The Pharma Innovation Journal 2021; 10(3): 530-536

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.03
TPI 2021; 10(3): 530-536

www.thepharmajournal.com
Received: 20-12-2020
Accepted: 09-02-2021

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A review on water management of crops and cropping system in India

Sandeep Kumar Maurya, RK Singh, Brijesh Kumar, Sarvajeet and Ranvir

Abstract
The water requirement of crops is the quantity of water required by the crops within a given period for their maturity and it includes losses due to evapotranspiration plus the unavoidable losses during the application of water and water required for special operations such as land preparation, puddling and leaching. The quantity of water needed for irrigation on different soil types per meter depth of soil profile at 50% of soil moisture availability is as follows. Sandy soils (25-50 mm), Sandy-loam (45-80 mm), Loam (70-110 mm), Clay-loam (80-120 mm) and Heavy clay (100-140 mm). Light soils, long-duration varieties during *Kharif,* medium duration varieties during summer. For low land rice, the practice of keeping the soil saturated of submergence of about 5 cm throughout the growing period is beneficial. The water requirement of rice is higher than that of any other crop of a similar duration, an assured and timely supply of irrigation water has a great influence on the yield of the crop. The dwarf wheat needs more wetness and the optimum moisture range is from 100-60% of availability. For tall wheat, the optimum-moisture range is from the field capacity to 50% of availability. Four to six irrigations are enough for the wheat crop. However, crown root initiation and heading stages are the most critical to moisture stress.

Keywords: Water requirement, moisture availability, crown root initiation, moisture stress

Introduction
Water is one of the most important inputs for crop production. It profoundly influences photosynthesis, respiration, absorption, translocation and utilization of universal nutrients and cell division besides some other processes. Both its shortage and excess affect the growth and development of the plants, yields, and quality of produce. Water management of the crops comprises irrigation and drainage or both. With proper irrigation and drainage facility, crop yields can be boosted manifold. The management of water in a cropping system is a much difficult task because here the need of every crop of the system is to be considered and one has to utilize the available water in the best possible way to get the maximum benefit from the whole system. Normally a crop has to be irrigated before soil moisture is depleted below 50% of its availability in the root-zone, but this rule does not apply to every situation hence water management is planned for the use of water for better utilization in agriculture. Thus crop planning should be done considering 1. Water requirement of crop and 2. Availability of water.

Water management based on water requirement
Water requirement differs according to crops and soil type. The water requirement of crops is the quantity of water required by the crops within a given period for their maturity and it includes losses due to evapotranspiration plus the unavoidable losses during the application of water and water required for special operations such as land preparation, puddling and leaching. The quantity of water needed for irrigation on different soil types per meter depth of soil profile at 50% of soil moisture availability is as follows. Sandy soils (25-50 mm), Sandy-loam (45-80 mm), Loam (70-110 mm), Clay-loam (80-120 mm) and Heavy clay (100-140 mm).
The water requirement of different crops is given below-

Rice
The amount of water required for growing rice varies widely under different conditions:
1000-1500 mm- heavy soils high water table, short-duration variety, *Kharif* season.
1500-2000 mm- medium soils *Kharif* or early spring season.
2000-2500 mm- light soils, long-duration varieties during *Kharif*, medium duration varieties during summer. For low land rice, the practice of keeping the soil saturated of submergence of about 5 cm throughout the growing period is beneficial.

The water requirement of rice is higher than that of any other crop of a similar duration, an assured and timely supply of irrigation water has a great influence on the yield of the crop. In the life cycle of rice plants, there are certain critical stages when water requirement is high. The water requirement is high during the initial seedling period covering about 10 days. Tillering and flowering are the most critical stage when rice crops should not be subjected to any moisture stress. Ensure enough water from the panicle initiation stage to flowering (heading). Flooding is not necessary if weeds can be controlled economically through chemical means or by manual weeding before the plants become vegetatively strong. The application of small quantities of water at short intervals to keep the soil saturated is more effective and economical than flooding at long intervals. Flooding is not necessary if the soil is saturated with water and bio-fertilizers have not been used. However, flooding suppresses the weed growth. It increased the availability of many nutrients, particularly phosphorus, potassium, calcium, iron, and silica.

In general, where is an assured water supply, until the transplanted seedlings are well established, water should be allowed to stand in the field at a depth of 2-5 centimeters. Thereafter, about five centimeters of water may be maintained up to the dough stage of the crop. Water should be drained out from the field 7 to 15 days before harvest depending on the soil type to encourage quick and uniform maturity of grain.

Wheat

The dwarf wheat needs more wetness and the optimum moisture range is from 100-60% of availability. For tall wheat, the optimum-moisture range is from the field capacity to 50% of availability. Four to six irrigations are enough for the wheat crop. However, crown root initiation and heading stages are the most critical to moisture stress. Depending upon the water availability, these should be applied as per the schedule given below-

1. Crown Root Initiation (21 days after sowing)
2. Late Tillering (42 days after sowing)
3. Late Joining (60 days after sowing)
4. Flowering (80 days after sowing)
5. Milk stage (95 days after sowing) and
6. Dough Ripe (115 days after sowing)

Among these stages, the crown root initiation stage is most critical. An irrigation delay of 2 to 3 weeks in this stage reduces the yield by 5 to 10 q/ha.

If the level of groundwater is well below the root zone (about 100 cm) and significant rainfall is not received during the growing season then 4 to 6 irrigations are considered optimum as demanded by soil type, local climate, and variety type.

The border method of irrigation is most suitable for the wheat crop as it ensures uniform distribution and high-water application efficiency.

Maize

The optimum soil moisture range is from 100-60% of availability in the maximum root-zone, which extends from 40-60 cm on different soil types. In the northern parts, 2-3 irrigation is required before the onset of the monsoon. In Karnataka 2, 5 irrigation are necessary during *Kharif* and *Rabi* respectively. At Rajasthan 4 irrigation (500 mm of water) is required during *Kharif*. The maize crop is sensitive to both moisture stress and excessive moisture, hence regulate irrigation according to the requirement. Ensure optimum moisture availability during the most critical phase (45 to 65 days after sowing); otherwise yield will be reduced by a considerable extent.

Barley

About 2-3 irrigation are adequate and the optimum soil moisture ranges from the field capacity to 40% of availability.

Sorghum and Other Millets

The optimum moisture range is from the field capacity to 40% of the availability. At boot stage and grain development, the water requirement is very important. Sorghum is mainly grown under the rainfed situation. Only about 8% of the sorghum area is irrigated. Sorghum crop is exposed to drought conditions very often during its growth and consequently, the yields are lower than the potential yield. So, if the farmers want higher sorghum yields even during the rainy season, the answer is irrigation if the water is available. Adequate soil moisture at sowing assure uniform plant stand and contributes to early plant growth. Pre-plant irrigation can supply this moisture when early rains do not fill the root zone before planting. If the seedbed contains sufficient moisture for good germination and early plant growth but subsoil moisture is lacking, water may be supplied by irrigating the crop after emergence. Allowing seeds to remain in dry soil for several days may result in poor germination and seedling vigor. So, irrigation before sowing is recommended if the water is available. Whether irrigating before or after planting, apply no more water than required to fill the effective root zone. Encourage deep rooting by maintaining only moderate soil moisture levels during early vegetative growth. Moderate plant moisture stress during early vegetative growth normally does not significantly limit grain yield. However, adequate moisture must be available by the boot stage. Irrigation at the milk to soft dough stages also has consistently maintained high yield potential.

Pluses or Grain Legumes

When grown alone, 1 or 2 irrigation would be beneficial. The grain legumes (gram, lentil, pea, and Indian bean) are irrigated 2 or 3 times during their growth. Drought stress is a complex syndrome involving several climatic. edaphic and agronomic factors, and characterized by three major varying parameters, the timing of occurrence, duration, and intensity. the complexity of the drought syndrome can only be tackled with a holistic approach integrating physiological dissection of the resistance traits and molecular genetic tools with agronomical practices that lead to better conservation and utilization of soil moisture and matching crop genotypes with the environment (Serraj *et al.*, 2003) [9]. Development of Short-Duration Genotypes Drought Avoidance Root Traits in Chickpea

Oilseeds

The crops are generally grown under rainfed conditions. Groundnut – 8 to 10 irrigation of about 50 mm each is applied at 10-15 days interval during its growth period. Safflower, Mustard, and Linseeds are grown alone are mixed with cereals should receive 3 or 4 irrigation during their growth.

Cotton

The optimum moisture range of soil moisture for the crop is from the field capacity to 20% of availability in 0-75 cm of the root-zone. Water requirements varied from 400-800 mm under different conditions and about 4-7 irrigation are required for cotton.

Table 1: Shows in Days after dibbling seeds

Stages	No. of Irrigations	Days after dibbling seeds	
		Light soil	Heavy soil
Germination Phase(1-15 days)			
Irrigate for germination and establishment	1	Immediately after sowing	Immediately after sowing
	2	Give life irrigation on the 5th day of sowing to facilitate the seedlings to emerge out	Give life irrigation on the 5th day of sowing to facilitate the seedlings to emerge out
Vegetative phase (16-44 days)			
Regulate	1	Irrigate on the 20th or 21st day of sowing, three days after hoeing and Weeding	Irrigate on the 20th or 21st day of sowing, three days after hoeing and weeding.
	2	Irrigate again on the 35th or 36th day of sowing.	Irrigate again on the 40th day of Sowing.
Flowering phase (45-100daysfor hybrids and 87 days for varieties)			
Irrigate copiously	1	48th day	55th day
	2	60th day	70th day
	3	72nd day	85th day
	4	84th day	100th day
	5	96th day	**

Jute

The optimum moisture regime is from the field capacity to 70% of availability in the maximum root-zone of the crop which can extend to about 45 cm of soil depth. Jute crop requires 500 mm of water. First irrigation is to be given after sowing and life irrigation on the fourth day after sowing. Afterward, irrigation can be given once in 15 days.

Sugarcane

The optimum soil moisture for sugarcane is 100-50% range of availability in the maximum root-zone, extending up to 50-75 cm in depth. In the north, the crop is planted during February-March and irrigated till the commencement of the monsoon. In Maharashtra irrigation is required throughout the year (2800-3000 mm per year).

1. Alternate furrow irrigation and skip furrow irrigation

Marginal yield reduction (49%) and more labor requirements (57%) were the constraints experienced in the adoption of alternate and skip furrow irrigation reported by one-third of the respondents.

2. Trash mulching and application of coir pith

It could be observed from the table that more than one-third (42%) of respondents stated that difficulty in intercultural operations and the possibility of pests and diseases (20%) were the constraints due to the adoption of trash mulching and application of coir pith.

3. Drip irrigation

It is evident from the table that constraints like lack of adequate technical inputs (55%) damage due to rats/rodents (58%) and high cost of spare parts, (51%) were experienced by respondents as major constraints in the adoption of drip irrigation. Further, more than one-third of respondents expressed that high initial cost (41%), salt encrustation (39%), inadequate extension or promotional activities, difficulty in getting the loan (35%) and cracking and clogging of drippers (33%) as other constraints for them.

4. Fertigation

Regarding fertigation, more than two-fifths of respondents reported high initial cost (27%), limited accuracy of application (25%) and expensive (22%) were the important constraints. More than 15 percent of respondents mentioned that pressure loss in the main irrigation line (19%), and non-suitability to small and marginal farmers (13%) as other constraints.

Tobacco

For cigar, hookah, and bidi tobacco the optimum moisture regimes are from the field capacity to 70, 60, and 50% of the availability respectively. Cigar tobacco needs light and frequent irrigation for 4 months. For hookah tobacco, 12-13 irrigation of 50 mm of water is required. Tobacco cannot tolerate waterlogging at any stage of growth but at the same time, the plants may not withstand drought also. An early drought is often preferred for better establishment and it enables the plant to withstand any moisture stress during the subsequent growth of the plant. The bulk of the roots of tobacco plants lie in the top 30 cm of the soil and 2/3 of the water loss is from this layer only. The field should be irrigated when the soil moisture falls to about 20 percent field capacity because higher soil moisture reduced the leaf quality. Hard water (saline) from wells must not have more than 50 ppm (50 mg in 1 lit) of chloride, otherwise, the leaves will have poor burning quality. Light irrigation at transplanting will often improve establishment and early growth in light soils. Irrigation will reduce the amount of scalding of upper leaves and the firing of lower leaves during dry weather. During the harvest period, occasionally, it may be desirable to irrigate tobacco. This should be done only during extreme drought. In general, for a tobacco crop of about 120 days, a field duration of around 20 irrigations is needed at 4-5 days intervals. The alternate/skip furrow method of irrigation is more economical and checks the wastage of irrigation water, electricity and time. It improves the leaf quality and gives a 10-20% higher yield than all furrow irrigation.

Forage Crops

The optimum moisture range is from field capacity to about 75% of availability. Berseem requires about 20 irrigation during its growth at intervals of about 20 days- December-January, 15 days-November-February-March. And 10 days-September-October-April. For Lucerne 1800 to 2000 mm of water required during the first year of growth.

Based on availability of water

When the land does not receive any irrigation, the cultivator takes a single crop in *Kharif* season on the available moisture in the soil. If the soil is heavy, the second crop in *Rabi* season after a short duration crop in *Kharif* season, but two seasonal or perennial crops is not beneficial. When irrigation becomes available the cropping plan can include heavy perennials like sugarcane and banana, light perennials like guava or orange, two seasonal crops like long-staple cotton, chillies, turmeric, etc. besides *Kharif* and *Rabi* seasonal crops, and also follow double-cropping such as groundnut green gram, black gram etc. followed by wheat or *Rabi* jowar, *Kharif* jowar or cotton followed by wheat, gram or some vegetable to seasonal crop followed by summer groundnut or some vegetable crop. The cropping plan in the irrigated areas is more intensive.

Green manuring can also be followed to maintain the fertility of the soil and to reduce the expenditure on organic manures and fertilizers. With the possibilities of double cropping its should see that it does not become lopsided.

Water management of cropping systems

Management of water supplies for irrigation is one of the most critical water-related problems especially in arid and semiarid agricultural lands. The objective of efficient and sustainable water management in an irrigated cropland is to ensure optimum linkage between water availability and water demand. This is best done by matching demand for water in terms of crop water requirements and available water supplies in time and in the required quantity. There are more than 30 types of cropping systems found in the country such as rice-wheat, rice-rice, rice-gram, rice-mustard, rice-groundnut, rice-sorghum, pearl millet-gram, pearl millet-mustard, pearl millet-sorghum, cotton-wheat, cotton-gram, cotton-sorghum, cotton-safflower, cotton-groundnut, maize-wheat, maize-gram, sugarcane-wheat, soybean-wheat, sorghum-sorghum, groundnut-wheat, sorghum-groundnut, groundnut-rice, sorghum-wheat, sorghum-gram, pigeon pea-sorghum, groundnut-groundnut, sorghum-rice, groundnut-sorghum, soybean-gram and so on.

Rainfed cropping systems

Many crop varieties grown in rainfed systems are adapted to exploit moisture stored in the root zone. Rainfed systems can be further improved by, for example, using deep-rooting crops in rotation, adapting crops to develop a deeper rooting habit, increasing soil water storage capacity, improving water infiltration and minimizing evaporation through organic mulching. Capture of runoff from adjacent lands can also lengthen the duration of soil moisture availability. Improving the productivity of rainfed agriculture depends largely on improving husbandry across all aspects of crop management. Factors such as pests and limited availability of soil nutrients can limit yield more than water availability *per se*[2, 3]. The principles of reduced tillage, organic mulching and use of natural and managed biodiversity are fundamental to improved husbandry (Wani *et al*., 2009) [11] The scope for implementing SCPI under rainfed conditions will depend, therefore, on the use of ecosystem-based approaches that maximize moisture storage in the root zone. While these approaches can facilitate intensification, the system is still subject to the vagaries of rainfall. Climate change will increase the risks to crop production. Nowhere is the challenge of developing effective strategies for climate change adaptation more pressing than in rainfed agriculture[4].

Other measures are needed, therefore, to allay farmers' risk aversion. They include better seasonal and annual forecasting of rainfall and water availability and flood management, both to mitigate climate change and to improve the resilience of production systems. More elaborate water management interventions are possible to reduce the production risk, but not necessarily to further intensify rainfed production. For instance, there is scope to transition some rainfed cropping systems to low-input supplementary irrigation systems, in order to bridge short dry spells during critical growth stages[5], but these are still reliant upon the timing and intensity of rainfall.

On-farm runoff management, including the use of water retaining bunds in cultivated areas, has been applied successfully in transitional climates, including the Mediterranean and parts of the Sahel, to extend soil moisture availability after each rain event. Off-farm runoff management, including the concentration of overland flow into shallow groundwater or farmer-managed storage, can allow for limited supplementary irrigation. However, when expanded over large areas, these interventions impact downstream users and overall river basin water budgets.

Extending the positive environmental and soil moisture conservation benefits of ecosystem approaches will often depend upon the level of farm mechanization, which is needed to take advantage of rainfall events. Simpler technologies, including opportunistic runoff farming, will remain inherently risky, particularly under more erratic rainfall regimes. They will also remain labour intensive.

Policymakers will need to assess accurately the relative contributions of rainfed and irrigated production at national level. If rainfed production can be stabilized by enhanced soil moisture storage, the physical and socio-economic circumstances under which this can occur need to be well identified and defined. The respective merits of low-intensity investments in SCPI across extensive rainfed systems and high intensity localized investments in full irrigation need careful socio-economic appraisal against development objectives.

With regard to institutions, there is a need for re-organization and reinforcement of advisory services to farmers dependent on rainfed agriculture, and renewed efforts to promote crop insurance for small-scale producers. A sharper analysis of rainfall patterns and soil moisture deficits will be needed to stabilize production from existing rainfed systems under climate change impacts.

Irrigated cropping systems

The total area equipped for irrigation worldwide is now in excess of 300 million ha[6], and the actual area harvested is estimated to be larger due to double and triple cropping. Most irrigation development has taken place in Asia, where rice production is practised on about 80 million ha, with yields averaging 5 tonnes per ha (compared to 2.3 tonnes per ha from the 54 million ha of rainfed lowland rice). In contrast, irrigated agriculture in Africa is practised on just 4 percent of cropped land, owing mainly to the lack of financial investment (Perry *et al*., 2009) [7].

Irrigation is a commonly used platform for intensification because it offers a point at which to concentrate inputs. Making this *sustainable* intensification, however, depends on the location of water withdrawal and the adoption of ecosystem based approaches – such as soil conservation, use of improved varieties and integrated pest management – that are the basis of SCPI. The uniformity of distribution and the application efficiency of irrigation vary with the technology used to deliver water, the soil type and slope (most importantly its infiltration characteristic), and the quality of management. *Surface irrigation* by border strip, basin or furrow is often less efficient and less uniform than overhead irrigation (e.g. sprinkler, drip, drip tape). *Micro irrigation* has been seen as a technological fix for the poor performance of field irrigation, and as a means of saving water. It is being adopted increasingly by commercial horticulturalists in both developed and developing countries, despite high capital costs.

Deficit irrigation and variants such as *regulated deficit irrigation* (RDI) are gaining hold in the commercial production of fruit trees and some field crops that respond positively to controlled water stress at critical growth stages. RDI is often practised in conjunction with micro-irrigation and “fertigation”, in which fertilizers are applied directly to the region where most of the plant’s roots develop. The practice has been adapted to simpler furrow irrigation in China. The benefits, in terms of reduced water inputs, are apparent but they will only be realized if the supply of water is highly reliable.

Knowledge-based precision irrigation

That offers farmers reliable and flexible water application will be a major platform for SCPI. Automated systems have been tested using both solid set sprinklers and micro-irrigation, which involve using soil moisture sensing and crop canopy temperature to define the irrigation depths to be applied in different parts of the field. Precision irrigation and precision fertilizer application through irrigation water are both future possibilities for field crops and horticulture, but there are potential pitfalls. Recent computer simulations indicate that, in horticulture, salt management is a critical factor in sustainability.

The economics of irrigated agriculture are significant. The use of sprinkler and micro-irrigation technologies, as well as the automation of surface irrigation layouts, involve long term capital expenditure and operational budgets. Rain guns provide one of the cheapest capital options for large area overhead irrigation coverage, but tend to incur high operating costs. Other overhead irrigation systems have high capital costs and, without the support of production subsidies, are unsuited to smallholder cropping systems.

The service delivery of many public irrigation systems is less than optimal, owing to deficiencies in design, maintenance and management. There is considerable scope for modernizing systems and their management, through both institutional reform and the separation of irrigation service provision from broader oversight and the regulation of water resources.

Drainage is an essential, but often overlooked, complement to irrigation, especially where water tables are high and soil salinity is a constraint. Investment will be required in drainage to enhance the productivity and sustainability of irrigation systems and to ensure good management of farm inputs. However, enhanced drainage increases the risks of pollutants being exported, causing degradation in waterways and connected aquatic ecosystems.

Protected cropping, mostly in shade houses, is enjoying increasing popularity in many countries, including China and India, mainly for fruit, vegetable and flower production. In the long term, highly intensive closed cycle production systems, using conventional irrigation or hydroponic and aeroponic cultures, will become progressively more common, especially in peri-urban areas with strong markets and increasing water scarcity.

Using water for irrigation reduces instream flows, alters their timing, and creates conditions for shocks, such as toxic algal blooms. Secondary impacts include salinization and nutrient and pesticide pollution of water courses and water bodies. There are other environmental trade-offs from irrigated systems; rice paddies sequester higher levels of organic matter than dry land soils, and contribute less nitrate runoff and generate lower emissions of nitrous oxide (N_2O). Offset against this are relatively large emissions of methane (from 3 to 10 percent of global emissions) and ammonia.

Crops normally use less than 50 percent of the irrigation water they receive, and irrigation systems that lie within a fully or over-allocated river basin have low efficiency. In accounting terms, it is necessary to distinguish how much water is depleted, both beneficially and unproductively. Beneficial depletion by crops – evapotranspiration – is the intent of irrigation: ideally, transpiration would account for all depletion, with zero evaporation from soil and water surfaces. There is some potential to improve water productivity by reducing non-productive evaporative losses.

Basin level improvements in water productivity focus on minimizing non-beneficial depletion[7]. However, the downstream impacts of increased water depletion for agriculture are not neutral: there is evidence of big reductions in annual runoff from “improved” upper catchments that have adopted extensive water harvesting in parts of peninsular India [8].

Water management is a key factor in minimizing nitrogen losses and export from farms. In freely drained soils, nitrification is partially interrupted, resulting in the emission of N_2O, whereas in saturated (anoxic) conditions, ammonium compounds and urea are partially converted to ammonia, typically in rice cultivation. Atmospheric losses from urea can occur, therefore, as both ammonia and N_2O are released during wetting and drying cycles in irrigation. N is required in nitrate form for uptake at the root, but can easily move elsewhere in solution. A number of protected and slow release fertilizer compounds are under development for different situations.

The dynamics of phosphate mobilization and movement in drains and waterways are complex. Phosphate export from agriculture can occur in irrigated systems if erosive flow rates are used in furrow irrigation, or if sodic soils disperse. Phosphate, and to a lesser extent nitrate, can be trapped by buffer strips located at the ends of fields and along rivers, which prevents them from reaching waterways. Hence, a combination of good irrigation management, recycling of tailwater and the incorporation of phosphate in the soil can reduce phosphate export from irrigated lands to close to zero.

The sustainability of intensified irrigated agriculture depends on minimizing off-farm externalities, such as salinization and export of pollutants, and the maintenance of soil health and growing conditions. That should be the primary focus of farm level practice, technology and decision-making, and reinforces the need for depletion water accounting and wiser water allocation at basin and catchment scales, and a better understanding of the hydrological interactions between different production systems.

Rice based cropping system

Rice is the most widely grown cereal in East, Southeast and South Asia. Depending on the supply of water, rice ecosystems are classified into upland, rainfed lowland, irrigated and flood prone. Within each of these ecosystems, further diversity arises from differences in temperature, soil type and season In terms of cropping intensity, rice-based systems range from single crop of rice under dry upland and flood-prone conditions to three crops under intensive irrigated conditions in tropical and subtropical environment (Randolph Barker *et al*., 2008) [5]. The release of photoperiod insensitive varieties allows multiple rice crops under tropical environments of East, Southeast and South Asia. This has also allowed growing summer rice in large parts of South and Southeast Asia where rice cultivation was traditionally done with the onset of monsoon in July. With one or two supplemental irrigations, rice is planted at the end of the spring season. Such rice crops take advantage of pre-monsoon rain in May and June and mature towards the end of the monsoon season in August-September. The summer rice crop utilizes long hours of sunshine, which allows higher biomass production and higher grain yield than the monsoon rice that completes half of the growing period under short day hours. Early maturing, photoperiod insensitive varieties have permitted rice cultivation in areas where long day and short night summer season was traditionally not suitable to grow photoperiod sensitive varieties. Thus, photoperiod insensitive rice varieties have helped in extending rice-based cropping systems in Asia (Gupta *et al.*, 2007) [6].

The total annual irrigation water requirement of the rice–wheat system ranges from 1100 to 1600mm/yr .Work initiated in Pakistan in close collaboration with the private sector, and later supported by RWC, has successfully adapted the technique of laser land levelling for use in the rice–wheat system. Laser assisted precision land levelling facilitates application of less water more uniformly under flood irrigation, reduces leaching losses and improves crop-stand and yields. In rice–wheat system, precision land levelling saves irrigation water in wheat season by up to 25%; reduces labor requirements by up to 35%; leads to about 2% increase in the area irrigated due to removal and/or reduction in size of bunds made to impound water for rice cultivation; and increases crop yields by up to 20% .Further work is now in progress in all the RWC countries to integrate other land-preparation and crop-establishment methods with laser levelling to reduce water use at the field/ farm/basin levels (Rice–Wheat Consortium (RWC), 2004).

Wheat based cropping system:

The wheat-based cropping systems are mostly annual, and include wheat–rice, wheat–maize, wheat–cotton, wheat–grain legumes–rice, wheat–potato–rice and wheat–millet–maize. However, a great diversity in wheat-based cropping systems exists in different countries depending on temperature, type of wheat grown (spring, facultative, winter) and water availability. For example, on the dry land of Central and West Asia, a single crop of wheat is grown under rainfed or supplemental irrigation. On the other hand, three crops are grown under intensive wheat-based cropping systems in South Asia (Sardas *et al.*, 2006) [8]. In many parts of the continent, two crops are grown in the wheat-based annual cropping system. However, rice-wheat cropping system in the non-traditional warm wheat growing environments on the Gangetic Plains allows only 90–120 days of crop cycle. Often, late harvest of traditional rice varieties compels the farmers to delay sowing of wheat until late December and early January instead of the optimum sowing date during the second half of November. Late-sown wheat completes the vegetative period under optimum temperature conditions; however, grain filling can be reduced by up to 50% (average 60 days reduced to 30 days) causing severe reductions in grain yield primarily due to reductions in biomass production. On average, yield declines at 37 kg ha^{-1} per delayed day in sowings later than 25 November. High temperatures during grain filling hasten senescence and crop ripening, curtailing potential assimilate production that reduces grain weight; the length of grain-filling period is positively correlated with wheat grain yield). Research efforts are underway to deal with this problem using a combination of breeding Most effort is directed at developing (a) early maturing rice using photoperiod insensitive varieties and (b) low-till wheat seeders that allow sowing wheat two to three weeks earlier than the traditional tillage practices. Such a system would allow for cool nights and warm spring days for wheat grain filling. The breeding × agronomy synergy sought to improve rice-wheat systems in Asia is the main theme of Chapter 2. Interestingly, many of the problems and opportunities for improvement in Asia cropping systems are comparable with those in developing novel, multiple.

Maize based cropping system

Maize is widely grown on uplands, where multiple year cropping systems also include fodder legumes and sugarcane. Recently, there has been increasing interest in expanding maize-based cropping systems in Asia. The traditional rice–wheat mega cropping system is losing a part of its area to the expansion of rice–maize. Summer rice followed by winter maize is becoming important both in South This system is becoming more important due to higher yield of winter maize over wheat and other alternative winter crops, and the increasing demand of maize for animal feed and biofuel. Even though maize has been traditionally a summer crop, the mild temperatures during winter allow for a maize crop cycle, with the advantage of increased water use efficiency associated with lower vapour pressure deficit in comparison to typical summer crops.

Oilseed base cropping system

Majority of oilseeds are rainfed crops, except groundnut and mustard .in south India groundnut is the alternate crop to rice in *Rabi* season both in command areas and well irrigation. If water is not sufficient for groundnut then sunflower is the next preferable crop. Castor is gaining important in past few years as a irrigated crop during *Rabi* season.

Sugarcane based cropping system

It offers scope for a number of intercrops due to its longer duration, and wider row spacing. Short duration pulses and oilseeds are generally preferred as intercrops during early phase of crop growth. In case of sugarcane-rice-potato, sugarcane plantlets grown in polybags are used for transplanting in June. Interspace between two cane rows are puddle once or twice in 5 cm standing water death and short duration rice is planted in July.

Conclusion

In Punjab rice-wheat system water diversions to rice are considerably higher than wheat. However the water actually consumed as transpiration by rice is almost similar to wheat. Consequently, the water productivity of rice is lower than wheat when measured in terms of total water input, irrigation inflow and evapotranspiration. However, the water productivity of rice when measured in terms of actual transpiration is comparable to wheat indicating more economic returns per unit of water actually consumed by the crop. The large amount of water applied to rice is most often recycled and used within the river basin. Therefore, at field scale rice is water inefficient crop but at basin scale it may not be true as water percolated from rice fields is often reused via groundwater abstraction. This indicates that the scale considerations are very important in evaluating the water productivity of various crops. The water productivity showed considerable variability both in space and time. The main factors influencing spatial inequalities in rice-wheat zone of Pakistan's Punjab were: soils; access to irrigation water, groundwater quality, and agronomic practices. Climatic variability, mainly the timing and amount of rainfall, was found to be the major factor causing temporal changes in water productivity. The overall water productivity in terms of gross inflow for rice, wheat and rice-wheat rotation showed a decline during the cropping year 2002-3 as compared to 2001-2. Neither lower rainfall during *Kharif* 2002, nor more rainfall during *Rabi* 2002-3 could work effectively in improving the water productivity. Since farmers pumped groundwater excessively to meet water shortages during *Kharif* 2002 and could not make optimal use of water, which reduced water productivity and gross margins per unit of water. During the *Rabi* 2002-3 the water productivity per unit of gross inflow was lower than that of *Rabi* 2002-2, but irrigation water productivity was high. However, this higher irrigation water productivity could not be generalized as more crop per drop because total water input remained higher and no significant gains in yield were observed. Therefore, it is concluded that to sustain or enhance water productivity over time more careful response is need to manage the uncontrollable factors such as climatic variability along with the improvements in controllable factors like agronomic and water management practices. The study also indicates that water productivity analysis should be done through a combined set of water balance and water productivity indicators. Restricting analysis to one or two indicators may not provide the real picture of the water availability, the farmers' way of using it, distribution to various agro-hydrological processes and benefits. This would greatly help water users, water managers and policy makers in the management of available resources in a way that will enhance the productivity of land and water resources.

Acknowledgement
The data used for this study was collected from the research work conducted at Soil Salinity Research Institute (SSRI), Pindi Bhattian and at the farmers' fields. The authors wish to thank SSRI and farmers (Syed Ijlal Haider Zaidi, Sardar Zahoor Ahmed Dogar and Malik Sajad Solomon) for the cooperation. Specially, we acknowledge the Rice-Wheat Consortium (RWC) of Indo-Gangetic Plain for initiating this applied and collaborative research at farmers' fields. Thanks go to Asian Development Bank (ADB) and International Water Management Institute (IWMI) for funding. More careful response is need to manage the uncontrollable factors such as climatic variability along with the improvements in controllable factors like agronomic and water management practices. The study also indicates that water productivity analysis should be done through a combined set of water balance and water productivity indicators. Restricting analysis to one or two indicators may not provide the real picture of the water availability, the farmers' way of using it, distribution to various agro-hydrological processes and benefits. This would greatly help water users, water managers and policy makers in the management of available resources in a way that will enhance the productivity of land and water resources.

References
1. www.indiaagronet.com
2. www.gktoday.in
3. www.agritech.tnau.ac.in
4. Ahmad MUD, Masih I, Turral H. Diagnostic analysis of spatial and temporal variations in crop water productivity: A field scale analysis of the rice-wheat cropping system of Punjab. Journal of Applied Irrigation Science 2004;39(1):43-63.
5. Barker R, Molle F. Irrigation management in rice-based cropping systems: issues and challenges in Southeast Asia. Food and Fertilizer Technology Center 2004.
6. Gupta R, Seth A. A review of resource conserving technologies for sustainable management of the rice–wheat cropping systems of the Indo-Gangetic plains (IGP). Crop protection 2007;26(3):436-447.
7. Perry C, Steduto P, Allen R, Burt C. Increasing productivity in irrigated agriculture: Agronomic constraints and hydrological realities. Agricultural Water Management 2009;96:1517-1524.
8. Sadras VO, Angus JF. Benchmarking water use efficiency of rainfed wheat in dry environments. Australian Journal of Agricultural Research 2006;57:847-856.
9. Serraj R, Bldmger FR, Chauhan YS, Seetharama N, Nigam SN, NP. Management drought in ICRISAT's cereal and legume mandate crops. In: Water Productivity In Agriculture: Limits and OpportUnities for Improvement, J.W. KIJne, R. Barker and D. Molden), CABI, Wallmgford, UK 2003.
10. UNDP. Human Development Report. New York, USA 2006.
11. Wani SP, Rockstrom J, Oweis T. eds. Rainfed agriculture: Unlocking the potential. Comprehensive Assessment of Water Management in Agriculture 7. Wallingford, UK, CABI Publishing 2009.