EFFICIENT AND PRODUCTIVE WATER USE FOR SUSTAINABLE WATER RESOURCES MANAGEMENT IN INDIA

S Masood Husain[1], Navin Kumar[2] and Chaitanya K S[3]

ABSTRACT

India is home to 1/6th of the humanity and its attainment and sustenance of food, energy and water security has a larger bearing on achieving 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals. India has largely succeeded in achieving food security with over five-fold increase in food grain production after attaining independence. Amongst other inputs, expansion of irrigated agriculture has contributed significantly to this. However, irrigated agricultural sector has been struggling with deep seated problems such as low water use efficiency and poor standards of management and maintenance of infrastructure.

Irrigation sector accounts for lion's share of water utilization in India even though domestic and industrial water demands are on the rise. Any saving in water use in the irrigation sector releases substantial quantity of water for meeting growing demands of other sectors. No realistic national level assessment of overall irrigation efficiencies is possible due to presence of multitude of players and lack of consensus on utilization data among the States, especially in water stressed river basins.

Achieving food, water and energy security and adapting to climate change while preserving robust health of environment are going to be major challenges ahead. This paper explores the utility of Water-Energy-Food nexus as a conceptual tool to understand the inter-dependencies, linkages and synergies between various sectors and what can be done to ensure sustainable water resources management. Specific instances of the nexus at regional and basin scales are discussed. Further, the paper proposes that water productivity alongside water use efficiency should gain currency and become part of sustainable water resources management in India. The paper also discusses the constraints in estimating 'Agricultural Water Productivity' and suggests the way forward to monitor the same.
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Keywords : India ; micro irrigation ; sustainability ; water-energy-food nexus ; water use efficiency ; water productivity

1. INTRODUCTION

'The waters in the sky, the waters of rivers, and water in the well whose source is the ocean, may all these sacred waters protect me' so goes an ancient Indian hymn offering prayers to the deity of water (Rig-Veda 7.49.2). Humanity has come a long way from the fear of the unknown to scientific understanding of natural processes and putting natural resources to use for betterment of human welfare. The inevitable cause of human socio-economic development is leading to intensive use of limited natural resources often in an unsustainable manner requiring their protection and sustenance.

[1] Chairman, Central Water Commission and Chairman, Cauvery Water Management Authority, 2nd Floor(S), Sewa Bhawan, Sector-I, R.K.Puram, New Delhi - 110066; E-mail: chairman-cwc@nic.in

[2] Member(Water Resources), Cauvery Water Management Authority, 9th Floor(S), Sewa Bhawan, Sector-I, R.K.Puram, New Delhi – 110066 ; E-mail: navinkumar-cwc@nic.in

[3] Deputy Director, Inter State Matters-2 Directorate, Central Water Commission, 5th Floor(S), Sewa Bhawan, Sector I, R.K.Puram, New Delhi - 110066; E-mail: chaitanyaks-cwc@gov.in

2. WATER RESOURCES SCENARIO IN INDIA

India is home to over 17% of the world population but it has only around 4% of the world's fresh water resources. India receives an average annual precipitation of about 1170 mm which corresponds to around 4000 billion cubic metres of water. There is considerable variation in distribution of rainfall, both temporally and spatially. Central Water Commission (CWC), an attached office of Ministry of Water Resources, River Development & Ganga Rejuvenation, Govt. of India made an assessment of average annual water availability in the country as 1869 billion cubic metres (CWC, 1993), out of which, it is estimated that owing to topographic, hydrological and other constraints, the utilizable water is estimated as 1137 billion cubic metres, comprising of 690 billion cubic metres of surface water and 447 billion cubic metres of replenishable ground water (CGWB, 2017).

India has largely succeeded in achieving food security for its growing population. Creation of storage projects played a pivotal role in mitigating droughts by ensuring availability of water for irrigation and other needs. Out of the required storage of 450 billion cubic metres to utilise the utilizable surface water resources of 690 billion cubic metres, live storage capacity of 257.812 billion cubic metres has been created till date which comes to about 213 m^3 per capita live storage based on 2011 census.

Table 1. Sector wise projected future water demands for the years 2010, 2025 and 2050, Report of the National Commission on Integrated Water Resources Development, 1999

Sector	Water Demand in BCM					
	2010	**%**	**2025**	**%**	**2050**	**%**
Irrigation	557	78.45	611	72.48	807	68.39
Domestic	43	6.06	62	7.35	111	9.41
Industry	37	5.21	67	7.94	81	6.86
Power	19	2.68	33	3.91	70	5.93
Others	54	7.61	70	8.30	111	9.41
Total	**710**		**843**		**1180**	

For the country as a whole, India has just enough utilizable water to meet future water demand up to the year 2050. However, given the spatial and temporal variability, many pockets of India are already severely water stressed. With population growth, industrialization, urbanization, lifestyle improvements and change in dietary habits, water demands of domestic and industrial sectors are on the rise and inter-sectoral competition for water and inter-state river water sharing disputes are also on the rise.

The per capita availability of water has decreased from 5177 cu. m. /year in 1951 to 1545 cu. m. /year in 2011. With the projected population growth, it may further go down to around 1340 cu. m. and 1140 cm. by the year 2025 and 2050 respectively (Parliamentary Standing Committee on Water Resources, 2017) .Climate change is likely to alter the hydrological cycle even though impact assessments are highly uncertain. It is inevitable that more storages need to be created and inter-basin transfer of water from surplus to deficit basins needs to be taken up, to tackle temporal and spatial variability of available water.

As seen from the projected sectoral future water demands in the Table 1, irrigation sector's share of the total water utilization is projected to come down to around 68%

by the year 2050. At the same time, aggregate irrigation water demand will increase with growing needs of food and fibre. The real challenge lies in balancing water demands of various sectors on a sustainable basis without adversely affecting the water, food and energy security of the country.

The overall water use efficiency in surface water based irrigation is generally estimated around 35-40% and in ground water based irrigation around 65-70%. Studies for realistic national level assessment of irrigation water use efficiencies could not be made due to presence of multitude of players and lack of consensus on utilization data among the competing basin States, especially in the water stressed river basins. Water resources projects are planned executed and managed by the State Governments as per their priorities and resources available with them. 'The Union Government renders assistance to States which is technical, advisory, catalytic and promotional in nature'. (Parliamentary Standing Committee on Water Resources 2017)

3. INITIATIVES FOR IMPROVING WATER USER EFFICIENCY

Improvement of water use efficiency is one of the thrust areas of the Govt. of India which is reflected in the unveiling of 'National Water Mission' as one of the 8 missions under 'National Action Plan on Climate Change' with 'increasing water use efficiency by 20% in all sectors' as one of the five identified goals.

Govt. of India is currently implementing a centrally sponsored scheme on micro irrigation under Pradhan Mantri Krishi Sinchayee Yojana (PMKSY), with an objective to enhance water use efficiency in the agricultural sector by promoting appropriate technological interventions like drip & sprinkler irrigation among farmers.

While adoption of micro irrigation techniques help in improving field application efficiency of irrigation water, lining of canals and adoption of Piped Irrigation Network (PIN) help in improving conveyance efficiency of irrigation water. Some notable initiatives taken by the States are (i) doubling of irrigated area through adoption of technology driven, community based integrated micro irrigation under Ramthal Project, Karnataka which is Asia's largest drip irrigation project, (ii) mandatory use of MI in Sanchore, Rajasthan for effective utilization of Narmada water brought from Sardar Sarovar Dam in Gujarat resulting in increase of the Culturable Command Area (CCA) from 1.35 lakh hectares to 2.46 lakh hectares (iii) making drip irrigation mandatory for sugarcane cultivation over 3 lakh hectares in Maharashtra, (iv) implementation of integrated solar based MI scheme in Haryana on a pilot basis in the commands of different canal outlets etc.,

Further, innovative ways of financing micro irrigation techniques are given a serious thought. A dedicated 'Micro Irrigation Fund' was set up which can be accessed by the States for innovative integrated projects, including projects in the 'Public Private Partnership' (PPP) mode.
CWC has been encouraging water auditing and benchmarking of irrigation projects by publishing general guidelines for the same as also the guidelines for improving water use efficiency in irrigation, domestic and industrial sectors.

CWC in consultation with other central organizations, State Govt. departments, private organizations brought out 'Guidelines for Planning and Design of Piped Irrigation Network (July, 2017)' for improving conveyance, distribution and application efficiencies of irrigation water. An international workshop with the collaboration of ICID was held in March 2017 at CWC Headquarters, New Delhi which had provided valuable inputs in the preparation of the guidelines. Piped irrigation network in comparison to canal irrigation network offer advantages of higher water use efficiency, regulated and controlled water supply for ensuring water to tail end farmers, minimal seepage and evaporation losses, minimal requirement of land acquisition etc., Adoption of piped irrigation wherever technically feasible is being promoted.

In addition, strengthening of Participatory Irrigation Management (PIM) as a non-structural intervention is being promoted through creation of water user associations and providing hand holding support so as to prepare them to take over the irrigation assets created under command area development works which will lead to overall saving in irrigated water.

4. UTILITY OF WATER-ENERGY-FOOD NEXUS AS A CONCEPTUAL TOOL FOR SUSTAINABLE WATER RESOURCES MANAGEMENT IN INDIA

4.1 The Concept

'The water-food-energy nexus is an approach to consider the interactions between water, food and energy, while taking into account the synergies and trade-offs that arise from the management of these three resources, and potential areas of conflict' (Reinhard at 2017)

In view of increasing competition for finite natural resources, adoption of water-food-energy nexus has become essential for realisation of many interlinked Sustainable Development Goals (SDGs) viz., SDG 2 on Ending hunger, SDG 6 on Access to clean water and sanitation for all, SDG 7 on Affordable and clean energy for all and SDG 13 on combating climate change and its impacts.

The word 'nexus' has its origin in Latin which conveys a meaning of 'binding together'. There is no doubt in saying that water, energy and food are inextricably linked to each other, more so, when realization comes to the fore that underpinning natural resources are limited and non-renewable in the short or medium term. As such the concept of water-food-energy nexus is not new and it was inherent in the development of Bhakra, Hirakud, Nagarjuna Sagar and many other multipurpose projects in independent India. These along with other technological advancements and inputs enabled India to achieve water and food security besides generation of cheap hydro power. However, the 'nexus' approach never made foray into the management practices largely because much attention was directed towards the development of water resources projects without much budgetary outlays for their operation and maintenance. Over time, sector-by-sector approach has taken over the planning and investment decisions.

There is a growing realisation across the world about the need to move away from 'sector-by-sector' approach to 'nexus' approach considering the interactions between water, food and energy. Water-food-energy nexus has the potential to emerge as a very useful conceptual tool to the aid of policy makers dealing with water, food, energy and related sectors for better understanding, systematic analysis of inter-sectoral interactions, generation of various scenarios and choosing the best among them for better and coordinated management of natural resources.

'Nexus interactions are complex and dynamic, and sectoral issues cannot be looked at in isolation from one another. It is about balancing different resource user goals and interests – while maintaining the integrity of ecosystems'. (FAO 2014)

Under ideal conditions, individual farmers tend to adopt cropping pattern based upon input prices, natural endowments of the region, output prices of the produce etc., However, if input resource prices are distorted by Government interventions for eg., provision of subsidies or assured market for agricultural produce, it leads them to take sub-optimal decisions. Many a time interventions are originally devised for larger causes such as achieving food security, socio-economic development of backward regions or sections of the society. However, due to lack of nexus approach such interventions may lead to unsustainable practices such as over drawl of groundwater, non alignment of cropping pattern with natural endowments of the region etc., jeopardizing the original cause itself in the long run.

In short, advantages of adopting nexus approach are as under:

(a). Enables to achieve goals related to a sector through targeted interventions in a related sector.

(b). With its flexibility and lack of a fixed framework provides new cross sectoral perspectives.

(c). Forces policy makers to think of tradeoffs & synergies and impacts of decisions across all related sectors

(d). Promotes coordination among multitude of institutions/ agencies and in a way promotes integrated land and water resources management.

(e). Promotes involvement of all stakeholders.

(f). Helps in filling existing knowledge gaps, promotes adoption of new technologies and generates cross sectoral data.

(g). Enables sharing of experiences and learning from best practices else where.

(h). Promotes optimal and efficient utilization of natural resources and thereby maximizes productivity and minimizes wastage

(i). There are certain limitations to nexus approach viz.,

(j). Nexus approach enables decision making after conducting systematic analysis. Sometimes requisite data may be hard to come by and available data may not be reliable and policy-relevant. It is not always possible to identify interactions on a quantifiable basis and obtain evidence given the complexities involved.

(k). Success of nexus approach ultimately depends upon the will of decision makers.

4.2 Gujarat: Successful Adoption of Water-Energy-Food Solution

Gujarat State in Western India has varied topographical and hydrological conditions with high water endowed southern region and semi-arid/arid regions in rest of the State. In the semi-arid/ arid regions wherever surface water sources are not available, farmers adopted ground water irrigation. With the advent of flat tariffs in 1988, there was spurt in tube well irrigation which came into direct conflict with power supply to rural areas resulting in low voltage conditions and frequent trip-pings. Lack of reliable power supply led farmers to overdraw groundwater in an unsustainable manner resulting in drastic fall of groundwater table levels. Even though it was realized that unsustainable drawal of groundwater and inter-sectoral conflict for reliable power supply can only be resolved through appropriate pricing of power, the political class and farmers were against any such move. A second best solution however was adopted through launching of Jyotigram Scheme (JGS) on pilot basis in 2003 which was later extended to the entire State.

The main element of JGS is feeder segregation for agricultural and non-agricultural uses after building of a new transmission network. It basically ensured uninterrupted full voltage power supply of 8 hours a day for irrigation with timing of the supply alternating between day and night every week with pre-announced schedules. Power separation scheme was originally based on a research partnership involving International Water Management Institute (IWMI) which later reported about the success of JGS that 'the high quality , predictable and reliable power supply for tube-wells incentivized farmers to grow crops with high returns and cultivate all land they owned'. Various studies have vouched that the fall in water table levels has decreased since the adoption of JGS. Rationing of power led to farmers moving away from cereal crops to high value crops requiring less water and reliable supply led to proper scheduling of irrigation water without overdrawal. JGS has also improved power supply to non-farm businesses and decreased the damage to pumpsets due to voltage fluctuation.(Reinhard et al. 2017)

JGS is a good example of application of nexus approach for arresting unsustainable drawal of ground water which needs to be conserved as a buffer stock meant to be used during drought years. At the same time, it can't be termed to be the best nexus solution as electricity prices are still subsidized, farmers without tubewells are unable to buy water from well owners as before raising concerns about equitable access to common water resource and night irrigation is a cause of inconvenience to many farmers. Still, it is the best possible nexus solution to begin with and many other States are planning to replicate the scheme.

4.3 Punjab: High time to adopt nexus approach

Punjab State was at the heart of India's Green Revolution in late 1960s and early 1970s which enabled it to become self sufficient in food grains. However, access to cheap electricity and adoption of annual Rice-Wheat cropping system with intensive water utilization in areas not irrigated by canal system have led to drastic depletion of groundwater other than negative impact on soil quality due to excessive use of fertilizers. 'The water table was falling an average of 18 cm/year in the 80s, accelerated to 42 cm/ year in 1997-2002 and to a staggering 75 cm in 2002-2006.'(FAO 2014)

Excessive use of power for irrigation has also affected non-farm economy of the State. Of late, burning of crop residue in harvested paddy fields has been creating severe air pollution problem in regions as far as National Capital Delhi.

'Punjab is the second largest producer of rice in India comprising of around 11 percent of total rice production in India and the second largest producer of wheat having a share of 17.4 percent in the total wheat production in India. The shift from traditional crops, like barley or cotton, to monoculture of rice-wheat system was driven by forces such as price policy, technological change, market infrastructure and low cost of irrigation.'(FAO 2014)

Most of the food grain production is procured by the Govt. of India based on Minimum Support Price which was devised for achieving food security as well as providing fair price to farmers.

There is an urgent need to take corrective action as unsustainable levels of groundwater drawl will adversely affect the crop production levels in the long run. Govt. of Punjab has been promoting late transplanting of paddy (from mid May to mid June) to realign the period of peak irrigation need with monsoon season. Other interventions such as Laser land leveling, 'System of Rice Intensification', Direct seeding of rice, and irrigation scheduling through monitoring of soil moisture conditions by low cost tensiometers are gaining traction among farmers. Punjab Agricultural University is involved in the later intervention making use of tensiometers. An ideal nexus solution to arrest unsustainable drawl of groundwater could be changing the cropping pattern through creation of incentive support price structure for produce of other crops, efficient and productive use of water and a gradual decrease of energy subsidies after taking all stakeholders on board.

5. IMPORTANCE OF WATER PRODUCTIVITY FOR SUSTAINABLE WATER RESOURCES MANAGEMENT IN INDIA

5.1 Agricultural Water Productivity

Increased demand for food and changing dietary habits necessitates improved agricultural productivity given the limited scope for expansion of cropland in India. Measures undertaken for increasing agricultural productivity also need to be sustainable. Plant breeding adapted to agro-climatic conditions, better agronomic practices such as mulching, water management practices such as precision application of water and soil nutrient management practices are generally prescribed methods for improving agricultural productivity.

While demand management is an important option to tackle growing water scarcity other than increasing water storage in its various forms as prescribed by National Water Policy of 2012, decentralized approach to water management involving construction of groundwater recharge and rain water harvesting structures has been a dominant theme in recent years. Often decentralized approach is promoted without basin perspective in mind. It is not difficult to realise that return flows from irrigated areas are not lost from the system but contribute to downstream flows.

'Classic irrigation efficiency focuses on establishing the nature and extent of water losses. In assessing the performance of water use in a large system, a basin or sub-basin, classic efficiency fails to capture the water re-use aspect. It ignores the beneficial use put to water re-captured and re-used in one part of the basin as a consequence of deep percolation and/or runoff losses that takes place elsewhere in the basin.' (Cook et. al 2006)

Improving water use efficiency rightly occupies the minds of policy makers and attempts are underway to improve water use efficiency in every sector. At the same time there has to be some sort of tradeoff between inter-sectoral, inter-regional uses to maximize productivity per unit of water consumed with due consideration of equity aspects. Water use efficiency doesn't give any indication about quantum of beneficial utilization of water. Water productivity alongside water use efficiency need to become part of sustainable water resources management in India.

The concept of water productivity though in existence for many years didn't gain much currency. The term 'Agricultural Water Productivity' has been often used vaguely with many definitions.

Mapping the spatial variation of crop water productivity is useful in identifying the existing gaps and enhancing crop water productivity values. 'GLOBAL-WP : Modelling and mapping global water productivity of wheat, maize and rice', Report to FAO's NRL Division (Bastiaanssen et al. 2010) used 'GLOBAL-WP' model for mapping water productivity of basic staple crops at global level through remote sensing. However, it can only be applied where crop under investigation is dominant in the pixel area and crop specific spectral signal is visible in the remote sensing inputs.

Yield Water Productivity, defined as the ratio of fresh harvestable yield divided by the accumulated amount of water consumed by evapotranspiration was mapped.

Table 2. Water productivity statistics of large rice producing countries (Bastiaanssen et al. 2010)

Country	Yield Water Productivity (Kg/m^3)
India	0.87
China	1.16
Indonesia	0.92
Bangladesh	1.12
Thailand	1.00
Vietnam	0.77
Philippines	2.09
Cambodia	0.69
Japan	1.05
Nepal	1.15
USA	1.53

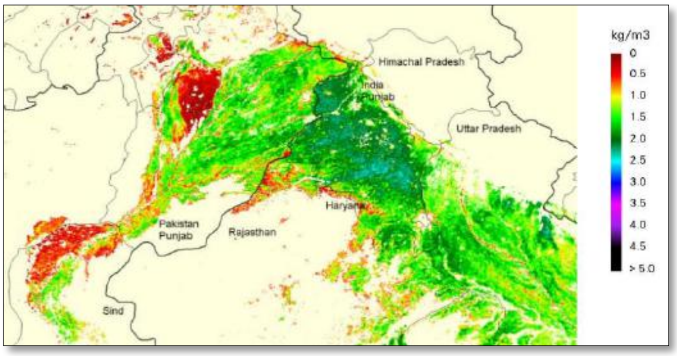

Figure 1. Wheat: Yield Water Productivity map - India/Pakistan (Bastiaanssen et al. 2010)

As per the study, India and Australia are two large wheat producing countries with a highly productive utilization of water resources. Contrasting crop water productivity values were found for Wheat at the border area of India and Pakistan, which indicates that local policies and institutions on water management play a large role in the lower water productivity values as found in Pakistan. The coefficient of variation is also low for India as compared to the Pakistan value, indicating a more homogeneous situation in India. In case of rice, USA and China show on average high water productivity, whereas Western India, Pakistan show on average low water productivity. No direct border effects are visible for India and Pakistan. However, within India a large variation is found. (Bastiaanssen et al. 2010)

A recent study on ‘Water Productivity Mapping of Major Indian Crops’ conducted by National Bank for Agriculture and Rural Development (NABARD) and Indian Council for Research on International Economic Relations (ICRIER) defined Physical Water Productivity(PWP) as ‘ratio of agricultural output to the total consumptive water use (TCWU) from all available source of water including rainfall which is based on the evapo-transpiration rate in the region’ , Irrigation Water Productivity(IWP) as ‘ratio of the crop output to the irrigation water applied’ and Economic Water Productivity(EWP) as ‘ratio of value of crop output to the amount of water consumed or to the amount of irrigation water applied by the farmer’. (NABARD and ICRIER 2018)

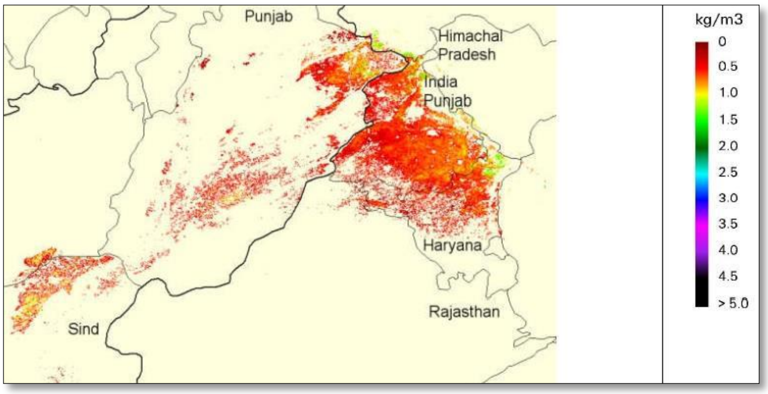

Figure 2. Rice:Yield Water Productivity map - India/Pakistan (Bastiaanssen et al. 2010)

The broad findings emerging out of the said study are as under:

(a). There are regions in India which are heading towards unsustainable agriculture with highly skewed distribution of water for certain crops.

(b). Paddy in Punjab and Sugarcane in Maharashtra have relatively low IWP though having high PWP indicating that they are not being cultivated in line with the natural water resource endowment.

(c). Paddy and sugarcane crops, using more than 60% of irrigation water available in the country, are being cultivated in the water scarce regions of the country restricting irrigation water availability for other major crops of the region.

(d). Skewed incentive structures for rice and sugarcane manifest in highly subsidized pricing of water, power, fertilizers on one hand, and assured markets for their outputs through procurement of rice in Punjab-Haryana belt, and of sugarcane by sugar factories at government determined prices in Maharashtra. The relatively water abundant States in eastern region lag behind in production of these crops as they have not been able to erect suitable procurement structures for Rice or attract Sugar mills in their areas. (NABARD and ICRIER 2018)

5.2 Constraints in Estimating Water Productivity

Aforementioned study on water productivity mapping was carried out using water and climate related data points, State level information on crop calendar and related statistics. Water productivity maps for dominant districts for each crop were prepared. IWP was estimated at the State level owing to district level data limitations. To estimate the amount of applied irrigation water, a variety of information available through farmer surveys and Government reports were used.

Lack of water utilization data comes in the way of estimation, monitoring and improvement of water productivity. Wherever utilization data is made available, there is seldom any agreement between basin States over such data especially in case of water stressed basins. Moreover, actual water depletion for crop growth out of total irrigation water supplied to the field (excluding seepage and evaporation from bare soil) can't be measured.

Remote Sensing data products offer to fill such data gaps in combination with in-situ data for easy monitoring by policy makers. Such datasets have some level of uncertainty and error as they indirectly estimate the hydrological processes. Mean absolute error for satellite based evapotranspiration products is around 5% (based on validation with ground observed data points at various locations). IHE-Delft, IWMI and FAO have developed a water accounting framework termed 'Water Accounting Plus (WA+)' which accounts for depletion of water. The framework follows a methodology making use of open access datasets of actual evapotranspiration, reference evapotranspiration, precipitation, net dry matter along with region specific crop growing seasons, harvest index and moisture index values to generate spatial water productivity maps at finer resolution (up to 250 m*250 m pixel size).

However, application of WA+ framework requires an accurate Land Use Land Cover (LULC) map with crop information for any period of study. LULC maps of National Remote Sensing Centre (NRSC) of India are water year based and has crop season/multi cropping classes viz., kharif, rabi, zaid, double/triple crop and fallow area but not actual crop classes. Through field surveys and ground truthing, LULC maps with crop classes and thereby water productivity maps can be generated for monitoring of water productivity values in various irrigation commands, identification of bright spots as well as lagging regions.

6. CONCLUSIONS

In order to have sustainable water resources development in India, it is imperative to increase water use efficiency for which a lot of efforts are being made under various schemes of the Govt. of India.

It is also equally important to increase water productivity. As brought out above, there is a need for change in the current discourse which is dominated by targets of improving water use efficiency and yield per unit of land. Water productivity concomitantly should become part of the discourse.

Nexus approach needs to be applied for obtaining long lasting solutions such as aligning the cropping pattern with natural resources endowment of the region concerned, effective crop produce procurement policy, effective pricing of electricity etc., to arrest unsustainable practices such as over drawal of groundwater

Given the constraints in obtaining water utilization data, mapping and monitoring of spatial variability of water productivity presents an effective option for taking corrective steps or suggesting policy interventions. Key interventions based upon improving water productivity of identified crops and through adoption of nexus approach would ensure efficient as well as productive use of water in irrigated agriculture and sustainable water resources management in India.

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