Improving Water Productivity in the Context of Climate Change: A Systematic Review from an Indian Perspective

Abstract: “In broadest sense, water productivity reflects the objectives of producing more food, income, livelihoods and ecological benefits at less social and environmental cost per unit of water, where water use means per either water delivered to a use or depleted by a use. Put it simply, it means growing more food or gaining more benefits with less water.” In: ‘Water for food and Water for life’ of the Comprehensive Assessment of Water Management in Agriculture (Molden and Oweis 2007).

Introduction:

At least 70% of all water withdrawals worldwide are accounted for by agriculture, making it the greatest consumer of water globally (Scheierling and Tréguer, 2018). According to FAO (2017), there will be a 50% increase in the need for water in agriculture by 2050 compared to 2013.

This is brought on by:

- According to FAO (2011), there will be a 60% increase in food consumption by 2050. Both the growing population (40%) and the increased per capita calorie intake (11%) are to blame for this.
- There is an equal demand for non-food items as there is for food. Between 2005 and 2030, there will be a 45% rise in the demand for timber and a 47% increase in the demand for round wood (FAO, 2009). Between 2010 and 2050, there will be an 81% rise in the demand for cotton.

Although efficient agricultural production is necessary for people's lives and the nation's food security, water is frequently the limiting issue. There is competition from other water users as well as the environment because water resources are limited. In order to increase food and water security as well as farm profits, it is crucial to increase the efficiency of water usage in agriculture. In order to address water scarcity and significantly lower the number of people affected by it, it is also explicitly reflected in Sustainable Development Goal (SDG) 6.4, which states: By 2030, significantly increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater.

It is commonly acknowledged that the world is currently experiencing an unprecedented water crisis, and that one of the main factors contributing to this situation is the agricultural sector's water management issues. Two fundamental factors are important to consider: first, the agricultural sector is by far the largest user of freshwater (Molden, 2007); and second, water use in agriculture tends to have lower net returns as compared to other competing uses (Sharma et al., 2015). Estimates suggest that the world's food systems will require 40-50% more freshwater than they do now over the next three decades. During this time, municipal and industrial demand for water will increase by 50–70%, while the demand for energy sector will increase by 85%. India has some of the world's most brittle and unpredictable water supplies, and the nation suffers from severe water stress. With a nearly 78% share, the irrigation sector controls the majority of India's water consumption, both now and in the future (Figure 2). Improving water productivity in agriculture is one of the primary responses to these new difficulties since even little gains might have a significant impact on regional and national water distribution and budgetary strategies. The Global Water Partnership (2000), USDA (2017), and FAO (2012, 2016) all hold this same opinion and see demand management as a viable means of addressing the water shortage, with increasing agricultural water productivity serving as the primary means of controlling water demand in the sector. The three most important resources in agricultural production are labor, land, and water. But unlike labor and land productivity, the idea of water productivity, or WP, has been around for a while but has only lately gained traction, particularly in developing nations (Barker et al., 2003). Over the past ten years, analyses of cropping systems, agricultural production systems, and WP of crops have included the well-known slogan "More Crop per Drop" (Molden, 2010) or "Per Drop More Crop," as renamed by the Indian Prime Minister (Kijne et al., 2003; Amarasinghe et al., 2007 ; Amarasinghe and Smakhtin, 2014).

The amount of biomass or marketable yield per unit of transpiration or evapotranspiration was the original definition of water use efficiency given by crop physiologists (Viets, 1962). "The ratio of irrigation water transpired by the crops of an irrigation farm or project during their growth period to the water delivered from a river or other natural source into the farm or project canals during the same period of time" is how irrigation scientists and engineers defined water (or irrigation) use efficiency (Israelsen, 1932). Despite certain advancements, this idea of water use efficiency only offers a portion of the picture since it fails to clarify that water lost to irrigation is frequently utilized by other users downstream or to show the full benefits generated (Seckler et al., 2003).

The advantages and disadvantages of using water for agriculture in terrestrial and aquatic environments are now included in the discussion of water productivity (Molden et al., 2007). In its broadest meaning, it represents the goals of reducing social and environmental costs per unit of water utilized while creating more food, income, livelihoods, and ecological benefits (Molden, 2013). The ratio of agricultural output to water consumption (from all available sources such as rainfall, irrigation, etc.) is known as physical water productivity. The evapo-transpiration rate in the area is used to calculate the total consumptive water use (TCWU) concept in PWP.

Due to the low overall efficiency of both surface and groundwater irrigation systems, the volume of irrigation water applied in the field is frequently greater than the actual water requirement of the crop, making this scientific estimation of water productivity based solely on PWP inappropriate for irrigation intensive crops like wheat, sugarcane, and paddy. We have therefore proposed the idea of irrigation water productivity, which calculates crop yield relative to the farmer's applied unit volume of irrigation water. Three important water-guzzler crops—rice, wheat, and sugarcane—have had their IWP and associated economic water productivity assessed. Together, these three crops use more than 80% of the nation's freshwater supply that is available for irrigation.

a. Physical water productivity is measured in kilograms of produce per cubic meter of water used (via evapo-transpiration) during crop growth, or kg/m3. It is the ratio of agricultural production to the quantity of water consumed from all available sources, including irrigation, rainfall, etc.

b. The ratio of crop yield to irrigation water applied by the farmer or irrigation system through surface canals, tanks, ponds, wells, and tube wells during the crop's growth is known as irrigation water productivity. Therefore, applying water (kg/m3) requires a farmer to incur specific expenses, making irrigation an economic activity.

c. The value of agricultural yield divided by the quantity of water used or irrigation water used by the farmer (expressed as Rs /m3) is known as economic water productivity.

Food and water security are the two greatest concerns confronting the globe now, and they are expected to get worse in the future mostly as a result of climate change (Foley et al., 2011). Global warming is predicted to result from climate change (CC), which is mostly caused by an increase in greenhouse gases (GHGs), during the course of the next century (M.J.Anand et al., 2020). Consequently, variations in mean climatic conditions may have a substantial impact on agricultural yield. However, under extreme climate change scenarios, the benefits of increasing CO2 may change the future yield on the other hand. Ultimately, productivity could be altered through the enhancement of photosynthesis due to the fertilization effect of increasing CO2, especially of C3 plants (P. Döll, 2002).Crop water productivity (WP), or More crops per drop of water, may be a key strategy to solve both challenges. From the standpoint of water use, CO2 fertilization may increase crop WP by causing a lower rate of transpiration at the leaf, which may drastically change the amount of water needed for crop production (Betts et al., 2007, Wullschleger et al., 2002). On the other hand, variations in rainfall patterns may also affect the crop fields' water balance. According to projections made by Döll (2002) and Gerten et al. (2011), certain locations may see a decrease in irrigated water to compensate for soil-water scarcities and increasing seasonal rainfall, while other regions may experience the opposite.

The majority of people in India are employed in agriculture, and the country has made significant progress in developing its water resources over the past 60 years. Modern agronomic practices combined with the expansion of irrigation systems have increased food grain production from a meager 51 million tonne in 1951 to over 315.7 million tonnes in 2021-22. Doubling land productivity in the next 40 years could help India meet most of its increasing food demand, which is expected to reach about 400-450 million tons by 2050 (Amarasinghe et al., 2017). However, in contrast to forty years ago, water is also running out. Water is essential for agriculture as well as other uses by people and ecosystems. A water crisis and a higher danger of extinction for 20–30% of India's plant and animal species are among the negative effects of climate change. The latter occurs if world average temperatures rise over 1.5–2.5 degrees Celsius. Deforestation will have a more detrimental effect on water control due to climate change. When river flows fall to 15-20% below average, irrigation shortages develop, even though the Indus system is now strong enough to handle shortfalls of 10–13% (Khan, 2009). Thus, variations in climate will have an impact on several aspects such as soil moisture, groundwater recharge, frequency of flood or drought episodes, and groundwater level.

In situations when water is more limited than land and other resources used in production, increasing crop water productivity is an important response strategy. A growing, wealthier, and more urbanized population places increasing demands on food, and improvements to agricultural water productivity—that is, the productivity of water used for crops, livestock, and aquaculture—help to meet those demands. At the same time, pressure to reallocate water from agriculture to cities and to make more water available for environmental uses adds to the urgency of making progress in agricultural water management.

Table 1: Projected Water Demand in India for Different Sectors

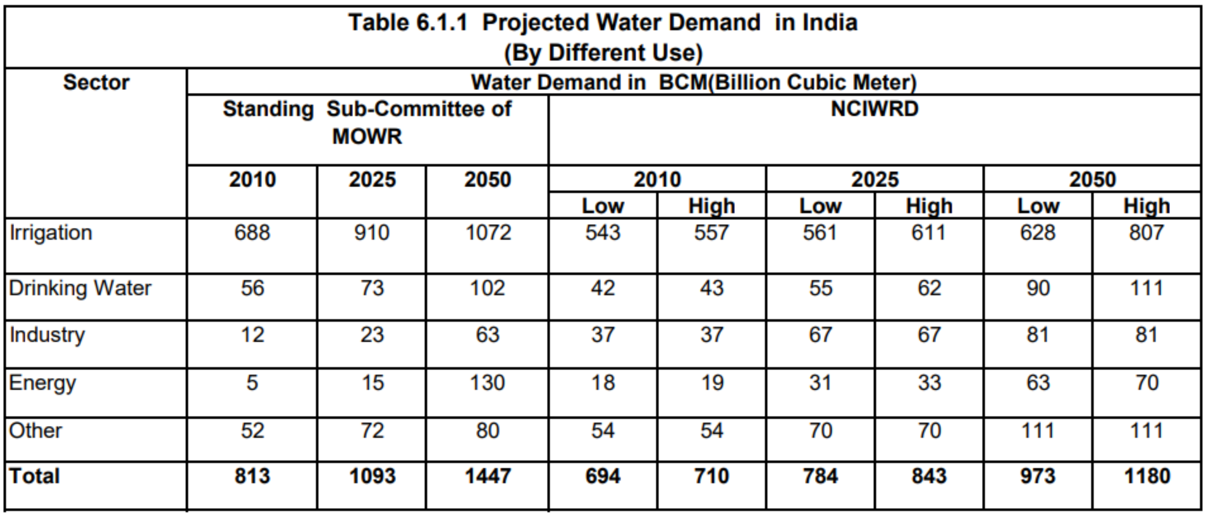

Table 6.1.1 Projected Water Demand in India
(By Different Use)

Sector	Water Demand in BCM(Billion Cubic Meter)								
	Standing Sub-Committee of MOWR			NCIWRD					
	2010	2025	2050	2010		2025		2050	
				Low	High	Low	High	Low	High
Irrigation	688	910	1072	543	557	561	611	628	807
Drinking Water	56	73	102	42	43	55	62	90	111
Industry	12	23	63	37	37	67	67	81	81
Energy	5	15	130	18	19	31	33	63	70
Other	52	72	80	54	54	70	70	111	111
Total	**813**	**1093**	**1447**	**694**	**710**	**784**	**843**	**973**	**1180**

Source: *Basin Planning Directorate, CWC, XI Plan Document*[64]

Note: *NCIWRD: National Commission on Integrated Water Resources Development; BCM: Billion Cubic Meters; MOWR: Ministry of Water Resources*

Please provide the justification for the review, outline the methods used, and include subtitles for the literature review along with their details.

Water Productivity: Concepts

The quantity of water required to produce a certain amount (or value) of produce is known as water productivity. Crop output divided by the sum of irrigation flow and rainfall is known as the water productivity per unit of gross inflow, or WPG. Water production may be measured, which makes it possible to record changes and promote quicker growth (Passioura, 2006). In fact, as long as they are used at the level of individual farmers or irrigation projects and are well defined, irrigation efficiency and water usage efficiency remain valuable metrics. Higher scales allow for the quantification of "water productivity," but clear definitions are also necessary for its useful application. While there are pressures to reallocate water from agriculture to cities and to make more water available for environmental uses, the primary motivation for improving agricultural water productivity (water productivity in crop, livestock, and aquaculture production) is to meet rising food demands from a growing, wealthier, and increasingly urbanized population (Molden et al., 2019).

Assessment of Water Productivity (WP)

In contrast to other major foodgrain producing nations in the globe, India's WP remains persistently low at this time (Molden et al, 1998; Rosegrant et al., 2002; Cai and Rosegrant, 2003). Foodgrains in India had a WP of just 0.48 kg/m3 of consumptive water usage (CWU) in 2000. The main cause of this was the modest rise in yields. India's food grain output grew by just 1.0 tons/ha between 1960 and 2000, to 1.7 tons/ha (FAO, 2005). In contrast, China's output (and soil-climate conditions) grew from 0.9 tons/ha in 1960 to around 4.0 tons/ha by the year 2000Additionally, China produces far more grain with less water from a much smaller crop area than India, which produces less grain in a much greater cropped area (205 million mt in 124 million ha). India may, in fact, raise the WP levels significantly just by boosting crop productivity. In many areas, improved water management can lead to a further rise in WP. Regional estimations reveal a notable geographical difference in WP between Indian states and districts.

The amount of water used to generate cattle and livestock-related goods and services, such as energy, is known as livestock water productivity, or LWP. When calculating the LWP benefits from livestock, the mix of livestock species owned by a household's milk output, carcass weight, draught usage, and manure values are calculated per unit of water utilized. Based on local market values, the amount of virtual water in the crop residue was calculated in relation to its grain worth. The amount of water used by livestock to produce various livestock products and to deplete or divert water is indirectly addressed in the context of water productivity, but most authors (Kijne et al., 2003) do not account for it in the water productivity equations, or if they do, they do not account for additional benefits provided by livestock (Singh and Kishore, 2004). If the amount of crop residues in livestock feed grows to fulfill the yearly need, there's a good chance that animal water productivity will also rise. ***Variations of water productivity among Indian states***:

According to Amarasinghe and Sharma (2018), the CWP (Table 2) varies amongst states, with the greatest value being 1.01 kg/m^3 in Punjab and the lowest value being 0.21 kg/m^3 in Orissa. The primary causes of these variations include different patterns of cropping and land use, yield levels, and CWU. There are notable distinctions between the different states. In the Indo-Gangetic basin (IGB), Punjab, Haryana, and Uttar Pradesh (UP) have the greatest water productivities. With a cropping pattern dominated by rice and wheat, these states account for 40% of India's overall foodgrain output but just 26% of the country's total CWU. Significantly, they produce 26% of India's rice and 70% of its wheat. These states have a large amount of irrigated land used for foodgrain production. In Uttar Pradesh, Haryana, and Punjab, it is 67, 85, and 97%, respectively, and accounts for 48, 72, and 75% of the CWU. West Bengal (WB), which is mostly in the IGB, and the peninsular basin states of Andhra Pradesh (AP), Tamil Nadu (TN), and Kerala, which are dominated by rice cultivation, have moderate to high WP.

While irrigation plays a significant role in CWU in TN and AP, it plays a smaller role in WB and Kerala. With a diversity of cropping patterns (more than 50% of the land under maize and other coarse grains and pulses), Maharashtra, Madhya Pradesh (MP), Karnataka, and Gujarat have lower WP. In Karnataka and Maharashtra, irrigation accounts for just 28% and 15% of the total CWU, respectively, and only covers 15% of the land. In MP and Gujarat, irrigation accounts for 29% of the grain area but produces 52% and 41% of the CWU, respectively. The states with the lowest water productivities are Orissa, Chattisgarh, and Jharkhand, which together account for 12.8% of the CWU but just 6.3% of grain output. In these states, the predominant crop is rice that is rainfed.

Every district in the nation has different water productivity (WP), ranging from 0.11 kg/m3 to 1.25 kg/m3 (Figure 1). WP ranges from 0.11–0.34, 0.34-0.45, 0.45-0.60, and 0.60–1.25 kg/m3 in the first through fourth quartiles. Despite making up just 22% of the overall CWU and 22% of the total grain land, districts in the fourth quartile of water productivities account for 38% of the total grain production. In this category, irrigation supplies water to 72% of the total grain acreage and accounts for 60% of the total CWU. In places with irrigation, irrigation makes up a significant portion (72%) of the overall CWU.

Strategies for Water productivity improvement

In its widest definition, water productivity refers to the production of more food, cash, livelihoods, and ecological advantages per unit of water input at a lower social and environmental cost. Water use, on the other hand, refers to the delivery of water to a use or the depletion of water by a use. The fundamental idea behind raising WP may be achieved in one of two ways: either by increasing the numerator (or yield) by closing the current yield gap between actual and maximal yield, or by adding more irrigation or choosing the right crops in mostly rainfed regions.

-Reducing the denominator (i.e., the CWU per unit land) while maintaining yield and returns per unit of water used.

There are several viable options available along the range from entirely rainfed to fully irrigated farming systems for increasing water production. These include minimum or zero tillage, mulching, bed planting, laser levelling, and small-scale water harvesting and storage, delivery and application techniques, auxiliary storage in the canal command areas, precision irrigation technologies (such as drips, micro-sprinklers, and sprinklers), deficit irrigation, soil fertility management, and supplemental irrigation. The following are a few of the more modern and cutting-edge methods and regulations for raising water productivity:

Adequate and timely irrigation:

Low yields in rain-fed locations are mostly determined by water stress during critical stages of crop growth, as is widely understood. A modest amount of additional irrigation applied correctly and on time during times of water stress might close the yield gap on its own; further irrigation combined with improved non-water input application could raise the average yield parallel to the growing path of the maximum yield. According to recent studies (Sharma et al., 2018), the major cause of crop (and investment) failures and low yields is the frequent occurrence of mid-season and terminal droughts lasting one to three weeks consecutively throughout the main cropping season. For a every crops crucial irrigation during critical irrigation could have increased yields from 29 to 114%.

Resource conservation technologies (RCTs):

Numerous well-known techniques exist for increasing agricultural water productivity, such as deficit and supplementary irrigation, water-saving devices, improved soil fertility, conservation of soil, and resource conservation technologies (RCTs) including bed planting and zero tillage. Laser land leveling, furrow bed planting, and zero tillage (or reduced/minimum tillage) are examples of RCTs. Numerous studies, particularly in the field, have demonstrated how well RCTs work to reduce the amount of water applied. Utilizing RCTs, such as laser leveling, zero tillage, and bed and furrow planting, decreased water usage by 23% to 45% while boosting yield. Water savings in rice-wheat systems can rise by up to 30% with the implementation of zero tillage (Hobbs and Gupta, 2003).

In the rice-wheat area of the Indo-Gangetic plains, a study revealed 25% to 30% savings in irrigation water under zero-tilted wheat compared to conventionally tilled (CT) (Gupta et al, 2002) regardless of cropping system, conservation tilled plots exhibited greater (14–22%) soil moisture than conventional tillage, which directly affects soil moisture recharge and crop absorption (Ghosh et al., 2010). Wheat water productivity in the bed planting method of crop establishment is generally higher than that under zero tillage and conventional tillage at plot level in the study (Chandra et al., 2017) on water productivity under zero tillage and bed planting (BP) in rice-wheat system in the western IG plains at Pabnawa Minor of Bhakra Canal System in Kurukshetra, Haryana.

Wheat planted in beds has higher water productivity than wheat planted in zero tillage, while wheat planted in zero tillage has higher water productivity than wheat planted in conventional tillage at all sizes, from the plot to the watercourse. Table 3 shows that while land productivity is lower than with conventional tillage, irrigation water productivity for rice under BP is greater (22–28%) than with CT. In bed planted rice, there is a trade-off between land productivity and water productivity. The analysis's findings show that, in addition to profitability, zero tillage is better to conventional tillage in terms of irrigation water productivity and land productivity in wheat.

As one goes from the plot level to the watercourse level, water productivity falls under both conventional and zero tillage (i.e., for the three levels of study). Benefits of water conservation under zero tillage at the watercourse level are suggested by higher levels of water production under zero tillage compared to conventional tillage at the farm and watercourse levels.

Auxiliary storage reservoirs in canal commands:

One of the main obstacles to attaining increased agricultural and water production in canal irrigation systems is frequently identified as the unreliable water supply. Additionally, it limits crop diversification choices, forces farmers to meet water and other agro-input requirements at key stages of crop growth, and results in yields that are only slightly above ideal. In rotating water distribution systems like Warabandi in north and north-west India and Pakistan, inflexible or incorrectly executed water delivery schedules are frequently linked to unreliable water supplies.

These water storage structures simplify the use of sprinklers for water application and provide farmers more control over on-farm water management. This immediately led to an increase in irrigable area and water conservation. If small landholdings cultivate high-value crops (fruits and vegetables), diversify their agricultural practices to include fisheries in these tanks, or employ a shared resource to lower the construction cost, these storage structures and application systems may prove to be a feasible choice.

Improving efficiency of irrigation systems:

When drip irrigation was used in place of the traditional surface technique of irrigation in a dry-land watershed at Saliyur in the Coimbatore district, banana yield increased by 72%. Water production may be increased by using water-saving irrigation techniques. According to Molden et al. (2017), switching from traditional surface systems to drip irrigation in India may increase water production for a variety of crops, including bananas, sugarcane, cabbage, cotton, grapes, potatoes, and tomatoes, by anywhere from 40% to over 200%. The estimated water productivity of the Low Energy Water Application (LEWA) device for wheat in Patna was 1.91 kg/m3, as opposed to 1.62 kg/m3 and 0.95 kg/m3 for surface irrigation and spray irrigation, respectively.

There are significant differences in the patterns of water demand and supply because of the low marginal and opportunity costs associated with the current policy and price structures in developing nations. The average input of rice was assessed to be 1,458 mm in a research conducted by IWMI in Pakistan Punjab (Jehangir et al., 2017), compared to the potential water needs of 532 mm. The low gross depleted percentage of 0.40 that was obtained showed that, primarily, seepage and deep percolation fluxes from the root zone accounted for roughly 60% of the water that was not used in rice ET. On the other hand, farmers often strive to make the most of the rains by under-irrigating the wheat crop.

In addition to the differences in the crops that need to be watered, the irrigation water source plays a significant part in water conservation and efficiency. Because groundwater irrigation allows for more control over timing and quantity as well as more controlled flows, it has been shown to be generally more efficient. Increased production and water saving are two major benefits of enhanced irrigation techniques. Most of the time, drip irrigation has been shown to save water by 25–80%. Crop water requirements may drop to 44.46 BCM at the national level if drip irrigation is adopted for eligible crops (Table 4) in the prospective areas. Kumar and others (2018). However, the economic viability of micro-irrigation depends upon a wide range of factors including market rural infrastructure

Integrated farming system approach for LWP improvement:

An increase in the percentage of agricultural residues used to satisfy the total needs for livestock feed is anticipated to result in higher livestock water productivity. Systems of integrated crop-livestock production have several opportunities to raise the current extremely low productivity per animal head. Appropriate multifunctional forage crops may be integrated into current agricultural systems to reduce topsoil erosion, boost crop land fertility, and boost the availability of nutrient-rich animal feed. LWP will rise even more if community-based projects are supported for better communal grazing land usage. These projects will concentrate on doable strategies for improving the productivity of community pastures by restoring damaged grazing area and addressing the overstocking issue. In the end, this would ultimately bring higher livestock productivity in a sustainable way.

Social awareness programme:

To help people and organizations modify their behavior and stop wasting water, a comprehensive strategy is needed. Through tools like public campaigns to instill a common vision of a wealthy and environmentally sustainable future, water-efficient public behavior may be fostered. The formal education system is another effective means of reaching a broad audience. Through the use of hands-on projects, practical learning, training, and better teaching materials, this system may encourage the efficient use of water.

Modelling approaches for improving CWP

Accurate crop yield and crop water productivity (CWP, defined as the ratio of crop yield to real evapotranspiration) data at a broad scale and high resolution are essential for a better understanding of the global water-food link. However, given the significant spatial and temporal variability across various geographical areas, standard approaches are insufficient for predicting agricultural yield and CWP on a worldwide scale19. There is a growing need to assist water and food policy and decision making at the international and national levels due to the increasing scarcity of water and the interconnectedness of the global economy.

It would be extremely helpful to have a systematic tool that can analyze water-food connections at high geographical resolutions. The variety of applications for a crop growth model may be expanded by integrating GIS with it. Liu et al. (2018) developed and evaluated a GIS-based model called EPIC (Environmental Policy Integrated climatic) that takes into account many aspects such soil qualities, climatic conditions, land use, water and fertilizer management, etc. to simulate agricultural production and CWP. GEPIC was used to model maize yield and CWP at a grid resolution of 30 arc-minutes on the land surface on a global scale.

Similar to this, the FAO's Water Unit created the agricultural water productivity simulation model AquaCrop, which is especially well-suited for decision-making in situations where water is a major limiting factor in crop output. It simulates the yield response of several herbaceous crops to water. It makes use of a small number of well defined, largely understandable parameters and input variables that may be determined using straightforward techniques. A helpful tool for many different users and applications, such as yield prediction under climate change scenarios, is AquaCrop. It is primarily meant for practitioners employed by NGOs, government organizations, extension services, and other types of farmer groups. Other fundamental water management models (SWAP, SWAT etc.) are also available and can be used to enhance CWP.

Epilogue

Raising water productivity throughout the transition from rainfed to irrigated farming systems may be accomplished through a number of viable routes. In areas with low consumptive water consumption, additional irrigation has the potential to treble current output levels. According to analysis, most crops' yields will increase by 50% with just one crucial irrigation in 25 Mha of prospective rainfed regions. This intervention is also commercially feasible, particularly for oilseed, rice, and pulse crops. Under most circumstances, resource conservation methods can assist in achieving water savings of 20–45% at the field size.

Under Indian conditions, improved irrigation systems like drip irrigation with a higher adoption rate and targeted subsidies have the potential to conserve approximately 44.5 BCM of irrigation water. However, in order to increase water productivity, there are still a few researchable issues that need to be addressed soon. The issues are:

- How can the development of better frameworks for analyzing and predicting water productivity in various agro-ecosystems be aided by advancements in information technology?
- In both brief and extended periods of severe water deficiency, how can crops' water productivity be maintained?
- How could the coordinated methodology be rehearsed alongside upgrading water efficiency for occupation security under environmental change situation?

There is no conclusion or future plan provided.

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Table 2 Variation in water productivity among the various Indian states

Sl. No.	States	Total (Irrigated+Rainfed)				
		Area (M ha)	**Production (M Mt)**	**Yield (t/ha)**	**CWU (mm)**	**WP (kg/m3)**
1.	Uttar Pradesh	20.3	43.4	2.13	351	0.61
2.	Madhya Pradesh	11.2	11.1	0.99	278	0.36
3.	West Bengal	6.6	15.2	2.31	447	0.52
4.	Bihar	7.1	12.1	1.71	373	0.46
5.	Rajasthan	11.7	11.7	1.00	220	0.46
6.	Punjab	6.3	25.5	4.07	404	1.01
7.	Haryana	4.3	13.4	3.13	363	0.86
8.	Uttaranchal	1.0	1.7	1.75	298	0.59
9.	J& K	0.9	1.2	1.38	271	0.51
10.	Himachal Pradesh	0.8	1.5	1.78	245	0.73
	India	123	205.4	1.66	344	0.48

Source: Amarasinghe U.A., and B. Sharma. 2018

Table 3. Water and land Productivity of bed planted Rice and conventional tillage rice

Locations	Method of sowing	Irrigation water productivity (kg/m$_3$)	Gross water productivity (kg/m$_3$)	Average yield (t/ha)
Pabnawa Head-end	Bed Planting	0.38	0.37	4.76
Pabnawa Middle1	Bed Planting	0.39	0.38	5.43
Pabnawa Middle 2	Bed Planting	0.49	0.46	4.93
Pabnawa Tail-end	Conventional tillage	0.31	0.30	5.53

Source: Dinesh Kumar, M and Amarasinghe U.A.,. 2018

Table 4. Aggregate reduction in crop water requirements possible with drip irrigation in India

Name of crop	Water productivity (kg/m3)	Improved water productivity (kg/ m3)	Reduction in crop water requirement (BCM)
Sugarcane	5.950	18.09	31.00
Cotton	0.303	1.080	10.42
Groundnut	0.340	0.950	1.453
Potato	11.79	17.21	0.127
Castor	0.340	0.670	0.497

Onion	1.544	2.700	0.963
Total			**44.46**

Source: Kumar et al., 2018

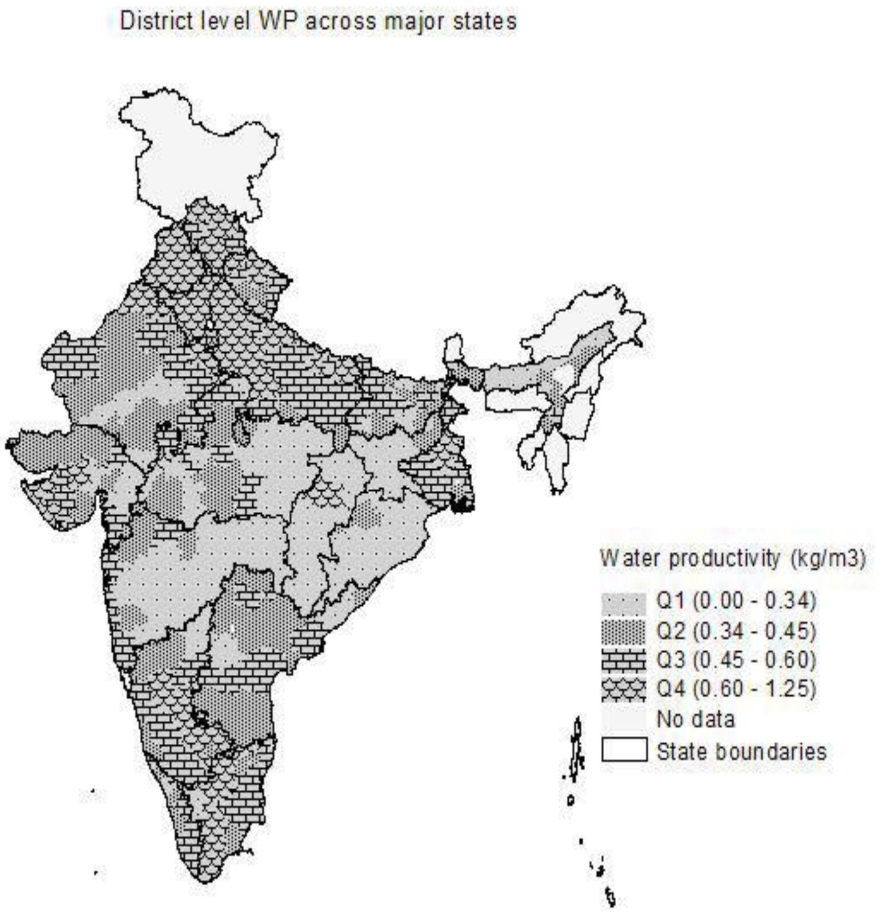

Figure 1. District level WP across major states
Source: Amarasinghe U.A., and B. Sharma. 2018