Best Practices and Technologies for Agricultural Water Management

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Water is one of the largest renewable natural resources but fresh water is expected to emerge as a key constraint to future agricultural growth. Globally and more particularly for many developing countries including India, Ethiopia, changing water availability and quality pose complex problems and management options are not easy. The changing situation comes partly from increasing demands such as population, industry and domestic requirements partly from consequences of climatic change. The demand for water has grown annually by 2.4 per cent. The present water stress (about 28%) of many countries is expected to be about 50% due to population growth and industry development. Indian statistics shows that per capita availability has come down from 5300 m^3 in the year 1955 to 1967 m^3 in 1997, which is projected to further decrease to 1500 m^3 by 2025 with wide inter-basin variations. Environmental scientists have categorically notified the critical water availability per capita to the extent of 1000 m^3 per annum (Selvarajan *et al* 2004); Water Availability Index (WAI) and Water Stress Levels (WSL) are reported in Table-1.

Table 1: Standards of Critical Water Stress Levels (Mitra A.P, 2004)

(WAI) M^3/capita/annum	Water Stress Level (WSL)
>1700	Satisfactory
1000-1700	Water stress
500 - 1000	Water scarcity
< 500	Water Storage

WAI=Water Availability Index

On the background of 6.0 Billion World population with geographic river basin water availability variation, the best water management practices with location specific technology are now inevitable for sustainable rural and agricultural development.

Rainfed agricultural lands are low in productivity and sustainability and are more prone to risk as compared to those in irrigated areas. This can be obviated to some extent by expanding irrigated areas through improving water management practices and enhancing water use patterns. Presently, the problem facing the country is not the development of water resources, but the management of the developed water resources in a sustainable manner. The bulk of agricultural land could be brought under irrigation provided that efficient water management practices including micro-irrigation would be adopted by the farmers.

The best practices and technology for agricultural water management refer to application of optimum water quantity scheduled at right time with highest water application efficiency. The application of too little water is an obvious waste as it fails to produce the desired production. Excessive flooding of the land is however likely to be still more harmful as it tends to saturate the soil for long time, inhibit aeration, leach nutrients, induce greater evaporation and subsequent salinization. Therefore, apart from wasting water, excessive irrigation contributes to its own demise by the twin scourges of water logging and soil salinization. The best irrigation methods are designated to apply a small measured volume of water at desired frequent intervals to where the roots are concentrated. The aim is to reduce fluctuations in the moisture content of the root zones without subjecting the crop either to oxygen stress or water stress.

Moreover, irrigation system should convey water to the field in concrete line channels so as to avoid seepage losses or preferably in closed conduits that avoids pollution. The objective of water management is to provide a suitable moisture environment to crops to obtain maximum yield with high water use efficiency. It is integrated process of diversion, conveyance, regulation, measurement, distribution time and requisite quantity of water. Efficient water management is depicted in a simple manner in Figure 1.

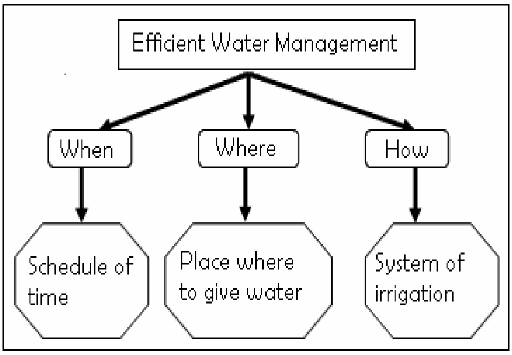

Figure 1. Efficient Water Management

The basic principles of irrigation water management could be summarized in a simple relationship of soil-water plant atmosphere continuum (SPAC) (Fig. 2). Moreover, 'Management Allowable water Deficit' (MAD) estimated based on pertinent physico-chemical properties (FC, PWP & AM) and soil moisture stress resistance of a crop are important parameters for selecting best practice of agricultural water management. Other soil parameters of infiltration rate, hydraulic conductivity, slope, advance and recession of water front and opportunity time, etc. are also important parameters in maintaining optimum MAD. In brief, root zone soil layer should be kept at about field capacity maintaining optimum level of soil moisture, aeration and microbial load.

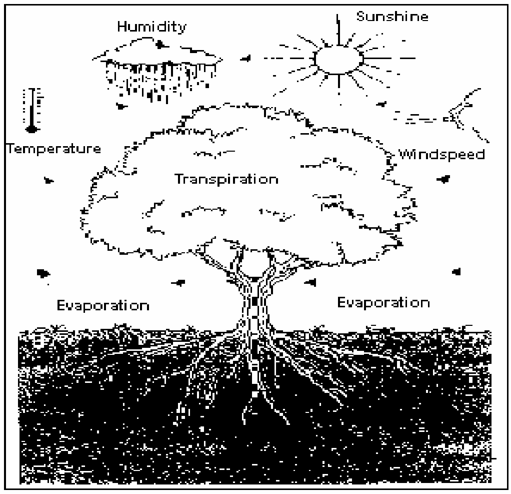

Figure 2. Soil Plant Atmosphere Continuum

The term water use efficiency is categorically used to analyze the best water management practices. Irrigation scientists have developed high precision technologies for achieving greater efficiencies such as 'conveyance efficiency', 'on farm application efficiency' or 'field application efficiency'. Finally, all the above indices of efficiency may be combined in a single concept, the overall agronomic efficiency of water use, Fag.

Fag = P/u

Where P = Crop production (unit dry mass or marketable produce)
u = Unit volume of water

The quantity of water applied in each irrigation is divided in several parts such as runoff (R), deep percolation loss (DP), evaporation from soil surface and transpiration from leaves (ET), evaporation during conveyance and application (EP), etc. The total water budget in between two irrigation rotations is depicted in fig.3. The modern technology is developed to improve water use efficiency (WUE) focused on conservation of water and enhancement of maximum quality marketable agricultural produce in terms of economics. However, soil is the media which needs to be given top priority for its assessment related to international classification to maintain its health.

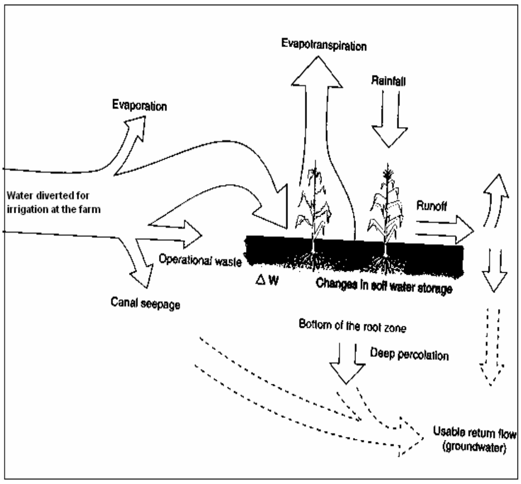

Figure 3. Hydrological parameters and water budget between two successive irrigations

The agricultural water management practices are classified under surface, sprinkler, micro-irrigation (Drip) and subsurface irrigation. Each and every irrigation practice has got its merit, demerit and limitations depending upon water availability cropping pattern, water quality, soil types, topography, climate & socio-economic status of the farmers. It is emphatically pointed out that irrigation system that may prove most appropriate in one country or region may not be suited in other country or region due to specific local physical conditions and cropping pattern. The economic background and government support to the farmers are also major factors. The large rotating wheel type sprinklers are common in California which rarely used in practice in other developing countries. Human factors include labor and management, training and skills are need to be given due consideration. Moreover labor cost, capital and energy availability, etc. are coupled with the expected returns. The modern irrigation methods (sprinkler and micro irrigation) are efficiently used in developed countries, but various alternatives with respect to their possible applicability in developing countries particularly in Africa need to be given special attention. The scientists are confident that low cost best practices with high WUE could be brought into practice provided that HRD component and farmers training are planned systematically.

The definition of 'HELPFUL Irrigation' is very innovative from FAO Development series 2 as it denotes: High frequency (H), Efficiency (E), low volume (L), partial area (P), Farm (F), Unit (U) and Low cost (L). (Hillel Daniel (1997). How could be the farmers be brought into this ideal system? It is necessary to categories the situation for selecting best combination of HELPFUL Irrigation.

CASE STUDY- 1.

Water scarcity area, Poor Socio-economic status, Untrained HR, cheap labor availability, Limited economic support from Government sector. Soil climate and topography. Here also profitable cropping pattern is possible. Best irrigation practice & technology will be the Pitcher irrigation system which is depicted in fig. 4 and fig. 5.

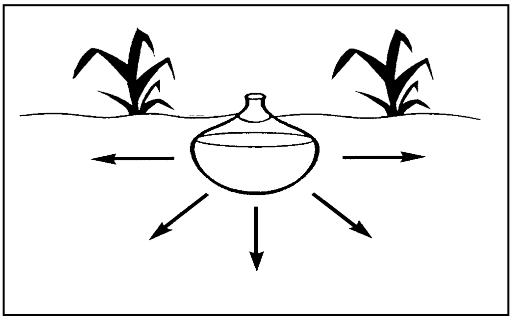

Figure 4. Pitcher Irrigation Method

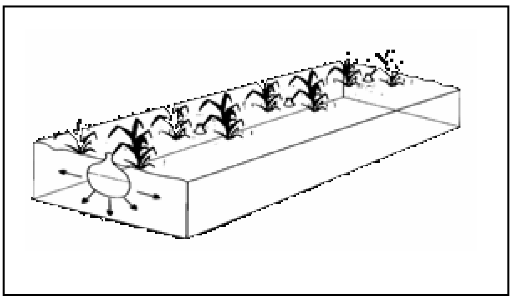

Figure 5. Pitcher Irrigation Method

Following parameters are considered for its efficient design and operation:

- Preferably clayey - clay loam texture soil type.
- Estimation of Net irrigation requirement in terms of LPD.

- Water application - daily or alternate day (high frequency).
- Reuse of pitchers for subsequent crops is possible.
- Use of liquid fertilizers through pitcher is possible.
- Broad Base Furrow (BBF) technique is very effective.
- Excellent SPAC relations are maintained throughout crop growth period.

The results of pitcher irrigation system on cotton crop at MPKV, Rahuri (M.S.) India, are reported in Table 2. However, filling of pitcher or jars with high frequency is the major limitation, which could be solved by arranging limited water conveyance PVC pipeline.

Table 2: Detail of irrigation, WUE and meteorological parameters under different irrigation methods

Particulars	Drip	Furrow	Drip *	Pitcher
Gross irrigation (cm)	43.14	89.53	43.14	31.38
WUE (kg/ha-cm)	64.32	25.12	49.96	63.47
Water saving (cm)	46.3	-	46.4	58.15
Water saving (%)	42.87	-	42.87	64.95
Yield (q/ha)	31.36	22.49	31.10	19.92

* Fertilizer through tank

CASE STUDY - 2

Optimum Water availability, command area of irrigation project, surface flow irrigation, middle class socio-economic status, soil, climate and cropping pattern favorable. Farmers are innovative and ready to accept new changes.

Good irrigation practice will be the surface irrigation with border or ridges and furrow irrigation layout:

- Rotational volumetric water supply system, conjunctive water use, possible land development with precise slope > 0.6%, mostly cash crops and cropping pattern with 200% intensity.
- The border or Ridge and furrow irrigation layouts are preferred with specific length, breadth, slope and discharge.
- The infiltration rate is also playing important role in achieving high water application efficiency.

These parameters are designed in such way that advancement of water without soil erosion and recession of water flow with high infiltration rate would be precisely adopted. The sufficient opportunity time is obtained so that soil moisture deficit in effective root zone is met out with minimum deep percolation losses at head and tail reach portions of border or furrow. The details of water applied with WUE are shown in Table 3 A and B. However, under no circumstances field application efficiency exceeds 60% and the deep percolation losses to the extent of about 10% are inevitable.

CASE STUDY - 3

Precision Technology of Sprinkler Irrigation - Any soil type, cash crop focused cropping pattern, assured water and energy supply, skill oriented, better socio-economic conditions. Sprinkler irrigation system parameters are indicated below:

- Limited field layout or sometime leveled field.
- Beneficial for hilly areas with variable topography, high frequency water application based on crop tolerance for soil moisture and MAD
- High energy requirement
- Prone to wind velocity drifting.
- Uniformity coefficient about 80%
- Water saving to the extent of 30-40% as compared to traditional system.
- Increase in the yield to the extent of 10-20% as compared to surface method

Table 3: Comparative studies on different irrigation methods

(A) Effect of methods of irrigation on the dry pod yield of groundnut

Treatments	Yield (q/ha)			Increase in yield over border (%)
	1985	1986	Pooled	
Border	18.32	18.29	18.31	--
Check basin	18.99	18.75	18.87	--
Sprinkler	22.42	21.87	22.15	20.97
S.E. ±			0.08	
C.D. at 5%			0.21	

(B) Yield of red dry Chilli, water expense and water use efficiency as influenced by methods of irrigation for Chilli (Pooled Mean)

Methods of irrigation	Yield of dry Chilli (q/ha)	Water applied (cm)	WUE (kg/ha-cm)
Furrow	17.15	39.00	44.27
Sprinkler	20.91	26.00	81.12
S.E. ±	0.35	--	--
C.D. at 5%	1.0	--	--

- High initial investment and capital cost solid and rotating systems.
- Shifting movable types are available.
- Design operation and maintenance are key parameters.
- Farmers have to be skillful and knowledgeable

The details of results obtained in India for sprinkler irrigation systems with its economic parameters are reported in Table 3 A and B. However, experiences in India show that sprinkler growth is steady and micro irrigation system is being accepted and adopted by farmers on larger scale.

CASE STUDY - 4

Modern Technique of Micro Irrigation or Drip/Trickle Irrigation- This is the best world wide accepted modern technique in water management system. It has got wide range acceptability under variable soil, crop and climatic conditions. From the recent past as share of water for agriculture is declining, the judicious use of every drop of water is gaining attention. And spread and use of micro irrigation has become need of the hour. Extent of the micro irrigation in the world is depicted in Figure 6.

The details parameters are as follows:

- Any water resource with optimum quality.
- High frequency (daily or alternate day)
- Low pressure (about 1 to 2 Kg/cm2)

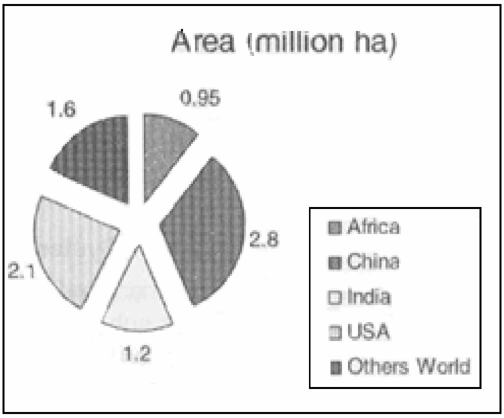

Figure 6. Micro- irrigation spread in the world

- Estimation of daily water requirement based on Pan evaporimeter data in terms of litres/day/plant (LPD)
- Solid system - network of LDPE pipes provided with specific type of emitters.
- Assured energy supply is necessary but its requirement is low.
- Very high Uniformity Coefficient > 95%
- Design, operation and maintenance skills

Table 4. Results of Studies on Micro-irrigation by Plasticulture Development Centre

Crop	Yield (Q/ha)		Irrigation (cm)		WUE (q/ha/cm)		Advantage of MI (%)	
	Surface	Drip	Surface	Drip	Surface	Drip	Surface	Drip
Beet	5.70	8.90	86.00	18.00	0.07	0.50	79.10	56.10
Bitter Gourd	32.00	43.00	76.00	33.00	0.42	1.30	56.60	34.40
Brinjal	91.00	148.00	168.00	64.00	0.55	2.30	61.90	62.60
Broccoli	140.00	195.00	70.00	60.00	2.00	3.25	14.30	39.30
Cauliflower	171.00	274.00	27.00	18.00	6.30	15.20	33.30	60.20
Chilli	42.30	60.90	109.00	41.70	0.39	1.50	61.70	44.00
Cucumber	155.00	225.00	54.00	24.00	2.90	9.40	55.60	45.20
Lady's finger	100.00	113.10	53.50	8.60	1.87	13.20	84.00	13.10
Onion	284.00	342.00	52.00	26.00	5.50	13.20	50.00	20.40
Potato	172.00	291.00	60.00	27.50	2.90	106.60	54.20	69.20
Radish	10.50	11.90	46.00	11.00	0.23	1.10	76.10	13.30
Sweet potato	42.40	58.90	63.00	25.00	0.67	2.40	60.30	38.90
Tomato	61.80	88.70	49.80	10.70	1.24	8.28	78.50	43.50
Banana	575.00	875.00	176.00	97.00	3.27	9.00	45.00	52.20
Grapes	264.00	325.00	53.00	28.00	5.00	11.60	47.20	23.10
Papaya	130.00	230.00	228.00	73.00	0.60	3.20	67.90	76.90
Pomegranate	34.00	67.00	21.00	16.00	1.62	4.20	23.80	97.00
Water melon	82.10	504.00	72.00	25.00	5.90	20.20	65.30	51.39

WUE = Water Use Efficiency; MI = Micro Irrigation

- Initial cost is high but quality and quantity of production are assured.
- Saving in Water is greater than 60%
- Increase in yield is greater than 60 - 70 %
- Spot application of water hence inter culturing expenses are minimum.
- Application of liquid fertilizer is possible
- Severe limitations of emitter clogging, water filtration, ground water quality physical impurities in water, local salt accumulation, etc.

- very high initial cost - Life is also limited drip material prone to physical injuries, careful handling
- Availability of Technical Manpower for maintenance.

Exhaustive research has been done by several institutes in several countries. India is not exception to that international research program. The details of research findings are given in Table 4. These research findings are confirmed to water saving and increased in the yield of several cash crops including vulnerable crops like sugarcane and cotton and low spaced vegetable cash crops. Water use efficiency with micro-irrigation for major crops is given in Table 5.

Selection of most appropriate method in given circumstances is a major task of water manager. This depends upon crop response to various level of moisture stress. Moisture availability in relation with field capacity and wilting point for crops under different methods of irrigation are depicted in Figure. 7

Table 5. Water use efficiency with micro irrigation (INCID, 1994)

Crop	Yield increase (%)	Water saving (%)	Increasing use efficiency (%)
Banana	52	45	176
Chilly	45	63	291
Grape	23	48	136
Sweet Lime	50	61	289
Pomegranate	45	45	176
Tomato	50	31	119
Water Melon	88	36	195

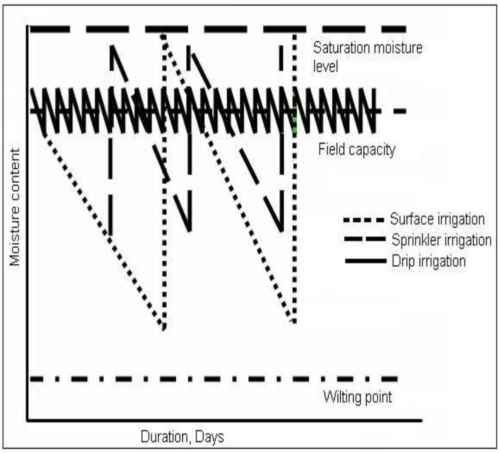

Figure 7. Moisture availability at various moisture stress levels for different methods of irrigations

Conclusion

Micro-irrigation coupled with Biotechnology, value addition, Information Technology and Watershed based approach of development will bring paradigm shift in agriculture as knowledge based profession. Latter will have wide spread and sustainable impact on enhanced agriculture production and productivity. The micro-irrigation technology will act as catalyst for evergreen revolution with precision farming. Sustainability, productivity, profitability and equity will become reality in every farmer's field with better water, fertilizer, energy, environment and human efficiency.

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