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Irrigation in India and needed strategies for sustainable Development

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INTRODUCTION

In November 2017 issue, I covered basics, historical development of irrigation and touched upon some aspects of present day irrigation practices. In this issue, I conclude the article on irrigation by focusing on irrigation practices adopted in India and needed steps to overcome various impediments. Some suggested strategies are detailed for sustainable development of irrigation In India**.**

Indian agriculture economy has phenomenally improved, with the advent of Green Revolution. Our food needs, since more than three decades, are met by indigenous production. However, due to monsoon aberrations, enhanced demand due to uncontrolled population growth, we are experiencing an amount of stress, since a decade .The deceleration or near stagnation in our food production especially in the last one decade is worrying one and all. To ensure a stable production it is essential to identify the stress factors and suggest strategies to dilute them. Our agriculture and irrigation experts are aware of the negative factors responsible for the deceleration. They are however unable to translate their theoretical knowledge into result oriented achievements, as there is no proper mechanism to build a viable strategy involving all the stake holders, especially the scientific and technical experts, government channels and the farmer. Unless, the existing multi branched approach is replaced by an integrated well articulated development oriented single module we will continue to achieve results in the form of reports and research papers that have no linkage with the reality. The present write up, covers some of these aspects to achieve stability in our agriculture reliant economy. I do, however, reinstate that a sustainable development can be achieved only when all the stake holders, relentlessly work to plug the leaks from production to consumption.

IRRIGATION SCHEDULING

One of the major problems being faced by the Indian agriculture sector is due to improper irrigation scheduling. Irrigation scheduling is the technique to timely and accurately dose water to the crop and is the key to conserving water, improving irrigation performance and sustainability of irrigated agriculture. The importance of irrigation scheduling has long been recognized and a substantial part of irrigation research has been directed towards this aspect, in many countries (especially the developed). A range of scientific and practical tools have been developed to help farmers supply water more accurately to crops. In spite of these efforts, the application of the irrigation scheduling tools in practice has been well below expectations, due to lack of proper transfer of technology to the end users; the farmers.

International Commission on Irrigation and Drainage (ICID) Working Group for Sustainable Crops and Water use carried out detailed study with the specific aim to identify the constraints which negatively affect the application of available water saving techniques and identified solutions which lead to improved irrigation management in practice, in water deficit developing countries. To address the various aspects which play a role in the introduction of and in the successful application of irrigation scheduling, six themes were identified.

The main results can be summarized as follows

1. Selection of the appropriate irrigation scheduling technique should be based on the specific technology level of the farm and on the conditions of water availability and water supply.**2**. Irrigation scheduling techniques and models need to differentiate according to the irrigation method used. Monitoring and improving the performance of the irrigation method should be part of an integrated package to improve irrigation management at farm level. **3**. Under conditions of limited water supply, salinity and variable rainfall, accurate irrigation scheduling techniques need to be used to minimize yield reductions and to optimize sustainable use of available water. **4**. A process of interactive communications and participatory research involving researchers, system managers, extension workers and farmers is needed to successfully adopt scientific scheduling methods.**5**. Most collective irrigation systems cannot adopt crop-based and water saving methods. Modernization of the irrigation system is required to provide flexible water delivery and greater autonomy for the users.**6**. Effective irrigation scheduling and water delivery require rules and regulations for flexible water allocation which are determined by a set of social, cultural and institutional conditions (**Source**: Irrigation scheduling: From theory to practice. Proceedings; http://www.fao.org/docrep/w4367e/w4367e02.htm#executive summary)

The above norms are to be essentially put in to practice to ensure proper irrigation scheduling. These details are given before we go in to the practices being followed in India, as such information helps to better understand our successes and shortcomings, and encourage intellectuals to come out with apt measures. We start with a report released by THE INDIAN COUNCIL OF AGRICULTURAL RESEARCH (ICAR) in 2001.Even though the report/ brief projects a dismal scenario, we do believe the resilience power of our society can bail us out. But, for that one and all, especially technical experts and public representatives, need to introduce various precautionary and remedial measures by encouraging participatory management.

Sustaining India's Irrigation Infrastructure

Water, as an input to agriculture, is critical for sustaining the food security. India faces the daunting task of increasing its food grain production by over 50 per cent by 2020. Increasing competition for water in agriculture, industry, domestic and environment uses is already manifested in inter- and intra-sector, basin, state, district and village level conflicts.

These will escalate further as India's annual per capita water availability goes below water scarce threshold level of 1700 cubic meter by about 2020-2025. In six of the country's 20 major river basins (with less than 1000 cubic meter of annual per capita availability), water resources are under stress and depleting. By the year 2025, five more basins will become water scarce and by 2050, only three basins in India will remain water sufficient. Supply expansion, to meet expanding needs, is constrained by availability and rising economic and environmental costs associated with its development and use. The status of irrigation infrastructure and prospects for its sustainability, both physical and financial, for future water-food security is the issue under focus.

IRRIGATION INFRASTRUCTURE

Existing status

Since 1950, India has made direct public investment of Rs 88100 crores (in five decades) in providing major, medium and minor irrigation infrastructure with an irrigation potential of 91 MHa. India Water Vision, 2025 estimated the gross water demand for multiple uses to double in 25 years (starting from 2000) with corresponding investment needs of Rs 20000 crore per year. As of now (starting of 21st century), India's irrigation infrastructure is expanding by 1.8 Mha of irrigation potential with a public outlay of Rs 7000 crore per annum. Current annual expansion is one-third less than the maximum growth achieved in the past. Deceleration in irrigation potential created through major and medium schemes started during 1980s as a consequence of declining real government expenditure on this sector.

Amidst competition from non-agricultural uses in households, industry and environment, supply of irrigation will have to keep pace with the targeted annual agricultural growth rate of over 4% in the Tenth Five Year Plan. To achieve this growth rate, irrigation sector should grow by at least 5% per annum, given 1% growth in rain-fed sector, Demand-supply management in water sector and efficiency in its every use is critical for providing sustainable water-food security to the country.

More importantly, existing and expanding irrigation infrastructure has to be physically and financially sustained for improving their efficiency. Yet concerns are emerging on the physical condition of the irrigation infrastructure created so far.

Vicious cycle

India's irrigation sector is caught in a vicious cycle. Inadequate funding for Operation & Maintenance (O&M) over years has resulted in the neglect of maintenance and upkeep of the irrigation system leading to deterioration in the quality of irrigation service. Physically, the irrigation and drainage system is not able to receive and deliver the planned quantity of water matching with the demand pattern. Poor irrigation service, often not matching with the crop water requirements over space and time, has resulted in low productivity of crops and income to the irrigators. Resultant dissatisfaction coupled with weak institutional linkage leads to under assessment of demand for water rates as well as low recovery of whatever is assessed. Progressive fall in the cost recovery increases revenue deficit causing adverse impact on O&M funding for maintenance works.

Deferred maintenance of surface irrigation infrastructure over years has led to further deterioration of its physical service. This is witnessed by stagnating or falling irrigation coverage affecting agricultural growth in several regions. Surely, with future expansion in food production growth critically depending on the performance of irrigation sector, what is happening to the physical status of existing and expanding irrigation infrastructure does not augur well for India's future food security and agriculture performance**.** Vicious cycle in irrigation sector needs to be broken by empowering the stakeholders to maintain and manage the scarce water resource. Stakes are high for the users to collectively use, account and pay for it and claim their due share for system maintenance. Existing system offers no scope to integrate this process. This has implications for the sustainability of irrigation infrastructure created and added upon annually. Policy directions are needed as follows before the available options further narrow down.

- Irrigation systems (major, medium and minor) need to be restored to the satisfaction of users along with simultaneous institutional development for effective transfer of the irrigation management. Donor driven institutional initiatives obviously cannot sustain for long.
- Farmer Organizations need to be empowered to assess the irrigation coverage, revise water charges, raise water rate demand and collect receipts. Streamlining of accounting procedure to link cost recovery and O&M funding in the budgeting process is essential.
- Irrigation department should be legally empowered to identify all water user categories for broadening the revenue base and enforce quantitative measurement of water supply, charging and collection from bulk users to start with, for realizing full cost recovery.
- Any funding for irrigation development with Central assistance should be linked with mandatory institutional development as above for smooth turning over of the system to the users.

Development of institutional frameworks for an efficient use of existing and expanding supplies is central to enhance and sustain the economic and welfare contributions of scarce water resources in India. Policies to reform irrigation sector are already evolving in different states. How quickly and genuinely the institutional reforms are pursued to cover all sources and uses of water will determine India's future water and food security.

(**Source**:Policy-Brief-15-iCAR;December,2001;http://www.ncap.res.in/upload_files/policy_brief/pb15/pb15.htm)

The above information from ICAR, released beginning of 21st century projects a gloomy picture, as against often released rosy statements by policy makers. With this as base input, let us look in to specifics presented by the government channels, manning irrigation.

IRRIGATION IN INDIA

In the last fifty years, the share of Indian agriculture in gross domestic product has decreased, but extensive use of High Yielding Variety (HYV) seeds, modern irrigation technology, and fertilizer have contributed in increasing the agricultural productivity and achieving self-sufficiency in meeting food demand. Given increasing trend of population, policy makers find it imperative for India to achieve higher agriculture production and continue to meet the food security objective of the country; and indicated that irrigation will play a key role in future in achieving higher yield and sustaining the food security. Many states register a decrease in irrigation intensity (IRI), and much of the decrease are noticed in states like Himachal Pradesh, Orissa, Tamil Nadu and Maharashtra. In these states, the proportional irrigated area is not high except in Tamil Nadu. The opportunity cost of increasing the irrigation intensity is higher than increasing the net irrigated area. As a result, Net Irrigated Area (NIA) has increased in these states with the development of minor irrigation. In West Bengal, however, IRI has increased by 39% in the post 1997 period. One may argue that the higher opportunity cost of increasing the extensive margin leads to higher irrigation intensity. The alternative hypothesis is that high endowment of irrigation land increases the reliability of irrigation water and induces higher irrigation intensity. There is an amount of fluctuating trend, which needs to be stabilized through a holistic approach.

Irrigation refers to the supply of water from Indian rivers, tanks, wells, canals and other artificial projects for the purpose of cultivation and agricultural activities. In country such as India, 64% of cultivated land is dependent on monsoons. The economic significance of irrigation in India is namely, to reduce over dependence on monsoons, advanced agricultural productivity, bringing more land under cultivation, reducing instability in output levels, creation of job opportunities, electricity and transport facilities, control of floods and prevention of droughts.

Irrigation Projects in India are classified into three categories viz. Major, Medium and Minor Irrigation. Projects which have a Cultivable Command Area (CCA) of more than 10,000 hector are termed as Major Projects, those Irrigation Projects which have a CCA of less than 10,000 hector but more than 2,000 hector are termed as Medium projects and those Irrigation Projects which have a CCA of 2,000 hector or less are known as Minor projects. A broad assessment of the area that can be ultimately brought under irrigation, both by surface and ground water, made by the various States in nineteen sixties has indicated that ultimate irrigation potential of the country would be of the order of 113m.ha (million hectare). However, the ultimate potential is 139 m.ha, the increase being primarily due to upward revision in assessed potential of minor ground water schemes and minor surface water schemes to 64m. ha. and 17m.ha., respectively. Minor irrigation projects have both surface and ground water as their source, while Major and Medium projects mostly exploit surface water resources.

Sustainable development in Irrigation

For the survival of the country, there is an urgent need to implement and plan irrigation strategies for now, and in future, as the population continues to grow. But that should not be at the cost of degradation of the present available resources of land and water, which means the natural resources that we have, should more or less remain the same after 50 or 100 years and beyond. This concept is termed "***sustainable***", which was not much of a problem earlier when compared to the resources the demand was less. But now it is reversed and for devising any planning strategy the constraints have to be kept in mind. As an example, the utilization of ground water may be cited. In many regions of India, there has been alarming withdrawal of ground water for meeting demands of irrigation and drinking water demand than that which can be naturally recharged. This has led to rise of further problems like arsenic and fluoride contamination. Since ground water recharge by natural means takes a long time, perhaps years and even decades, there is little hope of regaining the depleted table near future.

Next we look into the options available to the irrigation engineer for development of irrigation facilities within the constraints.

FUTURE DIRECTIONS

The question that is to be resolved is this: Are we capable of producing the required amount of food grains for the country? Apart from spreading the network of irrigation system further into the country, there is an urgent need on research- for better seeds, better water management and distribution practices, low cost fertilizer etc., Nevertheless, the possible options available to water resource engineer to meet the future irrigation and food requirement may, therefore, include evaporation control and reduction and losses during conveyance of water through channels, recycling of water, inter basin transfer, desalination of sea-water in coastal areas, rainfall by cloud seeding, improved technology, etc. Loss of top soil due to erosion is one of the forms of degradation that can be contained on a limited scale but problems of salinity, alkalinity, water logging, etc. reduce the productivity. The future lies in considering and bringing under cultivation additional area and considering intensified production on existing good agricultural land and water resource system optimization.

Constraints of land and water

The total geographical area of land in India is about 329 million hectare (M-ha), which is 2.45% of the global land area. The total arable land, according to an estimate made by the Food and Agricultural Organization (FAO), made available through the web-site ***Aquastat***, is about 165.3 M-ha which is about 50.2 % of the total geographical area (the average world figure is 10.2%). The web-site that may be checked for this and relevant data is that of FAO:

(**Source:** http://www.fao.org/ag/agl/aglw/aquastat/countries/india/index.stm)

India possesses 4% of the total average annual run off in the rivers of the world. The per capita water availability of natural run off is at least 1100 cubic meters/yr. The utilizable surface water potential of India has been estimated to be 1869 cubic km. But the amount of water that can actually be put to beneficial use is much less due to severe limitations imposed by physiographic, topographic, interstate issues and the present technology to harness water resources economically. The recent estimates made by the Central Water Commission indicate that the water resources utilizable through surface structures is about 690 cubic km only (about 36% of the total ground water is another important source of water).

Ground water is another important source of water. The quantum of water that can be extracted economically from the ground water aquifers every year is generally known as ground water potential. The preliminary estimates made by the Central Ground Water Board indicate that the utilizable ground water is about 432 cubic km. Thus the total utilizable water resource is estimated as 1122 cubic km. It must be remembered that this amount of water is unequally spread over the entire length and breadth of the country.

Of the total 329 M-ha of land, it is estimated that only 266 M-ha possess potential for production. Of this, 143 M-ha is agricultural land. It is estimated that 85 M-ha of land suffers from varying degrees of soil degradation. Of the remaining 123 M-ha, 40 M-ha is completely unproductive. The balance 83 M-ha is classified as forest land, of which over half is denuded to various degrees.

It is alarming to note that the per capita availability of land is half of what it used to be four decades ago. This would further reduce as our country's population continues to grow. At present 141 M-ha of land is being used for cultivation purposes. Between 1970-71 and 1987-88 the average net sown area has been 140.4 M-ha. The need for production of food, fodder, fibre, fuel in the crop growing areas has to compete with the growing space required for urbanization. The factors of land degradation, like water logging, salinity, alkalinity and erosion of soils on account of inadequate planning and inefficient management of water resources projects will severely constrain the growth of net sown area in the future.

Classification of irrigation schemes

Irrigation projects in India are classified into three categories –major, medium & minor, according to the area cultivated .The classification criteria has been detailed earlier.

The ultimate irrigation potential of the country from major and medium irrigation projects has been assessed as about 64 M-ha. By the end of the ninth plan period, the total potential created from major and medium projects was about 35 M-ha. The ultimate irrigation potential from minor irrigation schemes have been assessed as 75.84 million ha of which partly would be ground water based (58.46 million ha) and covers about two thirds. By the end of the ninth plan, the total potential created by minor irrigation was 60.41 million ha.

Major and medium irrigation projects vis-à-vis minor irrigation projects

While formulating strategies for irrigation development the water resources planner should realize the benefits of each type of project based on the local conditions. For example, it may not always be possible to benefit remote areas using major/medium projects. At these places minor irrigation schemes would be most suitable. Further, land holding may be divided in such a way that minor irrigation becomes inevitable. However, major and medium projects wherever possible are to be constructed to reduce the overall cost of development of irrigation potential.

According to the third minor irrigation census carried out in 2000-01, there are about 5.56 lakh ***tanks*** in the country, with the most occurring in **1**. West Bengal: 21.2 percent of all the tanks in the country;**2**. Andhra Pradesh& Telangana: 13.6; **3**. Maharashtra: 12.5; **4**. Chhattisgarh: 7.7; **5**. Madhya Pradesh: 7.2; **6**. Tamilnadu: 7.0; **7.** Karnataka: 5.0

(This data has been gathered from the web-site of the Ministry of Water Resources, Government of India: http://www.wrmin.nic.in/).

Due to nonuse of 15 percent tanks nearly 1 M-ha of Irrigation potential is lost. Another, around 2 M-ha of potential is lost due to under utilisation of tanks in use. Loss of potential due to nonuse is more pronounced in Meghalaya, Rajasthan and Arunachal Pradesh (above 30%), whereas loss of potential due to under utilisation is more than 50 percent in case of Gujarat, Nagaland, Rajasthan, A&N Islands and Dadar and Nagar Haveli. It also appears that the maintenance of the tanks has been neglected in many parts of the country and their capacity has been reduced due to siltation. It has been estimated that about 1.7 M-ha of net area has been lost under tank irrigation due to drying up of tanks and encroachment of foreshore area. Some advantages of minor irrigation should also be kept in mind. These are: small investments, simpler components, labour intensive, quick maturing and most importantly it is farmer friendly.

On the other hand, it is seen that of the assessed 64 M-ha of irrigation potential that may be created through major and medium projects, only about 35 M-ha have so far been created. Hence a lot of scope for development in this sector is remaining. These may be realized through comprehensive schemes including storage, diversion and distribution structures. Some of these schemes could even be multi-purpose thus serving other aspects like flood control and hydro power.

OUTLOOK OF THE NATIONAL WATER POLICY

Our country had adapted a national water policy in the year 1987 which was revised in 2002. The policy document lays down the fact that planning and development of water resources should be governed by the national perspective. Here we quote the aspects related to irrigation from the policy.

1. Irrigation planning either in an individual project or in a watershed as a whole should take into account the irrigability of land, cost-effective irrigation options possible from all available sources of water and appropriate irrigation techniques for optimizing water use efficiency. Irrigation intensity should be such as to extend the benefits of irrigation to as large a number of farm families as possible, keeping in view the need to maximize production. **2**. There should be a close integration of water use and land use policies. **3**. Water allocation in an irrigation system should be done with due regard to equity and social justice. Disparities in the availability of water between head-reach and tail end farms and between large and small farms should be obliterated by adoption of a rotational water distribution system and supply on a volumetric basis, subject to certain ceilings and rational pricing. **4**. Concerted efforts should be made to ensure that the irrigation potential created is fully utilized. For this purpose, the command area development approach should be adopted in all irrigation projects. **5**. Irrigation being the largest consumer of fresh water, the aim should be to get optimal productivity per unit of water. Scientific management of farm practices and sprinkler and drip system of irrigation should be adopted wherever feasible. **6.** Reclamation of water-logged/saline affected land by scientific and cost effective methods should form a part of command area development programme.

Command Area Development Programme (CADP)

This scheme, sponsored by the central government was launched in 1974-75 with the objective of bridging the gap between irrigation potential created and that utilized for ensuring efficient utilization of created irrigation potential and increasing the agricultural productivity from irrigated lands on a sustainable basis. The programme envisages integrating various activities relating to irrigated agriculture through a multi-disciplinary team under an area development authority in a coordinated manner.

For an overall appreciation of an entire irrigation project it is essential that the objectives of the CAD be kept in mind by the water resources engineer.

Participatory irrigation management (PIM)

Any irrigation project cannot be successful unless it is linked to the stakeholders, that is, the farmers themselves. In fact, people's participation in renovation and maintenance of field channels was the established practice during the pre-independence days. However, the bureaucracy encroached on this function in the post-independence period and a realization has dawned in recent times that without the participation of farmers, the full potential of an irrigation scheme may not be realized. Though a water resources engineer is not directly involved in such a scheme, it is nevertheless wise to appreciate the motive behind PIM and keep that in mind while designing an irrigation system. The national water policy stresses the participatory approach in water resources management. It has been recognized that participation of the beneficiaries would help greatly for the optimal upkeep of irrigation system and utilization of irrigation water. The participation of farmers in the management of irrigation would give responsibility for operation and maintenance and collection of water rates from the areas under the jurisdiction of the water user's association of concerned hydraulic level. It may be mentioned that more than a decade back the state governments of Andhra Pradesh, Goa, Karnataka, Tamilnadu, Rajasthan and Madhya Pradesh have enacted legislations for the establishment of the water user's associations. Subsequently, many other states have introduced these associations. The sustainability and success of PIM depends on mutual accountability between the water user's association and the irrigation department of the concerned state. The success of the PIM is also linked to the introduction of rotational water supply and water charges with rationalized establishment costs.

MANAGEMENT OF WATER FOR IRRIGATION

Of the two resources –land and water, management of the former is largely in the domain of agricultural engineers. Management of water, on the other hand, is mostly the purview of the water resources engineer who has to decide the following:

• How much water is available at a point of a surface water source, like a river (based on hydrological studies)? • How much ground water is available for utilization in irrigation system without adversely lowering the ground water table? • For the surface water source, is there a need for construction of a reservoir for storing the monsoon runoff to be used in the lean seasons? • What kind of diversion system can be constructed across the river for diverting part of the river flow into a system of canal network for irrigating the fields? • How efficient a canal network system may be designed such that there is minimum loss of water and maximum agricultural production? • How can excess water of an irrigated agricultural fields be removed which would otherwise cause water logging of the fields?

In order to find proper solution to these and other related issues, the water resources engineer should be aware of a number of components essential for proper management of water in an irrigation system.

Pricing of water

This is more of a management issue than a technical one. After all, the water being supplied for irrigation has a production cost (including operation cost and maintenance cost), which has to be met from either the beneficiary or as subsidy from the government. Since water is a state subject, every state independently fixes the rates of water that it charges from the beneficiaries, the remaining being provided from state exchequer. There are wide variations in water rate structures across states and the rate per unit volume of water consumed varies greatly with the crop being produced. In some states water cess, betterment levy, etc. are also charged. Hence, there is an urgent need of the water resources planners to work out a uniform principle of pricing irrigation water throughout the country, taking into account all the variables and constraints.

Procedure for setting up a major/medium irrigation project scheme in India

The central design organization of each state desiring to set up an irrigation project shall have to prepare a detailed project report of the proposed irrigation scheme based on the document "Guidelines for Submission, Appraisal and Clearance of Irrigation and Multipurpose Projects" brought out by the Central Water Commission. This report has to be sent to the project appraisal organization of the Central Water Commission.

It may be noted that a project of the magnitude of a major or medium irrigation scheme has wide impacts. Hence, the techno-economic feasibility report should also be supplemented with "Environmental Impact Assessment Report" and "Relief and Rehabilitation Plan". The project proposal submitted to the Central Water Commission shall be circulated amongst the members of the advisory committee of the ministry of water resources for scrutiny. Once the project is found acceptable it shall be recommended for investment clearance to the planning commission and inclusion in the five year plan/annual plan. (This section has been adapted from the information provided in the Ministry of Water Resources, Government of India web-site: http://wrmin.nic.in/).

(Main Source: India's Irrigation Needs and Strategies for Development; Version 2 CE IIT, Kharagpur)

In nut shell, from the details given above it is evident that in theory all the concerned are well aware of the importance of irrigation in India. However, the well-articulated irrigation scheduling is not implemented at execution level, due to various hurdles created by one and all. Unless, we reorient our implementation schedule, it would be difficult to achieve the projected targets. To achieve this goal in India we have to go for highly innovative technological initiatives to maximize production, by optimally utilizing the available precious input, namely, water. This can be achieved by encouraging our farming community to go for Precision Irrigation and Precision Agriculture. Some pertinent details are given below, hoping our farming community, who on an average hold one to two hectares of good quality agriculture land adopt these precise techniques, to maximize output.

STRATEGY FOR ENSURING BETTER OUT PUT THROUGH INNOVATIVE TECHNOLOGY

Precision Irrigation

The science of irrigation is well understood and irrigation technologies today are mature and very robust. However, concerns over water availability and water quality increasingly require more efficient use of water resources in irrigated agriculture.

Precision irrigation is not a new term in irrigation, as being precise about the uniform application of water has long been a goal of irrigation science. The new dimension of precision irrigation is accounting for the spatial dimension of water management, i.e., applying water based on the site-specific needs of a given location in the field. While the scientists describe precision irrigation as conceptually simple, they report that it has been primarily a research issue emerging in the early 1990's, with the majority of development done in continuous move in irrigation systems because they are particularly amenable to site-specific approaches because of their current level of automation. There are limited examples of commercialization, with the implementation efforts. Precision irrigation in fixed irrigation systems, used particularly on small farms or in high value crop production systems (e.g., tree fruit) has been limited. The research focus has been primarily on the control aspects of precision irrigation, with more efforts including real-time monitoring of soil and crop conditions to trigger site-specific irrigation. They recognize the most serious limitation to the execution of precision irrigation is lack of site-specific production functions that optimize water use at a given site at a given time resulting from an insufficient knowledge base to make management decisions. Commonly, whole field recommendations are applied on a more spatially precise scale. They emphasize that precision irrigation systems must incorporate agrochemical (fertilizer and pesticide) applications to be cost effective and therefore profitable. Position and alignment technologies are required to use spatially indexed data to set application rates for various sites within a field. The underlying notion is that improved irrigation water use efficiency in agriculture can be achieved by better targeting of water both spatially and temporally to more precisely meet the site-specific water requirements of plants while concomitantly improving environmental quality of irrigated cropland. Some scientists call this approach to irrigation precision irrigation, which they defined in terms of "site-specific water management, specifically the application of water to a given site in a volume and at a time needed for optimum crop production, profitability, or other management objectives at that specific site". The underlying rationale for precision irrigation is the presence of spatial variability within an irrigated field that affects water availability (sufficiency or excess) to a crop, limits crop yield or quality thereby affecting crop water demand, or regulates water application due to erosion, runoff, leaching or other environmentally sensitive problems. Common sources of within field variability derive from variation in soil properties and topography, either naturally occurring or induced by human management (e.g., compaction, erosion, organic matter depletion) that in turn regulate soil water holding capacity, soil and terrain hydrologic properties, and nutrient supply.

(**Source**: http://literatur.ti.bund.de/digbib_extern/dn046667.pdf & Landbauforschung Völkenrode, Special Issue 340, 2010)

Precision irrigation improves the crop yield. More water does not necessarily equal a better crop. You need to give the plant the exact amount of water it needs to ensure optimal growth. Over or under watering stunts growth of the plants. With fertilizer the situation could be even worse as too much fertilizer can induce plant toxicity. Precision irrigation conserves both water and fertilizer. It also improves crop yield. Take cotton for example. If you water cotton too much it will grow into a big plant but produce little cotton. With cotton you want to stress the plant and even dry it out. Only when it feels it is going to die, does the plant release all its cotton. Grapes for wine are another example. If you over water them they grow large but do not produce enough of the sugar which is important for wine making. So, precision irrigation is not just to save water, it is also for the more precise application of water. If you water improperly you damage the quality of the crop. It is possible to grow rice more efficiently using less water with precision irrigation. Most farmers irrigate with little idea as to how much they really need. Many are afraid of applying too little water so they irrigate too much. Some rely on agricultural consultants who recommend a general default amount, which is usually quite inaccurate. If they do not rely on consultants, they simply emulate what other local farmers do or rely on experience.

To achieve better results we need to make use of the two main parts to a precision irrigation system — the physical infrastructure that delivers the water to the plants and the control and management system which operates it. The control and management system itself consists of three sub-units: monitoring, growth management and control.

There are solutions today that can provide farmers with a wealth of raw data but little practical advice. Unfortunately, most of this information is very complex and most farmers don't know how to interpret the data provided and derive from it how much to irrigate. Most farmers are not very hi-tech savvy and they require simple systems to operate. They need a system that can process all the relevant information and give them simple advice regarding how much to irrigate their fields – 2mm, 4mm etc. Our goal must be to use sophisticated graphs, maps and data to provide simple recommendations regarding how much water to use for the next 7 days. This will be accomplished by the development of a sophisticated DSS module (decision support system). Unfortunately, this vital input is not in existence until recent times , mainly because existing systems were much too expensive for farmers to afford. Sophisticated sensors, communications gear, controllers and software are required. All together this equipment is very costly. However, in the last few years prices have declined. In addition today there is much easier access to big data. In the past farmers had a hard time accessing local weather data as well as information regarding land types and water sources. Today there are websites that provide all this information, making it much more accessible .Finally farmer's awareness has increased. They are more conscious today of the need to conserve water, increase yields and reduce pesticides. They now realize they need PI systems to optimize yield per amount of irrigation/fertilization, otherwise they will not survive. (**Source**:https://www.linkedin.com/pulse/precision-irrigation-solution-water-shortage-lior-doron/

Since Precision Irrigation is aimed at in maximizing farm output without degrading the quality of the land Precision Irrigation helps in having **Precision Agriculture**.

Precision farming is still only a concept in many developing countries and strategic support from the public and private sectors is essential to promote its rapid adoption. Successful adoption, however, comprises at least three phases including exploration, analysis and execution. Precision agriculture can address both economic and environmental issues that surround production agriculture today. Questions remain about cost-effectiveness and the most effective ways to use the technological tools we now have, but the concept of "doing the right thing in the right place at the right time" has a strong intuitive appeal. In the light of today's urgent need, there should be an all out effort to use new technological inputs to make the 'Green Revolution' as an 'Evergreen Revolution'. Ultimately, the success of precision agriculture depends largely on how well and how quickly the knowledge needed to guide the new technologies can be found. Precision farming provides a new solution using a systems approach for today's agricultural issues such as the need to balance productivity with environmental concerns. It is based on advanced information technology. It includes describing and modeling variation in soils and plant species, and integrating agricultural practices to meet site-specific requirements. It aims at increased economic returns, as well as at reducing the energy input and the environmental impact of agriculture (**Source:** http://jabonline.in/admin/php/uploads/170_pdf.pdf)

Precision agriculture (PA) is a farming management concept based on observing, measuring and responding to inter and intra-field variability in crops. The goal of precision agriculture research is to define a decision support system (DSS) for whole farm management with the goal of optimizing returns on inputs while preserving resources. The practice of precision agriculture has been enabled by the advent of GPS and GNSS. The farmer's and/or researcher's ability to locate their precise position in a field allows for the creation of maps of the spatial variability of as many variables as can be measured (e.g. crop yield, terrain features/topography, organic matter content, moisture levels, nitrogen levels, pH, EC, Mg, K, etc).Similar data is collected by crop yield monitors mounted on GPS-equipped combine harvesters, arrays of real-time vehicle mountable sensors that measure everything from chlorophyll levels to plant water status, multi-, and satellite imagery.This data is then used by variable rate technology (VRT) including seeders, sprayers, etc. to optimally distribute resources.(**Source**: https://en.wikipedia.org/wiki/Precision_agriculture).

Status of Precision Irrigation in India and probable future scenario

Post green-revolution era agriculture in India is facing a technological fatigue for two reasons; a) high rates of ground-water depletion and b) Soil salinity due to excessive irrigation in some pockets. Rapid socio-economic changes in some developing countries are creating new opportunities for application of precision agriculture (PA). The wide scale appeal of sustainable practices in agriculture and the newer developments in providing low cost/robust sensor based systems are likely to provide the necessary fillip in future agriculture world-wide. Currently the wireless sensor network (WSN) system has high probability of economic viability for high value crops. Despite the widespread promotion and adoption of precision agriculture, the concept of precision irrigation or irrigation as a component of precision agricultural systems is still in its infancy, in India. This can be changed if precision irrigation is given due importance by both the government and farmers. Precision irrigation system with robust components such as, sensing agricultural parameters, identification of sensing location and data gathering, transferring data from crop field to control station for decision making and actuation and control decision based on sensed data will find application in future agriculture. Thus the great potential of integrating the precision farming with WSN to interpolate over a large area for spatial decision making need to be tapped for making agriculture attractive in future.(Precision irrigation system with robust components such as, sensing agricultural parameters, identification of sensing location and data gathering, transferring data from crop field to control station for decision making and actuation and control decision based on sensed data will find application in future agriculture. Thus the great potential of integrating the precision farming with WSN to interpolate over a large area for spatial decision making need to be tapped for making agriculture attractive in future.

(**Source**:www.researchgate.net/publication/221927923)

As detailed above in India 80 % of the farming community holds 1 to 2 hectares of cultivable land. Because of this they find it difficult to switch over to sophisticated farming practices, including mechanization of farming activities. Before advocating heavy mechanized implements it is to be kept in mind that usage of heavy machinery leads to compaction of soils, making soil mantle less porous and the land significantly degradable. So, small and middle class farmers should be encouraged to use lighter mechanized farming implements, using good quality implements manufactured in Coimbatore (Tamilnadu) and high quality drip and sprinkler irrigation tools of Jain agriculture tools industry. Precision irrigation and precision agriculture can be first introduced in Punjab and Haryana, where farmers are more enterprising and then use their experiences to motivate farmers from eastern and southern states. This should be our main strategy during the next two to three years.

To make affordable and easily usable mechanized implements it is essential to encourage mechanical engineering and information technology students of IIT and other recognized institutes to develop multi faceted Robots to help the farmers to enhance quality farming operations. Area specific weather details and impact of undulatory topography on water dynamics it is essential to have map production units at mandal level to help the farmers on a weekly basis. All these developments can be achieved if there is a good co-ordination between all the stakeholders.

CONCLUSIONS

As population is growing unabated, demand for food products would enhance significantly. To meet the demand it is essential to introduce various water conservation and safety measures, as water available for irrigation is still monsoon dependent. Measures should be taken to make water management independent of monsoon rains, as monsoon aberrations have increased in the recent past. It is essential to introduce new varieties of cropping pattern that need water in lesser quantities. Instead of courtesy visits to countries like Israel, Australia by officials and elected representatives, we need to invite experts from these countries to practically demonstrate in different segments of our country various technical measures being adopted in arid tracts of these countries. Research in irrigation and agriculture should go hand in hand and come out with region specific strategies through on field experiments, in co-ordination with outside experts. The co-operation should start and end in the field and not confined to purely lab based modeling studies. Farmer participation in decision making needs to be encouraged to ensure proper utilization of irrigation facilities. Instead of the presently followed authoritative and centralized administrative procedures, we need to introduce farmer friendly socio-economic measures, in the form of quality advices and quality products. It is time we make it mandatory to adopt new irrigation techniques and mechanized farming (through co-opearative societies) to arrest agony for the farmer in the form of wastages, losses and below average production of agriculture products. It is time to encourage Precision Irrigation and Precision Agriculture techniques to precisely plan and execute various spatially and temporally variable state of the art technologies. If these measures are not taken at the earliest we are bound to face considerable problems in meeting our demands.

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Compliance with Ethical Standards

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