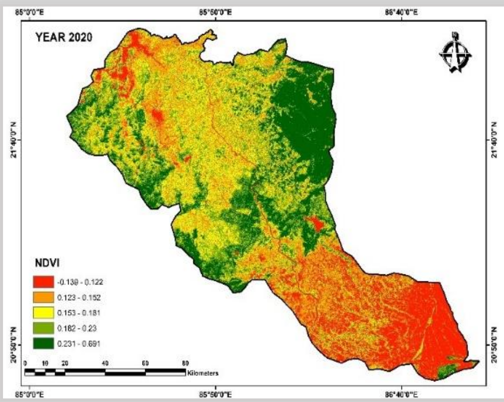
Advanced Water Management Technology for Enhancing Agricultural Productivity

Edited By:

Dr. R. R. Sethi
Dr. S.K.Jena
Dr. B. Renuka Rani and
Dr. S. K. Jamanal



ICAR -Indian Institute of Water Management (ICAR – IIWM)
Bhubaneswar
&
National Institute of Agricultural Extension and Management (MANAGE)

Advanced Water Management Technology for Enhancing Agricultural Productivity

Editors: Dr. R. R. Sethi, Dr. S. K. Jena, Dr. B. Renuka Rani and Dr. S. K. Jamanal

Edition: 2022.

ISBN: 978-93-91668-37-2

Citation: Sethi R. R, Jena S. K, Renuka Rani B. and Jamanal S K, (2022). Advanced in Water Management Technology for Enhancing Agricultural Productivity. ICAR -Indian Institute of Water Management (ICAR – IIWM), Bhubaneswar & National Institute of Agricultural Extension Management (MANAGE), Hyderabad, India.

Published for Dr.P.Chandra Shekara, Director General, National Institute of Agricultural Extension Management (MANAGE), Hyderabad, India by Dr.Srinivasacharyulu Attaluri, Program Officer, MANAGE and printed at MANAGE, Hyderabad as e-publication.

Forward

The ICAR-Indian Institute of Water Management was established by the Indian Council of Agricultural Research with the aim to cater the research and development need of agricultural water management at national level. The Institute has mandate to develop strategies for efficient management of on-farm water resources for sustainable agricultural productivity, coordinate research for generating location-specific technologies for efficient use of water resources and act as centre for training in agricultural water management. In order to meet the growing food demands of an increasing population in India, agricultural production needs to be enhanced, which largely depends on efficient management of the available water resources. Given the frequent occurrence of droughts and a more erratic monsoon rainfall, the rainfed agriculture, which covers 51% of the total 141 M ha of net sown area, is under water stress. Similarly, in 68 million hectare areas under surface and groundwater irrigation, still the traditional method of flood irrigation is a common practice, indicating low irrigation efficiency. Therefore, the contrasting problem of water stress in rainfed and water excess in irrigated ecosystem are the twin challenges that make agriculture vulnerable as well as less productive. This necessitates implementation of efficient water management practices that could play significant role for sustainable crop production and thus ensure food security for the country. Indeed, the 12th plan of Government of India has given highest priority to water management and Govt scheme “Pradhan Mantri Krishi SinchayeeYojana (PMKSY)” envisages judicious use of the available water resources for enhancing water productivity and also targets to provide irrigation facilities at farm scale.

Being the premium institute of the country ICAR-Indian Institute of Water Management aims to cater the research and development need of agricultural water management at the national scale. Due to the inherent diversity of soil, climate, and landscape, there is a need for location-specific solutions or an integration of tools and techniques of water management. Undertaking several national and internationally-collaborated projects, ICAR-IIWM has developed sustainable water management technologies and tested those in the farmers’ field. In particular, through the All India Coordinate Research Projects (AICRP) on Irrigation Water Management, ICAR-IIWM has synthesized efficient water management technologies for agro-climatic zone (ACZ) of the country. ICAR-IIWM has not only developed an expertise in this field but also at a stage now to share the rich information and expertize with those engaged in agricultural extension, in general. Under this background, the collaborative training programme on “Advances in Water Management Technology for Enhancing Agricultural Productivity” conducted during 4th May-7th May 2022 in collaboration with MANAGE will certainly help the Agricultural Extension Officers, Scientists, KVK scientists, Young researchers, NGOs, Students working in the field of water management to gain knowledge and carry confidence to demonstrate different water management technologies at their respective work place. I appreciate the team of ICAR-IIWM, Bhubaneswar for organizing this collaborative training program and bringing out the publication which would prove beneficial for all the stakeholders involved in enhancing agricultural water productivity in different region of India and help for successful implementation of flagship programmes of Government.

DIRECTOR

Preface

This e-book is an outcome of the Online Collaborative Training Program on “Advances in Water Management Technology for Enhancing Agricultural Productivity” with National Institute of Agricultural Extension Management (MANAGE), Hyderabad, Telangana. This book is intended to serve as a guide to scientists, faculty members, entrepreneurs, extension functionaries and all others who are working in the field of agricultural water management in different agro climatic condition of India. Furthermore, this e book will update their knowledge and create awareness about advanced water management technologies for enhancing agricultural water productivity in different region of India. The content of training programme was designed to provide updated information towards capacity building exercises through case studies and upgrade the field level technical knowledge for faster adoption of well proven agricultural water management technologies and for successful implementation of flagship programmes of Government. Attempt has been made to cover topics on recent advances in agricultural water management in groundwater and canal command areas. Topics on groundwater management with focus on community involvement and livelihood will be helpful to manage groundwater at regional scale by participatory approach. Farmer based recharge structure, an adaptive measure to combat climate change is a field scale model developed for sustainable groundwater development and management options. Similarly, water management options in canal command areas includes both surface irrigation system and micro irrigation system within the command area to enhance the cropped area as well as increase the water productivity. Other location specific options for enhancing land and water productivity in waterlogged areas, Water and nutrient management in self-reliant farming system for increasing farm income, Water harvesting based integrated farming system, Cost estimation, safety measures and maintenance of water conservation structures will be helpful to develop appropriate plan for increasing crop productivity of an area. ICAR-flexi rubber check dam, developed by ICAR- IIWM was an innovative technology for efficient water conservation. Hands-on practice on advanced techniques of remote sensing and GIS application to identify location specific water conservation structures, micro irrigation system design, irrigation scheduling and design of optimal cropping pattern for small and marginal farmers, Management of poor quality water for irrigation, Scientific planning of aquaculture activities for increasing water productivity, Creek irrigation system- Water management options for coastal saline ecosystem, Computer application in agricultural water management would be helpful for the participants to deisgn and plan for sustainable management of water resources in irrigation sector.

Valuable suggestions for future improvement are always welcome.

10 May, 2022 **EDITORS**

Contents

Water Management: Issues and Strategies

Atmaram Mishra
Director
ICAR – Indian Institute of Water Management, Bhubaneswar – 751023, Odisha, India
E-mail: atmaram.mishra@icar.gov.in

Water scarcity is becoming a major constraint in producing food for growing population, ecosystem protection, and maintaining health and social security. There is also threat to our environment like water logging and salinity in many canal commands, seawater intrusion in coastal areas, drying up of wet-lands and low-flows in streams etc. The climate change impact has taken its toll on water resources. The frequent occurrence of extreme events such as drought and floods further worsen the water scarcity situation and agricultural productivity. The spatial and temporal heterogeneity of flood and drought along with huge spatial disparity in expanding irrigated area are the challenges for a vast country like India. The irrigated agro ecosystem has got many challenges. Spatial disparity in expanding irrigated area in the country, poor irrigation efficiency mainly for the canal irrigation, regional disparity in groundwater development, and low use and filtration of wastewater for irrigation are the new challenges in our country. In rainfed argo-ecosystem, rainwater conservation in different land forms and its efficient utilization is one of the most appropriate strategy to create a favouruable water regime for better crop growth and yield. Management of waterlogged areas and flood prone areas are the most challenging one. But there are several technologies available to address the challenges. In irrigated agro-ecosystem, performance improvement of canal irrigation system, introduction of pressurized irrigation system, drip fertigation for better water and nutrient use efficiency, use of sensors for precise application of water in the field are some of the options to increase irrigation water use efficiency.

2.0 Water resources of India

2.1 Surface water resources

India accounts for about 2.45 per cent of world's surface area, 4 per cent of the world's water resources and about 17 per cent of world's population. The country is subjected to uneven distribution of water, challenged by the negative impact of climate change. Thus there is a need for proper water management and water conservation.

India receives an annual average rainfall of 1170 mm. Its uneven spatial and temporal distribution is a major concern for crop production. Out of the total 4,000 billion cubic meters (BCM) of total water resources, the utilizable water resources have been assessed as 1123 BCM (690 BCM surface water and 433 BCM groundwater sources). The mean annual flow in all the river basins in India is estimated to be 1,869 km^3. The projected water demand by 2050 will be 1447 BCM which is 324 BCM more than the present level of utilizable water resources. In addition to agriculture, the demand from other sectors such as industry, energy, municipal etc. are also increasing day by day. Thus, there is a need to identify and analyze the challenges in the agricultural water management sector and formulate strategies for (i) enhancing productivity of challenged agro-ecosystems, i.e. rainfed and water logged areas (ii) producing more from less water by efficient utilization of surface and groundwater in irrigated areas, and (iii) safe use of a portion of grey water for agricultural production purpose in a sustainable manner.

2.2 Groundwater resources

Groundwater plays an important part in India's economy. Unregulated groundwater extraction has led to overuse in many parts of the country, causing the groundwater table to plummet and drying springs & aquifers. The annual replenishable groundwater resource is 433 BCM and the draft is 245 BCM, which accounts for about 62 % of the net water available. Of this, 91 % was used for irrigation. However, the effects on groundwater in different regions of the country have not been uniform. The situation is alarming in regions where groundwater exploitation exceeds replenishment. States like Haryana, Punjab and Rajasthan now draw more water than is annually replenished.

3.0 Challenges in Water Management

3.1 *Rainfed* agro-ecosystem challenges

Rainfed agro ecosystem is a challenged ecosystem from water management perspective. It has both drought prone areas as well as flood prone/waterlogged areas which have unique characteristics of low agricultural productivity. Presently about 72 M ha area is under rainfed agriculture (net sown area under rainfed condition). It is noteworthy that about 33% of rainfed area receives more than 1100 mm of rainfall and another 33% receives rainfall between 750-1100 mm.

3.1.1 Spatial and temporal heterogeneity of flood and drought

Floods and droughts accounted for 51% of all natural hazards and 76% of the damages caused in India between 2000 and 2020 (EM-DAT, 2020). Floods and droughts are a recurrent phenomenon in India. The southwest monsoon rains, between June and October, account for over 70% of annual precipitation in states located in many large river basins (GOI, 2019). The large river basins, such as the Indus, Ganges, and Brahmaputra, generate significant monsoon runoff leading to massive flooding in the plains. About 43% of the Indian population is prone to recurrent floods (Amarnath *et al*., 2017). The northeast monsoon period (November to March) has mainly dry weather and a year with below-average monsoon causes droughts in many regions. Annually, droughts also expose a similar percentage of the population (Amarnath *et al*., 2017).

3.1.2. High spatial variation of crop production and productivity

The average national productivity of food grain is around 1.9 t/ha. The average productivity of Punjab was 4.2 t/ha, 3.3 t/ha in Haryana and 2.7 t/ha in Andhra Pradesh and in eastern Indian states, the productivity is 1.5 t/ha for Assam, 1.7 t/ha for Bihar, 1.0 t/ha in Chhattisgarh, 2.0 t/ha in eastern Uttar Pradesh, 1.7 t/ha in Jharkhand, 1.3 t/ha in Odisha and 2.4 t/ha in West Bengal (Directorate of Economics and Statistics, 2020). This wide gap of food grain production and productivity can be bridged to considerable extent by efficient irrigation water management.

3.1.3. Saline and waterlogged area

India has got about 11.6 million ha area as waterlogged. In addition to over irrigation, run-off congestion, unscientific *in-situ* water management, imbalance in inflow and outflow water in irrigated lands and obstruction of natural drainage networks also play very important role to create waterlogging. In arid and semi-arid region, it leads to build-up of soluble salts in the root zone causing twin problems of waterlogging and soil salinity simultaneously. Among all the regions of India, eastern India is having maximum waterlogged area. Because of high rainfall and saucer shaped topography, this region has significant area under water stagnation of various depths. In the waterlogged area the crop yield reduces drastically and at some cases total crop failure occurs.

3.2. Irrigated agro-ecosystem challenges

3.2.1. Spatial disparity in expanding irrigated area

The percent of cultivated area under irrigation is 49.2% on national basis. It is as high as 98.6% in Punjab and 91.4% in Haryana. However, it is only 47.7% in eastern India. The irrigation potential created and utilized with respect to ultimate irrigation potential is quite less in eastern India in comparison to national average. Hence, there is a need for creation of more irrigation infrastructure in order to bring more area under irrigation in the eastern region.

3.2.2. Poor irrigation efficiency

India has low water use efficiency compared to the developed countries. The overall irrigation project efficiency in developed countries is 50 – 60% as compared to only 38% in India. Thus, more water per unit of production is being required in India compared to similar crop grown in other countries. There are several technological options available to increase the overall project efficiency.

3.2.3. Regional disparity in groundwater development

The average groundwater development in India is 63.3 %. The stage of development in eastern and north eastern region are 40.7% and 2.4%, respectively which are very low. It is only 11% in Assam, 46% in Bihar, 44% in Chhattisgarh, 28% in Jharkhand, 42% in Odisha, 45% in West Bengal and 69% in eastern UP. The average stage of southern, northern and western region of India is 64.6%, 94.3% and 84.7%, respectively. Hence, this regional disparity needs to be minimized and water sufficient states are to be encouraged to increase the groundwater development.

3.2.4. Declining of groundwater table

The utilization of groundwater for irrigation is increasing rapidly after independence and on the contrary the surface water utilization has been declined (Fig. 1). The groundwater level in India has declined by 61 per cent between 2007 and 2017 and of the extracted water 89 per cent is used for irrigation, according to the census. Out of the total 6881 assessment units (Blocks/

Mandals/ Talukas/Firkas) in the country, 1186 units (17%) have been categorized as ‘Over-Exploited’ and 313 units (5%) are ‘Critical’. There are 972 semi-critical units (14%) and 4310 assessment units (63%) have been categorized as ‘Safe ‘. Apart from this, there are 100 assessment units (1%), which have been categorized, as ‘Saline’ as major part of the ground water in phreatic aquifers is brackish or saline (CGWB, 2019).

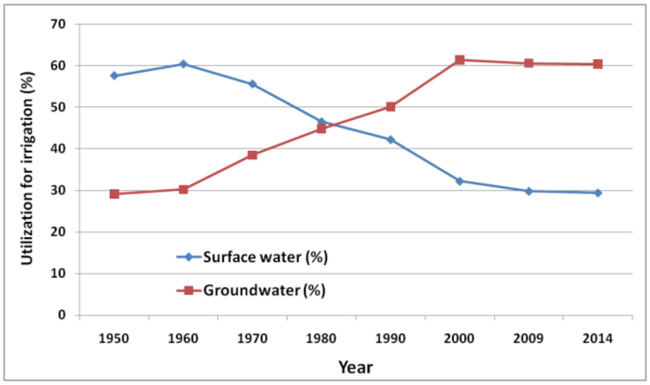


Fig. 1: Temporal trend in utilization of surface and groundwater resources for irrigation in India

3.2.5. Spatial heterogeneity in spreading micro irrigation

Micro irrigation in India is being popularized with a subsidy component, by both the central and state governments. As per the data provided by the Ministry of Agriculture and Farmers Welfare to the Lok Sabha the agriculture land covered under micro-irrigation is 12.9 M ha in which drip irrigation is 6.11 M ha and sprinkler irrigation is 6.79 M ha. This means that out of total irrigated land in the country only 19 per cent is under micro-irrigation. Maharashtra, Andhra Pradesh, Telangana, Karnataka and Gujarat together account for about 85% of total drip-irrigated area. In case of sprinkler system, Rajasthan and Haryana top the list. Madhya Pradesh, Punjab and Haryana lag far behind compared to their potential. However, groundwater development in these states is more than 100%.

3.2.6. Poor groundwater quality

Poor groundwater quality is one of the causes of water scarcity in certain parts of India. In some areas, groundwater is not suitable for irrigation due to salinity and/or geogenic elements. For example, instances of high fluoride in 13 states, arsenic in West Bengal, and iron in the north-eastern states, Odisha, and other parts of the country have been reported. In West Bengal, arsenic toxicity has been observed as a result of over-draft, particularly, more withdrawal of groundwater during lean period for summer paddy irrigation.

3.3. Issues related to wastewater management

3.3.1. High microbial load

Wastewaters are loaded with various types of microbes. It contains high concentrations of excreted pathogens such as viruses, bacteria, helminths eggs, and fecal coliforms. These excreted pathogens have the potential to cause disease if present in a human host in sufficient quantities. Intestinal nematodes pose the highest degree of risk of infection while bacteria pose a lower risk.

3.3.2. Rich source of organic and chemical pollutants

About 70% of the surface water resources and large proportions of groundwater reserves have been contaminated due to indiscriminate discharge of wastewater from the industry, agriculture, and households' sectors which contain biological as well as toxic organic and inorganic pollutants. Municipal sewage and industrial pollution contributes about 75 and 25% of the point source pollution, respectively. Class-I and Class-II cities together generate an estimated 38,254 million litres per day (MLD) of sewage (CPCB, 2015) and it will increase by three-and-a-half times to 132,253 MLD by 2050. Both water quantity and nutrients contained in urban and peri-urban wastewaters make them attractive alternative water source for agriculture and aquaculture. Treated wastewater from off-site treatment plants can be reused for irrigation.

4. Strategy for Improved Water Management in Agriculture

4.1. Water management strategies in *rainfed* agro-ecosystems

4.1.1. Rainwater conservation in different land forms and its efficient utilization

Rainwater conservation/water harvesting using appropriate techniques at plausible sites and efficient utilization of harvested rainwater has been considered as the key water management strategy to improve the productivity of rain-fed agriculture. Some of the promising techniques are field bunding, contour bunding, farm pond, terraces, mulching, micro-catchment rainwater harvesting, tillage practices, check dam etc. The tank cum well system involves construction of tanks and wells in series along the drainage line in a watershed. The technology is recommended for plateau areas with slope of 2 to 5%. Field bunding/contour bunding is adopted in flat to rolling lands (slopes less than 6%) to intercept the runoff flowing down the slope (Mishra *et al*., 1998). Dugout ponds are usually recommended in *rainfed* medium lands where water is not available for irrigation after monsoon prohibiting cultivation of *rabi* crop (Mishra *et al*., 2014). Rubber check dam is a flexible check dam, which is an inflatable structure built across a stream used for water conservation, flood control and regulating flow of water in the stream.

4.1.2. Management of waterlogged areas

The development of irrigation projects in arid and semi-arid regions invariably led to the waterlogging and soil salinity problems in irrigation command areas. Hence, for optimal and sustainable use of irrigated agricultural lands, irrigation and drainage systems need to be designed, constructed and managed as an integral unit. Due to saucer shaped topography and high monsoon rainfall, some parts of eastern India remain waterlogged (> 1 m surface water ponding). In these areas where the scope to dispose off the excess water is there, the excess water need to be removed through surface or sub-surface drainage.

Surface drainage is the safe removal of excess water from the land surface through land shaping or construction of channels. Subsurface drainage is required in agricultural land affected by high water table. While surface drainage removes the excess water before it enters the root zone, subsurface drainage lowers the water table and provides a better environment in the root zone. Tile drains including perforated pipes are a popular method of subsurface drainage. In seasonal waterlogged areas, water chestnut fish integration resulted in enhancing the productivity of rice by 31.2%. Cultivation of Makhana with fish is another profitable option, which is more popular in waterlogged districts of Bihar. Mitigation of waterlogging through exploitation of transpiration potential of vegetation is an eco-friendly solution compatible to existing physical method but also the additional source of biomass in terms of timber, fuel wood, fodder etc. generating additional source of income. *Eucalyptus* and *Casuarina* can be used as potential bio-drainage plants. Under submerged environment, waterlogging resistant varieties exhibit better adaptation and minimize yield loss. In case of flood prone areas, farmers may cultivate flash flood tolerant varieties like SwarnaSub1 which can resist submergence of crop under flood water for about 10 days' duration.

4.1.3. Management of flood prone areas

The flood prone areas are mainly found in the eastern India where the lakes remain almost under-utilized but have the potential to yield 2.0 to 2.5 t/ha/yr of fish in semi intensive culture system with suitable technological interventions. These lakes can be stocked with naturally collected or hatchery reared fingerlings of IMC (Indian Major Carps). The oxbow lakes (defunct loops of rivers cut off from the main rivers) are also predominant in Bihar, West Bengal and Assam. Fish production in these lakes with cage and pen culture practices, and selective stocking of IMC can yield 1.5 t/ha/yr (Bhatt *et al*., 2012).

4.2. Strategy for water management in irrigated agro-ecosystems

4.2.1. Groundwater Utilization and Management

After independence, the irrigated area has been increased many fold and the main contributor to this is the tube wells. Between 2001-02 and 2014-15, net irrigation in India increased by 20 per cent, with an alarming trend of massive groundwater extraction. While 41 % of the net irrigated area in India got water from tube wells in 2001-02, tube well irrigation increased to 46 % in 2014-15. Interestingly, during the same period, irrigation based on canal systems came down from 27 % to 24 % and well irrigation declined from 21 % to 17 % (Fig. 2). Not surprisingly, area under groundwater schemes are increasing, but the irrigated area under surface water schemes are declining across India.

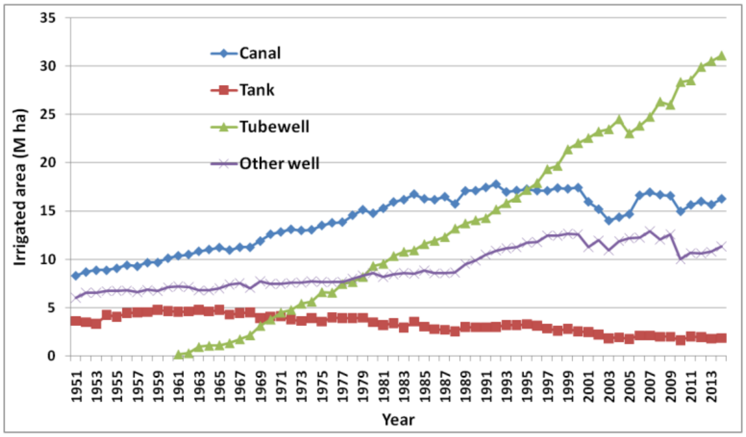


Fig. 2: Temporal trend of irrigation in India

With this, the regional development has very high variation. The eastern region needs groundwater development and western region needs recharge. There is a need for enhanced government spending in the field of groundwater exploitation. A planned government intervention will also reduce the negative effects of groundwater exploitation such as excessive drawdown, land subsidence and groundwater quality degradation. Groundwater withdrawal using open dug wells and tube wells should be designed in such a way that the total groundwater withdrawal should not exceed the groundwater recharge. Groundwater irrigation is more beneficial for irrigating low duty high value crops as it is costly because of energy required for pumping. Providing subsidy and encouragement to the farmers for opting solar pumps can increase the groundwater use and bring down the area of fallow lands during *rabi* season.

The geogenic contamination of groundwater with arsenic, fluoride and iron has caused havoc in India. For arsenic contamination one should avoid tapping groundwater from arsenic contaminated aquifer. Rainwater harvesting is essential. Conjunctive use of surface water and groundwater is a good option as it will dilute the effect of arsenic contamination. Treatment of groundwater for removal of arsenic using adsorption or precipitation and coagulation technique can be adopted. To combat fluoride contamination in groundwater and fluorosis mapping of contaminated area is needed

Pressurized irrigation systems are more suitable in groundwater commands as there is less chance of clogging of the system. Initial cost of drip and sprinkler irrigation systems is relatively high. Hence, government has been providing subsidies for larger adoption of these pressurized irrigation systems in order to have better water use efficiency. Besides, there are other advantages like increased yield, saving in fertilizers, energy and labour. Thus, there should be concerted effort to bring more and more areas under pressurized irrigation system.

4.2.2. Efficient utilization of canal water

Canal water management needs co-ordinated approach between individual, *Pani Panchayat* and state Government. Pani panchayat or water users association (WUA) is a good initiative to manage the operation and maintenance of irrigation minors and sub-minors. However, they need to be strengthened substantially for enabling the members to get inputs at right time and right price. Further, WUAs may be involved in developing market infrastructure which is vital for crop diversification and value addition.

In order to have efficient utilization of water the canal delivery schedule should closely match with the crop water demand of the command. In this regard, based on the research result, an alternative canal delivery schedule was established for deltaic area irrigation system of Odisha through simulation model and a field experiment. Rotational schedule was found better than the prevailing continuous schedule. Efficient rotational delivery of canal water during *rabi* resulted in saving 10.3% water as compared to the continuous delivery system (Mishra *et al*., 2008).

Secondary storage reservoirs in the command of the flow based minor irrigation systems can be created to augment the water resource for irrigation during dry season. Secondary reservoir harvests rainwater during rainy season and excess irrigation water during each irrigation period. Optimal size of the secondary reservoir and optimal cropping pattern was computed through a multi-objective optimization routine for a minor irrigation system of Odisha (Mishra *et al*., 2009).

Warabandi is an organised way of water distribution to a large number of cultivators in the irrigation system. '*Warabandi*' means weekly rotation with each farmer getting water on a fixed day of the week. Each farmer gets an equal share of available water volume per unit area based on allocated time to his field. Raised and sunken bed system is a technology which can be used in waterlogging portions of canal commands. Here alternate raised and sunken beds are created by digging out soil from one strip of land and placing it on an adjacent strip. In the sunken bed, paddy can be cultivated and in the raised bed, vegetables can be cultivated.
There is a need to follow best water management practices in the outlet command to judiciously utilize the available irrigation water and improve the productivity. Use of field channel, pressurized irrigation methods, proper planting geometry, alternate wetting and drying in paddy crop, system of rice intensification, raised and sunken bed technology, land lvelling etc. are some of the management practices which need to be followed appropriately.

4.2.3. Pressurized irrigation system

In both canal and groundwater irrigated areas pressurized irrigation system will be helpful. Drip and sprinkler irrigation systems have become more popular pressurized irrigation systems in the country. They are more suitable in groundwater commands as there is less chance of clogging of the system. Application efficiency of drip irrigation system varies from 90-95%. The advantages of drip irrigation includes about 50% saving in irrigation water, about 25% increase in crop yield due to frequent irrigation, improved fertilizer efficiency (saving of about 25% fertilizer), limited weed growth, less labour and energy requirement. Application efficiency of sprinkler irrigation system is about 75%.

4.2.4. Drip fertigation for better water and nutrient use efficiency

Drip fertigation is the most effective as it has high WUE with low loss of nutrient through runoff and leaching and minimize groundwater contamination. Urea is the most common and popular fertilizer used for drip fertigation. In the experiments under AICRP on IWM, it has been reported that drip fertigation can increase tomato yield by 71% over granular application of fertilizer (Nanda *et al*., 2021). For cotton, brinjal and chilli crops 25% NPK as basal and 75% NPK as drip fertigation is very remunerative.

4.2.5. Partial root zone drying

The efficiency of drip can also be increased by partial root zone drying technique. Partial root zone drying (PRD) is an irrigation method in which water application is withheld from a part of the plant's root zone while the remaining part is irrigated. The irrigation is alternatively applied to each side of the root zone allowing the wet side to dry and dry side to wet. The PRD technique is suitable for horticultural crops including vegetables. The partial root zone drying technology was evaluated for drip irrigated mango crop and highest water use efficiency was observed in 60% PRD treatment which is 85% improvement over full irrigation treatment.

4.2.6. Sensor based irrigation

Automation in irrigation system would further save water and enhance yield over manual irrigation. Panigrahi *et al.* (2021) studied automated drip irrigation and fertigation in banana crop based on soil moisture sensor and found that automated drip irrigation and fertigation system has given higher banana yield (70 t ha^{-1}) than manual drip irrigation system (60 t ha^{-1}) and surface irrigation system (44 t ha^{-1}). Sensor based system has also increased water productivity of banana crop.

4.3. Strategy for Wastewater Management

Almost 80% of water supply flows back into the ecosystem as wastewater. This can be a critical environmental and health hazard if not treated properly but its proper management could help the water managers in meeting the water demand. Currently, India has the capacity to treat approximately 37% of its wastewater, or 22,963 million litres per day (MLD), against a daily sewage generation of approximately 61,754 MLD (CPCB, 2015). Wastewater is also generating from mining overburden sites. Judicious use of wastewater to grow crops will help solve water scarcity in the agriculture sector. To manage the harmful effect of wastewater one should go for restricted use of wastewater for irrigation. Restricted irrigation refers to the irrigation of crops not intended for direct human consumption, and thus covers the irrigation of industrial crops (e.g., cotton, sisal, and sunflower); crops processed prior to consumption (e.g., wheat, barley, oats), and fruit trees, fodder crops and pastures. Filters can be used to reduce the harmful effect of wastewater. Bioremediation/phytoremediation of wastewater can be a good strategy for wastewater treatment.

5.0 Conclusions

In recent times India has made remarkable achievements in water sector, which is evident from the large growth in irrigated agriculture, increase in agricultural production, and advancements in drinking water supplies in rural and urban areas. In doing so, development of water resources has crossed the thresholds of physical sustainability in many areas, manifested by groundwater depletion, groundwater quality deterioration, dwindling supplies and increasing pollution of surface water. Recent advancements in water technology and water management in both the rainfed and irrigated ago ecosystems are capable enough to address and manage the challenges in water sector in India.

References

Amarnath, G.; Alahacoon, N.; Smakhtin, V.; Aggarwal, P. (2017). Mapping Multiple Climate-Related Hazards in South Asia; IWMI Research Report 170; International Water Management Institute: Colombo, Sri Lanka, 2017.

Bhatt, B.P., Haris, A.A., Dey, A. and Singh, K.M. (2012). *Technological Options for Agricultural Transformation in Eastern Region.* Bulletin No. R35/PAT23, ICAR Research Complex for Eastern region, Patna, pp. 99.

CGWB (2019). Dynamic Ground Water Resources of India, Central Ground Water Board, 2017. Ministry of Jal Shakti Department of Water Resources, River Development & Ganga Rejuvenation, Government of India. http://cgwb.gov.in/GW-Assessment/GWRA-2017-National-Compilation.pdf.

CPCB (2015). Central Pollution Control Board, Annual Report 2014-15. Ministry of Environment, Forest & Climate Change, Government of India.

Directorate of Economics and Statistics (2020). Directorate of Economics and Statistics Ministry of Agriculture & Farmers Welfare, Government of India.

EM-DAT (2020). The CRED/OFDA International Disaster Database. Available online: http://www.emdat.be/ (accessed on 20 January 2020).

GOI (2019). Government of India. Per Capita Net State Domestic. New Delhi, India: Directorate of Economics & Statistics of Respective State Governments, and for All-India—Central Statistical Organisation, Government of India.

Mishra, A., Adhikary, A.K. and Panda, S.N. (2009). "Optimal size of auxiliary storage reservoir for rain water harvesting and better crop planning in a minor irrigation project." *Water Resources Management*, 23: 265-288.

Mishra, A., Ghorai, A. K., Singh, S. R. (1998). "Rainwater, soil and nutrient conservation in rainfed rice lands in Eastern India". *Agricultural Water Management*, 35: 45-57.

Mishra, A., James, B.K., Mohanty, R.K. and Anand, P.S.B. (2014). "Conservation and efficient utilization of rainwater in the rainfed shallow lowland paddy fields of Eastern India". *Paddy Water Environ*, 12, 25–34.

Mishra, A., Verma, H.C. and Singh, R. (2008). "Alternative rotational delivery scheduling for better water regime in canal command." *Journal of Irrigation and Drainage Engineering* (ASCE), 134 (2): 175-184.

Nanda, P., Sandal, S.K., Mohanty, S., Dasgupta, P. and Mishra, A. (2021). Drip fertigation in crops: Experiences from AICRP on Irrigation Water Management. Director, ICAR – Indian Institute of Water management, Bhubaneswar, India. pp. 08.

Panigrahi, P., raychaudhuri, S., Thakur, A.K., Nayak, A.K., Sahu, P., Ambast, S.K. and Mishra, A. (2021). Automatic drip irrigation and fertigation in banana. ICAR – Indian Institute of Water management, Bhubaneswar. pp. 08.

Groundwater Management with Focus on Community Involvement and Livelihood

P.K. Singh[1] and Yogita Dashora[2]
[1]Professor and Dean, [2]Senior Research Fellow
College of Technology and Engineering,
Maharana Pratap University of Agriculture and Technology, Udaipur, (Rajasthan) 313 001
E-mail: pksingh35@yahoo.com

A number of states of India are facing problems related to groundwater-it is water below earth's surface. Even though Indian sub-continent has plenty of river systems still we are largest user of groundwater in the world. Our Country uses 25 percent of all groundwater extracted globally (India Water portal), ahead of USA and China. Despite this, the knowledge about groundwater is very scarce. And policies and practices doesn't support in sustaining it due to lack of understanding about this invisible resource. Unlike surface water system management of this groundwater is typical because government has lesser control over extraction. Sustainable use of groundwater requires effective participation from local communities along with technical, social, economic, policy and political inputs. Access to groundwater for farming communities is also an emotional and complex issue as their livelihood and survival depends on it. The causes of augmented groundwater use are also rooted in population growth and economic advance, and as result the annual groundwater use now probably exceeds the annual rainfall recharge in many parts of India. To address this issue education of and engagement with village communities, local NGO and government agencies to facilitate them working together to achieve sustainable groundwater management is most sustainable way (Maheshwari et al., 2014).

Groundwater management through community engagement

The groundwater is very complex phenomena, which requires better understanding of water cycle and its elements. Addressing the challenges of groundwater management through hydrogeological as well as social characterization need to include: (1) the classification and understanding of groundwater use, users and potential polluters, (2) the mapping of stakeholder influences and interests, (3) the assessment of pre-conditions and previous experiences with management of natural resources, and in particular groundwater resources and associated infrastructure (e.g. for domestic water supply or irrigation systems), and (4) the evolution of practical methods of social engagement, including systematic tools and metrics for socio-economic surveys (Barthel*et. al.*, 2017).

Science to understand groundwater + Community engagement for measurement for better management = Groundwater Management

Field research and analysis

Participatory Rainfall and Groundwater Monitoring

Participatory groundwater management is increasingly being recognized for its ability to address the challenges of equity, efficiency and sustainability. The monitoring setup can be divided in two parts one is scientific measurement of hydrogeological parameters and analysis of collected data for preparing localized management plans. Participatory groundwater management to develop social capital competences, with training programs aimed at supporting cognitive aspects of this social capital competence. The local community was trained to take measurements of groundwater level, rainfall and check dams nearby their village. Under this training community will be exposed to various instruments, measurement techniques, sampling protocols and reading and preparing local land use land cover, water resources mapping. In the advance version of training these people can learn how to calculate waster requirement of their own village, available water and ultimately water balance of their village for managing it for adverse conditions.

Salient features of groundwater management

The ground water management through scientific measurements enable village level ground water champions who can give accurate very high density of data points. Monitoring of remote water resources for its adequate and timely maintenance and sustainable use is also on eof its key feature. The data collected by community can be very reliable, robust and cost effective if photographic evidences are provided by them.

Harnessing of rain by harvesting it suitably and increasing the recharging possibilities of groundwater could only be the befitting answer in negotiating with the recurrent droughts. There is an urgent need to revive the traditional and the existing water harvesting system in various ecological regions of the country.

Qualification for making groundwater informed person

As the data collection for groundwater management require two things one basic literacy to read, measure and keeping record of hydrogeological data and life experience. Anyone who is interested in environment or has willingness to learn new things and care about local people will definitely work sincerely.

Monitoring requirements

The groundwater level, check dam water levels and rainfall measurements require a set number of locations spatially distributed in the village, covers all sort of geological setups, and representative of local conditions. The accessibility of site is also important for consistent monitoring throughout the year. For example, rainfall measurement requires timely measurement every day in monsoon period; whereas water level in well also require at least monthly monitoring of wells from representative geological strata.

Rainfall measurement

The rainfall is most important parameter of water cycle and all the planning and management strategies depends upon the amount of rainfall, its intensity and dry spells between two consecutive events. As shown in figure below the rainfall recording simple template and also a simple cylinder type rain gauge. This rain gauge is made of UV proof plastic and robust in its structure. It can easily be installed at home or at farms for measuring daily last 24-Hour rainfall. This calibrated rain gauge can measure 130 mm rainfall event.

Rainfall chart

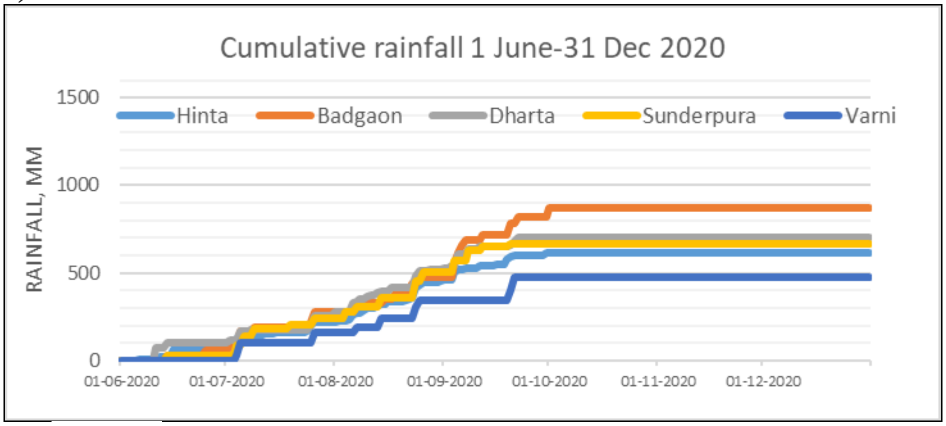
How to analyze rainfall data

As the community will collect all the rainfall event data it will give them idea about how much rainfall they are receiving at their village or field. We all know that due to climate change and pollution the behavior of rainfall pattern has changed tremendously. Due to which rainfall events are erratic and unevenly distributed even within few kilometers range. The participatory rainfall monitoring will facilitate to capture very localized events and farmers can plan their rabi season cropping pattern as per availability and distribution of rainfall. This measurement will equip them with data supported decision making which will ultimately improve their livelihoods. As proper data backed up planning will reduce the chances of crop failure due to lack of water availability information. In subsequent section various simple methods of rainfall analysis are represented.

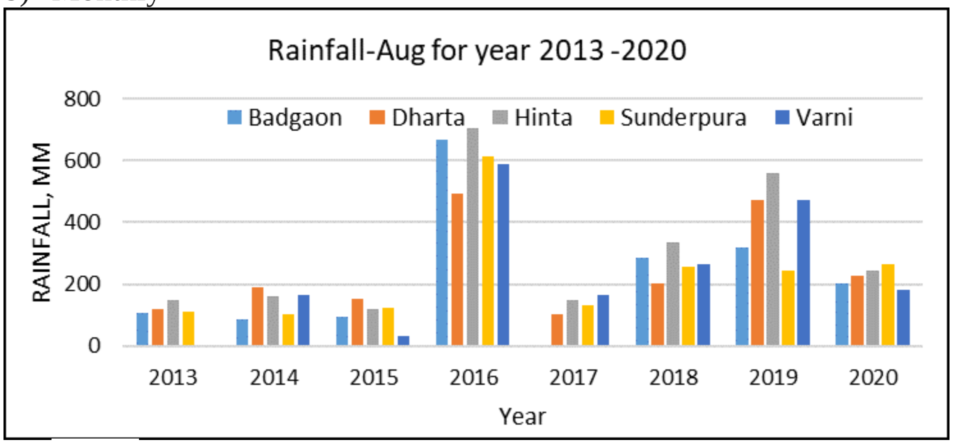
Groundwater level measurements

The community engagement in groundwater level measurement will provide a demystified but correct understanding of aquifers (underground rocks that are sources of groundwater), their properties and how they are used, so that we can make the critical mass of users and decision makers understand them and act on them appropriately. As these local champions have advantage of reachability to their groundwater resources can unable scientific community to have high intensity water level and water quality data of an invisible resource, which is otherwise very cost intensive exercise for any government agency to get such densely populated spatial and temporal data sets.

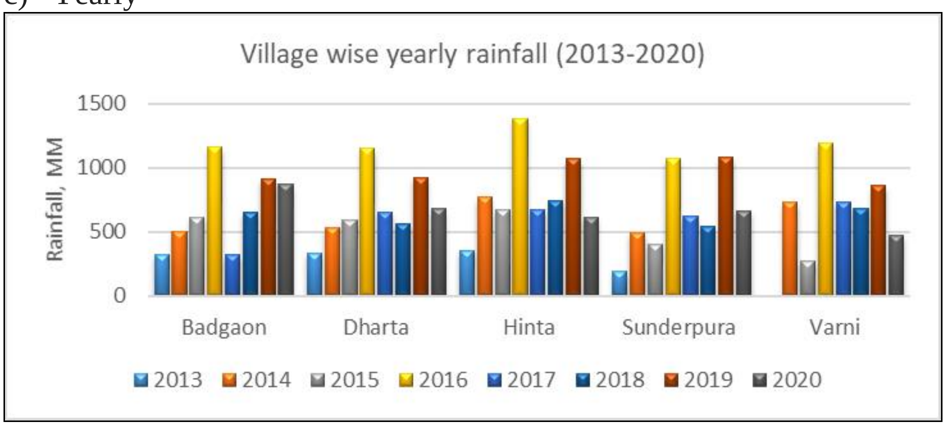
a) Cumulative



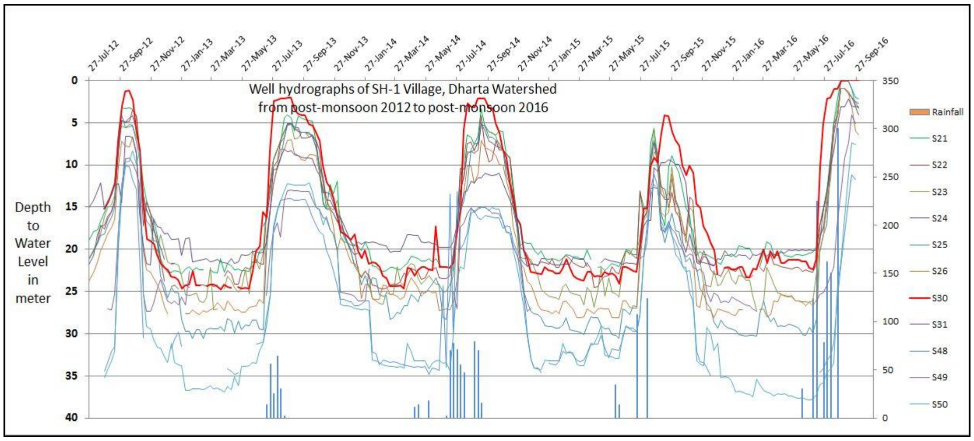
b) Monthly



c) Yearly



Rainfall variation



Water table fluctuations with respect to rainfall

Types of MAR structures

A number of MAR (Managed Aquifer Recharge) structures are being constructed throughout the country without considering the watershed characteristics, strata conditions and other technical feasibility and therefore, their applicability as MAR structure is still a big question. Hence, the best practices of MAR structure for hard rock region have been identified and their design details along with technical parameters, maintenance strategy etc. are described as under.

Percolation ponds:

A percolation pond or tank is constructed across a *nalla* or natural drainage line to collect and impound the surface runoff from the catchment during the monsoon. These also facilitate percolation of stored water into the soil substrata with a view to raising the groundwater level in the zone of influence of the percolation tank. Further, they hold the silt flow, which would otherwise reach the big multipurpose reservoirs and reduce their useful life. In designing a percolation tank the following technical considerations are important:

- The nalla bed should have soils with adequate permeability.
- The submerged area should not have impervious strata.
- The size of the pond should be decided by runoff expected on the basis of the dependable monsoon rainfall in the catchment.
- There should be adequate arable land and a sufficient number of wells in the zone of influence of the pond.
- The proposed site should be such that deep impounding is possible in order to reduce evaporation losses.
- Ponds should be located in places where adequate good soil is available for construction of an earthen embankment.

Subsurface Barriers / Dykes

The use of surface reservoirs to store water in areas with dry climates has several serious disadvantages, such as pollution risks, reservoirs siltation, and evaporation losses. Using groundwater is one way of overcoming these problems, but in some areas good aquifers are unavailable, or may only yield sufficient quantities of water seasonally. Recharging groundwater for conservation is certainly not a new concept. More recently, small scale groundwater recharging techniques have been developed and applied in many parts of the world, including India. There are basically two different types of groundwater dams, viz. subsurface barriers or dams and sand storage dams.

Subsurface dams are commonly constructed in river-bed aquifers consisting of sand or gravel. Other types of aquifers that may be dammed are weathered zones, alluvial or colluvial layers, or any type of overburden with sufficiently good aquifer characteristics. Infiltration conditions must be such that the reservoir is properly recharged during the rainy period. The storage reservoir must be contained by impervious or low-permeability layers that prevent vertical and lateral seepage losses. The containing layer must be at such a depth that it is technically feasible to carry out the excavation at reasonable cost. In general, the limit seems to be at around 4-5 m. It is imperative that suitable material for construction is available locally and at reasonable cost.

Subsurface Clay Dykes / Barriers

The clay dyke is mostly suitable for small projects in highly permeable aquifers of limited depth, such as sandy river-beds. Clayey top soils are generally available close to any construction site - they can be excavated and transported to the site at low cost. The use of clay is a labour-intensive alternative but requires no skilled manpower. Possible drawbacks are the large excavations generally required, the need for proper compaction and the risk of erosion damage to the clay surface due to the flow of groundwater. The general design feature of sub surface clay dykes is as under

- The construction of a clay dam should commence immediately after the monsoon and should be completed before the onset of monsoon.
- Clay is the primary construction material. Careful selection and compacting of the clay ensures an impervious dam and avoids infiltration through fissures and cracks.
- The foundation must be sound and watertight. This avoids seepage under the dam that can lead to loss of stored water.
- The dam must be two meters wide all the way down to the foundation.
- Protect the top of the dam against erosion from erosive velocity of runoff.
- An extension of the clay dam into the river banks should be made to prevent seepage and erosion between the river banks and the dam.
- Rocks should be piled against the banks, both upstream and downstream to protect them from erosion.
- The dam should be located where the river bed is narrower and the sand layer becomes thinner.

Conclusions

There are evidences where collective micro-level measurements to prepare a very reliable larger picture of current situation that can help in preparing well informed policies with better adaptability. As we know groundwater is disaggregated in terms of usage, availability and complicacy in larger part of India. Hence, the resolution of location specific groundwater problems needs disaggregated approaches to solve these problems. Groundwater management needs bottom up approach to address problems of this invisible resource. Involving local people in making solution based strategies for better management will help in simplifying science and ultimately, it will lead to better management plans. Our experience at MARVI (Managing Aquifer Recharge through Village-level Intervention) by involving communities and committed people in the development of the science, we can achieve improved decision making at any level. There is urgent need to pay more attention and investment in promoting groundwater monitoring, cooperative use and collaboration among users to manage this most threatened water resource of the world. For improving the rural Livelihood and increasing the productivity, the community watershed approach and rainwater harvesting must be made a national movement by creating it mandatory in rural as well as in urban areas and must be taken on community basis.

Management Options for Enhancing Land and Water Productivity in Waterlogged Areas

Susanta Kumar Jena
Principal Scientist & Coordinator - CRP on water
ICAR-Indian Institute of Water Management, Bhubaneswar-751023, India
Email: skjena.icar@gmail.com , Mob: 9437221616

An area is said to be waterlogged when the water table rises to an extent that the soil pores in the root zone of a crop become saturated, resulting in restriction of the normal circulation of air, decline in the level of oxygen and increase in the level of carbon dioxide. The water table which is considered harmful would depend upon the type of crop, type of soil and the quality of water (Jena, 2006). In India an area of 14.29 M ha is under waterlogging as estimated by NBSS&LUP soil degradation classes, derived from 1:250000 soil map during 1985-1995 and is reported by Maji et. al, (2010). Planners are increasingly concerned about changes in soil characteristics due to rise of water table and related water logging problems.

By National remote sensing agency (NRSA), Hyderabad wastelands class under waterlogged/ marshy land was reported as 1.66 M ha. However, at present in India the total degraded land due to waterlogging is 6.41 M ha out of which 1.66 M ha is mainly wasteland due to surface ponding and rest area of 4.75 M ha is under subsurface waterlogging. (Maji et. al, 2010). High intensity of rainfall combined with saucer shaped physiography and flat land near the coastal area in deltaic alluvial region is the most important reason for waterlogged wasteland (Jena et. al, 2006). Since land resources are finite, requisite measures are required to reclaim degraded and wastelands, so that areas going out of cultivation due to social and economic reasons are replenished by reclaiming these lands and by arresting further loss of production potential.

The water management in areas in humid tropics is complex, diverse and risk prone. The arable land affected under water logging with no rice or alternate crop is around 1.656 M. ha. out of which 0.855 M. ha lies in eastern region (Wasteland Atlas of India). This includes canal based waterlogged area, river delta congested waterlogged area and rainfed lowland where no drainage outlet is available. Presently paddy is the major crop area in this region and its yield is quite low. Hence there is an urgent need to reclaim all type of lowland or waterlogged land for bringing it to higher productivity so as to increase food productivity in the coming decade and that to more for waterlogged areas. Problems are too much stagnated water for duration more than the tolerable period of the crop; unavailability of drainage outlet, flash flood, saline water ingress in coastal area and low permeability and infiltration rate. Sometimes the yield is very poor or productivity of the region is too low due to poor socio-economic condition of the farmer.

There are mainly two inherent problems of waterlogged areas. First, due to difficult ecology and complex problem of soil and other edaphic factors, the crop yield is very low. Second, lack of crop diversification due to unfavourable situation for agriculture leads to rice cultivation as a compulsory option. Added to the problem is falling price of rice in the open market making economics of waterlogged area worse than ever. Under this backdrop there is a desperate need to look for an alternative farming system not only to increase production but for a system, which is economically viable as well as, vibrant. The impact of value addition is clearly perceived when traditional farming activities are integrated with pisciculture. This naturally adapted component has a tremendous potential to improve profitability of agricultural production system of waterlogged area.

The type of water logging is different in different area. Water logging may be due to heavy rainfall in a limited period or may be due to excessive irrigation in canal command areas or due to lack of drainage channel.
For low water logging conditions, there are same selective options, like growing water logging resistant variety of paddy and providing surface drainage measure if outlet is available.

Extend and type of water logging

The statistics on extend of water logging are varied. The rainfed lowland rice (since rice is predominant crop in waterlogged area) areas prone to water logging are in eastern Uttar Pradesh, West Bengal, Orissa, Assam and to lesser extent in north eastern states, Jharkhand, coastal districts of Andhra Pradesh, Tamilnadu, Kerala and Coastal Karnataka and Maharashtra. Extent of waterlogged area as estimated by various agencies is given in Table 1.

Table 1. Extent of waterlogged area as estimated by various agencies (lakh ha)

State	As per National Commission on (1970) Agriculture	As per National Commission Irrigation (1972)	As per estimated by Ministry of Agriculture (1990)	As estimated by CSSRI, Karnal (1997)	As estimated by waste land board & NRSA (2000)
Andhra Pradesh	3.39	NR	3.39	3.39	1.035
Assam	NR	NR	4.50	NR	1.633
Bihar	1.17	NR	7.07	3.12	1.198
Gujrat	4.84	NR	4.84	4.84	2.656
Haryana	6.20	6.50	6.20	2.75	0.238
J & K	0.10	NR	0.10	NR	0.246
Karnataka	0.10	0.07	0.10	0.36	0.032
Kerala	0.61	NR	0.61	0.12	0.136
M.P	0.57	0.57	0.57	0.57	0.051
Maharashtra	1.11	0.28	1.11	1.11	0.527
Orissa	0.60	NR	0.60	1.96	0.379
Punjab	10.09	10.09	10.09	1.98	0.352
Rajsthan	3.48	3.48	3.48	3.48	0.289
Tamilnadu	0.18	NR	0.18	1.28	0.415
U.P	8.10	8.10	19.80	19.80	4.981
West Bengal	18.50	18.50	21.80	NA	1.931
Delhi	0.01	NR	0.01	NA	0.024
Himachal Pradesh	NA	NA	NA	NA	0.015
Goa	NA	NA	NA	NA	0.041
N.E. States	NA	NA	NA	NA	0.379

Total	59.05	47.59	84.45	44.76	16.558

A comparison between the rice productivity of East and West Coast of India shows a greater variability. India, as a whole has about 55% of the total rice area under lowlands but the proportion is much higher in coastal tracts. West Bengal having the longest share of coastal area has about 90% of the total area under 30-90 cm depth of water during monsoon. A significant proportion of deep water rice is further subjected to devastating flood and cyclones in the coast.

Some of the hydrological situations that are likely to be encountered in the waterlogged areas are.

- Limited water during the seedling stage and excess water at later growth stages.
- Excess water at transplanting as well as at later growth stages.
- Excess water during initial period and less water during later growth period.
- Limited water during seedling stage, excess water at tillering stage and limited water at flowering stage.
- Lowland rice fields in which nature of flash floods is stochastic.
- Sea water intrusion during cyclone to cropped area.
- Lack of irrigation in *rabi* season.

The water level in the field rises from onset of monsoon till August end and then drops sometimes to low level during October end requiring minimum water for sustainable crop production.

Problems of water logging

The main problems of water logging area is drainage congestion. Sometimes outfall is not available, or the drainage line is choked or sometimes link drain is not constructed. The problem of drainage congestion can be divided into four broad categories depending on severity.

1. Areas unsuitable for any crop throughout the year which cannot be economically retrieved.
2. Area unsuitable for any crop throughout the year which can be improved economically.
3. Area unsuitable for cultivation during *Kharif* but suitable for growing crops during *Rabi*. These areas also sometimes become unsuitable due to heavy and prolonged monsoon but can be improved to grown *Kharif* and *Rabi*.
4. Area suitable for cultivation both during *Kharif* and *Rabi* but the yield suffers due to poor drainage which can be improved.

In most of these cases, the mouths of drains are silted up or shifted too much creating congestion. Obstructions have been created which add further to the malady. This becomes particularly damaging when rainfall in the delta synchronized with the high tide condition (full moon or new moon) in the area. Similar thing happened during the last cyclone on 3rd and 4th June 1982 when heavy cyclonic rain ranging up to 300 mm in 24 hours synchronized with the ingressing tidal surge due to the heavy cyclone. The tidal back waters besides its inundation and saline damaged, obstructed the surface drainage of the land, thereby flooding vast areas in the delta area. Agricultural areas situated as far as 30 to 40 km away from the sea remained submerged for a considerable period. The damages were colossal. The same things were experienced during the coastal cyclone of 1967 and 1971 also and more so in super cyclone of 1999 which are in recent memory.

Present Solution to Water logging

There are several solutions to water logging problem. They may be hardware solution or software solution. Hardware solutions are of engineering nature which is possible if both economic and outfall conditions are satisfied. The software solutions are of growing different waterlogged resistant varieties of paddy or different water loving crops like water chestnut, swamp taro, *makhana*, *colocasia* or other water loving greases.

I. Engineering Measures

1. Providing surface drainage facility to the area where clean out outfall is available.
   (a). Construction of field drain, link drain and main drain
   (b). Re-grading and re-sectioning the main drains whenever available.
2. Construction of one-way tidal structure to prevent ingress of drainage water into the outfall drains.
3. Recycling of drainage water: The drainage water is allowed to be stored in big evaporation tanks wherever low pockets are available. These tanks not only recycle drainage water at the time of drought, but it also helps to sow the seeds in the month of May (right time for paddy sowing in waterlogged areas). This will also help in integrated aqua culture along with growing water chestnut and other economic water loving plants.
4. Improvement of land form

   (a)There are several technologies available for improvement of land form in waterlogged area. One such is earthen embankments, preferably brick pitched, should have a side slope 3:1 on the river side and 2:1 on the country side with 1m free board above the high tide level. To effect drainage from such embankment areas one-way sluice gates are provided in the embankments.

   (b) Design of On-f arm Reservoir (OFR)
   The design parameters are shape, size, depth, side slope, capacity and location. The dug out type of OFR are most common in flat topography. The prevailing trapezoidal OFR with and without bund were considered to determine optimal size of OFR. The length width ratio of OFR was taken as 1:1 as it is having minimum parameter and attains maximum storage. Probable weekly rainfall value at 2 years return period was used for design of OFR. The size of OFR is to be kept 20-40% of farm area. The location was so made so that 100% runoff can come to the OFR.

   (c) Rice-Fish Integrated System
   Rice-Fish integrated system is quite useful for water logging up to 50 cm water level. The technology includes field construction and production technology of different enterprises. The design includes 2.5 m of the field area and a water harvesting cum-fish refuge system in the form of two 3 m wide and average 1m deep side trenches having gentle (0.5%) gradient towards a connecting pond refuge of 10m width and 1.75 m depth at lower end.

The dike height is kept at least 20 to 30 cm more than the maximum flood level. A guarded outlet/drain is provided in one corner of the pond refuge.

(d) Storage Drainage Structure
The storage drainage structures are recommended where saucer shaped flat land is waterlogged due to poor outfall condition. This is nothing but contour bunds in waterlogged areas where severity of water logging is reduced due to different stages in the catchment.

(e) Pond Drainage with integrated farming system
Where nothing is feasible i.e. drainage measures/alternate waterlogged resistant paddy crop, etc., there pond drainage with integrated farming system is recommended. The entire waterlogged area is converted into an integrated resource management unit where fishery, duck rearing, poultry or birds go together with horticulture, forest and other economic crops in bunds and vegetables in between.

(1) Integrated farming system in Mahandi delta

One such unit was developed in Khentalo village of Barmania Pat (waterlogged area) where waterlogging was up to 2 m depth. Out of 2.47 ha waterlogged area of the farmer, 1.64 ha was converted into grow-out pond for fish and prawn culture while vegetable, flower and fruits were grown on 0.83 ha of raised embankment all around the pond since 1989. Poultry sheds were also constructed for rearing 4000 birds in such a way that their droppings could fall into pond as organic manure and feed for fish. The average productivity of low land high yielding paddy was 3.5 t ha^{-1} as compared to 9.4 t ha^{-1} per annum fish equivalent (fish + prawn). Gross and net returns from fish and prawn culture alone during 2002 were Rs. 6,17,160 (Rs. 3,76,317 per ha) and Rs. 3,31,065 (Rs. 2,01,868 per ha) respectively. This accounted to Rs. 14.00 per m^3 of water productivity in the pond system alone. Whereas the gross and net returns from the whole system of 2.47 ha during the year 2002 were Rs. 6,51,110 (Rs. 2,63,607 per ha) and Rs. 3,62,515 (Rs. 1,46, 767 per ha) respectively. The farmer initially invested Rs. 1,23,910 in 1988 towards construction of the pond plus infrastructure and earned a net return of Rs. 40,554 per ha of whole system in 1989, which gradually increased up to Rs. 1,32,894 per ha in 1997. He again invested Rs. 1,30,000 towards stone pitching in 1998 and Rs. 3,20,000 towards poultry shed and the net return (after adjusting investment) was Rs. 2,17,600 (Rs. 88,097 per ha) during 1998 and a net loss of Rs. 1,16,900 during super cyclone year in 1999. The net returns per ha again increased steadily after cyclone from Rs. 27,465 in 2000 to Rs. 1,37,894 in 2001 reaching up to Rs. 1,46,767 (35 times higher of the paddy cropping) in 2002.

Adjacent to the developed integrated farming system, the farmer is cultivating 2.4 ha waterlogged paddy field giving net return of Rs. 4,166 per ha only (2.8% of the integrated farming system). WTCER has designed a deep water high density rice-fish integrated system of 1.2 ha out of the 2.4 ha waterlogged paddy field system and it is estimated that it will give net return of Rs. 1.5 to 1.6 lakh per ha per year. Revival of poultry component and addition of milch cattle in the system is going to make it more profitable and more sustainable utilizing surface and ground water of the waterlogged area. This is going to be a replicable integrated farming model for the coastal Orissa. It may also be replicated in irrigated alluvial land of other regions.

(2) Integrated farming system in coastal waterlogged area

In another case study under taken at Biswanathpur of Khurda district the conventional surface drainage measure alone could not fully reclaim the low-lying waterlogged area of this Mahanadi coastal delta because of flat, saucer shaped topography. This was integrated with land modification technology to cater low land pockets in the suffered area for arriving at a total solution package for the system. Hence in a low lying pocket in Satkabad village, an area of 2212 m^2 was developed into a raised bed system cum-pond in 1:2.7 ratio which could not be drained through surface drainage measure. The technology of two small ponds in the system, one in 1022 m^2 and the other in 600 m^2 were to cater the requirement of fish seeds, which was not available in that area during July-August. The benefit accrued from the system was 40% more than the adjoining low land. A scaffold covering 15% area of small pond was constructed and hung over to create additional space for creeper vegetables. The additional net economic return from the modified landform system over the prevailing landform system was estimated at Rs. 30,682/ha. Benefit Cost Ratio after 3 years' data showed marked improvement than conventional system.

(3) Integrated farming system in a research farm located in coastal waterlogged area

Directorate of Water Management research farm at Mendhasal, Khurda had about 1.75 ha of low lying area, which suffered waterlogging and was taken for experimental purpose. During monsoon the depth of ponding water was more than 50 cm and during driest period (May) of a year the water table was varying between 50-150 cm below ground level. The water quality was good and only paddy was grown in *kharif* in some years with 0.5 t ha^{-1} average yield. The soil was acidic with low available nutrient and iron toxicity was present. The land was only suitable for ploughing during May and early June and high water table restricted growing of any other crop during *rabi* season. The plot in the lowest elevation (EP4) having an area of about 0.264 ha was a degraded wasteland due to perennial water logging over years. To mitigate the above problems this project was initiated with objective to optimize micro level water resources design in waterlogged area using water balance simulation modeling at field level; to conserve and utilize runoff water for diversified aquaculture in waterlogged area; to develop integrated farming system in waterlogged area and to make reclamation study of waterlogged area through bio-drainage and cultivation of water loving co-existing crops.

For determining the design and dimensions of the micro water resources (ponds), collection and analysis of climatic data (rainfall, pan evaporation etc.) for the period 1975-2003 for Bhubaneswar was done. It was observed that rainfall is higher than evaporation during 24th week to 43rd week causing water congestion and excess water is to be stored in ponds for aquaculture and for irrigating *rabi* crops including vegetable and other cash crops. Whereas evaporation is higher than rainfall during 44th week to 23rd week indicating irrigation is required if any crop is to be grown during this period. Land modification by excavating ponds for storing excess water is desirable.

The daily water balance study had resulted the design dimensions of the experimental ponds which were 27 m x 27 m, 30 m x 30 m, and 34 m x 34 m at the top, with 2 m depth and side slope 1:1 in experimental plot 1, 2 and 3 respectively. The excavated soils were spread around the pond to elevate the surrounding area so as to keep the water table below 2 m from ground surface. Hume pipes of 30 cm diameter and 4 m length were used as inlet and emergency outlet of the pond. Since the objective of the study was to store excess water for reclamation of waterlogged area, the area of the ponds is kept within 20 to 25% of the total area considering the water balance component of the study area.

Integrated farming system approach was under taken by excavating three ponds and taking on-dyke horticulture and agriculture in the fields adjacent to the pond in waterlogged wasteland in WTCER farm. Aquaculture was undertaken in all the three ponds. In this experiment, as first crop average growth performance of *Magur* was highest in P_1 (163.5g) followed by P_3 (141.0g) and P_2 (130.5g). In this crop Yield of fish ranged between 1632-1710kg /ha /200days, SR%- 61-64.75, FCR- 1.39-1.47, PDI– 0.595-0.623. Indian major carp was taken as second crop in all these three ponds and showing normal growth performance.

II. Non Engineering Measures:

As a software solution where engineering measure fails, several alternate land use system has been developed.

1. Cultivation of waterlogged resistant deep water rice varieties

This is also a short term measure but feasible only in few locations. Different paddy varieties grown in different ecosystem is given in Table 2.

Table 2. Different paddy varieties under different water level condition.

Water level depth	Ecosystem	Suitable varieties
0-30cm	Shallow	Mahalaxmi, Rajashree, Jayashree, Savitri, Jaganath, Padmini, Moti
31-50cm	Intermediate	Utkal Prava, Gayatri, Tulasi, Panidhan, CR-260-77, Seema, Suresh, Mandira
51-100cm	Semi-deep	Nalini, Dinesh, Amulya, Durga, Lunishree
>100cm	Deep	Jaladhi-1, Jaladhi-2, Jalamagna, Jalanidhi

Alternate land use other than paddy

There are several crops like water chestnut, makhana and other greens cultivated in waterlogged areas. Prominent among them are water chestnut and makhana

A. Water Chestnut

Locally named as Paniphal or Pani singada, it is grown in parts of West Bengal, Bihar, Orissa and UP. Some pockets are in Maharastra also. It is an aquatic plant with roots attached to bottom and crown of floating leaves on the surface of water.

With onset of monsoon, young sprouting seedlings upto 0.5 to 1.0-meter length are planted in main pond. The main vegetative growth is for three months i.e. from mid-June to mid-September and crop covers entire surface of the water. The extensive flowering starts from September. The stagnant water ensures better flowering and fruiting. The first harvest is around third week of

September during Viswakarma Puja. There after every 10 days one harvest is done depending on the maturity. The yield during first harvest is generally low and is upto 1-3 t/ha. In $3^{rd}/4^{th}$ harvests it reaches upto 2-8 t/ha. However, after 6^{th} harvest, yield starts declining and continues till first week of November upto Deepavali. The total yield is 8-20 t/ha for entire season.

B. Swamp taro:

It is grown generally in poorly drained swamp lands or water logged area, or in peripheries of water bodies where water level fluctuated between inundation and drying. Entire plant parts like leaves, petioles, stolons (runners) and corms are consumed as vegetable. But most preferred and marketable part is a runner (lati or kachulati), which is consumed as vegetable.

The crop is vegetatively grown. Either the sprouting runners with well-differentiated roots or main stem with portion of petioles are used as planting materials. In January on flat bed at a spacing 60 x 45cm the crop is planted in fully saturated soil. The rate of NPK fertilizer is 50; 60:60kg/ha with FYM @8t/ha. In case of prolonged dry spell in April-May, irrigation is given as per need to save the crop.

The stolons start appearing from April month onwards and every 15days upto to 3 t/ha stolons can be harvested. Stolons are released from axil of each leaf from main stem and are harvested when it reaches approximately 0.5 to 0.75 meter in length. Periodical removal of old senesced leaves are useful for better sprouting of stolons. The sprouting of stolons continues upto September-October. At harvest, the corm yield is upto 15-17 t/ha, which is of course less preferred in market as vegetable. The yield of stolon is 20-25 t/h in addition to 15-17 t/ha. corn in total season.

C. Makhana (Euryale ferox):

The plant is a bottom rooted floating marcrophyte and belongs to family Nymphaeaceae. This aquatic cash is widely grown especially in North Bihar. Seasonal spread of the species varies from as low as 7.8% (in summer) to as high as 70% (in rainy season) in permanent wet lands in North Bihar (Rabi and Sharma 1991). The seed of makhana is commercially utilized as a spice or like corn seeds for making pop-makhana and other recipes

D. Kalmi Sag (Ipomoea aquatica: family Convolvulaceac):

This semiaquatic plant grows on the banks of waterlogged areas and grow as leafy vine on the surface of water. The vines are used as leafy vegetable

E. Thankuni sag (Hydrocotyl asiatica: family Umbelliferae):

This herb also grows naturally on swampy area. The creeping plant usually propagates by means of runners. The leaves are generally consumed either as raw paste with rice. It is consumed for its medicinal value for curing dysentery. Sometimes pastes are dried into tablets for medicinal use.

III. Bio-drainage

Water logging is well-appreciated problem worldwide impeding agricultural productivity. Various engineering approaches are adopted to control such situations like tube well installation, surface and sub-surface (tile) drains construction. All these measures are cost intensive, both in terms of commissioning as well as maintenance. Australian researchers have reported the ability of different trees in influencing water tables. Thus, a new approach is gaining momentum to use different types of plants to control shallow water tables. These plants draw their main water supply from ground water or from the capillary fringe just above it. Such types of plants are called **phreatophytes**. Main physiological features of such plants are luxriant transpiration in contact with ground water. Examples are tree species like poplar, *eucalyptus*, tamarix, muskit, *Acacia*, sissoo etc. Magnitude of transpiration in such species is as follows.

Plant type	Consumptive use of water (cu m/ha/annum)	Daily Consumptive use (litre) of 3yr old plant
willow	7700-13500	-
Poplar	6500-23500	45
Alder	168000	-
Tamarix	22000-28000	60
Adult Eucalyptus	-	132

It was estimated that annual rate of transpiration from (Eucalyptus) plantation area over 6-year period and the average was 3446 mm. The plantations were visualized as wells 500 m apart with pumping capacity of 33 m^3/hr. The observed draw down during a period of 6 yrs is between 7.8 – 8 m at various point of the plantation area with maximum draw down being 13-15 m. However, the efficacy of bio-drainage has been established through various reports after surveying of 80 sites in western Australia concluded that extensive planting covering as much as 70 –80 % of catchment area is necessary to achieve significant water table reduction in deep water table (often recharge area) situation. In shallow water table (often discharge areas) zones, for every 10 % increase in planted area water table was lowered by about 0.4 m. A comparative study of Casurina glanca and Eucalyptus camaldulensis showed that former had greater potential to discharge saline ground water. Use of Lucerne (Mediago sativa) a deep rooted relatevely salt tolerent perennial as a bio-drainage crop, showed it capable of both reducing recharge and use shallow ground water. Thus bio-drainage has been a successful concept to lower water table. In recharge areas with no assess to shallow ground water this technology is successful in long term basis. But in areas with shallow water table, salt removal and management of water table beneath the vegetation is needed perhaps through engineering method for viability of the system of sustainable basis.

Reclamation of coastal waterlogged wasteland through biodrainage

A Study on reclamation of coastal waterlogged wasteland through biodrainage plantation of trees like *Acacia mangium* and C*asuarina equisetifolia* and intercropping of pineapple, turmeric and arrowroot was taken up in Khurda district of Orissa coast. *Acacia mangium* was faster both in height, growth and collar diameter than *Casuarina*. However, *Casuarina* stem was less tapering than *Acacia mangium* at 12 months after planting. The average mortality of trees after one year for both the species were very less (< 6%). After four years of planting, the highest diameter at breast height (DBH) reached up to 20.1 cm for acacia and for casuarinas it reached up to 12.5 cm. However, the average values of collar diameter, DBH, height and canopy area were 178 mm, 143 mm, 15.4 m and 3.7 m respectively. For casuarina the average values of collar diameter, DBH, height and canopy area were 143.7 mm, 108 mm, 13.5 m and 3.85 m respectively by the same four years' period. Intercropping of pineapple, arrowroot, turmeric among the trees was also done successfully. In a year on an average 220 pieces of pineapple was harvested and 50 kg of turmeric seed and 40 kg of arrowroot seed was produced as intercropping in bio-drainage plantation. The depth to pre-monsoon water table changed from 0.5 m to 1.67 m due to well drained condition as well as due to bio drainage after one year of plantation and even went down to 2.20 m in the next year and to 3.20 m below ground level in third year and continuously declining. The soils of the experimental plots were highly acidic (pH: 3.5 - 5.0), low organic carbon (0.13-0.67%), and low in available nutrients (N<280 kg/ha, K: 50-170 mg/kg of soil, P: 5-10 mg/kg of soil) and high iron contamination which was restricting the growth and yield of crop prior to intervention, but got improved by land modification and biodrainage plantations over time. Successful establishment of trees and intercrops and its vigorous growth revealed that bio drainage species of acacia and casuarinas can be adopted for reclamation of waterlogged wasteland. However, acacia has better performance over casuarina.

Conclusions

Since waterlogged land, both manageable and unmanageable constitutes around 14.29 M ha, it has to be developed for growing remunerative crop and for increasing its productivity. The above discussed engineering and non-engineering measures which were tested in farmers' field can reclaim the waterlogged land and increase productivity and also protect the hazardous environment.

References

Jena, S.K. (2006). Waterlogged area management. Journal of Indian Institute of Public Administration. Vol. XIV: 357-368.

Jena, S.K., Sahoo, N., Roy Chowdhury, S., Mohanty, R.K., Kundu, D.K., and Mohanty, M. (2006). Optimizing Micro water resources design and integrated farming system approach for enhancing productivity of waterlogged area. Jl. of the Indian Society of Coastal Agricultural Research. 2006. Vol. 24 (1), pp: 180-183.

Maji, A.K., Reddy, G.P.O., and Sarkar, D. (2010). Degraded and wastelands of India: Status and spatial distribution, ICAR, New Delhi, P. 158.

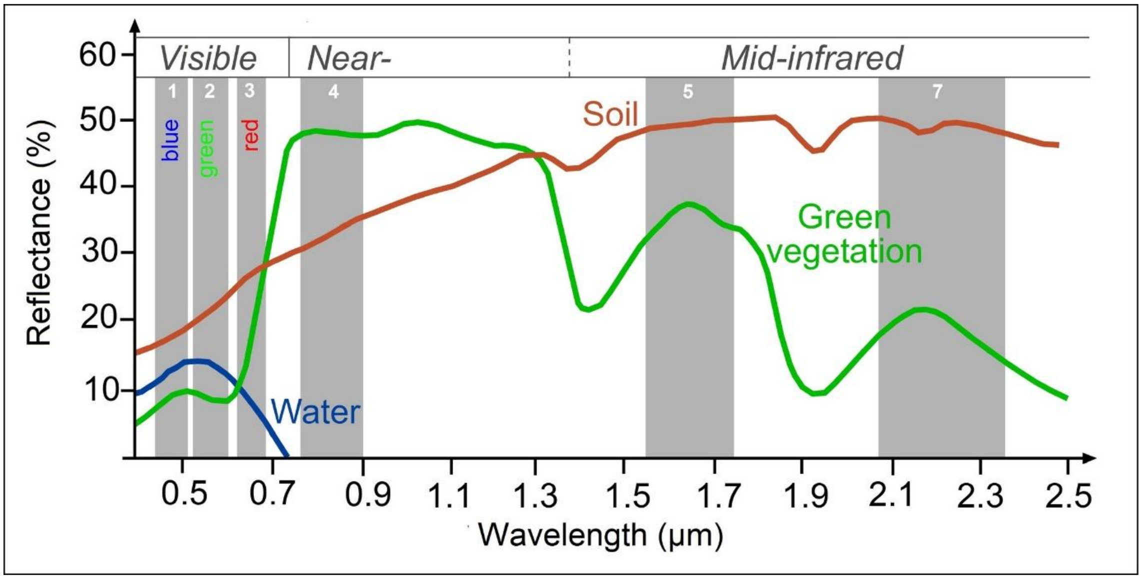
Remote sensing and GIS application to identify location specific water conservation structures- Theory and practical

Ranu Rani Sethi[1], Prasanta Kumar Patra[2]
[1]Principal Scientist, [2]Young Professional-II
ICAR-Indian Institute of Water Management, Bhubaneswar, Odisha-751023
E-mail: ranurani@yahoo.com

Remote sensing is the process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a distance (typically from satellite or aircraft). Special cameras collect remotely sensed images, which help researchers "sense" things about the Earth. Geographic information system (GIS) is software that converts data into productive information by getting data from GPS and RS, and then analyses the data and displays it as productive information. It gives an inexpensive way of map production, displaying the information on the map and makes the analysis easier.

Identification of Water bodies by using remote sensing and GIS

Water is becoming more and more important issue today as far as its sources are more and more exhausted. Agriculture (both planting and livestock production) consumes about 70 % of fresh water resources. Small water bodies represent an inevitable part of the hydrosphere. They are important for biodiversity and ecosystems functions and for their influence on larger water bodies (Biggs et al., 2017). With advent of modern technology of remote sensing and GIS we can easily highlight or identify surface water bodies. Using freely available satellite imagery from Landsat, IRS, Sentinel etc. we can find various water spectral indices like Normalized Difference Water Index (NDWI), Automated Water Extraction Index (AWEI)with the help of GIS software. These indexes are proposed to identify surface water bodies. Both Landsat and Sentinel data can be used to calculate various spectral indices (Yang, 2017; Zhou et al., 2017). Sentinel 2A MSI imagery was used to identify water bodies on basis of Normalized Difference Water Index (NDWI) (Yang et al., 2017). Many research revealed that all sensors and included indices provided reasonable results but Landsat 8 and Sentinel 2, provided more accurate results.



Spectral Reflectance Curve

Different Earth observing satellites and their band combinations:

Band combination of Landsat satellite images

Landsat-5 & 4 Thematic Mapper			
Band Number	Description	Wavelength	Resolution
Band 1	Visible blue	0.45 to 0.52 µm	30 meter
Band 2	Visible green	0.52 to 0.60 µm	30 meter
Band 3	Visible red	0.63 to 0.69 µm	30 meter
Band 4	Near-infrared	0.76 to 0.90 µm	30 meter
Band 5	Short-wave infrared	1.55 to 1.75 µm	30 meter
Band 6	Thermal	10.4 to 12.3 µm	120 meter
Band 7	Short-wave infrared	2.08 to 2.35 µm	30 meter

Landsat-7 Enhanced Thematic Mapper			
Band Number	Description	Wavelength	Resolution
Band 1	Visible blue	0.45 to 0.52 µm	30 meter
Band 2	Visible green	0.52 to 0.60 µm	30 meter
Band 3	Visible red	0.63 to 0.69 µm	30 meter
Band 4	Near-infrared	0.76 to 0.90 µm	30 meter
Band 5	Near-infrared	1.55 to 1.75 µm	30 meter
Band 6	Thermal	10.4 to 12.3 µm	60 meter
Band 7	Mid-infrared	2.08 to 2.35 µm	30 meter
Band 8	Panchromatic	0.52 to 0.90 µm	15 meter

Landsat-8 Operational Land Imager & Thermal Infrared Sensor			
Band Number	Description	Wavelength	Resolution
Band 1	Coastal / Aerosol	0.433 to 0.453 µm	30 meter
Band 2	Visible blue	0.450 to 0.515 µm	30 meter

Band 3	Visible green	0.525 to 0.600 µm	30 meter
Band 4	Visible red	0.630 to 0.680 µm	30 meter
Band 5	Near-infrared	0.845 to 0.885 µm	30 meter
Band 6	Short wavelength infrared	1.56 to 1.66 µm	30 meter
Band 7	Short wavelength infrared	2.10 to 2.30 µm	60 meter
Band 8	Panchromatic	0.50 to 0.68 µm	15 meter
Band 9	Cirrus	1.36 to 1.39 µm	30 meter
Band 10	Long wavelength infrared	10.3 to 11.3 µm	100 meter
Band 11	Long wavelength infrared	11.5 to 12.5 µm	100 meter

Band Combination of IRS satellite images

Satellite	Launch date	Sensor complement	Spectral Bands (µm)	Spatial resolution (m)	Swath width (km)	Repeat cycle (days)
IRS-1A	17.03.1988	LISS-I, and LISS-II A/B	0.45-0.52	72.5 m LISS-I	148	22
		(3 sensors)	0.52-0.59	36 m LISS-II	74 x 2 (swath of 148 km)	
			0.62-0.68			
			0.77-0.86			
IRS-1B	29.08.1991	LISS-I and LISS-II A/B	same as for IRS-1A		148	22
					74 x 2	
IRS-P2	15.10.1994	LISS-II M	0.45-0.52	32 m x 37 m	66 x 2	24
			0.52-0.59		(131 km for combined swaths)	
			0.62-0.68			
			0.77-0.86			
IRS-1C	28.12.1995	LISS-III	0.52-0.59	23.5	142	24
			0.62-0.68	23.5	142	
			0.77-0.86	23.5	142	
			1.55-1.70	70	148	
		PAN	0.50-0.75	5.8	70	24 (5)
		WiFS	0.62-0.68	188	804	5
			0.77-0.86			
IRS-P3	21.03.1996	WiFS	0.62-0.68	188	804	5

			0.77-0.86			
			1.55-1.70			
		MOS-A	0.75-0.77	1500	195	Ocean surface
		MOS-B	0.41-1.01	520	200	
		MOS-C	1.595-1.605	550	192	
		IXAE	Indian X-ray Astronomy Experiment			
IRS-1D	29.09.1997	Satellite and instruments are identical to those of IRS-1C				
IRS-P4 (OceanSat-1)	26.05.1999	OCM	0.4-0.9	360 x 236	1420	2
		MSMR	6.6, 10.65, 18, 21 GHz (frequencies)	105x68, 66x43, 40x26, 34x22 (km for frequency sequence)	1360	2
IRS-P6 Resource Sat-1	17.10.2003	LISS-IV	0.52-0.59	5.8	70	24 (5)
			0.62-0.68	5.8		
			0.77-0.86	5.8		
		LISS-III*	0.52-0.59	23.5	140	24
			0.62-0.68	23.5		
			0.77-0.86	23.5		
			1.55-1.70	23.5		
		AWiFS	0.62-0.68	70	740	5
			0.77-0.86	70		
			1.55-1.70	70		
IRS-P5	05.05.2005	PAN-F	0.50-0.75	2.5	30	2-line stereo camera
CartoSat-1		PAN-A	0.50-0.75	2.5	30	
CartoSat-2	10.01.2007	PAN camera	0.50-0.85	< 1	9.6	
OceanSat-2	23.09.2009	OCM	0.40-0.90 8 bands	360 x 236	1420	2
		SCAT	13.515 GHz	25 km x 25 km	1400	
		ROSA	GPS occultation			
RISAT	2011	SAR instrument	5.350 GHz (C-band)	< 2 m to 50 m	100 - 600	
Megha	2011	MADRAS	5 chan. radiometer	40 km x 60 km	1700	2

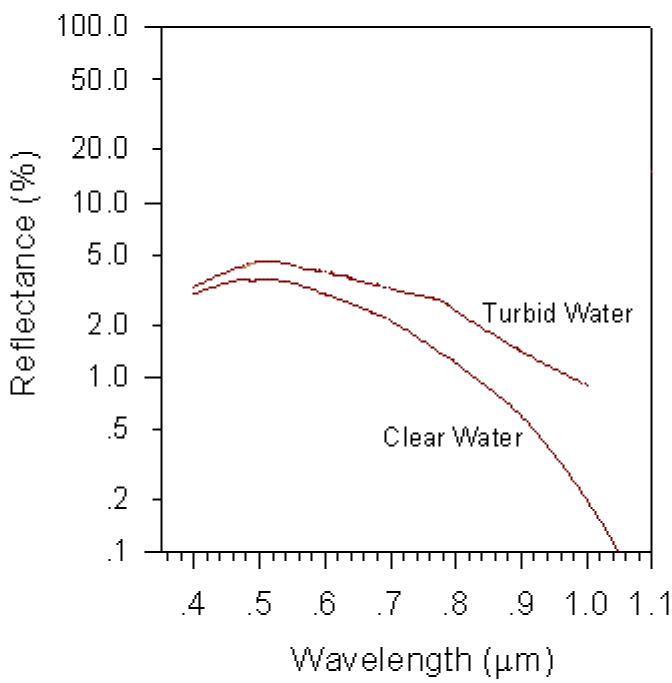
Tropiques		SAPHIR	Atmos sounder			
(ISRO/CNES)		ScaRaB	Radiation budget			
		GPS-ROS	Occultations			
SARAL (ISRO/CNES)	2011	AltiKa	35.75 GHz Ka-band altimeter			
		DORIS	S/C tracking for POD services			
		Argos-3	Data collection system			
		LRA	Satellite laser ranging			

Band combination of Sentinel-2 satellite images:

Band	Resolution	Central Wavelength	Description
B1	60 m	443 nm	Ultra blue (Coastal and Aerosol)
B2	10 m	490 nm	Blue
B3	10 m	560 nm	Green
B4	10 m	665 nm	Red
B5	20 m	705 nm	Visible and Near Infrared (VNIR)
B6	20 m	740 nm	Visible and Near Infrared (VNIR)
B7	20 m	783 nm	Visible and Near Infrared (VNIR)
B8	10 m	842 nm	Visible and Near Infrared (VNIR)
B8a	20 m	865 nm	Visible and Near Infrared (VNIR)
B9	60 m	940 nm	Short Wave Infrared (SWIR)
B10	60 m	1375 nm	Short Wave Infrared (SWIR)
B11	20 m	1610 nm	Short Wave Infrared (SWIR)
B12	20 m	2190 nm	Short Wave Infrared (SWIR)

NDWI (Normalized Difference Water Index):

The Normalized difference water index (NDWI) is a remote sensing derive index that is used to highlight surface water features from satellite imagery, it also stands out water bodies from soil and vegetation. This index was proposed by McFeeters in 1996. This index uses green band and NIR (Near infrared) band of satellite image for effective capture of surface water bodies.



Formula for NDWI = $\frac{Green-NIR}{Green+NIR}$

The visible green wavelengths maximize the typical reflectance of the water surface. The near-infrared wavelengths maximize the high reflectance of terrestrial vegetation and soil features, while minimizing the low reflectance of water features.
The result of the NDWI equation is positive values for water features and negative ones (or zero) for soil and terrestrial vegetation

For Landsat 7 data:
NDWI = (Band 2 – Band 4)/ (Band 2 + Band 4)

For Landsat 8 data:
NDWI = (Band 3 – Band 5)/ (Band 3 + Band 5)

For Sentinel 2 data:
NDWI= (Band 3 – Band 8)/ (Band 3 + Band 8)

Now we will discuss about the basics of downloading the satellite data from freely available site (USGS) and analyzing it for identifying the water bodies for further detail analysis.

Steps to Register in USGS site

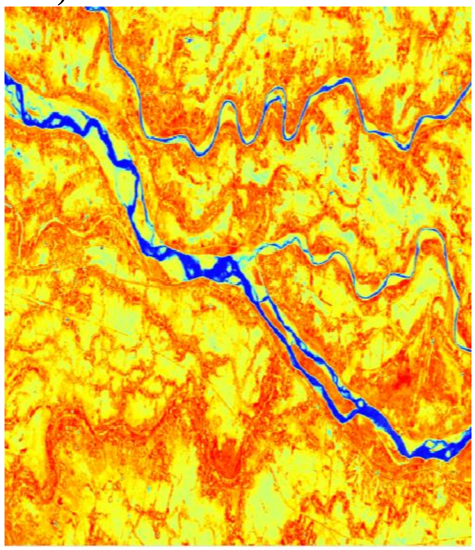
1. Browse USGS site (https://earthexplorer.usgs.gov)
2. Register in USGS Earth Explorer to create account
3. Give your prefer username and set password
4. Fill contact demographics and contact information tab
5. complete your registration by clicking on submit button
6. A verification link will be sent to our register mail id by clicking on that link
7. Registration process completed
8. Log in

Steps to download the Landsat satellite image

1. Login to USGS account
2. Click on Address/Place tab and provide your location name
3. Click on Show tab
4. click on name of your location on newly opened interface
5. Your location area will be zoom in on image window
6. Make mark on image window by clicking around your ROI to fetch image
7. Provide your date range as per your need
8. Keep cloud cover under 10%
9. Click on Data set tab →Landsat→ Landsat collection 2 level 1→ check on Landsat 8-9 OLI/TIRS C2 L1
10. Click on Results
11. Set of mages captured on different dates will appear Now you can download your required image in GeoTiff format

Finding NDWI (Normalized Difference Water Index) from satellite data

1. Open ArcGIS software
2. Click on add data button and browse to add green band and NIR band of Landsat-8 GeoTiff data and also shape file of ROI (Region of Interest).
3. Click to open Arc Tool Box
4. Select spatial analyst tool
5. Map Algebra
6. Click to open Raster Calculator
7. Use formula NDWI = (Green-NIR)/(Green+NIR)
8. Provide output path to save Resulted NDWI of Whole Image
9. Now we have to mask out the ROI NDWI from whole Scene
10. Go to Arc Tool Box
11. Spatial analyst tool
12. Click Extraction
13. Click Extract by mask
14. Give NDWI and ROI as input and provide output path to Save final NDWI of Required Area



References

1. https://directory.eoportal.org/web/eoportal/satellite-missions/i/irs

2. https://eos.com/make-an-analysis/ndwi/#:~:text=The%20Normalized%20Difference%20Water%20Index,also%20known%20as%20NDWI%20GAO.

Water Management Options in Canal Command Areas

R. K. Panda
Principal Scientist, ICAR-Indian Institute of Water Management, Bhubaneswar, Odisha-751023
E-mail: pandark1@rediffmail.com

With approximately 68.4 million ha of net irrigated area, India ranks first in the world in terms of irrigated area. India invested nearly 4000 million US dollars in public canal systems during 1991-2007 (Dhawan, 2017). In spite of that the canal-irrigated area decreased by 38 lakh hectares during that period, as infrastructure is old with unreliable water supply. This resulted in low efficiency of water use (approximately 40 per cent for surface irrigation and 60 per cent for ground water irrigation) in irrigated agriculture. According to the Food and Agriculture Organization (FAO), the overall water use efficiency for irrigated agriculture in developing countries averages to 38 per cent. For instance, 10 per cent improvement in WUE can add 14 million ha of additional irrigation in India. The pity is that the open canals result in severe loss of water by evaporation, seepage, wastage and unauthorized over drawl by the farmers through unauthorized outlets. The key issues faced by the irrigation sector in India are low pricing, low water use efficiency, high cost of surface irrigation, depleting groundwater and lack of focus on demand side management (Gulati and Banerjee, 2016). Thus, in order to increase the water use efficiency in canal commands, there is need of mechanisms to bring the water back to use in the cropped area, which can be achieved through improved conveyance and distribution mechanism.

There are wide variations in the water use efficiencies in the canal systems in the country. It is seen that efficient canal systems in the country perform with the water use efficiency in the range of 95 to 97.5 percent at the end of main canal to 47 to 57 per cent after field application. Where watercourses are not yet lined, the efficiency is still lower. A case study carried out by ICAR-IIWM, Bhubaneswar in Hirakud canal command area at distributary level revealed conveyance loss of 27.5 ls^{-1} in 100 m and 181.25 ls^{-1} in 100 m in lined and unlined canal sections, respectively. Similarly, irrigation application efficiency is observed within the range between 28.7 –53.1% (Panda et al., 2016). Canal automation with adequate conveyance *vis-a-vis* pressurized irrigation system application will increase water use efficiency in canal commands, there is no second thought. Thus the study on water productivity is required to aim to assess the efficiency and to pin point maladies in the system and usher in reforms.

Further, optimal crop planning developed for the Hirakud command area through various scenarios revealed that the cropping pattern obtained under Scenario i.e. to utilize the maximum area for cultivation, under the constraint of limiting water availability for each outlet was found to be feasible for optimal land and water utilization and generation of requisite employment. However, keeping in view the affinity of the farmers towards paddy (a heavy duty crop), Scenario i.e. to utilize the maximum area for cultivation with the constraints of limited irrigation water availability, and providing irrigation to heavy duty crops for at least one-third of the culturable command area of each outlet, can be adopted (Panda et al., 2018).

Uncertainty attached to efficient canal rostering in the backdrop of climate change scenario often stands as serious impediment in entire planning process. Thereby, consideration for conservation of available water resources in auxiliary storage structures along the canal reach can be thought as a better proposition for efficient canal delivery for crop production. Research studies carried out by ICAR-IIWM while computing the optimal size of auxiliary storage reservoir in Minor Irrigation Project of Odisha state revealed that the optimal surface area of secondary storage reservoir as the percentage of the command area can be as 19.00, 17.40, 15.73, and 14.00% for 25, 50, 75 and 100% of water availability in the main reservoir, respectively. Considering that on an average by the end of monsoon season about 50% of the main reservoir capacity will have irrigation water for the dry season crops, the optimal surface area of the secondary storage reservoir was considered as 17.40% of the command area (Mishra et al., 2010).

The Ministry of Water Resources, Government of India is taking several steps to improve the water availability and to meet the requirements till the year 2050. This very optimistic goal is expected to be achieved by the implementation of integrated water resource management (IWRM) plans and enhancement of the water use efficiency as stated in the National Water Mission 2008. As the farmers are the end-users, they have to be informed during implementation of the improvements planned and of the anticipated benefits which they may gain. Modern irrigation technologies can improve the water productivity and could lead to water savings of more than 50 per cent. Thus in order to bring promising agriculture in canal command areas, emphasis is required on increasing efficiency, equitable distribution with peoples' participation keeping environmental sustainability at place.

Canal command performance improvement strategies

Success stories developed through experimental researches in ICAR-IIWM, Bhubaneswar (Odisha) are enumerated below, which depict successful attempt of utilization of efficient water resources in canal commands.

(A) Farm-pond fed pipe conveyance based pressurized irrigation system (Nagpur minor irrigation system)

The study area is located in two villages namely; Nagpur and Hirapur under Umadei Brahmapur Gram Panchayat, Balipatna Tahasil, district Khurda of Odisha. Nagpur minor canal off takes from Puri main canal at RD 35.620 km (L) and passes through Nagpur and Hirapur villages. The minor runs a length of 3.0 km with design discharge of 0.3 cumec and command area of 156 ha.

Prior to taking up the interventions in the study area, farmers were mostly growing Paddy in *kharif* season and no crop during *rabi* season. During pre project period 2017-18, the hydraulic performance indicators like adequacy, equity and relative water supply of 0.3, 0.68 and 0.72, respectively revealed the under performance of the irrigation system. Thus, in order to increase its effectiveness in terms of crop yield and water productivity. Irrigation provision of PVC pipe conveyance system, PVC pipe conveyance along with sprinkler irrigation system and PVC pipe conveyance along with drip irrigation system were laid out in head, middle and tail reaches in the proposed minor irrigation system to address water requirement needs of the farmers during post monsoon season. The created conveyance facilities were connected to the existing auxiliary water storage structures.

During four years' study period (2017-2021), overall pipe conveyance based pressurized irrigation system in all the three reaches of the canal system out-performed in terms of crop yield and water productivity in comparison to farmers' practice of channel based conveyance irrigation system. However, among the three different irrigation practices, in the lower reach, pipe conveyance based drip irrigation system out-performed other two irrigation systems while resulting in enhancement of crop yield of groundnut, pointed gourd and bitter gourd in the range of 34.5-47.2% and water productivity of 137.1-151.8 % with less irrigation water use of 40-45.4%, respectively, when compared with channel conveyance system. Channel conveyance system resulted in the crop yield with the range of 1.4-11.8 t/ha, water productivity of 0.5-3.9 kg/m^3 and total water use of 270-300 mm (total 3 nos. of irrigation ranging 90-100 mm each time). However, among the three irrigation systems, pipe conveyance based sprinkler irrigation system was lauded by the farming community as it required less effort for operation and maintenance (Annual Report of ICAR, DARE 2021-22). Further, even if the above proposed interventions were found feasible in addressing the performance enhancement options in the canal system, but due to temporal uncertainty in canal flow, farmers opined for additional provision of few tube well facilities in the command area for assured water availability.

	
Pipe conveyance system being laid out	Farmer irrigating pointed gourd crops

(A) Dug well fed pipe conveyance based pressurized irrigation system (Ghurlijore minor irrigation system)

Dug well fed pipe conveyance based pressurized irrigation system was taken up in Ghurlijore Minor Irrigation system in Sundargarh district of Odisha with the objective to improve the land and water productivity through augmenting the irrigation infrastructure. Accordingly, two highly populated S.T. community villages namely; Birjaberna and Mohuljhore villages in Sundargarh district (Odisha) were selected. Three nos. of irrigation infrastructures namely; inlet, outlet and surplus escape were constructed in the existing Birjaberna Gadhuamunda linkage tank for judicious conveyance of canal water in the command area. Further, a dug well based sprinkler irrigation system was developed in Birjaberna village for promoting *rabi* season crops. In order to minimize the conveyance loss in irrigation, HDPE pipe lines were provided to 48 tribal farmers in both the villages. Impact of the service reservoir along with the dug well was studied for the *kharif*, *rabi* and summer seasons during 2015-16 and 2016-17.

From the results, it is evident that due to creation of irrigation infrastructures, crops like rapeseed in *rabi* season, and groundnut and green gram in summer season could be grown after *kharif* rice during 2015-16 and 2016-17 as against of paddy-fallow cropping system prior to the interventions. Moreover, supplemental irrigation could be provided to *kharif* rice due to developed water resources through PVC pipe conveyance line at the site. The yield of paddy crop (var. Lalat) under the study was 3.7 t ha^{-1} with water productivity of 0.35 kg m^{-3}, whereas the paddy yield of same variety in non-intervened areas near to the study site was 2.8 t ha^{-1} with water productivity of 0.26 kg m^{-3}. The increase in yield and water productivity of paddy by 32% and 35%, respectively over that in nearby non-intervened area was due to supplemental irrigation (300 mm) provided from the dug well and service reservoir at the site.

	
Surplus Escape in canal linked service reservoir	Dugwell fed sprinkler system

Rapeseed crop (var. Parvati) yielded 1.25 t ha^{-1} with water productivity of 0.42 kg m^{-3} during *rabi* season. Further, introduction of sprinkler irrigation could produce 27% higher yield with 31% less water use, resulting in 84% higher water productivity compared with check basin irrigation in groundnut (var. Smruti) during 2015-17. Similarly, paired row furrow irrigation system helped in saving 15% irrigation water with producing 15% higher yield resulting in 36% higher water productivity compared with check basin irrigation in groundnut. In green gram, yield enhancement of 25% with 33% less water use was observed under sprinkler irrigation compared to check basin irrigation. The higher yield with less water application in groundnut under sprinkler irrigation was attributed to better uniformity of distribution and application efficiency of water under sprinkler compared to paired row and check basin irrigation.

Based on the facilities developed in Birjaberna village, net return from the cropping system (rice-rapeseed-groundnut) including pisciculture established Rs. 1.78 lakhs ha^{-1} (Panda et al., 2018). However, considering the cost of creation of the infrastructures on annuity basis i.e. Rs. 0.48 lakh ha^{-1}, net return per year from the system as a whole was obtained as Rs. 1.30 lakhs ha^{-1}.

(B) Scenario based alternative cropping patterns and water cost curve model (Sina medium irrigation system)

An ICAR-IWMI collaborative research project on Enhancing Economic Water Productivity (EWP) in Irrigation Canal commands was pilot-tested in the Sina medium irrigation system in Maharashtra, India focusing water Influence Zone (WIZ), scenario based alternative cropping patterns and water cost curve. While considering culturable command area (CCA), WIZ of one km buffer area outside the command (whose water requirement is met by return flow from the canal only), and reservoir lift area into consideration as a whole against only CCA, it was observed that the area utilized for productive agriculture is more than 1.0.

Water availability is the primary constraint in water-scarce irrigation systems, even under normal rainfall conditions. The pilot study developed scenarios of alternative cropping patterns and a water cost curve (WCC) for EWP to assess hydro-economical tradeoff. The WCC for the irrigation system showed the increases in the net value of output (value of production – the cost of cultivation) per m^3 of irrigation CWU against the increases in EWP (gross output per m^3/ha of irrigation CWU. It assessed the financial tradeoff of conventional crop cultivation methods with advanced irrigation technologies (drip and sprinkler irrigation, sub-surface drip, drip with fertigation, etc.), and with advanced agronomic and irrigation practices (system of rice intensification, alternative wet and dry irrigation, direct seedling, ridge and furrow, integrated nutrient, etc.)

Based on the WCC, it is found that crops with low EWP, such as sorghum, pulses, oilseeds, etc., dominate the cropping patterns in one of the highest rainfall year (2010-11) in the last two decades and with a diverse cropping pattern. Fruits (pomegranate) and fodder (Lucerne) with considerably higher EWP constitute a small area (~2%). Vegetables (onions) have the second-highest EWP but are highly climate-sensitive. Sugarcane also has high EWP but requires more than 9,000 m^3/ha of irrigation CWU, compared to only 4,200 and 6,000 m^3/ha for fodder and fruits.

Thus changing cropping patterns was essentially required for enhancing the resilience of farmers in the Sina irrigation system. The alternative cropping patterns were found financially viable options in Sina or in any similar water-scarce canal irrigation systems. The water cost curve (WCC) for EWP facilitated assessing the financial tradeoff of the conventional cropping patterns with those including advanced technologies (drip, sprinkler, laser leveling, etc.) and agronomic practices. The WCC shows that fruits (banana, pomegranate), vegetables (onions, tomatoes), the fodder (Luzerne) crops have a relatively higher gross and net value of out per m^3 of irrigation CWU. Sugarcane and mangoes have higher EWP but have a lower net value of output per m^3. Groundnut and chickpeas have a higher net value of production but slightly smaller EWP.

Alternative cropping patterns, even with advanced technologies and agronomic practices were found financially viable. The crops and technologies/practices considered were fruits (pomegranate with drip irrigation), fodder (Luzerne with sprinkler irrigation), vegetables (onions with sprinkler irrigation), sorghum and wheat with conventional irrigation, pulses (Chickpeas with integrated water management), oilseed (groundnut with integrated nutrient management), sugarcane with drip, fertigation and integrated pest management (Amarasinghe et al., 2021 and Amarasinghe et al., 2021).

Conclusion

Prominent reasons of unsatisfactory canal functioning are due to reasons like lost capacity of the canal system, which were constructed long back; ill maintenance of the canal reaches; heavy and unregulated drawals of water in the head and middle reach; illegal installation of pumps in the canal directly; adoption of water intensive paddy crops mostly in the canal commands etc. Thus, based on the above success stories carried out in various canal commands, it is imperative that provision of micro irrigation linked through canal fed auxiliary water harvesting structures (farm pond/Dug well), consideration of water Influence Zone (WIZ) beyond canal command area, scenario based alternative cropping patterns and water cost curve could be viable solutions to address enhanced physical and economic water productivity in the canal ecosystem.

References:

Amarasinghe, U.A., Sikka, A., Mandave, V., Panda, R.K., Gorantiwar, S., Chandrasekharan, K. and Ambast, S.K. 2021. A re-look at canal irrigation system performance: a pilot study of the Sina irrigation system in Maharashtra, India. *Water Policy*, 23(1): 114-129.

Amarasinghe, U.A., Sikka, A., Mandave, V., Panda, R.K., Gorantiwar, S., and Ambast, S.K. 2021. Improving economic water productivity to enhance resilience in canal irrigation systems: a pilot study of the Sina irrigation system in Maharashtra, India. *Water Policy*, 23(2): 447-465.

Annual Report 2021-22. Strategies for improved water productivity in the canal commands. ICAR, DARE, Ministry of Agriculture & Farmers Welfare, Govt. of India, New Delhi, pp. 11-12.

Dhawan, V. 2017. Water and agriculture in India. Background paper for the South Asia expert panel during the Global Forum for Food and Agriculture (GFFA), pp.15.

Gulati, A. and Banerjee, P. 2016. Emerging water crisis in India: Key issues and Way Forward. *India J. of Economics*, Special Centennial Issue, Vol. XCVI, No. 383: 681-704.

Mishra, A., Adhikary, A.K., Mohanty, R.K., Anand, P.S.B., Ghosh, S., Panda, S.N. and Kumar, A. 2010. Performance Enhancement of a Minor Irrigation System through Secondary Storage and Multiple Use Management. *Research Bulletin No. 49*, Directorate of Water Management (Indian Council of Agricultural Research), Chandrasekharpur, Bhubaneswar - 751023, India. page : 38.

Panda, R.K., Mohanty, S., Brahmanand, P.S., Kumar, A., Raju, P.V., and Rao, V.V. 2016. Appraisal of canal hydraulics and field water balance components at distributary level in Hirakud canal command. *Indian J. of Soil Conservation*, 44(1): 19-24.

Panda, R.K., Panigrahy, N., Mohanty, S., Brahmanand, P.S., Kumar, A., Raju, P.V., and Rao, V.V. 2018. Optimal cropping pattern design for a major distributary of Hirakud canal command in India. *Sustainable Water Resources Management*, 4: 1051-1062.

Panda, R.K, Sethi, R.R., Rautaray, S.K., Mohanty, R.K., Panigrahi, P., and Ambast, S.K.. 2018. Enhancing water productivity through conjunctive use of surface and groundwater resources in upland plateau region of Odisha. *Indian J. of Soil Conservation*, 46(3): 343-350.

ICAR-Flexi Rubber Check Dam: An Innovative Technology for Efficient Water Conservation

Susanta Kumar Jena
Principal Scientist & Coordinator, CRP on Water
ICAR-Indian Institute of Water Management, Bhubaneswar-751023, India
Email: skjena.icar@gmail.com , Mob: 9437221616

In climate change scenario we experience more extreme events of cyclone, flood, drought, long dry spells etc. The intensity, amount and distribution of rainfall are also not as per the crop requirement. Secondly land and water are the two most vital natural resources of the world and these resources must be conserved and maintained carefully for environmental protection and ecological balance. Prime soil resources of the world are finite, non-renewable over the human time frame, and prone to degradation through misuse and mismanagement. Total global land degradation is estimated at 1964.4 M ha, of which 38% is classified as light, 46% as moderate, 15% as strong and the remaining 0.5% as extremely degraded, whereas present arable land is only 1463 M ha which is less than the land under degradation (Koohafkan 2000). The annual rate of loss of productive land in the whole world is 5 to 7 M ha, which is alarming. In India, out of 328 M ha of geographical area, 182.03 M ha is affected by various degradation problems out of which 68 M ha are critically degraded and 114.03 M ha are severely eroded whereas total arable land is only 156.15 M ha (Velayutham 2000). It was reported that in India 0.97% of total geographical area is under very severe erosion (> 80 t ha^{-1} yr^{-1}), 2.53% area under severe erosion (40-80 t ha^{-1} yr^{-1}), 4.86% area under very high erosion (20-40 t ha^{-1} yr^{-1}), 24.42% area under high erosion (10-20 t ha^{-1} yr^{-1}), 42.64% area under moderate erosion (5-10 t ha^{-1} yr^{-1}) and rest 24.58% area under slight erosion (0-5 t ha^{-1} yr^{-1}) (Singh et al. 1992). Therefore, the problem of land degradation due to soil erosion is very serious and with increasing population pressure, exploitation of natural resources, faulty land and water management practices, it will further aggravate. Land degradation also reduces the world's fresh water reserves. It has a direct impact on river flow rates and the level of groundwater tables. The reduction of river flow rates and the lowering of groundwater levels lead to the silting up of estuaries, the encroachment of salt water into groundwater, the pollution of water by suspended particles and salinization, which in turn reduces the biodiversity in fresh and brackish water and consequently fish catches. Lower river flows also interfere with the operation of reservoirs and irrigation channels, increasing coastal erosion and adversely affecting human and animal health.

Proper watershed management, which is a comprehensive term meaning the rational utilization of land and water resources for optimal production and minimum hazard to natural resources could be the solutions to all these problems (Jena 2002). There are several measures such as mechanical (engineering) and biological (agricultural) which are used for soil and water conservation in watershed management. Check dams are engineering measures which are mainly used for soil and water conservation in watersheds. In India, several types of check dams are being used for regulating runoff in watersheds which in turn help in assured water supply to crops. Generally, most of the check dams in watersheds are made of steel, concrete, soil, rock (permanent) or with vegetation (temporary). The use of rubber as a construction material is a technological innovation in materials application. At the same time, the check dams are rigid one and they cannot allow more water to pass over it at times of heavy flood/runoff or store sufficient runoff at lean season of rainfall for use in Rabi season by farmer for different Rabi crops like pulses, oilseeds and vegetable. To give more flexibility in release and control of water flow across the streams, research efforts were made at ICAR-Indian Institute of Water Management (IIWM), Bhubaneswar in collaboration with Indian Rubber Manufacturers Research Association (IRMRA), ICAR-Central Institute for Research on Cotton Technology (CIRCOT), and Kusumgar corporate Pvt. Ltd. (KCPL), Mumbai to fabricate and install rubber sheets instead of cement concrete/ stone material for check dams and to study their impact on crop performance.

Rubber dam (ICAR Flexi-check dam)

Rubber dam (ICAR flexible check dam) is an inflatable structure build across a stream used for water conservation, flood control and regulating flow of water in the stream. When it is inflated, it serves as a check dam/weir and when it is deflated it functions as a flood mitigation device and sediment flushing. Rubber dams are installed to function as weirs or barrages which are relatively low-level dams constructed across a river for the raising of river level for the diversion of flow in full, or a part, into a supply canal or conduit for irrigation, domestic, industrial use (Tam 1998). Most of the civil engineering structures constructed in the history of humankind are made of steel, concrete, soil, or, rock. The use of rubber as a construction material is a technological innovation in materials application (Tam and Zhang 2002).

The head or height of rubber dam is variable. This variable head also regulates the depth of flow in the irrigation diversion channel present in the upstream side of the check dam or in irrigation canals and distributaries. This can also be used in coastal creeks, estuaries, streams and channels to restrict the inflow of sea water into land mass. During high tide it can also prevent the high tides to enter into the fresh water system.

As an innovative hydraulic structure, the rubber dam mainly consists of the following parts: (i) a concrete foundation with head wall extension, side wall and wing wall of a normal check dam; (ii) the head wall replaced by rubberized fabric dam body; (iii) anchoring system (anchoring of rubber sheet with bottom and side of the check dam); (iv) Inflation deflation system (an inlet/ out let piping system for inflation and deflation by water); and (v) a pump for filling water for inflation.

The span or length of the rubber dam can vary from 1 m to 10 m (depending upon the width of the stream). For wider streams also, there can be several spans.

The detail specification of the composite rubber is available with ICAR**.**

Rubber dam at Konkan region, Dapoli.

Advantages of rubber dam

- Traditional check dams get silted due to continuous inflow of sediment from upstream side thus reducing the storage capacity. Rubber dam can be occasionally deflated during flood to flush out all the sediment to the downstream side.
- During dry period/ lean season the head wall can be easily inflated to store more water.
- Due to flexibility of the head wall, during extreme events of high intensity rainfall and extreme flood situation, the structure can be easily deflated, so there is no damage to the structure and there is no breaching of stream bank/ levees and no scouring or erosion of stream bed.
- Earth quake, land slide cannot damage the head wall as it is made of rubber and repair to the side and wing walls can be easily done without dismantling the structure.
- There will be no conflict of interest of farmers and other beneficiaries as desirable amount of water can be easily delivered to downstream side by storing desirable quantity in the upstream side and maintaining environmental flow in the downstream side.

Cost of the structure and operational cost

The cost of rubber dam along with its RCC base structure varies from Rupees one lakh to 10 lakh in small watershed streams for 3 m to 15 m width. Since the head wall is semicircular in shape and hydraulic jump occurs very close to the structure, a long apron is not required, thus reducing the cost of the base structure. The head wall is replaced by a composite rubber sheet. The cost of rubber composite sheet is around Rs. 3000- 3800 per m^2 for 8 mm thick at present. However, the cost will reduce when produced on commercial scale in large quantity. The operating cost is variable and is required to deflate during high flood, inflate during dry period or any other emergency condition and then pumping cost for inflation. On an average 4 to 5 times inflation/ deflation is required which will cost around Rs.1000 per year.

Installation and field evaluation

Initially, five rubber dams were installed in watersheds at different locations of Khurda district, Odisha with innovative manufacturing, fabrication and installation technology. These are the first indigenous rubber dams which were been fabricated and installed in our country by Indian scientists. The Table-1 shows the location of sites where rubber dams have been installed and evaluated.

Table 1. List of ICAR-Flexi Check Dam (Rubber Dams) installed in India by IIWM

Sl. No	Name of the Indian State	Name of the district	No of rubber dams
	Odisha	Khordha	5
		Koraput	3
		Nabarangpur	1
		Baleswar	3
		Dhenkanal	1
	Maharashtra	Ratnagiri	3
		Pune	3

	Gujarat	Navsari	4
	Uttarakhand	Dehradun	3
		Tehri Garhwal	1
	Meghalaya	Ri-bhoi	1
	Himachal Pradesh	Kangra	2
	Tamil Nadu	Nilgiris	1
	West Bengal*	West Medinipur	2

**Technical support provided to West Bengal Govt. for installation of 2 no. of Rubber dam at Medinipur (WB)*

Enough care has been taken during development of the rubber composite along with nylon reinforcement that when installed across streams it does not have any adverse effect on water quality (may be due to oozing out of chemicals or any extracts from the rubber composite) and also on crop productivity. It does not have any adverse impact on environment.

Rubber composite sheet manufactured by IRMRA was fixed with concrete base structure through double rows anchoring mechanism. The angle of inclination of side anchoring to the base has been optimized by IIWM to minimize wrinkles and easiness to inflate and deflate. The spacing between bolts and also the dimension and structural strength of different bolts were tried. The dimension and strength of different anchoring bots were optimized by IIWM for different dimensions of rubber dam. The structure was made leak proof (no water flow between top of the base of the concrete foundation structure and the rubber sheet) using different proportions of adhesives like Sillica gel etc. and were tested by filling with water through inlet pipe using at least 1.5 hp kerosene operated petrol start centrifugal pump. Two of the installed rubber dams at Chandeswar are presented through plate 1.

Plate1. Rubber dams installed in watersheds of Odisha by IIWM, Bhubaneswar

Impact of rubber dam on crop performance

The Chandeswar and Baghamari check dams are operated and maintained by farmers for paddy cultivation during kharif and pulses, oilseed and vegetable cultivation during rabi and summer season in the surrounding field. Various types of evaluations of rubber dams were done such as water storage and impact of rubber dam on crop yield and other agricultural and watershed parameters.

Majority of farmers under rubber dam command area in Baghamari and Chandeswar (Khurda district of Odisha) have small and marginal landholdings and they were not in a position to generate good returns due to poor crop establishment and crop productivity before installation of rubber dam. The adoption of technology has enhanced the rural livelihood options. It has enhanced the crop productivity, crop production, crop diversification, cropping intensity thus increasing the rural income. It stores an additional amount of water in the range of 4500m^3 to 10000 m^3 and irrigates around 10 to 20 ha during kharif to 2-5 ha during summer depending upon the slope and capacity of the stream. The additional water resource created by installation of rubber dam has helped in supplemental irrigation there by resulting in higher cropping intensity, crop productivity which in turn generated additional net returns to the farmers. The economic analysis indicated that the intervention of rubber dam has potential to enhance the gross returns of the farmers by 62% from Rs. 28,700 ha^{-1} to Rs. 46,700 ha^{-1} if farmers grow only rice crop. At the same time, the total gross returns of the farmers may increase from Rs. 45184 ha^{-1} to Rs. 70792 ha^{-1} if farmer practices rice-green gram cropping system with the additional water available through rubber dam and the total gross returns may increase to Rs. 72500 ha^{-1} and Rs. 75135 ha^{-1} if farmers practice rice-cucumber and rice-sunflower cropping system. Similarly, the net returns of the farmers will increase from Rs. 12400 ha^{-1} to Rs. 27600 ha^{-1}, Rs. 43942 ha^{-1}, Rs. 43200 ha^{-1} and Rs. 47935 ha^{-1} under sole rice cropping, rice-green gram, rice-cucumber and rice-sunflower cropping systems respectively. The rice-vegetable cropping system has potential to enhance this margin by additional Rs.12000 per ha. The migration rate of the farmers was also found reduced by 22% during post installation phase of rubber dam compared to the pre-project phase.

This ICAR Flexi Check dam technology was commercialized and an MoU was signed in between the ICAR and Zenith Industrial Rubber Products Pvt. Ltd., Mumbai for a period of 3 years. Thereafter the MoU has been signed with M/s Forech Mining & constructions International LLP, New Delhi. The consultancy of the technical team of ICAR-IIWM, Bhubaneswar can be taken by any agency for installation of ICAR flexi check dam (rubber dam).

Limitation of the technology

The technical textile reinforced rubber composite sheet used in rubber dam installation can be damaged by human being with a sharp knife having wrong intentions. However, it will not be damaged by any natural events such as flood, cyclone etc. and not also by floating animal carcass, broken glass bottle, stones and pebbles, uprooted trees or bamboos coming with flood water. Similarly, the rubber sheet can be damaged by fire.

Conclusions

From the agricultural and hydrologic data observation it is apparent that, rubber check dams can be well utilized for achieving sustainable crop production and could be instrumental for enhancing crop and water productivity in watersheds. It does not have adverse impact on environment. It can be easily installed, operated by farmers of the watersheds. There is almost no maintenance except the running cost of filling (inflating) with water at the time of need.

Contact details for technology related queries

Director, ICAR- Indian Institute of Water Management, opposite to Rail Vihar, Chandrasekharpur, Bhubaneswar-751023, Odisha, India. Phone: +91-674-2300060, fax: +91-674-2301651, email: director.iiwm@icar.gov.in, Web site:www.iiwm.res.in

References

Jena SK (2002) Development and evaluation of hydrological models for agricultural watersheds using remote sensing and GIS. Unpublished PhD Thesis. Indian Institute of Technology, Kharagpur, India

Koohafkan AP (2000) Land resources potential and sustainable land management-An overview. Lead paper of the International conference on Land resource management for food, employment and environmental security during November 9-13, 2000, New Delhi, India. pp: 1-22.

Singh G, Babu R, Narain P, Bhushan LS, and Abrol IP (1992) Soil erosion rates in India. J. of Soil and Water Conservation 47(1): 97-99.

Tam PWM (1998) Application of inflatable dam technology-problems and countermeasures. Canadian Journal of Civil Engineering 25: 383-388.

Tam PWM, and Zhang X (2002) Management of rubber dams in Hong Kong, Canadian Journal of civil Engineering 29: 409-420.

Velayutham M (2000) Status of land resources in India. Lead paper of the International conference on Land Resource Management for Food, Employment and Environmental Security during November 9-13, 2000, New Delhi, India. pp: 67-83.

Water and nutrient management in a self-reliant farming system

S.K. Rautaray
Principal Scientist (Agronomy)
ICAR-Indian Institute of Water Management, Bhubaneswar-23, Odisha
E-mail: sachinrautaray@yahoo.com

A **self-reliant farming system** (SRFS) is envisaged as a system where the requirement of water, plant nutrient, animal feed and energy is produced largely within the farm itself (Rautaray et al., 2016). The dependence on external sources for meeting such needs is minimal. This is very important in the context of climatic change which is likely to impact significantly upon freshwater resources availability. An increase in number of dry days, a decrease in frequency of light to medium precipitation events and increased frequency of high rainfall events may result in increased deficit as well as excess water stress causing difficulty in water management, especially in the rainfed ecosystem. In the context of increased population, cost of land, water, nutrients and energy, alternative system such as SRFS holds good, being least input intensive. Such a system is likely to be sustainable due to conservation of soil, water, and nutrients; and minimized use of fossil fuels, chemical fertilizers, and synthetic pesticides. Moreover, now the consumers are interested in farm fresh products subjected to little use of agrochemicals during the production, processing and storage.

For practicing SRFS, *in-situ* rain water harvesting and management is required for self-reliance on water and high water productivity. One has to rely on crop rotation, animal manures, legumes, green manures, and mineral-bearing rocks, to meet the plant nutrient requirements. These practices along with reduced tillage are essential to maintain soil tilth and productivity. Selected cultural practices and biological pest control are desired in sustainable pest management. Similarly, *in-situ* use of solar energy reduces the requirement of external sources for meeting the energy need.

Water management

One important way to cope with the rainfall variability under climate change scenario is to harvest rainwater in farm ponds. Water can be lifted from such ponds to meet the moisture defcit during dryspell(s) in *kharif* season and also sometimes to grow a light duty crop in *rabi* season. In Eastern India, monsoon is active for a prolonged period (June to October) with good amount of annual rainfall (1500 mm). Water used from farm ponds during dry spell in *kharif* season is usually refilled from rainfall and surface runoff within the season. Thus, during *kharif*, enough water is available in farm ponds for meeting the water requirement of dyke crops through capillary contribution.Water harvested by November is useful for meeting the irrigation requirement of dyke crops and field crops in *rabi* season.

About Rs 1 lakh is spent for creating a water harvesting structure of 15 m × 15 m × 3 m. Another Rs 0.5 lakh is required if polylining of farm pond of this size is done using 50 mm polythene. Polylining is must if the seepage percolation rate exceeds 10 mm/day. However, poly lining can be provided even under moderate seepage percolation rate (5-10 mm/day), provided the harvested water is used judiously by microirrigation method and for growing high value crops.Thus, a good amount of money is spent in creating the pond while the amount of water harvested is limited. Estimated annual cost of pond making for a farm pond of 15 m × 15 m × 3 m dimension results in cost of water at Rs 12.1/m^3 without polylining and Rs 17.3/m^3 with polylining (Table 1).This warrants economic use of water using micro-irrigation, preferably to be used in nearby area of the pond, so that the conveyance loss is minimized. Further observation reveals that the cost of water harvesting was reduced enough to Rs 8.3/m^3 when the pond dimension was 20 m × 20 m × 3 m.

Table 1. Cost of water harvesting in farm ponds with or without polythene lining (year 2019-20)

Size of Farm pond (Length × breadth × height) in m	*Cost of pond making MGNREGA rate	Cost of pond making (manual excavation, no cost for sign board etc)	**Cost of pond making (JCB for excavation)	$Annual cost of pond making	$$Volume of water harvested	Cost of harvested water (Rs/m^3)
10 × 10 × 3	55200	46916	38090	3428.1	270	12.7
15 × 15 × 3	126600	112227	89102	8019.2	665	12.1
20 × 20 × 3	163000	143395	113661	10229.5	1235	8.3
15 × 15 × 3 (Polylining)	176600	162227	139102	11519.2	665	17.3

*Indicative cost of pond making under MGNREGS during 2017 to 2020 as per Directorate of Soil Conservation & Watershed Development, Govt. of Odisha. The cost includes manual excavation and also additional cost for sign board, supervision charges and drinking water facility/medicine/crèche etc.

** Excavation charge less by 25% due to JCB use, and cost for sign board, supervision charges and drinking water facility/medicine/crèche etc. not included

$For calculating annual cost, pond life was considered was 25 years with 50% as junk value, 5% interest rate and 2% annual maintenance cost.

$$Volume of harvested was estimated at 0.5:1.0 slope as these were small ponds. Also, water harvest in pond was estimated at 0.5 m above the field level in rainy season.

At present, utilization of water from farm ponds is largely sub-optimal. As an example, in Odisha state about 41000 farm ponds were constructed during the last 5 years (2014-15 to 2018-19). Maximum number of ponds were constructed by MGNREGA (15000 nos) followed byWatershed Development (9700), Agriculture and Horticulture departmentscombinely (9300), and Fishery department (7000). These farm ponds provide life saving irrigation to crops in 5600 ha, pisciculture in 4000 ha and integrated farming system (IFS) in mere 560 ha. The state has a target of 5 lakh ponds in the next 5 years. The big size state like Maharashtra has a target of 25 lakh ponds in the next 5 years as water is a very scarce resource for the state. At national level, 2.36 M ha of ponds and tanks are suitable for freshwater aquaculture and only 40 % of the area is utilized for such purpose (ICAR, 2013). The area under pond based IFS can easily be enhanced by economic use of harvested water in tanks and ponds. Multiple use of harvested water for pond crops (fish, lotus etc), dyke crops and field crops may enhance profit level and hence incentvize for the creating more water harvesting structures. Dyke crops are important component of pond based IFS requiring irrigation in dry season only as in wet season rainfall and capillary water can meet the demand. Thus,crop intensification on dykes can be achieved by using suitable crops and drip irrigation in dry season. We evaluated one such system in a water harvesting structure at the Research Farm of ICAR-Indian Institute of Water Management, Bhubaneswar.

Water harvesting structure and additional surface area created

The water harvesting structure was developed in an area of 5840 m^2 (80 m × 73 m). Pond area was 3894 m^2 area (66 m × 59 m) and the dyke area was 1946 m^2. Dykes were 7 m at base and 5 m at top with 1:1 slope. For each m length of dyke, the surface width was 7.828 m (5 m at top + 2 slanting sides of 1.414 m each). So, additional surface area created for each running m due to the land shaping was 0.828 m^2. For 248 m running perimeter (64 m× 2 sides + 60 m × 2 sides), additional surface area (slant area) created was 205.34 m^2. This is about 4.32% increase in surface area with land shaping.

'Three stage rain water harvest'

In rainy season, rainfall was sufficient for wet season rice at the experimental farm at Bhubaneswar receiving 1500 mm rainfall. About 73% of the annual rainfall was received during the monsoon season (June-September), 15% during the post monsoon season (October-January) and the remaining 12% during the pre-monsoon season (February-May). In such situation, SRFS model was developed in 1.584 ha area, with a water harvesting farm pond (3894 m^2) surrounded by dyke (1946 m^2). The catchment area of the water harvesting farm pond was 6 ha. In such situation, rainwater was harvested in the first stage in the medium land using 20 cm high dykes around the rice field with the provision of a weir. The runoff water from the rice field under the SRFS and other rice fields in the catchment was collected through the weirs in the low land field having rice-fish integrated system (second stage rain water harvest). The surplus water from the rice-fish field after sedimentation was collected in the water harvesting farm pond through an 'inlet' (third stage rain water harvest). The excess water from the farm pond was drained through a 'surplus structure' joined with a natural drain. After the wet season, when there was no overflow of water, volume of water harvested in the pond for the first, second and the third year were 9932, 10300 and 10085 m^3, respectively, with a water depth of 2.55 m, 2.65 m and 2.59 m. The farm pond could meet irrigation requirement of light duty *rabi* crops in 1 ha (provided by flexi pipes) and also of the dyke crops (provided by drip irrigation).

Drip irrigation for dyke crops

On the dyke top, two rows (5 m apart) of culinary banana were planted with plant to plant spacing of 2.5 m within a row (Plate 1). Between two rows of banana, one row of papaya hybrid 'Red Lady' was planted in diagonal pattern. At the centre of each square with 4 banana plants, a papaya plant was planted. Spacing between two papaya plants in a row was 2.5 m. A drip irrigation system was installed for irrigating the banana and papaya plants on the embankment of the water harvesting structure (Plate 2). The system included sand filter, screen filter, fertilizer tank apart from the mainline, sub-mains, laterals and emitters. The system was designed to irrigate 3 rows of plants on each side. Two numbers of emitters with 4 litres per hour (lph) discharge capacity were provided per plant. The hydraulics of the drip system was satisfactory with average emitter discharge of 3.87 lph, and distribution uniformity of 96.1%. Bottom part (0.6 m height) of the slanting surface was used for hybrid napier grass cultivation. In addition to crops on dyke top, intensive cropping is possible using pine apple, fodder grasses like para grass, hybrid napier and creeping vegetable like pumpkin in the slanting surface of the dyke. Water loving fodder like para grass can be suitably grown on the slanting area facing pond.

Nutrient management

Sesbania was grown in-situ as pre-rice green manure-cum-cover crop. The green manure crop was harvested at about 48 days stage. Fresh biomass yield of 14800, 13500 and 14600 kg ha^{-1} were recorded for the respective years with the dry weights of 2790, 2579 and 2788 kg ha^{-1} (Table 3). Mean nutrient supply due to green manuring for this period was 58.3 kg N, 4.4 kg P and 16.1 kg K ha^{-1}. After considering the nutrient added using green manure, the mean differential amount of 21.7 kg N, 13.1 kg P and 17.1 kg K ha^{-1} (from the recommended dose) was met from vermicompost. The application rate for vermicompost was 3040, 3097 and 2886 kg ha^{-1} for the year 2015, 2016 and 2017, respectively. After harvest of wet season rice, 6 dry season crops were grown in cropping sequence. The nutrient demand was met by using legume crops in a part of the system and using vermicompost as the source for plant nutrient. Our experience with 1.584 ha farm for three years (2015-16 to 2017-18) revealed that 8.1 t vermicompost was produced in 3 batches from 24 t agriwastes produced within the farm area. Out of this, 3 t was used for paddy crop and the remaining 5.1 t was used to meet nutrient requirement of dry season crops and dyke crops.

Yield and return from dyke crops

The economic cycle of papaya crop was 2 years for the test variety. The crop yielded 15.5 kg/plant in the first year (2014-15) while 32.8 kg/plant in the second year (2015-16) under drip irrigation. Banana crop yielded 68.5 and 67.0 fingers/plant for the first and second year, respectively. Papaya was sold at Rs12/kg and banana at Rs4/finger. Gross income per annum from these two dyke crops (180 banana and 80 papaya plants) was Rs72780. Economic performance of the drip system was compared with the surface irrigation system for the initial 2 years. Gross income from surface irrigation system was Rs 58422. Thus, increase in income due to drip system was Rs14556. The cost of the drip irrigation system was Rs 60000 (year 2014-15). Assuming average life of the drip system as 8 years and 10% as annual depreciation value, the variable cost of the system for the first year worked out as Rs 6750. Considering interest on borrowed capital as Rs 3000 and maintenance cost of Rs1200, total cost for drip for the first year was Rs 10950. Thus, net benefit due to drip system was Rs 3606 with B:C ratio as 1.33.

The economics for the second cycle (third (2016-17) and fourth year (2017-18)) was calculated. The mean yield for the second cycle was similar to the first cycle (mean papaya yield of 23.1 kg/plant and banana yield of 61.5 fingers per plant under drip irrigation. Papaya was sold at Rs 13/kg and banana at Rs 4.5/finger. Gross income per annum from these two dyke crops (180 banana and 80 papaya plants) was Rs 73746. Gross expenditure per annum was Rs 24430. The mean economics for the two cropping cycles (4-year study) was calculated. The mean gross return was Rs 72856 with gross expenditure of Rs23560 and net return of Rs49296 from the papaya and banana crop grown on dyke (Table 2). Additionally, Hybrid Napier grass was grown on 3 sides of the dyke slope (209 m). Mean fodder yield was 4166 kg/year with gross return of Rs5000/year and net return of Rs 2761/year. Thus, the dyke provided mean net return of Rs52056/year from 1946 m^2.

Table 2. Economics of the dyke crops under pond based IFS (Mean per annum)

Component crops on dyke	Yield	Gross Return (Rs)	Expenditure (Rs)	Net Return (Rs)
Papaya (80 plants)	23.6 kg/plant	23578	6890	16688
Banana (180 plants)	64.6 fingers/plant	49278	16670	32608
Hybrid Napier	4166 kg	5000	2239	2761
Total		77856	25799	52057

Rice equivalent yield (REY) for the dyke crops (4.48 t/ha) was obtained by diving gross return from the three dyke crops (Rs 52057) with the average price of paddy grain (Rs 11620/t).

Yield and return from different components of the SRFS

Combined net return from dyke crops was Rs 52057. Similarly, net return from fish was Rs 27995. Combined net return from fish and lotus was 33328. Net return from field crops was Rs 64813. On unit area (1 ha) basis, net return was highest from dyke crops (Rs 267503) followed by pond crops (Rs 85588) while lowest with the field crops (Table 3). Regarding land productivity (rice equivalent yield), the highest was obtained from dyke crops (23.02 t/ha) followed by field crops (11.3 t/ha) and lowest with pond crops. Field crops in spite of second highest productivity had the lowest net return/ha. This was due to high cost of cultivation associated with the field crops as compared to dyke and pond crops. Among the different crop based farming systems, it was highest from vegetables followed by groundnut.

Table 3. Economics (mean) of the pond based IFS

Components of the IFS	Area (m^2)	On actual area of components of the IFS		Estimated per ha area of components	
		Rice equivalent yield (t)	Net Return (Rs)	Rice equivalent yield (t/ha)	Net Return (Rs/ha)
Pond	3894	2.27	33328	5.83	85588
Dyke	1946	4.48	52057	23.02	267503
Field	10000	11.3	64813	11.30	64813
Total	15840	18.05	150198	-	-

Rice equivalent yield (REY) was obtained by diving gross return with the price of paddy grain for that year (mean REY pond 2.27 t + dyke 4.48 t + wet season rice 4.46 t + dry season mean 6.84 t) from 1.584 ha area.

Water use and productivity of the self-reliant farming system

Volume of water harvested for the first, second and the third year were 9932, 10300 and 10085 m^3, respectively, with a mean of 10106 m^3. The system area was 1.584 ha and the pond area was 0.38 ha. Thus, the pond could cater irrigation need of about 3.2 times crop area. Water productivity in terms of net economic return per unit water volume for the IFS was high (Rs 6.94

m^{-3}). The value was arrived after considering the annual cost of water harvesting farm pond for the experimental site for the year 2014-15. This was due to multiple use of water for fish, lotus, dyke crops and field crops. Water productivity was 2.1 times higher as compared to the prevailing practice of rice-fallow system (Rs 3.35 m^{-3}) and 1.7 times higher as compared to the rice-*utera* cropping system using blackgram (Rs 4.07 m^{-3}).

Summary

The present study reveals that three stage rain water harvest, use of drip irrigation for intensively grown dyke crops, pipe conveyance for field crops, and multiple use of water resulted in net return of Rs Rs70141/ha which was higher by 2.3 times as compared to the prevailing practice of rice-fallow in rainfed areas. Plant nutrient was managed by growing Sesbania green manure before the rice crop, growing legume crop in part of the system and recycling of 24 t agriwaste as vermicompost in 1.584 ha of the system area.

Hands-on Practices on Micro Irrigation System

Pravukalyan Panigrahi
Principal Scientist (SWCE)
ICAR-Indian Institute of Water Management, Bhubaneswar-751023, Odisha
E-mail: pravukalyan@rediffmail.com

Water scarcity becomes a major constraint in crop production. The unevenly distribution of rain in space and time causes the crop failure in different regions of the country. Moreover, due to changing climate and environment, the water requirement and availability of water for crop production are in dynamic state. Irrigated agriculture has to face the challenges of making a rational and optimal use of the water resources effectively. In this scenario, water resource development and its efficient management in crop production are utmost essential. Different production techniques have been standardized for better crop productivity in both rainfed and irrigated agro-ecosystems of the country. Out of the production technologies, pressurized irrigation or micro irrigation plays a pivotal role in efficient irrigation management in crop production.

2. Pressurized irrigation systems

Pressurized irrigation system (drip, sprinkler, micro-sprinkler and micro-jet), otherwise called micro-irrigation system has many advantages over surface irrigation methods, mainly in terms of better uniformity and partial wetting of the soil surface, and equally effective on sloppy lands. In India, the adoption of micro-irrigation is not so encouraging, in spite of severe water scarcity in different regions of the country.

Merits of micro-irrigation systems

Micro-irrigation systems hold following advantages over conventional method of irrigation:

- Water saving up to 30-60 % over surface irrigation method
- Yield increases around 40-60 % over basin method with improved benefit: cost ratio
- Weed reduction by 40-50 %, thereby reduce the labor cost on weeding.
- Saline water for irrigation can be safely used
- Equally effective on undulating land used for cultivation
- Enhances better crop growth.
- Prevents soil erosion and runoff under surface irrigation.

Essential components micro-irrigation system

Following are the essential components of micro-irrigation system

- Water source: well, tube well, canals, river, pond, etc.
- Electrical pump: mono-block or submersible
- Filters: sand, screen and by - pass arrangement

- Back wash arrangement and pressure gauges
- Fertilizer tank/injection tank/ venturi
- Main pipe line and control valves
- Laterals (12, 16, 20, 25 mm)
- Drippers (4, 8, 16 lph) and micro-jets (180^0, 300^0, 360^0)

Drip irrigation system

Drip irrigation is a method, which optimizes the effective use of irrigation water through uniform distribution and applies water into the root zone of the plants through a closed network of plastic pipes and drippers of different water discharging capacities. The basic principle involved in drip irrigation is frequent application of water as per crop water requirement at low discharge rate (drop by drop) directly to root zone. The soil moisture held under the drippers is at optimum level that favors better nutrient and water uptake, which results in better growth, yield and yield quality of plants.

Precautions before/during drip (micro-irrigation) installation: Before installation of micro irrigation systems, the following points should be considered for smooth installation and operation of the system:

- Soil physico-chemical analysis of field and water analysis of water source
- Sand and screen filters for water containing debris, algae etc.
- Main and sub-mains of PVC to be installed at 1.5 to 2.00 feet below ground.
- If the land has slope, then sub-main should be laid along with slope and lateral across the slope
- Design should be done as per the slope, orchard land topography and plant requirement
- In drip system for 12 mm diameter lateral, 40-50 m long lateral and for 16 mm diameter, 60-70 m long lateral in field should be usually used
- Drippers should be installed on upper side of the slope and at the convenient distance as per the plant age

Maintenance of drip (micro-irrigation) system: After successful installation of the micro irrigation system, maintenance of the system is a vital component, which requires sufficient technical knowledge. The following points should be kept in mind for better maintenance of the system:

- Laterals and sub-main pipelines should be flushed at least once in a week keeping the system at 1.5 to 2.0 kg/cm^2 operating pressure.
- Regular checking of the drippers for operation, breakups or some leakages
- Clogged drippers should be treated in acid (12N HCl) at least once in six months
- Laterals of the drip system should be rolled and kept inside the safe place during the rainy period
- Chlorination (calcium hypo chloride solution at 45 g/l) should be done as per requirement or once in 6 months
- Cleaning of screen filter and sand filter once in a week or as and when required

3. Irrigation scheduling

Quantification of irrigation

The formula of 'ABCDE 'is usually used for computing the water requirement.
where,
A – Canopy area of the plant/ crop area,
B – Pan Evaporation Factor (0.6 in winter and 0.8 in summer) take average 0.7,
C – Crop Factor,
D –Wetting factor (0.2 to 1.00 up to full growth) and
E – USWB pan-evaporation, mm per day

Water requirement (lit/day/plant) = A× B×C×D×E.

Example-1. Find the water requirement (WR) of mature citrus plants (6 × 6 m spacing), where E_{pan} is 10 mm/day and root-zone wetting is 60 %.

Ans: WR = (6× 6) × 0.7× 0.6×0.6× 10 = 90.72 lit/day/plant

Frequency of irrigation

Frequency of irrigation assumes greater significance in maintaining the plant growth and orchard productivity on sustained basis. The interval may vary 10 to15 days in winter and 7 to 10 days in summer days. During the hot periods, the topsoil dries up quickly and light irrigation is advisable. Bearing trees should be irrigated at shorter intervals than non-bearing trees. Irrigation during harvest period should be avoided because it reduces TSS and acid.

In surface irrigation methods (basin, furrow)

- 14-21 days in winter (Oct. to Jan.)
- 6-7 days in summer (Feb. to June)

In drip/micro-jet irrigation

- On clay soils 2 to 3 days
- On clay loam soils 1 to 2 days
- On sandy soils daily

4. Design and estimate of micro irrigation system

Design methodology of micro irrigation

After knowing the crop water requirement, the size of main pipe, sub-main pipe and lateral pipe is decided. The design of the system involves the following steps:

(i) Collection of general information: General information on water source, crops to be grown, topographic conditions, type and texture of soil and climatic data are essential for designing the drip irrigation system.

(ii) Lay-out of the field: The layout of the field by giving the path and lengths of main line, sub-main line and lateral lines in meters is worked out to connect water source with the existing/planned crop in the area.

(iii) Crop water requirement: The monthly crop water requirement is estimated with the formula,

$V = PE \times K_c \times K_p \times A \times N$ liters

Net Volume of water to be applied (Vn) = $V - R_e \times A$ liter.

Number of operating hours of system (T) during a month

$$= \frac{\text{Vn} \times \text{Wp}}{\text{No. of drippers per plant} \times \text{No. of plants } \times \text{dripper discharge}}$$

Where,
V= Volume of water required in liters;
PE= Mean pan evaporation for the month in mm/day
K_c = Crop factor;
K_p = Pan factor
A= Area to be irrigated (sq. m)
N = Numbers of days in the month
R_e = Effective rainfall in mm;
Wp= Percentage wetting
Nm= Number of application per month
T = Number of operating hours per month

(iv) Hydraulic design of system: The ideal irrigation system is one in which all drippers (or orifices) deliver the same volume of water in a given irrigation time. From the practical point of view, it is almost impossible to achieve this ideal performance.

(v) Selection of components: The finalization of dimensions of main, sub-mains and laterals and selection of pump are normally done based on the empirical formulae and availability of materials in market.

Design example

Crop: Papaya; Spacing: 2.5 m × 2.5 m; Land area: 150 m × 150 m = 22500 m^2 = 2.25 ha (3600 plants), Soil Type: Sandy loam soil; Land topography: Plain; Evaporation/ day (peak) = 11 mm; Water source: Well (Static Head = 9.5 m); available discharge: 3 lps; Root depth: 90 cm

Ans:
I. Water requirement (ET_c): $ET_c = K_p \times E_p \times K_c = 11 \times 0.7 \times 0.8 = 6.16$ mm/day

Volume of Water required
= Plant-to plant spacing × Row-to-row spacing × % wetted area× Depth of water
= 2.5 × 2.5× 0.4 × 6.16 (as, for papaya 40% wetted area is optimum)

= 15.4 litre/day/plant

II. Emitters/ Dripper Selection, Positioning & Time of Operation
As peak water requirement is 15.4 litre / day; 4 litres per hour dripper are sufficient
Time of operation: 15.4 / 4 = 3.85 h (assume 4 hr)

III. Layout of design
Number of lateral pipe = 150 m/ 2.5 m = 375 No;
Length of lateral pipe = 375× 150 m = 56250 m
Main/sub-main length=75 m+ distance of land from water source (assume 20 m) + 150 m
= 245 m
Pipe line requirement: Spacing between successive emitters = 2.5 m;
Number of emitters per lateral = 75 /2.5 = 30 No.

IV. Discharge through one Lateral (q)

q = 30× 4 lph = 120 lph = 0.12 m^3/hr
Discharge available per hour from well = 3 × 3600 = 10800 litre
No. of lateral that can be operated at a time = (10800) / (120) = 90 No
For this design; F = 0.38 (for 30 outlets per laterals); L = 75;
L_e = Emission point × factor = 30 × 0.38 = 11.40 m;
C = 140; Q = 0.120 m^3/hr;
Taking D = 12 mm;
$J = 1.526\times 10^4 (0.12/140)^{1.852} \times (1.2)^{-4.87} \times (75 + 11.40)\ 0.38 = 0.43$ m;
As computed J = 0.43 m, which is less than 1.0 m, the lateral of 12 mm size is sufficient to meet the hydraulic requirement.

V. Size of Sub-main Pipe (main fold)/Main Pipe

Head loss at the outlet main fold = 10 m + 0.43 m = 10.43 m
No of main fold required = 2;
Length of main fold = 75 m
Discharge in main = discharge through lateral × No. of laterals
= 120× 60 = 7200 lit/hr = 7.2 m^3/hr
From Table F = 0.36; L = 75 m; Le = 60 × 0.35 = 21.6 m; C = 140; Taking D = 50 mm

J = 1.526× 104 (7.2/140) 1.852 × (5.0) -4.87× (75 + 21.6) 0.36
= 0.86 m (within allowable variation)

VI. Calculation of HP of pump

Total Dynamic Head (H)= $H_{sub\text{-}main} + H_{lateral} + H_{static} + H_{local}$ = 2 (0.86)+ (0.43× 60) + 9.5 m + 0
= 1.72 m + 25.8 + 9.5 m + 0 = 37.02 m
HP = (Q× H)/ (75 x pump efficiency) = {(7200 lit/3600) × 37.02}/ {75× 0.7} = 1.41 HP = 1.5 hp

VII. Size / Capacity of Screen and / Sand Filter: same as discharge of pump

Indicative cost estimation of the drip irrigation system:

Sl. No.	Items with technical specification	Quantity	Unit price (Rs.)	Total price (Rs.)
1	PVC Pipe (50 mm x 6 kg/cm^2)	235 m	60.00	14100.00
2	Lateral pipe (Black colour, 12 mm)	9000 m	9.00	81000.00
3	Drip emitters (4 lph)	3600	3.00	10800.00
4	Grommet take off (16 mm)	120	5.00	600.00
5	End cap (16 mm)	120	2.50	280.00
6	Control valve (50 mm)	2	450.00	900.00
7	Screen filter (25m^3/hr)	1 set	4000.00	4000.00
8	Fertilizer tank (30 litre capacity) with assembly	1 set	5000.00	5000.00
9	Pump (2 hp, single phase, 25-30 m head)	1 set	15000.00	12000.00
10	Fittings and accessories	1 set	5000.00	5000.00
	Total			133680.00
11	Vat (@5%)			6684
12	Installation Charge + Charge for making Trenches	---	---	7000.00
	Total Cost			1,47,364
	Total Cost (Rs.)/ha			65,500/-

5. Sprinkler irrigation system

Sprinkler irrigation is normally recommended for closely growing crops like wheat, pulses, etc. This system requires higher pressure to operate the sprinkler heads. The system consists of Pump, high density polyethylene (HDPE) pipe, riser pipe and sprinkler head with nozzles. The HDPE pipe of size 63 mm and/ 75 mm diameter are normally used through couplers for conveying irrigation water from source. The pump capacity required for sprinkler irrigation system is calculated using the same formula that used for drip irrigation. Sprinkler irrigation enhances yield of the crops from 30 to 60% with 40–60% water saving compared with surface irrigation in different crops.

6. Micro-sprinkler and Micro-jet irrigation system

Micro-sprinkler and/ micro-jet irrigation systems are normally used for under tree irrigation and closely grown vegetables. The system requires more pressure/energy for operation. The capacity of pump is calculated using the same procedure used in DI. The water throwing diameter in case of micro-sprinkler and micro-jet systems varies from 3 m to 6 m, depending upon the size of nozzles and pressure of operation.

7. Automation of irrigation systems

Using automation in micro-irrigation, one can control the irrigation valves, pump, fertilizer injectors automatically with minimum or even no manual interventions. Different types of automations like time based, volume based, sensor based and real time feedback systems are available. For automation of drip and micro-jet irrigation system, hybrid station controller and solenoid valves are needed in addition to existing micro-irrigation systems.

8. Conclusion

Efficient use of water and nutrients is the important issue for sustainable agriculture. Rainwater should be harvested on top slopes and the harvested rainwater should be applied through mechanized/gravity-fed drip irrigation system to the crops grown on slopes. Different water soluble or liquid form fertilizers as per the requirement of the crops and site condition should be applied through drip irrigation. Efficient land use management with suitable cropping under micro irrigation and other water conservation practices should be encouraged.

Water harvesting based integrated farming system: A case study

S. Mohanty
Principal Scientist (SWCE)
ICAR-Indian Institute of Water Management, Bhubaneswar
E-mail: smohanty.wtcer@gmail.com

Micro-water resources planning and management plays a major role in natural resources management in watersheds. It can be achieved by conserving and harvesting rainwater by construction of water harvesting structures and later recycling it during non-rainy period. Construction of on-farm water harvesting ponds on medium and low lands are helpful in storing surplus precipitation in monsoon season. These ponds are useful in facilitating diversification of marginal rice farms in any region. Harvesting of surplus rain water during monsoon season enhances opportunity for diversification in the dimension of space and time (Sahoo and Behera, 2017). Water productivity is substantially enhanced due to multiple use of pond water compared to farmers practice of rainfed farming (Das et al., 2013). Ghosh et al. (2009) reported increase in cropping intensity, farm income, and employment generation owing to rainwater harvesting in farm ponds and its efficient recycling. Narayan Biswas (2012) suggested that rainwater harvesting and recycling through a farm pond can successfully be practiced for providing supplemental irrigation during dry spells in monsoon season and available water in pond can also be utilized for providing pre-sowing irrigation to post-monsoon season crops for increasing the growth, yield and water use efficiency in order to augment the productivity of large rainfed areas in the country. The byproducts of enterprises in integrated farming system are suitably recycled to the crop component within the system. The recycling of produce/ by products of any one of the component in the system as input for the other component linked in the farming system could reduce the cost of production leading to increase the net income of the farm as a whole. These complimentary attributes when carefully chosen, keeping in view the soil and environmental conditions usher in greater dividends in the farming system. This approach helps the marginal farmers to improve their standard of living by providing sufficient employment and income generation.

A Case Study

Development of water harvesting based integrated farming systems, their economic analysis and impact analysis were carried out in one of the study at IIWM, Bhubaneswar. The study was carried out in two clusters of villages in Dhenkanal district of Odisha (Mohanty et al., 2016). Ten water harvesting structures were constructed in farmers' field on participatory basis in which the farmers contributed a part of the expenditure. Multiple use of water in the water harvesting structures was done for agriculture, on-dyke horticulture, pisciculture, poultry & dairy farming, mushroom and vegetable cultivation to develop them as integrated farming system (IFS) components; and this was continued for a period of four years from 2010-11 to 2013-14.

The economic analyses of integrated farming system units were done based on collection of data on yield, production, market price of produce and cost of cultivation of different components of multiple use of water through a questionnaire survey on the farmers. The analysis was done for two scenarios: i) without considering the fixed cost of the system, and ii) considering the fixed cost of the system. The net income/ha from different IFS involving different combination of land components is presented in Table 1. It was observed that the net income from the IFS area per hectare without considering the fixed cost of the system varied from a minimum of Rs. 25,298/- to a maximum of Rs. 336089/- per hectare. Similarly, the net income from the IFS area per hectare considering the fixed cost of the system varied from a minimum of Rs. 16708/- to a maximum of Rs. 250624/-. The analysis indicated that by taking up poultry in the uplands and doing intensive cultivation on the bund area in addition to fish culture in the pond would increase the net income substantially from the WHS based IFS models. The huge variation in the net income/ha in different IFS models also emphasized the extent and role of the farmer in building a successful model. If the farmer is enterprising and sincere in his/ her approach, the farming system models would be successful.

Table 1– Per hectare net return from different combination of land components

IFS unit	Net return/ ha (Rs./ha)				
	Pond + bund area	Pond+ bund + upland area	Pond+ bund + paddy area	Total IFS area without considering fixed cost	Total IFS area considering the fixed cost
P1	90039	323683	29895	94628	68691
P2	48533	54776	21520	27200	22017
P3	51133	59120	20425	25928	20817
P4	197086	475736	97543	336089	250624
P5	53232	47904	28180	29387	18837
P6	162188	106164	51369	55330	32836
P7	129778	87169	47382	48888	32908
P8	80931	331349	37452	221647	144549
P9	47211	46571	23529	30673	17769
P10	54231	48103	24781	28079	16708

Apart from the water harvesting structures, the farmers were also benefited from the other interventions in the project. The impact analysis of the interventions was studied by doing the comparative analysis of physical, social, financial, human and natural assets of the farmers before and after adoption of the technology intervention. The above-mentioned variables under five types of assets were measured on the basis of the responses of 10 farmers on a 5-point continuum scale (minimum and maximum value is 1 and 5, respectively) during interview using a pre-tested survey schedule. Overall standard of living of farmers was assessed on the basis of their assets holding before and after the technology intervention; the value of overall level of living ranging from 5 to 25.

The change in overall standard of living of the 10 farmers is presented in Fig.1. It is inferred from the figure that living standard of all farmers except the two was below average level (score < 15) prior to adoption of technological packages. However, with the change of farming situation, adoption of technologies helped in bringing the living standard of all but one farm family at above average level (score >15). Level of living of the farmers, who were engaged in more multiple use activities in the IFS model improved relatively better. Mean value of overall level of living of all the 10 farmers derived through addition of the mean values of five assets, indicated that this has been increased from 13.47 to 17.08 (minimum and maximum possible value is 5 and 25, respectively). The minimum score increased from 9.83 to 13.26 while the maximum score increased from 16.21 to 19.1 which showed the improvement in overall level of living of all the farmers due to adoption of technological options. The maximum increase in level of living of the farmers was observed in model P4 (increase of 5.7) followed by model P8 (4.35) and P1 (4.1). It was observed that the improvement in standard of living of the farmers was in tune with the increase in net economic return from the IFS models (Table 4).

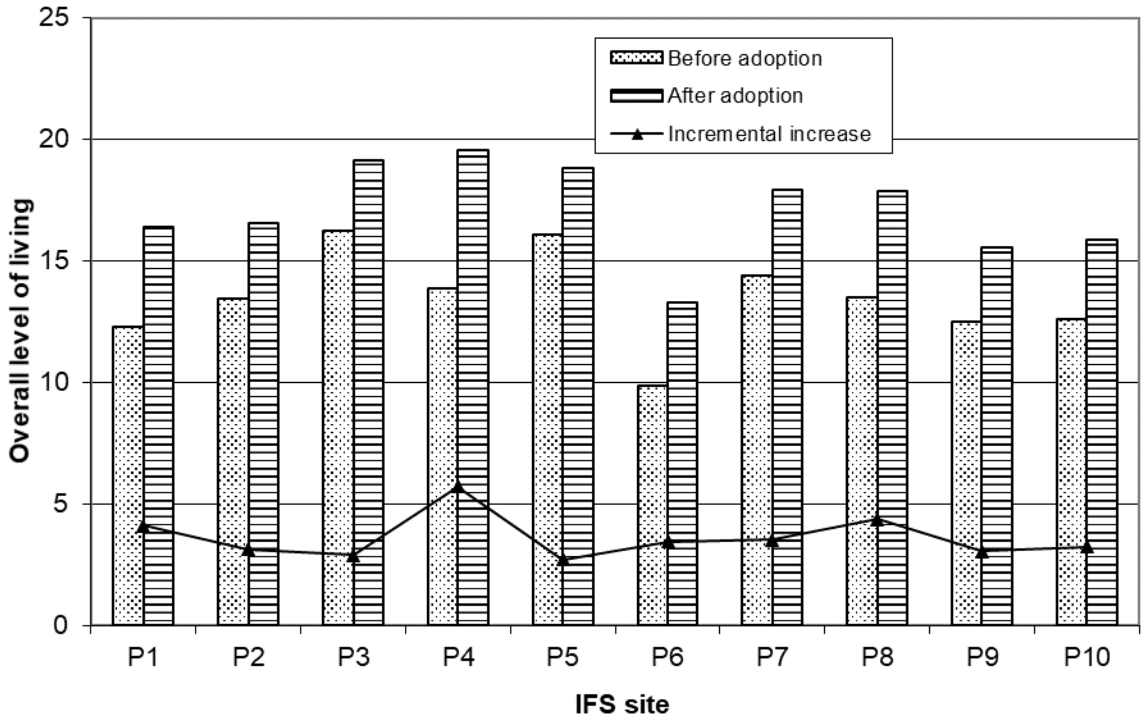


Fig. 1: Overall standard of living of selected farmers before and after adoption

Of the water harvesting based integrated farming system models in the project, One farmer (P4) from Khallibandha village of Dhenkanal district was a real success story. Initially, a water harvesting structure of 800 m^2 with a capacity of 1400 m^3 was constructed in a land of 5160 m^2 area, which was earlier used only for paddy cultivation. The farmer contributed a part of the total expenditure for construction of the pond in the year 2009-10. The cross-sectional area of the pond at the ground surface was 40 m × 20 m with a depth of 2.2 m. A part of the excavated earth from the pond was used for making the embankment of the pond. The rest of the excavated earth was used for filling up the depression around the site, and thereby converting a part of the paddy land to situations like upland to facilitate cultivation of high value vegetable crops and for making a poultry yard. The constructed pond was very effective for harvesting of rainwater as well as tapping the seepage water from the upstream side of the structure.

The water from the water harvesting pond was used for agriculture, on-dyke horticulture, fish culture, poultry farming, dairy, mushroom and vegetable cultivation. The multiple use of water led to the development of an integrated farming system model in the 4-year period (2010-11 to 2013-14). The total area of the system was 5160 m^2, out of which 800 m^2 was the pond area, 360

m^2 bund area, 2400 m^2 upland area and 1600 m^2 area paddy area. The pond area was used for fish culture and the bund area for on-dyke horticulture, whereas the upland area was used for dairy, poultry, mushroom and vegetable cultivation. Banana, papaya and drum stick were planted on the pond embankments. Vegetables like potato, brinjal, ladies finger, tomato, cauliflower and onion were cultivated either as *kharif* (monsoon) or *rabi* (post-monsoon) vegetables. The harvested water in the pond was used as irrigation to crops grown during post-rainy season, and also for supplementary irrigation to paddy crop during dry spells in the monsoon season. During dry spells, the supplementary irrigation to paddy substantially increased the paddy yields (50-110%) in the pond-command area in comparison to the paddy yields from outside command area.

On-dyke drumstick plant

Poultry in upland

Vegetable cultivation in upland

Paddy cultivation in command area

Initially, a low lift hand pump was provided to the farmer from the project fund for lifting of water and a storage tank made out of RCC open well rings was constructed to store the water. The stored water was used for irrigation to vegetables by gravity fed irrigation. Later, with the help of agricultural schemes of the State government, the farmer constructed a tubewell of 125 m bore depth at the project site. After availing the subsidy, the farmer had to spend Rs. 50,000/- for installation of the tubewell. A 1.5 HP submersible pump was installed and a discharge of 2 litre per second was obtained. A drip irrigation system was also installed coupled with the tubewell to irrigate the horticultural crops grown on the embankment and the upland area. The tubewell was also used to supplement water to the pond during low water level period. The economic analysis showed that the net income from the integrated farming system model was Rs. 2.5 lakh/ha/year

Optimum size of water harvesting structure

For determining the optimum size of on-farm reservoir (OFR) in the rice field in rainfed uplands, a water balance simulation model was developed for the OFR. The computer programme was written using Visual Basic 6.0 for simulation of water balance components. Computation of inflow and outflow components of field water balance was carried out on daily basis all through from the sowing to the end of turn-in period every year and thus, the simulation continued for 30 years from 1985 to 2014. Simulation of each year started from the day of onset of monsoon and continued for 114 days till the end of turn-in period in paddy field.

The programming was done in such a way that simulation starts with an initial size of the on-farm reservoir i.e. in 5% of the farm area. On any day during the simulation of the model, if adequate balance is not available in the OFR then, the size of the OFR is increased by 0.1% and the simulation starts again from the day of sowing. Thus, the pond size continues to increase till a size is reached at which the water demand of the crops matches with the available storage in the OFR. With the increase in OFR size, simultaneous decrease in crop area occurs. It was programmed such that on the end day of turn-in period, the storage in the OFR is adequate to meet the proposed water demands of winter crops. If the storage balance in the OFR is not sufficient to meet this requirement, then similar increment in the size of the OFR takes place and the simulation restarts from the day of sowing of rainy season crops till available storage becomes adequate. Thus, the size of OFR evolved is the actual size for that year. The simulation was done for 30 years' period and the size of the OFR was found for every year; this ranged from 6% to 49% of the farm. At 70% probability, the size of the OFR was standardized as 14% of the farm area.

References

Das, A., Choudhury, B. U., Ramkrushna, G. I., Tripathi, A. K., Singh, R. K., Ngachan, S. V., Patel, D. P., Layek, J. and Munda, G. C. (2013). Multiple use of pond water for enhancing water productivity and livelihood of small and marginal farmers. *Indian Journal of Hill Farming*, 26(1): 29-36.

Ghosh, P. K., Saha, R., Das, A., Tripathi, A. K., Samuel, M. P., Lama, T. D., Mandal, S. and Ngachan, S. V. (2009). Participatory rain water management in hill ecosystem: a success story. Technical Bulletin no. 67, ICAR Research Complex for NEH region, Meghalaya, 37p.

Mohanty, S., Mohanty, R.K., Mandal, K.G., Ghosh, S., Rautaray, S.K. and Kumar, A. (2016). Impact of water resources development and technology introductions on livelihood of farmers in eastern India: A case study. *Irrigation and Drainage*, 65(5): 724-733.

Narayan, D. and Biswas, H. (2012). Augmenting crop production through rainwater harvesting and recycling in red soils of Central India. Indian Journal of Soil Conservation, 40(1): 52-59.

Sahoo, H.K. and Behera, B. (2017). Integrated farming system for resource recycling and livelihood security for marginal farmers in three disadvantaged districts of Odisha. *Indian Journal of Soil Conservation*, 45(2): 203-213.

Farmer based recharge structure: Adaptive measure to combat climate change, augmenting groundwater and increasing farm income

Satyendra Kumar* and Bhaskar Narjary
Principal Scientist (SWCE)
Central Soil Salinity Research Institute, Karnal – 132001 (Haryana)
*E-mail: s.kumar2@icar.gov.in

Climate change is expected to produce more extreme weather events around the globe with abrupt changes in air temperature and rainfall. A significant change in rainfall pattern and its highly uncertain spatial and temporal distributions in India are expected due to climate change (Sathaye, et al., 2006). These changes will have profound effects on agriculture-a source of livelihood for millions of people and water resources (Mall et al. 2006). In recent time, it has been seen that the crop of low line fields gets submerged during extreme rainfall event and causes crop damage and yield loss. The magnitude of loss depends upon crop and its stage. If it coincides with the period of maturity, there are chances of heavy loss as compared to vegetative stage. For example, untimely heavy rain may cause great losses to wheat/maize crop and even 2-3 days' water stagnation is not desirable for good yield. To combat this adverse situation a proper drainage is needed. However, for the low lying field, a point source drainage option is required to dispose of accumulated rain water because of unfavourable condition or in absence of natural drainage. Diverting excess water directly to aquifer through groundwater recharge structure could be an ideal option (Kamra et al 2010). That will not only save crop but also improve the quality of poor groundwater in addition to augmentation of water resources.

Farmer based groundwater recharge structure:

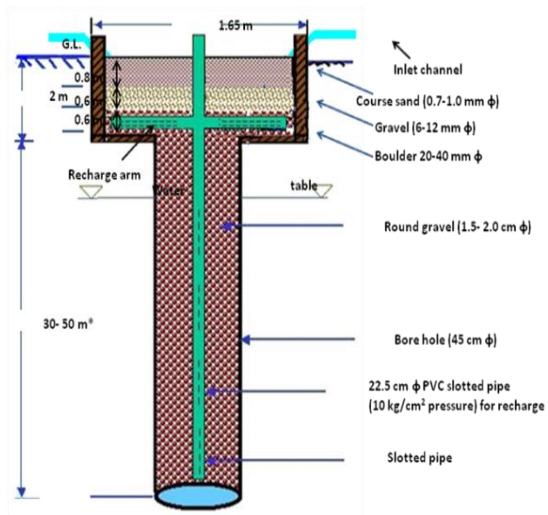
A number of agencies in India including the Central Ground Water Board (CGWB), research institutes, universities and non-governmental organizations (NGOs) have undertaken various studies on artificial groundwater recharge (Chadha,2002). But, these studies were based on big structures installed at community level which may not be suitable at farm level. Further, a limitation with big artificial groundwater recharge structures was poor post-installation maintenance due to common liability. In view of limitations of big structure, ICAR-Central Soil Salinity Research Institute (CSSRI), Karnal, designed and developed a small recharge structures which was suited to individual farmer. To safeguard against clogging, runoff water was first passed through a filtering unit consisting of layers of coarse sand, gravel and boulders and perforated pipe wrapped with synthetic filter in a small brick-masonry chamber (Kumar *et al*., 2012; Kumar *et al.* 2014). The developed structure was demonstrated at 70 farmers' field in Haryana, Punjab, Gujarat, Uttar Pradesh etc.

Farmer based groundwater recharge systems were based on well injection techniques and involve passing of excess rain and canal water under gravity to suitable aquifer after filtration at the faster rate than natural process. The consideration of recharge structures of different designs, depths and costs (recharge shafts, recharge cavities and abandoned wells) was based on hydro-geological investigations and quantum of potential runoff water available at specific locations. The developed recharge structures can be adopted by an individual farmer at his field where runoff water from 10-15-hectare area or more gets accumulated and posing problem for standing crop (Kumar et al. 2020). Three types of small recharge structure were developed and demonstrated at farmer's field. The design details are described below

Design details:

Recharge shaft:

The recharge shaft consists of a bore hole of 45 cm ϕ and varying depths filled with gravel pack of 1.5 – 2.0 cm ϕ to carry filtered recharge water to subsurface sandy zones. To safeguard against clogging, the surface runoff from rainfall or excess canal water is first passed through a graded recharge filter consisting of layers of coarse sand, small gravel and boulders in a small brick masonry chamber. A high pressure PVC pipe, of 12.5 cm ϕ and slotted in sandy zones, is provided in the middle of the shaft to circulate compressed air for cleaning of clogged sediments in the shaft after a couple of years.



Sketch diagram of recharge shaft

The depth of recharge shaft is decided based on the criterion to provide 10- 15 m cumulative sand layers for recharge.

Recharge cavity:

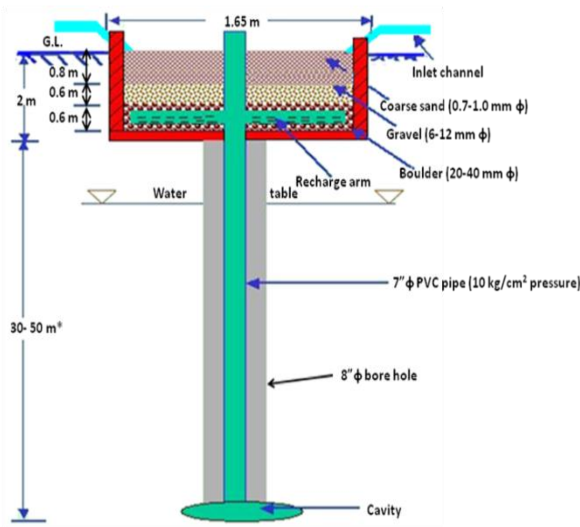
The recharge cavity consists of a conventional cavity tube well coupled with a recharge filter similar to the one described above in recharge shaft for recharging of excess water and can also be used for occasional pumping.

Abandoned cavity:

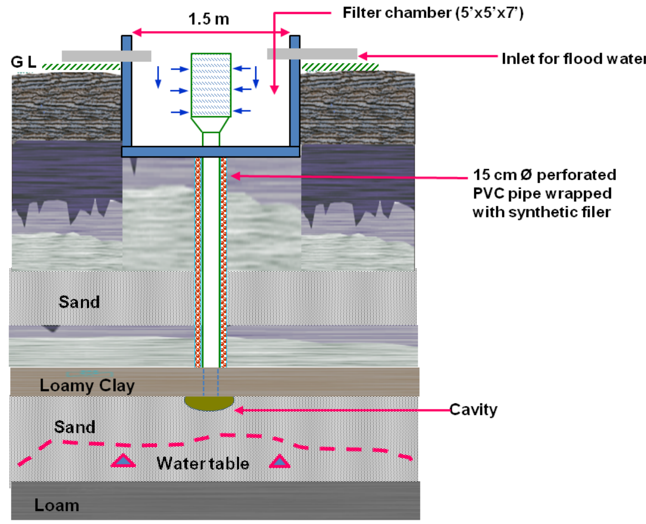
Abandoned tube well can also be converted into drainage cum recharge structure by providing suitable option for retaining physical impurities carrying with the runoff water. Filtration option consists of brick masonry and larger size perforated pipe wrapped with nylon net which is fixed with abandoned tube well pipe. The perforation is in upper 3 ft and 1.5 ft pipe length at the bottom is kept blind to facilitate sedimentation.

Filtration unit:

The clogging of recharge filter was found a major constraint in the performance of recharge structures. Field and lab studies have indicated that thickness of upper sand layer of recharge filter to be the primary factor influencing clogging, while size of gravel in the middle layer also influences effectiveness of sand as a filter (Kumar et. al 2012). The vertical sand filters consisting of layers of coarse sand, gravel and boulders, installed in earlier project, have practical problems in cleaning of clogged sediments during high rainfall events.



Recharge cavity type structure



Abandoned cavity type structure

Without cleaning of deposited clogged material from upper sand layer, the recharge rates are reduced drastically, sometimes virtually to zero rate. In the recharge wells installed at new sites in Haryana, the vertical filters have been replaced by horizontal filters consisting of synthetic and fiber layers wrapped on concentric pipes of larger sizes around the well pipe. The filter chamber in horizontal filters is similar to that for vertical sand based filter; it however is empty with about 2.5 m well pipe in the middle. The lower 1 m pipe is blind while the upper 1.5 m pipe of either same or preferably larger size is perforated and wrapped with synthetic or jute material. The concentric larger size pipes of PVC or other materials around the well pipe have perforations all along its length and are wrapped with same or different material as on the well pipe.




Performance appraisal of farmer based recharge structures:

Performance appraisal of few sites based on farmers' feedback and data collected periodically is described below

Recharge shaft and cavity

The encouraging results on the effectiveness of recharge shaft and recharge cavities to replenish groundwater and improve its quality was found. Recharge rates of 6- 10 litre/sec were estimated for 4 recharge cavities (2 abandoned, 2 new) provided with differently designs and timely cleaned radial filters in Haryana. The temporal changes in depth, EC and RSC or pH of groundwater at another 2 representative sites are presented graphically in Fig.1. It is seen that recharge events, indicated by arrows, cause both a rise in water table depth beneath the structure and reduction in EC as well as RSC of groundwater. The improvement in salinity and RSC of groundwater at different selected sites in Haryana and Punjab ranged from 0.3- 2.4 dS/m and 0-4.46, respectively.

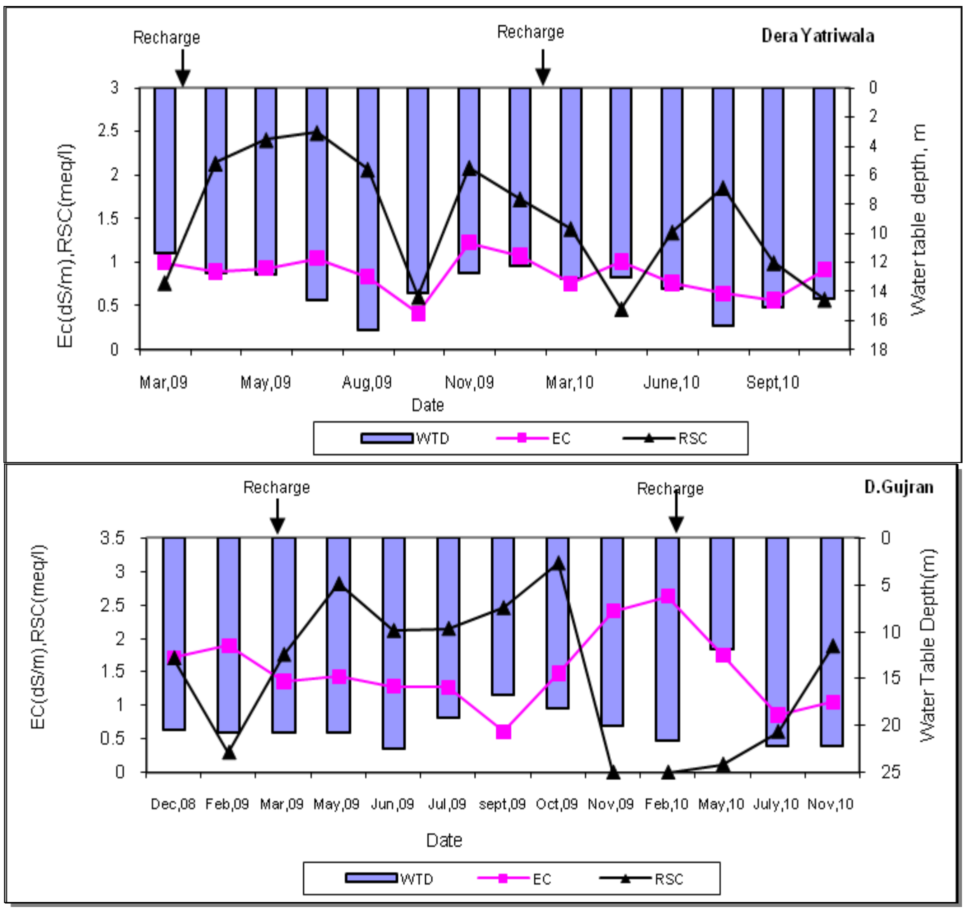


Fig. 1. Temporal changes in depth, EC and RSC or pH of groundwater at two representative sites

Abandoned tube well

One abandoned tube well was converted into drainage option at agricultural field with providing suitable filtration option to retain physical impurities carrying with runoff water. It contains brick masonry of 4.4 x 4.5 x 4.5 ft. The tube well pipe was extended up to the field surface with perforated pipe of larger diameter. After creation of drainage option, farmer went for crop diversification and cultivated maize in *Kharif* in place of water exhaustive rice and wheat crop successfully. The economics worked out on the basis of observation recorded and feedback received from the farmers is presented in table 1. Due to sensitivity of water logging during establishment and early vegetative stage, maize crop was earlier damaged to the extent of 50-75% every year. However, with provided drainage option through recharge structure, he saved more than 50% of maize and 30% of wheat crop when heavy rainfall occurred. In monitory term, he could get additional income of Rs 40000/- and Rs 48000/- by saving his maize and wheat crops, respectively from submergence.


Renovated dainage cum groundwater recharge structure

Table 1. Economic analysis of recharge well during high intensity rain

Crop	Area (ha)	% saving	Additional production from saved crop (q)	Income from saved crop (Rs)	Payback period
Maize	1 ha	50-75%	35-50	Rs 40000/-	In one season
Wheat	2 ha	30%	30	Rs 48000/-	
Total				Rs 98000/-	

Conclusions

The farmer based groundwater recharge structures are simple in design which can be installed at the lowest point of the filed/ low lying area and serve as point source drainage option for accumulated runoff water during extreme rain. It is proven as an effective adaptive measure to combat adverse effect of extreme rainfall event due to climate change. The recharge structures are highly effective in augmenting groundwater, improving its quality and enhancing water productivity and farmers' income. They also provide opportunity of crop diversification with Kharif maize as a replacement to high water demanding rice in the area. Practical designs of recharge filters and quality of water being recharged are the focus of current research at CSSRI, Karnal.

Rererences

Chadha, D. K. 2002. State of art of artificial recharge applied on village level scheme in India. In: (Ed. Tuinhof, A. and Heederik, J.P). Proc. Seminar on Management of Aquifer Recharge and Subsurface Storage: Making better use of our largest reservoir, Wageningen, The Netherlands, 18- 19, 2002.

Kamra, S.K. 2010. Recharge and skimming: Opportunities and technologies for poor quality groundwater areas. In: Use of Poor Quality Water in Agriculture (Ed. Yadav, R.K., Meena, R.L., Jat, H.S., Singh, R.K., Lal, K., and Gupta, S.K.), Central Soil Salinity Research Institute, Karnal, India, 134- 143 pp.

Kumar, Raju, R, Sheoran, P., Sharma, R., Yadav, R.K., Singh, R.K., Sharma, P.C. and Chahal, V.P. (2020). Techno-economic evaluation of recharge structure as localized drainage option for sustainable crop production in sodic agro-ecosystems. *Indian Journal of Agricultural Sciences,* 90 (1): 212–219

Kumar, S., Kamra, S. K., Yadav, R. K. and Narjary, B. 2014. Effectiveness of horizontal filter for artificial groundwater recharge structure. *Journal of Agricultural Engineering* 51 (3): 24 - 33.

Kumar, S., Kamra, S. K. Yadav, R. K., Sharma, J.P. 2012. Evaluation of sand based storm water filtration system for groundwater recharge wells. *Current Science*. 103 (4), 393- 404.

Mall, R. K., Gupta, A., Singh, R., Singh, R. S. and Rathore, L. S. R. 2006. Water resources and climate change. *Current Science* 90(12):1610-1626

Sathaye, J., Shukla, P. R. and Ravindranath, N. H.2006. Climate change, sustainable development and India: Global and national concerns. *Current Science* 90(3):314-325

Computer application in agricultural water management

Ashok K. Nayak
Principal Scientist (Computer Science)
ICAR-Indian Institute of Water Management, Bhubaneswar
E-mail: aknayak75@rediffmail.com

Information Technology (IT) is the electronics technology used for collecting, storing, processing and communicating information to the end users. IT is a key component for success in this age of information revolution. It plays an important role between the individual and the environment. Information and communication technology (ICT) is often used as an extended synonym of information technology, but it is more specific term that stresses the role of communication technologies. A web based information system namely agriculture water management portal was developed for better utilization of water resources in agriculture. The information available under All India Coordinate Research Project on Water Management Centres regarding their general information and information related to their research activities were collected, compiled in the form of webpages. Webpages were prepared for researchers and other stakeholder to access information related to agriculture water management. The background information, centre information, theme of research, location map, soil type, along with the major accomplishments done by the individual centre is available in the website. An e-learning module is also prepared in different languages in the web portal for the farmers and other researchers. The web portal containing different domains like research domain, farmer's domain, service domain, e-learning and contact information for the use of different user groups.

***(Key words**: Information technology, database system, web portal, e-learning)*

Water is a natural resource which is the fundamental to life, livelihood and food security. India has more than 18 percent of the world's population, but has only 4% of world's renewable water resources with 2.6% of world's land area. There are further limits on utilizable quantities of water owing to uneven distribution over time and space (CWC, 2014). With a growing population and rising demand in a fast developing country as well as the given indications of the impact of climate change, the availability of utilizable water will be under further strain in future. Low awareness about the scarcity of water and its life sustaining and economic value, results in its mismanagement, wastage and inefficient use (Ghorbani and Moradi, 2014). In addition, there are inequities in distribution and lack of a unified perspective in planning, management and use of water resources. Rapid industrialisation and urbanization coupled with continuous decline in per capita water availability is putting a lot of pressure on the available water resources in the country. As per report of standing sub-Committee for assessment of availability and requirements of water for diverse uses in the country, the future water requirements for meeting the demands of various sections in the country for the year 2025 and 2050 have been estimated to be 1093 BCM and 1447 BCM respectively (CWC, 2010). The increasing gap between water availability and demand highlights the need for conservation and proper utilization of water.

The Information Technology is used in development of a portal mainly for collecting, storing, processing and communicating information to the end users. Information and Communication Technology delineates how these various forms of digital mediums interact with each other through web based applications to meet a specific objective (Nayak, 2015). A Rice Knowledge Management Portal (RKMP), the first step towards enabling the use of ICTs in agriculture was developed by ICAR. The RKMP served as an information highway for sharing rice knowledge through latest ICT tools. It helps agricultural departments' ongoing activities in reaching out to the farmers through extension advisory services, in a most effective way for information communication (RKMP, 2015). In national level, one portal on water management was developed as India Water Portal (IWP, 2015), which is a web-based interactive platform for sharing water management knowledge amongst practitioners and the general public. The portal covers topics closely related to the challenges in the water sector in India and practical solutions for day to day water related problems faced in the country. The topics broadly covered in the portal include rainwater harvesting, agriculture, drinking water, urban water management, sanitation and wastewater management. But, there is no proper web based information system available specifically on agriculture water management aspects. Therefore, an attempt has been made to develop a web portal with the objective is to provide proper water management techniques for better agricultural development.

Methodology

There are various steps to create a web portal such as information gathering, planning, design and development, testing and maintenance. The first step, the information gathering is very important in developing a successful web portal. Many things need to be taken into consideration when the look and feel of the site is created. Using the information gathered from phase one, planning is required for developing the web pages. The site map is a list of all main topic areas of the site, as well as sub-topics. The end-user of the web site must be kept in mind in designing the site. Target audience is one of the key factors in development of a web portal. The portal is to be tested before uploading for public and regular maintenance is required for updating the information available for general public. The literature on research work and extension activities on agriculture water management were collected for developing the web portal and e-learning module for the farmers and other stakeholders. The web pages have been prepared on open source PHP language (Holzner, 2007).

Webpage formats

Using the information communication technology application, a web based information system namely agriculture water management portal was developed. The portal was created on web 2.0 standards with different modules such as research, extension, farmers, general information, e-learning and contact details for use of different group of stakeholders as shown in Fig.1. The information of All India Coordinate Research Project (AICRP) on Water Management Centres regarding their general information and information related to their research activities were collected and compiled in the web pages. Webpage format has been prepared for researches carried out by AICRP Centres across the country to share the related information to the public. The background information, centre information, theme of research, location map, soil type, alongwith the major accomplishments done by the centre so far was uploaded on the website (Fig. 2).

An e-learning module of the web portal was developed for the use of farmers and other researchers based on the literature on research carried out and extension activities specific to agriculture water management. The webpage format for e-learning is shown in Fig.3. The published literature, bulletins and leaflets for agriculture water management in Hindi and Odia language were made available on the webpages as e-books. The bulletins published by the Institute and e-books already available in the Institute website have also been linked with the web portal.

The success stories on agricultural water management by different coordinating centres of All India Coordinate Research Project (AICRP) on Water Management has also been incorporated in the portal. The success stories and technologies are categorized on the basis of different agro-ecological regions, irrigation methods for easy interpretation of the data by end users as shown in Fig. 4. A user after entering to the website can get the information about the major technologies available across the country and their application in agriculture. The progressive farmers who have been awarded for adopting different kind of agricultural technologies in their fields was also available in the web portal. The web pages are also prepared on various technologies developed under different research aspects at this Institute viz. rainwater conservation, micro level water resource development, farm pond based agriculture, crop diversification, rubber check dam for watersheds, raised and sunken bed, system of rice intensification, sub-surface water harvesting structure and waterlogged area management as depicted in Fig. 5. The information has also been created in Hindi language. The list of progressive farmers who were awarded by the Institute are also made available in the portal alongwith their adopted technologies.

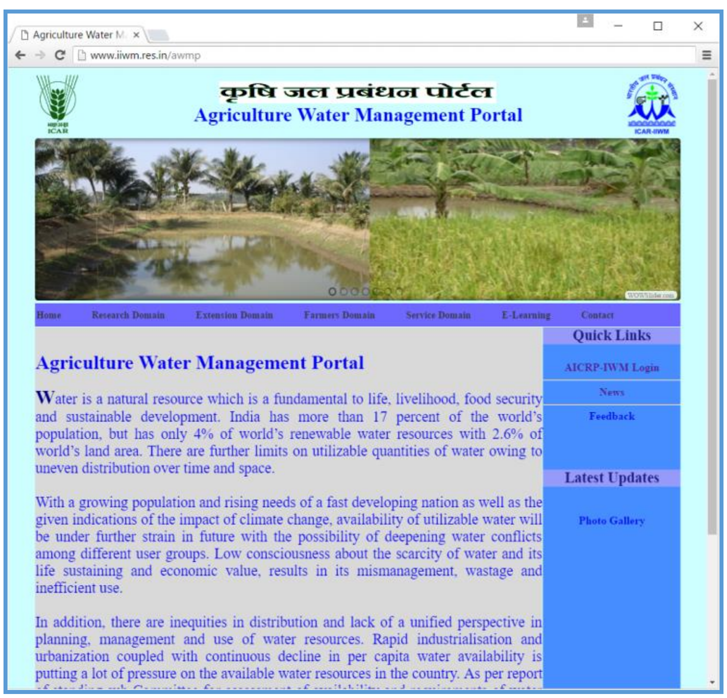


Fig. 1. *Homepage of the Agriculture Water Management Portal*

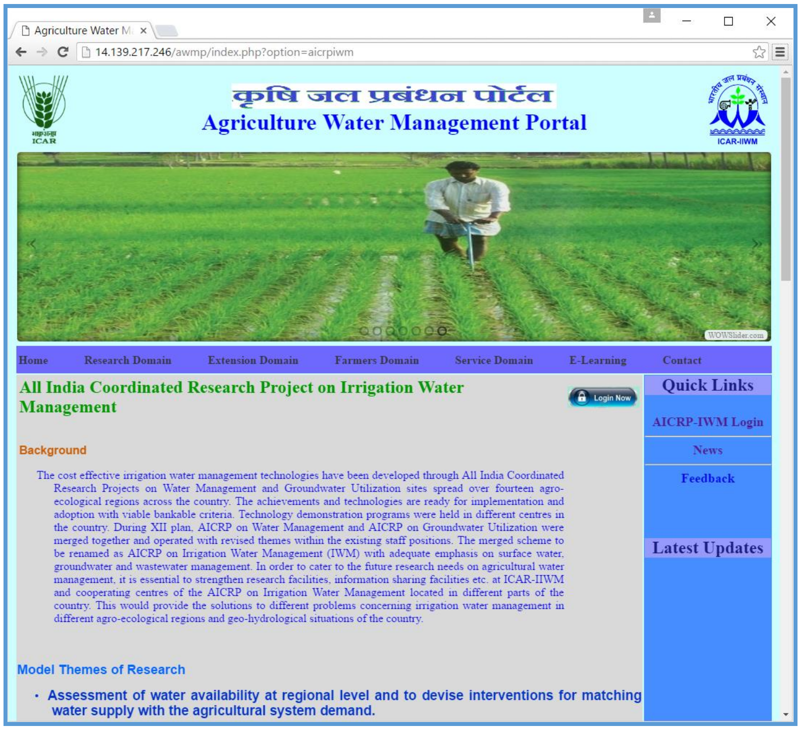


Fig. 2. Webpage depicting the AICRP information

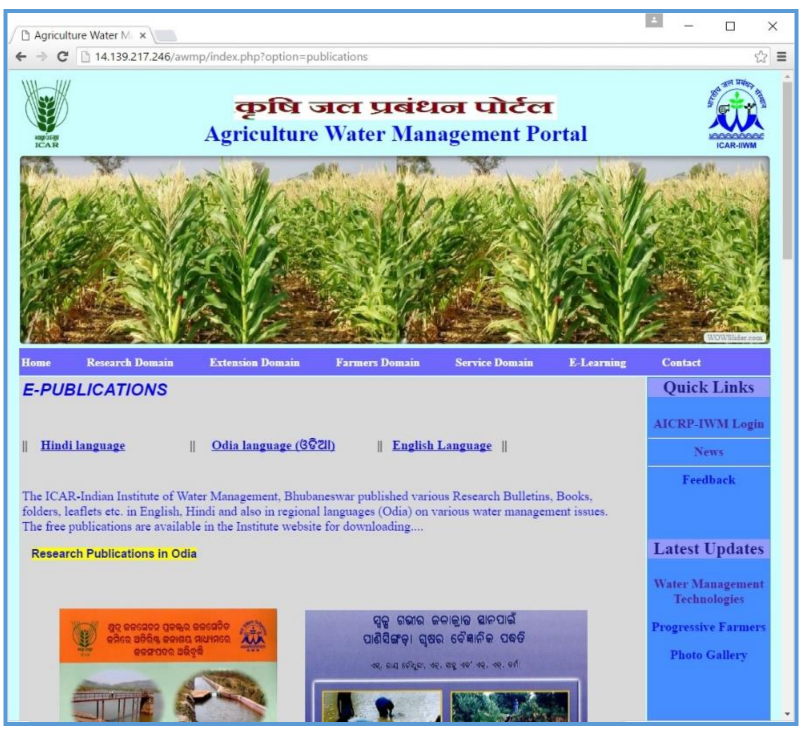


Fig. 3. Webpage showing the e-publication module

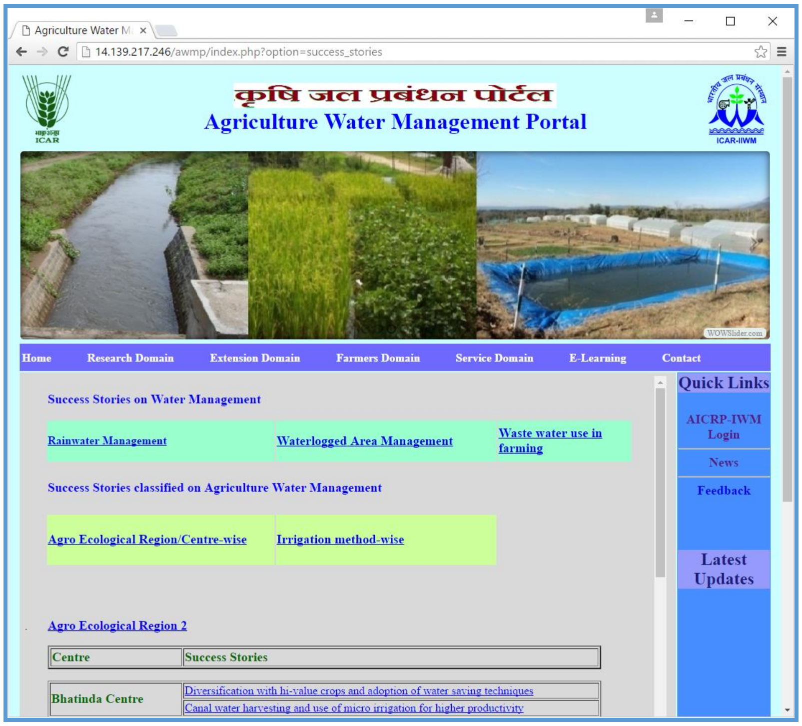


Fig. 4. *Webpage for success stories categorization*

Fig. 5. *Webpage showing the technologies available in the portal*

Conclusion

The growth of ICT in developing countries offers a new technological aspect and new opportunities for sharing useful information for farmers and other stakeholders. The mechanisms is sharing the information on agricultural water management through web portal for farming community, which has long been plagued with problems related to technologies for soil, water and management aspects. In this connection, the developed web based information system on agriculture water management will be useful for better utilization of water resources in agriculture. The information available in the web portal are useful for researchers, farmers and other stakeholder to know the agricultural technologies developed across the country. The published literature, bulletins and leaflets for agriculture water management in English, Hindi and regional language are made available on the webpage in the form of easily accessible e-books which can be viewed by general public. The success stories available in the portal on agricultural water management by different coordinating Centres of AICRP on Water Management in the country are useful for the farming communities. The success stories and technologies are categorized on different agro-ecological region-wise, irrigation method-wise for easy interpretation of the data by end users.

References

Central Water Commission. (2010). Report of the Standing Sub-Committee on "Assessment of Availability & requirement of Water for Diverse uses-2000". Basin Planning Directorate, CWC, XI Plan Document.

Central Water Commission. (2014). Guidelines for improving water use efficiency in irrigation, domestic & industrial sectors. Ministry of Water Resources, Central Water Commission, New Delhi. pp19.

Ghorbani M and Moradi, H. (2014). Social and policy networks in water governance. In First International Symposium on Urban Development. WIT press. 329-332p.

Holzner, Steven (2007). PHP: The complete Reference. McGraw-Hill publication.

IWM. (2015). Indian Water Portal (http://www.indiawaterportal.org).

Nayak, Ashok K. (2015). Application of ICT in water management. *In* "Improving water productivity for sustainable livelihood and food security". (*Eds*. Das, M. Sinha, M.K., Verma, O.P. and Ambast, S.K.). ICAR-Indian Institute of Water Management, Bhubaneswar. 134-139p.

RKMP. (2015). Rice Knowledge Management Portal. (http://www.rkmp.co.in).

Irrigation Scheduling and Design of Optimal Cropping Pattern for Small and Marginal Farmers

P.S. Brahmanand
Director-Research, Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar
E-mail: psbanand@yahoo.com

Water is elixir of life and it is one of the most important natural resources available on the Planet Earth. It plays vital role in agriculture and its optimum availability is important in augmenting and sustaining crop productivity. The main role played by water is in the form of key factor in photosynthesis, resulting in production of carbohydrates and thereby playing significant role in enhancing the economic yield of different crops. It also plays an important role in other metabolic activities of plants which significantly influences the crop production. Crops differ in their water requirement mainly due to their varying duration and nature of preferential habitat, soil and climate. Understanding water requirement of crops is crucial in irrigation scheduling and in planning the water management practices for obtaining optimum yields. Majority of the water requirement of the crops is met by rainfall especially during kharif season. However, the uneven distribution of rainfall on both temporal and spatial basis necessitates us to provide irrigation to the crops during some phases. At the same time, irrigation sector is facing tough competition from Industry and domestic sectors in the recent years (Table 1). Therefore, judicious use of irrigation water has potential to enhance the crop productivity of small and marginal farmers which in turn would lead to food security. The 2030 Water Resources Group (2009) estimates that about half of the demand for water will be unmet by 2030 if the current pattern of demand continues. The per capita per year availability of water resources of India has been declining from 5176 m3 in 1951 to 1703.6 m3 in 2007 and it is expected to decline to 1140 m3 by 2050.The availability of water for agriculture in India is expected to decline from 84% in 2010 to 74% by 2050.As water resources are getting diminished day by day, the accurate understanding of the water requirement of different crops, optimal irrigation scheduling and analyzing the trend of existing cropping pattern and making desirable shifts to make our path towards optimal crop planning would be needed for addressing the food security objectives of the nation.

Table 1: Sector wise projected water demand in India

(billion cubic meters)

Sector/Year	2000	2010	2025	2050
Irrigation	541	688	910	1072
Domestic	42	56	73	102
Industry	8	12	23	63
Energy	2	5	15	130
Others	41	52	72	80
Total	634	813	1093	1447

(Source: Central Water Commission, 2010)

Present status of water resources

The analysis of existing status of water resources in India is required for efficient crop planning and irrigation planning. At present, about 53% of total annual precipitation i.e. 4000 BCM is in the form of evaporation and ground water recharge and the remaining 47% is in form of the annual potential flow in the rivers. It is also estimated that the utilizable water resources of the country is about 1123 BCM which includes surface water resources of about 690 BCM and groundwater sources of about 433 BCM. The spectacular growth in food grain production (265 M t in 2013-14) of India has been mainly contributed by water management in general and significant expansion of irrigated area in particular. The gross irrigated area in the country increased from 23 m ha in 1950-51 to 88 m ha in 2008-09 and the gross water demand by irrigation sector alone contributes 71% of the gross water demand by all users by 2025. Major irrigation source in India is through tube wells and other wells (60%) followed by canal irrigation (26%). Tank irrigation is confined to few pockets accounting for less than 5%. Agriculture sector is the largest consumer of water (82.8%) and it is estimated that the significant portion (910 BCM) out of total demand of water (1093 BCM) will be required by irrigation and it will face stiff competition for its water from different sectors. In addition, ground water extraction through open dug wells and tube wells is also on increasing trend putting tremendous pressure on water resources.

Water requirement and irrigation scheduling: The concept

The amount of water that is required by any crop during its life cycle can be called as water requirement in simple terms. It refers to the quantity of water regardless of its source, required by a crop or diversified pattern of crops in a given period of time for its normal growth and development under field conditions at a given place. It is expressed in depth per unit time. Water requirement (WR) can be expressed in both demand and supply perspective.

On demand side, WR includes the quantity of water needed to meet the losses due to evapo-transpiration (ET), plus the losses during the application of irrigation water (unavoidable losses) and the additional quantity of water required for special operations such as land preparation, transplanting, leaching of salts below the crop root zone etc. The major portion of water applied to crops is utilized for meeting the demand of evapo-transpiration. The evaporation is a phenomenon in which water is lost from any surface in the form of vapour. Similarly, the transpiration is a phenomenon in which water is lost in the form of gas from the leaves of the plants. Stomata present in the plant leaves help in the process of transpiration. The amount of water required for meeting the requirement of evapo-transpiration and metabolic needs of the plants is termed as consumptive use. However, when we apply water to the field, it gets lost in the form of leaching, seepage, percolation and runoff. This requires us to apply more water than the actual water needed by the plants. This is referred as net irrigation requirement. In a larger command area, when irrigation water is supplied, some portion is lost in the form of application and conveyance. Once, we take them in to consideration, we get far higher quantity of water to be supplied at the beginning source point, this is referred a gross irrigation requirement.

On demand side, WR can be expressed as follows:
WR = ET or CU + Application losses + Special needs if any

On supply side, water requirement can be expressed follows:
$WR = IRR + ER + \Delta S + GWC$

Where:
IRR = Total depth of irrigation water during crop life
ER = Effective rainfall received during crop life
ΔS = Profile water use i.e., difference in soil moisture in the crop root zone at the beginning and end of the crop
GWC = Groundwater contribution, if any.

The term consumptive use (Cu) is used to designate the sum of losses due to evaporation + transpiration from the cropped field as well as that water utilized by the plants in its metabolic activities for building up of the plant tissues. Since the water used in the actual metabolic processes is insignificant (about 1% of evapotranspiration losses) the term consumptive use is generally taken equivalent to evapotranspiration. It is expressed similar to ET as depth of water per unit time i.e., mm/day or cm/day.

a) Daily consumptive use: It is the total amount of the water used in ET plus water used in metabolic activities by a crop during a single day or 24-hours period and is expressed in mm/day or cm/day.

b) Seasonal consumptive use: The total amount of water used by the crop in ET and metabolic activities for building up of plant tissues during its total growing season. It is expressed as depth of water in mm or cm per season. Seasonal consumptive use values are needed to evaluate and determine seasonal irrigation water supplies and irrigated crop acreages.

c) Peak period consumptive use: The average daily water use rates in terms of ET plus that consumed in metabolic process during the highest consumptive use period (6 – 10 days) of the season is called peak period consumptive use rate. This is the design rate to be used in planning an irrigation system. The peak-use consumptive period generally occurs when the crop is starting to build up its harvestable produce, wherein the canopy area is maximum and capable of intercepting maximum photosynthetic active radiation and atmospheric demand is high.

Irrigation requirement is the total amount of water applied to a cropped field for supplementing effective rainfall, soil profile and groundwater contribution to meet the crop water requirements for optimum growth. In other words, irrigation requirement is exclusive of ER + ΔS + GWC.

$$IRR = WR - ER + \Delta S + GWC$$

Net Irrigation Requirement (NIR) is the amount of irrigation water just required to bring the soil moisture content in the effective crop root zone depth to field capacity. Thus, the net irrigation requirement is the difference in depth or percentage of soil moisture between field capacity and the soil moisture content in the root zone just before application of the irrigation water. in terms of depth, it can be expressed as:

$$NIR = \sum_{I=1}^{n} \frac{Mfc - Mbi}{10} \times pbi \times dsi$$

Where,

NIR = Net irrigation requirement to be applied at each irrigation (mm)
n = Number of soil layers considered in root zone depth ds
Mfc_i = Gravimetric moisture percentage at field capacity in ith layer
Mbi = Gravimetric moisture percentage just before irrigation in ith layer
Pbi = Soil bulk density in ith soil layer (g/cm^3)
dsi = Depth of ith soil layer (cm)

Net Irrigation Requirement (NIR) = CU + leaching loss + runoff loss +seepage loss + percolation loss

Hence, excess water is needed than the actual crop water needs to offset these losses if any. Thus gross irrigation requirement is the total amount of water required to bring the crop root zone to field capacity (NIR) inclusive of the water required offsetting the application losses. Which in other words, NIR + Application & other losses. It can be calculated as follows:

Gross Irrigation Requirement = (NIR/Irrigation application efficiency) ×100

Evapo-transpiration is estimated using standard methods evolved over a period of time. Potential evapo-transpiration (PET) is a phenomenon in which water is lost through combined process of evaporation and transpiration from crop grown land at a standard height of cm.

PET estimation methods

Blaney Criddle Method

The relationship is expressed as follows:

ETo (mm/day) = c [p (0.46 T+8)]

Where:
ETo = Reference crop evapotranspiration in mm/day for the month considered
T = Mean daily temperature on oC over the month considered
P = Mean daily percentage of total annual daytime hours obtained for a given month & latitude
c = Adjustment factor which depend on minimum relative humidity, sunshine hours and day time wind estimates

Thornthwaite method

The relationship is expressed as:
$E=1.6\ (10T/I)^a$

Where

E = Monthly potential evapotranspiration (cm) or reference crop ET (i.e., ETo)
T = Mean monthly temperature (°C).
I = A heat index for a given area which is the sum of 12 monthly index values 'i'.

'i' is derived from mean monthly temperatures using the following formula: $i=(T/5)^{1.514}$
a= an empirically derived exponent which is a function of 'I',
$a=6.75\times10^{-7}I3 - 7.75\times10^{-5}I2 + 1.79\times10^{-2}I + 0.49$;

Radiation method

The relationship is expressed as

ETo (mm/day) = c (W. Rs)

Where:
ET_o = Reference crop evapotranspiration in mm/day for the period considered
Rs = Solar radiation in equivalent evaporation in mm/day
W = Weighting factor which depends on temperature and altitude
c = Adjustment factor which depends on mean relative humidity and day time wind conditions

Modified Penman method

The relationship is expressed as:
ETo (mm/day) = c [W. Rn + (1-W). f(u). (ea-ed)]

Where:
ETo = Reference crop evapotranspiration in mm/day
W = Temperature related weighing factor
Rn = Net radiation in equivalent evaporation in mm/day
f(u) = Wind related function
(ea – ed) = Difference between the saturation vapour pressure at Tmean and the mean actual vapour pressure of the air both in mbar
c = Adjustment factor to compensate for the effect of day and night weather conditions

Penman – Monteith method

Allen et.al. (1998) proposed the Penman – Monteith equation.
The mathematical relationship is as follows:

$$ETo = \frac{0.408\Delta(R_n-G)+\gamma(900/T+273).\ U_2\ (es-ea)}{\Delta+\gamma\ (1-0.34\ U_2)}$$

ETo = Reference crop evapotranspiration (mm/day)

Rn = Net radiation at the crop surface (MJ/m2/day)
G = Soil heat flux density (MJ/m2/day)
T = Air temperature at 2 m height (°C)
U2 = Wind speed at 2 m height (m/s)
es = Saturation vapour pressure (kPa)
ea = Actual vapour pressure (kPa)
(es – ea)= Saturation vapour pressure deficit (kPa)
D = Slope vapour pressure curve (kPa/°C)
g = Psychrometric constant (kPa/°C)

Pan evaporation method

The relationship is expressed by:
$ETo = K_{pan} \times E_{pan}$
Where:
ETo = Reference crop evapotranspiration in mm/day for the period considered
Kpan = Pan evaporation in mm/day and represents the mean daily value of the period considered

Epan = Pan coefficient

Etc refers to crop evapo-transpiration and can be estimated as a product of PET and crop coefficient (Kc value). The crop coefficient is the ratio between crop evapotranspiration (ETc) and reference crop evapotranspiration (ETo). The crop coefficient values vary from one crop growth stage to other. Crop coefficient curve is constructed by dividing crop growing period into four growth periods and placing straight line segments through each of these periods with the lines through the initial and mid-season periods being horizontal. The four growth stages of crop growing period are as follows:

a) Initial period – planting to 10% ground cover
b) Crop development – 10% ground cover to effective cover i.e., flowering
c) Mid-season – Effective cover to start of maturity i.e., senescence of leaves
d) Late season – Start of maturity to harvest.

Crop coefficient values vary with the development stage of the crop. In the case of annual crops, Kc is typically low at seedling, emergence and establishment stage, increases with increase in ground cover and attains maximum value at mid-season stage and thereafter decreases towards ripening and maturity stage

Effective rainfall is that portion of the total annual or seasonal rainfall which is useful directly and/or indirectly for meeting the crop water needs in crop production at the site where it falls but without pumping". Maximum portion of water requirement of crops during kharif season is met by effective rainfall. The remaining portion is met by irrigation sources. Understanding these basic concepts will certainly help us in planning, creating and efficiently managing these water resources for irrigation.

Concept of Irrigation Scheduling

Irrigation scheduling refers to knowledge and management practice of right time of applying irrigation water and optimizing the quantity of irrigation water with an objective of optimum crop yield and water use efficiency without causing damage to the soil (Reddi and Reddy, 2017).

Irrigation scheduling is based on the following approaches:

1. Soil water regime approach
2. Climatological approach
3. Plant indices approach

In soil water regime approach the available soil water present between field capacity and permanent wilting point inside the effective crop root zone depth is considered as a criterion for irrigation scheduling. Feel and appearance of soil method, depletion of available soil moisture (DASM) method and soil moisture tension method come under this category. In climatological approach, the amount of water loss in the form of either cumulative pan evaporation or potential evapotranspiration is taken as a criterion for irrigation scheduling. It comprises of different methods like potential evapotranspiration method, cumulative pan evaporation method and IW/CPE ratio. In plant indices approach, plant characteristics which show direct or indirect response to water stress are considered as criteria for irrigation scheduling. It comprises of visual plant symptoms, soil-cum-sand mini-plot technique, plant population, rate of growth, relative water content, plant water potential, canopy temperature, indicator plants and critical crop growth stage approaches.

Crop planning

Crop planning is essential to facilitate optimum utilization of available water resources in any geographical region with an objective to enhance water use efficiency and water productivity and thereby ensuring food security. It is well reflected through analysis of cropping pattern. The cropping pattern is referred to the yearly sequence and spatial arrangement of crop or of crops and fallow on a given area, region, province or country attributing due consideration to natural features, crop efficiency, and capability, socio-economic structure, technological and extension infra-structure and the national agricultural policy. Cropping pattern of a region is based on available natural resources and socio-economic conditions.

Analysis of existing cropping pattern

The current trend of cropping pattern at national level indicates that the area under paddy is 22 % and it has remained stable during the last two decades. For wheat, it has slightly increased from 13 per cent in 1990-91 to 15 per cent in 2009-10. The trend of temporal change in area share of the crops in India indicated that the area under cereals in terms of percentage of gross cropped area has been found to be diminished from 56.53 in 1991 to 51.74 in 2008 (Srivastava *et al.*, 2010) (Table 2). At the same time, the area under pulses has also come down from 23.74 in 1991 to 22.77 in 2008. The area under oil seeds during the same time period has enhanced from 24.2 million hectares to 26.9 million hectares. An increase in proportion of area under fruits, vegetables and spices was also witnessed during the same period. The need of the hour is to prioritize the preferential crops that suit well under each agro-climatic region of the country so that higher net returns can be achieved by the farming community through crop diversification. However, at regional level, there is indication of significant change in cropping pattern mainly based on economic advantage. Sustainable use of water and land is to be considered while developing cropping pattern of a region. There is a strong need to reduce the water demand in agricultural sector by making desirable shift from existing cropping pattern to alternate cropping pattern giving preference to cultivation of low duty crops.

Table 2: All-India temporal change (%) in the area share of main crop and crop groups, 1991 to 2008

	Area (million hectares)	
Crop	TE 1991*	TE 2008
Cereals	103.68 (56.53)	99.01 (51.74)
Pulses	23.74 (12.94)	22.77 (11.90)
Oil seeds	24.2 (13.24)	26.97 (14.09)
Fruits	3.09 (1.68)	5.54 (2.89)
Vegetables	5.17 (2.82)	7.48 (3.91)
Spices	2.26 (1.23)	2.47 (1.29)
Gross cropped area	183.42 (100.00)	191.36 (100.00)

Figures within parentheses are share in gross cropped area.
*For fruits, vegetables and spices data pertain to triennium ending (TE) 1993.

Need for design of optimal cropping pattern

The trend of cropping pattern in the recent years shown that rice and wheat crops dominate the maximum portion of cultivable area among cereals. In some specific zones, the tendency for shifting from rice and wheat crops to new crops was seldom present which indicates that the inherent soil and climatic factors might be quite congenial for the existing cropping pattern. At the same time, the small and marginal farmers have shown interest in changing cropping pattern in some regions where the better cost effectiveness was experienced with new crops. This was also facilitated by some policy initiatives like better market pricing, irrigation infrastructure creation, power policy etc. This necessitates us to devise crop planning based on thorough study and analysis of the crop water demand for existing cropping pattern in comparison with different sources and amount of water resources in India. At the same time, the suitable areas in which alternate cropping pattern or optimal cropping pattern have to be suggested. The emphasis on crop diversification was given for two main reasons. First, the prices of food grains like rice and wheat were relatively lesser resulting very low net returns even during years of bumper production (Brahmanand *et al.*, 2013). By diversifying to other crops like pulses, oil seeds and commercial crops, the farmers have better chance to earn higher profits. Second, the yield rate of rice and wheat was poor in some regions especially in less favorable ecosystems such as uplands and dry lands due to imbalance in the supply and demand side factors of water condition in the field. However, the design of optimal cropping pattern needs to be done based on scientific empirical evidence. Hence we need to consider water balance scenario and potential alternate crops and the cultivated land utilization index (CLUI) while designing the optimal pattern

(Brahmanand *et al.*, 2021) (Table 3; Fig.1 and Fig. 2). For example, in case of Odisha, the alternate crops have been suggested based on the cropping index and

Table 3. Cropping pattern, gross cultivated area (GCA), cropping intensity (CI) and cultivated land utilization index (CLUI) of different districts in Odisha

District	GCA* (×000 ha)	Major cropping pattern	% of GCA under		CI (%)	CLUI
			Rainy season	Dry season		
Angul	301.5	Rice (78), Pulses (57+46), oilseeds (30)*, Vegetables (24)*	62	30	168	0.591
Balasore	322.2	Rice (195), Rice (31)	63	33	169	0.640
Bargarh	473.0	Rice (241+84), Pulses (64+18), Oilseeds (23+14)	72	27	142	0.492
Bhadrak	235.9	Rice (118), Vegetables (87), Pulses (23)*	88	18	139	0.533
Bolangir	489.4	Rice (200), Pulses (74+77), Fibres (41), Vegetables (21+20)	73	24	168	0.576
Boudh	138.3	Rice (66.0), Pulses (14+23)	67	29	163	0.566
Cuttack	303.1	Rice (118), Pulses (113)*, Vegetables (22)*	44	52	193	0.657
Deogarh	108.5	Rice (50), Pulses (13+10)	68	26	175	0.647
Dhenkanal	261.4	Rice (91.8), Pulses (22+49), Oilseeds (20+14), Fruits (25)	57	33	195	0.736
Gajapati	150.2	Rice (38), other cereals (28), Pulses (11+22)	59	29	198	0.655
Ganjam	704.4	Rice (251), Pulses (38+213), Oilseeds (24+38)	56	39	181	0.561
Jagatsingpur	177.2	Rice (80), Pulses (56)*	48	48	197	0.681
Jajpur	279.5	Rice (124), Pulses (67)*, Oilseeds (34)*, Vegetable (11+13)	54	43	198	0.678
Jharsuguda	81.0	Rice (40)	71	22	133	0.491
Kalahandi	616.9	Rice (209+40), Pulses (83+117), oilseeds (15+33), fibres (45)	62	35	184	0.599
Kandhamal	188.5	Rice (46), Other cereals (20), Oilseeds (14+19), Pulses (12+15)	66	22	176	0.666
Kendrapara	262.6	Rice (133), Pulses (78)*, vegetables (9+14)	56	42	194	0.660
Keonjhar	393.3	Rice (173), Pulses (28+46), Vegetables (27+23), Oilseeds (15+17)	70	24	161	0.559
Khordha	207.4	Rice (97), Pulses (55)*, Fruits (20)	56	35	192	0.742
Koraput	400.3	Rice (112+21), Other cereals (101), Pulses (16+21), Oilseeds (25)	71	18	147	0.494
Malkangiri	230.8	Rice (98), Oilseeds (28+19)	70	16	170	0.693
Mayurbhanj	491.8	Rice (301), Pulses (32+36)	74	19	138	0.524

Nabarangpur	289.7	Rice (146), Other cereals (66)	81	12	160	0.513
Nayagarh	242.3	Rice (101), Pulses (10+72), Fruits (20)	56	36	192	0.701
Nuapada	290.8	Rice (100), Pulses (59+44), Oilseeds (22+13)	73	24	156	0.492
Puri	256.0	Rice (103+33), Pulses (62)*, Fruits (23)	42	49	191	0.730
Rayagada	268.9	Rice (64), Other cereals (39), Pulses (36+21), Fibres (28)	73	20	168	0.550
Samabalpur	273.2	Rice (140+22), Pulses (28+17)	67	26	153	0.580
Subarnapur	230.4	Rice (109+28), Pulses (16+29), Vegetable (13+9)	63	33	190	0.672
Sundargarh	385.6	Rice (209), Pulses (36+30)	76	19	136	0.489
Odisha	9054.0	-	65	29	167	0.585

Figure within the parentheses (X) indicates X area under a particular crop during the rainy season; (X+Y) indicates X area under the crop during the rainy season and Y area during the dry season (winter and summer seasons); ( )* indicates area under the crop during dry season. * GCA includes the total cultivated area under rainy season, dry seasons and area under fruit crops (throughout the year).

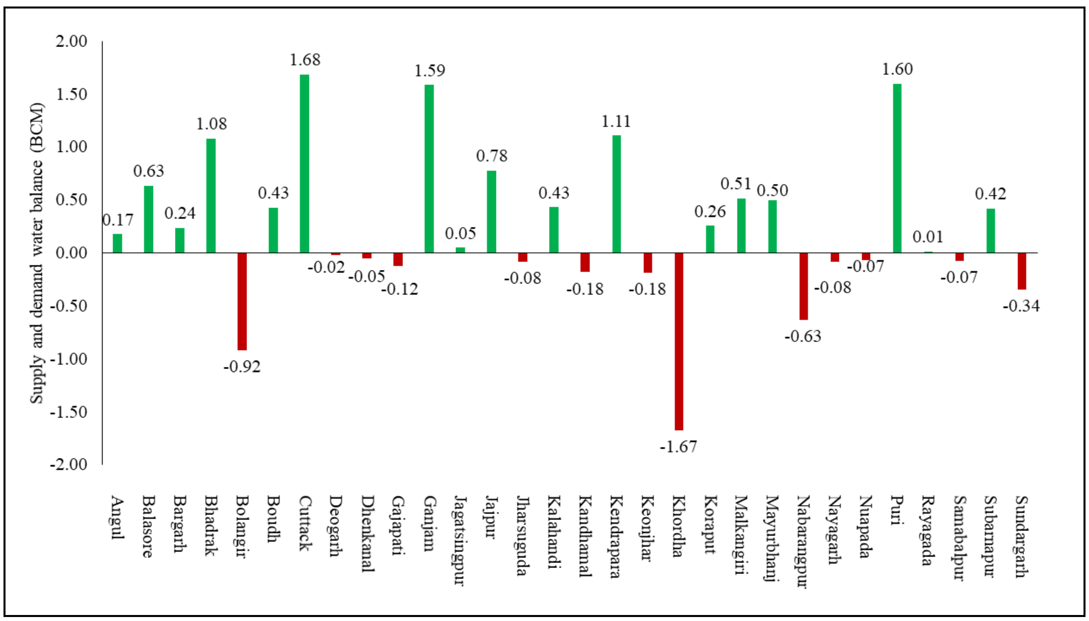


Figure 1. Supply and demand water balance in different districts of Odisha

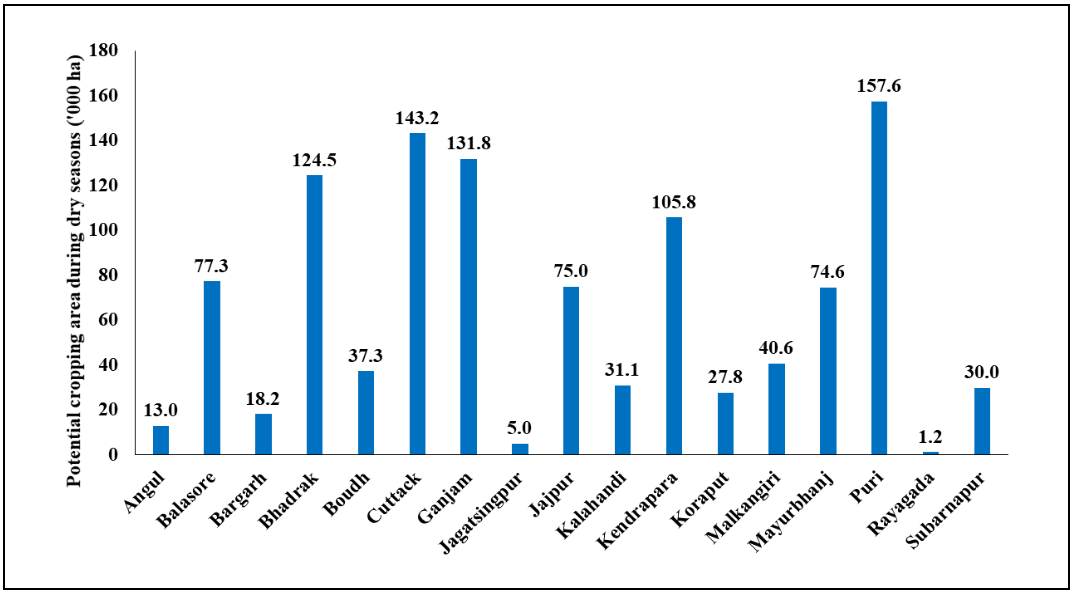


Figure 2. Potential cropping area during dry seasons

Agro-climatic region wise analysis of cropping pattern would be of immense help in this context, as existing cropping pattern was considered as one of the units to achieve homogeneity within each zone. There is a need to classify the regions based on area index and yield index for identification and prioritization of areas with higher potential to shift to new cropping pattern and to evolve strategies for developing improved water saving techniques through alternate cropping pattern which would facilitate optimal use of irrigation water. There is a strong need to analyze the existing cropping pattern in different regions of India and to devise optimal crop planning. Simultaneously, we require to perform critical analysis of positive impact of optimal crop planning on irrigation water use, water demand and food grain production in the country. This would help us to develop policy guidelines for district wise irrigation and crop planning and converging various government schemes including Pradhan Mantri Krishi Sinchayee Yojana (PMKSY). The need of the hour is the speedy adoption of alternate cropping pattern along with water use efficient interventions and supporting irrigation infrastructure to reduce pressure on existing water resources and maintaining optimum balance between crop diversification and food security objectives of the nation. This would certainly help the small and marginal farmers of India who constitute the maximum proportion of cultivators.

References

Brahmanand, P.S., Behera, B., Srivastava, S.K., Singandhupe, R.B. and Mishra, A. 2021. Cultivated Land Utilisation Index vis-a-vis Cropping Intensity for Planning Crop Diversification and Water Resource Management in Odisha: A critical analysis. Current Science.120 (7) : 1217-1224.

Brahmanand, P.S., Kumar, A., Ghosh, S., Roy Chowdhury, S., Singandhupe, R.B., Singh, R., Nanda, P., Chakraborthy, H.C., Srivastava, S.K. and Behera, M.S. (2013). Challenges to Food Security in India. Current Science, 104 (7).841-846.

Reddi, G.H.S. and Reddy, T.Y. (2017). Efficient use of irrigation water. Kalyani Publishers, India, P:492.

Srivastava, S. K. (2010). Economic analysis of demand and supply of high value agricultural commodities. Ph D thesis submitted to PG School, Indian Agricultural Research Institute, New Delhi.

2030 Water Resources Group. 2013. Catalysts for action. Partnership for sustainable water resource management, 2012 Annual report. P:40.

Poor water quality and its management for use in irrigation purpose

Madhumita Das
Principal Scientist (Soil Science)
ICAR-Indian Institute of Water Management, Bhubaneswar, Odisha
E-mail: mdas6@yahoo.com

Water quality is an emerging issue owing to increasing trend of water pollution and its substantial impact on society, agriculture and the environment. Water that does not meet the established guidelines of irrigation is termed as 'poor quality water'. It is the resultant effect of geogenic factor, anthropogenic intervention or their combined impact on water resources.

Poor quality water – nature and occurrence in India

The poor quality waters are impaired by salinity (Electrical conductivity) as evident in Punjab, Haryana, Delhi, Maharastra, Gujarat, Uttar Pradesh, Rajasthan (mostly in arid and semi-arid region), and the coastal India. High pH results in sodicity, and high RSC are also evident in several locations of Rajasthan, Haryana, Delhi, and Uttar Pradesh. Water available at shallow and also deep underground aquifer in east and north-east India are impaired by high content of iron. Low pH and excess presence of Mn are also observed in some places in east and north-east India. In vast area of Rajasthan, Odisha, parts of Andhra Pradesh, Telengana and Karnataka, ground waters are reported to impair by Fluoride.

Salinity and TDS

There are two types of salinity, coastal and inland salinity. Coastal salinity is mainly due to the influence of the seawater. India has a long coastline of 6100 Km covering Gujarat, Maharashtra, Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, Orissa & West Bengal, where fresh water overlies saline water and saline water overlies fresh water are a common occurrence. This apart increase of salinity by seawater intrusion due to over exploitation of groundwater aquifer has also been reported from Minjur area of Tamil Nadu and Mangrol – Chorwad- Porbander belt along the Saurashtra coast.

The Inland groundwater salinity mainly occurs in Maharashtra, Punjab, Rajasthan, Haryana, Gujarat, Karnataka, Uttar Pradesh, Delhi, and Bihar. A mapping of groundwater quality for irrigation use at 1: 6 million scale was carried out by Gupta et al., (1994), where saline water was divided into three distinct categories,

i. Saline water EC > 2.0 and Sodium Adsorption Ratio (SAR) < 10
ii. High SAR saline water EC > 4.0 and Sodium Adsorption Ratio (SAR) > 10
iii. Alkali water of Residual Sodium Carbonate (RSC) > 2.5 with variable EC and SAR

where EC was in dS/m, SAR in $(\text{millimole/litre})^{0.5}$ and RSC in me/litre.

Rajasthan and Haryana are dominated by all the three types of saline water and parts of Punjab, U.P, Andhra Pradesh, Maharastra and Karnataka, are dominated by alkali water. Around 32 – 84% of the groundwater of arid and semi-arid states belongs to these categories.

Fluoride

Nineteen states of India are identified with problem of excess of Fluoride in ground water. The maximum concentration level varies from 7.0 in Tamil Nadu (Erode) to 48.0 mg/L in Haryana (Rewari)

Iron

High concentration of Iron in ground water has been observed in more than 1.1 lakh habitations in the country. The highly contaminated ground water by iron is in Assam, West Bengal, Orissa, Chhattisgarh, and Karnataka; and localized pockets are observed in Northeastern states, Bihar, UP, Punjab, Rajasthan, Maharashtra, Madhya Pradesh, Jharkhand, Tamil Nadu and Kerala.

Arsenic

The Committee on Estimates (2014-15) reviewed the occurrence of high arsenic content in groundwater and reported that 68 districts are affected by high arsenic contamination in Groundwater in 10 states e.g. Haryana, Punjab, Uttar Pradesh, Bihar, Jharkhand, Chhattisgarh, West Bengal, Assam, Manipur and Karnataka.
The occurrence of Arsenic in ground water is mainly in the intermediate level of aquifer between 20 -100 m from ground surface.

Nitrate

Decomposition of organic matter, percolation loss from water soluble fertilizers, disposal from urban waste and landfills are the major causes of nitrate pollution in groundwater. It is otherwise an essential nutrient for plant. In India, highest nitrate concentration was found in Bikaner, Rajasthan.

Thus, ‘poor quality water’ indicates a vast group of water which are impaired by single, double or multiple parameters and hence needs separate attention for their appropriate utilization in crop irrigation. In irrigation, the largest share of groundwater (including dug wells, shallow tube-wells and deep Tubewells) is around 61.6% followed by canals (24.5%) and others. Assessment of poor quality ground water is therefore a prerequisite for deciding management strategies for its use in irrigation. A study conducted by Central ground water board had revealed the number of states and districts affected by geogenic contaminants as on July 2014.

Number of states and districts affected by geogenic contaminants

Geogenic contaminants	No. of affected states	No. of affected districts
Arsenic	10	68
Fluoride	20	276
Nitrate	21	387
Iron	24	297

Guidelines of water quality for irrigation

The suitability of irrigation water depends upon several factors, such as, water quality, soil type, plant characteristics, irrigation method, drainage, climate and the local conditions. The integrated effect of these factors on the suitability of irrigation water (SI) can be qualitatively expressed by the relationship:

SI = QSPCD

where

Q = quality of irrigation water, that is, total salt concentration, relative proportion of cations, etc;

S = soil type, texture, structure, permeability, fertility, calcium carbonate content, type of clay minerals and initial level of salinity and alkalinity before irrigation;

P = salt tolerance characteristics of the crop and its varieties to be grown, and growth stage;

C = climate, that is, total rainfall, its distribution and evaporation characteristics; and

D = drainage conditions, depth of water table, nature of soil profile, presence of hard pan or lime concentration and management practices.

Irrigation water quality standards

Parameters	**Threshold levels for irrigation water**
pH	6.5 – 8.5
EC dS/m	0 – 4.0
Na (mg/L)	0 – 150
Chloride (mg/L)	75 – 350
TDS (mg/L)	2500 – 5000
SAR $(mM/L)^{0.5}$	0 - 10.0
RSC, me/l	0 – 2.5
NO_3^- (mg/L)	45 – 100
SO_4^{-2} (mg/L)	0-200
Zn (mg/L)	0 - 2.0
Fe (mg/L)	0 - 5.0
Mn (mg/L)	0 - 0.2
Mg/Ca	0 -3.0
Cl/SO_4	0 – 2.0
B (mg/l)	>1.0 – 2.0
Cd, mg/l	0 – 0.01
Cr, mg/l	0 – 0.1
As (arsenic)	0-0.10
F (fluoride)	0 – 10
Mn (manganese)	0 - 0.20

RSC is Residual Sodium Carbonate; SAR is Sodium Adsorption Ratio

Strategies for managing poor quality water for irrigation

Conjunctive use of poor and normal quality water

To reduce the harmful impact of poor quality water irrigation, cyclic or alternate use of poor and normal quality water is suggested if normal quality water is available for irrigation purpose. According to crop water requirement, planning of conjunctive use will be made for effective utilization of poor water. If the normal water is available in less amount and crop is not at the water sensitive stage, then 2:1 alternation of poor: normal water may also be practiced for irrigation. This use is mainly focusing to appropriating maximum utilization of available poor quality water without generating significant effect on soil, and crops as well. This type of practice is usually prescribed for conventional irrigation methods, focusing to reduce the negative impact of poor quality water e.g. salt stress or ion accumulation around the crop root zone, so that the growth of the crop will remain unaffected. Blending water of different qualities has also been reported for augmenting poor quality water irrigation but it is confined to small scale agriculture, or irrigating high value crops. Despite water quality, soil type, volume of rainfall and crops are interlinked with irrigation, the AICRP on Management of salt affected soils and use of saline water in agriculture at ICAR – CSSRI, Karnal Haryana, has come up with the following table for suitable use of saline water in arid and semi-arid regions

Suitability of poor quality saline groundwaters (RSC < 2.5 me/l, SAR <10 (mmol/l)$^{1/2}$) for irrigation in India

Soil texture group	**Crop tolerance**	**EC_{iw} (dS/m) limit for rainfall (mm) region**		
		< 350	**350-550**	**> 550**
Fine	S	1.0	1.0	1.5
(>30 % clay)	ST	1.5	2.0	3.0
Sandy clay, clay loam, silty clay loam, silty clay, clay	T	2.0	3.0	4.5
Moderately fine	S	1.5	2.0	2.5
(20 to 30 % clay)	ST	2.0	3.0	4.5
Sandy clay loam, loam, silty loam	T	4.0	6.0	8.0
Moderately coarse	S	2.0	2.5	3.0
(10 to 20 % clay)	ST	4.0	6.0	8.0
Sandy loam, loam, silty loam	T	6.0	8.0	10.0
Coarse	S	--	3.0	3.0
(<10% clay)	ST	6.0	7.5	9.0
Sand, loamy sand, sandy loam, silty loam, silt	T	8.0	10.0	12.5

S indicates Sensitive, ST indicates Semi-Tolerant and T indicates Tolerant

i) The use of waters of 4.0 dS/m EC and above is solely confined to winter season crops only. During emergencies not more than one or two protective irrigations should be given to the Kharif season crops. ii) For soils having (i) shallow water table (within 1.5 m in kharif) and (ii) presence of hard subsoil layers, the next lower EC_{iw} is applicable.

Growing ion specific suitable crops

Information available on crops' tolerance to different ions helps to select the crops for growing under respective poor quality water irrigation. In India, salinity and alkalinity are the two major issues in poor quality water, therefore comprehensive information on crops' tolerance to salinity and sodicity are available in comparison to F or As tolerance crops. Growing crops conforming with the salinity / sodicity of the irrigation water could avoid the respective stresses and in consequence sustain the production. List of crops suitable to salinity / sodicity are as follows:

Crop groups based on response to salinity

Sensitive Group		Resistant Group	
Highly sensitive	Medium sensitive	Medium tolerant	Highly tolerant
Lentil	Radish	Spinach	Barley
Mash	Cow pea	Sugarcane	Cotton
Chickpea	Broad bean	Indian mustard	Sugar beet
Beans	Vetch	Rice (transplanted)	Turnip
Peas	Cabbage	Wheat	Tobacco
Carrot	Cauliflower	Pearl millet	Safflower
Onion	Cucumber	Oats	Rapeseed
Lemon	Gourds	Alfalfa	Karnal grass
Orange	Tomato	Blue panic grass	Date palm
Grape	Sweet potato	Para grass	Ber
Peach	Sorghum	Rhodes grass	*Mesquite*
Plum	Minor millets	Sudan grass	*Casuarina*
Pear	Maize	Guava	*Tamarix*
Apple	Clover, *berseem*	Pomegranate	*Salvadora*

Management of Arsenic enrich water for irrigation

Arsenic (As) maintains similarity with P as both are in the Group 15 of the Periodic Table. Application of P fertilizer thus has found to help in escaping As – bio-availability when applied through irrigation. Water management has key role to control As – toxicity particularly in rice field. Under deficit irrigation practice it has been found that As – loading in soil was reduced from ponding > intermittent ponding > saturation > aerobic cultivation. Low As content in leaf and grain was noted under intermittent ponding. According to Sarkar et al. (2012), imposition of intermittent ponding only at the vegetative stage is best as it resulted in a reduction in As concentration in straw and grain by 23% and 33%, respectively, over continuous ponding without a decrease in grain yield.

Biochar application is a novel approach, although this practice has numerous other benefits, particularly for upland crops. The ability of biochar to adsorb metals, particularly metalloids from contaminated aqueous solutions is related to electrostatic interactions between metal cations and carbon negative surface charge, ionic exchange between biochar surface protons and metal cations, and acidic oxygen groups, mineral impurities and basic nitrogen (N) groups (Xu et al., 2013; Agrafioti et al., 2014).

Total As concentration has also found to decrease (by 7%) when the water passed through irrigation channel amended with jute - mesh structure which trapped / adsorbed the particle prior to reach to the crop field. Increase in residence time by passing water through irrigation channels also found to lessen As concentration than field to field irrigation (Polizzotto et al., 2015).
Use of As hyper accumulator plant e.g. *P. vittata, Azolla, Chlorela* in rotation / combination with rice have found to escape the As bioavailability to crops (Lalith et al., 2018). Arsenic in irrigation water presents as As(III) which under aerobic condition oxidized to less soluble As(V). Irrigation with As enrich water thus creates more problems under submerged rice than other crops grown under aerobic condition in general.

Management of F enrich water for irrigation

Choudhary et al. (2019) has reported a review on fluoride in water. This focused that fluoride accumulation is characterized by tip and marginal necrosis that progress to leaf bases and later chlorosis or chlorosis along the leaf veins (Threshow, 1970; Miller, 1993). Fluoride toxicity causes reduction in root length and shoot length due to unbalanced nutrient uptake by seedlings (Sabal et al., 2006).

Technologies for fluoride removal or reduce fluoride toxicity from water are

A. Nalgonda Technique (Dahi et al., 1996): Alum (aluminum sulphate or potassium and aluminum sulphate) and lime (calcium oxide) are added and rapidly mixed with the fluoride contaminated water. Flakes develop (aluminum hydroxides) by subsequent gentle stirring and are removed by simple sedimentation. By combining sorption and ion exchange with some of the hydroxide groups produced, the main contents of the fluoride is removed along with the flocs.

B. Tri-calcium phosphate: The product is prepared by reacting phosphoric acid with lime. With 1% NaOH solution followed by gentle acid rinse, the medium is regenerated. 700 mg of fluoride / L can be eliminated.

C. Florex: A mixture of tri-calcium phosphate and Hydroxy -apatite, commercially known as Florex, had the ability to remove 600 mg of fluoride per liter and was regenerated with a 1.5% solution of sodium hydroxide.

D. Activated Carbon & Lime: Different types of activated carbon have been described as having a high fluoride removal capacity. Limestone has also been used to reduce fluoride concentrations in wastewater. Using naturally available materials, e.g. red soil that has found to remove substantial amount of fluoride followed by brick, fly ash and charcoal.
After removing the Flouride from the water the water can safely be used for crop irrigation.

Probability of micro irrigation for poor quality water use
Drip and sprinkler irrigation can be effectively used for poor quality water irrigation. The logic behind the techniques is supply of small water volume to meet water requirement of the crops

and thus stripping off the negative impact of poor quality water. However, to avoid clogging and other allied impacts, water quality guidelines has been established and given below:

Water quality evaluation scale for use in micro-irrigation

Problems and Related Constituents	Problem Severity		
	Low	Moderate	High
Clogging			
Suspended solids (ppm)	< 50	50-100	> 100
pH	< 7.0	7.0 - 8.0	>8.0
Manganese (ppm)	< 0.1	0.1 - 1.5	> 1.5
Iron (ppm)	< 0.2	0.2 - 1.5	> 1.5
Hydrogen sulfide (ppm)	< 0.2	0.2 - 2.0	> 2.0
Bacterial population (count per milliliter)	< 10,000	10,000 - 50,000	> 50,000
Crops sensitivity			
EC* (mmho/cm)	< 0.75	0.75 - 3.0	> 3.0
NO3-N (ppm)	< 5	5 -30	> 30
Specific ion toxicity			
Boron (ppm)	< 0.5	0.5 - 2.0	2.0 - 10.0
Chloride (meq/liter)	< 4	4 - 10	> 10
Chloride (ppm)	<142	142 - 355	> 355
Sodium			
Evaluated by Adj. SAR	< 3.0	3.0 - 9.0	> 9.0
Soil permeability			
EC* (mmho/cm)	> 0.5	< 0.5	< 0.2
Adj. SAR #	< 6.0	6.0 - 9.0	> 9.0

** TDS (approximately) in ppm = 640 x E.C. (dS/m or mmho/cm),*
#Adj. SAR is adjusted sodium adsorption ratio. It is calculated based on the concentrations of sodium (Na), calcium (Ca), magnesium (Mg), carbonate (CO_3), and bicarbonate (HCO_3) to account for dissolution of $CaCO_3$ from the soil or precipitation of CaC_3 from the water.

Sources: D.A. Bucks, F.S. Nakayama, and R.G. Gilbert. 1979. "Trickle irrigation water quality and preventive maintenance". Agricultural Water Management, Vol. 2:149-62;
F.S. Nakayama and D.A. Bucks. 1991. "Water quality in drip/trickle irrigation: A Review". Irrigation Science, Vol. 12:187-92;

Soil and Plant-Tissue Testing in California, H.M. Reisenauer (editor). 1978. Bulletin 1879, Division of Agricultural Sciences, University of California.

Conclusion

It is evident that owing to shortage of normal quality water, use of poor quality water in irrigation is imminent. Poor quality waters widely vary in availability and quality, as per its type and amount under a specific unit, different management strategies can be adopted for promoting its safe use for sustainable agriculture

References

Agrafioti E, Kalderis D, Diamadopoulos E. 2014. Ca and Fe modified biochars as adsorbents of arsenic and chromium in aqueous solutions. J Environ Manage. 146: 444–450.

Aslam, M. and S.A. Prathapar, 2006. Strategies to mitigate secondary salinization in the Indus Basin of Pakistan, A selective review, Research Report 97, IWMI, Colombo Sri Lanka

Ayers R.S. and D.W. Westcot, 1985. Water quality for agriculture, FAO Irrigation and Drainage Paper 29, FAO, Rome. 174 p., rev 1992.

Choudhary, S., Rani M, Devika Siva O, Patra, A., Singh, R K.and Prasad, S. K. (2019). Impact of fluoride on agriculture: A review on it's sources, toxicity in plants and mitigation strategies. International Journal of Chemical Studies, 7(2): 1675-1680.

Dahi E, Mtalo F, Njau B, Bregnhj H. Defluoridation using the Nalgonda Technique in Tanzania, Ecological Engineering. 2013; 52:211-218.

Lalith D. Suriyagoda B. Dittert Klaus and Lambers Hans (2018). Arsenic in Rice Soils and Potential Agronomic Mitigation Strategies to Reduce Arsenic Bioavailability: A Review. Pedosphere 28(3): 363–382.

Miller GW (1993). The effect of fluoride on higher plants with special emphasis on early physiological and biochemical disorders. Fluoride.26:3-22.

Polizzotto M L, Birgand F, Badruzzaman A B M, Ali M A. 2015. Amending irrigation channels with jute-mesh structures to decrease arsenic loading to rice fields in Bangladesh. Ecol Eng. 74: 101–106.

Sarkar S, Basu B, Kundu C K, Patra P K. 2012. Deficit irrigation: An option to mitigate arsenic load of rice grain in West Bengal, India. Agric Ecosyst Environ. 146: 147–152.

Sabal D, Khan TI. Saxena R. Effect of sodium fluoride on cluster bean (*Cyamopsis tetragonoloba*) seed germination and seedling growth. Fluoride. 2006; 39:228-230.

Threshow M. Environment and plant response, Department of Biology, University of Utah, 1970.

Xu X Y, Cao X D, Zhao L. 2013. Comparison of rice husk- and dairy manure-derived biochars for simultaneously removing heavy metals from aqueous solutions: Role of mineral components in biochars. Chemosphere. 92: 955–961.

Scientific planning of aquaculture activities for increasing water productivity

Rajeeb K. Mohanty
Principal Scientist (Aquaculture)
ICAR-Indian Institute of Water Management, Bhubaneswar-23
E-mail: rajeebm@yahoo.com

Aquaculture is one of the most vibrant sector of the global food production system, providing roughly 50% of the worldwide fish consumption. The dynamism of Indian aquaculture and capture fisheries sector has been marked by 18-fold increase in fish production in just seven decades, i.e. from 0.75 million tons in 1950-51 to 14.16 million tons in 2019-20. This resulted in an average annual growth rate of 4.35% over the years, thus putting India on the forefront of the global fish production scenario, only after China. Out of 14.16 million tons of total fish production, Inland fisheries sector contributes 10.43 million tons with an average annual growth rate of 7.3%. This rate is substantially higher than that of poultry (4.6%), pork (2.2%), dairy (1.4%), beef (1.0%), and even food grains (1.4%) over the same period. Freshwater aquaculture with a share of 34% in inland fisheries in mid 1980s has increased to about 90% in recent years. The three Indian major carps, *Catla catla*, *Labeo rohita* and *Cirrhinus mrigala* contribute to the extent of 85% of the total fresh water fish production, while others contribute the rest. Currently, only about 40 percent of the available potentially suitable area of 2.36 million hectares of ponds and tanks has been utilized under freshwater aquaculture. The national mean production levels from ponds has gone up from 600 kg/ha/year in 1975 to 3300 kg/ ha/ year at present, although there are examples of higher production levels up to 8–12 tons/ ha/ year. Globally, more than 8 752 000 ha freshwater ponds are in use out of which, about 850 000 ha pond area is under carp cultivation in India.

However, under the changing climate scenario, water scarcity has posed serious challenges to aqua food security and ecosystem sustenance, along with the threat from the population growth expected to reach 9.6 billion by 2050. In fact, uncertainty in monsoon rain due to climate change and limited availability of freshwater resources necessitate wise-use of land and water resources in aquaculture and warrants a more holistic approach to water management. Furthermore, in aquaculture sector, carp aquaculture is water-intensive and its future growth would be constrained by the freshwater availability.

As in other agro-climatic conditions, there is considerable scope for aquaculture in watersheds with / without integration of agriculture to improve water productivity. A range of technical options is available to increase aquacultural water productivity for a particular situation or hydro-ecological condition. The two major requirements in improving aquacultural water productivity are the blue water required for culture and the input management. Presently, on-farm water use in aquaculture can be as low as 500–700 l in super-intensive re-circulation systems and as high as 45,000 l of water per kilogram of produce in extensive pond system. The technology developed for composite fish culture in ponds/ tanks in which more than one type of compatible fishes is cultured together, is the most advanced and popular now a day in the country. Any perennial fresh water pond/ tank retaining water depth of more than 1.5 metres can be used for composite fish culture purpose. Even seasonal ponds/ water bodies/ WHSs can also be utilized for short/ long duration fish culture.

Composite fish culture-based agriculture and integrated fish farming not only accommodates crop diversification, enhance productivity, generate employment opportunity, increase income and provide nutritional security to resource poor farming community but also distribute the risk (both biological and economic), since two or more subsystems are involved instead of a single-commodity farming system. However, water productivity in this system can further be improved with scientific manipulation/ adjustment in stocking density, feed and water quality management, periodic growth and health monitoring, and finally input management. Practices not directly related to water management also impact water productivity because of interactive effects such as those derived from improvements in soil fertility, pest and disease control, species/ crop selection or access to better markets.

Composite Fish Culture under IFS

The most successful system of inland aquaculture is the polyculture (composite fish culture) of three Indian major carp species – *C. catla, L. rohita and C.mrigala* along with three Chinese carps (non-predatory, fast growing and compatible with IMCs) viz. silver carp (*H. molitrix*), grass carp (*C. idella*) and common carp (*C. carpio*). Indian carps such as *Catla catla*, *Labeo rohita*, *Cirrhinus mrigala*, and *Labeo calbasu* are cultured in the northern belt whereas *Labeo fimbriatus*, *L. kontius, Cirrhinus cirrhosa,* etc. in the southern belt of the country. Their farming is widespread and thus the systems differ according to the availability of the species, market demand, and local consumer preferences etc. In general, in a pond, the surface is occupied by floating organisms like plankton, the column region with live and dead organic matter sunk from the surface and the bottom with detritus or dead organic matter. The different trophic levels of the pond can be utilized for increasing the water productivity and profitability of fish culture. Therefore, composite fish culture is a polyculture system in which compatible fishes of different species having different feeding habits are selected and grown under one aquatic environment in the pond to exploit all types of food available in the different regions of the pond for maximizing fish production.

The aquatic vegetation, plankton, decayed organisms and other debris available in the surface, middle and bottom water layers are utilized as feed by the stocked surface, column and bottom feeder fishes. The best results in terms of fish production in this system results not only through a judicious combination of species, but also due to appropriate management techniques including pond fertilization, supplementary feeding and health care. On the basis of growth performance of different species, modifications are often made in stocking density, species ratio, fertilization schedule and supplementary feeding programme in different agro-climatic conditions.

The carp culture system as a whole is operated as a three-tier culture system where the practices are adopted for rearing fish during their different stages till they are harvested. Spawn (post larvae) are reared up to fry (2–3 cm) stage in nursery ponds, fry to fingerlings (8–12 cm) in rearing ponds and finally fingerlings to table-size fish (> 700g) in composite fish culture ponds or stocking ponds. Relatively smaller, seasonal ponds are mainly used for rearing spawn to fry stage and harvested after 2–3 weeks. Several crops (3–4) of fry are usually taken during the season. Pond fertilization by cattle manure and feeding with 1:1 mixture of oil cakes and rice bran is the usual practice. Fry raised in nurseries are reared up to fingerlings in slightly bigger ponds (0.05 – 0.1 ha) of seasonal or perennial in nature. Fingerlings are removed after 3 months and stocked in composite fish culture grow-out ponds.

Initially, under this system, average productions were around 1000 kg/ha/year. After extensive experimentations, the average production rate has been increased by 2-3 times. However, much higher production than this (10-12 t/ha/year) is also reported from commercial farmers of Andhra Pradesh and Punjab. Though possible, productions at this level not only deteriorate the pond productivity but also enhance the associated risk factor many fold. Therefore, a moderate production target without any significant environmental degradation is advisable. A production as high as 3000 - 3500kg/ha/5-6 months (two crops a year, i.e., 6-7 t/ha/yr) at farmer's field (with technical intervention of DWM, Bhubaneswar) has recently been obtained by stocking Indian major carps @ 7,500 fingerlings (70-85g size)/ha in the ratio of 30:30: 40: SF:CF:BF.

Rearing fish for 5-6 months instead of one year (market price of harvested fish in both case is almost same) not only minimizes the risk factor but also prevent pond's early environmental deterioration. Usually, to produce 500g-sized fish, the requirements are - one cubic meter water, one fingerling/2-3 advanced fry, 750g manure, 50-75g inorganic fertilizer, 1kg supplementary feed and 5-6 months' time. However, these requirements vary from site to site and largely dependent upon the degree of management. The technology of polyculture or composite culture of Indian major carps includes mainly the pond preparation, removal of predatory fishes by using suitable ichthyocide, fertilizing the pond with both organic and inorganic fertilizers, manipulation of stocking density, feeding the fishes with supplementary feed and periodic water quality and health monitoring.

Pond preparation

Perennial ponds that retain water throughout the year to a minimum depth of 1.5m are suitable. For fish culture, the waterweeds had to be removed from the ponds/tanks either with weedicides or manually. After removal of the weeds, the pond should be free from predator fished by dissolving Mohua Oil Cake @ 200 kg/Ac. After this, the pond is fertilized with both organic and inorganic fertilizers. Raw Cow Dung @ 3500 kg/Ac. is to be applied in the Pond/Tank. This is followed by application of inorganic fertilizers like Single Super Phosphate @ 120 kg/Ac. Add Ammonium Sulphate @ 100-120 kg/Ac. Generally, the inorganic fertilizers are added to tank in installments throughout the culture period. When the tank is fertilized in this manner, it develops proper natural food of the fish i.e. Plankton. The inorganic fertilizers are to be applied after 3 or 4 days of application of Raw Cow Dung. For good production, the pond water should have pH ranging between 7.5 – 8.00. In order to have this, lime will be applied in the pond as a basal @ 200 kg/Ac. per annum. The lime should be applied after 15 days of application of Mohua Oil Cake. Periodic liming @ 50 kg/ha and bi-monthly manuring with RCD @ 500kg/ha is essential in maintaining bloom. The lime also helps in the eradication of any fish parasites existing in the pond and enables proper reaction of fertilizers. Now the pond is ready for stocking.

Stocking Pattern

After 15 days of application of inorganic fertilizers, the seed should be stocked. As far as possible, pond should be stocked with surface feeders and their density should not exceed more than 30 %. Growth is normally affected if their proportion in the stock is more than 35%. Rohu feeds in the underwater are called a column feeder and do grow well in deeper water. Therefore, ponds having more than 2-meter depth of water need to be stocked with maximum 30% of rohu. In shallow ponds the stocking density of rohu should not increase more than 20% of the total stocking density. Bottom feeders such as mrigal and common carp are stocked at a higher ratio which may together account to about 40–50%. Freshwater prawn, *M. rosenbergii* can also be stocked as bottom feeder instead of mrigal and common carp, or with 50:50 combinations, which is highly profitable. Availability of aquatic weeds in the pond or in the vicinity decides the stocking density of grass carp. It is always desirable to keep 5 to 10% grass carp, and manages to feed it with aquatic weeds, green vegetables or even with land grasses.

It is seen that in aquaculture, as the number of fish is increased production of fish increases to a maximum and then decreases again. Under crowded conditions fish compete for the food supply, and they also suffer stress due to aggressive interaction. Under stress fish are found to eat less and grow more slowly, while in static ponds there is reason to believe that the excretory products of the fish may themselves tend to suppress their growth. Thus there is an optimum-stocking rate, which gives the highest production and the largest fish. Overcrowding may lead to biological crowding resulting in waste build up, decreased availability of feed and dissolved oxygen, deterioration of water quality etc., and hence it is advisable to stock 5000 - 7500 fingerlings per hectare of water spread area.

Feeding

The fish seed i.e. fry/ fingerling start feeding on the natural food in the water by occupying different ecological zones of the tank. However, natural food alone is not sufficient to achieve the expected production. Hence, supplementary feeds like floating feed or pellet feed or mixture of 40% Groundnut Oil cake (GOC), 55% Rice Bran (RB) and 5% fishmeal are fed to the fishes during the culture. The supplementary feed is to be fed in 1:1 ratio, twice a day. Supplementary feeding @ 4-3% of body weight in the initial 2 months of stocking and 3–2% of body weight from 3rd month onwards on daily basis is necessary for proper health and faster growth of the fish.

Fish health management

Outbreaks of communicable diseases are result of interactions between the three factors - the pathogen, a susceptible host the fish and the pre-disposing environmental condition prevailing in such ponds. Under high level of intensification the risk increases. In order to achieve optimum production, the fish must be kept as healthy as possible throughout the culture period which can be achieved through proper fish health management involving three sequential steps, viz., (i) prophylactic measures, (ii) fish health monitoring and (iii) treatment. Prophylactic measures include sanitation of ponds using disinfectant like bleaching powder or quicklime prior to stocking. Prophylactic therapeutic treatments against parasites and other microbial pathogens are done prior to stocking as well as during trial netting and subsequent handling.

Apart from adopting prophylactic measures it is essential to check the health status of cultured fish quite frequently. This helps in timely detection and diagnosis so that immediate treatment measures can be adopted depending upon the nature of the disease. Significant differences in growth rate among population of the same age may often be a sign of some chronic internal diseases. Diseased fish exhibit either or both physical and behavioral signs among which most common are (a) slowing down or a complete stoppage of feeding (b) loss of equilibrium, abnormal swimming pattern and (c) surfacing and scrapping against the bottom, sides or some objects in the pond. Common clinical symptoms shown by the fish are: (i) excess mucous secretions, (ii) change in normal coloration, (iii) erosion of scales, fins, part of skin etc., (iv) erosion of gill lamellae, discoloration of gills, (v) formation of cysts, patches over the gills, body etc. and (vi) abdominal swelling and bulging of eyes etc. These necessitate immediate diagnosis of the disease and the proper treatment.

Management of Rearing Environment

Proper management of rearing environment offers optimum environmental conditions for the growth and better health of the cultivated fishes. It also strengthens the defense mechanism of the fish body to fight against invading disease producing organisms. Eradication of predatory and weed fishes, disinfecting the pond, selection of quality and healthy seed for stocking, maintaining proper species ratio and stocking density, water quality regulation, proper feeding and proper handling are the various steps of this management measure. Though water exchange has no significant impact on growth, survival and yield, it is essential to maintain a cleaner aquatic environment. Therefore, water exchange criteria should be based on emergency basis ‘as and when required’, thus will have a significant impact on water productivity.

Water quality monitoring

Some of the physico-chemical parameters of water have their direct influence upon the fish health. Any abrupt and wider fluctuations of such values often cause state of stress in fish resulting sometimes in widespread disease outbreaks. Dissolved oxygen content, pH, turbidity, temperature, introduction of some chemicals, detergents, pesticides and naturally produced toxic products like hydrogen sulfide, ammonia, dinoflagellate toxins etc., are most potential stress related parameters. Excessive application of inorganic fertilizers and accumulation of organic matter in older ponds may cause over production of phytoplankton, appearance of algal and bacterial bloom etc., leading to dissolved oxygen (DO) depletion to lethal level. For health and optimum growth, the D.O. level should not drop below 4 mg/l.

Carbon dioxide concentration upto 20–30 mg/l can be tolerated by fish provided oxygen is near saturation. At lower levels of DO the toxicity of carbon dioxide increases. The optimum pH range is between 7.3 and 8.5 and liming agents may be applied to correct low pH. Ammonia concentration above 1 mg/l indicates organic pollution. Hydrogen sulfide toxicity increases with decreasing pH and it is harmful even at 1 mg/l concentration level. Making the pond environment more congenial and hygienic eliminates the risk of stress and provides safety to fish. Proper and timely management of soil and water by manipulating feeding, fertilization, liming, addition of water, aeration, bottom recking, etc., eliminates most of the environmental stressors and provides better and healthy environment for the healthy growth of fish. If possible the pond may be dewatered as it eliminates all the unwanted species of fish and other animals such as insects, molluscs, tadpoles and frogs at the same time sun drying of the bottom is an effective disinfection method. For making it more effectives freshly dewatered pond bottom should be treated with bleaching powder @ 500 kg/ha and then left to react for 7–10 days before refilling it. An interval of 5–7 days between the end of filling the unit with water and the stocking eliminates most of the obligatory pathogens from the environment.

Understanding the aquaculture pond dynamics

Aquaculture ponds are living dynamic systems that undergo series of chemical reactions and physical changes, thus exhibit continuous and constant fluctuations. Exchange of atmospheric gases (Oxygen, nitrogen and Carbon dioxide) with the pond water are vital to the process of fish metabolism and plant photosynthesis. Inorganic substances (minerals) dissolve from the pond walls and bottom while precipitation of dissolved minerals occurs. Physicals exchanges between the pond its surroundings include absorption of sunlight /radiant energy to fuel photosynthesis and supply oxygen with in the pond, heat exchange and volume changes caused by evaporation and precipitation (rain). Changes in the volume of a pond are very important as they affect the concentration of dissolved substances and correspondingly requirements for treatment. Hence, the pond dynamics not only depend on its own characters and conditions but also on the surrounding atmospheric weather conditions. Good production from aquaculture ponds can be achieved when the pond and surroundings make chemical and physical exchanges at a steady state. When all of the processes balance, a state of equilibrium is achieved. Pond equilibrium is the optimum set of conditions for aquaculture, a state completely in harmony with nature. By realizing the overriding significance of water chemistry, it is important to have a firm grasp of some basic concepts related to water quality parameters.

Temperature

Aquaculture organisms are cold-blooded animals. They can modify their body temperature to the environment in normal condition. Temperature tolerances of fish are broadly categorized into cold water, cool water, warm water and tropical water. For each species, there is a minimum and maximum tolerance limit, as well as an optimal temperature range for growth. Increase in temperature increases the activity level and the metabolism thus increases the growth rate of cultured species. If the temperature increases beyond the threshold limit of physical and nutritional tolerance, and if the environment does not improve the culture organisms may get infected by germs, swim in a disoriented way to the surface or due to exhaustion. If the temperature falls below optimum, the feed intake and metabolism reduces, resulting in poor growth and survival. During the rainy season, there is a greater possibility of occurrence of thermal stratification in pond water column, as well as the dissolved oxygen stratification. This is a point worth noting, since every 10°C increase in temperature doubles the rate of metabolism, chemical reaction and oxygen consumption in general. Water depth and water volume also affect the thermal capacity of the pond and the extent of light penetration.

Dissolved Oxygen dynamics

The only way that oxygen can be introduced from air to water is by diffusion. Likewise, oxygen is lost to the atmosphere when pond water has supersaturated with oxygen. The solubility of oxygen in water decreases with increase in temperature, humidity and depth. Oxygen is one environmental parameter that exerts a tremendous effect on growth and production through its direct effect on feed consumption and metabolism and its indirect effect on environmental conditions. Oxygen affects the solubility and availability of many nutrients. Low levels of dissolved oxygen can cause changes in oxidation state of substances from the oxidized to the reduced form. Low DO can be directly harmful to culture organisms or cause a substantial increase in the level of toxic metabolites. It is therefore important to continuously maintain dissolved oxygen at optimum levels of above 4.0 ppm.

Photosynthesis plays a major role in oxygen production; respiration of all living organisms in the pond is the major factor involved in oxygen consumption. Oxygen concentration in pond water exhibits a diurnal pattern, with the maximum occurring during the peak of photosynthesis in the afternoon and the minimum occurring at dawn due to night time respiration. Photosynthesis of phytoplankton is the major contributor of DO during the day and diffusion accounts for increases when DO is below saturation at night. Photosynthetic oxygen production is also significantly limited when a plankton die-off occurs. The phenomenon is commonly observed when a cyclone occurs. Under these conditions, flushing out decaying plankton, providing for additional aerators and aerating for additional hours may be necessary to maintain DO at optimum levels. When plankton density is high, it has a shading effect which limits the penetration of sunlight in water thereby reducing photosynthetic oxygen production in the bottom of the water column. High plankton density often results from high nutrient loads and other these conditions, large quantities of feed and fecal wastes are found on the pond bottom. This causes an increase in bacterial population and metabolic activity in the bottom sediments, which are several orders of magnitude higher than that in the water column. Consequently, DO consumption is much greater in the bottom sediment. Limited light penetration and increased DO consumption in the bottom may cause significantly lower DO compared to the top layer of the water column. Circulating the pond water helps remove or minimize stratification by agitators. It is found that the 4-HP paddle wheel aerator is capable of elevating the dissolved oxygen level from 0.05 to 4.9 mg/l within 4 hours in 0.5 ha Pond. It is also suggested that the low dissolved oxygen values in the aquaculture ponds be improved rapidly by combination of aeration and water exchange.

pH monitoring

The concentrations of hydrogen ions (H+)/ concentration of bases and acids in the water determines its pH. The The pH scale extends from 0 to 14 with 0 being the most acidic and 14 the most alkaline. PH 7 is a condition of neutrality and routine aquaculture occurs in the range 7.0 to 9.0 (optimum is 7.5 to 8.5). When water is very alkaline (> pH 9), ammonium in water is converted to toxic ammonia, which can kill fish/ prawn. On the other hand, acidic water (< pH 5) leeches metals from rocks and sediments. These metals have an adverse effect on the fishes' metabolism rates and ability to take in water through their gills, and can be fatal as well. At pH values below 4.5 or above 10, mortalities occur. At higher temperatures fish are more sensitive to pH changes. It is an important chemical parameter to consider because it affects the metabolism and other physiological processes of culture organisms. A certain range of pH (pH 6.8 –8.7) should be maintained for acceptable growth and production. In well-buffered ponds (with alkalinity over 50-100 ppm), pH typically fluctuates one or two units daily. As carbon dioxide is removed from the water, its pH increases. The highest pH of the day is typically associated with the highest level of dissolved oxygen. pH changes in pond water are mainly influenced by carbon dioxide and ions in equilibrium with it. pH can also be altered by (a) organic acids, these are produced by anaerobic bacteria from protein, carbohydrates and fat from feed wastes, (b) mineral acids such as sulfuric acid (acid-sulfate soils), which may be washed down from dikes during rains and (c) lime application. The pH should be monitored before dawn for the low level and in the afternoon for the high level. Normally, one should maintain the daily fluctuation within a range of 0.4 difference. Control of pH is essential for minimizing ammonia and H_2S toxicity.

Ammonia

One of the important stress factors is the increase of dissolved metabolic organics in culture water. It can increase ammonia and microorganisms. The best way to facilitate the removal of metabolic wastes in a pond is by flushing out water from the bottom. Constantly maintaining high DO in the pond through supplemental aeration and water exchange, enhances nitrification. Nitrification is a major mechanism for ammonia removal in well-aerated ponds. Ammonia is the second gas of importance in fish culture; its significance to good fish production is overwhelming. High ammonia levels can arise from overfeeding, protein-rich, excess feed decays to liberate toxic ammonia gas, which in conjunction with the fishes, excreted ammonia may accumulate to dangerously high levels undercertain conditions. Fortunately, ammonia concentrations are partially 'curbed' or 'buffered' by conversion to nontoxic nitrate ($NO3^-$) ion by nitrifying bacteria. Additionally, ammonia is converted from toxic ammonia (NH_3) to nontoxic ammonium ion ($NH4^+$) at pH below 8.0.

Hardness

Numerous inorganic (mineral) substances are dissolved in water. Among these, the metals calcium and magnesium, along with their counter ion carbonate comprise the basis for the measurement of 'hardness'. Optimum hardness for aquaculture is in the range of 40 to 400 ppm of hardness. Hard waters have the capability of buffering the effects of heavy metals such as copper or zinc which are in general toxic to fish. The hardness is a vital factor in maintaining good pond equilibrium. Hardness is important, especially in the culture of commercial species where, these species do not grow well. Hardness should be above 50 ppm and low hardness can be adjusted by the addition of lime or calcium chloride.

Turbidity

Water turbidity refers to the quantity of suspended material, which interferes with light penetration in the water column. In ponds, water turbidity can result from planktonic organisms or from suspended clay particles. Turbidity limits light penetration, thereby limiting photosynthesis in the bottom layer. Higher turbidity can cause temperature and DO stratification in ponds. Planktonic organisms are desirable when not excessive, but suspended clay particles are undesirable. It can cause clogging of gills or direct injury to tissues of prawns. Erosion can be the source of small (1-100 nm) colloidal particles responsible for the unwanted turbidity. The particles repel each other due to negative-charges: this can be neutralized by electrolytes resulting in coagulation. It is reported that alum and ferric sulfate are more effective than hydrated lime and gypsum in removing clay turbidity. Both alum and gypsum have acid reactions and can depress pH and total alkalinity, so the simultaneous application of lime is recommended to maintain the suitable range of pH. Treatment rates depend on the type of soil.

Redox potential

Redox Potential is an index indicating the status of oxidation or reduction. It is correlated with chemical substances, such as O_2, CO_2 and mineral composed of aerobic layer, whereas H_2S CO_2, NH_3, H_2SO_4 and others comprise of anaerobic layer. Microorganisms are correlated with the status of oxidation or reduction. With the degree of Eh, it is indicative of one of the parameters that show the supporting ability of water and soil to the fish/prawn biomass. In semi intensive culture photosynthetic bacteria plays an important role through absorption and conversion of organic matter into the minerals and nutrients as a secondary production, compared to the primary production of algal population. Photosynthetic bacteria exist particularly due to low oxygen level and high intensity of light and can significantly improve the culture environment.

Plankton management

Phytoplankton play a significant role in stabilizing the whole pond ecosystem and in minimizing the fluctuations of water quality. A suitable phytoplankton population enriches the system with oxygen through photosynthesis during day light hours and lowers the levels of CO_2, NH_3, NO_2 and H_2S. A healthy phytoplankton bloom can reduce toxic substances since phytoplankton can consume NH_4 and tie-up heavy metals. It can prevent the development of filamentous algae since phytoplankton can block light from reaching the bottom. A healthy bloom also provides proper turbidity and decreases temperature loss in winter and stabilizes water temperature. An ideal ratio of phyto & zoo plankton in a pond should be 10:1.

Table 1. Optimum aquaculture water quality parameters

Water parameter	**Optimum level**
Temperature	26-32 ^{0}C
Salinity	nil
Dissolved oxygen	>4.0 ppm
pH	7.5-8.5
Total Ammonia Nitrogen	<1.0 ppm
Total Nitrate Nitrogen	<5.0 ppm
Nitrite Nitrogen	<0.01 ppm
Sulphide	<0.03 ppm
BOD	< 10 ppm
COD	<70 ppm
Transparency	25-45 cm
Ratio of Phyto & Zooplankton	10:1

Water requirement and water productivity

In its broadest sense, water productivity aims at producing more food, income, better livelihoods and ecosystem services with less water. Water productivity is the net return for a unit of water used or the ratio of the net benefits from aquaculture systems to the amount of water used to produce those benefits. Physical water productivity is therefore defined as the ratio of aquacultural output to the amount of water consumed – 'more crop per drop' –, and economic water productivity is defined as the value derived per unit of water used. The term 'increasing or improving water productivity' implies how best we can effectively improve the yield of a crop with the water currently in use.

In this backdrop, an innovative research work was carried out at Balasore, since 2009, by a team of scientists from Directorate of Water Management (ICAR), Bhubaneswar. The aim of the project was to estimate the water requirement and water productivity along with feeding management for improving water quality and triggering compensatory growth performance of Indian major carps, giant freshwater prawn and black tiger shrimp in grow-out culture system. The approach of cyclic feed restriction and refeeding that triggers compensatory growth ultimately enhanced the yield by 16-18% and maintained water quality, thus minimizes the water requirement for exchange. This also helps in enhancing water productivity by 34%, preventing wastage of water and operational cost by 20-25% in grow-out aquaculture. Under BWMP, regulated water exchange has significantly higher net water productivity over periodic water exchange while, periodic water exchange has no significant impact on growth and biomass gain, but essential on demand basis to maintain a cleaner aquatic environment. Further, the team has estimated the water requirement (without hampering the growth, yield and water quality) of 6.5 m^3/kg biomass in composite freshwater fish and prawn culture at a stocking density of 5000 fingerlings/ha. This will give a new dimension to aquaculture industries and would help in minimizing the wasteful use of water in grow-out aquaculture

Water balance study

Commercial aquaculture ponds seldom receive direct inflow of water from streams. Further, aquatic weeds are disallowed from growing in and around edges of ponds, while water is rarely used for activities other than aquaculture. Thus stream inflow and transpiration are seldom major factors (Boyd & Gross 2000). Therefore, the general water balance equation, inflow = outflow ± change in volume (ΔV), was used to make precise estimates of water use by ponds for carp polyculture. Water use in aquaculture are mainly the total water use/ requirement (TWR), consumptive water use (CWU) and non-consumptive water use (NWU). TWR is the sum of all possible inflows to ponds such as precipitation (P), runoff (R), stream inflow, management additions or regulated inflows (I), and groundwater seepage (S_i). CWU includes the possible outflows such as evaporation (E), seepage (S_o), overflow (O_f), intentional discharge or regulated discharge (D), transpiration and water content in harvested biomass. Further, the difference between the total and consumptive water use, refers to non-consumptive water use (NWU). In embankment aquaculture ponds, runoff is negligible and groundwater inflow is also seldom a factor (Boyd & Gross 2000). Thus the appropriate equation is:

$$P+I = E + S_o + O_f + D \pm \Delta V \quad \ldots\ldots\ldots\ldots\ldots(1)$$

In this study, total volume of water use (precipitation + management additions or regulated inflows) and consumptive water use, CWU (evaporation + seepage + intentional discharge or regulated discharge + water in harvest biomass) was estimated. Average water in harvest biomass is about 0.75 m^3/t (Boyd et al. 2007) was taken into account. To estimate the CWU, a recording water level gauge was installed in each pond to measure the usual water loss (evaporation + seepage). Water level gauge was also used to record the outflow and inflow during water withdrawal and addition. Further, to separate the evaporation from the usual water loss, evaporation was estimated using the following equation:

Pond evaporation (mm) = Pond-pan coefficient × Class-A pan evaporation (mm) …………(2)

Pond pan coefficient of 0.8, most appropriate for ponds, was used in the above equation as suggested by Boyd & Gross (2000). The pond seepage was quantified by subtracting the evaporation loss from the total loss. Consumptive water use index (CWUI) that indicates the amount of water used per unit production of fish biomass was calculated as described by Mohanty (2015).

Water productivity and economic efficiency

To evaluate the efficiency of water management, the gross total water productivity (GTWP), net total water productivity (NTWP) and net consumptive water productivity (NCWP) is calculated in Indian rupee (INR m^{-3}) keeping the total volume of water used in to account as shown below: GTWP = Total economic value of the produce (INR) / Total volume of water used (m^3) ……..(3)

NTWP = Total economic value of the produce (INR) – Total production cost (INR) / Total volume of water used (m^3) ……………………………(4)

NCWP = Total economic value of the produce (INR) – Production cost (INR) / volume of consumptive water use (m^3) ……………….…(5)

Water budgeting in Aquaculture-based Integrated Farming System

A model study on ‘Aquaculture-based IFS’ was carried out (*under CRP on Water, Theme-5, ICAR-IIWM*) integrating aquaculture (carp polyculture), agriculture (*kharif* rice followed by green gram and vegetables), on-dyke horticulture (banana and papaya) and poultry ‘*Vanaraja’*. Out of System’s total crop water use (3.14×10^4 m^3 240 d^{-1}), the estimated TWU, consumptive water use index (CWUI) and productivity in carp polyculture alone was 2.3×10^4 m^3 240 d^{-1}, 2.6 m^3 kg^{-1} fish production and 2.86 t ha^{-1}, respectively. The estimated evaporation and seepage losses were 2.8 and 2.1 m^3 water kg^{-1} fish production respectively and contributed significantly to CWU. System as a whole, resulted in net profit of Rs.1,07,117 ha^{-1} with an output value - cost of cultivation ratio of 2.7 and net consumptive water productivity of Rs.16.2 m^{-3}. This integrated farming not only accommodates crop diversification, enhance productivity, generate employment opportunity, increase income and provide nutritional security to resource poor farming community but also distribute the risk (both biological and economic), since two or more subsystems are involved instead of a single-commodity farming system.

Further, out of four different fish production systems such as (1) IMC grow-out culture : single stock-single harvest system, (2) IMC grow-out culture : single stock-multi harvest system, (3) IMC grow-out culture : multi stock-multi harvest system, (4) intercropping of IMC-Minor carp; Multi Stock-Multi Harvest system (MSMH) was found to be more efficient, productive and profitable in terms of water use efficiency (0.57 kg m^{-3}), productivity (4.6 t ha^{-1}), FCR (1.51), total water footprint (998 m^3 t^{-1}) and net consumptive water productivity (INR 9.2 m^{-3}). Next to Multi Stock-Multi Harvest system, intercropping system of IMC-Minor carp was considered efficient, productive and profitable.

Options for improving water quality and production

Conventional earthen ponds, where fish are fed with supplemental feeds and without aeration, generate annual yields of 2000 to 3500 kg/ha. On a global scale, even in India, most ponds produce on an average closer to the lower end of this range. The challenge is to raise pond production by exploring the limits of fish production based on creating congenial water quality, natural pond productivity, and to increase feed efficiency.

Large-scale expansion of extensive pond aquaculture is not possible because of constraints associated with the availability of suitable land. Assuming an annual production of 2000 kg/ha, 5m^2 of pond area is needed to produce 1 kg fish. Raising the annual fish supply by 14 kg/capita, even if we conservatively assume that only 50% of this increase will be produced in extensive ponds, requires an additional 30 m^2/capita. Thus, a world population of 10 billion people would require an additional 300,000 km^2 of ponds. This analysis is conservative because it considers only productive water surface area, and not the additional area required for dikes, channels, roads and farm buildings, which would increase the need for land by an additional 20–30%. Considering growing population pressure and competitive uses of land in areas suitable for aquaculture development, such large-scale expansion of pond area is highly unlikely. Consequently, increased aquaculture production will have to come primarily from increased intensity rather than from added area and greater water consumption, while decreasing the quantity of fish caught for feed. The challenge is to raise productivity while maintaining environmental sustainability. Considering the current contribution of small-scale farmers to global production, a large fraction of the production increase must be realized through low-cost technologies.

Restricted feeding protocol using floating feed for improving water quality

Introduction of floating feed can change the feed and water management scenario in aquaculture. Feed comprises about 65% of the production cost. In addition to extra expense, water quality can deteriorate unnecessarily due to over feeding. Extruded, vacuum coated floating feeds offer the advantage of watching the feeding response as opposed to a sinking, steam -pelleted feed. Floating feed has many advantages over sinking feeds such as minimal wastage of feed, minimal deterioration of water quality, low FCR, easy to digest, faster growth, higher yield and water productivity. Further, one potential way of reducing operational cost/feed cost is to take advantage of the phenomenon of compensatory growth (CG). Compensatory growth offers the possibility of improving the growth rates of fish/prawn by a careful choice of feeding schedules/

protocol, in which periods of feed deprivation are followed by periods of satiation feeding. If CG can completely make up for growth lost during starvation, there could be an opportunity to save on fish feed by starving the fish and making up for lost growth when feeding resumes. Using CG is therefore, perceived as a way to increase water quality, water productivity and profits of aquaculture operations. Usually, compensation is improved when the duration of growth restriction is short and is not too severe. Otherwise, severely stressed fish and very young animals often fail to express CG.

Increasing pond productivity through biofloc technology

In aquaculture production systems where fish are fed a concentrated feed, nutrient recovery in harvested fish represents typically 25% of applied nutrients. Aquaculture can improve nutrient utilization efficiency by considering waste nutrients as resources and designing systems to promote recovery. Integrated agriculture–aquaculture farming is such an approach. Besides integration, intensification also enhances nutrient recovery. Biofloc technology (BFT), based on microbial control of water quality within the pond, is an approach toward intensification. Water exchange in BFT ponds is very low, with some systems operating with no water exchange for extended periods. Metabolic wastes from production animals stimulate the development of high-density microbial communities. From the perspective of microbial growth, metabolic wastes in aquaculture production systems are relatively rich in nitrogen compared to carbon. By adding carbonaceous substrates (e.g., molasses, cassava meal, bagasse, etc.) microbial production is enhanced while inorganic nitrogen, including potentially toxic ammonia and nitrite, are immobilized and hence controlled. In addition, many aquatic species obtain nutritional benefit from the microbial biomass. Protein utilization in BFT systems can be twice as high as in conventional ponds. Microbial flocs utilized by fish or shrimp contain significant levels of vitamins and minerals. These systems are considered to be environmentally benign because few nutrients are released to the outside environment.

Enhancing nutrient utilization

A minor fraction of the nutrients applied to semi-intensive ponds is retained in harvested production: 5–25% N, 20% organic carbon (OC) and 5–18% P. A large fraction of the input nutrients ends up in the sediment: 66–70% N, 38–46% OC and 35–86%P. The harvested animal production from ponds on a dry weight basis represents only a minor fraction (0.85–1.7%) of the primary production. Assuming that half of the production realized in ponds receiving supplemental feeds is based on natural foods available in the pond, only 0.4–0.8% of the primary production is harvested. After careful preparation of the pond bottom prior to stocking, removing accumulated organic matter through drying and scraping, the role of microbial flocs in BFT systems is replaced by a dense aerobic microbial community that develops on the pond bottom, and which contributes to shrimp nutrition.

Deploying submerged surfaces in ponds to stimulate the development of attached microbial communities (periphyton), increases pond production by 50–180%. Periphyton communities consist of bacteria, algae and other micro-organisms that utilize suspended and dissolved organic matter, reducing accumulation of organic matter at the pond bottom. Within these communities, autotrophic or heterotrophic biomass dominates, depending on light, dissolved oxygen, and nutrient availability. Compared to organic matter at the bottom, the organic matter trapped by substrates in the water column is decomposed in more oxygen-rich water, thus contributing to a beneficial microbial food web. Manipulating the Carbon:Nitrogen ratio of the water increases the production of both bio-flocs in the pond water and of bio-films on submerged surfaces. A further increase can be reached by increasing the submerged surfaces and by stocking the ponds with species using different niches in the aquatic food-web thus creating synergies. Carp polyculture systems are designed to exploit multiple spatial and feeding niches in aquaculture ponds. In pond systems, C: N ratio manipulation doubles protein input efficiency, substrate addition increases production 2–3 fold, and using the right mix of species in polyculture doubles production.

Conclusion

A wide-range of technical options is available to enhance aquacultural water productivity for a particular situation or hydro-ecological condition. Though species type, stocking density and input management influence water productivity, the two major requirements in improving aquacultural water productivity are the blue water required for culture and the input management, especially the feed. Minimization of unnecessary water exchange/ replenishment and taking advantage of the compensatory growth response, also perceived as a way to increase water productivity and profits in aquaculture operations. Addition of duckery to the pond system and utilization of nutrient rich pond water for life-saving irrigation to on-dyke horticulture and low-duty *rabi* crop in the adjacent field would further help in enhancing the system's overall water productivity. Further, Multi Stock-Multi Harvest system (MSMH) is found to be more efficient, productive and profitable in terms of water use efficiency, productivity, FCR, total water footprint and net consumptive water productivity.

Cost estimation, safety measures and maintenance of water conservation structures for enhancing agricultural productivity

D. C. Sahoo
Principal Scientist (SWCE)
ICAR-Indian Institute of Soil and Water Conservation, Research Centre, Koraput, Odisha
E-mail: dcsahoo@gmail.com

An estimate is a calculation or computation of the quantities required and expenses likely to be incurred in the construction of a work. It is necessary in order to have an idea about the financial requirement for executing the project. This is also needed for obtaining the approval and sanction of the competent authority. Further it helps in assessing feasibility of the project by way of computing benefit cost ratio. For viability of the project the B.C ratio should normally be more than1. If the estimated cost is higher than the funds available, then attempts can be made to reduce the cost by varying/changing the specification or reducing the work. They are not static, but have to be reviewed continually to keep them current. The actual cost is known only after the completion of the work in all respect as per the schedule and specifications. For detailed estimate the work is divided into different items of work and the quantities under each item are taken out and then an 'Abstract of estimate' is prepared at suitable rates. From the detailed estimate the quantities of various materials and labour required may also be calculated.

Importance of quality cost estimates

Accuracy in estimate is very important. The reliability of project cost estimates at every stage in the project development process is necessary for responsible financial management. Unreliable cost estimates result in severe problems in budgeting, planning and executing. Inaccuracy in preparing estimate, omission of items, changes in designs, improper rates etc. are the reason for exceeding the estimates. In framing a correct estimate, care should be taken to find out the dimensions of all items correctly and to avoid omissions of any kind f work or part thereof. Cost estimating is not an exact science; however, estimators are expected to prepare reasonable cost estimates that represent the cost to complete the project. These costs include those required not only for the contractor to construct the project but, also includes the costs for the purchase of right of way, mitigation of environmental issues and any other costs that will be incurred to complete the project. Project alternatives and their associated cost estimates must be thoroughly compiled by diligently using all of the available data, modifying that data with good judgment and using past cost estimating experience so that the cost estimates can be used with confidence. Coordination between the project planning, the design cost estimates and the specifications and policies that will be in place during the construction of the project is required.

Types of Estimate

It is the probable cost of the work which includes the labour cost, material cost and other charges. There are different types of estimates as detailed below:

i) Approximate or preliminary or rough estimate
ii) Detailed estimate

iii) Revised estimate
iv) Supplementary estimate

Approximate or Preliminary estimate or rough estimate

This type of estimate is necessary to decide the financial involvement and policy for administrative sanction by the competent administrative authority. Nearly correct/rough cost of the work calculated roughly by the concept of unit of work multiplied by unit rate of work. This estimate should show separately the cost of major components of work and cost of land if any. A brief report explaining the necessity and urgency of work is also submitted along with the site plan. The estimate is prepared from the practical knowledge and cost of similar works undertaken in near past.

Detailed estimate

This is the accurate estimate and based on the plan and drawing of the work. The quantities of item for each component of words are calculated from the dimensions taken from the drawling while the total cost is worked out in the form of abstract of cost. The rates of different item of works are taken as per schedule of rates available with the department. This schedule of rate is based on prevailing market rate for labour and material for finished item of works.

Normally 3 percent is added for unforeseen items under the head called contingencies. The total cost thus comprises of material and labour cost plus contingencies. This estimate is prepared for technical sanction and withdrawal of funds from competent authority and work is executed accordingly. This estimate is supported by (a) report of work (b) detailed specification (c) detailed drawing showing plan and section with complete dimensions (d) schedule of rate, and (e) analysis of rate for non-scheduled items.

Revised estimate

This estimate is also detailed estimate when the original sanctioned estimate is likely to exceed during the execution of work. The revised estimate is then prepared incorporating the component of work/rate which is responsible for the escalation of the cost. This is necessary for obtaining the revised sanction of authority.

Supplementary estimate

This is the first detailed estimate of the additional work in addition to the original one and is prepared when the additional work is required to supplement the original work as a result of the further development during progress of the work. The abstract of cost should show the amount of original estimate and the total amount including the supplementary amount for which sanction is required.

The following format is utilized for preparation of the estimate of various works.

i) Name of the work ………………

ii) Location of the work ………………
iii) Cost estimate ………………

Sl. No	Description /particular of item	Number	Measurement			Unit	Quantity	Unit Rate (Rs.)	Total Cost (Rs.)
			Length (Unit)	Width (Unit)	Height (Unit)				
1.									

Total ………...........
Contingencies (3%) ....…………
Grant total ....…………
Prepared by ………………
Checked by ………………
Approved by ………………

Analysis of rate

The determination of rate per unit of a particular item of work from the cost of quantities of material, cost of labourer and other miscellaneous petty expenses required for its completion is known as analysis of rate. A reasonable profit usually 10% of the total cost of labour and material for the contractor is also included in the analysis of rates. The cost of material is taken as the rates for delivery at the site of work and includes the cost at origin, cost of transport, loading, unloading, freight and taxes if any. The rates of material and labour varies from place to place, hence, the cost of work also varies from place to place. Normally, the analysis of rates known as schedule of rates is used for preparation of estimate. However, where such rate is prepared and enclosed along with the estimate.

Analysis of rates comprised of the following items:

1) **Cost of material:** In analysis of rates the cost of material is taken at site including carriage, local taxes etc. The cost of material is calculated depending upon the quantities and their nature.
2) **Cost of labour:** Labour required for each item depends on nature of work so the wages as per man hour required for particular item of work is taken into account while arriving the cost of work.
3) **Tools and plants and sundries:** A lump sum amount is provided in analysis of rates for tools and plants (T&P) and other petty items (sundries) which cannot be accounted in detailed estimate. Normally 2.5 % to 3% of labour cost is considered both for T&P and sundry charges for these items in analysis of rates. A provision for water charge at the rate of 1.5 % of the total cost is also added where water is not available at the site.
4) **Carriage:** If the construction site is located in a remote place then proportionately the analysis of the carriage of material may also be added.

5) **Contractor's profit:** The provision of 10% as contractor's profit may also be added to obtain the rate per unit of the item work. The material, which is supplied by the department, the contractor profit of 10% need not to be added on them.

Analysis of rate form

Standard specifications		**Description of material/ work**	**Per**	**Rate**	**Amount**
Quantity	**Size**				

Points to be considered while preparing estimate

These are the some of the points need to be considered while preparing an estimate for soil and water conservation works as well as while executing the works

- Materials should be taken from nearby market
- Cost of transport involved from the market to the site is to taken into account
- Cost of lead and lift
- Locally available material should be used as far as possible viz. stone for LBCD and contour stone wall
- Material at site register should be maintained for cement, steel rod etc daily and signature is to be obtained from the concerned person.
- Cost of curing is to be kept in mind while preparing estimate.
- Earthwork involved is to be measured as and when work is completed.
- The details of work done has to be entered in Measurement book for making payment to the party.
- Wide publicity is to be made for inviting quotation.
- Reliable and registered contractor should be awarded works
- Over writing in the Measurement book is to be discouraged
- While entries are cancelled in a particular page of Measurement book (MB) take the signature of the Officers and reason to be clearly recorded.

Safety measures and maintenance of water conservation structures

Following are the points to be considered for safety measures and maintenance of water conservation measures

- Soil and Water conservation measures need to be constructed to encounter sudden drop, excessive velocities and poor grass cover if vegetation is not capable to conduct concentrated water down the slope. Most desirable and suitable location of the water conservation measures should be selected.
- The construction water conservation measures should start from top of the catchment / field and proceed downwards. Diversion of runoff water may be made for upper catchment area if the area is unbunded to prevent the overflow damages
- Soil for construction be taken from borrow pits which may be located in upstream side in case of shallow and medium soils and on either sides in case of medium deep and deep soils

- The spacing between two conservation measures is expressed in terms of V.I or H.I. This would depend on soils, rainfall, slope of the land and vegetation during the period of erosive rains. However up to 25% extra V.I. can be provided for soils having high infiltration and good conservation farming practices like contour cultivation. In case of low infiltration soil, the spacing should be reduced by 15 % from the estimated value.
- In case of earthen bunding, borrow pits of equal size are excavated after leaving a uniform berm from the bund line. Usually a 3m berm is left between the bund line and the borrow pits. Berms between borrow pits should be kept as few as is practically to avoid bumpy bunds. The berms between borrow pits are retained to avoid concentration of the water towards depression
- Ramps are provided for the free passage of cattle, agricultural implements and bullocks-carts carrying seed and fertilizers into the fields and produce out of the fields
- Even though the water conservation measures are designed to store all the runoff water, surplusing arrangement are necessary as the high rainfall intensities occurring sometimes produce high rates of runoff. The structures are usually constructed in the lowest spaces in a holding and are termed as waste weir. The waste weir may be clear overfall stone weir, Channel weir, Cut outlet, pipe outlet and Ramp cum waste weir.

References

Singh, Gurmel, Venkataramanan, C., Sastry, G., and Joshi, B.P. (1990). Manual of Soil & Water Conservation Practices. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi.

Tideman, E.M. (1996). Watershed Management. Guidelines for Indian conditions. Omega Scientific Publishers, New Delhi-110 024.

Sharda, V.N., Juyal, G.P, Chandra Prakash, Joshi, B.P. (2007). Training Manual Soila Conservation & Watershed Management, Volume-II, published by the Director, CSWCRTI, Dehradun, Uttarakhand

Murty, V.V. N and Jha, M.K. (2009). Land and Water Management Engineering, Kalyani Publishers, Ludhiana

Suresh, R. Soil and water conservation Engineering. (1997). Standard Publishers Distributors, Delhi.

Creek irrigation system- Water management options for coastal ecosystem

Ranu Rani Sethi
Principal Scientist (SWCE)
ICAR-Indian Institute of Water Management, Bhubaneswar,
E-mail: ranurani@yahoo.com

Nearly 40% of the world's population lives within 100 kilometers of the coast, which increases pressure on natural resources of coastal areas. The increase in population density in these areas leads to loss of biodiversity, siltation, polluted water quality etc. Moreover, ccoastal regions face saline water intrusion as one of the major issues all over the world. Hence these areas are very sensitive in terms of managing natural resources. There are very little options available to intervene for increasing land and water productivity. Eastern coastal areas of India stretches 480km along the Bay of Bengal. Odisha, being one of the Eastern State, has geographical area of 155.71 lakh hectares of which total cultivated land is about 61.80 lakh hectares (39.69% of the total geographical area). The net area sown is about 54.24 lakh hectares constituting 34.8% of the geographical area of the State. Small and marginal farmers constitute more than 90% of the farming community. Even though soil quality is favourable for growing crops, still more than 80% of cropped land remained fallow during post monsoon and summer season. On an average, most of the area receives nearly 1000 mm of rainfall with 59 rainy days during monsoon season against potential evapotranspiration (PET) demand of 690 mm. During non-monsoon season, only 410 mm of rainfall is received against 1350mm of water demand. With this rich natural resources, fallow land dominates in the non-monsoon season. Hence a comprehensive water resource planning was developed for 3900 ha area located in coastal tract of Odisha, which lies within 15 km away from the coast line in Mahakalpada block of Kendrapara district, Odisha (India). Scientific planning of water resources could help to increase the cropped area which ultimately increased the farm income. Detail activities are given below.

Study area

The study was conducted in Mahakalapada block of Kendrapara district of Odisha. The area is situated at latitude & longitude range from 20.40^0 to 20.50^0 N and 86.45^0 to 86.75^0E respectively. The mean sea level is only 0-3m along the coast line. Mahakalapada is the most populous and largest in having geographical area of 490.57 sq. km. amongst all the blocks in Kendrapara district of Odisha. Mean annual rainfall (1994-2013) is 1409.58mm, out of which, 1236.735 (87.73%) is received during monsoon season (June-October). The maximum and minimum temperature varies upto 38.6^0C in May and 11.2^0C in January. Groundwater table depth varies from 1.2m to 3.5 m during February to May, whereas water level remains 0.5 to 1m above the ground surface during monsoon and post monsoon season.

Methodology

For comprehensive water resource planning, hydrological study through rainfall and runoff analysis; change detection analysis through remote sensing image classification analysis; periodic monitoring of soil and water quality in the study area was carried out. Water availability in creeks and existing water harvesting structures were measured and estimated. Then based on the crop water requirement, redesign of water harvesting structures and creeks were proposed for maximizing production from the study area.

Rainfall –runoff analysis

Daily rainfall data of 21 years (1994 to 2014) were analysed for Kendrapara district of Odisha. Monthly rainfall data for the period of 1994 to 2014 was considered for estimation of effective rainfall by using the FAO CROPWAT model. Curve number method was used for estimating runoff from rainfall depth developed by Soil Conservation Service (SCS 1964; 1972).

Spatial analysis of soil and water quality

Grid based soil samples (0-15 cm) were collected from 20 locations and analyzed for textural classes. The soil moisture characteristics curves were plotted for 0.33, 1, 2, 3,5,10 and 15 bar matric suction with moisture content by pressure membrane extractor. A total of 20 water samples (10 from surface creek and 10 from bore wells) were collected from the study area during the month of October 2013 (post monsoon) and March 2014 (Pre monsoon). The sampled underground wells, representing 30% of the total groundwater well numbers in the region were selected using a complete randomized approach. Sampling site geo-positions (latitude and longitudes) were determined by using a Global positioning system (GPS). Shallow groundwater levels were measured as the distance from soil surface to water surface using a water level indicator.

Water availability in creeks, sub creeks and water harvesting structures

Velocity of water was measured from different segments of Sunity creek and sub creek during November 2014, 2015 (post monsoon) and January 2015, 2016 (winter) by Current meter. There is presence of 65 numbers of water harvesting structures (WHS)/water bodies, which was delineated from toposheet and remote sensing image of the study area.

Design of Sluice gate structure

Presence of creeks is quite common in the coastal areas. It is used both for irrigation and drainage purpose in most of the coastal areas. Spatio-temporal variation in water quality from both surface (creek) and subsurface (hand operated bore wells) showed that creeks get salinized (EC of 6 to 27dS/m) from March onwards upto monsoon season. Ingression of saline water through creeks and drainage of excess water is checked by construction of sluice gate in the mouth of creek. The hydraulic design of creeks was proposed to carry the discharge of 25 m^3/sec of water.

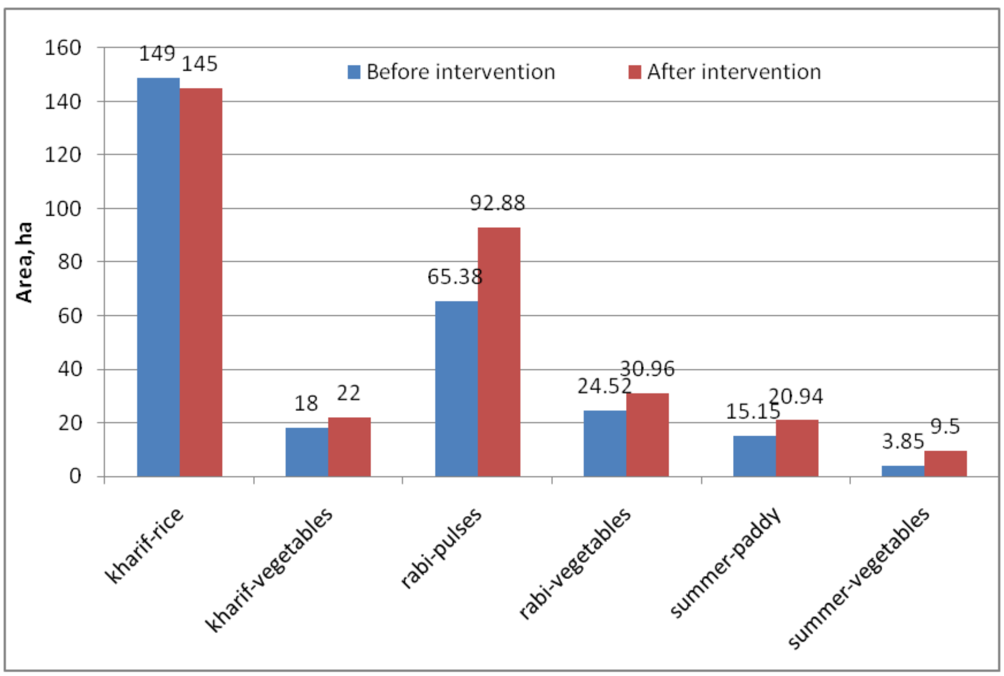
Optimization model (Simplex method) for Crop planning

Linear programming was solved through simplex method. Objective function was to maximize profit by considering constraints like water requirement, area, irrigation, salinity, fertilizer application and labor constraints etc. were considered while solving the model.

Crop water requirement

Crop water requirement was calculated based on the existing cropping pattern. Major crop in *kharif* season is paddy (1200 ha) and vegetables (122 ha) followed by pulses (green gram and black gram) in *rabi*, which covers around 500 ha and vegetable area for 65 ha. During summer season, only 50 ha area is under summer paddy and 150 ha area under vegetable crops leaving most of the areas under fallow. Total crop water requirement was estimated at 15376000 m^3, 2055000 m^3 and 1750000m^3 during *kharif*, *rabi* and summer season respectively. During *kharif* season, 80% of crop water demand is fulfilled from rainfall, whereas in *rabi* and summer, water availability in creeks and water bodies is sufficient to meet the irrigation demand. But due to ingression of saline water during high and low tides, available water in the creeks are saline, which is not used for growing crops in these region. Hence almost 57% of the cropped area and 85% of the cropped area remains under fallow during *rabi* and summer season respectively.

In order to bring more area under crops and to optimize the land allocation in these areas, a Liner programming model was developed with simplex algorithm for optimum land allocation to 3 existing major crops i.e. paddy, pulses and vegetables. Crop planning was proposed based on the irrigation water availability in natural creeks and water bodies. LP model with simplex algorithm was used for optimum land allocation to 3 existing major crops i.e. paddy (497 ha), pulses (289 ha) and vegetables (238 ha) for maximum production from the area. In order to meet the crop water demand, existing water harvesting structures were standardized for average capacity up to 7000 cubic meter with depth constraint within 2.5 to 2.8 m below ground surface.



Cropped areas after construction of sluice structure

Conclusion

A comprehensive water resource planning was developed for 3900 ha area, which is located within 15 kilometer away from the coast line in Sunity village of Mahakalapada block in Kendrapara. Study area is bounded by the natural creeks all along its boundary with 1320 ha of cropped area. But due to saline water intrusion through the creeks, *rabi* cropped area was restricted to only 565 ha. Hence in order to bring more area under crops during *rabi* and summer season, and to check the ingression of saline water through creeks, a sluice gate structure was constructed in the mouth of Sunity creek in collaboration with Department of Water Resources, Govt of Odisha. Spatio-temporal variation in water quality from both surface (creek) and subsurface (hand operated borewells) were monitored before and after construction of sluice gate structure. Then LP model with simplex algorithm was used for optimum land allocation to 3 existing major crops i.e. paddy, pulses and vegetables for maximum production from the area. In order to meet the crop water demand, redesign of existing water harvesting structures and creek hydraulic structures were proposed. Sample survey result showed that after operation of sluice structure i.e 2015-2016 there was 27 and 37% increase in *rabi* and summer cropped area. Analysis on agriculture land, production and cost during pre and post interventions showed that during first year there was 20% increase in cost of production from the sample survey area.

References

Todd DK (1974) Salt-water intrusion and its control. Water Technology/Resources. J Am Water Works Assoc 66:180–187

Cheng A, Halhal D, Naji A, Ouazar D (2000) Pumping optimization in saltwater-intruded coastal aquifers. Water Resour Res 36:2155–2165

Rejani R, Jha M K, Panda S N (2009) Simulation-optimization modelling for sustainable groundwater management in a Coastal Basin of Orissa, India. Water Resour Manag 23(2):235–263

Ru Y, Jinno K, Hosokawa T, Nakagawa K (2001) Study on effect of subsurface dam in coastal seawater intrusion. In: 1st Int conf saltwater intrusion and coastal aquifers, monitoring, modelling, and management (Morocco).

Sethi, Ranu Rani, Sahu Amiya Sagar, Srivastava, R.C.Srivastava, Das, Madhumita, Kumar, Ashwani and Tripathy, Jugal Kishore. (2014). Monitoring Land Cover Changes in Coastal Tract of Odisha Using Landsat ETM+ Imagery. *Current World Environment* Vol. 9(2), pp. 430-436.

Sethi, Ranu Rani Sethi, Srivastava, R.C., Das, Madhumita, Anand, PSB, Tripathy, Jugal Kishore. 2016. Comprehensive Water Resource Management in Coastal Ecosystem of Odisha: A critical review. Accepted for publication in the scientific journal Nature Environment and Pollution Technology (p-ISSN 0972-6268; e-ISSN 2395-3454).