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Expert Consultation on

Promoting Efficient Irrigation Technologies for Water Saving Across Scales and Sectors

25 February, 2022

Proceedings and Recommendations

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Acronyms and Abbreviations

ADG	Assistant Director General
AI	Artificial Intelligence
AICRP	All India Coordinated Research Project
APMIP	Andhra Pradesh Micro Irrigation Project
BCM	Billion Cubic Meters
CGIAR	Consultative Group for International Agricultural Research
CA	Conservation Agriculture
CAZRI	Central Arid Zone Research Institute
CGIAR	Consultative Group on International Agricultural Research
COVID	Corona Virus Disease
CSSRI	Central Soil Salinity Research Institute
DARE	Department of Agricultural Research and Education
DDG	Deputy Director General
DSR	Direct Seeded Rice
DT	Drought Tolerant
ET	Evapotranspiration
FAHP	Fuzzy Analytical Hierarchy Process
FLD	Frontline Demonstrations
GAPs	Good Agricultural Practices
GGRC	Gujarat Green Revolution Company
GHG	Greenhouse Gas
GoI	Government of India
GR	Green Revolution
HP	Horse Power
HT	Heat Tolerant
IARI	Indian Agricultural Research Institute
ICAR	Indian Council of Agricultural Research

ICID	International Commission on Irrigation and Drainage
IFPRI	International Food Policy Research Institute
IISW&C	Indian Institute of Soil and Water Conservation
IIWM	Indian Institute of Water Management
IoT	Internet of Things
IRAP	Institute for Resource Analysis and Policy
IT	Information Technology
IWM	Irrigation Water Management
IWMI	International Water Management Institute
KC	Crop Coefficient
MI	Micro-irrigation
MoA&FW	Ministry of Agriculture and Farmers' Welfare
MoJS	Ministry of Jal Shakti
MoWR	Ministry of Water Resources
MPKV	Mahatma Phule Krishi Vidyapeeth
MSP	Minimum Support Price
NABARD	National Bank for Agriculture and Rural Development
NAPCC	National Action Plan on Climate Change
NGOs	Non Governmental Organization
NIAP	National Institute of Agricultural Economics and Policy Research
NRM	Natural Resource Management
NWM	National Water Mission
NWP	Netherlands Water Partnership
PIM	Participatory Irrigation Management
PJTSAU	Professor Jayashankar Telangana State Agricultural University
PMKSY	Pradhan Mantri Krishi Sinchayee Yojana
PPP	Public Private Partnership
PVC	Polyvinyl Chloride
RDI	Regulated Deficit Irrigation
RW	Rice-Wheat
S&WM	Soil & Water Management

SAUs	State Agricultural Universities
SDGs	Sustainable Development Goals
SDI	Subsurface Drip Irrigation
SPV	Solar Photovoltaic
SRI	System of Rice Intensification
SSD	Sub-Surface Drip
SSPS	Shared Socioeconomic Pathways
SWDs	Sub-watersheds
TAAS	Trust for Advancement of Agricultural Sciences
TANHODA	Tamil Nadu Horticulture Development Agency
TSMIP	Telangana State Micro Irrigation Project
UAV	Unmanned Aerial Vehicle
WEF	Water-energy-food nexus
WEFE	Water, Energy, Food and Ecosystems
WP	Water Purifier
WTC	Water Technology Centre
WUA	Water Users' Association
WUE	Water Use Efficiency

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BACKGROUND

Water scarcity has become a crucial social, economic, and environmental issue worldwide. The global water withdrawals increased substantially in the last century from 600 to 3,900 km^3. This increased water demand was due to rapid population growth and inefficient water management practices. As a result, many parts of the world, including the north-western part of India face severe water shortages. Probably, worsening water deficit is experienced due to unprecedented depletion of groundwater reservoirs, which is a highly reliable resource for multiple sectors. Water scarcity will further exacerbate in the coming decades due to combined effects of misuse, ever-increasing water withdrawals due to heavily subsidized power for extraction with price support for water guzzling crops, climate change, and an increase in competing multi-stakeholder water demands. The shared socio-economic pathways (SSPs) indicate that by 2050, water withdrawals will increase by 55-113 per cent. Irrigation has the largest share, accounting for over 70 per cent of the global water withdrawal and over 90 per cent in some countries. Climate change will have a pronounced impact on Indian agriculture, where around 85 per cent of farmers are small and marginal, and 54 per cent of agriculture is dependent on annual rainfall. Thus, specifically these farmers may not have enough water to satisfy the increased water demand by 2050. Therefore, it is imperative to promote water-saving practices in agriculture on a large scale, and to reduce or remove policies and subsidies that incentive water overuse, which has been highlighted as one of the crucial solutions to this much-discussed aggrandizing water-stress situation. The increasing groundwater use without proper water conservation and augmentation measures intensifies declining groundwater levels which entails higher energy requirement leading to more greenhouse gas (GHG) emissions as well.

Among the demand driven management options, micro-irrigation is being widely promoted especially in water-scarce areas. There are policy instruments in the form of *Pradhan Mantri Krishi Sinchayee Yojana* (PMKSY) 'More Crop Per Drop' and other government programs that promote scaling-up of micro-irrigation. Use of micro-irrigation resulted in increased yields, decreased irrigation water application and non-beneficial water consumption, 75-95 per cent increase in water use efficiency, energy saving, reduced GHG emissions, and reduced fertilizer and labour requirements. Fertigation increases fertilizer/nutrient use efficiency and reduces fertilizer expenditure cost. Additionally, micro-irrigation provides an opportunity for expansion of cultivation in degraded lands and water deficit areas. We are aware that micro-irrigation while leads to significant water savings in terms of crop per drop, i.e. more crops can be grown. There is general consensus that these technologies reduce valuable return flows (when considering larger scale) and limit aquifer recharge. When comparing flood/surface irrigation to drip, there is a reduction in "seepage and percolation" from 40-45 per cent to 5 per cent. Dr Chris Perry cited the example of northwest India, where water is surplus during the *kharif* season, and deficit during *rabi* and summer months. In this context, "losses" from inefficient irrigation in one season are an important source of recharge to aquifers that are already over-exploited. On the other hand, where groundwater is saline, which is also common in the same areas, reducing recharge during *kharif* is a genuine water saving. The implication is that the impact of improving irrigation technology must be evaluated on spatially and temporally relevant scales to draw useful conclusions. Simplistic, single season, farm level analysis is an inadequate basis for these decisions. Separately, and precise because "savings" at farm scale make water more valuable to the farmer, the adoption of these technologies in areas where access to groundwater is uncontrolled (as in India) will result in increased demand for water and more rapid depletion of aquifers.

The whole food system is an important driver of water use and increasing system efficiency can be achieved through various actions in different sub-components. International Water Management Institute (IWMI)'s perception clearly indicates that water management should not be viewed in isolation as energy and food policies/interventions can have significant impact on water management and governance. Adopting drip irrigation saves energy and results in higher economic water productivity and energy productivity, which is very encouraging to promote crop diversification, reduce fallow areas, and increase cropping intensity and crop productivity besides reduced emission. The water saving linked energy saving is to be also kept in view together with mitigation benefits, especially in groundwater irrigated areas. Of course, the growing concern on water-saving techniques like drip irrigation consuming large water volumes is debatable and should not be abandoned altogether. Combining these water-saving irrigation techniques with other techniques, well-tested policies, and management actions can bring sustainable solutions to this highly debated issue. Achieving real water savings would require proper designing of institutional, technical, and accounting measures that accurately assess across a spatial (farm/field to system to basin) and temporal (seasonal and annual) scales. It is an important issue that needs to be looked into from many angles and lenses including energy use lens, mitigation, geographies and scales.

Water is primarily a state subject in India, with each state free to deal with issues linked to supply, distribution and storage on its own unless the river happens to flow into a neighboring province. While water issues did take centre stage when the government recently initiated two mega water supply schemes, concerns over management will not be addressed unless the Centre deals with it through legislation. India also plans to have a new National Water Policy (NWP) which will, for the first time, focus on managing and conserving water resources through public-private partnership (PPP) mode and work on modalities to implement ongoing programs. The policy may also suggest enactment of a 'National Water Law'. Once the Centre comes out with a new NWP, states may also revise their policies keeping in mind basic concerns of water-stressed districts. Three existing draft Bills of the Union Ministry of Jal Shakti—National Water Framework Bill, River Basin Management Bill and "Model Groundwater Bill" to regulate and control the development and management of groundwater will also be then eventually revised.

THE EXPERT CONSULTATION

In view of the above, the Trust for Advancement in Agricultural sciences (TAAS) New Delhi, a 'Think tank' in collaboration with ICAR-Indian Institute of Water Management (ICAR-IIWM), Bhubaneswar and International Water Management Institute (IWMI), India organized an **'Expert Consultation on Promoting Efficient Irrigation Technologies for Water Saving Across Scales and Sectors'** on 25 February 2022 in virtual mode. The Expert Consultation brought together diverse stakeholders from Central and State Governments, scientific institutions, SAUs, NGOs, entrepreneurs, policy makers and farmers to address weaknesses and challenges, discussed trade-offs of adopting micro-irrigation across scales and geographies; context specific policies on using micro-irrigation and demand management; explore, understand, and assess 'Real' water savings as against 'Apparent' water savings; and to develop a 'Road Map' for management intervention for saving water and increasing water productivity. The key focus was to examine how water demand side management in general and micro-irrigation in particular can help in water saving across scales, actors and geographies.

OPENING SESSION

The Opening Session was Co-Chaired by Padma Bhushan Dr RS Paroda, Chairman, Trust for Advancement of Agricultural Sciences (TAAS), Former Secretary, DARE and Director General, ICAR; and Dr Mark Smith, Senior Director of Water Systems, CGIAR, and Director General of the International Water Management Institute (IWMI), Colombo, Sri Lanka.

Dr SK Chaudhari welcomed the Chief Guest, Dr T Mohapatra, Secretary DARE and DG, ICAR; Dr RS Parada and Dr Mark Smith, Co-Chairs; Dr Chris Perry, Former DDG, IWMI; Dr Stefan Uhlenbrook, Strategic Program Director - Water-Food and Ecosystems, IWMI and Dr Alok Sikka, IWMI Country Representative India; Dr Claudia Ringler, IFPRI Washington; Dr HP Singh, Former DDG (Horticulture), distinguished invitees, eminent experts and participants. Dr Chaudhari emphasized on the importance of the expert consultation on promoting efficient irrigation technologies for water-saving across scales and sectors and mentioned about importance of water in agriculture leading to national economy.

Dr RS Paroda while introducing the agenda and setting the context of the expert consultation mentioned that Green Revolution (GR) resulted into rapid increase in the yields of wheat and rice by bringing improved varieties combined with the expanded use of water, fertilizers and chemical inputs. It has had a dramatic impact on incomes and food supplies in many developing countries. In fact, introduction of dwarf wheat and rice has turned India from food deficit to food surplus country. Later, besides Green Revolution, the Rainbow Revolution enhanced production in different commodities through integrated development of crop cultivation, horticulture, forestry, fishery, poultry, animal husbandry and food processing. He emphasized that water is a scarce resource and a critical input for agricultural production. It plays an important role in food security. Irrigated agriculture represents 20 per cent of the total cultivated land and contributes 40 per cent of the total food produced worldwide. Around 70 per cent of freshwater withdrawals go into agriculture. With a growing food demand, agricultural production will need to expand by 70 per cent by 2050. Given that irrigated agriculture can be up to twice as productive as rainfed cultivation systems, it is certain that water consumption for agriculture will keep growing, although net cultivated area for agriculture in India is now static (142 mha). India has the potential to increase the coverage of net cultivated area under micro-irrigation to 69.5 mha (Rajasthan-16.85, Maharashtra-12.71, Andhra Pradesh-11.63, Karnataka-8.47 and Gujarat- 8.20 mha), while the present coverage stands around 10 -12 mha. Further, the budget for the year 2020-21 saw a higher allocation (41%) but a stronger push is needed to double the area in next 5 years. He further stated that India has already created irrigation potential of 65 mha, which can be expended to cover more area through water use efficiency. This would help in enhancing further the cropping intensity which presently stands at 136 per cent.

Recently, GoI has created a separate Ministry of Jal Shakti (MoJS) with the goal of integrated water resources management so that all issues related to water are dealt with in a holistic manner. The *Pradhan Mantri Krishi Sinchayee Yojana* (PMKSY) has been formulated with the vision of extending the coverage of irrigation (*har khet ka pani khet mein)* and improving water use efficiency (more crop per drop) in a focused manner with end-to-end solution on source creation, distribution, management, field application and extension activities. He further stated that under micro-irrigation and drip irrigation, coverage is around 10 mha and 4 mha, respectively. GoI needs to rethink about micro-irrigation subsidy through appropriate policies. Grey areas can be made green due to better water use efficiency (WUE). Such incentives ensure effective governance and empower farmers to conserve biodiversity, protect ecosystems and minimize environmental impacts which can take place through irrigation institutions that must respond to the needs of farmers. The reliable delivery of sufficient water, achieving efficiency and equity in access, are some of the main targets to be achieved. This will also require changes in attitudes among farmers, as well as Government's investments in infrastructure modernization, institutional restructuring, and the upgrading of the technical capacities of farmers and water managers. The shift towards micro-irrigation is thought to 'save' water and boost crop yields. The externality imposed on an unsuspecting farmer dependent on return flows (via surface runoff or *aquifer)* is "No Drop No Crop". The impact of micro-irrigation and plastic mulching on water demand management would affect in 'catchment outflows' thereby lack of aquifers reducing the consumptive use of irrigated crops. As stated before, average cropping intensity has increased to 136 per cent, whereas Punjab tops with 146 per cent. On the contrary, around 55 per cent area is still rainfed. Hence, we need to devise a 'Road Map' for saving water by re-orienting water use policies through mid-course corrections such as pricing the water and discouraging the flood irrigation system.

Dr Mark Smith highlighted that Sustainable Development Goal 6 (SDG 6) calls for the availability and sustainable management of water and sanitation for all. Unless we achieve SDG6, there is risk of failure to attain many of other SDGs, including those related to poverty reduction, food and nutrition, human health, gender equality, energy, economic growth, sustainable cities and the environment. The devastating COVID-19 pandemic reminds the importance of access to water, sanitation and hygiene facilities, and many people are still without them. He emphasized on reducing water use by increasing its efficiency. The attention water receives in global discourse on climate change is limited. He argued that agriculture accounts for around 70 per cent of water withdrawals world-wide, but in India, the share is about 83 per cent. He stated that the 2021 edition of the United Nations World Water Development Report focuses on valuing water. There is enough water for all provided we use and manage it efficiently. We invest too little, and ineffectively but use too much water creating scarcity. Due to population growth, urbanization and increased industrialization, water competition among different sectors has become more severe in India and around, threatening agricultural production and food security while also affecting water quality. Water scarcity is likely to worsen due to the impacts of climate change. The need of the hour is to manage irrigation water efficiently. It has often been stated that water is undervalued. He further stated that we have to manage water demands, and accordingly, institutional measures and scales and sectors need to be taken care of.

Dr T Mohapatra appreciated and extended his gratitude to Dr RS Paroda for organizing this important consultation. He asserted that water is a key resource and central for every sector, hence deliberations on each aspect are very important. Water use is crucial especially for agricultural sector. In India, we use over 80 per cent available water resources for agriculture and allied sectors. For higher cropping intensity, increase in water use efficiency (WUE) is a must. The country has 50 per cent area under irrigation and 50 per cent area is rainfed. GoI has focused on *Pradhan Mantri Krishi Sinchayee Yojna* (PMKSY) to achieve convergence of investments in irrigation at the field level, expand cultivable area under assured irrigation, improve on-farm water use efficiency (*har khet ko pani*) to reduce wastage of water, enhance the adoption of precision-irrigation and other water saving technologies (more crop per drop), enhance recharge of aquifers and introduce sustainable water conservation practices by exploring the feasibility of reusing treated municipal waste water for peri-urban agriculture and attract greater private investment in precision irrigation system. The task is not easy to catch the rainwater, collect and use it. Irrigation efficiency can be improved through altering farming practices, such as crop diversification, crop rotation (plant crops according to seasons and soil conditions) and conservation tillage (leaving a previous year's crop residue on the field to reduce soil erosion and runoff) that help improve soil moisture conservation. Drip irrigation is the most efficient water and nutrient delivery system for growing crops wherein 95 per cent water is utilized and only 5 per cent is wasted. He advocated for use of direct seeded rice (DSR) method. He further stated that in case we go for drip irrigation, it helps in improving environment and reduces evaporation loss. Mulching, DSR and conservation agriculture (CA) practices, and other possible GAPs also save water and improve water use efficiency.

He further stressed that water has been recognized as being vital to India's economic growth, wellbeing of its people, and the sustainability of ecosystems. Over the past few years, the GoI as well as State Governments have been implementing a range of projects focused on groundwater recharge; responsible use of water for agriculture; and use of technologies such as micro-irrigation. More significantly, the Government has consolidated institutional structures under the Ministry of Jal Shakti (MoJS) to bring interrelated water management functions together and drive more effective outcomes. 85 per cent of water resources are used in agriculture. Price of water is not taken into account while declaring the minimum support price (MSP) for different crops. Suitable incentive needs to be given to farmers to grow crops using less water. Alternative way needs to be found out to use canal water, reduce water loss and increase irrigation efficiency.

THEMATIC PRESENTATIONS

The Session on Thematic Presentations was co-chaired by **Mr AC Pandya**, Secretary General, International Commission on Irrigation and Drainage (ICID) and **Dr JC Katyal**, Former DDG (NRM), ICAR. **Dr Pandya** highlighted the issues such as addressing evaporation aspect of water management, use of solar power in micro-irrigation practices, efficient water use technology, and subsidy dependent approaches. The four thematic presentations made included: i) Does improved irrigation technology save water? by Dr Chris J Perry, Former DDG, IWMI; ii) Improved water savings from efficient irrigation and water management technologies jointly by Drs SK Chaudhari, DDG (NRM), ICAR and Dr Atmaram Mishra, Director, ICAR-IIWM Bhubaneswar; iii) Integrated thinking across scales for optimizing water use and saving in agri-food systems, jointly by Drs Stefan Uhlenbrook and Dr Alok Sikka, IWMI, New Delhi; and iv) Assessing scale-dependent water saving changes from an economic perspective by Dr Claudia Ringler, IFPRI, Washington, USA.

Dr Perry noted that increased competition for water, unsustainable rates of pumping, and aquifer depletion were evident across the world. Where access to groundwater is uncontrolled (as in India), the problem is particularly severe. Historically, when pumping was by suction pumps, these systems were self-regulating at a maximum depth to water table of about 10 m. However, the introduction of cheap submersible pumps from the mid-1970s allowed profitable pumping from much deeper aquifers, and continuous decline in many aquifers has ensued and recharge setting the limits to annual use. However, in recent decades the proliferation of large-scale storage-based systems and the development of deep tube well technology have resulted in dramatic increases in water withdrawals. He emphasized that many improved technologies are under development for Rice-Wheat (RW) systems, with multiple objectives including increased production, improved soil fertility, greater input use efficiency, reduced environmental pollution and higher profitability for farmers. More than 90 per cent of the major rice-wheat areas in Northwest India are irrigated at least partially from groundwater. Here, reducing deep drainage does not "save water" nor reduce the rate of decline of the water table. In these regions, it is critical that technologies that decrease evapotranspiration (ET) and increase the amount of crop produced per amount of water consumed as ET are implemented. The best technologies for achieving this are delayed rice transplanting and short duration rice varieties. The potential for replacing rice with other crops with lower ET is less promising. Reduction in non-productive evaporation is expected as irrigation techniques improve, and water is applied more accurately to the crop.

In groundwater systems, the arrival of cheap, portable engines and submersible pumps vastly increased the potential to exploit water-pumping from rivers, streams, and most significantly from aquifers at rates that resulted in continuous falls in water tables. While many counties promote hi-tech irrigation on the assumption that reduced demand for water will automatically follow, the sequence is actually the opposite: when access to water is controlled to the sustainable level, farmers will automatically seek technologies and management strategies that maximise returns to water within the allocated quantity. Hi-tech will often be part of that strategy. Any changes in land use whether converting forests to farmland, water harvesting, modernizing spate irrigation or more formal introduction of water storage and control for irrigation has implications for water availability elsewhere in the system and requires revision of projected water balances.

It would therefore be entirely inappropriate for India to promote a blanket policy of subsidies and promotion of hi-tech irrigation in areas where groundwater levels are already falling. India also needs to enhance its 'water accounting' capacity and justify its development trajectories towards future sustainable levels of water consumption and set progressive and monitorable operational boundaries for water consumption. A strong coordination between Ministry of Agriculture and Farmers' Welfare (MoA&FW), Ministry of Water Resources (MoWR) and Ministry of Jal Shakti (MoJS) is required from planning to implementation of irrigation projects, to address the implication for water saving at the two major scales: on-farm and basin/watershed.

The bottom line is the commodity like water that is neither measured at any given scale nor fairly priced. Thus, it is difficult to achieve higher water use efficiency. Also, a good diplomacy at State and Inter-State level would ease the take-off of the water infrastructure projects.

Dr Atmaram Mishra in his presentation (jointly with **Dr SK Chaudhari)** highlighted that there has been rapid expansion of irrigation facilities in India since independence. Presently, the net irrigated area of the country is about 68.65 mha which is about 49 per cent of the net sown area. Further, about 64 per cent of the irrigated area receives water from groundwater resource. Irrigation consumes about 75 per cent of the total utilized water resource. Demand from other sectors is steadily increasing and, therefore, irrigation has to be more efficient. The present level of irrigation efficiency from surface and groundwater irrigated area is about 35 per cent and 50 per cent, respectively. In order to make irrigation sector more efficient, micro-irrigation has been found to be one of the most appropriate technologies, the area under which has risen to about 12.54 mha as of March 2021. There exists regional and state level disparity with regard to adoption of micro-irrigation (MI). The southern region has the highest level of adoption followed by western region, while adoption in eastern region is abysmally low. Groundwater availability, labour availability, groundwater depth, subsidy, electricity uses in agriculture, canal irrigated area and size of land holdings are some of the determinants which decide the adoption rate of MI.

Micro-irrigation saves irrigation water to surface irrigation and reduction in groundwater recharge. Drip is considered for widely spaced crops and sprinkler for closely spaced crops. The criteria for water saving were 25 per cent for sprinkler irrigation and 45 per cent for drip irrigation. On an average 15 per cent of applied irrigation water has been considered as recharge to groundwater considering that the depth of groundwater is in the range of 10-25 m range below ground level. For sprinkler irrigation, 1 per cent of applied water has been considered as recharge and for drip irrigation, we have considered zero recharge. The salient points which need focused attention include: i) total micro-irrigation penetration is 12.54 mha. Six states i.e., Rajasthan, Andhra Pradesh, Maharashtra, Karnataka, Gujarat and Tamil Nadu cover 80 per cent of total MI in India, ii) availability of groundwater along with pump set are the key determinants for adoption of MI in India. High initial investment and maintenance cost are the main determinants of non-adoption of MI, iii) drip irrigation can save 8-73 per cent water and increases crop yield by 4-109 per cent, whereas the sprinkler irrigation can save 2-50 per cent and increase crop yield by 11-57 per cent, respectively, iii) by adoption of MI at 100 per cent potentiality, we can save more than 122 BCM irrigation water by which we can irrigate additionally nearly 24 mha using surface irrigation and 32 mha using MI. By adopting MI, groundwater recharge may be reduced by 56 BCM, but we can save more than 122 BCM water.

Dr Stefan Uhlenbrook in his presentation, jointly with **Dr Alok Sikka** stated that sustainable and resilient food systems depend on sustainable and resilient water management. Increasing water scarcity, due to climate change and other environmental and societal changes, makes putting caps on the consumption of water resources indispensable. Implementation requires an understanding of different domains, actors, and their objectives, and drivers and barriers to transformational change. He suggested a scale-specific approach, in which agricultural water use is embedded in a larger systems approach (including natural and human systems) which is the basis for policy coherence and the design of effective incentive schemes to change agricultural water use behavior and, therefore, optimize the water we eat. There is an urgent need to promote efficient irrigation technologies. Sustainable and resilient food systems depend on sustainable and resilient water management. Increasing water scarcity, due to climate change and other environmental and societal changes, makes caps on water resource consumption indispensable. Implementation requires an understanding of different domains, actors and their objectives, and drivers and barriers for transformational change. A scale-specific approach is suggested in which agricultural water use is embedded in a larger systems approach (including natural and human systems). This is the basis for policy coherence and the design of effective incentive schemes to change agricultural water use behavior and, therefore, optimize the water we eat.

He emphasized on the following key points which need urgent attention for consideration: i) agricultural water management needs to be designed and implemented within a wider systems approach, ii) multiple policy instruments are needed to achieve multiple objectives of agricultural water management, iii) understanding the state of water resources and its uses requires detailed monitoring and assessment, iv) complexity of scales both spatial (farm/field to command area to sub-basin/basin) and temporal, sectors and actors (users and uses) needs to be considered in planning and promoting efficient irrigation technologies and to analyze water savings across scales and actors, v) there is a need to look at the tradeoffs of micro irrigation and/or any water efficient technology across scales and geographies and also look at policies on the use of micro- irrigation and the road map for saving water and increasing productivity, vi) policies on water management, especially in groundwater irrigated areas have to be critically looked at the energy and food (agriculture) policies together to exploit synergies, vii) it is important to follow a systems approach and bundling water efficient technologies with other crop, agronomic and soil management interventions including options for solar irrigation besides smart farming technologies, digital agriculture, and value chain propositions, viii) scaling-up of efficient irrigation technologies for water saving would require institutionalization of convergence of relevant government schemes and programs for harmonizing synergies and encourage co-financing for scaling-up at a scale. Incentivization for conserving and saving water needs to be looked at as a viable policy instrument, ix) research initiatives should also focus on addressing the question of Real and Apparent water savings across water efficient irrigation technologies for promoting water saving. Research investment needs to be made in terms of more accurate water accounting, water budgeting including digital tools.

Finally, the sustainable water consumption caps (instead of limits on withdrawal rates) need to be set, monitored, and enforced. Sustainable boundaries for resource use cannot be exceeded. As water management decisions are made at different scales but actions are implemented locally, these caps need to be defined locally, informed by a basin-wide water accounting, and result from a consultative process. Necessary changes in water use behaviors should be facilitated through a delicate balance of a regulatory system with sanctions and incentives and sharing of benefits that drive behaviors of the actors. The latter is often more promising if well designed, and if implemented considering multiple sectors, scale dependencies, and local circumstances. The stakes are high and, no doubt, accelerated action is needed. Policy makers will have to make difficult choices about how to manage increasing resource deficits and set priorities, and policy implications will help ensure water management decisions.

Dr Claudia Ringler in her presentation emphasized on the need to assess water savings in irrigation including irrigation efficiency, water use efficiency and water productivity. If we could actually reduce global agricultural water consumption by just 5 per cent, then we would have made a significant contribution to environmental outcomes, to non-irrigation outcomes and to the SDGs where increased water use efficiency (WUE) is a stated target in SDG 6. The global crop water management needs to focus on improving productivity of rice, wheat, sugarcane and maize. India is facing large-scale water shortages and environmental degradation that will lead to increased outmigration and human misery of poor women and men farmers, unless substantial policy change is considered by the Government. One of the most effective measures to save irrigation water has been the development of modern plant varieties, particularly semi-dwarf and short duration varieties using less water for the same or higher grain-yield. The focus on drought/heat stress tolerant varieties that mature under more extreme climates can similarly improve irrigation efficiency as do measures to improve value chains and cold storage as well as other measures to reduce post-harvest losses.

The concept of water use efficiency (WUE) and water savings is of great relevance at the irrigation system level and some advances have been made to improve efficiency at that scale. From an economic perspective, broader water savings can be achieved through: i) investment in seed technologies (DT, HT, salt and submergence tolerance, plant and root architecture); ii) removing policies that are harmful for the water source and do not make economic sense; and

iii) eliminating crops that are harmful for water and human health. Semi-dwarf, short duration varieties use less water for the same or higher grain yield (higher grain to biomass ratio, faster growth); drought/heat stress tolerant varieties mature under more extreme climates; transpiration efficiency traits show great promise; nutrient use efficiency traits are crucial. We have to see whether India is investing enough in these technologies. She pointed out that India faces the largest water scarcity/quality challenges. Free or subsidized electricity and high levels of fertilizer subsidies are key contributors of these challenges. Focus on rice exports and large sugar exports and growing sugarcane in inappropriate (semi-arid) agroecological zones do not help saving water. Instead, there is an urgent need to clarify water savings for whom and what; and focus should be on broader policies if water savings are a goal. There is large under-invested innovation space in agriculture (plant architecture, root structure, transpiration efficiency) but also water.

Savings of 5 per cent of current irrigation water use globally or in large irrigation water using countries, such as India, could go a long way in supporting non-irrigation water demands, including the environment and growing urban-industrial uses. But most water saving efforts are instead directed at growing more food and are used to expand irrigated areas further, often putting at great risk to failure of irrigation water deliveries, particularly as a result of climate change. The use of subsidized irrigation technologies has failed to reach the intended target for transfer of flows from irrigation to in-stream uses. The reversal of subsidies alone would dramatically improve water use efficiency and generate water savings beyond the level that micro-irrigation systems could. A recent study showed a substantial decline in groundwater tables in Punjab as compared to Haryana when the former switched to free electricity from an already subsidized flat-rate tariff. Such policies suggest that water savings are not an important political goal and additional subsidization of counter measures would remain largely futile as long as first-order measures, such as substituting free electricity policies with direct payments to farmers, which would save resources for both the government and farmers themselves, are not being considered and implemented.

PANEL DISCUSSION

The panel discussion was moderated by **Dr Alok Sikka**, IWMI Representative, India; and Dr **SK Chaudhari,** DDG (Natural Resource Management), ICAR. There were seven panelists who made their interventions and have provided useful suggestions for the way forward.

Dr Tushar Shah emphasized that conjunctive management provides an opportunity for increasing irrigation efficiency which may be one of the country's best responses to some of the major challenges in the irrigation sector which include: i) steady decline in the management and performance of all government and community-managed surface and groundwater irrigation systems; ii) regulating groundwater overdraft and quality deterioration; iii) increasing the sustainability of groundwater irrigated agriculture; and iv) reducing power subsidies in groundwater irrigation. Water, power, and other public services are in the domain of state governments, so responses to irrigation challenges vary from state to state. In Punjab, Haryana, and Rajasthan, groundwater depletion is growing, power subsidies are mounting, and performance of canal irrigation is deteriorating. In Gujarat, where power subsidies are declining; groundwater balance is improving; and agricultural economy is booming. In improving canal irrigation systems, many states are trying participatory irrigation management. To regulate groundwater overexploitation, governments are enacting new laws and regulations.

India's irrigation economy has been undergoing a dramatic transformation with the control of irrigation shifting from the government to the individual farmers through millions of wells owned and operated by them. Though the booming tube well irrigation has generated substantial socio-ecological dividends in terms of flood mitigation and reduction in water logging and soil salinization, it has also been responsible for resource depletion and contamination of ground water in some parts of the country, leading to various adverse environmental and socio-economic consequences. There is need for achieving the right balance between supply and demand side measures for forging a sustainable ground water governance regime. Problems of groundwater overexploitation in India are bound to become more acute and widespread in the years to come unless corrective mechanisms are put in place before the problem becomes insolvable or not worth solving. Lack of information and absence of systematic monitoring of availability and withdrawal of ground water is a major barrier that prevents the transition from groundwater development to management mode. Further, unlike in the case of surface water irrigation systems, public agencies have only an indirect role to play in the national ground water sector due to its development mostly in the private, 'informal' sector and the quality and amount of application of science and management to this sector has been much less when compared to the former.

Ms Sangita Ladha opined that water is a critical input for agricultural production, therefore, incentivising farmers to improve water use efficiency is a matter of prime consideration. Technologies such as micro-irrigation systems can improve fertiliser and power use efficiency by 28 per cent and 30 per cent, respectively, along with reduction in labour cost and enhanced productivity. At the same time devising easier financing options for small and marginal farmers who face the challenge of having inadequate financing for extending their share for micro-irrigation (MI) installation is crucial. This calls for more awareness among lending institutes as well as beneficiaries. The Government of India has been proactive about water management in agriculture and launched *Pradhan Mantri Krishi Sinchayee Yojana* (PMKSY) in July 2015. With a view to provide impetus to micro-irrigation systems, a Micro-irrigation Fund was created with National Bank for Agriculture and Rural Development (NABARD). Government and industry need to come together for effective implementation of such programs. However, with multiple developmental schemes available in the irrigation sector, run by different government departments, it is necessary to bring in coherence and efficiency. For example, PMKSY (Per Drop More Crop) scheme can be dovetailed with PMKSY – '*Har Khet Ko Paani*'. These two schemes can be operated by the same nodal agency in the state. Such planning will lead to more impactful implementation of Government vision of per drop more crop. She highlighted how smart farming increases the quantity and quality of agricultural products with sustainable agricultural production, based on a more precise and resource- efficient approach through efficient use of water and enabling policy interventions are a must for enhancing micro-irrigation coverage in the country.

Dr Man Singh highlighted that increase in irrigation efficiency must be accompanied by robust water measurements and accounting. These measurements need to be linked with fair price of water that is used in irrigation sector, domestic purpose and industrial usage. Better understanding of the incentives in terms of free electricity, waiving of irrigation bills and unregulated mining of ground water and behavior of irrigators are highly desirable. The emphasis should not be given only to the behavior of irrigators rather it should be the behavior of each and every citizen of the country in general, should India achieve the agenda of SDG 6. Time is ripe to manage water through a principle of 'Measure and Treasure' and the pending bills, namely, i) National Water Framework Bill, (ii) River Basin Management Bill, and (iii) Model Bill to regulate and control the development and management of ground water need to be passed on a priority. The farmers maintain their own irrigation tube-wells quite well. But, the conditions of government-managed tube-wells and other irrigation infrastructure are not that good. His ground experience shows water cannot be managed efficiently unless we measure the resources scientifically and put a price on it. The balance between 'discharge' and 'recharge' has damaged so much that up to 1990, groundwater used to be pumped through 'centrifugal pump' but now 'submersible pumps' are required. Groundwater reservoirs/aquifers have become so much unbalanced that several rivers also dried up automatically. The gap between 'discharge' and 'recharge' of water should be minute or zero.

Dr HP Singh mentioned that irrigation project should be planned as integrated agricultural irrigation project having last mile connectivity (on-farm micro-irrigation) for every farmer. The approach should be “From Resource to Root”. While conceptualization, planning and designing any major/medium/minor irrigation project, water productivity and value creation must be the base criteria. All irrigation projects should be designed to deliver minimum 70 per cent overall irrigation efficiency. Micro-irrigation systems should be considered as part of irrigation and treated as extension/integral part of irrigation projects. Micro-irrigation industry should be brought under infrastructure industry status and classified as priority sector. Renewable energy (such as solar energy) needs to be integrated with micro-irrigation systems ensuring the sustainability of the projects. The Government needs to make micro-irrigation mandatory. Also, all earthen canals need to be changed to pipes canal so that water losses are curbed.

Dr V Praveen Rao stated that despite academic and practitioner recognition of the benefits of drip irrigation technology, growing irrigation equipment industry, convincing economic viability (NPV, payback period & IRR) and extensive promotion by the government over the past 2-3 decades through subsidies and schemes, the spread and penetration of the technology has remained low. Currently drip, sprinkler and flood irrigation account for 6.23 per cent (6.11 mha), 6.92 per cent (6.79 mha), and 86.8 per cent (85.1 mha) of the gross irrigated area (98 mha), respectively in the country. Mapping of drip and sprinkler irrigation potential considering both horticulture and agricultural crops in each state backed by innovative financial, technical, and implementation solutions (such as GGRC in Gujarat, APMIP in Andhra Pradesh and TSMIP in Telangana, TANHODA in Tamil Nadu) would improve its penetration in the country. Lack of innovative institutional instruments such as SPV in each state, variable and low government subsidies in different states, technical & economic efficiency issues, social and implementation issues (e.g., delayed release of budgets; schemes run for only 2 to 12 months in different states) issues, which need to be identified and addressed.

Making drip irrigation mandatory for water guzzling crops in several states needs attention. Taking a crop-specific focus would yield quicker results with large areas brought under micro-irrigation in shorter periods of time. In recent years, some notable innovative community based integrated micro-irrigation projects were commissioned in Karnataka (*Ramthal* drip irrigation project), Telangana (*Erravalle* community drip irrigation project) and Rajasthan (*Indira Gandhi Nahar Pariyojana*) which have shown a great promise for water control and timing of inputs, increase in gross irrigated area, crop yields, higher average net value of output per ha. A policy framework for such projects can potentially be a game changer for the spread of micro-irrigation, surface irrigated tank, lift and canal commands in the country.

Opportunities for market-led drip irrigation promotion also exist in the value chains of high-value cash crops such as cotton, vegetables, fruits, and sugarcane. In fact, the benefits to agriculture appear to outweigh the benefits to irrigation alone and therefore the farmers need to be incentivized for better agriculture economics rather than for only water savings which appear at the cluster level and not at the farm level. The following research gaps need to be addressed urgently: i) develop grower-appropriate scheduling products to develop generalized indexes so that the alternative scheduling approaches can be used over a broader range of conditions, ii) develop technologies that can help forecast crop water stress and improve or optimize micro-irrigation management, such as IoT, AI including machine learning, mobile apps, unmanned aerial vehicle (UAVs) or satellite-based remote sensing platforms, automated monitoring and control systems, plant water stress sensors, and soil water sensors, etc., iii)develop more accurate, site-specific and micro-irrigation system-specific (e.g. surface drip, SDI and micro-sprinkler) estimates of Kc for diverse agri-horticultural crops, iv) undertake research in major fruit crops, viz., mango, pomegranate, guava, citrus, etc., to develop improved irrigation strategies to manage soil water and nutrients within the regulated deficit irrigation (RDI) context, v) promote precision agronomic innovations like conservation agriculture (CA) and short duration legumes and oilseeds coupled with surface & subsurface drip irrigation (SDI) and fertigation to address multiple challenges of food, nutrition, water, energy, soil health & climate, vi) develop fertigation recommendations for agri-horticultural crops (viz., higher-value field crops, fruits, vegetables, spices, tree and vine crops) since micro-irrigation systems are well suited to applying nutrients both in a spatial and temporal contexts to augment performance of micro-irrigation systems in the country, vii) undertake water management sustainability analyses under the water, energy, and carbon trade-offs at different levels—field, system, and basin, and viii)conduct studies involving surface drip and SDI systems for the injection of systemic pesticides, fungicides, nematicides and herbicides (chemigation) and some microbial solutions (microirrigation).

Dr M Dinesh Kumar in his intervention emphasized that understanding the state of water resources and its uses requires detailed monitoring and assessment. Water stocks, water flows, uses of water throughout the system and their variability in space and time have to be developed to ensure well-informed planning and management, and to increase transparency in decision making. He further highlighted on the need to understand eco-water balance, soil moisture change, drip and mulching and reducing evapotranspiration, etc. and determining real water savings.

Mr Sunil Arora discussed on water use efficiency, reducing conveyance losses,evapotranspiration, use of water by weeds, public awareness, micro-irrigation, mulching, and diversification of crops, etc. Further, he focused on bringing a behavioral change in the minds of masses for conservation of water, water use efficiency, and impact of climate change on water resources. He mentioned about driving the national agenda on water conservation and management, especially the "*Jal Shakti Abhiyan*: Catch the Rain" campaign" that reaches out to every citizen across the country. He also reiterated that *climatic* changes in the form of variations in rainfall patterns, decline in precipitation, untimely patterns of floods and droughts, and sudden rise in temperatures have been experienced by communities across India in the recent years which have impacted the daily lives and livelihoods of the common people, particularly the marginal people. Therefore, considering the importance of climate change impact on water resources, the GoI established National Water Mission (NWM) under National Action Plan on Climate Change (NAPCC) with the objective of "conservation, minimizing of wastage and ensuring its equitable distribution both across and within States through integrated water resources development and management". In the age of climate change and water scarcity, micro-irrigation can help increase crop yield and decrease water, fertilizer and labour requirements.

PARTICIPANTS' VIEWPOINTS

Dr V Rathore stated that in the north-western hot arid regions, groundwater has been depleting at alarming rate and posing serious threat to agriculture. In these regions, halting the groundwater table decline is more important than enhancing water productivity (WP). For this, more radical changes like replacing high water (as well energy) requiring crops by low water requiring crops are the key measures which needs urgent attention. Furthermore, water-energy-food nexus (WEF) is equally important. Policy interventions for incentives for low water requiring crops (like cumin, *isabgol*) are required. If surface irrigation systems are recommended, there will be enormous energy implications.

Dr NR Panwar mentioned that to reduce evaporation losses on soil surface for higher moisture retention, water productivity and productivity reflective (mineral) mulches may be a good option, if it is used with drip irrigation system in open as well as protected cultivation. In western Rajasthan, surface water bodies are important source of water. More than 20,000 *diggis* are constructed in this area from which 30-40 per cent water is lost through evaporation. A cost-effective innovative approach using thermocol balls as a surface cover measure wherein thermocol balls of two different sizes are used which reduces open area to <2 per cent. Under field conditions, thermocol balls decreases evaporation losses by >40 per cent. Some formulations can be used which reduces the evaporation losses even below 10 per cent. The saved water can be monetized by using conserved water through micro-irrigation (Drip IS).

Dr PS Brahmanand opined that smallholder-friendly water management practices need to be promoted which would help in *in situ* water conservation. At the same time, instead of blanket recommendation of crop diversification from water guzzling crops, we need to identify clusters / blocks where higher scope for successful implementation of crop diversification exists based on existing water gap, current crop productivity, and edaphic as well as economic aspects.

Dr Shilp Verma informed that Gujarat tried to bundle micro-irrigation with farm power connections and failed miserably. This example amply demonstrates that careful planning is indeed very important before launching micro-irrigation schemes.

Dr MJ Caledonia mentioned that drip irrigation saves water. It helps farmers, in groundwater irrigated areas, to increase crop area and cropping intensity. The need of time is to finalize crop areas on the basis of water budget even in case of drip irrigation. If this issue is not addressed properly, initially there is increase in irrigated areas and after some years, groundwater wells start drying and farmers lose everything. This has actually happened in pomegranate areas of Maharashtra where farmers are now concentrating on groundwater recharge.

Dr Umesh Srivastava expressed the view that appropriate policies need to be instituted for exploiting participatory irrigation management in the conjunctive use of rain, canal and ground water. Considering the poor facility of electricity in most of the States, attractive schemes are necessary to promote low energy low lift pumps to tap shallow water table as supplemental irrigation during critical growth stages. Further, water stocks, water flows, uses of water throughout the system and their variability in space and time have to be developed to enable develop well-informed planning and management. Understanding the state of water resources requires detailed monitoring and assessment.

Dr Ram A Jat opined that in North-West India, rice needs to be replaced with less water requiring crops. Likewise, laser land leveling is important for enhancing WUE in surface irrigation. He further opined that more government subsidy on PVC pipes for water conveyance should be considered to reduce water losses during conveyance in pond/well irrigated areas. In heavy soils drippers are not suitable (lead to soil compaction while repairing/replacing in wet soil) rather inline laterals should be used.

Dr Mausumi Raychaudhuri said that maintenance of micro-irrigation system should be user friendly and economic; else it will be difficult to extend areas under micro-irrigation system.

Dr Harish Awari stated that location-specific pipe network designs and their execution is necessary in command areas to increase more crop per drop.

Dr SD Gorantivar remarked that delineation of potential zones for implementation of conservation measures above the entire watershed is inaccessible as well as uneconomical; consequently, it is a prerequisite to apply viable technique for prioritization of sub-watersheds (SWDs). The morphometric characterization showed imperative role in distinguishing the topographical and hydrological behaviour of the watershed. Based on Fuzzy Analytical Hierarchy Process (FAHP) approach, sub-watersheds were evaluated as vulnerability assessment zones and alienated into five prioritization levels: very less, less, medium, high and very high classes. The results illustrated that 60.85 per cent of sub-watersheds (five sub-watersheds) were in the medium to high susceptible zones, which depicted potential areas for necessity of establishment of conservation interventions for the sustainable watershed management planning.

Dr Shivendra Srivastava opined that the objective of sustainable water management may not be met till we use only engineering approaches and ignore institutions and governance part of water management and address the issues in holistic ways.

GENERAL DISCUSSION

The Session was moderated by **Dr Adlul Islam,** ADG (S&WM), ICAR. In his quick comment, **Dr JC Katyal** remarked that in the entire consultation program, states could have been considered and theusers should have also been involved. **Dr V Praveen Rao** commented that the decisions regarding the management of water and energy resources are profoundly affecting our economic and environmental future. Climate change and other stresses are limiting the availability of clean water and cheap energy. A large amount of energy is expended to supply, treat and use water, meaning that water-oriented strategies can result in significant reductions in energy use and greenhouse gas (GHG) emissions. These issues need to be considered. **Dr DK Singh** emphasized that the most efficient method of irrigation is the one through which it is possible to keep the applied water within the root zone more particularly in the active root zone, which is possible through micro-irrigation. It is true that the micro-irrigation will not lead to groundwater recharge but certainly the groundwater pumping will be much lesser than the conventional method of irrigation. Irrespective of recharge or no recharge, the concern is how to reduce the groundwater pumping. That is possible through groundwater recharge. Groundwater irrigation is practiced where surface/ canal water is not adequate. In such areas, the concern is to enhance irrigation intensity with minimum groundwater pumping. That is possible with micro-irrigation. Ground recharge is said to be accomplished when the infiltrated/ percolated water reaches to the water table not just retained in the vadose zone. In groundwater irrigated area, water table is far below and even if irrigation is done through conventional method many times percolated water reaches to the water table.

CONCLUDING SESSION

Dr SK Chaudhari in his concluding remarks emphasized that unless we have the enabling policies in place, we cannot make much progress towards efficient groundwater utilization. He further stressed that water productivity data for different crops should be gathered through using standardized methodologies so as to enable proper comparison. Region-specific water production functions for different crops and their varieties and different water application technologies are urgently needed. Database of soil hydraulic properties also needs to be developed for water balance modeling, proper irrigation scheduling and irrigation water management. Hydro-meteorological database along with near real-time flood/ drought forecasting/warning tools are required for disaster risk management. **Dr Alok Sikka** mentioned about bundling precision agronomic innovations like conservation agriculture (CA), and mulching sectors, and also on policy coherence. On watershed, he said adoption of participatory integrated watershed management within a river basin perspective provides a framework for climate change adaptation through reduced runoff, increased groundwater recharge, improved crop productivity and increased carbon sequestration. The general perception of canal irrigation systems in India is one with built infrastructure with low service performance.

Dr RS Paroda, in his concluding remarks, summarized the comprehensive deliberations of the expert consultation. He emphasized that we should have better irrigation technology for water saving which is the need of the hour. Micro-irrigation (MI) is important but will not charge aquifers. There is need to improve efficiency for MI taking holistic view. GoI also needs to subsidize MI significantly. We need to possibly look for enabling policy to speed up the process with renewed vigour. Further, the water availability for food production is becoming stressed from growing and competing demands from urbanization and industry, natural resource degradation and exacerbated spatial–temporal variability due to climate change. There is a vast scope for increasing the production and productivity of rice-wheat cropping system through better management of water resources. Interventions like System of Rice Intensification (SRI) and Direct Seeded Rice (DSR) provide opportunities to enhance rice productivity, minimize the use of water and other inputs and protect the environment, but their efficacies should be assessed rigorously. He stressed that water is often viewed as a resource that is free of cost compared to other agricultural inputs and no restriction on its supply leads to overexploitation and excessive irrigation. Depleting water resources further impacted by the adverse effects of climate change are major areas of concern for India.

Dr Paroda further highlighted that it is pertinent to take a close look at the need for enhancing water-use efficiency (WUE) in agriculture. The key to ensuring sustainability in agricultural water management is to pay greater attention to varied aspects such as cropping systems, technology adoption, governance institutions and policy frameworks. Formation of partnership models with the use of modern technology is an important approach to demonstrate how water can be managed successfully for agricultural use. As the need for practicing water-efficient agriculture grows, collaboration between stakeholders and formation of partnerships with community mobilization are very important to integrate the efforts of water management and implement water efficiency effectively. The looming water scarcity in India has already led to a paradigm shift towards growing crops that use less water. The adoption of modern and innovative technologies and methods is necessary for smartly using water in agriculture. Precision irrigation methods are solutions that have been developed for effective water use not only in water-scarce regions but also in regions where the availability of water is abundant. Adopting micro-irrigation has increased the volume of crop production. Further, he suggested that a 'Strategy Paper for Scaling Micro-irrigation' needs be developed on priority. Necessary changes in water use behaviors should be facilitated through a delicate balance of a regulatory system with sanctions and incentives and sharing of benefits that drive behaviors of the actors. The latter is often more promising if well designed, and if implemented considering multiple sectors, scale dependencies, and local circumstances. The stakes are high and, no doubt, accelerated action is needed. Policy makers will have to make difficult choices about how to manage increasing resource deficits and set priorities. While concluding, he appreciated the good efforts made by all concerned for successful conduct of this specific expert consultation.

The expert consultation ended with a vote of thanks by **Dr Bhag Mal** to co-chairs, speakers, panelists, moderators, distinguished invitees and participants. He also expressed sincere thanks to all the co-organizers for their all out help and support and all others who helped directly or indirectly in making the consultation a great success.

KEY RECOMMENDATIONS

I. Research and Development

1. 'Micro-irrigation Fund' has to be utilized effectively enhancing the area under micro-irrigation in innovative ways. Strategies for promoting micro-irrigation for water guzzling crops such as sugarcane, rice, cotton, etc. be evolved and implemented on priority. For this, interaction with States needs to be

strengthened for Canal Command/Community Based Irrigation projects involving all concerned stakeholders. Effective coordination and convergence of water use related programs and scaling of innovations such as MI, conservation agriculture, direct sowing of rice, etc., sub-surface drip (SSD) irrigation, etc. need to be promoted on priority.

2. Complexity of scales both spatial (farm/field to command area to sub-basin/basin) and temporal, sectors and actors (users and uses) are very important to be considered in planning and promoting efficient irrigation technologies and to analyse water savings in different ecosystems. Hence, information on this aspect must be collated and analysed for eco-region specific planning.
3. Suitable technologies need to be developed that can help forecast crop water stress and improve or optimize micro-irrigation management, such as Internet of Things (IoT), Artificial Intelligence (AI), including machine learning, mobile apps, unmanned aerial vehicles (UAVs) or satellite-based remote sensing platforms, automated monitoring and control systems, plant water stress sensors, and soil water sensors, etc. Developing more accurate, site-specific and micro-irrigation system-specific (e.g., surface drip, sub-surface drip irrigation (SDI) and micro-sprinkler) estimates of crop coefficient (Kc) for diverse agri-horticultural crops. Regulated deficit irrigation (RDI) is a controlled root volume technique especially suited to drip irrigation. Concerted research is needed in major fruit crops, viz., mango, pomegranate, guava, citrus, etc. to develop improved irrigation strategies to manage soil, water and nutrients in the context of RDI.
4. Research initiatives need to focus on addressing the Real and Apparent water savings across efficient irrigation technologies. Higher research investment needs to be made in terms of more accurate water accounting, water budgeting including digital tools. Scaling-up of efficient irrigation technologies for water saving would require institutionalization and convergence of relevant government schemes for required synergies and for possible co-financing for accelerated scaling of innovations.
5. Shifting cropping patterns in alignment with agro-climatic conditions in different regions in the country can lead to improved management of water usage in agriculture. Replacing water-intensive crops such as rice and sugarcane with the ones that require less water (such as millets, oilseeds, pulses, etc.) can reduce water requirement for irrigation. Moreover, intercropping or mixed cropping can also be beneficial for small and marginal farmers. Therefore, efficient cropping practices linked to smart irrigation technologies that are specifically suited for different eco-systems need to be promoted.

6. A participatory approach is critical in water-use management in agriculture, requiring users, service providers and policymakers to be on the common platform. Therefore, water users' associations (WUAs) and water user groups (WUGs) need to be established to promote community-led initiatives for sustainable and efficient water-use management in agriculture.
7. Formation of partnership models with the use of modern technology is an important approach to demonstrate how water can be managed successfully for agricultural usage. For this, an effective collaboration among the key stakeholders with enhanced community participation has to be strengthened for effective implementation of water-efficient technologies in agriculture. Sustainable water consumption caps (instead of limits on withdrawal rates) need to be set, monitored and enforced locally.
8. There is need for detailed monitoring and assessment for understanding the state of water resources and its uses. Water accounts, i.e., the stocks, flows, and uses of water throughout the system, and their variability in space and time have to be developed to enable well informed planning and management, and to increase transparency in decision making. Modern earth observation methods (remote sensing of precipitation, evaporation, biomass, etc.) supported by big data approaches (e.g., internet of things, citizen science, and artificial intelligence) can complement traditional ground-based monitoring networks. This is especially critical in the context of climate change which is likely to increase water scarcity.
9. Scaling of micro-irrigation and water demand management in agriculture requires specific approaches since "one model does not fit all". Therefore, it is necessary to understand the local conditions for interventions (biophysical, social, economic and political) including how irrigation development systems are embedded in the whole basin/system (larger natural and human systems).
10. It is important to follow a systems' approach and bundling water efficient technologies with other crop, agronomic and soil management interventions including options for solar irrigation to harness synergy at the systems level, besides smart farming technologies, digital agriculture, and value chain propositions.
11. The facilities of services for repairing and maintenance of micro-irrigation systems at the village level are limited, which hinder the adoption of micro-irrigation by small and marginal farmers. Hence, there is great need for training of village youth to enhance their skills and create a cadre of trained service providers and extension agents for repair, maintenance and installation of micro-irrigation systems.

II. Strategies and Enabling Policies

12. There is need to make higher investment in water infrastructure, and water measurement facility. Pricing of water has to be considered a priority and be agreed upon quickly by all the states and centre for reducing water use in agriculture by improving WUE. Also, the allocations under the "Water Infrastructure Fund" at the national level has to be doubled to speed up scaling of micro-irrigation and other water smart technologies. Also, a good relationship between Centre-State and Inter-State level would ensure much faster take-off of the water infrastructure projects. Re-engineering of the Government's strategy for achievement of positive environmental externalities also needs to be considered seriously. And most importantly, the overall ecosystem strategy should encourage policymakers, the private sector and users to adopt a 'water stewardship' approach so as to enhance water-use efficiency at the national level.
13. In view of ever-increasing importance of water, the Government of India has proactively introduced sustainable water management and has created a new Ministry of Jal Shakti (MoJS). The initiatives by the central and state governments towards devising new schemes to address this issue are noteworthy but for these schemes to be effective and beneficial, there is need to promote new technologies for use of water in agriculture. Further, adoption of innovative technologies by small and marginal farmers has to be accelerated at much faster pace.
14. There is an evident need to look at the trade-offs of micro irrigation and/or any water efficient technology across scales and geographies and also to review the policies on use of micro-irrigation for saving water and increasing productivity. Policy coherence across the water, energy, food and ecosystems (WEFE) nexus is important but not evident presently. This leads to overlapping decision spaces, competing objectives, poorly understood trade-offs and synergies. Investment decisions hence be taken through an integrated approach of biophysical and socio-economic parameters across the WEFE nexus.
15. Policies on water management, especially in groundwater irrigated areas, have to be critically looked at energy and food (agriculture) policies together to exploit synergies across them as these are interconnected and, therefore, policy coherence within the larger framework of water, energy and food nexus assumes high importance and thus needs to be given urgent attention.
16. Agricultural water management needs to be designed and implemented within a wider systems approach including natural systems and human systems, taking

the changing climate into account. Policy measures and interventions (e.g., water allocation and re-allocation, land use decisions or implementation of incentives) are influenced by processes and dynamics at different scales. Not recognising this complex situation, or lack of understanding of interactions of the natural systems (e.g., evaporation and surface–groundwater interlinkages) with the human systems (e.g., food, energy, and social systems), can lead to unintended consequences, including suboptimal water management. This is a major challenge requiring coordination and collaboration among wider set of actors. In the, process, the long-term benefits are likely to exceed the short-term costs of such integration.

17. Multiple policy instruments are needed to ensure agricultural water management, for instance, to conserve water resources, to make water allocations available for other uses, or to increase agricultural production or farmers' incomes. Some objectives are complementary and have co-benefits (e.g., increase agricultural production and farmers' incomes), while others lead to conflict (e.g., increase in agricultural production and conservation of water resources, including recharge of aquifers in areas of water scarcity).
18. Sustainable water management in agriculture can be achieved by implementing an enabling policy ecosystem at the national level. A consistent and suitable policy framework can lead to effective and affordable technology interventions for smart water utilisation in agriculture, judicious distribution of usage rights and the establishment of institutions to ensure efficient management of different systems. The policy ecosystem needs to use information technology (IT) in a strategic manner and create solutions to ease accessibility for small and marginal farmers. Furthermore, capacity building of frontline workers, extension specialists, private extension and convergence of other related schemes, with effective use of IT, would be highly advantageous.
19. Creation of a package of incentives could ensure adoption and also needed access to beneficiaries. Furthermore, introducing subsidies for the adoption of solar-powered technology interventions can lead to input-related cost reduction in agricultural practices, including saving on electricity, and subsequently reduce greenhouse gas emissions. However, the adoption of technology by farmers needs adequate support, such as: handholding, follow-up in users' experience and maintenance-related advisory. This is an area where private sector could play a significant role.
20. The existing challenges need to be addressed in an integrated manner for effective and faster results. The following holistic approach can increase the operational efficiency of ongoing government schemes: i) farmers may

focus on reducing glitches and increasing the operational efficiency of micro-irrigation schemes; ii) various policies on agriculture, climate change, forestry, water conservation, livelihood, skill development and women empowerment can be implemented in tandem and in an integrated manner; iii) involvement of beneficiaries and their ownership of water resources are key factors for successful implementation of any scheme. Hence, participatory irrigation can be promoted adopting innovative ways; iv) latest and enabling IT technology shall act as catalyst in increasing operational efficiency through precision farming and water-efficient irrigation systems, and new IT interventions like AI, IoT, satellite imaging and drones needs to be effectively utilised.

21. It was unanimously agreed to develop a 'National Strategy Paper for Scaling Micro-irrigation' on priority covering all aspects of micro-irrigation (MI), especially its tangible benefits vis-a vis adverse impact on account of lack of water recharge of aquifers in areas where water table is quite low. Also, incentivization for adoption of water conserving technologies be considered a viable policy option worth perusing on priority. Such a strategy must also define a clear 'Road Map' for irrigation water saving while increasing water productivity.

Technical Program

25 FEBRUARY 2022; 15:00-18:15 (IST)

15:00-15:45	**OPENING SESSION**	
Co-Chairs	**: RS Paroda**, Chairman, TAAS **: Mark Smith**, DG, IWMI	
15.00-15.10	**Welcome**	**SK Chaudhari**, DDG (NRM), ICAR
15.10-15.20	**Setting the Context**	**RS Paroda**, Chairman, TAAS
15.20-15.30	**Special Remarks**	**Mark Smith**, DG, IWMI
15.30-15.45	**Address by Chief Guest**	**T Mohapatra**, Secretary, DARE & DG, ICAR
15.45-16.45	**SESSION-I: THEMATIC PRESENTATIONS**	
Co-Chairs	**: AB Pandya**, Secretary General, ICID **: JC Katyal**, Former DDG, ICAR	
15.45-16.00	Does improved irrigation technology save water?	**Chris J Perry**, Former DDG, IWMI
16.00-16.15	Improved water savings from efficient irrigation and water management technologies	**SK Chaudhari** and **Atmaram Mishra**, ICAR
16.15-16.30	Integrated thinking across scales for optimizing water use and saving in agri-food systems	**Stefan Uhlenbrook** and **Alok Sikka**, IWMI
16.30-16.45	Assessing scale-dependent water saving changes from an economic perspective	**Claudia Ringler**, IFPRI

16:45-17:30	**SESSION-II: PANEL DISCUSSION**	
Co-Chairs : Alok Sikka, IWMI Representative, India **: SK Chaudhari**, DDG (NRM), ICAR		
	Tushar Shah, Research Fellow, IWMI **Sangita Ladha**, Business Director, Rivulis Irrigation India Pvt. Ltd **Man Singh**, PD, ICAR-IARI (WTC) **HP Singh**, Founder & Chairman, CHAI **V Praveen Rao**, VC, PJTSAU **M Dinesh Kumar**, ED, IRAP **Suneel Kumar Arora**, Advisor (C&M), NWM	
17.30-17.55	**General Discussion** **Moderator : Dr Adlul Islam**, ADG (S&WM), ICAR	
17:55-18:10	**Concluding Remarks**	**Alok Sikka**, IWMI Representative, India **SK Chaudhari**, DDG (NRM), ICAR **RS Paroda**, Chairman, TAAS
18.10-18.15	**Vote of Thanks**	**Bhag Mal**, Secretary, TAAS

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6. Stakeholders Dialogue on Enabling Policies for Harnessing the Potential of Genome Editing in Crop Improvement - Proceedings and Recommendations, 17 March, 2021 (June, 2021).
7. Harnessing Genome Editing for Crop Improvement – An Urgency : Policy Brief, May, 2021.
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