NITI Aayog

DEVELOPMENT MONITORING AND EVALUATION OFFICE

Evaluation of Centrally Sponsored Schemes

Best Practices Compendium:
Water Resources Sector

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Survey Partner: Hansa Research Pvt. Ltd.

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Overview

In August 2019, NITI Aayog commissioned an evaluation of Umbrella Centrally Sponsored Schemes (UCSS) under the Water Resources Sector. A part of this evaluation was focused on identifying global and home-grown best practices, case studies, interventions etc. to strengthen the implementation of various schemes under the Water Resources Sector.

This document is a by-product of the evaluation and presents a compendium of best practices collected through primary and secondary sources, and provides details on implementation mechanisms and impact of such practices. The document is intended to facilitate knowledge sharing and highlighting high impact and innovative practices which have resulted in positive changes for all stakeholders in education sector, both in India and outside.

Thirty one practices have been documented, covering areas like innovation, technology, convergence, involvement of civil society organizations etc. These practices have been included based on their key impact and contribution to the wider public policy context, by highlighting lessons learnt which may be useful for scale-up or cross-adoption.

It is highlighted that the practices included in this document are not exhaustive, and it is acknowledged that various high-impact interventions and activities are being undertaken across the country, based on global and local lessons, which may not have been included in this document.

This document is expected to be used by policy makers, scheme managers, and implementers for learning lessons from proven successful implementation of interventions. The document aims to bring in one place the available resource of best practices and promulgate knowledge sharing.

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1. Enhancing existing resource utilization through effective irrigation system management by WRD department, Madhya Pradesh

Problem statement: During 2009-2011, area under the WRD department in Madhya Pradesh witnessed a sharp decline in irrigation system utilization (i.e. % of irrigation potential utilized against the irrigation potential created) – 32% and 34% utilization were recorded in 2009-10 and 2010-11 respectively. During 2010-11, out of the 2.79 mha area under WRD management in Rabi season, only 0.94 mha (35%) has been utilized.

Solution offered: In 2011-12, the WRD department set a target to arrest the gap between IPC and IPU and increase the irrigation potential utilized to 1.6 mha in rabi season, which is almost a 70% increase over the preceding years. To bridge the gap between IPC and IPU, emphasis on pre-irrigation maintenance, rehabilitation of old irrigation projects and improved management using target setting and monitoring through conventional and web-based tools were adopted.

Some of the key initiatives adopted by the department are summarized below:

- Real-time measurement and monitoring of the available water resources
    - Web-based monitoring of smaller reservoirs and tanks were established, thus eliminating the need of paper-based reporting
    - To avoid internet connectivity constraints, a SMS based module for major reservoirs water readings was developed which was integrated into the WRD Enterprise Information Management System (EMIS)
    - Web-based monitoring system facilitated in disclosure of real-time data for target and actual irrigated area and thus helped in ensuring accountability and transparency; the public information was also triangulated through ground truthing by tail reach farmers, members of WUAs, etc.
    - Regular monitoring by higher management using ICT and video-conferences were set up; water access at tail-end villages was fixed as one of the key performance metrics
- Timely pre-emptive maintenance was given utmost priority to improve system performance

- Pre-Rabi inspections were made mandatory for WRD staff to ensure FSL at main canal. This was complimented by delegation of additional authority to divisional offices to conduct small maintenance work during the month-long maintenance timeframe between mid-September to mid-October

- Last-mile connectivity were ensured through rehabilitation of 4,000 minor irrigation schemes, lining of old earthen canals which led to a jump in area served from 0.37 mha to 0.76 mha in just 2 years

- The above initiatives were supported by adequate and timely budget support from the state government; annual expenditure per unit area increased from Rs. 112/ ha in 2009-10 to Rs. 820/ ha in 2015-16

- Also, participation of WUAs was ensured through delegation of civil works of less than Rs. 50 lakh each to 50 WUAs under Madhya Pradesh Water Sector Restructuring Project

Impact: During 2009-10 to 2015-16, the state succeeded in creating 2.06 mha of which around 64% was achieved through improved management of existing schemes and the remaining through construction of new schemes. The average utilization efficiency increased from 32% in 2009-10 to 85% in 2015-16. All these concerted efforts also resulted in increase in irrigated area from 2.53 mha in 2013-14 to 2.69 mha in 2014-15 and 2.81 mha in 2015-16 and increase in food grain production from 30.07 MT in 2013-14 to 34.09 MT in 2014-15 and 37 MT (expected) in 2015-16.

Sustainability: The sustainability of the irrigation management measures undertaken is bolstered to some extent by the adoption of the following practices: real-time public disclosure of system outputs (like irrigated area) and constant feedback from tail reach farmers ensuring proper accountability and performance of the irrigation staff, commitment of additional regular funds for maintenance by state government through shift in approach from build-neglect-rehabilitate model to one of sustainable irrigation development and management and empowerment of the WUAs.

(Reference: RS Julaniya et al., A Management Approach to Increase Irrigated Area and Production in Madhya Pradesh, India; Dr Tushar Shah (2016) "Har Khet ko Pani?: Madhya Pradesh's irrigation reform as a model"*)*

2. Improvement in water use efficiency through canal automation under PMKSY-AIBP ERM project at Narayanpur Left Bank Canal, Karnataka

Problem statement: The Narayanpur Left Bank Canal system in Karnataka was suffering from various system deficiencies – it was operating at 31.75% WUE (water use efficiency) against the designed efficiency of 51%; water shortages were being recorded in 1,05,632 Ha of tail end villages and 37,000 ha area reported water logging and salinity issues. Some of the key contributing factors were high seepages in unlined portions of canals, pooling owing to excessive siltation, canal breeches and damages in sluices and gates leading to water-logging incidences, unauthorized water withdrawal and violation of rotational/ warabandi schedule affecting water supply at tail ends, absence of any water regulatory system and rampant violation of the cropping pattern and over-irrigation leading to salinity and absence of adequate operators for canal maintenance and operation.

Solution offered: The Krishna Bhagya Jala Nigam Limited (KBJNL) initiated remodelling and automation of the NLBC system along with SCADA implementation and GIS based Irrigation Management Information system (INMIS) to improve the water efficiency. Phase I of the system was launched in 2014 and it was later incorporated under PMKSY – AIBP ERM projects in 2016. As on date, Phase I of SCADA automation and GIS system has been completed while Phase II is in progress. Some of the key projects features are summarized below:

- Implementation of SCADA system: SCADA system software was implemented for monitoring and operation of the automated gates and integration of the system information with the wider information system network.

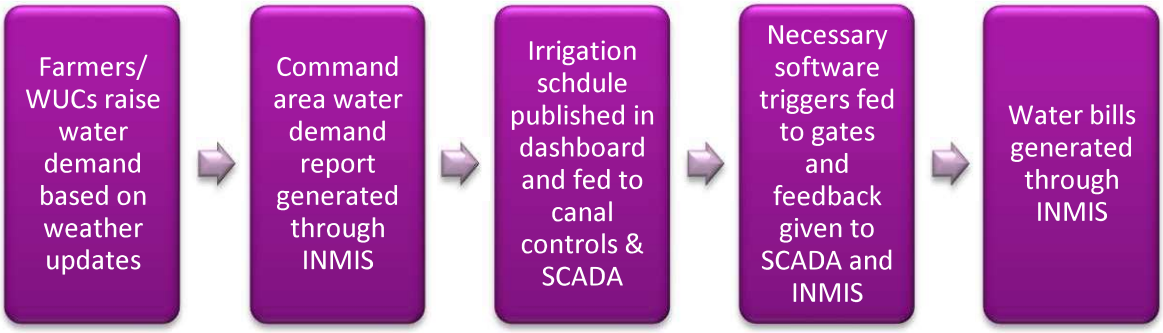
- Automation of the existing gates: All existing radial gates at CR and HR locations were retrofitted with SCADA based electrical and mechanical fitments comprising water level sensors, remote gate control panels, adequate wireless data communication networks etc. for ensuring automatic flow discharges and metering applications. The automated gates are powered by solar powered system.

- Setting up a hybrid wireless data communication network: Considering huge span of the canal network, a main SCADA centre, data concentrator station and slave stations were set up to ensure hybrid wireless data communication network.

- Establishment of an Irrigation Network Management System (INMIS): An INMIS was set up and integrated with existing systems of KBJNL to ensure seamless data flow between the irrigation management staff and end users. This system controls all information related to water demand and usage and is integrated with the SCADA software for canal water regulation and revenue bill generation.

- Setting up information kiosks for farmers: 210 information kiosks were set up for dissemination of information to farmers in relation to irrigation schedule, weather forecasts, state wide commodity prices, access to other important government links. It also stores details of the farmers along with canal jurisdiction offices, cropping pattern adopted and water demands.

A graphical representation of the modus operandi of the entire system is illustrated below:



Outcome:. Automated gate control reduced water losses endemic in manual operations and systematic water allocation and distribution resulted in overall improvement in system efficiency. Water was delivered to the tail end reaches for the first time. Online water demand raising and automatic bill generation facilitated increase in operational efficiency. Improved system responsiveness and dissemination of information improved user experiences. The completion of works is expected to result in improvement in total water use efficiency to the tune of 21.69% - while conveyance efficiency is expected to increase from 60% to 75%, on farm field application efficiency from 53% to 71% and drainage efficiency from 71% to 80%.

Sustainability: To ensure sustainability of the scheme benefits, active involvement of the water users has been initiated through establishment of Facilitation Centres for farmers at Narayanpur and regular conduct of IEC activities in the command area by the

irrigation officials. Interactive information exchange, assurance of demand based supply and performance based disbursements to WUCs are facilitating in generating more interest among the water users.

(Reference: Sidharth Charkha et al (2019)., "Narayanpur Left Bank Canal Automation Project"; documents shared by project authorities during KPMG primary survey; Krishna Bhagya Jala Nigam Limited "Presentation on Improvement in Water Use Efficiency")

3. Facilitating canal restoration and effective WUA operation through community mobilization by specialized agency at Satak Tank project in Khargone district, Madhya Pradesh

Problem statement: The Satak tank minor irrigation scheme at Khargone in Madhya Pradesh was facing deterioration in irrigation system structures with decline in water availability at tail reaches. This was further exacerbated by the lack of any legal provision for enabling the WUAs to impose any collection levy on the water users to conduct regular maintenances.

Solution offered: Action for Social Advancement (ASA), an NGO, was appointed to facilitate capacity building of the WUAs for the Satak minor irrigation scheme in Khargone district. The key objective was to ensure effective functioning of the Satak WUAs and generate adequate funds for the canal restoration process through community collection drive. Some of the steps taken by ASA to ensure the same are summarized below:

a. Community mobilization through awareness campaigns:
    - ASA held series of awareness campaigns using village wise quiz competitions, local folk media (Kalki-turra) and wall paintings. 36 community volunteers were trained as Jal Praharis, who also helped later in the water distribution process. Baseline surveys were conducted to understand the needs of the farmers and also agriculture support services were provided.

b. Capacity building initiatives:
    - A training module was prepared by ASA – in the 1st phase emphasis was put on communicating the rights, role and responsibilities of the WUA and its members while in the 2nd phase, attention was focussed on developing the institutional capacity of both the WUA and WRD through training programmes

on water distribution management, gender sensitization and dispute resolution. Training were conducted on social audit.

- Exposure visits were conducted to neighbouring states

c. Community contribution collection drive:

- To ensure a transparent collection process, a formalized instrument of agreement 'anshdaan anuband' was introduced between the WUA and the users. Contribution receipts were given to the payees and collected fund was deposited in the common bank account
- To encourage more collection, letters of appreciation were issued to the payees and printed posters were pasted at the gram choupal

d. Gender mainstreaming

- WUA voting rights were extended to spouses of the existing WUA members through necessary amendment in the PIM act.
- Extensive awareness campaigns were conducted to sensitize the villages about women participation and franchise rights
- Self-help groups were set up to ensure women empowerment

Impact:

- Community contribution by farmers touched 20% of the cost of physical works which exceed the 10% target set by the authority (ICEF). Such contributions for canal restoration also helped to create a sense of ownership among farmers.
- Increase in irrigation rotation frequencies resulted in 20-30% improvement in wheat production (in Balkhar village), increase in jobs for agricultural laborers with greater adoption of labour intensive commercial crops like cotton and chilli which greatly helped the landless labourers
- Around 73% of spouses of landowners casted vote in the last reported WUA elections
- Social audits were conducted in every 6 months

Sustainability: Hand-holding activities and capacity building programmes organized by ASA improved the technical competency of the WUAs. Also the half-yearly social audits and the transparent mechanisms set up for fees payment and undertaking of physical works helped to instil of sense of trust among the WUA members. However, in terms of sustainability the following concerns were reported:

- Scope for further hand-holding of sub-committee member and women participants were reported for ensuring sustenance of their operation
- Continuation of equitable water distribution particularly to tail end farmers is dependent on the physical condition of the canal structures to operate at full discharge capacity

- Financial sustainability of the WUAs need to be ensured by retaining their ability to levy and collect taxes and through establishment of backward and forward market linkages to agricultural activities.

(Reference: Action for Social Advancement, "ICEF-M.P. WRD Project on Participatory Restoration and Management of Irrigation Systems by Water Users Associations in M.P.")

4. Ensuring effective convergence with other government programmes like MNREGS at Dhar district, Madhya Pradesh

Problem statement: The CAD guidelines have proposed executing works in convergence with existing watershed programmes and MGNREGA schemes; however the extent of actual convergence achieved was reported to be quite low due to absence of any detailed enabling policy guidelines and tardy implementation of the same by the implementing authorities.

Solution offered: In 2008, the MP Panchayat and Rural Development department formulated two schemes for facilitating development and management of irrigation infrastructure using MNREGS funds. Some of the key features of the implementation strategy is highlighted below:

- Enabling policies: MNREGS funds used for canal rehabilitation and construction of field channels under Sahastradhara scheme.
- Joint planning: Joint walk-throughs conducted with farmers by NVDA to prepare detailed estimates of minor canal repairs followed by submission of technical sanction plan by Executive Engineer to the Panchayat.
- Faster fund disbursal: Funds were directly transferred to the WUA's account by the Jilla Panchayat (thus bypassing the Gram Panchayat)
- Hand-holding by specialized agencies: NVDA together with the appointed NGO Development Support Centre (DSC) provided technical support to the WUAs in relation to technical planning and estimation, MNREGS labour orientation, training of supervisors (/ mate), preparation of job cards, bookkeeping and accounting. Exposure visits for WUA members were arranged by DCS to successful projects in Madhya Pradesh, Gujarat and Maharashtra. 20 local youths were trained as Kolaba Sahayaks/ mate of MNREGS works. IEC and awareness campaigns involving graphic and visual shows were arranged to sensitize the villagers.

- Implementation by WUAs: The WUAs got the opportunity to carry out the R&M under the MNREGS assisted canal repairing works themselves, thus obviating the need for appointment of departmental/ private contractors.

Impact:

- 147 km of canal network was repaired and 93 km of earther field channels were created in Maan and Jobat projects. New field channels facilitated water access to tail end users in Kukshi block.
- Direct transfer of MNREGS funds to WUAs instilled a sense of ownership and accountability among the members.
- 6,500 ha of additional area was brought under irrigation. Irrigated area in Maan and Jobat projects increased from 7000 ha and 5000 ha in 2007-08 to 11,400 ha and 7,700 ha in 2009-10 respectively.
- The farmers reported increase in net income by Rs. 10,000/ ha. Majority of the farmers were able to irrigate more than 50% of their land and sow two crops in a season by adoption of new crops like wheat, cotton, chilly, pulses, etc.
- Substantial increase in groundwater was reported in areas where field channels have been constructed.

(Reference: Tapan Patel et. al. (2010), "Best Practices on MNREGS Assisted Canal Rehabilitation under Participatory Irrigation Management in Dhar, Madhya Pradesh).

5. Ensuring proper maintenance of field water courses through innovative community contribution facilitated by Khairani WUA at Baksa, Assam

Context: The Khairani WUA was set up by a group of volunteers in Assam to restore flood mitigation structures. It was formally registered in 1990s mainly with an intention to streamline the receipt of government subsidies and technical assistance of the irrigation officials. As on date, the WUA is functioning effectively with 14 Central Level Committees (CLCs) and has adopted certain set of uniform working rules and compliance methods. Considering the economic position of the WUA members where a large chunk of the members hail from scheduled tribes and backward classes with agriculture as the primary source of income and thus the economic, an innovative contribution system has been developed.

Solution: The WUA's working rules have no provision for monetary collection of water taxes. All the taxes are collected in the form of labour and activities undertaken by WUA.

Participation and contribution of labour for WUA's activities are mandatory for each member, failing which stiff monetary penalty of Rs. 150/ day is imposed. Absence in more than 3 consecutive days attracts an additional penalty of Rs. 125/ day. Additional penalties are further applied in case of absence in more than 50% working days. In case of non-payment of penalties, strict actions like seizing of properties worth the penalty fees are applied. Also, fines are imposed in case of withdrawal more water compared to the allotted one. The penalty fees form an important source for conducting repair and maintenance organization.

(Reference: Vasant P. Gandhi et al., November 2019, Institutional Structure, Participation, and Devolution in Water Institutions of Eastern India)

6. Enhancing water storage capacity through community-based tank desiltation works: Mission Kakatiya, Telangana

Problem statement: While agriculture in Telangana has traditionally been dependent on tanks; most of these ran dry by 2014 owing to continued negligence and reducing tank storage capacity. Hence, dependency on groundwater increased and water table in the vicinity depleted.

Solution offered: "Mission Kakatiya" was launched by the Government of Telangana in 2014 to prioritise restoration of 46, 531 minor irrigation tanks to their original capacity towards effective utilisation of water allocated for minor irrigation sector (255 TMC).

The strategy adopted is as follows:

- Identification and prioritisation of tanks:
    - Reconciliation survey was conducted to ascertain number of different types of minor irrigation sources viz. percolation tanks, private kuntas and small tanks for restoration.
    - The tanks for which repair works had already been undertaken under programs like RRR/ state plan were identified.
    - The tanks with greater ayacut and those which had not been covered under any other program were given priority. The order of prioritisation was decided in consultation with district minister/ local MLA/ public representatives.
- Civil works:
    - Tanks were desilted, dilapidated sluices/ weirs were repaired and bunds were strengthened.

- Irrigation channels were re-sectioned to ensure smooth distribution of water to fields.

- The importance of the program was publicised and end-users were motivated to participate.

- Interdepartmental coordination was ensured by constitution of District Level Implementation, Monitoring and Evaluation Committee; which constituted members from irrigation and CAD, agriculture, fishery, rural development, forest, fishery, revenue, groundwater and public relation department.

Impact: By March 2018, the program was successful in restoration of 22,500 tanks, leading to outcomes like increased water storage capacity and enhanced on-farm moisture retention. It resulted in reduction of gap ayacut by 63%, agricultural diversification, reduced use of chemical fertilisers, enhanced on-farm water retention, improved soil nutritive value and water accessibility to small and medium farmers. Additionally, it also led to development of fisheries and livestock, increase in groundwater levels and income augmentation of farmers.

(References: Composite Water Management Index by NITI Aayog, August 2019. Selected best practices in Water Management, prepared by NITI Aayog with the support of Teri University, August 2017. Mission Kakatiya, Irrigation and CAD Department, Government of Telangana*)*

7. Ensuring water security through community-based tank desiltation: Gaalmukt Dharan Gaalyukt Shivar Yojana

Problem statement: Out of 580,000 tanks of various sizes spread across India, Maharashtra has the highest i.e. 42% of irrigation tanks. Since these come under the purview of state government; various line departments are involved in management while community involvement is limited. As a result of siltation, compounded by lack of regular maintenance; the storage capacity of these traditional structures diminished, leading to cascading effect on environmental and socio-economic condition of the state.

Solution offered: Gaalmukt Dharan Gaalyukt Shivar Yojana' (silt free water reservoirs and silt applied farms), launched in 2017, is an initiative by Maharashtra Government towards ensuring water security through activities like community-based tank

desiltation under RRR and WDC, along with awareness generation for efficient water utilisation.

- A Desilting Policy Committee was established by the state, which recommended desiltation of 31,459 small dams and water tanks in the state.
- Considering its potential in improving drought resilience, the program was included as part of revised state water policy in 2019.
- Active involvement of CSRs/NGOs was promoted: While the state government provided fuel subsidy; machine rent cost was contributed by community/ pooled through CSR/ NGO funds.

Impact: Impact evaluation study by The Nature Conservancy and Watershed Organisation Trust indicates:

- Increase in water holding capacity and improved organic carbon in the soil after silt application. However, the effect was found to vary depending on soil characteristics: texture, bulk density and water holding capacity.
- The total area under cultivation increased during both Rabi and Kharif season while proportion of rainfed and wasteland areas reduced. Additionally, area under water saving technology increased by more than 2 times.
- A reduction in per acre cost of fertilisers was observed for major crops.
- The average annual income was found to increase from Rs. 37, 489 to Rs. 92, 855. This further led to enhancement in socio-economic status of farmers:
- With benefit-cost ratio of 1.31 (for three tanks), desiltation was found as economically viable activity, even when only enhancement in soil fertility was considered. Other direct-indirect benefits of desiltation like increased water storage capacity and improved soil texture were not accounted for in calculations.
- Other impacts: reduction in migration, increase in biomass leading to more fodder for livestock and groundwater recharge.

(References: Zade et al, 2020. 'Gaalmukt Dharan, Gaalyukt Shivar (Tank Desiltation) Scheme in Maharashtra, India: Policy Concerns and the Way Forward', 16/0 Law, Environment and Development Journal. Sood et al., 2018. 'An Impact Evaluation Study and Proposed Guidelines for Water Tank Desiltation in Maharashtra' by The Nature Conservancy, India and Watershed Organisation Trust.)

8. Technical strategies to operate minor and medium irrigation schemes towards improving groundwater systems: Vavuniya, Sri Lanka

Problem statement: With increase in abstraction of groundwater resources due to rise in population, the pressure on groundwater resources is increasing. This has led to issues like declining water table and waterlogging.

Solution offered: A regional aquifer simulation model was developed for a restricted catchment: 185.23 km^2 in Vavuniya district, Sri Lanka. This was used to find out operational policy favouring groundwater conservation. It found:

- Case 1: Foregoing cultivation by 25-35% for two consecutive seasons reduced water table loss by 45-65% in 80% of the catchment area.
- Case 2: Peripheral boundary treatment to reduce permeability by 35-45% lead to rise in water table by 0.457-0.838 m in areas closer to treated boundary during recharging season.
- Case 3: Combining 1&2 i.e. peripheral reduction in permeability by 35-45% and foregoing cultivation by 45-55% lead to increase in water table by 1.067 - 1.448 m during discharge season. Similar trend was observed during recharge season but to lesser extent. Overall, 60-70% of loss in water table was reduced between two seasons in 95% of the catchment area.

Envisaged impact: The gain in water table would reduce the cost of energy (fuel/ electricity). This shall increase the degree of economic cultivation per unit irrigation water, thereby increasing economic crop yield. It would also indirectly contribute to GDP and GNP.

(Reference: Sivakumar, 2013; Conjunctive Use of Surface and Groundwater to Improve Food Productivity in Vavuniya District in the Dry Zone Area)

9. Comparative Benefit-Cost analysis to evaluate most appropriate material for canal lining: Case Study of Neera Devdhar Canal

Problem statement: Water flowing in canals is prone to seepage and evaporation losses. Seepage losses are dependent on channel geometry while evaporation losses are proportional to area of free surface. Increased seepage losses in unlined canals may lead to rise in water table, resulting in waterlogging and soil salinity. This would reduce cultivable area and may further need installation of costly drainage systems.

Solution offered: The benefits of canal lining and corresponding B-C ratio were evaluated in Neera Devdhar canal. The results obtained upon lining are as follows:

	HDPE + Concrete	HDPE + Shotcrete	IITD + Concrete	IITD + Shotcrete
B/C ratio	10.43	7.33	9.59	6.88

- Seepage losses were found to reduce by 70% upon lining with concrete while they reduced by 90% when lined with shotcrete. However, these materials would also require continuous maintenance due to expansion and contraction of cracks.
- The study concluded HDPE sheets as best option for lining to aid in reducing seepage losses from lining cracks. Subsidies are also provided by the government to use these sheets for lining.
- Concrete and shotcrete may be used as covering, towards protecting HDPE from damages.
- Further, sensor system (Radar/ bubbler) may be used to evaluate discharge at different sections of canal. This could aid in locating section-wise seepage losses.

Impact: With the help of HDPE sheets and sensor system, seepage losses in canal may reduce up to 100%. This would lead to increase in command area, reduce requirement for maintenance and increase channel capacity.

(Reference: Kadu, Rajmane and Hailkar (2017), 'Case Study of Neeru Devdhar canal seepage losses and canal lining0, International Journal for research in applied science and engineering technology.)

10. Solar Powered Community Lift-Micro-irrigation Project in Talwara and Hazipur Blocks of District, Hoshiarpur

Problem statement: The Kandi belt comprising 10% of the total area of Punjab is mostly rainfed. The area suffers from severe shortage of drinking water and poor socio-economic conditions of the farmers. Hoshiarpur district falls in this Kandi belt. Soil erosion is another major concern in this area as during monsoon period most of fertile soil gets eroded, resulting in unavailability of assured irrigation source coupled with soil degradation. Being sub-mountainous and remote area, the electricity supply is highly unreliable. The productivity is also very less as the farmers are only able to do mono-cropping and that too depends on rainfall only. The Govt of Punjab, taking stock of this situation, constructed Kandi canal which became lifeline of Kandi area. However, there was another problem in that area. The right canal bank being at lower elevation is possible to be irrigated through gravitational flow whereas the left canal bank being at higher elevation could be irrigated utilizing lift irrigation only.

Solution offered: The Govt of Punjab approved a Solar Powered Lift-Micro-irrigation project with total cost of Rs. 42.10 Cr. with funding from under RKVY and NABARD. The project was started in January 2015 and commissioned on 7th August 2017. The project is operated and maintained by hand holding local community and Water User Associations (WUA's) for initial 7 years thus providing gestation period for farmers to develop their fiscal and technical capacity. The project was designed as integrated solar powered, fully computerized and automated micro-irrigation project. The solar energy gives leverage over grid-based systems. The micro-irrigation and automation (SCADA, Remote Terminal Units, Hydraulic Valves, Level Transmitters, Pressure Transmitters etc.) help in water conservation and equitable distribution of scarce resource respectively. The project consists of 3 main lift points from Kandi canal and booster stations (sump wells) are also provided at various points to enable water to reach at higher elevations. A total of 1,200 households and 8,500 beneficiaries have been benefitted by this project. The project beneficiaries include 3,730 women and 2,450 SC people.

Impact:

- Increase in income has been observed in the range of around 85% to 229% (Maize: 85%, Wheat: 127%, Mustard: 125%, Sesamum: 229% etc.)
- The project has given employment opportunity to local youth, who are working in the project as helper, guard etc.

- People who earlier migrated for work have started cultivating their own lands. Linkages established with local processing units are also helping these farmers getting instant cash return
- The farmers are getting demo of best practices, knowledge about latest agricultural practices, water conversation technologies etc. through the established training centres and experts from prestigious institutions. These training centres are also providing livelihood-based training sessions to landless and women community
- Due to proximity of urban areas, allied activities such as dairy farming is also growing

Replicability: Water scarcity issue is also prevalent in many other states (e.g. Haryana, Rajasthan etc.) in India. In those states, many areas suffer from unreliable electricity supply. Hence, similar model can be adopted across those areas to leverage benefits of micro-irrigation and improve socio-economic condition of farmers.

Sustainability: Being solar energy based, the project has ensured sustainable resource use in terms of energy. The project has focused on sustainable water resources management through efficient water use by micro-irrigation systems. Training centres are educating the beneficiary farmers and WUAs for effective O&M of irrigation assets, sustainable use of water etc., helping in proper utilization and maintenance of irrigation assets.

(Reference: https://dswcpunjab.gov.in/contents/success-stories/Solar-Powered-Community-Lift-Micro-Irrigation-Project.html)

11. Ramthal Drip Irrigation Project, Ramthal, Karnataka

Problem statement: Around 60% water was being lost due to conveyance, evaporation, percolation and seepage in traditional methods of canal network and flow irrigation. Being a drought-ridden state, it was difficult for Karnataka to afford such huge water loss. There were other problems in the canal command areas including inequitable distribution of water, salinity problem due to excess irrigation, gap in design and actual area and flow, poor drainage, less water at the tail end of canals, no measuring device or control structures, uneven crop growth and yield, soil deterioration at canal head ends due to water logging and poor drainage etc.

Solution offered: The Govt. of Karnataka launched Asia's largest drip irrigation programme under Stage II of Ramthal Lift Irrigation Project in 2017. This project is an example of Integrated Micro-irrigation. In this project, canal water is delivered directly using HDPE/PVC piping network to irrigate around 24,000 ha area. Salient features of this project:

- Mega community drip irrigation project
- Total beneficiary: More than 15,000 farmers
- Infrastructure cost borne by the Govt.
- System operation through wireless automation
- O&M of system for first 5 years by Krishna Bhagya Jala Nigam Limited (KBJNL)
- Formation of WUA and marketing linkages

Impact:

- 90% additional area coverage using same quantity of water (i.e. 12,571 ha area covered in stage I by flood irrigation through canals vs 24,000 ha area covered in stage II by integrated drip irrigation. In both stages, water requirement remains same i.e. 2.77 TMC)
- Doubled the no. of beneficiaries with same resources
- Equitable distribution of water irrespective of topography and distance of farm from the water source
- Improved standard of living of project beneficiaries
- Improved crop quality and produce

Replicability: Similar integrated micro-irrigation project can be adopted in other states where canal or other assured irrigation source is available. Govt. of Haryana is also planning for similar project powered by solar energy.

Sustainability: O&M by 3rd party, participatory irrigation management by WUAs and marketing linkages will be helpful for maintaining sustainability of this project.

(Reference: http://pmksy-mowr.nic.in/aibp-mis/Manual/Ramthal%20Micro%20Irrigation,%20karnataka.pdf; http://www.kbjnl.karnataka.gov.in/kbjnlenglish/content/ramthal-marol-lift-irrigation-scheme)

12. Upliftment of SC farmers to mitigate migration: A case study of Jangalahalli village of Kapalamadagu GP in Kolar (Karnataka)

Problem statement: Under Batch-4 PMKSY-WDC programme implemented in Mulbagal taluk, Schedule Caste (SC) farmers having aggregate landholdings of up to 10 hectares in Jangalahalli village of Kapalamadagu GP were migrating to towns in search of jobs. Their lands were unproductive and were left barren/fallow.

Solution offered: After project intervention due to land treatment from upper reach to lower reach and via various watershed activities such as bunding, construction of Nalabund and check dams, agroforestry, dry land horticulture, boulder checks and diversion channels have converted uncultivable land into productive cultivable lands. Water stored in the water harvesting structure has helped the farmers to undertake intensive cultivation of commercial crops.

Impact: In Jangalahalli village, watershed development programme has not only raised the income level of SC farmers but also facilitated them to sustainably settle down in their farm, thereby reducing migration and poverty.

Sustainability: By overall upliftment of farmers' economic condition along with sustainable management and conservation of soil and water the watershed project in Jangalahalli village has contributed substantially towards the sectoral challenge, national priority and Sustainable Development Goals (SDG). The intervention has helped the farmers to sustainably settle on their land with adequate sources of livelihood.

(References: As reported by WCDC of Kolar in the written response to the questionnaire)

13. Construction of Recharge Shafts to improve groundwater table; a Case study of Tamil Nadu

Problem statement: Recharge of groundwater sources in a cost-effective manner

Solution offered: SLNA of Tamil Nadu reported that they have adopted the construction of Recharge Shafts to improve the groundwater table as a cost-effective and innovative intervention. It was reported by the SLNA that Recharge Shafts are the most efficient and cost-effective structure to recharge the shallow aquifers. Recharge Shafts of 0.5 to 1 metre diameter and 10 to 15 metres deep were constructed across the state watersheds.

Impact: The impact reported was the rise in groundwater level from 0.33 meter to 3.28 meter in the intervention watershed areas of Tamil Nadu.

Sustainability: Given the success and cost-effectiveness, so far 17,879 Recharge Shafts have been created with an expenditure of Rs. 68.10 Cr. These structures are sustainable and are effective for long duration leading to sustainable recharging of groundwater sources.

(Reference: Based on written response against questionnaire submitted by the SLNA of Tamil Nadu)

14. Environment Sustainability: A Case study of Salulamang village in Mokokchung district of Nagaland

Problem statement: Salulamang is one of the few villages in Mokokchung district where public transportation is not available. The main occupation of the villagers was Jhum cultivation and Jhum cultivation was practised extensively before the intervention of PMKSY-WDC. Around 60 households were engaged in Jhum cultivation over a total area of around 90 Hectares in 2012.

Solution offered: In the initial 2-3 years, mixed cropping was done in the rubber plantation area. About 27 units of piggery have been initiated under livelihood activities, rubber plantation has been encouraged on a large scale and setting up of micro-enterprise unit has provided a source of income for the villagers. Technical inputs on land use and construction of engineering structures, viz. water harvesting structures and gully plugs have made water available for use in fields and other plantation areas. The technical assistance provided through the programme for management of orange plantation has been beneficial to the farmers and contributed to the success of the activity, eventually increasing production and generating more income for the farmers.

Impact: However, after the intervention of WDC, Jhum cultivation has gradually decreased and the villagers have taken up rubber plantation. During the study and monitoring visits by the evaluating agency, it was noted by the agency that the Land Resources Department has been performing commendably in reaching out to villages through PMKSY-WDC. The average land under Jhum per household has exhibited a decreasing trend, i.e. 1.5 Hectare per household in 2012 to 0.75 Hectare per household in 2016, resulting in a reduction of the total area under Jhum to 22.5 Hectares (2016) from 90 Hectares (2012).

Sustainability: Green coverage created by plantation crops over abandoned Jhum land provides safe shelter for wildlife, birds, insects and microbes. Thereby, through watershed intervention and promotion of economic activities in the villages under PMKSY-WDC, there has been a significant reduction in Jhum practice in the state which has a favourable impact on the environment.

(Reference: Various social impacts of PMKSY-WC with special focus on reduction of Jhum cultivation, 2016, MELD in Nagaland-NABARD Consultancy Services Pvt. Ltd.)

15. Recharge of groundwater sources; Case Study of Gokak Taluk of Belagavi district

Problem statement: The latest Assessment of Dynamic Groundwater Resources of the State 2017 is made jointly by the Central Ground Water Board and the State Ground Water Department. As per the last report, Gokak taluk was categorised as "Semi Critical" based on the stage of groundwater development ('Semi Critical' is where Groundwater extraction is between 70 to 90%).

Solution offered: Karnataka Watershed Development Department is implementing PMKSY-WDC (formerly IWMP) in a phased manner all over the State. As per the department, the watershed development activities have helped in water conservation, groundwater recharge, reduction in soil erosion, increased productivity etc. The project (IWMP-20/11-12) was sanctioned in the year 2011-12 to treat an area of 2080 hectare in Gokak Taluk of Belagavi district at an estimated cost of Rs. 312 lakh under Batch-III. In an area of about 548 hectares bunding was done and 127 Water Harvesting Structures (WHS) was constructed by spending Rs. 265.77 lakh.

Impact: The interventions made through watershed development activities in the form of rainwater harvesting structures have led to a spurt in recharge of the aquifers in the area. Thus cumulatively 20,310 cubic metres of rainwater is made available for recharge to groundwater body in the area annually. However, the watershed development activities have helped in augmenting the water resources in the taluk and has restored the taluk to "Safe" category. The farmers were favourably impacted as their wells were getting groundwater inflows as before. The effect of watershed activities observed in the rejuvenation of defunct wells is demonstrated as the irrigated area increased from 0 to 37 acres in Kharif and 0 to 25 acres in Rabi.

Sustainability: The permeable topsoil and weathered and fractured rocks underneath are the factors that lead to good recharge. Such recharge has rejuvenated the defunct wells, can sustain additional wells in the area, and also can sustain the water yield from wells over an extended period.

(Reference: Rejuvenation of defunct Dug wells due to watershed development activities', 2020, Watershed Development Department, Government of Karnataka.)

16. Sustainable livelihood opportunities for women; Case Study of Yeiikha and Yow Miijaiim Self-Help Groups (SHGs) in Phek district of Nagaland

Problem statement: Providing sustainable livelihood opportunities to landless and women

Solution offered: Land Resource Department of Phek District facilitated the formation of two SHGs, namely; Yeiikha SHG & Yow Miijaiim SHG in the year 2017 with ten women members in each group. The primary purpose of collectivizing and forming the groups was to improve the socio-economic status of poor rural women, especially to enhance their income. Seed money amounting to Rs. 10,000 each was given to both the groups. Tree beans (Parkia), a very important multipurpose tree species, having many utilities such as rich nutritional value as it is abundant in minerals and vitamins, medicinal value, use as insecticides and pesticides, enriching the soil by fixing atmospheric nitrogen, etc. Besides, tree bean (Parkia) the SHG members are also engaged in weaving and kitchen gardening.

Impact: Each SHG has been earning Rs. 40,000-50,000 annually from the sale of Parkia. The Self-Help groups collect the entire produce of their village and transport it to the nearest market which is 114 km away from their village and sells it.

Sustainability: The group maintains cash book, savings book, meeting minutes register and all other relevant registers thereby facilitating their financial independence in the long run. The livelihood component of the programme has helped the women in the SHGs to earn a sustainable livelihood thereby contributing to equity.

(Reference: Success stories: Bringing visible changes in the economy of the rural community, Booklet provided by SLNA of Nagaland)

17. From source of sorrow to place of prosperity, Swan River in Himachal Pradesh

Scheme details:

- Scheme Name: Channelization of Swan River
- Target Area: Swan River watershed, Una district, Himachal Pradesh
- Total Project Cost: Rs. 945.49 Cr.
- Broad Scope:
  - Afforestation
  - Civil works for soil and river management (check dams and embankments, etc.)
  - Soil protection and land reclamation (terracing and soil addition, etc.)
  - Livelihood improvement activities (agricultural development, small-scale infrastructure installation, income generating activities, etc.)
  - Institutional building (purchase of equipment, training, hiring of facilitators, etc.)
- Implementing Agency: Forest Department and Irrigation and Flood Control Department, Government of Himachal Pradesh
- Area covered: 95 Gram Panchayats of Una District, within which 61, 900 Ha of land were treated to protect the land from soil erosion and floods, regenerate the forest cover and enhance agricultural productivity.

The Problem: District Una is situated on the bank of Swan River, which flows from North to West direction. This river during monsoon period creates devastating floods in District Una. Due to continuous silting, the bed of Swan River had risen constantly due to which meandering action took place. The width of the river had increased, and fertile land situated on both banks was turning barren due to silt deposits. Besides, some of the fertile land situated near the banks had been lost during the floods.

Approximately, 10,000 ha. of agriculture land was affected by floods and annually 2,000 ha. of fertile land were not being cultivated owing to fear of floods. During the past 10-12 years extensive damage to civil structures, properties, human life and livestock had been reported. The estimated loss to crops and property was to the extent of Rs. 15 Cr. per annum.

Solution offered: The forest department was the nodal department for the project. The participating line departments were agriculture, horticulture and animal husbandry. The overall administration, planning and implementation of the project was with the Project Management Unit (PMU). The Chief Project Director was the overall in charge of the project and responsible for all administration and financial matters and maintaining liaison with the government. He was assisted by a team of Additional Director, Joint Director (administration), Deputy Project Directors Agriculture, Horticulture, Animal Husbandry, Social Development Expert, Environment Education Expert and Training Expert. Three Project Implementation Units were established at Una, Amb, and Gagret headed by the Deputy Directors. At Panchayat level Panchayat Development Committees (PDCs) were established in all the 96 Gram Panchayats of the Project area.

The Detailed Project Report for providing embankments on both banks of Swan River for a length of 16.67 km. from Jhalera bridge to Santokhgarh bridge in Phase-1 was prepared based on mathematical modelling studies carried out by Central Water Power Research Station (CWPRS), Pune. This project amounting to Rs. 102.71 Cr. was accepted by the Technical Advisory Committee of Ministry of Water Resources, Govt.

of India. To adopt an integrated approach, it was proposed to treat the entire catchment instead of just the sanctioned portion of 16.67 km. In all 42 most vulnerable points requiring emergent flood control works were identified. Out of these, 40 have since been completed at a cost of Rs. 9.28 Cr. An additional amount of Rs. 24.57 Cr. has been approved under NABARD for phase-I.

Also, a provision of Rs. 106.83 Cr. has been made for treatment of catchment area of tributaries falling from Jhalera bridge to Santokhgarh bridge. The Forest Department has planted around 60,000 trees of different varieties in 50 ha. In addition to this, check dams in the tributaries and planting of grass and bushes for bank protection have also been done.

Community involvement: People's participation was key to the success of this project and community participation was seen as an important aspect. No fund needed to be allocated for land acquisition as the villagers had come forward and donated their land for the project. This led to savings to the tune of Rs. 500 Cr. The people donated their land with the expectation that the agriculture in the remaining portion of land after construction of the project would give them better returns. The report by JICA says that "The project will be implemented on national forests and on private land chosen through community participation. The project will not involve any land acquisition or involuntary resettlement."

Impact: The Swan River Project has benefitted the villages situated by the side of the river from the massive erosion and siltation caused by the flash floods. During the Focus Group Discussion with villagers of Una, the villagers reported "*Since the Channelization of Swan River has been implemented by the Government, it changed our destiny for better as today, we are earning a reasonable money by producing seasonal vegetables and cash crops on the reclaimed land and have shifted back to our traditional vocation of farming*". Some of the benefits are summarized below:

- The analysis of cropping pattern revealed that the total area under cereals decreased from 69% to 54%; however, with the increase in the irrigation facilities by the project interventions, the area under vegetable crops increased from 31% to 46 % of total cropped area. The cropping intensity increased from 193% to 199% after the project implementation.
- During the project implementation period, the average size of livestock unit increased from 1.62 to 2.71. The share of milk to the total income from livestock was found to be highest among different livestock products.

- As a result of increases in the income from agricultural crops, fruit crops and livestock by about 43%, 35%, and 55%, respectively, the overall farm income has increased by 50% during the project implementation period.
- The employment generation in agriculture has increased with the implementation of the project. The annual per farm labour employment in horticulture and livestock, showed an increase of 213% and 65% respectively.
- Community-based groups formed under the project are involved in marketing of produce.

Sustainability: In order to ensure the proper utilization of created facilities over time, there is a need for adopting certain measures at local level - local asset management committees may be formed under the guidance of the block and district authorities.

(References: *FGD & KII as part of primary survey; Research Report No. 70: Impact analysis of integrated watershed project in Swan catchment, Una district, Himachal Pradesh, Department of Agricultural Economics, Extension Education and Rural Sociology, CSK HPKV, March 2014)*

18. Combating flood with information driven actions, Bihar

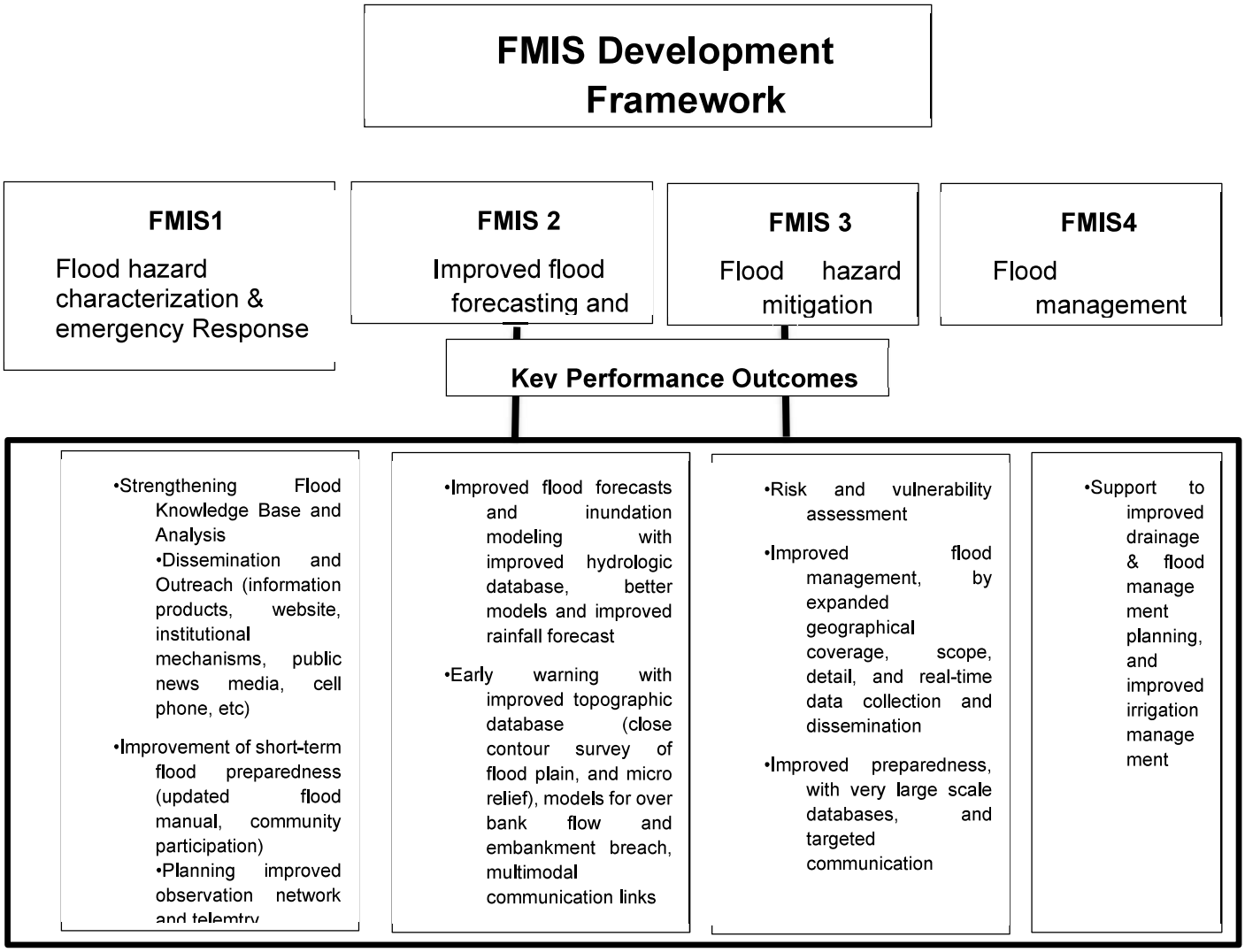
Project details:

- Scheme Name: Flood Management Information System (FMIS)
- Target Area: Bihar
- Total Project Cost: Bihar – Rs. 10.86 Cr. funded by World Bank
- Scheme Scope:
  - Development of technical and institutional capacity of the State for flood management
  - Improved flood forecasting in terms of lead time and accuracy
  - Prediction of expected inundation
  - Development of updated flood control manuals
  - Upgrading hydrologic measurements
  - Use of Online Analytical Processing (OLAP) and data mining tools for planning of schemes using forecasted data
- Implementing Agency: Flood Management Information System Cell (FMISC), Government of Bihar
- Area covered: Phase – I : Flood prone area in North Bihar, from Burhi Gandak river in the west to Kosi river in the east, including the districts of East Champaran, Muzaffarpur, Begusarai, Samastipur, Dharbanga, Sitamarhi, Sheohar, Madhubani, Supaul, Saharsa, and Khagaria covering about 26,000 sq. km. in area; Phase – II: Entire North Bihar together with Patna, Bhagalpur and Munger district have been targeted to be developed.

Solution offered: Flood Management Information System, Bihar finds its genesis in the brainstorming meeting on Jan 18, 2006 in which the Government of Bihar (GoB) and the World Bank agreed on a water sector partnership matrix and action plan in three time horizons. In the short term, it was proposed to improve the technical and institutional capacity of the State of Bihar for flood management, introduce extensive use of modern information technologies, and develop and implement a comprehensive Flood Management Information System (FMIS) in priority areas. Flood Management Information System Cell (FMISC) was created under the overall supervision of Chief Engineer (CE), Monitoring and Planning, in Water Resources Department (WRD), GoB, and under Superintending Engineer (SE), Flood Monitoring Circle, to develop and operate the Flood Management Information System (FMIS) with technical assistance from the World Bank. Currently, one Executive Engineer as In-Charge, and six Assistant Engineers (and one peon) have been deputed to FMISC.

Major functions of FMISC are:

- To ensure operational readiness of FMIS prior to each flood season.
- To operate and disseminate information products as per plan and schedule.
- To respond to emergency data requirements through the use of FMIS.
- To follow-up on dissemination to enable effective utilization.
- To analyze feedback and experience of every flood season for improving FMIS.



The FMIS in the first stage covered the focus area from Burhi Gandak River in the west to Kosi River in the east in North Bihar which is the most flood prone area in the State. This included 11 districts i.e. East Champaran, Sheohar, Sitamarhi, Muzaffarpur, Madhubani, Dharbanga, Samastipur, Supaul, Saharsa, Khagaria, and Begusarai covering 26,000 sq. km.

The FMIS Phase I was initiated in August 2006 and was scheduled to be completed by October 2007. Further extension to the project till June 2008 was granted by the World Bank and the project was eventually completed on this date. The project components

included development of FMIS, improvement of flood forecasting, update of Bihar Flood Information Website, preparation of updated flood control manual, conducting training and upgradation of hydrologic measurements and telemetry.

FMIS Phase-II started on May 2010. In the meantime, the FMIS sustained itself on the internal resources of the Water Resources Department during 2008 to 2010. The FMIS Phase II was scheduled to be completed by 31 December 2012 , which was extended till 30 November 2014.

Impact: As a result of FMIS in Bihar, following achievements have been realized:

- Flood modelling: Real-time Flood Forecasts are made using statistical and deterministic model.
- FMISC is releasing monthly E-Bulletin since May-2007. This is an in-house production and gives a brief account of activities in FMISC.
- Flood Management Information System Cell, Bihar, Patna issues Daily Flood Information Bulletin during monsoon season generally from 15th June to 15th October. The bulletin carries information on observed rainfall in Nepal, Bihar and three days maximum rainfall forecast from IMD and river water level for all six sub-basins/rivers of North Bihar viz Gandak, Burhi Gandak, Bagmati (including Adhwara group of rivers), Kamala, Kosi and Mahananda.
- Inundation Maps: These maps indicate the extent of flood water spread. The inundation extent is derived from RADARSAT Layers/ Imagery provided by NRSC in processed 1bit image format.
- FMISC also provides regular embankment news, detailing the status of embankments in Bihar. Embankment Assets Management System for Bagmati and Kosi is currently functional and is providing up to date information on embankment conditions by collecting information from department officials and select community members through field data collection application and SMS.
- Following information products are regularly uploaded in the website for public viewing:
    - Inundation map
    - Flood intensity map
    - Village level inundation map
    - River status map during flood
    - Post flood River Status Map

Replicability: In order to address the flood situations in the flood prone states in India, the FMIS need to be rolled out across all states. Further the FMIS should contain modules

for addressing land planning, zoning of flood plains, silt management besides integrating with flood forecasting and hydro-meteorological observations. The water flow data can also be used for irrigation in arid and semi-arid regions.

Sustainability: Sustainability analysis mechanisms, including 'Dynamic Sustainability' concepts, may be adopted in the flood management planning process. To ensure sustenance of benefits realized through FMIS, it is imperative to upgrade the application models in the FMIS and also ensure seamless integration with new applications.

(References: http://www.fmis.bih.nic.in; KII as part of primary survey)

19. IT based enumeration of Irrigation Census in Andhra Pradesh

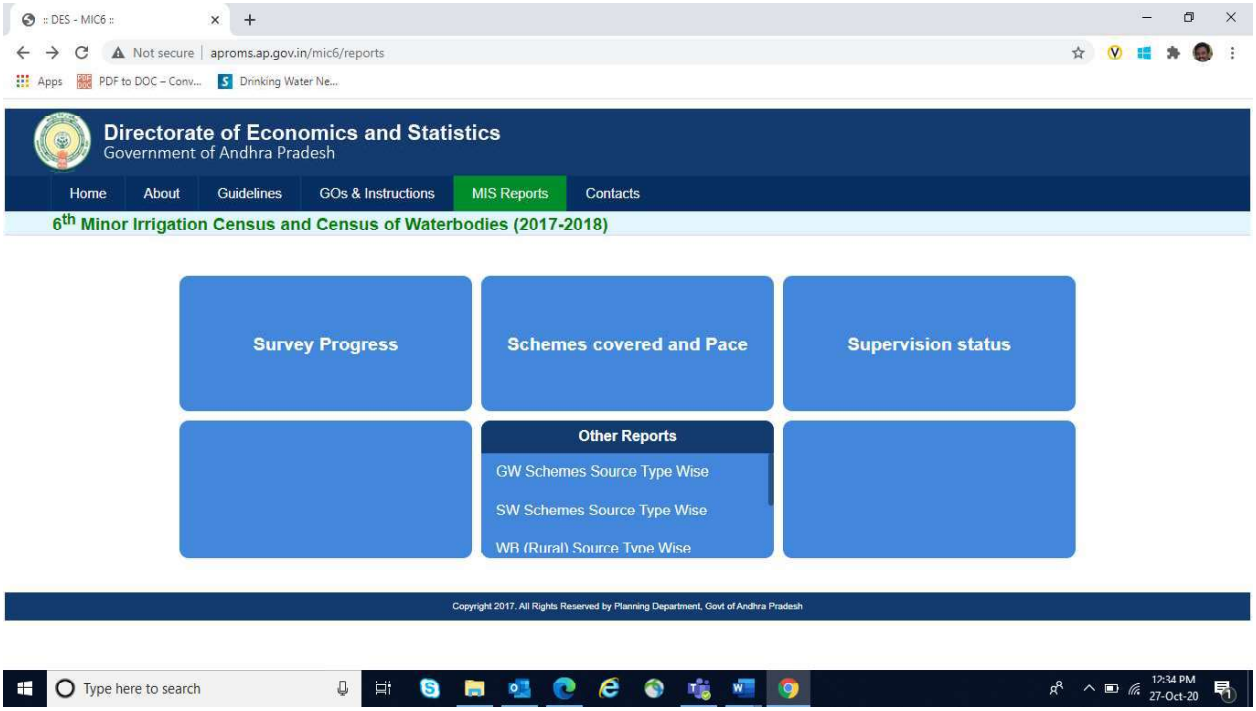
Problem Statement: Irrigation Census involves enumeration of data for all groundwater and surface water minor irrigation sources across all villages in India. The 6th Irrigation census also involved canvassing of data for water bodies in villages and urban local bodies. The enumeration process is done by canvassing five schedules to cover all aspects of minor irrigation. Huge data collection leading to issues like manual errors, missing data, operational issues are frequently experienced leading to increased time and resource lag, needless to say of issues like coordination, data tabulation and data validation techniques.

Solution offered: Andhra Pradesh is one of the few States that have conducted "Paperless" 6th Minor Irrigation Census. During the State Level Coordination Committee (SLCC) meeting prior to execution of 6th MI census, it was decided to conduct the survey through tab/ mobile app without canvassing the schedules to save time and avoid data entry errors. Accordingly, customized software was developed in-house. Tab / mobile app was developed with android version for canvassing all schedules of 6th Minor Irrigation Census and Census of Water Bodies. All the 5 schedules (Ground Water, Surface Water, Census of Water Bodies in Rural and Urban areas and Village schedule) as designed by GoI were integrated into the 3 schedules covering all the information. "Postgre SQL" is used for storing the captured data through tab/ mobile application.

Trainings were conducted for the field and supervisory functionaries at State, District and Mandal level before commencement of the census.

Pilot survey was done to test the application covering all the schedules of groundwater, surface water schemes and water bodies @ 2 schemes each in all 13 districts both in Rural and Urban areas. 'All the table' scrutiny checks were incorporated in the app as per instructions of GoI. Photographs along with latitudes and longitudes of water bodies are captured in the Census of Water Bodies. The app has been developed with provision to upload the canvassed data automatically in the NIC software structure in one go through back end bulk data entry.

Exclusive Web portal (http://aproms.ap.gov.in/mic6/dashboard) was established for day to day monitoring of the fieldwork of 6th MIC & CWB featuring different MIS Reports viz., (1) Survey progress (2) Schemes covered and pace (3) Supervision status and (4) Other reports.



WhatsApp group was formed to resolve the field level issues and to share the clarifications. Senior Officers from DE&S were allotted districts for monitoring and supervision. Core Group Team was constituted with group of officials. The team visited all districts and explained the process of rectification of errors in the portal at Mandal level as part of validation of the enumerated data.

Impact: The application has immensely benefitted the enumerators in terms of data collection and primary data validations, thus saving time and resource. The data consolidation was done in much lesser time. The progress of data collection was effectively monitored by the supervisors using the desktop application. The gaps or delays were monitored, and corrective actions were taken immediately.

Replicability: The applications that were used for Irrigation Census in Andhra Pradesh are very common and widely used in various IT applications across all sectors of business and social sectors. The modules can thus be replicated in other states and UTs. Furthermore, MI Stat wing, can further improve the application and incorporate provisions for online transmission of data to the server for data tabulation. Inbuilt data validation modules may be made a part of the overall application to complete correctness of data prior to tabulation.

Such an approach may be adopted for survey of medium and micro-irrigation schemes as well. A consolidated IT based application operatable with mobile / tab containing multiple schedules with inbuilt validation modules for all irrigation schemes can be

thought of. The application may also use Machine Learning / AI techniques for analysis and predictions pertaining to water availability and demand. Such prognosis will immensely help the irrigation sector as a whole in identifying area specific issues and devise plans accordingly.

(Reference: KII with Nodal Officer, Andhra Pradesh as part of primary survey)

20. Automating the Irrigation Census – ensuring data reliability

Problem Statement: Minor Irrigation schemes in India are large in number and the data generated at field level are collected through manual canvassing of paper schedules. As a result, inadvertent delays and errors are experienced during validation and tabulation of data. On account of the massive importance of MI census data in terms of its applicability by various important government agencies like MoWR, CWC, CGWB, Water Resources Departments at State level for framing policies pertaining to appropriate usage of groundwater and rejuvenation of the sources, a need for having web-based application for accuracy and quick processing of data was felt by the MI Stat wing, MoWR. It was understood that adoption of the system may led to certain advantages like elimination of duplicate entries, timeliness, need based generation of tabulated data and archiving of historical data.

Solution offered: National Informatics Centre (NIC) was requested to develop a software, meeting the above-mentioned requirements. The work was adequately taken up by all States and extended to the districts, wherein adequate manpower was appointed for data entry. In the 5th MI census, a web-based software was created for the first time wherein, three different schedules for data entry namely, village schedule, ground water schedule and surface water schedule were introduced. For the 6th MI census and 1st Census of Water Bodies, five schedules viz., village schedule, ground water schedule, surface water schedule, urban schedule and the water body schedule, were incorporated for web-based data entry. The reliability of the data was checked through sample checks by the supervisors. In order to ensure data accuracy, timely tabulation of data and analysis, a software was developed with the following features:

- User friendliness
- Data verification ability
- Modules for data tabulation
- Data dissemination through websites
- Inbuilt models for identifying trends like pattern
- Decision Support System with Query Module

The overall objective of the project was to gather correct data. The databases collected from all States/ UTs have been merged for making a National level database and several reports have been generated. The application has been divided into three modules based on their functionality i.e. Data Entry Module, Abstract Creation and

Decision Support System (DSS). The objective of Data Entry Module is to gather the validated base/enumerated data. Abstract Creation Module will process these data (base/enumerated data) for generating a database that will be used by Decision Support System. DSS Module will generate all types of reports, queries and provide useful information.

Impact: Some of the major impacts noticed due to wide application of the web-based software are as follows:

- Efficient planning and decision making for development of Water Resources through consistent and consolidated information.
- Empowerment of end users to perform in-depth analysis
- Prediction of irrigation potential utilization and segmentation of areas through Online Analytical Processing (OLAP) models.

Replicability: The application documentation can be shared with other sectoral departments. Currently the scope of Irrigation Census is limited to Minor Irrigation only. The modules can be made applicable for medium and micro-irrigation schemes as well. Such an approach will bring majority of the irrigation schemes and their data under single accessibility. This will facilitate coverage of broader issues pertaining to irrigation and will help the policy makers in framing better schemes or revising components of the existing schemes as well.

Sustainability: Such a system can definitely be sustained by enabling strong data archives and archives of the analyses. Introduction of newer modules, software and update of the application on regular basis will ensure easier use of the application. Better analysis through application of Machine Learning techniques will also help the researchers towards analysis of village specific irrigation issues in a detailed manner.

(Reference: KII with DDG, MI Stat wing, DoWR, Govt. of India)

21. Balanced and sustainable development of river ecosystem through bio-monitoring efforts

Problem statement: The presence and growth of flora and fauna in rivers to a large extent depends on the quality of river water. Hence, it is important to monitor the presence of bio-organisms in the river to assess river health.

Solution offered: Odisha State Pollution Control Board (OSPCB) regularly undertakes biomonitoring of rivers. The mechanism involves sampling flora and fauna such as micro invertebrates and calculation of a bio-diversity index based on the population of different types of samples. The higher the bio-diversity index, the more diversity of micro-organisms in the river water, which indicates cleaner river water.

Impact: Regular bio-monitoring mechanism has helped OSPCB in assessing the river health and taking appropriate measures in notifying the concerned department about actions.

Replicability: Such bio-monitoring mechanisms can be adopted by other State Pollution Control Boards to assess the health of the river ecosystem and presence of flora and fauna in the rivers.

(Reference: KII with Odisha State Pollution Control Board)

22. Financial support for projects through assistance from multilateral funding agencies

Problem statement: It was noted that the funds available with NRCD is inadequate to bridge the existing sewage treatment gap in the country. In addition, multiple proposals submitted for central funding under NRCP scheme have been rejected in recent years due to shortage of funds. Hence, external funding options such as multilateral funding agencies needs to be explored.

Solution offered: The Mula Mutha River Project in Pune is being implemented by the Pune Municipal Corporation under NRCP scheme with a loan assistance from JICA. The loan amount is 19.064 billion Yen. The remaining project cost is being shared between Government of India and Pune Municipal Corporation in the ratio of 85:15. Although, the funding pattern for states (other than north-eastern states) is 60:40, here since a significant portion of the project cost is being funded by JICA, central funding for the remaining cost is higher than in other cases.

Impact: Financial support has helped the Pune Municipal Corporation to take up such a large project (396 MLD STP) on River Mula Mutha.

Replicability: Since 2014-15, proposals amounting to Rs. 5,400 Cr. have been rejected by NRCD citing shortage of funds. Considering the shortage of funds with NRCD, such innovative funding mechanisms such as loan assistance from MFIs will enable large projects to be undertaken under NRCP scheme.

(Reference: KII with National River Conservation Directorate and Pune Municipal Corporation)

23. Improving sustainability of assets created under NRCP through appointment of private contractors for long terms

Problem statement: In many cases, the operational efficiency of the STPs created under NRCP is low and some STPs have become defunct due to lack of operations and maintenance (O&M) primarily owing to lack of funds and technical expertise. Hence, there is a need to involve private contractors for long term O&M to improve sustainability of the assets being created.

Solution offered: The Kolhapur Municipal Corporation has appointed a private contractor for a period of 15 years on Design, Build, Operate and Transfer (DBOT) mode. The contractor is responsible both for construction and O&M post construction. The contractor is made quarterly payments only during the O&M period. There is no fixed construction period. The contractor is incentivized to complete construction early and start operation so that they can get paid early.

Impact: The involvement of the private contractor has ensured smooth running of the 76 MLD STP in Kolhapur on River Panchganga. The STP is currently operating at 95% capacity. This has also ensured regular upgradation, retrofitting and modernization of sewage treatment technology to meet extant NGT discharge standards.

Sustainability: The involvement of private contractors has helped improved sustainability of the assets created under NRCP scheme and incentives such as renewal of contract based on contractor performance can also ensure that desired performance levels are achieved.

(Reference: KII with Kolhapur Municipal Corporation)

24. Holistic river conservation through maintaining of minimum environmental/ ecological flow in rivers

Problem statement: Most rivers in India except the Himalayan rivers have become seasonal with no flow in them during the lean season. They only have flow in them during the months of June-February. In the lean season, they almost have no flow. pollutants have an assimilative property and river water dilutes the pollutants. Hence, when there are very low levels of surface water, the pollution level measured in terms of BOD and COD will be high. It is important to maintain a minimum environmental or

ecological flow in the rivers to dissipate the pollutants. This is currently not under the purview of NRCP scheme.

Solution offered: NMCG has provisions for Aviral Dhara or Wholesome River. Environmental water requirement (EWR) assessment methods, for ascertaining how much water should be retained in rivers to sustain ecological functioning and desired levels of biodiversity, have been developed under Aviral Dhara. Under NMCG, there is special focus on increasing base flow and aquifer recharge. Minimum environmental flows have been notified for different sections of the Ganga and violation of the e-flow norms would lead to closure of respective water-consuming projects such as hydroelectric projects and/ or imposing heavy penalties.

For non-perennial rivers it is often difficult to get data on hydrology, and ecological functioning. However, many tributaries of Ganga like the Damodar, Hindon, Kali etc are non-perennial. Hence the learnings from "Aviral Dhara" programme remains applicable.

For non-perennial rivers a case study through a method known as "DRIFT-ARID"[1] was adopted in South Africa which needs to be looked upon in the case of NRCP as well. This method explores refining the normal technique of EWR measurements over a period, through different types of non-perennial rivers. Many non-perennial rivers have enough water even during the dry season to carry out EWR measurements to be extrapolated using the DRIFT model data of perennial rivers. The fundamental requirement of such method is availability of enough data. Hence this needs to be adopted initially in select non-perennial rivers with a minimum e-flow and be replicated to others over time.

Impact: Adoption of such measures will ensure a minimum ecological flow in the rivers throughout the year and help reduce pollution in river water.

Sustainability: Additional project components for inclusion of the measures discussed above is needed for the NRCP scheme. This will help improve efficacy of the scheme and enhance sustainability.

(Reference: KII with National Mission for Clean Ganga and Environmental Water Requirements of Non-Perennial Rivers, Michael C Grenfell)

[1] Environmental Water Requirements of Non-Perennial Rivers, Michael C Grenfell

25. Holistic river conservation through river front development measures

Problem statement: Protection of riverbanks is an integral part of river conservation. In particular, during monsoon, regular floods affect the structures created on the riverbanks, habitations and cause soil erosion in adjacent lands. Hence, riverbank protection is needed for holistic river conservation.

Solution offered: Sabarmati riverfront project in Ahmedabad under which the Sabarmati riverfront has been beautified and developed as a tourist attraction.

Impact:

- Protection of riverbank and retention of water flow
- The abandoned land of riverbed and nuisance at the centre of the City was converted into people's attraction; tourist destination; creation of infrastructural and recreational facilities
- The capex spent could be recovered through direct revenue collected via tourist footfalls and indirect revenue in the form of taxes.

Replicability: The model is replicable for any river front and can be adopted as a measure to protect the riverbanks especially during floods.

(Reference: KII with Ahmedabad Municipal Corporation)

26. Holistic river conservation through afforestation measures

Problem statement: Protection of riverbanks is an integral part of river conservation. In particular, during monsoon, regular floods affect the structures created on the riverbanks, habitations and cause soil erosion in adjacent lands. Hence, riverbank protection is needed for holistic river conservation.

Solution offered: NMCG currently working with Department of agriculture for 5-7 km belt along Ganga to undertake organic riverbed farming along the rivers in Uttarakhand. A pilot research is being undertaken on Agri-run off and promotion of organic farming along the Ganges. MoEF&CC is also taking this up to extend to other 13 rivers and looking at convergence with CAMPA funds.

Impact: Such afforestation measures not only protects riverbanks but also is a source of revenue generation through organic farming.

Replicability: The model is replicable for any river front and can be adopted as a measure to protect the riverbanks.

(Reference: KII with National Mission for Clean Ganga)

27. Holistic river conservation through adoption of river basin conservation approach

Problem statement: Since the fund available with NRCP is limited, projects for conservation and sewage treatment along major river basins should be prioritized to be taken up under the scheme. Hence, there is a need to take an approach towards river basin conservation of major rivers.

Solution offered: The Rhine river flows across Switzerland, France, Germany and the Netherlands to reach the North Sea. During the rapid industrialization of 1800s, there was rampant river pollution where untreated chemicals from industries as well as untreated sewage was thrown into the river much like in India today. Multiple actions and international cooperation were targeted through the Rhine Action Programme. However, results only started being visible in the 1980s. Restoration of river water quality to drinking standards, ecological rehabilitation, restoring salmon population were few of the key success indicators. Currently, Rhine 2020 programme is ongoing to continuously monitor and maintain the river health including flood prevention and groundwater protection. This entire programme wouldn't have been successful without intense trans-boundary cooperation between multiple governments and citizens.

Impact: The Rhine 2020 program has been immensely successful in improving the quality of water of River Rhine.

Sustainability: A key learning from the Rhine Action programme is that a river basin conservation effort is not a one-time effort but a continuous process and spans decades and requires immense collaboration and stakeholder engagement throughout the process.

(Reference: Rhine 2020 Action Program)

28. Exploring revenue generation options during O&M through wastewater reuse

Problem statement: The NRCP scheme focuses on sewage treatment infrastructure only and the full responsibility of the O&M of the STPs created rests with the state government and PIAs. In some cases, it was noted that Project Implementing Agencies (PIAs) are unable to provide adequate funds and hence limited maintenance activities are being undertaken on the assets created such as upgradation to new technologies, retrofitting, cleaning etc. This has led to some STPs becoming defunct and not functioning to full capacity. There is also limited focus on revenue generating activities during O&M.

Solution offered: Learnings can be derived from the case study of River Nag and Pili in Nagpur on wastewater treatment and reuse. In April 2020, pollution abatement works on Rivers Nag and Pili in Nagpur has been approved at a total cost of Rs. 2,324 Cr. to be funded by JICA and partially (15%) by Nagpur Municipal Corporation. The project includes construction of 2 STPs (48 MLD and 43 MLD respectively) and laying of 1,362 km of sewage lines for diversion of sewage from 100 small streams that flow into River Nag/ Pili downstream. An arrangement of water swap has been undertaken for wastewater reuse. Raw water sent in bulk to the industries under Nagpur Municipal Authority is diverted to water treatment plants for the city, thus increasing availability of potable water for Nagpur residents. In turn, recycled water from the city is again being diverted for industrial use. This water swap arrangement, operational since 2015, is additionally using municipal treated wastewater from Nagpur for cooling purposes in the power plants at Koradi, Khaparkheda and Mauda.

Impact: The above water swap arrangement has helped Nagpur Municipal Corporation take up wastewater reuse in a unique way and ensuring long term sustainability of the project.

Sustainability: The above model is sustainable in the long term since there will always be a demand for water from the industries and there will always be wastewater generated from the city. This model can be adopted where there are major towns and cities situated on riverbanks.

(Reference: Nagpur Pili river water swap arrangement published in news articles)

29. Water resources management balancing economic principles, ecological sustainability and political contexts, Murray-Darling River Basin in Australia

Problem statement: The Murray-Darling River Basin in Australia, which accounts for almost one-seventh of the total land mass of Australia, witnesses extreme spatial and temporal variation of rainfall. The rainfall, within the Basin, varies from 1,400 mm/ year in the highlands to 300 mm/ year in the northwest. The basin also witnesses large variation in seasonal rainfall year to year – annual variation to the extremes of 10,000:1 has been reported in the Darling river. Notably, the basin also has relatively low annual discharge compared to other river systems in the world.

Solution offered: Water shortages together with environmental concerns and degrading water quality (as indicated by declining biodiversity, increase in algal bloom and water salinity), led to the adoption and evolution of various frameworks and legislations in the Basin related water allocation, inter-region water trading, water quality trading and water delivery and pricing, as discussed below.

- Cap on surface water diversion, along with periodic monitoring and audits, to contain the declining river health
    - Various caps on water diversion are set for the states
    - Periodic audits of compliance to the Cap on water diversions are enabled by the Murray-Darling Basin Agreement and agreements by the Council of Australian Governments (COAG). The Murray-Darling Basin Authority (MDBA) has developed Sustainable Diversion Limit Reporting and Compliance Framework to manage water use exceeding limits in dry and wet years. Compliance to these agreements are further incentivized through tranche payments to the states based on the status of the reforms undertaken.
    - Water allocation plans, as prepared at the local level, are given the status of statutory documents and thus states are accountable to implement them.
    - These Cap measures are further facilitated by introduction of inter-region water trading.
- Introduction of inter-region water trading
    - Different instruments of water trading have been introduced like high security licences where agreed volume of water is provided except in drought condition

and low/ general security licences with varying water volume from year to year based on availability.

- Introduction of legislations by some states (like South Australia and New South Wales) allowing separation of land and water titles and practice of both permanent and temporary (say lease of water for a particular period) trades allows even persons with no land to posses water licence as an investment. Also, water title holders may sell surplus water without selling the land.
- To account for transmission gains and losses in the system, various exchange rates have been introduced; e.g. transfers upstream are assigned exchange rate of 0.9 (10 ML in South Australia = 9 ML in New South Wales which is upstream).

- Development of a system for dealing with salinity issues
  - Introduction of salinity interception schemes with various restrictions on states; e.g. states like Victoria and New South Wales are not allowed to approve any proposals, that may increase salinity by 0.1 EC in the Murray river, unless they have any access to salinity credits.
  - A Salinity Audit was undertaken to develop a new salinity strategy and strengthen the existing salinity interception schemes.
- Development of frameworks and legislations in relation to water pricing and delivery
  - Various economic considerations in relation to water pricing and fees collection were codified by the COAG in its water pricing policy.
  - Various states have established adequate institutional mechanisms to facilitate the cost recovery measures.
    - States like New South Wales have set up an Independent Pricing and Regulatory Tribunal (IPART) which is responsible for determining the cost structure for bulk water pricing.
    - In South Australia, a catchment water board is responsible for levying water charges based on future infrastructure and water requirements. Different pricing slabs are introduced for industrial and domestic users while irrigators with only valid licenses are allowed to draw water. All new infrastructure/ projects are approved based on full cost recovery principle.

- Involvement of various stakeholders and separation of the role of planning and regulation from operation
    - Skill based local boards, set up in various jurisdictions, are responsible for determination of water allocation.
    - Day to day operations and water delivery are entrusted to the corporations, who have no direct role in policy development. Many of the states have undertaken 'corporatization' of the operations of water delivery through involvement of private parties, e.g. the Murray Irrigation Limited, a private entity, holds around 75% of New South Wales general water security entitlements.

Impact: During the initial year, New South Wales recorded sales amounting to more than 10% of total entitlements while a two year pilot project in the Malle region of South Australia, Victoria and New South Wales saw trade volumes to the tune of 9.8 GL. Water trading facilitated the adoption of water efficient practices and gradual shift from lower to higher value agricultural products like viticulture and horticulture crops. Under the salinity interception schemes, states like Victoria and New South Wales have earned salinity credits of 15 EC. The salinity interception schemes led to reduced salinity in South Australia and more awareness and adoption of cost effective measures to protect irrigated lands from land degradation. 'Corporatization' of the water delivery mechanisms including the involvement of consortiums of private irrigators ensured buy-in from the water users in both the planning and delivery processes including cost recovery.

As on July 2020, 13 water resource plans are in place and over 2,100 GL of water is managed by the Basin's environmental water holders. The 2020 Basin Plan Evaluation report highlighted achievement of various positive ecological responses including delivery of adequate water to Coorong, Lower Lakes and Murray Mouth during the drought season. The report also noted how ongoing reforms in water trading markets (surface water), particularly in the well-established southern Basin market, have led to improvement in drought resilience and transition towards high value water usages.

Sustainability: In order to ensure the sustenance of the water management practices introduced earlier, it is imperative to update the provisions based on the recent developments. For example, the initially exempted institutes like Australian

Commonwealth Territory and Queensland need to adopt the water Cap measures to avoid any potential conflict with other water users who are currently under the ambit of the Cap measures. Various contentious issues like introduction of Cap on groundwater and farm diversions need to be reconsidered. To further facilitate the water trading mechanisms, there is a need to reduce the transaction costs (like the brokerage fees, time cost and approval costs). Also, provisions like strengthening the long-term commitments need to be introduced to account for the ecological impacts of the trade.

The Interim Report (August 2019) of the Australian Competition and Consumer Commission (ACCC) has highlighted various deficiencies in relation to settings and governance of water trading mechanisms, that are understood to undermine the efficiency of the trading mechanisms. The 2020 Basin Plan Evaluation report identified six priority areas for the future ranging from full implementation of Basin plan to adoption of various climate resilience and integrated water management practices to achieve social, economic and environmental outcomes.

(Reference: Darla Hatton Mac Donal and Mike Young, International Water Management Institute " A Case Study of the Murray-Darling Basin"; Murray-Darling Basin Authority "The 2020 Basin Plan Evaluation" https://www.mdba.gov.au/sites/default/files/pubs/bp-eval-2020-overview.pdf, Murray-Darling Basin Authority website https://www.mdba.gov.au*)*

30. Addressing water shortages through quota control and economic incentives, Shiyang River Basin in China

Problem statement: During the early 2000s, the Shiyang River Basin, an inland river basin in Northwest China, was witnessing significant decline in both surface water and groundwater levels owing to increase water demand, resulting in severe water conflict among the water users in the different reaches. From 1950 to 2003, irrigated area in this region increased by 30% while water use increased by 75%.The increasing water demand led to a decrease in surface water flow from 500 million m^3 in 1950s to 98 million m^3 in 2003 while the number of tubewells in the Minqin County alone peaked to 14,000.

Solution offered: To mitigate the water shortages and the ecological crisis, a River Basin Management Bureau was set up and a comprehensive water management plan (CWMP) was approved by the Ministry in 2006 outlining the following targets – increase in surface water availability in downstream Minqin area from 98 million m^3 in 2003 to 290 million m^3 by 2020, decrease in groundwater extraction from 517 million m^3 in 2003 to 86 million m^3 by 2020 in the Minqin area and from 747 million m^3 to 418 million m^3 in the whole basin during this period. A number of institutional mechanisms and economic measures have been initiated to meet the targets, the most notable being introduction of water consumption permits, as discussed in detail below:

- Water consumption permits have been granted to the individual households, which were determined based on the number of household members and type of crops cultivated. For example in the Minqin County, the permit allows water consumption for developing 2.5 mu of irrigated area per capita while household with more than 2.5 mu irrigated area per capita could obtain additional water through plantation of horticulture crops and transforming land to greenhouses.
- An Integrated Circuit Card (IC card) technology was introduced to monitor water consumption permit. The electronic systems were installed in the tubewell and the respective WUAs were allotted the IC card. Each farmer was entitled to purchase maximum water permits of 415 m^3 per mu. The WUAs coordinated the consumption patterns of the members to ensure equitable distribution.
- In irrigated areas dependent solely on groundwater or a mixture of both surface water and groundwater, a two-part (basic + volumetric) has been introduced. Also, different tariff levels were set for various cropping patterns – water for greenhouse and drip irrigation were exempted from the basic water fee and also eligible for availing 20%

and 50% discounts in surface water and groundwater fees respectively while tariff for water intensive crops attracts a premium of 50% for groundwater and 30% for surface water respectively.

- Steep premiums, to the tune of 150% to 300%, were imposed on fees charged, in case of consumption exceeding the permissible limits.

Impact: Water cost recovery in the area has significantly improved over time, with surface water fee per m^3 in the middle reaches increasing from 0.08 yuan to 0.2 yuan during 2007 to 2017, while that in the lower reaches recording increase from 0.1 yuan to 0.24 yuan. Water consumption permits facilitated adoption of water efficient practices with the economic output per m^3 of water increasing from 1.3 yuan in 2009 to 9.33 yuan in 2015. These measures facilitated the shift from traditional grain crops to cash crops in the SRB province with farmer's income registering a two-fold increase. As reported, implementation of various provisions of the CWMP led to a jump in average agricultural water-use coefficient from 0.53 to 0.58 and reduction in water use per irrigated land from 626 m^3 to 430 m^3 during 2007 to 2015.

Sustainability: As per the evaluation reports released by the Gansu government, significant improvement in water usages during 2007 to 2015 have been reported owing to these measures. To ensure sustenance of these benefits, measures like water consumption benefits were supplemented by adequate changes in institutional and funding mechanisms like development of WUAs and special fund/ subsidy allocations.

However, it may be noted that the water permit trading has been limited to only between the WUAs within the same ID. Also, a decline in trade volume was recorded between 2015 and 2016. At the local level, the trade was limited due to heterogeneity issues, while at the national and state levels, it was impaired by lack of necessary regulatory framework and legislation.

(Reference: Liuyang Yao et al., MDPI, "China's Water-saving Irrigation Management System: Policy, Implementation and Challenge", December 2017*)*

31. Improvement in water fees collection through canal contracting in Jinghuiqu Irrigation District in China

Background: In the late 1900s, the Jinghuiqu irrigation bureau initiated a number of institutional reforms including reforms of lateral canal management – lateral canals were contracted to private parties (individual or consortium). As on 2000, 428 of the 538 lateral canals were contracted. Some of the key features of the contracting mechanism are highlighted below:

- The using rights of the lateral canals were auctioned with minimum bid price of 2,000 yuan per km
- The terms of validity ranged from 10-15 years for irrigation staff to 15-20 years for other contractors
- Each contractor was entitled to minimum water diversions based on the past five years data with an annual increase of 3% in future
- Development of right of land along the lateral canals was entrusted to the contractor
- A performance linked salary mechanism was introduced for the administrative staff in each irrigation bureau

Impact: In general, as noted in the article 'Irrigation reform in Asia: A review of 108 cases of irrigation management transfer' by Aditi Mukherjee et al. (2010), the model of lateral canal contracting to private contractors yielded 'better results' compared to Participatory Irrigation Management PIM in China. In the Jinghuiqu irrigation district, the contracting reforms facilitated a substantial reduction in number of staff in the irrigation stations which led to savings to the tune of 1.4 million yuan for the irrigation bureau.

Sustainability: To sustain the irrigation facility management and avoid potential issues in relation to water allocation, water volume metering and fee collection, the irrigation bureau released standardized rules for invoicing, metering, construction cost for lateral canal improvement projects and water fee for the reformed canals. To ensure transparency, the methods of water charging and amount charged need to be publicly disclosed.

(Reference: Yongsomg Liao et al., International Water Management Institute, "China's Water Pricing Reforms for Irrigation: Effectiveness and Impact", 2008*)*

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