Efficient Water Management for Agricultural Productivity in North East

World scenario

The total water resources of the earth are about 1,384 mkm^3. More than 97 percent of the world's water resources are in the oceans and seas and are too salty for most production uses. The water in the ocean has a salt content of about 3 % and not fit for direct use by humans or in agriculture. Two-thirds of the remainder is locked up in ice caps, glaciers, permafrost, swamps and deep aquifers. Only 2.6 % is fresh water. Of the fresh water also, only a small fraction (0.52 %) is available as surface water. The survival of mankind for all practical purposes is mainly dependent on this surface source. Other source, ie., ground water needs a lot of infrastructure and planning for effective use. Every year, about 108 000 billion m^3 precipitates on to the earth's surface. About 60 percent of this (61 000 billion m^3) evaporates directly back into the atmosphere, leaving an annual water resource of 47 000 billion m^3. If this amount were distributed evenly across the world's population, there would be approximately 9 000 m^3 per person per year. However, water availability varies across continents, with North and South America being better watered than Africa, Asia and Europe. Furthermore, much of Africa and Asia's potential supply is lost through runoff caused by heavy seasonal rains. It is estimated that only 9 000 to 14 000 billion m^3, or about a quarter of the annual water resource, may ultimately be controllable. At present, an estimated 3 400 to 3 700 billion m^3 is utilized

Agriculture is the largest consumer of water, using 70 percent of the total worldwide and 87 percent in developing countries. Whereas, if developed countries are considered, it only 30% (Fig.1). With growing demand for water for non-agricultural uses (domestic, municipal, industrial and environmental), the proportion available for agriculture is projected to decline to 62 percent worldwide and 73 percent in developing countries.

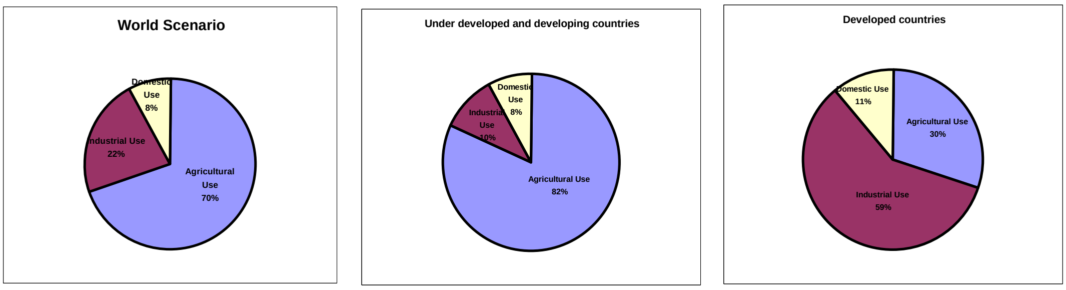


Fig.1: World Scenario of Water use in Different Sectors

Water resources of India and North East

Water is prime natural resource, a basic human need and precious national perspectives. Irrigation is crucial

for human development; it has profound impact on global water bodies and on irrigated crop lands and impact, which is expected to be more severe in the future. Water will soon be sold like oil through pipelines and tankers and that 21st century wars will be over disputed water sources (Chatterjee, 2002). About 1.3 billion persons lack safe water and 2.4 billion are denied sanitation. About 6000 persons die every year due to contaminated water (Satapathy and Sharma, 2006). By 2015, water demand will exceed supply by a staggering 30%. The per capita availability in Brahmaputra basin is more than 14000 m^3 compared to only about 120 m^3 in Kutch area of Gujarat. Total annual water resources of the country have been estimated at 1,953 km^3. The utilizable resource has been estimated as 690 km^3 surface and 450 km^3 ground water equalizing a total of 1,140 km^3. In India, 80% of water is used for farming, 5% for domestic use and 15% for industrial and other uses. The per capita availability of water at National level has reduced from about 5,177 m^3 in 1951 to the estimated amount of 1,820 m^3 in 2001. Over 80% of the domestic water supply is dependent on ground water. This source is also depleting fast and there is steady decline in ground water table. According to world water institute, India will be a highly water stressed country from 2020 onwards. The definition of water stress is that less than 1000 cubic meter of water will be available per person per annum. The annual demand for irrigation water in India and North East during the year 200 was 460 and 20 km3 and for 2025 estimated at 810 and 32 km3, respectively (Satapathy and Sharma,2006). The average annual precipitation in the country is about 4000 km^3, a part of it goes as run off, a part of it lost as evapo-transpiration and remaining goes to recharge ground water.

North East India is endowed with bounty of water resources accounting for about 46% of the total water resources in the country, almost equivalent to 60 m ha m. the region has the worst water resource problem in form of floods and water logging rendering huge sufferings to thousands of people every year. The region also suffers from acute shortage of even drinking water in many areas due to mainly due to lack of proper management of rain water. It becomes almost impossible to take a second crop in rabi/dry season due to soil moisture status and lack of irrigation facilities. On the other hand, in land locked valleys, after harvesting paddy, the field left unutilized. A second crop of vegetables can't be taken due to excess soil moisture status and lack of drainage facilities. A proper land configuration strategies like raised and sunken bed system could allow proper drainage and improved soil condition thereby allowing to take a profitable second vegetable crops.

The NE region has a surface and ground water potential of 1487.2 and 25.3 km^3, respectively (Borthakur *et al*, 1989). Out of on irrigation potential of 36, 810 km^2, only 5,120 km^2 or 15.3% of the potential has been exploited in NE region (Sharma, 2003). Out of total irrigated area 69.8% are in Assam alone. Manipur has 25.5% of the net sown area, compared to 13.8% in Meghalaya. Present cropping intensity of 135% (Thasanga and Saxena, 2000) of the region would go up to 200% if full irrigation potential is utilized.

The average annual rainfall of the country is 1120 mm and that of NE is about 2450 mm. Droughts and floods are the adverse climatic conditions rising out of deficit and excess rainfall, respectively. Drought assumes significance mainly in rainfed conditions of North East. Creation of sufficient irrigation facilities may reduce the impact of drought in crop production significantly. On the other hand flood is limiting factor in the flood plains of Brahmaputra, Barak and their tributaries in the North Eastern region. About 35840 km^2 area (14% of total geography area of the region) are prone to floods out of which 3760 km^2 is affected by floods annually (Satapathy and Sharma, 2006). Heavy destructions of forest lands in the catchments of these rivers and unplanned construction of river embankment are mainly responsible for flood problem in these areas. Multipurpose river valley projects supported by judicial land use planning may reduce the intensity and impact of flood.

Table. Inland water resource potential in NE states (000ha) and utilizable groundwater resource for irrigation (m ha m).

State	River length (km)	Reservoirs	Tanks/ponds	Lakes	Ground water resource (m ha m)
Arunachal pradesh	2500	0.38	1.00	2.50	0.1223
Assam	4850	36.04	16.47	83.84	1.8421
Manipur	3360	0.10	5.00	4.00	0.2681
Meghalaya	5600	1.17	1.82	0.21	0.1042
Mizoram	1748	-	1.60	-	-
Nagaland	1600	9.50	4.94	0.21	0.0615
Tripura	1200	4.50	9.60	0.50	0.2135
Total	19,468	51.69	40.44	91.26	

Source: Satapathy and Sharma, (2006)

Importance of water

A. Agriculture

- Plant cant live without water since it constitutes 80-90% of most plant cell
- Water is required for germination
- Play a important role in plant growth and development
- Maintains turgidity in plant systems.
- Serves as a solvent for plant nutrients
- Act as a carrier for plant nutrients from soil to plant systerm. Helps in transporting metabolites/plant food from source to sink i.e., vegetative to reproductive parts.
- Maintains soil and weather temperature.
- Helps for land preparations like ploughing, puddling etc.

B. Human activities and others

- It influences the atmospheric weather
- Support humans and animal life
- Provides drinking water
- Act as a means of transport
- It is an important industrial commodity
- Provides land escapes and adds beauty to the nature
- As a source of recreations
- Saves wild life habitat.
- Used fro washing, cleaning, construction etc.

- As a means of power generations.
- Maintains ecosystem
- Helps in keeping the environment clean and pollution free

Some facts

- Amount of water required to produce a kilo of plant dry matter: 500lt
- Amount of water required to produce a kilo of rice: 3500lt
- Conveyance loss of water: 20- 60 %
- Water saved by Drip irrigation: 50%
- Water saved by sprinkler irrigation: 30-40%
- Rice cultivation alone consumes about 66 % of water in agriculture.
- SRI method of rice cultivation saves up to 40% water
- Aerobic method of rice cultivation saves more than 50% water.

How to save and effectively use water:

-Improved conservation and management of rainwater
-Improved conveyance of irrigation water from source to field
-Using modern technology like drip irrigation, sprinkler irrigation etc.
-Avoiding excessive use of water unnecessarily.

- Recycling of water from domestic and agricultural use.
- Roof water harvesting
- Devising various water harvesting structures for harvesting runoff water.
- Conjunctive use of water from various sources

Sources of Water

Ultimate source of all kinds of water is the rainfall. Based on its sources of availability it can be classified as surface water and subsurface water.

Surface water includes precipitation i.e., rainfall and dew, water available from river, tank, pond, lake, bills, etc. Snowfall also contributes some amount of water in heavy snowfall area like Jammu, Kashmir and Himalayan region.

Subsurface water includes under ground water, water from aquifer and well etc.

Rainfall

Major rainfall season can be classified as-

Winter (Cold dry period) –Jan-Feb: It contributes a good rainfall in many years. Vegetables like carrot, radish, frenchbean etc. are grown.

Summer (Hot weather) – March - May: Also called pre-moonsoon/pre-*kharif* season accounts for about 25% of annual rainfall in the north east. Moisture conservation practices in this season improves crop yield substantially. Tomato, beans, ginger, turmeric, green gram etc. are sown in north east during this time.

Kharif/rainy season (South-West monsoon)- June – July: In North East about 70% rainfall is received during this season. This season is also called as monsoon season. Main crops grown with this are rice, maize, Bhindi, groundnut, soybean etc.

Rabi (North- East monsoon) – October- December: Very little rainfall is received in this season in the region. Cole crops,pea,lentil, mustard etc. are sown during this season. Wheat is also sown in the month of October-November.

The rainfall in north east is mostly associated with storm and is generally heavy with average number of days having 25 mm or more rainfall are over 100 except southern Meghalaya, where there is an average of two days in three.

Characteristics of good rainfall:

- Quantity should be sufficient to replace the moisture depleted from the root zone.
- Frequency should be so as to maintain the crop without any water stress before it starts to wilt.
- Intensity should be low enough to suit the soil absorption capacity
- Indian and the north eastern rainfall does not have the above good characteristics to maintain the crop through rainfall alone.

Water requirement of crops

Water requirements (WR) may be defined as the quantity of water required by a crop or diversified pattern of crop in a given period of time for its normal growth under field conditions at a place. It includes the losses due to evapo-transpirations (ET), amount of water used by plants (WP) for its metabolic activities, generally less than 1% of total water absorption by the plant and other application losses (AL) like conveyance loss, percolation loss, runoff loss etc. and the water required for the special purposes (WSP) like puddling, ploughing, land preparations, leaching requirements, weeding, dissolving fertilizer and chemicals etc.

Hence , WR is symbolically given by

WR= ET + WP+AL+WSP.

The other application losses and special purposes are mostly for wet land cultivation.

Water requirement of important crops

Crop	Water requirement (mm)
Rice	1200-1400
Maize	400-550
Sorghum	400-550
Wheat	450-550
Ragi	350-550
Pulses	350-450
Groundnut	350-650
Sunflower	300-500
Cotto	600-850
sugercanen	1400-2000
Banana	1650-2250
Plantation crops	1250-1850

range of different crops

Irrigation requirements

The field irrigation requirement (IR) of crops refers to water requirement of crops exclusive of effective rainfall and contribution from soil profile. It may be given as

IR = WR –(ER+S)

WR = Water requirement
ER = Effective rainfall
S= soil moisture contributions
The useful portions of rainfall which is stored and supplied to the crop for its consumptive use is called effective rainfall.

Factor influencing irrigation methods

Soil type

The physical properties of soil such as texture, structure, porosity, water holding capacity etc. greatly influence the method of irrigation water.
Heavy textured soil restricts water movement and has higher water holding capacity.
Sandy soil has very low water holding capacity and sa a result more irrigation water are required.

Climate

Rainfall, temperature, humidity, etc. influence the irrigation methods. In north east, where rainfall is very high, irrigation by furrow methods for vegetables are advocated for better results.

Water source

The total water available, flow velocity and quality of water also influence the method of irrigation.

Method of cultivation

Crops to be irrigated, geometry of crop, method of cultivation etc. also greatly influence the irrigation methods. Eg. Rice may be irrigated by flooding method. Again if rice is grown under SRI method of cultivation, alternate drying and wetting may be followed instead of continuous submergence.

Crops to be grown

Since drip and sprinkler irrigation needs higher investments, its preferred for high value crops. Recently in Meghalaya, Drip irrigation method is becoming popular for strawberry cultivation.

When and how much to irrigate (Irrigation scheduling)

The basic questions how much to irrigate, how to irrigate and when to irrigate – need special consideration for efficient on-farm water management in field crops. Various practices are adopted by the scientists and farmers throughout the world. These three aspects are discussed below.

Irrigation depth

The quantity of water applied at each irrigation will depend on root zone depth, solid characteristics and water deficit before irrigation. In general, the depth of each irrigation will depend on soil-plant-water characteristics and irrigation methods. In light textured soils, light but frequent irrigation, will be required. However, it should be kept in mind that partial replenishment of root zone reservoir by light irrigation not only improves field application efficiency, but also forces the plant to extract relatively more water from deeper layers of soil profile (Singh and Singh, 1995a). It also provides some storage capacity in soil profile if there is increase a rainfall after irrigation. The irrigation depth could vary widely at different stages of crop development, time of the year and location. For this purpose the knowledge of crop coefficients (Kc) is important during emergence and early growth stage, there is little crop cover. Thus, evaporation from soil surface dominates evapotranspiration. Because soil surface dries rather quickly and dry surface limits evaporation, the water loss is considerably below potential evapotranspiration and Kc is small. As plants grow and cover more of the soil, transpiration begins to dominate evapotranspiration, and Kc increases. The increased evapotranspiration occurs because water is not limiting for transpiration even though the surface has dried enough so that water becomes limiting for soil evaporation. The values of Kc for different periods of crop growth of some important crops are summarized by Singh (1996a). This information is very useful to adjust the depth of individual irrigation as per water requirement at different stages of crop growth.

Table. General guidelines for selection of irrigation methods (Singh, 1996a)

Method of irrigation	Soil texture	Infiltration rate	Land topography and slope (%)	Stream size (litres/sec)	Crops
Check basin	Light or heavy	0.5 – 10	Leveled, less than 0.1	Large, more than 15	All crops except those on ridges and susceptible to water logging
Border strip	Medium	1-2	Uniformly graded, 0.1-0.3	Any more then 12-15	All crops
Furrow	Light to moderate	0.5 - 2.5	Moderate, 0.3-3.0	Small, more than 12	Row crops and vegetables
Sprinkler	Very light	2.5 – 2.0	Rolling and undulating (Sand dunes)	Any, more than 5	All crops except rice and jute
Drip	Light to heavy soils	0.5 or more	Level to undulating	Any, more than 5	Widely spaced vegetable and fruit crops

The timing of irrigation could be decided by using any of of the following methods-

Indicator plant: Growing an indicator plants in association with a crop that exhibits water stress sysmptoms earlier than the crop itself has been used for irrigation scheduling. There are certain plants, which are more sensitive to water stress eg. Sunflower, tobbaco etc could used.

Soil moisture depletion approach

The crop is irrigated when the soil moisture in the root zone is depleted to a particular level. For crops like maize, wheat etc. water is applied when the soil moisture is depleted by 25%. For other crops that are resistance to stress like millets, pulses, cotton etc. irrigation water may be applied uoro 50% depletion.

Climatological approach

Climatological factors are used to calculate the amount of water lost by evapotrnaspiration. The important environmental factors affecting evapotranspiration are light intensity, atmospheric vapour pressure, temperature, wind velocity and soil water supply to roots. Plant factor include the extent and efficiency of root system in absorption, crop cover, canopy architecture are and stomatal behaviour. When ET reaches predecided level, irrigation is scheduled. The most practical among this is the **IW/CPE approach.** A known amount of irrigation water is applied when cumulative pan evaporation (CPE) reaches a predetermined level. The amount of irrigation waterwater generally applied is 5cm. Scheduling irrigation at an IW/CPE ration of 5cm means 5cm irrigation wateris applied when the CPE reaches 5cm.

Critiocal stage approach:

There are certain critical periods of water requiremnt for each crops. If the crop experiences stress during this period, there is drastic reduction in yield. Therefore if the crop is irrigated at this stage, the optimum productivity can be obtained.

Water sensitive stages of different crops

Crops		**Critical stages / Sensitive stages**
Rice	-	Panicle initiation critical staps, heading and flowering
Sorghum	-	Flowering and grain formation
Maize	-	Just prior to tasseling and grain filling
Ragi	-	Primordial initiation and lowering
Wheat	-	Crown root initiation, tillering and booting
Oilseeds		
Groundnut	-	Flowering peg initiation and penetration and pod development

Sesame	-	Blooming to maturity
Sunflower	-	Two weeks before and after flowering
Soybean	-	Blooming and seed formation
Safflower	-	From rosette to flowering
Castor	-	Full growing period
Cash crop		
Cotton	-	Flowering and Boll formation
Sugarcane	-	Maximum vegetative stage
Tobacco	-	Immediately after transplanting
Vegetables		
Onion	-	Bulb formation to maturity
Tomato	-	Flowering and fruit setting
Chillies	-	Flowering
Cabbage	-	Head formation to maturity
Legumes		
Alfalfa	-	Immediately after cutting for hay crop and flowering for seed crop
Beans	-	Flowering and pod setting
Peas	-	Flowering and pod formation
Others		
Coconut	-	Nursery stage root enlargement
Potato	-	Tuber initiation and maturity
Banana	-	Throughout the growth
Citrus	-	Flowering, fruit setting and enlargement
Mango	-	Flowering
Coffee	-	Flowering and fruit development

Growth stages of cereals in relation to irrigation

Germination	The appearance of radicle
Tillering	The formation of tillers
Jointing	The stages when nodes becomes visible or internodes elongation begins
Booting	The end of jointing and just prior to the emergence of ears
Heading	The emergence of the earhead from the tube formed by the leaf sheaths.
Flowering	Opening of flower
Grain formation	Period of gerain formation from fertilization to maturity and divided into
	Milk stage- after flowering where the ears bear milk like substances
	Dough stage- the contents of grain become thicker and doughy in consistency
	Dead ripe- ripe for harvesting, grain become gard.

Guide for judging the amount of available soil moisture for irrigation

Available soil moisture range	Coarse texture (Loamy sand)	Moderately coarse (Sandy loam)	Medium texture (Loam and silt loam)	Fine texture (Clay loam and silty clay loam)
Field capacity	On squeezing, no free water appears on soil, but wet outline is left on hand.	Similar symptoms for all types of soils.		
75 to 100%	Tends to stick together slightly, sometimes forms a weak ball under pressure	Forms weak ball, breaks easily, doesn’t stick	Forms a ball, is very pliable slicks readily	Easily ribbons out between fingers, has slick feeling
50 to 75%	Appears to be dry, do not form a ball with pressure	Tends to form a ball under pressure but seldom holds together.	Forms a ball somewhat plastic sometimes slick slightly with pressure	Forms a ball, ribbons out between thumb and forefinger

25 to 50%	As above, but ball is formed by squeezing very firmly	Appears to be dry, do not form a ball unless squeezed very firmly	Somewhat crumbly but hold together with pressure	Somewhat pliable, forms ball under pressure
0 to 25%	Dry, loose, single grained, flows through fingers	Dry, loose, flows through fingers	Powdery, dry, sometimes slightly crusted but easily broken down into powdery conditions.	Hard, baked, cracked, sometimes has loose crumbs on surface.

Importance of irrigation management

- To help in nation building through proper use of water for improving crop production, other uses like industrialization, power generation etc.
- To store and regulate the water resources for further use or off season use
- Balance equity distribution among the stakeholders
- To use the water efficiently without much conveyance loss
- To apply sufficient quantity to crops and reduce wastage
- To use the water considering the cost-benefit ie. Economical use of water
- To distribute the available water without any social problems
- To meet the future requirements for other purposes like domestic use of individual and to protect against famine.
- To protect the environment and ecosystems ie., environmentally safe use of water.

Impact of excess and insufficient use of water

- Excess use of irrigation water leads to unnecessarily wastage of water, leaching of beneficial plant nutrients, imbalance of beneficial microbes in the soil, leads to salinization, water logging leading to yield loss and making the land unproductive.
- Insufficient water leads to poor growth and development, reduced yield and quality of produce or sometime even complete failure of the crop.

Methods of irrigation

There are three major methods of irrigation

A. Surface or gravity method: In this method, water is applied directly to the soil surface from a channel, pond or any other source of water. The advantage of the method is that it is easy to maintain, low cost and required no technical skill. The most common method of surface irrigation are flooding, check-basin, border strip, basin, border strip, and furrow method. Efficiency of surface irrigation methods can be improved, if distribution systems are constructed scientifically to provide adequate control of water to the fields and proper land shaping is done for uniform distribution of water over the field.

i. Wild or uncontrolled flooding: This is the easiest method of irrigation water is simply allowed to enter to the plot from one end until the whole field is irrigated. The efficiency of this method is very low. In north east this method is used for rice and other crops also.

ii. Controlled flooding, classified as

a. Border strip method : The field is divided into number of long parallel strips by providing small parallel earthen bunds of 15-20 cm height or levees or dykes along both sides of the strips. The length of the strip ranges from 30 to 300m and width ranges from 3 to 15 m. The size of the border strip depends on the stream size, soil structure and slope or on the contour. Each strip is irrigated separately from upper end and water flow as thin sheet and uniformly spread along the strip. The water is turned off when the required volume is delivered to the strip. This method is most suitable for soil with low to moderate rate of infiltration. This method is suitable for close growing crops and medium to heavy textured soil, but not suitable for sandy soils. Large irrigation streams can be effectively used. Compared to check basins, labour required for field layout and irrigation is less. However, distribution of water is not uniform due to more opportune time for water at the beginning of the strip leading to consuming more water. The application efficiency of this system is 75 – 85%.

b. Check Basin Method

It is most common method of surface irrigation and used for closely growing crops like groundnut, wheat, finger millet etc. It is however not a common method of irrigation in north eastern region of India. In this method field is surrounded by bund around the four sides of the plots. Water from the head channel is supplied to field channels one after another. The size of the check basins ranges from 4m x 3m to 6m x 5m depending upon the stream size and soil texture. Bigger size of streams required bigger size of basins. The main advantage of this method is that even small streams (2l/s), can be effectively utilised and water can be applied uniformly in the field. The major drawbacks include more labour for field layout and irrigation, wastage of more land for channels and bunds and inter-cultivation is difficult due to frequent obstruction by the bunds.

c. Basin method

This is a common method of irrigation for fruit and trees. A basin is made around the base of the tree and water from field channels are allowed to enter to each basin. The basin size is increased as the tree grows.

B. Furrow irrigation

Small channels are formed along or across the slope of a field and water from open ditches or pipes is diverted into the furrows. It is a common method for row planted crops like Maize, sugarcane, potato, beet root, vegetable crops. Water applied in the furrow infiltrate slowly into the soil and spread laterally to wet the area between furrows. Based on soil slope and stream size the length can be fixed. The furrow width varies from 60-120cm, which again depends on the crops to be grown. The depth varies from 15-20 cm which depends upon soil type, flow size and irrigation methods. This method is mostly suitable for medium to moderately fine textured soil which allows free water movement both horizontally and vertically. The labour requirement for forming the furrows is relatively higher than the other surface method of irrigation. However, in sandy or coarse textured soil;, this method is not suitable because here the water movement is primarily downward and very little in horizontal direction. Besides, the length of ridges or furrows to resist the velocity of flow is very low which in-turn may lead to breaching of the structure.

The furrow method can be classified as ,a. Corrugated furrow, b. graded furrow c. level furrow and d. Contour furrow.

Corrugated furrow: It is a small furrow as the furrow is made by a plough or some other inter-cultivation equipments. Applying irrigation thoough this channels are called corrugation irrigation. The close growing crops like wheat, groundnut, setaria etc. occasionally irrigated by this method though they were planned as rainfed crop.
Graded furrow: Generally graded furrows are open ended which facilitate more opportunity time for infiltration and uniform distribution along the furrows. For the land having more slope, this method is suitable.
Level furrow: This method is adopted for land having little or no slope or levelled lands.
Contour furrow: The irrigation water is applied through the furrows that are formed along the contours.

Irrigation water is applied through every furrow when there is sufficient water for the purpose. Irrigation water moves laterally and downwards when advances though the furrows and eventually the lateral wetted fronts of the adjacent furrows meet and there after the movement is mainly downward. However, when irrigation water is scarce or during dry spell, to save water irrigation water can be applied through every alternate furrows and this method is called alternate or skip furrow irrigation. In this method, irrigation water is applied only to one side of the crop row/furrow. Due to lateral movement of water, the whole of the furrow slowly get wetted. Through this method about 1/3rd of the irrigation water can be saved and water is used effectively without much loss. Another effort to save the irrigation water is wide spaced furrow irrigation. In this method a few number (2-4) may be skipped in between two furrows that are irrigated. This method is suitable for medium to fine textured soils. The water The water movement is both lateral and down ward in this method and so the advance of water is slow in this method compared to every dfurror irrigation. About 50% of water can be saved by this method compared to irrigating every furrows of the crops.

Types of furrow irrigation and there suitability

Types	Principal features	Where adaptable
i. Flat land furrows	Slopes less than 0.15 and essentially straight.	Best suited for new crops.
ii. Corrugation type furrows	Moderate to steep slopes ,small U-shaped or V-shaped closely spaced grooves	Suitable to irrigate close growing crops in areas where the topography is steep and uneven.
iii. Contour furrows	Follows contours on steep lands and hill sides	Suitable to irrigate steep and uneven slopes. Hazardous in high rainfall areas.
iv. Furrows of misc. shapes	Special cross section like V-shaped or brad base	Adapted for special soil, slope and crop production problems.
v. Furrows of miscellaneous arrangements	Circuitous or straight	Used in orchards for wetting the soil. Also used for vegetable crops.

Pressurized Irrigation Methods

Sprinkler and drip irrigation systems are called pressurized methods as pressure is used to apply the water through a network of pipelines.

Sprinkler Irrigation Systems

In this method irrigation water is sprayed to the air and allowed to fall on the ground surface more or less resembling rainfall. It is also known as overhead irrigation as water is applied from the top over the crops. In North East, this method is used in tea gardens for irrigation. Due to undulating topography of most of the tea gardens, sprinkler method is favourable for irrigating the tea plantations. The introduction of light weight poly tubing and coupling made this system a portable one and thereby economically competitive with surface methods.

Advantages

- It is especially suitable for sandy soils where infiltration rate is very high.
- For soils where levelling is difficult, sprinkler irrigation is possible.
- For lands having undulating topography and steep slopes sprinkler irrigation is feasible.
- Even small stream size can be utilized in this method.
- Application of fertilizer (Fertigation) and pesticides are possible through irrigation system which reduce labour costs.
- It controls canopy temperature as water is applied from overhead on the top surface of the whole plants.
- By means of light and frequent irrigation ,it facilitate early germination and establishment specially in soils where crusting is problem.
- Requires less water and saves up to 50% water.
- Saves land as no channels or bund are required for conveying the water to the plants root zone.

Disadvantage

- The main disadvantage is that it is very costly to install and maintenance cost is also higher. However subsidy is available from the government as it is a very efficient method of irrigation with negligible loss of water unlike other methods.
- In saline water conditions, it cause leaf burns besides corrosion and clogging of the pipeline systems.
- Continuous power supply is required to operate the system to maintain the pressure.
- Uniformity of irrigation water application is difficult.

Components of Sprinkler Irrigation System

The major components of a sprinkler irrigation system are:

Pump set: A high speed centrifugal or turbine pump can be used for operating the sprinkler systems for individual fields. Centrifugal pump is used when the distance from the pump inlet to the water surface is less than 8m. From pumping water fro the deep weels or more than 8m, turbine pump is suitable. An electric motor or an internal combussion engine can be used a driving unit of the pump.

Network of pipe lines: The pipe lines consists of main line, laterals and sublaterals etc. The main line conveys water from the source and distribute to the submains or laterals. The submains again conveys water to the sublaterals which in-turn supply water to the sprinklers.

Alluminium pipes are used for portable systems, while steel pipes are usually centre-pivot laterals. Asbestos, PVC and wrapped steel pipes are usually used for buried laterals and main lines. Couplers are used for joining two pipes quickly.

Sprinklers : Sprinklers are the adjustments that distribute the water uniformly over the field without runoff or excessive loss due to deep percolation. Sprinklers may be either rotating of fixed type. Rotating types can be used for a wide range of application rates and spacings. Fixed head sprinklers are used for lawns and gardens. A sprinkler may have 1-3 nozzle depending upon the water pressure. The performance of a sprinkler is described by its discharge, distribution pattern, distance of throw, application a rate and drop let size.

Discharge is the volume of water flowing out of the sprinkler per unit time. The volume and rate of water application varies depending upon the distance from the sprinkler and this variation is called distribution pattern. The spacing between the adjacent sprinkler depends on the distance of throw. A sprinkler is fixed on a riser pipe which in turn is fixed on a laterals. Sprinkler has to be above the crop height so that its jets is not obstructed by the crop foliage and accordingly rises height has to be adjusted.

Other accessories

The other minor accessories needed are coupler, riser pipes with tripod stands, Tees, water meters, pressure gauge, flanges, hydrants, plugs and crosses.

Drip Irrigation

Drip irrigation is defined as the precise, slow application of water in the form of discrete or continuous or tiny streams of miniature sprays through mechanical devices called emitters or applicators located at selected points along water delivery lines.The term trickle or drip irrigation are synonymous.

Components of drip irrigation

Drip irrigation system consists of the following components:

i. Pump to lift the water from the source of supply.
ii. A head unit consisting of a tank to maintain the required pressure for circulation of water,
iii. A central distribution system, connected to the main water supply, which regulates water pressure and quantity,
iv. A fertilizer tank, connected to the central distribution system, to supply soluble plant nutrients along with irrigation water,
v. A filter, connected to the central distribution system to remove materials suspended in water,
vi. PVC main supply pipe of suitable diameter and length to deliver the desired discharge,
vii. Sub/mains/or laterals of suitable diameter and length connected in a parallel way to the main, and
viii. Plastic drippers inserted in the laterals at the desired spacing (equal to the intra-row spacing of the plant), which control the release of the desired quantity of water.

Pump : The duty of the pump in terms of flow and pressure is determined after the diameter, length and discharge of all the mains, laterals and emitters are decided and the friction losses are estimated.
Head : The water lifted from the source of supply is stored in a head tank, usually 3x3x3 m size, resting on a raised platform top maintain pressure head about 4 to 5 m. The heads is connected top the central distribution system. It regulates the pressure and amount of water supplied.
Central distribution system : It consists of check valves, water meters, gauges, fertilizer and filtration units fixed on the main. A check valve just down stream of he pump is open when flow is from the pump and closed when the flow is from the opposite direction towards the pump when pump I shut down. This prevents water containing suspended materials, fertilizer nutrients or pesticides from flowing back to the pump. A water meter is installed in the main line close to the tank for measurement of the discharge that passes through. Each main line and sub-main should have a valve at its upstream end to provide 'on' and 'off' service and for isolation purposes.
Fertilizer unit: The drip system may include equipment for metering into the irrigation system, fertilizer, pesticides and anticlogging chemicals. This unit consists of a tank, flow meter, regulator valves, liquid fertilizer pump or venture control valves and sometimes injector pumps and pressure reducing valves; this unit is installed in the upstream of the filter. The fertilizer is injected into the system at a predetermined rate. Fertilizer injection requires that the pump operate at a higher pressure than the drip system. The capacity of the tank and injection system depends on the concentration rate and frequency of application. The fertilizer tank capacity is important. The entire quantity of fertilizer must be dissolved initially demanding large size of tank and the use of highly soluble chemicals. Less fertilizer solution and more frequent application requires smaller and less costly units. If two injection points are provided, one before and another after the filter, the filter can be bypassed if filtering is not required. The discharge line from the fertilizer tank is sometimes provided with a filter and also the suction side of the cylinder injector. Injection points are provided so that injected fertilizers are properly mixed before the flow divides in several directions.

Filtration system : Filtration of irrigation water is essential to prevent clogging of emitters, which can be a major problem in the drip system. The clogging may be due to presence of salts in water, microorganisms, suspended organic and inorganic matter, clays, silt, etc. Filter is connected to the central distribution system. There are two common types of filters:
Screen (mesh) filter: This is useful primarily for removing suspended inorganic particles in water containing sufficient amounts of organic matter. The screen filter does not remove large amounts of suspended particles and organic particles without reducing the flow of water through the filter. It is, therefore, necessary to frequently flush the screen mesh filter to remove accumulated particles.
Sand filter : Sand filter is most effective in the removal of inorganic and organic particles from water. It can extract and retain large quantity of suspended solids without reduction in delivery of the rated flow of filtrated water. The sand filter is normally provided with a back flushing arrangement.

Main line : The main line design is based on topography, the operating pressure, the field layout of laterals and submains and the required discharge from each outlet along the line. The main line system has changing flow capacity with respect to length. It has higher discharge in the upstream, sections than in the downstream sections. The main line design is to select the proper pipe diameter for each section to deliver water at the required rate to all submains and distribution lines in the system. There are a number of pipe sizes to meet the hydraulic requirement of a given layout.

The Darcy-Weisbach equation is the most accurate in predicting friction loss in pipelines. But it is cumbersome to use. Hazen and Williams formula is the most widely used. Tables and nomographs using this equation are available for use. The tables and nomographs provide head losses, pipe sizes, velocities etc.

The mains are PVC pipes usually of 25 mm to 75 mm in diameter. In the nomenelature of PVC and HDPE pipes only the Outer diameter is quoted Pressure rating of OVC pipes is determined by the PVC material used and dimension ratio. The dimension ratio is a function of pipe diameter are generally available in 2.5, 4.0, 6.0 and 10.0 kg/cm^2 pressure rating.

Sub-main : The sub-main distributes the same discharge to all the laterals fitted to it. The area covered by the sub-main is dependent on field layout, slope of the land, water supply and irrigation demand and uniformity requirement within the subunit. Usually pipes of 25-50 mm diameter and suitable length are used.

Laterals: The laterals are provided in the main line or sub-main for each row of the crop. Correct evaluation of friction head loss in the laterals is essential to achieve optimum uniformity for emitter characteristics and variability of manufacturing in addition to pressure variation. In the case of lateral design as water flows through laterals, it is gradually discharged through the drippers. A close value for head loss of pipe, which loses water along its entire length can be obtained from Christiansen's equation. Considerations for design are elevation, multiple outlet factor, frictional loss in the lateral and emitter discharge versus performance.

The uniformity of discharge through the extreme dripper on a lateral should be based on 20 per cent of the difference in flow or under turbulent conditions within the lateral; the pressure difference may be 44 per cent. The significance of 44 per cent total head pressure difference is that it allows for greater span in head design and therefore, longer and more economic drip laterals. The laterals should be designed to carry uniform discharge for any supply of water through the drippers with acceptable uniformity. The lateral size should be selected to carry the maximum water required for one row per unit time. The slope of the lateral line affects the discharge through the emitters as it causes pressure changes in the line. In the drip laterals the pressure drop between the lateral lines must not exceed 20 per cent of the emitter operating pressure. Where number of emitters are fixed, the length of the laterals is determined by the pressure drop between the lateral lines or the uniformity of emitters discharge. In the drip system the dripper uniformity must not be less than 90 per cent. Usually 9, 12 and 15 mm pipes are used as laterals and fitted on both sides of sub-main or mains. They are usually placed above the ground.

Drippers/Emitters

A perfect dripper should meet the following objectives:

1. Compact, serviceable and inexpensive,
2. Relatively of low discharge,
3. Not vary significantly with pressure, and
4. A relatively large cross-section area to avoid clogging.

The object is to have a high system efficiency by means of high emission uniformity, a manageable system which can be operated and maintained easily, keep both initial and annual costs to a minimum and adequately satisfy crop requirement. Spacing of the dripper is according to the intra-row spacing of the plants. Water application rate is adjusted by using drippers which discharge at the desired application rates. The drippers discharge about 2.4 litres/hour. There are various types of drippers. They are short path, long-path, short orifice, pressure compensating, self-flushing and porus tubing emitters. These designs can be grouped into two types, point source and line source. Point source systems discharge water from individual or multiple outlets that are spaced at least 1 m apart. Line-source systems have perforations, holes or porus walls in the irrigation tubing that discharge water at close spacing or even continuously along a lateral line. Point source systems are used for widely spaced crops and line-source systems for close growing crops. The self adjusting drippers discharge water within permissible limits even if there is pressure variation

Generally, a maximum velocity of 1.5 m/s is used as criteria for pipe selection. Friction losses should not exceed 5 m/1000 m of piping. The lowest annual cost, accounting for both initial annual power costs is worked out to determine the best pipe size. The allowable pressure variation should be minimum. The emitter achieves a three demensional differential spread of water keeping the soil in the root zone close to field capacity. In the conventional irrigation, the plant has excess water in the root zone at the time of irrigation and for a day or two after irrigation and then the moisture in the root zone decreases day after day till the next irrigation. Beyond the critical moisture tension level, water is not equally available to the plant. Between two irrigations, plant experiences moisture stress in conventional irrigation, unless irrigation frequency is more. But when irrigation frequency is more, the wastage of water through evaporation, deep percolation and surface runoff will be more. Loss of dissolved nutrients also takes place. In the case of drip irrigation, it is predetermined quantity of water to meet exactly the plant needs. Water is supplied only in small quantities and there is negligible evaporation and no surface runoff. The moisture in the root zone is at field capacity and the plant does not experience moisture stress at any stage of growth and development. Nutrient availability is high near field capacity. The plant grows well and likely to given higher yields.

Types of drip irrigation systems

Different drip irrigation systems are available. The most common method is the surface drip irrigation system wherein the laterals and drips are on the soil surface. The advantage of surface drip irrigation is ease in installation, inspection, changing and cleaning emitters. In case of subsurface drip irrigation system, the laterals are buried below the soil surface. Spray irrigation systems apply water as a small spray, fog or mist to the soil surface. This is mainly used for the crops. Pulse irrigation system supplies water in series of pulses or discharges with an interval of 5, 10 or 15 minutes.

Fertigation through drip irrigation system

Fertigation is the application of fertilizer nutrients through irrigation water. The drip system offers an opportunity for precise application of water, soluble fertilizers and other nutrients to the soil at appropriate times in desired concentration. The major advantages of fertigation are better timing, uniform distribution, less damage of fertigation are better recovery of fertilizer nutrients by the plant, minimum loss of plant nutrients due top leaching and high yielding.

The fertilizers and chemicals applied through drip system have to meet the following criteria (i) avoid corrosion, softening of plastic pipes and tubing or clogging of the component system, (ii) not react adversely to salts and other chemicals present in irrigation water, (iii) be completely soluble in water, and (iv) when more than one fertilizer is used, they should not react with each other to form a precipitate.

The most favoured form of nitrogen for use in drip system is urea because it is highly soluble in water. The solubility of urea is 78 parts in 100 parts of cold water. Generally, injection of phosphorus fertilizers is not recommended as they create physical or chemical precipitation and clogging of the system. Potassium chloride can be used provided it is not incompatible with other fertilizer used. The solubility of potassium chloride is 35 parts in 100 parts of cold water.

Most crop needs for nutrients may be met in the drip irrigation system with a concentration of 100 mg/1 in irrigated water. Water soluble fertilizers to meet wide range of requirements are available. Urea phosphate is one such fertilizer. It also highly acidic and prevents clogging of the equipment.

Fertilizer is applied in the drip system through fertilizer tanks or fertilizer pumps or venturi type meters. Fertilizer units must be capable of operating with a duration oration of 1:200 or 1:100.

Application rates: 1 g/1 = 1 kg fertilizer in 100 l of water.

100 mm irrigation water over one hectare = 1,00,000 = 100 m^3.

Control of clogging

The major problem with drip irrigation is clogging of system components by particulate, chemical and biological material. Drip irrigation system have low flow rates and extremely small passages for water. These passages are easily clogged by organic debris and mineral particles carried in irrigation water and by chemical precipitates and biological growths that develop within the system. Clogging adversely affects rate of water application and uniformity of water distribution and increases operating cost.

Sand, silt, clay and debris are too large in size to pass through small openings of filters and drippers. Silt and clay particles are often deposited in the low velocity areas in the laterals. Precipitates are formed within the drip system and on the outer surface of the drippers die to soluble salts in irrigation water. Precipitates are also formed with some types of fertilizers and other chemicals introduced into the drip system, rapid growth of bacteria and algae takes place within the drip system when environmental conditions are favourable.

Organic (aquatic plants, alagae, fish, snakes etc) and inorganic suspended particles can be removed by using settling ponds, water filtration and periodical flushing of filters, main line, laterals and drippers. Injection into the drip system of acids, oxidants, algaecides and bacteriocides control clogging due to chemical (Calcium carbonate, Calcium sulphate, heavy metal, hydroxides, oxides, fertilizer phosphate, aqueous ammonia, iron etc) and biological (Filaments, microbial deposition) contributors. Filtration removes suspended particles. Sand filters remove suspended particles of size range >20 to 100 µm. Screen filters of 100-200 mesh remove particles of size range >100-150 µm. Filters are cleaned to remove particles filtered substances that have accumulated in the pores of the filter material. This is accomplished by reversing the direction of water flow through the filter and bypassing the effluent. This is known as back flushing and is done when the pressure drop has increased beyond 70 k Pa (10 psi). Normally, monthly flushing is adequate.

Chlorine in the form of bleaching powder is used to control algae and bacterial slimes. The bleaching powder is dissolved in water and this solution is injected into the system for about 30 minutes and the system shut off for 24 hours. After 24 hours the lateral ends and flush valves are opened to flush out the water with impurities. Technical hydrochloric acid (36%) of 0.5-2.0 % concentration introduced into the system for 10 minutes removes precipitates. Acid treatment is given when Ca and Mg in irrigation water exceeds 50 ppm of each. Sulphuric and hydrochloric acids are injected once in 15 days to reduce chemical precipitates. Occasional chemical treatment of water with sodium hypochlorite at 500 ppm helps to remove clogging of drippers. Sub-mains and laterals are also flushed periodically by removing end stops.

For proper maintenance of the system, the functioning of the drippers, wetting pattern of root zone, leakage of pipes, filter gaskets, fittings, etc., have to be checked periodically.

Advantages of drip irrigation

The major advantage of Drip irrigation is in terms of water saving and increased yield in a wide range of crops. The increase in yield ranged from 20% to as high as 100%. The highest increase in yield of 100% has been reported in banana, 40-50 % in sugarcane, pomegranate, tomato and chillies and around 25% in grapes and cotton. The saving in irrigation water compared to conventional method of irrigation was 40-70 %. The saving of water depends on crop, soil and environmental conditions. The main reasons for saving of water are absence of conveyance and runoff losses, reduced evaporation due to lesser wetted area and minimum or no deep percolation. Drip irrigation provides opportunity for enhanced plant growth and yield. Drip irrigation provides sufficient amount of water throughout growing season unlike other methods where soil moisture fluctuates from field capacity to different degrees of dryness between irrigations. Drip irrigation reduces salinity hazard to plants due to low salty concentration owing to high availability of water continuously. Weed infestation is less with drip irrigation because only a small area is wetted.

C. Sub surface or sub irrigation: This method is not so famous in India. Used is dry areas to avoid water loss due to evaporation.

Life saving irrigation: Life saving irrigation with pots, rose cans or any container with limited water gives very high use efficiency as no water is wasted. In this methods the water is applied directly in root zone and gives very good response. This method is used by almost every small farmer in the region. The advantage with this method is that it can be used in any type of topography. In kitchen gardens and under small scale farming this method is used.

Water lifting devices used in North East: In north east indigenous irrigation practices are mostly used even till today. Water stored in reservoirs, ponds, nalas, wells, ditches or rivers are used for irrigation during dry seasons. Various indigenous practices used are, using a boat like structure when the head depth is upto 1m, or a tin mostly oil container of rectangular size having capacity of 10-20lt when the head depth is upto 2-3m. In case of a small boat like structure mostly made of wood are designed in such a way that one end is open and the other end is closed similar to a small fishing boat. The closed end is downed upto the water source and lifted to through the water using the principle of a liver. Where as in case of a tin , one side of the container is opened and four ropes are tied in four opposite corners (two in each side) and water is lifted from the deeper source by two persons. Another indigenous water lifting device used by the local people, which are operated by a single person. This is made of a single bamboo stick of 1to 2m length in one end of which a triangular structure made of tina or woven bamboo is attached. This also worked on the principle of a liver.

Now a day the peoples also started using electric pump sets of various capacities to lift water from the various sources. Small pumps of 1-2 HP are mostly used by the hill farmers for lifting water upto the top of the hillocks for domestic and agricultural purposes.

Water Management in Crops and Cropping System in North East

In Jorhat condition application of 5 cm water 3 days after dissipation of ponded water (DADPW) could save up to 56 % of irrigation water compared to farmers practice of continuous submergence and recorded at significantly higher grain yield and water use efficiency (WUE) on boro rice (spring rice). Pitcher drip method of irrigation and banana pseudostem drip was found promising for irrigating betel vine plant in Assam. For rajmash in *rabi* season two irrigation at flowering and pod formation gave highest yield under Assam condition. IW / CPE = 1.2 was found appropriate for tomato crop to gave higher yield. However, IW / CPE = 0.8 gave highest WUE. Under Barapani condition (Meghalaya) intermittent irrigation gave higher yield of rice compared to continuous flooding.

Water saving technologies in rice

Out of total water used for various purposes 80 % is used for agriculture. Again out of the water used in agriculture, about 66 % goes to rice alone. The water use efficiency in rice is less than 25 %. The daily consumptive use of rice varies from 6-10mm. The average water requirement of rice is about 1240mm. One hectare of rice requires as much water required to grow 3- 4 ha or even more of other seasonal crops. The evaporation loss varies from 180-380mm,transpiration from 200-500mm and percolation from 200-700mm. 50 – 60% water loss through deep percolation and can be reduced through proper puddling to create an impervious layer in the subsoil, confinding rice to clay soil, proper land leveling, shallow depth of submergence, application of clay tank silt etc The water requirement for various stages of cultivation are given in the Table -

Table. Water requirement of rice (mm)

Item	**Values**	**Percent of total requirement**
Nursery	40	3
Land preparation	200	16
Planting to Panicle initiation	458	37
Panicle initiation to flowering	417	34
Flowering to maturity	125	10

High depth of water will lead to deep transplanting resulting in reduced tillering. A 5cm level of water from transplanting to vegetative stage until 21 days after full flowering. Drainage for a day or two during the period of maximum tillering helps to stimulate the vigorous growth of roots and check the development of non-effective tillers. The respiratory function of root is highest at this stage, an introduction of air into the soil by draining the field leads to vigorous growth of roots. This is known as midseason drainage.

Rice responds well to adequate drainage. Rice grown in ill drained soil is subjected to toxic effects of reduced products as sulphides and methane, especially in soil with high organic matter content. The benefits of drainage are attributed to better aeration and/or removal of toxic substances such as high concentration of ferric iron and hydrogen sulphide. Therefore, unnecessarily, ponding of water should be avoided in such soils. Only maintaining a saturated level is sufficient to get a good yield of rice.

Rotational irrigation is often recommended to irrigate a large area with a limited water supply and to ensure better equity among water users. In this system water is applied at regular intervals. A major advantage of rotational irrigation is possibly the more effective use of rainfall. Shallow submergence is advantageous during critical period of the crop.

Alternate drying and wetting method adopted specially in the modern method of SRI cultivation saves up to 50% water. Irrigation is given when hairy cracks are seen in the field. The aerobic method of rice cultivation where the varieties can withstand water stress and cultivated under aerobic condition also saves a good amount of water (upto 60%). Studies have indicated that maintenance of a saturated condition is sufficient foor good yield of rice under condition of low evaporative demand in kharif/rainy season like one in north east specially under high water table conditions. Unwanted flooding under such conditions results loss of nutrients through percolation and free movement of water to the down streams. Proper plastering and plugging of all field bunds, crevices and crab wholes avoid water loss through seepage and increase efficiency. Soil compaction also economizes water use under coarse textured soil. Addition of organic manure, clay silts improves water use efficiency by holding water for longer duration.

Various studies indicated that continuous flooding through out the growing season may not be required. In *kharif* rice intermittent pondnig saves substantial amount of irrigation water without affecting yield. The intermittent period (number of days after disappearance of ponded water) may vary from 1-5 days, depending upon rainfall, depth of water table and soil texture. Irrigation after desaturation period of 3 days resulted a saving of 23 to 60 % water compared to continuous submergence. This also enables use of rainfall and reduce percolation loss (Yadav et al., 2000).

Irrigation efficiency : Irrigation efficiency is defined in terms of the amount of water required for evapotranspiration (ET) divided by the amount of irrigation water diverted into the system. The efficiency of rice-based systems is less than 50 percent and lower in the wet than in the dry season. In India the efficiency of irrigation water use in canal irrigated area is about 38% and for groundwater scheme it is about 60%.

The strategy for improving efficiency will vary from level to level depending on a number of factors, including cost considerations. Increasing efficiency at the farm or system level may not lead to greater efficiency at the next level up (i.e. system or river basin). This is because surface runoff (R) and S&P at either the farm or the system level can be used elsewhere in or outside the system (wastewater reuse or recycling). For example, the often recommended practice of canal lining to save water may simply reduce groundwater recharge. Based on this premise, and looking from the basin level perspective, a number of recent reports argue that improvements in water efficiency, where lost water is recovered downstream, result only in "paper" or "dry" water savings. Therefore it is only useful to save water (real water savings) which would otherwise be lost to a sink (saline water body or the ocean). However, wastewater recovery or recycling often involves an additional cost which should influence the water management options selected by farmers, irrigation system managers and regional- or basin-level policy-makers.

Saving water does not necessarily lead to increased water productivity.

Irrigation water productivity, defined as "the amount of food produced or the gross value of output per unit volume of water used". Interventions at the farm level, such as the introduction of new varieties, which increase the output per unit of ET, will lead to greater farm-, system- and basin-level productivity. However, most interventions are designed to improve water management efficiency by reducing S&P and R even though unless it is known what happens to water that is lost in this way, i.e. the off-site or downstream impact, it is impossible to judge whether increasing irrigation water efficiency will lead to gains in water productivity. Furthermore, alternative interventions which lead to gains in water productivity should be judged on the grounds of cost-effectiveness.

Practices and strategies for increasing irrigation water productivity

The productivity of irrigation water can be increased by doing one of the following: increasing the value of output per unit of water transpired (T); reducing losses to evaporation (E); reducing losses due to seepage (S) and percolation (P); reducing surface runoff (R); or reusing or recycling water, either within the system or elsewhere in the basin. A range of alternative practices and their potential effects on one or more of the above are described below-

Developing improved varieties. The use of early-maturing, high-yielding varieties of rice over the past three decades has led to a rapid growth in rice output per unit of land and water in many parts of the world. Advances in biotechnology could facilitate further improvement of varieties with tolerance to drought, salinity and cold temperatures, leading to a further increase in output per unit of T.

Improving agronomic management. Introducing optimum combinations of improved technologies or management practices, such as pest control and nutrient management, can raise crop yields and output per unit of T.

Changing the crop planting date. The rate of evaporation varies between wet and dry zones and, within a given location, between wet and dry seasons. By planting in time it possible to avoid the months of high losses to evaporation (E) before canopy closure.

Reducing water use for land preparation. The land preparation period, which currently lasts more than a month in many areas and accounts for as much as one-third of the water diverted, can be reduced to a few days. This might require using more field channels instead of plot-to-plot water delivery and a change in land preparation practices including dry tillage. The result would be a substantial reduction in losses caused by E, S&P and SRO.

Changing rice planting practices. Wet-seeded rice (WSR) higher amount of water, compared to transplanted rice (TPR) . Dry-seeded rice (DSR) appears to offer even greater potential for water saving. A substantial amount of this saving appears to be caused by the associated change in land preparation practices. Thus, the shift results in a reduction in losses to E, S&P and SRO

Reducing water use in the crop growth period. Puddling the soil during land preparation is one of the most common practices for reducing S&P during the crop growth stage. Studies have shown that maintaining a saturated soil or alternate wetting and drying after the flowering stage, compared with continuous shallow submergence, could reduce water applications to the field (E, S&P and SRO losses) by 40 to 70 percent without significant loss in yield.

Making more effective use of rainfall. To make optimum use of storage for dry season irrigation, water releases must be managed carefully in the wet season to take full advantage of the rainfall and to reduce irrigation inflow requirements. This would reduce losses to S&P and SRO. However, considerable management coordination is needed between farmers, who must adjust their planting schedules, and irrigation administrators, who must provide timely release of water.

Water distribution strategies. Farmers at the head of the lateral or turnout receive ample water, while those at the tail receive too little or, in some cases, too much, which leads to water logging. Particularly in the dry season, it may be impossible to achieve an even distribution of water over the upper, middle and lower reaches of a system with rotation, which would reduce losses to S&P and SRO and provide water to a larger area. Several forms of irrigation rotation are possible according to the level in the system, the time schedule, etc.

Water recycling and conjunctive use. SRO and S&P from the field and the conveyance network may eventually be reused or recycled (RCL). In some instances, water may flow from one farm field to the next. In others, water may recharge aquifers and be pumped up for reuse outside the system to which it was initially delivered. This is an effective way of increasing the productivity of water in the basin. Water recycling and conjunctive use of groundwater are rarely considered in the original design of irrigation schemes. The shift to tube wells often happens as a desperate response from farmers who are unable to gain access to irrigation water from the canal. In India it now exceeds the area irrigated by tanks and canals.

How to use irrigation water efficiently

- Conveying the water from the source to the field with minimum loss
- Following right method of irrigation

- Applying water to the crop at the right time
- Applying water in proper amount
- Selecting right type of crop, varieties that are high yielding
- Grow crop that require less water in areas where availability is scarce
- Mulching to reduce evaporation

Application efficiencies of major irrigation methods

Basin irrigation	58%
Graded border irrigation	53%
Furrow irrigation	57%
Sprinkler irrigation	67%
Drip irrigation	80%
Rice cultivation	32%
Soil types and application efficiencies	
Light soils	55%
Medium soils	70%
Heavy soil	60%

Drainage

It is the process of removal of excess water as free or gravitational water as free or gravitational water from the surface and the sub surface of farm lands with a view to avoid water logging and creates favorable soil conditions for optimum plant growth.

Causes of water logging

- Excessive use of water when the water is available in abundance or due to the belief that more water will give better yield
- Improper selection of irrigation method
- Percolation or other types of seepage from canals and reservoirs located at nearby elevated places
- Improper lay out and land locked patches as in the North East.
- Presence of impervious layer
- Upward movement of water from shallow ground water table.

Effects of water logging

- Reduce availability of air in the soil and there by creates problems for root respiration and soil beneficial microbes.
- High availability of soil CO_2 and may kill plant roots.
- Superficial root system or air space in root system will develop.
- Due to poor aeration intake of water and nutrient will reduced.
- Nutrients are lost due to leaching
- Toxic elements will be formed under anaerobic condition.
- Reduces the availability of N.Mn,Fe, Cu, Zn etc.
- Reduces soil temperature
- Destruct soil structure
- Increases the incidence of pests and diseases.

Methods of drainage

- By providing proper out let to drain the water
- Adapting proper land configuration like raised and sunken beds, bun methods etc.
- Two methods – i. Surface method ii. Subsurface method

Surface drainage:

a. Lift drainage- Water to be drained is lifted normally by opened devices or by pumping or by mechanical means

b. Gravity drainage- Water is allowed to drain from the areas under higher elevation to lower reaches through the regulated gravity flow through the out let of various types. This system is practices in wetland rice with gentle to moderate slope.

c.Field surface drainage-The excess water received from the rain or irrigation is drained through this method. The irrigated basins or furrows are connected with the drainage under lower elevation which is connected to the main out let and to the farm pond used for water harvesting. If the slope of the land is sufficient to drain excess water from the individual plot, this drain water may be collected and stored locally in reservoir for recycling for life saving irrigation. This drainage method is cheap and effective but there is possibility of soil erosion and distribution of weed seeds along the flow of drainage water

d.Ditch drainage-Ditches of different dimension are constructed at distance to drain the excess water accumulated on the surface and inside the soil up to the depth of ditch. Such ditches may be **interceptors or relief drains**. This method is adopted in nurseries, seed beds and rainfed crops. This is an effective and efficient method but requires smoothening of surface and construction of ditches. This involves cost and wastage of crop lands

Subsurface drainage

Subsurafce drainage systems are not so popupar in India. It requires more investment and skill. The various methods of subsurface drainage are

a. Tile drainage
b. Mole drainage
c. Vertical drainage
d. Drainage wells

Land configuration for effective drainage in North East:

In North East due to very high rainfall the drainage is problematic during rainy season. Many a time crop plants suffers from poor drainage leading to crop failure. The hill and mountain topography of the region further aggravates the situation. The excess water from such lands comes down as runoff and creates temporary flooding. Even in winter season, the water table in valley foot hills remains high mainly because of seepage from surrounding hillocks and uplands. Therefore specially in low land after kharif rice it practically becomes impossible to to take a second crop. However, experiment conducted at the ICAR Reseracg Complex for NEH Region, Umiam, Meghalaya proved that simply by a proper land configuration a second crop is possible to be taken. Depending upon the type of soil, amount of water logging, resources availbel with the farmers and crops to be grown various types of configurations are developed (table). The configurations may be permanent or temporary as per farmer’s wishes and labour cost. In permanaent raised and sunken beds, the raised area is used for cultivation of vegetables and other remunerative crops, where as sunken area is used for double cropping of rice ie., cropping intensity is doubled. The land utilization is 100 % in these systems. Whereas, for temporary systems, after harvesting kharif rice, temporary raised beds are constructed to cultivate vegetables on raised beds only. The width of raised bed may be 1m and a drainage channel of 50 cm is provided.Or the width of raised bed may be 3m and the drainage/sunken bed may be 1m. In temporary system the sunken area is not used for cultivation. The wastage of land is therefore fore (25 to 50%). The soil from sunken area in this system is used for raising the height of raised area by cutting and filling method. The height of raised bed should be more for marshy/water looged soil. Depending upon the soil type and water logging, the height may vary from 30 – 60cm. Temporary raised beds in low lands specially for drainage after kharif rice are visible in almost all part of the Meghalaya. Due to cutting and filling the soil conditions improved in this method. The soil from the sunken area which is either marshy/water logged and contain partially decomposed organic matter are used for filling the raised area. The aeration improves and due to this the nutrient ststus also improves. Each of the system works as micro watershed. Where the water from the raised area accumulates in sunken area. During dry period the water from sunken area may be used for providing pot irrigation to the crops raised in the raised area. This way the soil moisture is managed under this system effectively, which improves productivity and efficiency of water use.

Types of configuration	Ratio of raised to sunken beds	Land situation	Remarks
Permanent raised and sunken beds	3 : 2	Depth of water logging more than 0.5 m	Sunken beds for pre-kharif rice cultivation
	1: 1	Depth of water logging less than 0.5 m	Sunken beds for pre-*kharif* rice cultivation

Temporary raised beds after kharif rice	3 : 1	Normal depth	20-25 % to drainage
	2 : 1	Normal depth	30-40 % to drainage

Characteristics of good drainage systems

- It should be permanent
- It must have adequate capacity to drain the area completely
- Threshold be minimum interference with cultural operation
- There should be minimum loss of cultivable area
- It should intercept or collect water and remove it quickly within shorter period.

Efficient water management

Water is the most crucial input for agricultural production. Vagaries of monsoon and declining water table due to its over use resulted in shortage of fresh water supplies for agricultural use, which calls for an efficient use of this resource. Strategies for efficient management of water for agricultural use involves conservation of water, integrated water use, optimal allocation of water and enhancing water use efficiency by crops. Acharaya and Bandyopadhyay (2002) listed various strategies for efficient management of water for agricultural use and are described below-

Conservation of water

In situ conservation of water can be achieved by reduction of runoff loss and enhancement of water losses through deep seepage and direct evaporation from soil,. Runoff is reduced either by increasing the opportunity time or by increasing infiltrability of soil or both. Opportunity time can be manipulated by land shaping, tillage, mechanical structures and vegetative barriers of water flow and the infiltrability can be increased through suitable crop rotations, application of amendments, tillage, mulching etc. Water loss by deep seepage can be reduced by increasing soil-water storage capacity through enlarging the root zone of crops and increasing soil-water retentivity. Direct evaporation from soil can be controlled with shallow tillage and mulching.

Ex situ conservation of water can be achieved by harvesting of excess water in storage ponds for its reuse for irrigation purpose

Integrated water use

Efficient utilization of water resources and minimization of detrimental effect of water management on soil and water resources can be achieved by the integrated use of water from different sources viz. by irrigation to supplement profile stored rainwater, conjunctive use of surface-water and groundwater, poor and good quality water and recycled (waste) water for irrigation. Supplemental irrigation for growing crops is an integrated use of rainwater stored in the profile and the irrigation water regardless of its sources.

Small (30-50 mm) early post-emergence irrigation stimulates root extension into deeper layers thus causing greater use of profile-stored water. So the water extraction obtained from the supplemental irrigation at crucial crop growth period is more than the proportionate increase in the level of supplemental irrigation, which is referred as priming effect of the supplemental irrigation. The priming effect varies with soil type, fertility level and amount of irrigation. It generally increases with the increase in the N rate, soil water rentIentivity and decreases with the increases in the amount of irrigation after a certain threshold value.

Optimal allocation of water

Optimal allocation of available water among the competing crops and optimum timing of application is to be decided under adequate and limited water supply situation so as to maximize economic returns from available water. Under adequate water supply situation optimal allocation involves timing of irrigations so that crop yields are maintained at their achievable potential, as per climatic conditions of the location. Under limited water supply situation irrigation water must be allocated so that periods of possible water deficits coincide with the least sensitive growth periods. Thus irrigation scheduling should be deiced based on the water availability.

Enhancing water-use efficiency crops

Water-use efficiency (WUE) crops can be improved by selection of crops and cropping systems based on available water supplies and increasing seasonal evapotranspiration (ET). The later can be achieved by selection of irrigation method, irrigation scheduling, tillage, mulching and fertilization. The average WUE of different crops varies from 3.7 to 13.4 kg/ha per mm of water (**Table.**).

Table. WUE of some important field crops in India.

Crops	WUE (kg grain/ha per mm of water)
Rice	3.7
Fingermillet	13.4
Wheat	12.6

Sorghum	9.0
Maize	8
Groundnut	9.2

Selection of crops and cropping system

Selection of crops and cropping systems for high water-use efficiency should be done on the basis of availability of water under rainfed crops limited irrigation crops and fully irrigated crops.

Rainfed crops

The amount of rainfall converted into plant-available soil water is determined by the amount and intensity of rainfall, topography, infiltrability and water rententivity of soil, depth of root zone and soil depth. Depth of soil due to its effect on the available water storage capacity decides the type of cropping locality. On medium soil depth monocropping or intercropping can be practiced whereas in deep soil with 200 mm available soil moisture status double cropping can be practiced.

Limited irrigated crops

Selection of crops and cropping sequences under limited irrigation situation should be done as there should be minimum water stress during the growing season although some water-stress to the crops and associated yield reduction is inevitable. Therefore, along with selection of crops special care should be taken for irrigation scheduling of these crops.

Fully irrigated crops

Under fully irrigated condition selection of crops is not constrained by water availability but by adoptability of the crops to prevailing climatic and soil condition. In general, water use efficiency of C4 plants than C_3 plants, particularly under semi-arid environment

Increasing seasonal evapotranspiration

Seasonal evapotranspiration (ET) is a measure of consumptive water use by the crops. Increasing the transpiration (T) component of ET, results in higher utilization of water by the by the crops to increase the productivity. The T can be increased by following improved irrigation methods, irrigation scheduling, tillage, mulching and fertigation

Irrigation method

Efficient micro-irrigation methods and technologies like sprinkler and drip irrigation for utilization of available water in case of scarce in lean season developed mainly for high value horticultural and plantation crops could save upto 50% of water and also increase the crop yield and quality substantially

Irrigation scheduling

Under adequate water availability the main emphasis is on securing potential yield of the crops without wasting water. Whereas, under limited water supply, the objective is to achieve maximum water use efficiency (WUE). There are different methods for irrigation scheduling viz., critical crop growth stages, feel and appearance method, soil moisture depletion approach, irrigation water at different cumulative pan evaporation method (IW/CPE) etc.

Tillage

Tillage affects the WUE by modifying the hydrological properties of the soil and influencing root growth and canopy development of crops. Tillage methods influence wettability, water extraction pattern and transport of water and solutes through the profile through its effect on soil structure, aggregation and total porosity and pore size distribution. Tillage system suitable for a soil depends upon soil type, climate and cropping system practiced. Shallow inter-row tillage into growing crops reduces short term direct evaporation loss from soil even under weed-free condition by breaking the continuity of capillary pores and closing the cracks.

Deep tillage to a depth of 30-45 cm at 60-120 cm intervals helps in breaking subsoil hard pans in Alfisols facilitating growth and extension of roots and improving grain yield of crops as well as increase in the residual soil moisture. However, the benefit is absent in subnormal rainfall years and restricted to only deep-rooted crops in high rainfall years.

Conservation tillage practice normally stores more plant available moisture than the conventional inversion tillage practices when other factors are same. The high soil moisture content under conservation tillage is due to both improved soil structure and decrease in the evaporation loss due to crop residue mulch cover. Increase in the available water content under conservation tillage, particularly in the surface horizon, increases the consumptive use of water by crops and hence improves the water use efficiency.

Off season tillage or summer ploughing opens th e soil and improves infiltration and soil moisture regimes.

Mulching

Mulching influences water use efficiency of crops by affecting the hydrothermal regime of soil, which may enhance root and shoot growth, besides it helps in reducing the

evaporation (E) component of the evapotranspiration. Under moisture stress conditions, when moisture can be carried over for a short time or can be conserved for a subsequent crop, mulching can be beneficial in realizing better crop yield.

Fertilization

There is strong interaction between fertilizer rates and irrigation levels for crop yield and water use efficiency. Application of nutrients facilitates root growth, which can extract soil moisture from deeper layers. Further more, application of fertilizers facilitates early development of canopy that covers the soil and intercepts more solar radiation and thereby reduces the evaporation component of the evaporation.

Weed control:

Weed management is the most efficient and practical mans of reducing transpiration. Weeds compete with crops for soil moisture, nutrients and light. Weeds transpire more amount of water compared to associated crops plants.

Indigenous Water management practices of North East

A variety of typical water management techniques based on local skill and resources are prevalent in the region. Based on long experience under existing soil and climatic conditions as well as the availability of large numbers of hill stream, farmers in certain areas have developed typical systems of water management which are very effective under the existing condition of topography and terrain. Some of these practices mostly confined to the places of their origin have been documented by Prasad and Sharma (1994) and Satapathy (2006) are briefly described below.

Bamboo drip irrigation system: Tribal farmers of War Jaintia Hill districts of Meghalaya have evolved this indigenous technique of bamboo drip irrigation (Sharma, 1982) for irrigating the crops of beetlevine, arecanut and black pepper. Topographic condition of the landscape induced them to device such an excellent system about 200 years ago and the system is still relevant in the present situation. Now this system is being followed in other parts of the Meghalaya where soil has low water holding capacity, irrigation requirement of the crop is low and water is scarce. In this system, stream located at higher elevation is diverted to the site with the use of network of bamboo channels through the gravity flow. The discharge of the system at the plant site ranged from 10-80 drops per minute. About 15-25 litres per minute water from a perennial stream is diverted in the main bamboo channel and distributed to the smaller channels in number of stages to obtain the desired rate of water application. To ensure proper gravity flow, the ground clearance of the channel is reduced gradually by decreasing the height of channel supports. This system works satisfactorily for elevation difference of few hundreds meters. The special feature of the while system is the joining of the bamboo channels with no leakage or loss on the way. Bamboo of larger diameter (approximately 10 mm or more) is used for fabrication of the main channel and the bamboo size is subsequently reduced as per the requirement of the water (Singh 1979; Singh and Singh, 1981).

Zabo Farming

Zabo is local term which means impounding of water. This indigenous system of rice cultivation is practiced on sloppy land at an altitude of more than 1200 m in Phek district of Nagaland. The system is a combination of agriculture, forestry and animal husbandry with well founded conservation base for soil erosion control, water resource development and water management as well as protection of environment. Under this system, cultivation of crop is done in topo sequence on a hill slope. Top of the hill is necessarily kept under forest, which serves as catchment to feed the perennial streams. Water harvesting tank is constructed in the middle portion of the hill and paddy cultivation is done at the foothills on the terraced land. Usually water harvesting pond of 300 to 600 m^3 with depth varying from 1.5 to 2.5 m is embankment-cum-dugout. Another small pond is dug above the main storage tank. This pond acts as silt retention tank. Thus clean water is stored in the main tank. The silt retention tank is desilted periodically. The bottom and inner sides of the ponds are rammed and compacted to reduce the seepage loss. Paddy husk is mixed with the soil of pond bottom and puddle through treading of human, cattle and wooden sticks to minimize the percolation losses. The paddy of cultivated on well made level terrace. Before making the terrace, the fertile topsoil is scrapped and heaped separately. After construction of the terrace, the heaped topsoil is spread over the terrace uniformly to avoid loss of fertility. Weathered shales are also collected and spread over the terrace which disintegrates into fine clay after coming in contact with water. This plugs the pore spaces minimizing the percolation

losses. The cultivation fully depends on the amount of water stored in the pond (Sonowal et al., 1989; Sharma and Sharma, 2004b).

Water Management Practices of Apatani Plateau

Apatani tribe of Subansiri district of Arunachal Pradesh has evolved unique technique of land and water management at an elevation of about 1600 m. about 200 ha of area having mild slope is properly bench terraced for rice cultivation. The terraces are perfectly leveled with strong bunds. Bunds are supported by the wooden of bamboo pegs at the base to safeguard against erosion by runoff water. The size of bunds generally varies from 0.6 to 1.4 m in breadth and 0.2 to 1.6 m in height depending upon the gradient of the land and shape and size of the terrace. The only consideration in the terrace making is perfect leveling to ensure the ponding of water in the terrace for paddy cultivation. Every stream emerging from the surroundings hills is tapped and channelised at the rim of the valley and diverted to the paddy fields through the network of primary, secondary and tertiary channels. The lay our of fields and channels are made in such a way that, the entire plateau functions as a water course without inflicting damage to the land. The terraces are connected by "Huburs" which is wooden or bamboo ducts. At outlet of Hubur of each terrace wooden pegs are installed in semi circular manner to act as an energy dissipaters to check the soil erosion. About 10 cm depth of ponding water is maintained by adjusting the height of the opening of the outlet. The outlet in terrace is provided at the opposite side of the upper terrace i.e. alternately right and left end. Apart from conserving the soil, the farmers are taking up plantation of Terminali myrinalia, Altingia excelsa, Michelia sp., Mangolia so., Pine and bamboo on the surrounding hilltops. This helps in maintenance of flow of streams to plantation of Terminalu myrinalis, Ltingia excelsa, Michelia sp., Mangolia so., Pine and bamboo on the surrounding hilltops. This helps in maintenance of flow of streams to fulfil the water requirement for the crop and domestic consumption (Singh *et al.,* 1981; Sharma and Sharma, 2005).

***Panikheti*- a sytem of rice cultivation in terrace**

'Pani' mean water and 'kheti' mens cultivation. Angami and Chakesang tribes of Nagaland have developed unique system of rice cultivation on bench terraced land on steep slopes (up to 100% or more) through the continuous flow of water. Bench terraces are made with the risers supported of bamboo pegs. Water is allowed to flow from one terrace to another by providing openings at the ridge bunds. The water source is diverted from the top terrace and water is allowed to pass through the entire downstream terrace. Water source emerging from the forests brings humus and other organic matter with them thus providing nutrients to the paddy crop. Continuous flushing of the terrace eliminates the iron toxicity, which is very harmful to the paddy crops. As the rice is the staple food on the diet of the people of the region, land with shallow soil depth is brought under paddy cultivation with continuous flow of water. This system has been widely adopted by the farmers of the other north eastern states like Manipur and Sikkim. This system is called locally as *Panikheti* system of rice cultivation.

Stream Flow Lift Irrigation

The traditional methods of irrigation in hills consists of harnessing the hill streams during monsoon buy constructing temporary check dams on streambed for diversion and conveyance of water through earthen channel. Boulder, timber and earthen dams are built across the stream to raise the level of water or diversion. There is a tradition of such irrigation works being done by village / community as a whole in carrying water from streams over long distance. Water lift system (Satapathy, 1983) is essential in the cast tracts which can not otherwise be served by the diversion works. The lift irrigation potential in the region, however, remains largely unexplored. Vast flat lands along the sides of rivers remain under natural fallow with wild bushes. Damaging land use practices (mainly shifting cultivation), extensive feeling of forests and friable soils in the hill coupled with high rainfall produces heavy flow loaded with soil particles, pebbles, debris. The heavy flow of water proceeds through steep mountain courses / soft rock formations and thus comes down to the foot hills with enormous force distributing the existing channel configuration and raising other river beds. The portable water lift system with pump and engine installed on tired wheeled bullock cart-cum-trolly was found feasible for river situations where the site and water course changed every year.

Pitcher Irrigation: The pitcher irrigation system (Fig.) is the indigenous system of irrigation developed and adopted by tribal farmers of NEH region. Since this is the low cost system, this system of irrigation could be one of the most important management components for horticultural crops. This will supply water slowly to the crops and will reduce the unnecessarily wastage.

8. Irrigation Status

The cropping intensity in the region is very low except in Tripura and Manipur mainly due to lack of proper irrigation facilities in the state. Currently, the area under irrigation is 832 thousand ha., which is about 22.6% of the total irrigation potential. Considering the net sown area, Manipur has the maximum area under irrigation (46.4%), followed by Tripura(23.7%), Nagaland (22.6%), Assam (20.8%) and

Meghalaya (20.8) (Table).

Table .Irrigation status of different NE states

States	Surface water potential (km2)	Net cultivated area ('000 ha)	Irrigation potential (000ha.)	Net irrigated area (000ha.)	Irrigation potential explored (%)	% Irrigated are to net sown area
Arunachal Pradesh	558.8	185	266	31	11.6	16.8
Assam	366.0	2751	2670	572	21.4	20.8
Manipur	31.3	140	240	65	27.4	46.4
Meghalaya	19.8	221	120	46	38.3	20.8
Mizoram	67.2	109	80	8	10.0	7.34
Nagaland	14.1	261	90	59	65.5	22.6
Tripura	7.6	277	215	51	23.7	23.7
Total	1064.8	4039	3681	832	22.6	20.6
All india		142,600				

Rain water harvesting

Rain water harvesting besides helping to meet the ever increasing demand for water, helps to reduce the runn off, avoids flooding of roads/habitat areas, augment the groundwater storage, reduce groundwater p0ollution, improve quality of groundwater, avail more water for industrial use and reduce soil erosion. Various approaches used for direct harvesting of rainwater are:

i. **Roof water harvesting in tanks:** Various structure are designed to collect the rainwater from the house roof in a storage vessel or tank to use during the periods of scarcity. This method of water collection is specially preferred in hill top, where other sources of water supply are difficult.

ii. **Roof water harvesting for groundwater recharge**: Excess roof top rainwater can be diverted to the existing open/bore for e\recharging the groundwater.

iii. **Rainwater collection in the lined ponds**: Ponds of suitable size are constructed and subsequently lined with plastic sheets like silpolin or HDPE. The rainwater from roof top, run off or springs may be diverted to such pond and may be used for irrigation or household purpose.

iv. **Water harvesting ponds**: Generally three types of harvesting ponds viz., embankment type, dug out type (excavated) and dug out cum embankment are constructed as per the land situation, soil type etc. for collection of excess run off from rain water. In north east, all the above types of pond are possible. Embankment type ponds need less investment as only a strong dyke is provided to close one or two sides of the pond. For successful pond constructions various factors need to consider are type of soil, topography, requirement of water, water load etc. In West Khasi hills Nongstoin, ICAR has constructed a series of various types of pond successfully. The main pond constructed in community land is having the capacity of 2 million lt (49m x26mx1.8m). It is a dug out cum embankment type pond. Polythene linings were provided on the inner side of the outer dyke to control seepage of water. The full development process was achieved with the participation of the local people.

v. **Jalkund:** A micro rainwater harvesting structure designed by ICAR, Umiam for harvesting rainwater at hill top. A small tank of 5 x 4 x 1.5 m is dug and lined with LDPE-Agrifilm of 250 µ. Cushioning materials like pine needles, thatch grass etc. are used for improving the life expectancy of the polythene

sheets. The cost of per liter of harvested water after three years averaged to 50 paisa only. Depending upon the resources available and need, the *jalkund* of various sizes ie., 6000 to 20,000 litre can be constructed. Such stored water should be used only in lean season as live saving irrigation.

Agronomic measures for soil and water conservation

1. Crops and cropping systems: The crops and cropping systems adopted in the farm, influences the soil and moisture conservation to a great extent. Inclusion of pastures, legumes and other close growing crops reduces soil and moisture loss substantially. Growing a crop that produces good vegetative cover, reduce runoff and soil loss. Inclusion of thick growing crops like cowpea, groundnut, rice bean, ipomea etc. reduces soil and moisture loss. In multiple cropping, the soil remained covered with crops throughout the year. The rainwater gets more opportunity time to enter into soil.

The various management practices like application of manure and fertilizers provides early cover due to faster growth and helps in soil and moisture conservation.

2. Contour farming

In sloppy areas, chances are more for loss of topsoil along with water. To prevent this, contour farming in hilly areas should be practiced that includes across the slope cultivation, along contours. By ploughing and sowing across the slope, each ridge of plough furrow and each row of the crop act as an obstruction to runoff provides more opportunity time for water to enter into the soil and reduce soil loss.

3. Cover cropping

Growing cover crops in wastelands and cultivated fields helps to cover the soil. Because of this, raindrops will be falling on the leaves of these cover crops and this reduces the impact of it on the soil and protect from soil erosion. The cover crops also help to reduce the growth of weeds and minimize the loss of soil moisture due to evaporation. They will also add fertility to the soil on decomposition. *Peuraria*, *Calapagonium*, *Centrosema*, *Mucuna,* and *Mimosa* are some of the ideal cover crops that can be grown for this purpose. It is noticed that these crops, on an average can give around 5 tonnes of biomass from one hectare of land.

4. Mulching

It is a common practice in many areas to burn all the fallen leaves, crop residues and other waste materials in the field. As this is not very ideal, it is recommended to use them as mulch between and around the plant basins. Mulches will cover the soil and reduces the loss of soil moisture especially during dry periods. It will also help to reduce soil erosion during rainy time. It adds to soil fertility after decomposition. Thick mulching will also help to reduce the quick depletion of soil humus due to fast decomposition in tropical regions.

A mulch is any material used to cover the soil surface. Plant residues used as mulches (organic mulch) help to reduce evaporation of water from soil surface thus conserving soil moisture and also have a moderating effect on soil temperature. Experiments conducted have proved that mulches help to conserve soil moisture, which can be utilized by crop plants and thereby, enhance productivity of crops. Locally available grasses, weed species, paddy straw and any other crop or plant residues can be used as mulching material. These organic materials on decomposition also add organic matter to the soil and consequently contribute in building up the soil nutrient status. Through use of straw mulch vegetable crops like potato, tomato, cauliflower, cabbage, etc. and oilseeds like mustard can be successfully grown during the winter season with significantly higher yields due to increased moisture availability as compared to those grown without mulches.

In-situ residue management: A simple and very low- cost technique of *in–situ* moisture conservation has been developed for *rabi* crop (mustard) using residue of preceding maize crop grown during rainy season. *In-situ* residue management of preceding maize crop supplemented with *Ambrossia* sp., a local weed, @ 10t/ha applied before sowing of mustard, maintained optimum soil moisture for supporting good germination, growth and higher yield of mustard both under terrace and flat upland situations.

c. Conservation tillage system: Conventional tillage leaves no land unploughed and leaves no residues on the field**.** Conservation tillage is disturbing the soil to the minimum extent necessary and leaves up to 30% residues on the soil. Zero tillage, minimum tillage and stubble mulch tillage are included in this. Conservation tillage can reduce soil loss by 50% and conserves soil moisture to a great extent. Zero tillage consists of a one pass operation which places seed and fertilizer into an undisturbed seedbed, packs the furrow and retains adequate surface residues to prevent soil erosion. It involves planting seeds into soil that hasn't been tilled after the harvest of the previous crop. The crop germinates in residual water left by the previous crop, saving up to a million liters of water per hectare. Zero tillage seeding offers you the benefits of retained surface residues and reduced soil water losses. Zero tilled crops were sown by hand dibbler in all the plots shown below. In case of pea crop, which has been taken as succeeding crop followed by rice, better crop performance found under 75% rice stalk retention as compared to 50% rice stalk retention and complete removal of rice crop.

With zero-tillage technology, farmers can produce higher yields and reduce production costs by up to ten percent. They also save on diesel for tractors, and the fertility and structure of the soil improves. The Zero tillage not only favourably moderated the soil rhizosphere and produced higher grain yield in long term aspect but also improved the water economy during dry periods by permitting downward movement of water across the root boundary. Thus this technology may provide greater opportunity for low cost crop cultivation through better management practices for sustaining crop production in the hilly eco-system.

5. Grass cropping

Cultivation of suitable grasses in areas prone to soil erosion helps to minimize the loss of soil. This method is not only economic, but also help to produce sufficient fodder materials when cattle rearing are also undertaken. Raising of fodder grasses on the contour bunds and soil bunds will enhance the life of such structures.

6. Crop rotation

Continuous cultivation of sloppy lands with crops that enhance soil erosion will lead to more erosion. Repeated cultivation of same crop in an area is not ideal due to many reasons. This will lead to depletion of soil of the same nutrients over the years and also lead to build up of same pest and disease problems. Hence after the harvest of one crop, another crop of different nature is to be raised in that field. For example, raise leguminous cow pea or similar crop after tapioca. This will help to become a cover for the soil and helps to reduce soil erosion and add organic matter on decomposition. Cow pea, Sesamum, Ground nut, Sweet Potato or Vegetables can be grown after the harvest of upland paddy in such areas.

7. Strip cropping

It is a system of cropping in which long and narrow strips of erosion –resisting crops (close growing crops) are alternated with strips of erosion permitting crops (erect growing crops). This method of cultivation can be adopted across the slopes in areas when crops that cause soil erosion are to be raised. Some of the erosion resisting crops suitable for north east are ricebean, groundnut, lablab lab bean, ipomea etc. Upland paddy, cowpea, fodder grasses, vetiver etc. are also ideal for strip cropping. Maize, millet and other wider spacing crops are erosion permitting in nature. Strips of close growing crops reduce the transporting and eroding power of water by forming obstruction to the runoff and filter out soil from the runoff and retained in the field. It also gives more opportunity time to the rainwater to enter into the soil. Depending on the intensity of slope, trenches can be made at intervals of 3 to 7 m along the contours and soil conservation can be made more effective. These kinds of trenches and different crops raised on strips will help reduce soil and water loss to a considerable extent.

8. Conservation agro-forestry

Planting ideal tree species in combination with agricultural crops help to prevent soil erosion in slopping lands. Trees having timber value such as Jack, Teak, Artocarpus etc and others like Cashew, Aonla, Neem and Silver Oak can be grown in this manner.

9. Integrated farming or mixed farming

This approach aims at appropriate integration of all those agricultural and non-agricultural enterprises that can be adopted and practiced in an area. The main or by-product of one crop or agricultural practice is made use as basic resource for another activity or enterprise. In a system, raising banana, pine apple, fodder grass and cow pea in an area helps to produce necessary feed material for cattle, piggery, apiary and pisciculture. Recycling of bio mass maintains soil fertility and eventually brings higher net return for the system as a whole.

10. Vegetative barriers: Vegetative barriers are closely spaced plants usually a few rows of grasses or shrubs- grown along the contours or around the farm for eroion crol and moisture conservation.

Nagaland photo

11.Multi storied cropping system : This system makes efficient use of difference in height of component crops above ground and the spread of root system below ground. In this method, crops requiring more sunlight form the upper canopy, while those requiring less light occupy the lower canopy. Because of this arrangement, competition for sunlight is reduced to the minimum. Crops selected should also have different rooting behaviour and root system. This helps to forage different soil layers for plant nutrients as well as moisture and enhance soil fertility due to decomposition of fallen leaves.Apart from reduction in soil loss and runoff, it is also possible to increase net income per unit area of land.

12. Cultivation in toposequence : Cultivation in toposequence helps in conserving soil and moisture. It allows better use of moisture in the system. In this system natura\

Soil Moisture Conservation through Land Configuration

Land configuration means any mechanical manipulation done to modify the existing surface terrain of the land like making bunds, ridges and furrows or raised/ sunken beds. Such techniques can be used for *in situ* harvesting of rain water by allowing rain water to infiltrate into the soil thereby increasing soil moisture storage and conserving soil moisture.

a. Raised - Sunken bed system**:** Raised and sunken bed (RSB) system is a well-documented technology that can be used for inter-plot rainwater harvesting in rice fields to increase crop productivity in plains. The surface soil layer of each sunken bed was removed and deposited on the adjacent raised beds about 30 cm height. The raised beds were leveled in such a way that the 50% of run-off water from half of the each raised bed will drain off into its intervening sunken bed. The length of the all the plots was same (6 m). Standard width ratio of raised and sunken bed (1:2.5) was tested and evaluated for better crop production. The raised and sunken bed of 1 m: 2.5 m width ratio and 30 cm elevation was effective for inter-plot water harvesting (4.9 cm. submergence) and rice (39 q/ha) – french bean (118.69 q/ha green pod) cropping system.

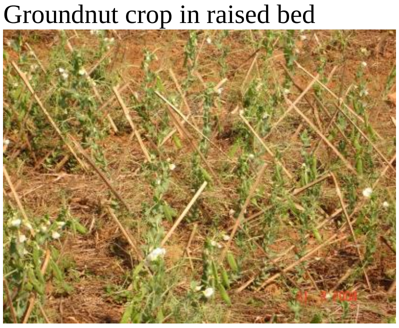
Rice crop in sunken bed

Potato and pea crops in raised - sunken bed system

b. Raised beds: Optimum soil moisture regime plays a vital role in the development of root system, vegetative growth as well as crop production. Raised bed (15 cm. height) system without any side bunds was found to be very effective during rainy season for crop production than the other soil moisture regime treatments. Soil hydraulic properties were also found better under raised bed condition, enabling luxuriant crop growth and higher yield. A succeeding crop of pea was possible only in raised bed system on residual soil moisture.

Groundnut crop in raised bed

Groundnut crop in flat bed



Good crop performance of Pea under raised bed

Poor crop performance of Pea under flat bed

Mechanical and Engineering Measures

Mechanical and engineering measures are adopted to supplement the agronomical measures. The various measures that can be included are contour bunds and trenches, bench terracing, check dams, gully control measures etc.:

1) **Contour bunding: -** A series of contour bunds divide the area into strips and act as barriers to the flow of water, thus reducing the amount and velocity of runoff. When bunds are constructed strictly on contour lines, it will hold the entire water coming from the interspaces between two successive bunds and the water stored will gradually infiltrate into the soil which helps in replenishing soil moisture and ground water storage. In addition, the eroded soil will be deposited behind the bund.
2) **Terracing**: - Bench terracing principally consists of transforming relatively steep land into a series of level or nearly level strips

running across the slope . These strips are separated by vertical risers. It reduces the slope length and consequently erosion. Terraces are favoured on slopes steeper than 15% and where fertile deep soil is available. The use of terraces on steep slopes not only retards erosion losses but also makes cropping operations on these lands possible and safe.

Terracing may be (a) level/table top, (b) sloping outward or c) sloping inward. For north eastern condition of high rainfall areas terraces with sloping out wards are preferable.

3) **Moisture conservation pits:** Small pits can be constructed across the slope to harvest rainwater (Fig.5). Eroded soil will be deposited in the pits and water collected will be gradually infiltrated into the soil thus increasing the moisture regime of agricultural land. They are suitable in between plantation crops grown on flat and slightly sloping lands. Pits of size 1.5 m x 0.6 m x 0.6m may be constructed at suitable intervals according to the site conditions.

4) **Contour trenches:** They are narrow trenches built along contours for collecting and draining overland flow as well as for increasing soil moisture (Fig.6). They can be constructed continuously across the slope or in a staggered manner. Contour trenches are suitable on steep slopes where perennial crops are grown with less interspaces. They are also recommended in lateritic wastelands for intercepting overland flow.

5) **Half-moon terrace**: This type of terraces are constructed along the hill slopes. A half moon type cut is given depending upon the plants to be grown along the hill slope . It is generally of 3 ft radious and 3 ft depth. The manures are mixed with the soil and saplings of fruits are planted. Since only a part of the field is disturbed, the soil and moisture loss is less. The other part of the field is covered with natural grasses.

6) **Checkdams :** Checkdams are embankments constructed across the flow of water. They can be either made of locally available materials like brushwood, loose rocks, sand bags, plants etc. or a RCC structure (Fig.7). The major uses of a checkdam are

- To reduce the gully bed slope thereby reducing the velocity of runoff water, preventing the eroding and down cutting of gully beds.
- To encourage the deposition of silt and create favourable soil moisture regime for the establishment of plant cover.

Where stones or rocks of appreciable size and suitable quality are available, they may be used to make check dams in gullies that have small to medium size drainage areas. Loose rock/boulder check dams reinforced with vegetative measures will form a very effective barrier against the flow of water (Fig.7). Such structures can be strengthened by encasing in woven wires called Gabion structures.

Brush wood check dams are low cost structures that can be constructed across streams in such locations where the velocity of runoff is not high. Poles of bamboo, arecanut, casuarina etc. may be drived in two rows across the drain and the space in between the poles is filled with waste materials such as coconut leaves, jungle wood etc. The poles drived are tied together with few poles placed across them using G.I. wire so as to form a stable structure.

7.**Vegetative filter strips:** In places where runoff water is coming from upper hill areas in considerable volumes, bunds of height 15 cm to 45cm can be constructed across the slope and pineapple, vetiver and other grass strips can be established to filter the runoff and to prevent soil loss.

7) **Ponds:** Ponds are common structures used for rainwater harvesting (Fig.9). New ponds can be constructed on the sides of the drainage line. Side protection works such as rubble walls/stone pitching etc. can be done. The existing ponds can be rennovated by desilting and strengthening sides with vegetative or structural measures. In addition, stone quarries left in the field after cutting can be effectively used for collecting runoff water by constructing suitable diversion drains.

For ensuring sustainability in each and every watershed management projects, people of the area need to participate and intricately involve themselves in planning, implementation and maintenance of watershed resources. The watershed based institutions need to be strengthened with active participation of the stakeholders, which in turn maximizes the possibility of better post-project sustainability.

Participatory soil and water management or watershed management involves conservation, development and management of these resources. Since water plays a catalytic role in healthy development of plants, animals and human resources, concept of watershed has assumed needed importance. It involves integrated use and management of rainwater, in-situ soil moisture, surface and ground water together with development and management of land, vegetation and crop in a watershed to meet its various needs (Sikka, 2008). Typically the participatory process in watershed management involves-

- Meeting with watershed community
- Problem appraisal and plan formulation
- Formation of local people institution
- Social acceptance and approval of plantn by society
- Capacity building

- Sustenance and follow up

Measurement of Irrigation Water : Since the water is becoming scarce day by day and the demand is increasing, its very important to quantify water for various purposes like pricing, quantity to distributed/released etc. **Some of the available methods of w**ater measurement are-

1. Volumetric measurements
2. Velocity – area methods
3. Measuring structures (Parshall flume,Weirs,orifices etc.) and
4. Tracer methods.

Volumetric measurement

A simple method of measuring small irrigation stream is to collect the flow in a container of known volume for a measured period of time. An ordinary bucket or barrel is used as the container. The time required to fill the container is recorded with a stop watch and the rate of flow is measured by the formula

$$\text{Discharge rate, litres per sec} = \frac{\text{Volume of container in litre}}{\text{Time required to fill in seconds}}$$

This method can be used to determine the discharge rate of pumps and other water discharging units like sprinkler etc.

Velocity – area method

The rate of flow passing a point n a pipe or open channel is determined by multiplying the cross-sectional area of the flow section at right angles to the direction of flow by the average velocity of water.

Discharge = Area x Velocity

Q = A x V

Where,

Q = Discharge rate, m^3/sec

A = Area of cross section of channel or pipe (m^2) and

V = Velocity of flow, (m/sec)

Float Method

The float method is making a rough estimate of the flow in a channel and is done by noting the rate of movement of a floating body. A long necked bottle partly filled with water or a block of wood may be used as the float. To determine the velocity of water at the surface of the channel, the length of the trial section is divided by the average time taken by the float to cross it. Since the velocity of the float on the surface of the water is greater than the average velocity of the stream, it is necessary to correct the measurement by multiplying by a constant factor, which is usually assumed as 0.85.

Current Meter Method

The velocity of water in a stream or river may be measured directly with a current meter and the discharge is estimated by multiplying the mean velocity of water by the area of cross section of the stream. The current meter is a small instrument containing a rotations wheel or vane that is turned by the movement of water. The number of revolutions of the wheel in a given time interval is obtained and the corresponding velocity is recorded from a standard calibration table or graph on the instrument.

Water Meters

Water meters utilise a multi-blade propeller made of metal, plastic or rubber rotating in a vertical plane and geared to a totalizer in such a way that a numerical counter can totalize the flow in any derived volumetric units.

Weirs

Weirs are used to measure the flow in a n irrigation channel or the discharge of the well or canal at the source. A weir is a notch of regular form through which irrigation water is made to flow. It may be metal or timber with a sheet of metal weir plate fixed to it. They may be built as stationery structures or portable. The notch may be rectangular, trapezoidal, triangular, etc.

The general formula for calculating discharge

= $Q = CLH^m$

Where,

Q = discharge

C = a coefficient or constant depending on the crest and approach condition

L = length of crest

H = head on the crest

m = an exponent, depending on the weir opening

90^0V notch = $Q = 0.0138\ H^{5/2}$

Measurement of Irrigation Water

Where,

H = Head over the crest in cm

Q = lit/sec

Rectangular weir

Suppressed = $Q = 0.0184 \times LH^{3/2}$

Both ends = $Q = 0.0184 \times (L – 0.2\ H)^{3/2}$

Contracted

Cipoletti = $Q = 0.0186 \times L\ H^{3/2}$

Parshall Flume

It is one of the improved designs for free flow condition, which operates with a small drop in head. It is a self cleaning device, sand or salt in the flowing water does not affect its operation or accuracy. The size of the flume is determined by the width of the throat. Throat width ranging from 7.5 cm to several meters have been calibrated and for which standard discharge tables also have been developed as ready reckoner.

Q = 0.140 H 1.55 for 7.5 cm throat

Q = 0.260 H 1.58 for 15 cm throat where

H = depth of flow and Q = lit/sec

Orifices

Orifices in are usually circular or rectangular openings in a vertical bulk head through which water flows. The edges of the openings are sharp and often made of metal. They may operate under free flow or submerged flow conditions.

$Q = 0.61 \times 10^{-3}\ a \times \sqrt{2gH}$

Where,

Q = discharge lit/sec

a = area of cross section of orifice cm^2

g = acceleration due to gravity = 981 cm/sec^2

H = depth of water over the centre of orifice in case of free flow orifice (or) difference in elevation between the water surface at the upstream and downstream faces of the orifice in submerge orifics (cm).

Tracer method: In this method a substance in concentrated form is introduce into the flowing water and allowed to be mixed thoroughly. The concentration of the tracer is then measured at the down stram section. There is no need to measure velocity of water, depth, head etc and only concentration at upper and down head are sufficient. Sodium chlrode, sodium dichromate etc are used as treacer.

Calculations to be remembered in irrigation management

1 TMC = 1000 million cubic feet

1 feet cube = 0.027 m^3 or cubic meter

Therefore,

1 TMC = 27,000,000 m^3

1 m^3 = 1000 litres

Therefore,

1 TMC = 27,000,000 / 1000

= 27,000 litres

100 m^3 = 1 ha cm

Therefore,

1 TMC = 27,000,000 / 100

= 270,000 ha cm

Suppose the depth of irrigation is 5 cm

At a time the area that can be irrigated with 1 TMC of water = $\frac{270,000}{5}$ = 54,000 ha

Water requirement for rice is 120 cm for a season.

Area can be irrigated for a season = $\frac{270,000}{120}$ = 2250 ha

1 cusec = flow of 1 cubic feet per second

If one cusec flow for 24 hours. How much area can be irrigated to a depth of 5 cm.

$$1 \text{ cusec} = \frac{ft^3}{sec}$$

Approximately

= 30 x 30 x 30 cm^3 = 27,000 m^3

24 hours = 60 x 60 x 24

= 86,400 seconds

Flow of water for 24 hours = 27,000 x 86,400

/ = 2332800000 cm^3

1000 cm^3 = 1 litre

2332800000 cm^3 = 2332800000 / 1000

= 2332800 litre

1000 litre = 1 m^3

2332800 litre = 2332800 / 1000

= 2332.8 m^3

100 m^3 = 1 ha cm

Therefore,

2332.8 m^3 = 2332.8 / 100

= 23.328 ha cm

If depth of irrigation is 5 cm the area can be irrigated with 1 cusec of water flowing for 24 hours is

= 23.328 / 5 = 4.665 ha

CALCULAION OF WATER USE EFFICIENCY

The water utilized by crop is evaluated in terms of Water Use Efficiency. This water use efficiency can be classified into

1. **Crop Water Use Efficiency (CWUE)**

   It is the ratio of crop yield (Y) to the amount of water used by the crop for evapotranspiration (ET).

   $$CWUE = \frac{Y}{ET}$$

2. **Field Water Use Efficiency (FWUE)**

   It is the ration of crop yield (Y) to the total amount of water used in the field (WR)

   $$FWUE = \frac{Y}{WR}$$

3. **Physiological Water Use Efficiency (PWUE)**

   The physiological WUE is calculated in terms of the amount of C_2O fixed per unit of water transpired

   $$PWUE = \frac{\text{Rate of Photosynthesis}}{\text{Rate of Transpiration}}$$

4. **Irrigation Project Efficiency**

   Many irrigation projects throughout the world operate with 25 to 40 per cent overall efficiency. Thus, perhaps one third of the water released at the project head work is actually beneficially used for evapotranspiration by crops. In many areas increased irrigation efficiencies would result in increased irrigated acerage and production as well as decreased problem with salinity and drainage. The decrease in efficiency can be attributed to losses occurring at various stages. Some of the reasons are:

   Application efficiency: It can be defined as the “depth of water needed to meet the water loss through evapotrnsapiration of a disease free crop, growing in large fields under non-restricting soil conditions including soil water and fertility and achieving full production potential under the given growing environment”. It can be given as-

   $$Ea = \frac{\text{Water directly available to the crop = (FC level)}}{\text{Water received at field inlet}} \times 100$$

Conveyance efficiency (Ec) : It is the efficiency with which irrigation water is conveyed to fields**.**

$$Ec = \frac{\text{Water received at inlet to a block of fields}}{\text{Water released at Project Head works}} \times 100$$

Project efficiency (Ep): It represents the efficiency of the entire operation between diversion of source of flow and the root zone.

$$Ep = \frac{\text{Water made directly available to the crop}}{\text{Water released at Head works}}$$

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