along colonial settlements on the Highveld. Besides, the irrigation project at Matopos Research Station that was developed by Government during the first decade of the 20th century, irrigation development was largely private-sector driven through companies such as the British South Africa Company (the holding company of the colonial Government at the time until 1923) that established Mazowe Citrus Estate, and through Irrigation Boards where colonial farmers came together to develop shared irrigation infrastructure. By 1930, 2770 ha (37.4%) of the total of 7400 ha of developed irrigation land were under functional irrigation systems. The remainder was non-functional or not utilized owing to different reasons such as poor financial performance of the irrigation projects leaving the infrastructure lying idle (Government of Zimbabwe then Southern Rhodesia, 1930).

The surge in irrigation development came through direct Government involvement in the development of small-to-medium sized dams during what can be termed as the first hydraulic mission of 1929-1955. The colonial Government at the time used what was termed as “Development by Segregation” (Punt, 1979) and strived to increase agricultural production from settler colonial farmers. This phase also marked the development of the first formal irrigation schemes in African communal lands of Zimbabwe, particularly in the eastern province – Manicaland with irrigation schemes such as Mutema and Mutambara being established. The irrigation schemes in the African communal lands were Government-managed with the main proponents for their development being what were then termed as Native Commissioners whereas Government provided loans for the settler Colonial farmers to drive their on-farm irrigation development and management and also guaranteed the uptake of their produce through established governmental marketing boards. The primary aim of the irrigation schemes in the African communal lands was to alleviate famine and prevent the African farmers from moving to urban settlements due to food insecurity in their communal lands. The trend continued during what may be termed as the second hydraulic mission from 1955 to 1979 where the Government funded the development of large dams such as Kariba Dam, Lake Muturikwi and others. This also marked the phase where Zimbabwe joined the International Commission on Irrigation and Drainage in 1955. The use of alluvial aquifers for large scale irrigation development commenced during this second mission and was anchored along the banks of the Limpopo River and its tributaries as well as the banks of the Save River; both of which are trans-boundary water courses. This led to the establishment of the first communal irrigation schemes in south-Western Zimbabwe at Shashe Irrigation Scheme in Matabeleland South Province and others that followed. Since independence, Government has been gradually empowering the communal farmers in Government-funded communal irrigation schemes to take up greater responsibility in the management of their irrigation schemes through irrigation management transfer programmes.

2.2 Extent of irrigation development in Zimbabwe

The extent of irrigation development in Zimbabwe has not been quantified in recent years. However, estimates indicate that the functional area under irrigation is 193,000 ha. This is a 70-fold increase from the functional area under irrigation in 1930. The exponential increase is largely due to Government interventions in the development of water resources particularly through the construction of dams, and in the offering of concessionary finance for on-farm irrigation development to commercial farmers and estates. The irrigated area is largely attributed to commercial farmers in the high rainfall regions; commercial estates such as sugar, citrus, and tea estates; Government estates under the Agricultural and Rural Development Authority; informal irrigation projects; and public-funded communal irrigation schemes that have a total area of 20,000ha or 10.3% of the functional irrigated area. Similarly, the extent of agricultural land drainage networks has not been quantified in recent years. Estimates indicate that the drained agricultural lands are about 25,000 ha. In terms of irrigation methods, the area under sprinkler irrigation methods is estimated at 90,000 ha, the area under surface irrigation methods is estimated at 58,000 ha, the area under micro-irrigation methods is estimated at 25.000ha, and the remaining area estimated at 20,000 ha is under informal irrigation including wetland cultivation and stream water abstraction using buckets and other manual methods for irrigation. The bulk of the irrigated area is in commercial estates and individual commercial farms. This leads to the dominance of sprinkler irrigation methods, especially the automated types such as center pivots, as agricultural labour is generally scarce in farming areas limiting the opportunity to hire casual labour for irrigation operations. Large-scale individual commercial farmers have almost entirely abandoned surface irrigation methods and manual sprinkler irrigation systems for automated sprinkler irrigation systems. The Government has partly offered incentives for this transition through co-financing automated sprinkler irrigation systems and reducing import duties on irrigation equipment. In the citrus and fruit horticultural agricultural production systems, large-scale commercial producers opt for micro-irrigation using micro-jet

sprinklers. The private sector is responsible for the supply, installation, and provision of after-sales services for the irrigation equipment.

2.3 Irrigated agriculture production

An estimated 193,000 ha of Zimbabwe's cultivated land area of 4.1 million ha (4.7%) is under irrigation. Irrigation is however recognized as a means of attaining food security and reducing rural poverty and greater efforts are being made to put more agricultural land under irrigation especially to meet the Southern Africa Development Community (SADC) target of 7% cultivated land to be under irrigation. Paragraph 6 of the Schedule (Section 9) of the Zimbabwe Water Act [Chapter 20:24], outlines the powers of the Government Officers mandated to carry out provisions of the Act to include "To obtain and record information concerning the extent of land under irrigation in Zimbabwe, the quantity of water used for irrigation and the amount, nature and value of crops obtained through irrigation." Despite being empowered to collect information on the extent of irrigation development and the production information from irrigated agriculture, that information has not been collected in recent years by the said "Officers". The agricultural production data published by the Zimbabwe National Statistical Agency (ZimStat) does not distinguish production from irrigated agricultural lands. Therefore, the value and quantity of crops produced through irrigated agriculture in Zimbabwe cannot be accurately stated. However, crops such as wheat, sugar cane, and citrus are produced exclusively from irrigated lands. Zimbabwe managed to produce 375,000 tonnes of wheat during the 2022 winter wheat season and that quantity was sufficient to meet the annual national wheat requirements. As of the 2023 winter wheat season, the total area planted under wheat was the highest total in recent years with 86,000 ha of planted. Government through various programmes and also through public-private sector partnerships has financial and input support schemes to enhance agricultural production from irrigated lands. Examples of such recent programmes are the on-going National Enhanced Agricultural Productivity Scheme and the recently concluded Command Agriculture Programme also known as Special Maize Programme for Import Substitution. These programmes support irrigated agricultural production through input subsidies and concessionary finance, as well the funding of on-farm irrigation infrastructure development.

3.0 Assessment of modernization and revitalization requirements

3.1 Irrigation modernization and revitalization

Irrigation modernization is "the process of upgrading infrastructure, operations and management of irrigation systems to sustain the water delivery service requirements of farmers and optimize production and water productivity" (Makin, 2020). This process does not exclusively mean the adoption of new high-end irrigation technologies in terms of upgrading irrigation infrastructure (FAO, 2007). Irrigation revitalization is "a broad development-focused process that carries with it the expectation of rebuilding socially uplifting, profitable agri-business on existing irrigation schemes and in the communities surrounding schemes. It emphasizes human capital development both individually and organizationally, empowerment, access to information, marketing and business strategy development, alongside repair and redesign of existing infrastructure" (Denison and Manona, 2007; Mwendera and Chilonda, 2013). Revitalization of irrigation schemes places greater importance on the financial sustainability of the irrigation schemes and incorporates concepts such as the establishment of operation and maintenance funds in addition to infrastructure repairs and upgrades. An emerging concept in the Zimbabwe irrigation sector is that of climate-proofed irrigation modernization and revitalization whereby climate-resilience of irrigation infrastructure and irrigation scheme governance underpins the modernization and revitalization efforts.

3.2 Irrigation modernization and revitalization programmes in Zimbabwe

As indicated above, the largest area under irrigation in Zimbabwe (153,000 ha) is attributable to individual large-scale farmers and commercial estates. This sub-sector has largely preferred sprinkler and micro-irrigation technologies that allow automation of irrigation activities and greater control of water resources. Historically, the Government of Zimbabwe has provided technical services and concessionary finance for the development of on-farm dams and irrigation infrastructure. The private sector has been contracted to perform construction activities and irrigation equipment installations. In commercial estates that utilize surface irrigation methods, modern techniques of land preparation such as laser land levelling have been employed to modernize the surface irrigation methods and improve the efficiency of water application. The commercial sugar and tea estates have research stations that investigate the most appropriate irrigation techniques. The commercial irrigation projects are generally financially sustainable and the farmers are represented in water governance boards to ensure sustainable access to water resources. The revitalization of the irrigation projects in commercial farms and commercial estates is largely farmer/owner-driven with Government support in the establishment of irrigation and water governance institutions and financial support as well as subsidies for irrigation development and upgrades. The outlook of the irrigation infrastructure in the commercial sub-sector is one of modern and revitalized systems.

There is further limited scope available for the greater modernization and revitalization of irrigation projects in the commercial sector particularly through the use of remotely-sensed data to improve water use and the use of smart technologies to schedule irrigation events. Communal and informal irrigation schemes covering over 40,000 ha have the largest need for modernization and revitalization. According to Unver et al. (2018), management performance is one of the issues to be tackled during modernization efforts and requires the introduction of appropriate management approaches that require investments as much as irrigation infrastructure upgrades. Furthermore investments are required in drainage services as more land is lost to increasing soil salinity levels. However, the need to invest in the modernization and revitalization of irrigation drainage infrastructure has largely been ignored leading to loss of irrigated land at communal irrigation schemes such as Silalabuhwa Irrigation Scheme in southern Zimbabwe. A pilot revitalization programme was introduced in 2011 – 2013 through a project financed by the Swiss Development and Cooperation Agency (SDC) through the International Water Management Institute Southern Africa office to develop a framework for the revitalization of communal irrigation schemes. A full-scale project funded by the Government of Zimbabwe through a grant from the International Fund for Agricultural Development and a loan from the OPEC Fund for International Development was launched in 2018 to out-scale revitalization of communal irrigation schemes in four provinces of Zimbabwe that have the largest area under communal irrigation schemes. This programme known as the Smallholder Irrigation Revitalization Programme runs until November 2023. The modernization and revitalization of public-funded communal irrigation schemes is largely driven by the Government. The private sector is contracted to carry out irrigation infrastructure upgrades and the enhancement of crop value chains from irrigated crop production.

3.3 Opportunities, challenges, and requirements in irrigation modernization and revitalization issues at irrigation projects

The opportunities for irrigation modernization and revitalization in the commercial irrigation sector and the communal irrigation schemes are as identified in section 3.2 above. They include the use of electronic sensors and remotely sensed data to improve irrigation system performance as well as inclusivity in water governance issues. The option of tradable water permits should be explored. In the communal irrigation sector, the opportunities for modernization and revitalization are more abundant as the sub-sector faces greater operational challenges that require more innovations for them to be improved upon. Government is largely responsible for forming the development trajectory for this sub-sector. The informal irrigation sub-sector requires the adherence to water and environmental laws before modernization and revitalization efforts can be undertaken.

4.0 National factors affecting irrigation and drainage services, including water policy, institutions, and human resource capacities

4.1 Zimbabwean water and environmental laws and policies

Irrigation is an environmentally prescribed activity according to the Zimbabwe Environmental Management Act [Chapter 20:27]. This means that new and existing irrigation projects have to conform to environmental laws such as environmental impact assessments, and environmental management plans. This is because irrigation leads to intensive agricultural production systems that present a larger threat to the environment if not properly managed. The Water Act [Chapter 20:24] governs water resources planning, development and utilization for irrigation. Farmers and other agricultural water users are required to have water permits to access water for commercial purposes. All water resources in Zimbabwe are vested in the State and there is no private water. Both the water and environmental policies recognize the important role played by irrigation in food security and adaptation to climate change. Zimbabwe can be considered as a pro-irrigation nation. The water policy particularly states that "To revitalize agriculture, Government will resuscitate the National Farm Irrigation Fund (NFIF) that will provide loans for irrigation rehabilitation and development. Where possible Government will facilitate contract farming partnerships which include infrastructure rehabilitation, based on mutually beneficial agreements." The above-sections indicate that the Government is taking measures to meet this policy objective.

4.2 Roles and responsibilities for actors and institutions in irrigation modernization and revitalization

The Ministry of Lands, Agriculture, Fisheries, Water, and Rural Development leads the policy formulation and strategies for irrigation development, modernization, and revitalization. The Ministry has various agencies including the Department of Irrigation, the Zimbabwe National Water Authority, the Agricultural Advisory and Rural Development Services Directorate, the Department of National WASH Coordination, the Agricultural and Rural Development Authority, the Department of Water Resources Planning and Management, and other parastatals that are involved in the marketing, financing and value chain development for irrigated agricultural produce. The Ministry of Finance and Economic Development, the Ministry of Local Government, the Ministry of Women Affairs, the Ministry of Industry and Commerce, and the Ministry of Environment play important roles in the provision of

irrigation and drainage services that are also provided by the private sector with largely Government financial support through works contracts or farmer subsidies. The Department of Irrigation coordinates the irrigation sector and ensures stakeholder participation through the Zimbabwe Committee on Irrigation and Drainage (ZwCID).

4.3 Human resource capacities

Continuous efforts are being undertaken by the Government to upgrade the skills of its technical irrigation professionals. These measures are supported by various development partners. The private sector has greater skill in the installation of irrigation equipment through skills transfer from equipment manufacturers. Technical capacity on water resources development exists in Government but is complemented by consultancy services from the private sector. The private sector makes greater investments in human resource capacity. It is essential for the Government to also do so to ensure sustainable irrigation and drainage services.

5.0 Priority issues for modernization of I&D services

The priorities for the modernization of irrigation and drainage services are elaborated in Section 3 of this paper. They include separate focus on the commercial sector as well as the communal irrigation sector and informal irrigation sector. Government prioritizes the financial sustainability of communal irrigation schemes although this is not always achievable due to limiting irrigation design criteria. The commercial sector drives its modernization and revitalization agenda with Government support.

6.0 Conclusions and Recommendations

6.1 Future modernization plans

The Zimbabwe Accelerated Irrigation Rehabilitation and Development Strategy 2021-2025 targets the conversion of about 60,000ha of surface irrigation systems to pressurized irrigation systems with the hope of improving irrigation efficiency. The plan is also to modernize 45,000ha of irrigated land. However, in fully developed river basins and sub-river basins this may not result in the increased availability of water resources for irrigation development as the water lost through inefficient application may already be recovered and reused within the river basin. Furthermore, modernized surface irrigation systems may attain the same efficiencies as manual sprinkler irrigation systems if properly designed and maintained. The surface irrigation systems also save on energy as most are gravity-fed.

6.2 Recommendations

Irrigation modernization and revitalization improve the overall performance of irrigation and drainage systems thereby making greater contributions to food security, and efficient resource utilization in the face of climate change. Well-informed irrigation modernization and revitalization strategies are required in Zimbabwe. These should not make basic assumptions about irrigation systems and technologies but should be based on research and evidence obtained from local and other international experiences. Knowledge sharing through internal work-bodies such as the ICID Working Group on Modernization and Revitalization may prove pivotal to attain sustainable irrigation systems. Government should continue supporting irrigation modernization and revitalization efforts with the private sector also ensuring that Government technical departments also develop skills in modern and robust irrigation technologies through collaboration efforts.

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KEY APPROACHES OF WATER RESOURCES DEVELOPMENT AND MANAGEMENT IN SRI LANKA

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ABSTRACT

Sri Lanka's water resources availability to use is about 43 billion-cubic-metres (BCM), of which only 35% has been utilized so far – 28% for irrigation and environment and 7% for drinking and industrial uses – and the remaining is discharged to the sea. The country's rapid economic development triggered by urbanization, industrialization, and growing population has resulted in increasing demand for domestic and industrial water uses. Climate change has resulted in an increase in the intensity of rainfall during monsoons and subsequent flooding in the low-lying urban areas, causing loss of life, damage to property, and threats to dams and reservoirs. Further, climate change has shifted monsoons resulting in seasonal and local water shortages in water-scarce areas and even droughts in some areas, affecting the food security of the country. In this context, characterizing the key approaches of water resources development and identifying strategies for managing the water demand is a key for sustainable use and management of water resources in Sri Lanka. This paper aims to explore the following seven key approaches in Sri Lanka: (I) trans-basin diversions; (II) new reservoir developments; (III) augmentation of existing reservoirs where feasible; (IV) upgrading existing tanks and reservoirs; (V) increasing water use and conveyance efficiencies, (VI) land consolidation; (VII) laser levelling of the farm plots. Efficient implementation of these approaches is expected to contribute to optimal use of the available water resources in the country's 103 river basins providing significant socio-economic rewards to the nation.

Keywords: climate change; Sri Lanka; sustainable water management; water resources development.

1. INTRODUCTION

Sri Lanka is a small island nation lying between 6° N and 10° N latitude and 80° E and 82° E longitude in the Indian Ocean (Figure 1), with a land area of approximately 6.56 million hectares (Mha), of which 1.3 Mha (20%) is arable land. Population is projected to remain at 21 million between 2022 and 2050. Population densities with respect to total land area and arable land are projected to be 333 people/km^2 and 1680 people/km^2, respectively. The country's rapid economic development triggered by urbanization and industrialization has increased the demand for domestic and industrial water uses.

There are 103 River basins in the country (Figure 2). Rivers in Sri Lanka originate from the central hills of the country and flow towards the sea covering the entire country. Out of 43 billion-cubic-metres (BCM) of water available to use in Sri Lanka, 28% has been utilized for irrigation and environment, 7% for drinking and industrial uses, and remaining 65% goes to the sea without any beneficial use, seeking for efficient use of available water resources (Irrigation Department, 2006, cited in Dharmasena, 2006).

Rainfall pattern in the country varies significantly, due to great influence by the winds from the Indian Ocean and Bay of Bengal. With climate change, the intensity of rainfall during monsoons has increased creating floods that move rapidly to the low-lying urban areas, causing loss of life, property damage and threats to dams and reservoirs. Further, climate change has shifted in monsoons resulting in seasonal and local water shortages in water scarce areas and even droughts in some areas, affecting the food security of the country. This calls for efficient use of water resources in the dry and intermediate zone (Figure 2), which heavily rely on supplement irrigation for plant production. In fact, the irrigation sector plays a dominant role in agriculture production and water resources development in Sri Lanka.

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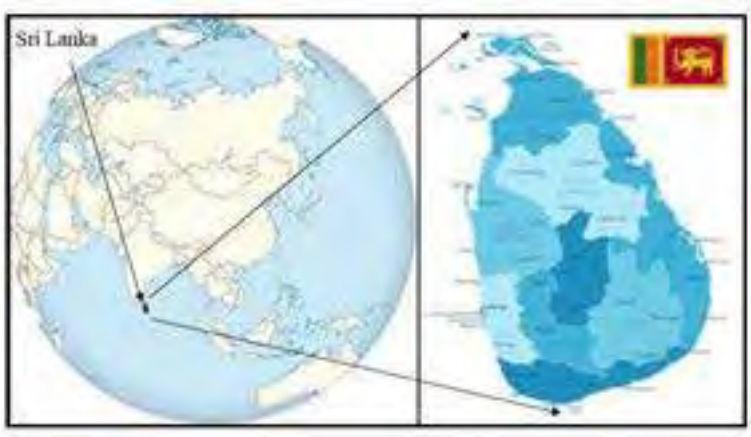

Figure 1: Location of Sri Lanka

There are three distinct forms of manmade perennial water bodies in the country: (I) ancient irrigation tanks which are restored; (II) tanks and reservoirs built during the recent past for irrigation; (III) multi-purpose (hydropower, irrigation, and flood control) reservoirs built under various development projects. In addition, there are thousands of medium-scale reservoirs and small seasonal tanks in the lowland drainage basins. The construction of reservoirs either by partial diversion or by damming a stream is an ancient legacy of Sri Lanka which has now been coupled with modern technologies. However, many irrigations schemes are still performing below the optimal efficiency level.

In this context, characterizing the key approaches of water resources development and identifying strategies for managing the water demand is a key for sustainable use and management of water resources in Sri Lanka. This study has proposed seven approaches of water resources development and management in Sri Lanka. Efficient implementation of these approaches is expected to contribute to optimal use of the available water resources in the country providing significant socio-economic rewards to the nation.

2. STUDY DESCRIPTION

This study is based on the existing databases obtained from a variety of sources and country-specific data sources. Sri Lanka's water sector is the focus of this study because it is the most vulnerable sector in the country with regard to food security and potable water security. The country is increasingly experiencing a water crisis due to rapidly growing demand. There is a crucial need to use available water more efficiently to address the various water demands such as irrigation, domestic and industrial use.

This study consisted of two steps. In the first step, seven potential approaches of water resources development and management are explored. In the second step, socio economic impacts of the proposed water resources development and management options are highlighted.

3. FINDINGS

3.1 River Basins of Sri Lanka

Over 90% of the country is underlain by Pre-Cambrian crystalline rocks of low primary porosities that reduces the infiltration thus, a relatively high percentage of the rainfall is converted to runoff. Large scale runoff follows a radial pattern from the central hills of Sri Lanka covering 103 distinct river basins as shown in Figure 2. These river basins cover about 90% of the total land area of Sri Lanka. It is observed that the 12 large river basins comprise 80% of the total basin area and 25 river basins carry 80% of the total annual runoff to sea. This shows an imbalance in spatial distribution of available water resources, demanding for strategic planning to meet the water demands across the country. The Mahaweli river basin (Yellow coloured in Figure 2) is the largest river basin covering 10,327 Km^2 (16%) of the country. It discharges about 19% of the total runoff to the sea (Katupotha, 2007) therefore, smart water management solutions is required to minimise the runoff (Lee et al., 2015)

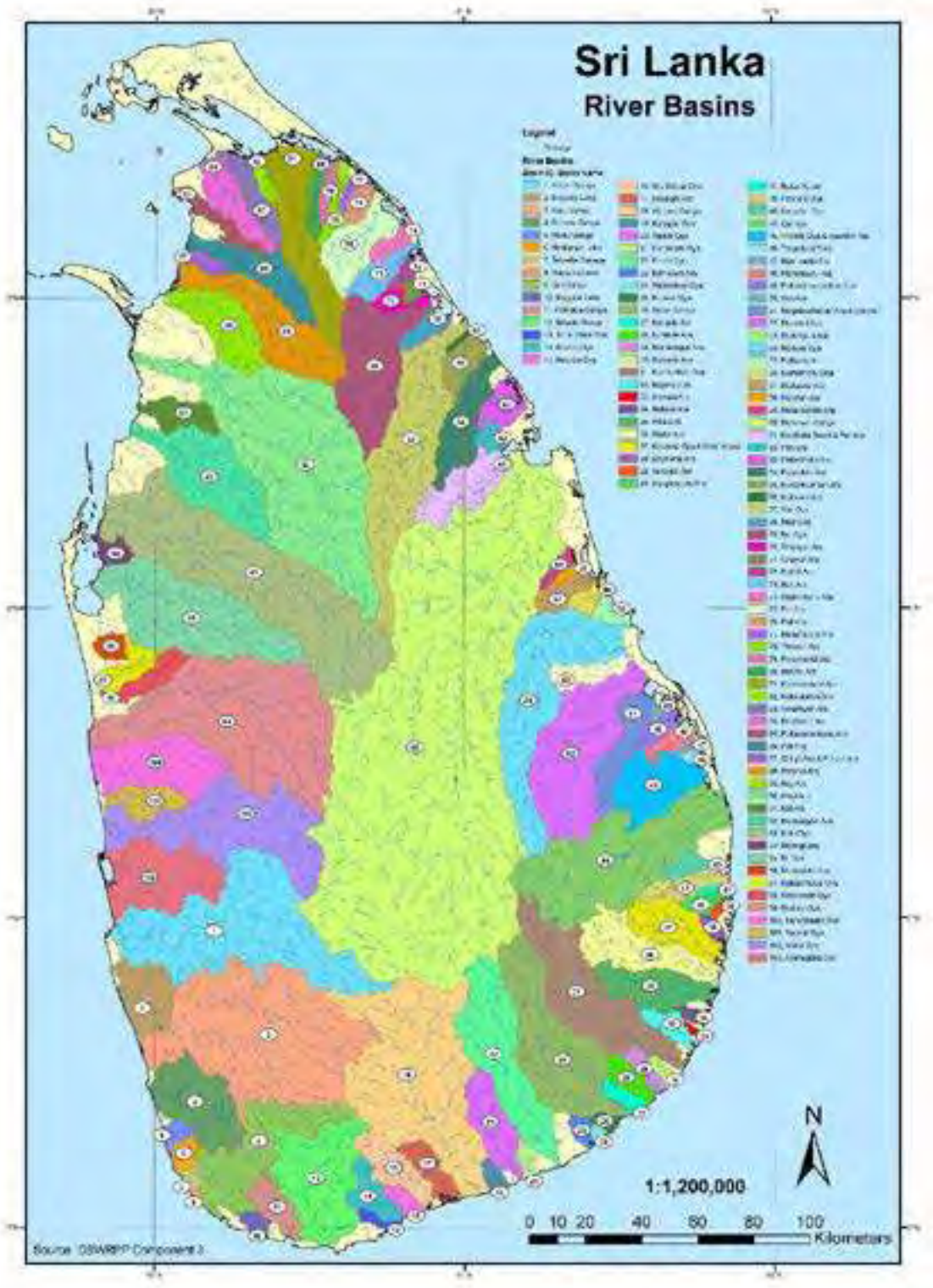

Figure 2: River Basin Map of Sri Lanka (Ministry of Irrigation and Water Resource Management, 2018)

3.2 Agro Ecological Zones of Sri Lanka

An Agro-ecological region represent a particular combination of rainfall, soil and elevation. Sri Lanka has been divided in 24 Agro-ecological regions and 46 Agro-ecological sub regions (Figure 3).

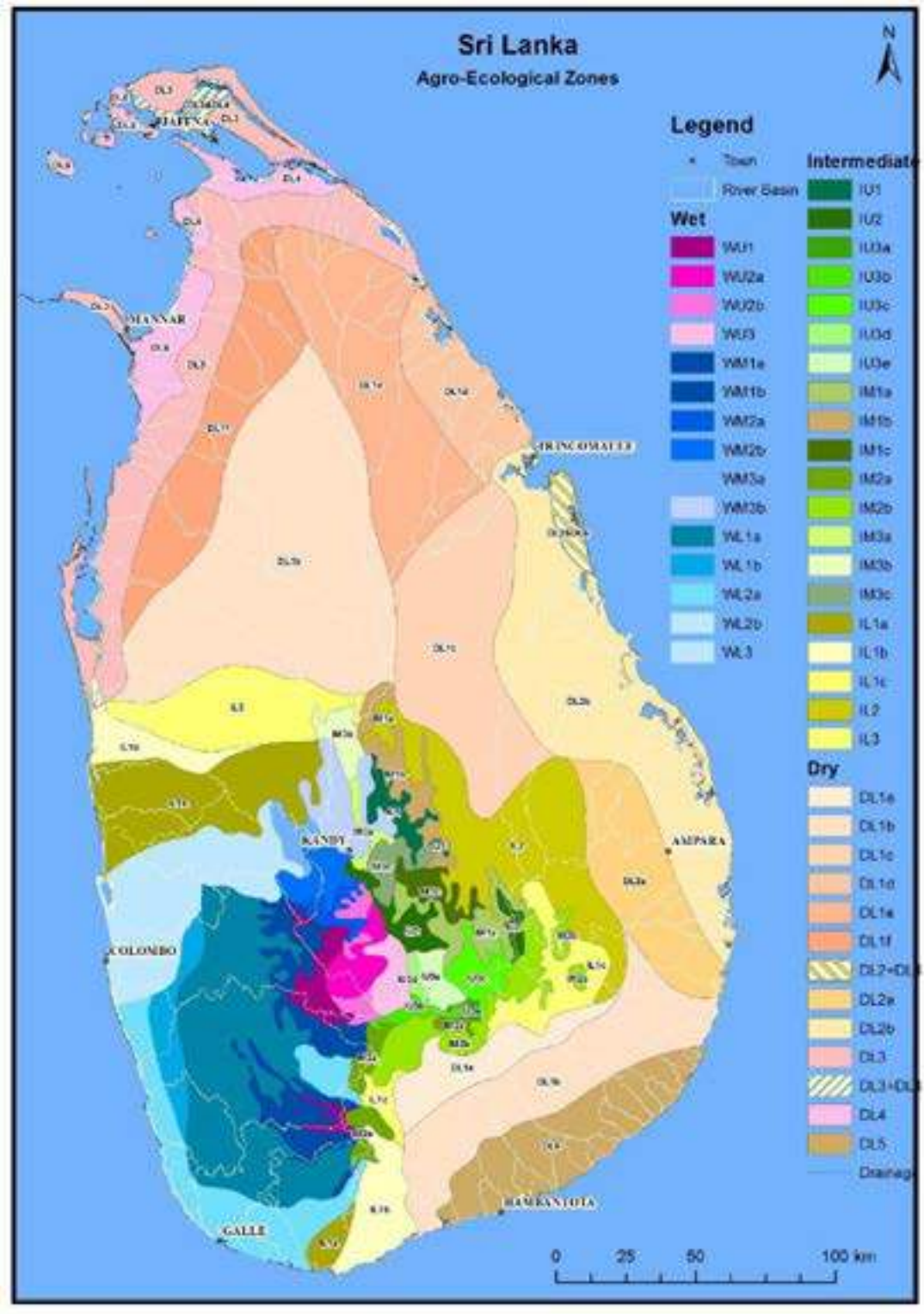

Figure 3: Agro Ecological Zones of Sri Lanka (Ministry of Irrigation and Water Resource Management, 2018)

The 24 Agro-ecological regions have been classified into three zones, based on annual rainfall amount: (I) Wet Zone; (II) Intermediate Zone; (III) Dry Zone. The wet zone receives more than 2500 mm of annual rainfall whereas the dry zone receives less than 1750 mm. The intermediate zone receives between 1750 to 2500 mm of annual rainfall (Katupotha, 2007). The Dry Zone covers over 60% of the land area of Sri Lanka, where strategic water management is key for all human activities including agriculture (Bandara, 1985).

3.3 Available Water Resources Development and Management Strategies in Sri Lanka

Policy directions: There are two main policy directions for irrigation and water resources development and management in Sri Lanka: (I) ensuring water availability to water users; (II) providing water in adequate quantities with improved management and water use efficiency while paying attention to the spatial variation of water availability in the country.

Organisation structures: There are multiple agencies responsible for development, conservation and management of the water resources in Sri Lanka. Large surface water storage systems have been constructed and managed by the State. The primary responsibility of managing surface water for irrigation systems falls under: (I) Irrigation Department (ID); (II) Mahaweli Authority of Sri Lanka (MASL); (III) Provincial Irrigation Departments (PID); (IV) Ceylon Electricity Board (CEB); (V) National Water Supply and Drainage Board (NWS&DB); (VI) Department of Agrarian Development (DAD).

River basin approach: Two agreed approaches of water resources planning, development and management in Sri Lanka include: (I) the river basin should be the basic physical unit for planning and water management operations and needs to be an integrated approach to water resources development, management and protection; (II) the priority should be identified in consultation with the stakeholders.

3.4 Proposed Approaches of Water Resources Development and Management

Due to climate change (CC), Sri Lanka's mean temperature is expected to increase by approximately 0.9 – 4 °C by 2100, compared to the baseline 1961-1990 (Eriyagama et al, 2010). This is expected to be accompanied by changes in the quantity and spatial distribution of rainfall. Although, it is difficult to reach any consensus regarding CC impacts on water resources due to contradicting rainfall projections, the dominant school of thought is that while Sri Lanka will actually gain in terms of mean annual water availability due to CC, there will be increased variability and inequitable spatial distribution (wet areas getting wetter and dry areas getting drier) (Eriyagama et al, 2010). The increase in temperature may lead to an increase in irrigation water requirement for different crops, for example, for paddy it is expected to increase by 13-23% by 2050 compared to that of 1961-1990. It has been projected that coconut yield after 2040 may not be sufficient to cater to local consumption. Reduction in rainfall amount is expected to reduce agriculture production. It is expected that a reduction in the monthly rainfall by 100 mm could reduce per ha tea production by 30 - 80 kg. Due to CC and increased water allocations to sectors other than agriculture, there will be less water available for agriculture. While demand for food will be increasing due to urbanization and food habit change. To address these issues, seven possibilities are identified as the key approaches in water resources development and management in Sri Lanka: (I) trans-basin diversions; (II) new reservoir developments; (III) augmentation of existing reservoirs where feasible; (IV) upgrading existing tanks and reservoirs; (V) increasing water use and conveyance efficiencies; (VI) land consolidation; (VII) laser levelling of farm plots.

(I) Trans-basin diversions: This approach is currently in practice in Sri Lanka under Mahaweli Water Security Investment Program (MWSIP). It consists of constructing bulk water conveyance and storage infrastructure to transfer water from the Mahaweli basin to the water scarce and drought prone areas of the Northern, Northwestern and Eastern provinces of Sri Lanka. The MWSIP has the objective of completing the Mahaweli Development Program commenced in the 1970s whose aims included equitable transfer of water currently flowing to the ocean to water short areas in the dry zone of North-western Province (NWP), Northern Provence (NP) and North Central Province (NCP) for improved agriculture of 100,000 ha of existing and proposed agricultural lands, hydro power generation, domestic and municipal uses. This water transfer is achieved partly through gravity flow and partly by pumping. The Asian Development Bank (ADB) in 2015 started financing MWSIP for phase 1 which includes construction of infrastructure for the diversion of water to NWP and NCP areas. Later in phase 2, a connection would be construction to divert water for NP area. According to the water balance study carried out, it was observed that diversion capabilities are 805 million cubic metres (MCM) along the Upper Elahera Canal for NCP area, 82 MCM along the NWP canal to NWP area, 516 MCM along the NCP Canal to NP area and 282 MCM Pumping at Janaranjana tank to Kaudulla and Kantale reservoirs. Further, it is expected to generate an additional 140 giga what hour (GWh) of hydro electric energy annually to the National grid and 244 MCM of additional water for drinking Ministry of Irrigation. 2020..

In addition to MWSIP, Uma Oya Multi-purpose Development Project, which is also a trans basin diversion project, was nearing completion by the end of 2022. The main objective of the Project is to divert 145 MCM of excess water in Uma Oya basin to Kirindi Oya basin for alleviating the water scarcity in the South-eastern dry zone of the country without affecting the water uses in Uma Oya basin. This will provide irrigation water to around 5000 ha of agricultural land in Moneragala District and 30 MCM drinking and industrial water in Moneragala and Hambantota Districts while generating 290 GWh of hydro electric energy annually to the National Grid.

(II) New reservoir developments: Climate change is expected to increase the variability and inequitable spatial distribution of mean annual rainfall in Sri Lanka (Eriyagama, et al, 2010). To address this issue, new reservoirs need to be constructed to increase the per capita storage as well as to increase the system diversion flexibility. Keeping this in mind, some new reservoirs havebeen constructed and some are being constructed. For example, Moragahakanda, Kaluganga, Uma Oya with downstream development and Yan Oya reservoirs are newly built reservoirs and Lower Malwatu Oya, Talpitigala, Lower Uma Oya, Hasalaka and Heen ganga reservoirs have been planned for construction. The water retaining capacity of Sri Lanka in 2020 was around 8690 MCM and by constructing new reservoirs as planned, the water retaining capacity could increase up to 10,100 MCM.

(III) Augmentation of existing reservoirs where feasible: Cascade systems located in Northwestern Province (NWP) and North Central Province (NCP) are getting inadequate water for cultivation. Therefore, it is proposed to augment these cascades by delivering water from the NWP and NCP canals, respectively. The Northwestern Province Canal Project (NWPCP) will construct 96 km of new canals, a 940 m long tunnel and two 25 m tall new earth gravity dams impounding the Mahakithula and Mahakirula Reservoirs. It will transfer water from the Bowatenna Reservoir and the existing Nalanda and Wemedilla Reservoirs to existing command areas and water supply reservoirs (Asian Development Bank (ADB); 2015). The target area includes 250 minor tanks in Cascades with existing irrigable area of 12,500 ha.

The NCP canal project targets 128 cascade systems in Anuradhapura and Vavuniya districts located in the arid area of the north-central region of Sri Lanka. These cascades include 1,024 tanks covering five river basins: Malwathu Oya; Yan Oya; Ma Oya; Parangi Aru; and Kanagarayan Aru with area of 31,446 ha Japan International Cooperation Agency (JICA). 2018.

(IV) Upgrading existing tanks and reservoirs: It is utmost important to strengthen existing tanks and reservoir to withstand the probable maximum flood as a result of CC. Realising the importance of upgrading existing tanks and reservoirs, Government of Sri Lanka has rehabilitated most of the water infrastructures under the World Bank funded Dam Safety and Water Resource Planning Project. In addition, existing minor/medium tanks have been rehabilitated under the Wari Saubhagya program funded by the Government of Sri Lanka with regard to increasing the tank capacities as well as to strengthen the appurtenant structures of the tanks. Since the commencement of the Wari Saubhagya Program in 2021, rehabilitation works with regard to 1200 rural tanks/anicuts were started and rehabilitations of 1000 rural tanks/anicuts were completed in 2022. The rehabilitation works also included redesigning spills way, improving spill tail canals, and strengthening bunds with redesign of rip raps.

(V) Increasing water use and conveyance efficiencies: Climate change may adversely impact on irrigated agriculture in Sri Lanka. Higher temperatures may change in the timing and intensity of seasonal rainfall that may further contribute to water shortages while, demand for irrigation water is expected to increase leading to a reduction in paddy yield. Therefore, it is proposed to improve water use efficiencies by improving conveyance efficiencies to ensure sustainable agricultural production. In addition to improving efficiencies of the conveyance systems, it is equally important to improve drainage systems to ensure good water management within the farmland. On top of this, introducing advanced technologies are essential to enhance land, water and crop productivity. Hence, after the above interventions, it is expected to increase cropping Intensity from 1.0 to 1.5 in rural tanks, average paddy yield from 4.5 ton/ha to 8 ton/ha and water productivity from 0.2 kg/m^3 to 0.6 kg/m^3.

(VI) Land consolidation: Land consolidation is a must to materialize the concepts of agriculture modernization and farm mechanization. Therefore, it has been proposed to carry out a pilot study on land consolidation in Anuradhapura District, under the assistance of the Japanese Institute of Irrigation & Drainage (JIID) (Ministry of Irrigation. 2019).

(VII) Laser levelling of the farm plots: Laser land levelling (LLL) reduces the duration of irrigation timing and use of water for irrigation, while increasing crop yield. Reduced duration of irrigation corresponds to decrease in energy use for agriculture and thus lowers greenhouse gas emission from agricultural activities. Therefore, increasing the use of LLL contributes to climate change mitigation. In addition, less use of water for irrigation also provides scope for the water saving that can be used in other sectors such as drinking water and industries. In a study carried out by Aryal et al. (2015), irrigation time in laser levelled fields was reduced by 47–69 hour/ha/season in rice and by 10–12 hour/ha/season in wheat while, rice and wheat yields were 7% and 7–9% higher, respectively, compared to traditionally levelled fields.

3.5 Socio Economic Impact of The Proposed Approaches

A large proportion of Sri Lankans are dependent on agriculture for their livelihoods. However, agriculture in the Dry Zone covering 60% of the land area of Sri Lanka, has been heavily impacted by CC. The loss of production from climate-related hazards has affected farmers, and undermined domestic food security as well as livelihood opportunities. Even at the National level, both food security of the Nation and foreign income from crops export are adversely affected due to the impacts of CC. In the intermediate and dry zones, there are large, medium and small-scale reservoirs and water diversion systems providing water for domestic purposes, livestock, crops and inland fisheries for several generations. Farmers in these areas heavily depend on irrigation for agriculture as rainfall alone is not sufficient to meet crop's water requirement. Due to lack of sufficient irrigation schemes, existing irrigation schemes have to irrigate considerable amount of land. Water resources in the area continue to be vital for the life, health and well-being of villagers. However, CC is compounding numerous other constraints affecting the agriculture sector. Services provided by the irrigation systems are adversely affected, contributing to deteriorating water quality and quantity. In the intermediate and dry zones, people's health has also been deteriorated at an alarming rate, for which poor-quality water has been cited as a contributing factor.

With mounting concerns about the impact of climate change on the agriculture sector, the Government of Sri Lanka is paying the highest attention to minimize worsening crisis in the intermediate and dry zones. Several projects and programmes aiming at improving the resilience of the vulnerable communities to climate change have been implemented in the recent times. Many of them have a sector specific focus and some have integrated approaches to mitigate the adverse impacts of climate change. The increased realization of the inter-dependence of various issues and sectors such as drinking water, health and agriculture has become more prominent. It has also been realized that substantial investments in irrigation and agriculture, especially in the intermediate and dry zones, can make the country self-sufficient in rice and other crops. Different studies have shown that in addition to structural and institutional solutions, climate forecasting and early warning systems need to be improved to comprehensively address the impacts of climate change on the agriculture sector. Hence, efficient implementation of the proposed key approaches of water resources development and management in Sri Lanka will strengthen the resilience of farmers to ensure the domestic food security as well as livelihood opportunities in the intermediate and dry zones and beyond. In addition, the implementation of the proposed water management approaches may bring significant positive impacts on poverty alleviation, local economy such as employment and livelihood, land use and utilisation of local resources, water use, while minor negative impact may occur in water pollution, soil contamination, biodiversity, topography, and geographic features.

4. CONCLUSIONS

Intermediate and dry zones in Sri Lanka are suffering from water shortages, particularly during the dry season, resulting in low cropping intensities and thereby reducing crop yields and worsening household food security and incomes. Therefore, transfer of water from the south-central wet zone to the northern dry zones is essential to address spatial distribution in water demand. Construction of reservoirs, conveyance canals/tunnels, and upgrading of existing irrigation infrastructure is equally important to improve water supply to existing irrigation systems. Improvement in water use in the existing irrigation systems through improved water resources planning, development and management are at the centre for socio-economic development, food security and poverty reduction in Sri Lanka. Utilization of water resources can be expanded and improved by: (I) trans-basin diversions; (II) new reservoir developments; (III) augmentation of existing reservoirs where feasible; (IV) upgrading existing tanks and reservoirs; (V) increasing water use and conveyance efficiencies; (VI) land consolidation; (VII) laser leveling of the farm plots. Efficient implementation of these approaches is expected to contribute for maximum use of the available water resources in the country's 103 river basins providing significant socio-economic rewards to the Nation.

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Question 64: What alternative water resources could be tapped for irrigated agriculture?

Quelles ressources alternatives en eau pourraient être exploitées pour l'agriculture irriguée?

Question 65: Which on-farm techniques can increase water productivity?

Quelles techniques agricoles peuvent augmenter la productivité de l'eau?

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