Benchmarking of Irrigation Projects

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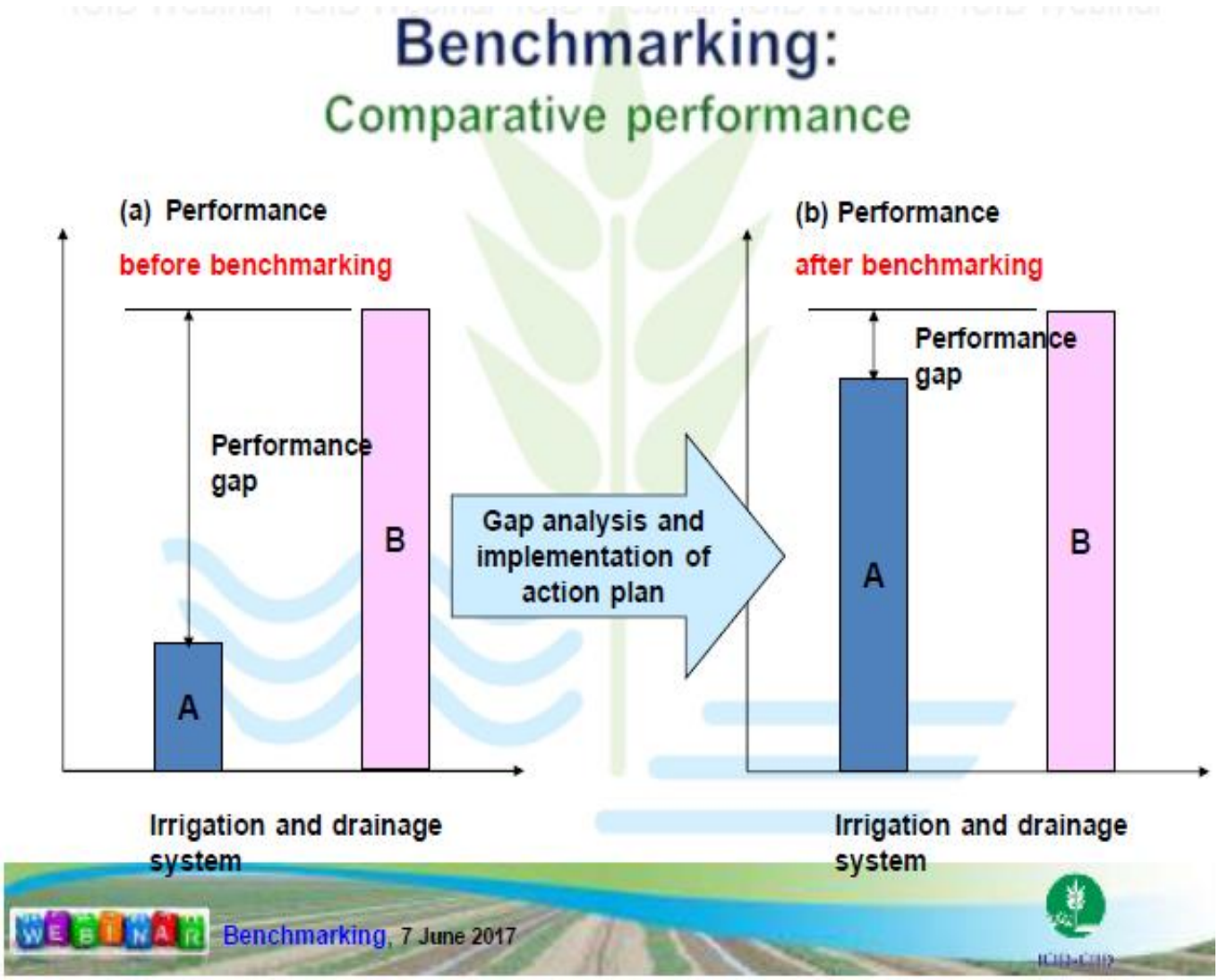
Benchmarking of Irrigation Projects

- Benchmarking is process through which we intend to improve performance irrigation system by comparing it with the best managed irrigation system

- It is a tool used to evaluate and measure the performance of a system and compare it with the best system to identify the process and practices which have potential to improve the performance of the system

- A systematic process for securing continual improvement through comparison with relevant and achievable internal or external norms and standards (Malano and Burton, 2001)



Source: Burtton, 2017 (Webinar on Practicalbenchmarking for improving performance of irrigation and drainage schemes)

Benchmarking of Irrigation Project: Potential

- Inadequate of-farm and on-farm infrastructure: Unlined canal and farm channels
- Poor overall irrigation efficiency: average 38%
- Average conveyance efficiency: 69%
- Average on-farm application efficiency: 52%

Achievable irrigation efficiency in canal commands

	Maximum	Minimum
Overall irrigation efficiency (%)	62 (Koil Sagar Project) Mahbubnagar, Telangana	15 (Narayanpuram Project) Yadgir, Karnataka
Conveyance efficiency (%)	91 (Vamsadhara Project) Andhra Pradesh and Odisha	50 (Srisailam Project) Telangana and Andhra pradesh
On-farm application efficiency (%)	80 (Matatila dam project) Uttar Pradesh	28 (Yeluru Project) Andhra Pradesh

Benchmarking of Irrigation Project: Potential

Water Use Efficiency of Completed irrigation projects based on Field Measurements of Losses

Sl. No.	Name of Project	Culturable Command Area (Hectare)	Conveyance Efficiency (%)	On Farm Application Efficiency (%)	Overall Project Water Use Efficiency (%)
(1)	(2)	(3)	(4)	(5)	(6)
1.	Bhairavanithippa Project	4,856	86	67	58
2.	Gajuladinne (Sanjeevaiah Sagar Project)	10,300	57	45	26
3.	Gandipalem Project	6,478	73	38	28
4.	Godavari Delta System (Sir Arthur Cotton Barrage)	4,10,108	83	54	45
5.	Kurnool –Cuddapah Canal System	65,465	62	45	28
6.	Kaddam Project	27,519	51	36	18
7.	Koil Sagar Project	11,700	83	75	62
8.	Krishna Delta System (Prakasam Barrage)	5,29,000	87	46	40
9.	Nagarjuna Sagar Project	8,89,000	56	39	22
10.	Narayanapuram Project	15,855	47	32	15
11.	Nizamsagar Project	93,659	87	45	39
12.	Srisailam Project	59,900	50	34	17
13.	Rajolibanda Diversion Scheme	35,410	82	51	42
14.	Somasila Project	54,650	56	32	18
15.	Sri Ram Sagar Project	3,71,054	78	57	45
16.	Tungabhadra High Level Canal	45,800	81	58	47
17.	Tungabhadra Low Level Canal	61,163	72	45	32
18.	Vamsadhara Project	82,087	91	58	53

Source: Report of the Working Group On Major & Medium Irrigation And Command Area Development for the XII Five Year Plan (2012-2017), Government of India Ministry Of Water Resources (2011)

Water Use Efficiency of Completed Major/Medium Irrigation Projects based on Field Measurements of Losses

Sl. No.	Name of Project	Culturable Command Area (Hectare)	Conveyance Efficiency (%)	On Farm Application Efficiency (%)	Overall Project Water Use Efficiency (%)
(1)	(2)	(3)	(4)	(5)	(6)
19.	Yeleru Project	27,240	50	28	14
20.	Augmentation Canal Project	85,443	79	72	57
21.	Dholabaha Dam Project	2,600	74	71	53
22.	Ranjit Sagar Dam Project	3,00,000	51	65	33
23.	Ahraura Dam Irrigation Project	14,964	70	70	49
24.	Matatila Dam Project	1,79,880	68	80	54
25.	Naugarh Dam Irrigation Project	64,221	71	70	50
26.	Pili Dam Project	4,044	58	65	38
27.	Walmiki Sarovar Project	6,271	62	62	38
28.	East Baigul Reservoir Project	16,605	64	65	42
Average			69	52	38

Water Use Efficiency

Efficiency of projects varies from as low as 14% to high up to 62%.

- Average efficiencies:
  - ➢ Conveyance: about 70 %;
  - ➢ Application : About : 50 %;
  - ➢ Overall project efficiency: about 35 %

- ➢ On-Farm application Efficiency is relatively less in comparison to conveyance efficiency
- ➢ Message is clear that we need to give more emphasis on improvement of on-farm water management

Benchmarking of on-farm efficiency with precise measurement using modern gadgets is required.

Source: Report of the Working Group On Major & Medium Irrigation And Command Area Development for the XII Five Year Plan (2012-2017), Government of India Ministry Of Water Resources (2011)

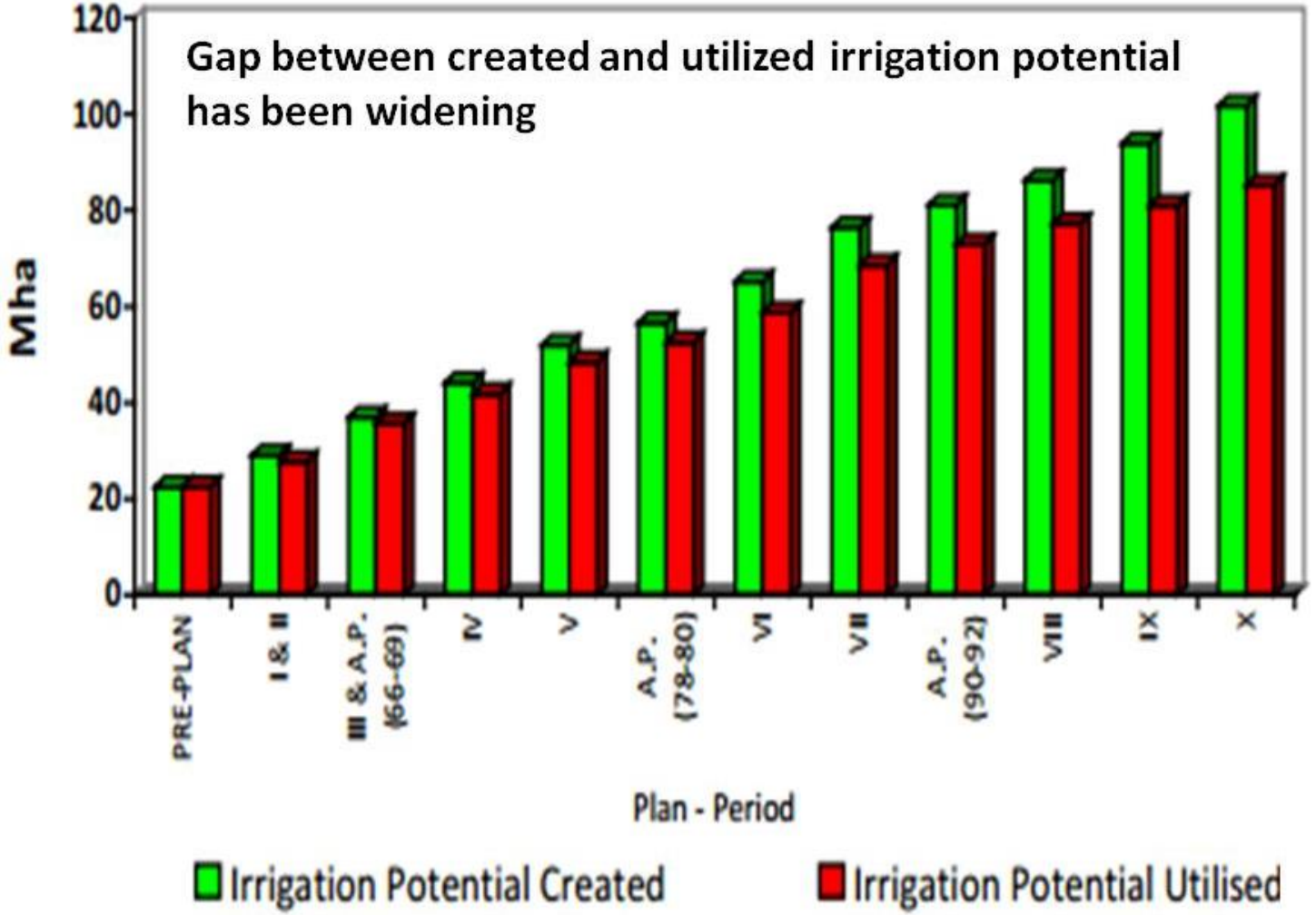
Common maximum attainable values of the field application efficiencies

Irrigation water application method	Maximum attainable ratio (efficiency)
Surface irrigation	
Furrows, laser levelling	0.70
other quality levelling methods	0.60
Border strip, laser levelling	0.70
other quality levelling methods	0.60
Level basins, laser levelling	0.92
other quality levelling methods	0.80
Sprinkler	
Hand move system	0.60
Overhead rain drops	0.80
Downward fine spray	0.90
Micro-irrigation	
Drip	0.95
Micro sprinkler	0.95

Source: M.G. Bos, M. A. Burton and D. J. Molden 2005. *Irrigation and Drainage Performance Assessment: Practical Guidelines.*

Benchmarking of Irrigation Project: Potential

Increasing gap between created and Utilized irrigation Potential



Source: CWC 2013

Benchmarking of Irrigation Project: Potential

- Inadequate and irregular canal water supply in many commands
- Non availability of control structures and regulation gates
- Poor maintenance of canal and distribution network

Benchmarking of Irrigation Project: Potential

Benchmarking helps in improving the conditions of the canal

Benchmarking of Irrigation Project: Constraints

- Data availability
- Collection of primary and secondary data
  - Reliability of data
  - lack of modern tools and gadgets required for measurements (in third phase of NHP it may improve)
- Lack of coordination among participating organizations
- Precise methodology
- Trained man power
- Budget

Way Forward

- The main aim of irrigation projects are to increase productivity and production without causing to land , water and environment.

  This can be achieved by supply of adequate water in the entire command, improvement in irrigation efficiencies, application of measured quantity of water through efficient method of irrigation

- On-farm application losses are more ***(Average on-farm application efficiency is only 52%)*** than the conveyance losses.

  There is need to give more emphasis on bench marking of on- farm irrigation efficiencies of various irrigation projects

- **Bench marking may be extended to small, minor and medium irrigation project also**

  Let us give new dimension to the benchmarking of irrigation project by including all irrigated area irrespective of source of irrigation (As envisaged in PMKSY)

Application efficiency can easily be increased in case of small lift irrigation projects and groundwater and pond irrigated areas.

- Promoting participation of users in benchmarking process

- Bench marking may coupled with water audit

- Process indicators such as conveyance efficiency, application efficiency, crop water deficit, relative evapo-transpiration, relative soil wetness and biomass yield over water supply may be included as performance indicators

- With the introduction of piped water supply in place of canal, some new system performance indicators for piped irrigation may be developed

- More emphasis should be given on on-farm performance indicators with primary data measured using modern flow and soil moisture measurement devices

- Improvement in methodology used for estimation of various indicators

- Used of modern tools such as Information Technology, Remote Sensing and GIS for mapping of soil and crop, and yield forecasting

- There is need to introduce more performance indicators which address the farmers issues, credit availability, availability of others input

- Strengthening of ground water level measurement for estimating the impact indicator

- Incentive to next performing irrigation projects to bring competitiveness

Emerging indicators from remote sensing

- *Crop water deficit:* difference between the potential and actual evapotranspiration of the cropping pattern in an area

$$\text{Crop water deficit} = \text{ET}_\text{p} - \text{ET}_\text{a} \ \text{(in mm/month)}$$

- *Relative evapotranspiration*: dimensionless ratio of actual evapotranspiration over potential evapotranspiration

$$\text{Relative evapotranspiration} = \frac{\text{ET}_\text{actual}}{\text{ET}_\text{potential}}$$

Emerging indicators from remote sensing

- *Relative soil wetness*: a measure for the ease with which the (irrigated) crop can take water from the root zone

$$\text{Relative soil wetness} = \frac{\theta_{\text{actual}}}{\theta_{\text{FC}}}$$

where θ_{actual} = measured (actual) volumetric soil water content in the root zone (cm^3/cm^3), θ_{FC} = volumetric soil water content at field capacity (cm^3/cm^3).

- *Biomass yield over water supply*: relates the crop growth expressed as above-ground dry biomass growth (kg/ha per month) with the volume of irrigation water supplied to the irrigated area (m^3 /month)

$$\text{Biomass yield over irrigation supply} = \frac{\text{Bio}}{V_c}$$

Measurement of flow in on-farm channel using star flow meter

Application of measured volume of water required

Controlled irrigation through pipe network

WTC Farm

Farmer's Field Muzaffarnagar

Broad Bed and Furrow Raised Bed System

saves about 20-30% water

System of Rice Intensification

saves about 20-30% water

Drip Irrigation

- Drip irrigation an efficient method
- Fertilizer can be applied with water
- Saving of water and fertilizer
- Design procedures well developed
- Irrigation scheduling for crops in different soils with respect to water and nutrient movement/ distribution-needs attention

There is need to develop fertigation strategies and schedule for different crops grown in different regions

Sprinkler Irrigation

Achievable groundwater irrigation efficiency through improvement in on-farm irrigation infrastructure and cultivation practices

Achievable groundwater irrigation efficiency (%)		Management options
Rice	Other crops	
55	65	Leveling, proper irrigation scheduling
60	70	laser leveling, irrigation scheduling, efficient irrigation methods
65	80	SRI and aerobic rice cultivation, sprinkler irrigation in mustard and wheat, drip irrigation in sugarcane

Prevailing irrigation efficiencies in groundwater irrigated area: rice-50 %, other crops – 60 %

Overall consumed ratio (efficiency)

- Quantifies the degree to which the crop irrigation requirements are met by irrigation water in the irrigated area

- Overall consumed ratio $=$

$$\frac{ET_p - P_e}{\text{Volume of water supplied to command area}}$$

where ET_p = potential evapotranspiration,

P_e = effective precipitation.

Source: M.G. Bos, M. A. Burton and D. J. Molden 2005. *Irrigation and Drainage Performance Assessment: Practical Guidelines.*

Field application ratio (efficiency)

- Field application ratio $= \dfrac{ET_p - P_e}{\text{Volume of water delivered to field(s)}}$

where ET_p = potential evapotranspiration,

P_e = effective precipitation.

Common maximum attainable values of the field application ratio

Irrigation water application method	Maximum attainable ratio (efficiency)
Surface irrigation	
Furrows, laser levelling	0.70
other quality levelling methods	0.60
Border strip, laser levelling	0.70
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Source: M.G. Bos, M. A. Burton and D. J. Molden 2005. *Irrigation and Drainage Performance Assessment: Practical Guidelines.*

Depleted fraction

- This is the ratio that compares three components of the water balance of an irrigated area

- Depleted fraction $= \frac{ET_a}{P_e + V_c}$

where ET_a = actual evapotranspiration from the gross command area,

P_e = precipitation on the gross command area,

V_c = volume of surface water flowing into the command area.

Drainage ratio

- The drainage ratio is used to quantify water use

- $$\text{Drainage ratio} = \frac{\text{Total drained water from area}}{\text{Total water entering into the area}}$$

Outflow over inflow ratios

- Used to quantify the water balance of a canal system (or reach)
- Often named efficiency
- Outflow over inflow ratio =

$$\frac{\text{Total water supply from canal}}{\text{Total water diverted or pumped into the canal}}$$

Delivery performance ratio

- Enables a manager to determine the extent to which water is actually delivered as intended during a selected period and at any location in the system

- Delivery performance ratio $= \dfrac{\text{Actual flow of water}}{\text{Intended flow of water}}$

Water productivity

- This is the productivity in terms of actual evapotranspiration and in terms of the volume of supplied irrigation water

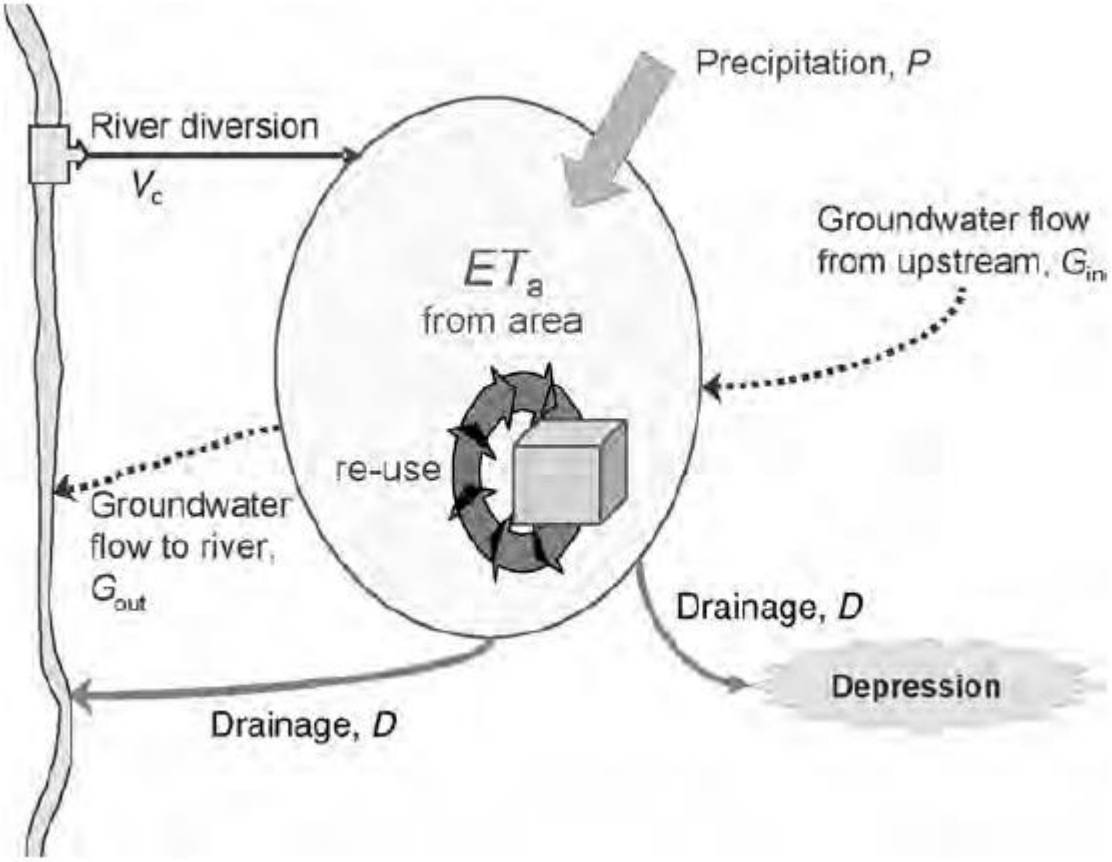
- Water productivity (ET) $= \frac{\text{Yield of harvested crop}}{\text{ET}_{\text{actual}}}$

- Water productivity (m^3) $= \frac{\text{Yield of harvested crop}}{\text{Volume of supplied irrigation water}}$

Crop yield ratio

$$\text{Crop yield ratio} = \frac{\text{Actual crop yield}}{\text{Intended crop yield}}$$

Schematic representation of flows in the water balance of an irrigated area



Source: M.G. Bos, M. A. Burton and D. J. Molden 2005. *Irrigation and Drainage Performance Assessment: Practical Guidelines.*

THANK YOU

Key points in implementation of benchmarking of irrigation projects

- Identification/quantification of gap (in terms of performance indicators) in performance of poorly and better managed projects

- Identification of means and methods to bridge up the gap betwee poorly and better managed projects through diagnostic analysis

- Goal setting: this is very important. It is advisable to select a best performing project for benchmarking of s selected project

- Identification of key process and indicators which have the potential to improve performance of the project

  (Different types of irrigation projects (Reservoir based/barrage based/lift irrigation) located in different regions may require quantification of few or all or some additional indicators and processes)

Key points in implementation of benchmarking of irrigation projects

- Indicators should be selected in such a way that they are easy to estimate/measure with available infrastructure and facilities

- Collection of data is an important activity in implementation of benchmarking. Schedules for data collection/recording should be as simple as possible so that the personnel engaged/employed do not face problems in data collection

  It is essential to tell them that the data collected by them will be used for a very important analysis and any error may result in unrealistic assessment

Steps in implementation of benchmarking

Collection of basic information about the irrigation project

- ✓ The basic detail of the irrigation project for which benchmarking is to done should be collected to get insight identifies the performance indicators. INCID (2002) has prepared detail guidelines for benchmarking of Irrigation Systems in India

- ✓ The basic information collected under this are presented in detail in Table 2 and Appendix A1 of the guidelines for benchmarking of irrigation systems in India prepared by Indian National Committee on Irrigation and Drainage prepared by INCID (2002).

Selection of best system

Benchmarking is process of measuring one's own performances and practices against the best one. Hence selection of the best performing irrigation system is very important

Data collection, processing and analysis

Data Collection

Benchmarking requires several types of primary and secondary data for estimation of performance indicators. Data collection is a very important activity in benchmarking. It would be better to prepare a schedule for data collection. Trained manpower should be *employed for data collection. The key performance indicators are given in Annexure II.*

- **Primary data and secondary data**
  - *Some indicators are estimated from primary data such as inflows volume, revenues collected from water users and total operation expenditure*
  - *Certain indicators require estimation of other parameters like evapo-transpiration which is estimated from secondary data such as weather data which can be collected from participating organisation*

(Date required to be collected for benchmarking is given in detail in Table 3 of the guidelines for benchmarking of irrigation systems in India prepared by Indian National Committee on Irrigation and Drainage prepared by INCID (2002)

Units

Since benchmarking involves comparison of performance of irrigation projects, data should be presented in similar units as specified in Appendix A2 of the guidelines for benchmarking of irrigation systems in India prepared by Indian National Committee on Irrigation and Drainage prepared by INCID (2002)

The schedule prepared for collecting date should include

- Summary of benchmarking indicators
- Salient project Features
- System Performance
- Financial Indicators
- Agricultural Productivity
- Environmental Aspects

Analysis

- In benchmarking, data analysis involves estimation of ratios produce the value of the required performance indicator
- Participating organizations might have collected data in different format
- These should be arranged in the manner outlined in Appendix A2 of the guidelines for benchmarking of irrigation systems in India prepared by Indian National Committee on Irrigation and Drainage prepared by INCID (2002)
- Before analysis it necessary to do the auditing of collected data to remove anomalies.

Programme implementation

- After collection of data performance indicators are estimated as per the benchmarking guidelines of by Indian National Committee on Irrigation and Drainage prepared by INCID (2002)

- Periodic reviews should be done so that the programme remains flexible and relevant to the benchmarking partners. If required new performance indicators may be included to ensure that emerging issues and processes are taken care off.

Guidelines for Benchmarking of Irrigation Systems in India (Table 2)
Indian National Committee on Irrigation and drainage, New Delhi (2002)

Salient features of the Project/system/sub-system*

Code	Item	Possible options
Location		
D1	State	-
D2	District	
D3	Name of the Project/Scheme	-
D4	Name of System/Sub-system	
D5	River/Basin/Sub-Basin	
D6	Latitude/Longitude	
Climate and Soils		
D7	Climate	Arid Semi-arid Humid Humid tropics
D8	Average annual rainfall (mm)	-
D9	Average annual reference crop potential evapotranspiration, Etc (mm)	-
D10	Peak daily reference crop potential evapotranspiration, (Etc (mm/day)	
D11	Predominant soil type(s) and percentage of total area of each type	Clay Clay loam Loam Silty clay loam Sand
Institutional		
D12	Year first operational	
D13	Type of management	Government agency Water Users Association/ Federation of WUAs

* Considering that the records connected with works, personnel employed etc. are maintained at the level of an Irrigation Section, the System/Sub-System adopted should be at least at the jurisdictional level of a Section.

Guidelines for Benchmarking of Irrigation Systems in India (Table 2)
Indian National Committee on Irrigation and drainage, New Delhi (2002)

Code	Item	Possible options
D14	Agency functions (to indicate the extent the Agency controls the system/sub-system)	Irrigation and drainage service Water resources management Reservoir management Flood control Domestic water supply Fisheries Others
D15	Type of revenue collection	Tax on irrigated area Charge on crop type and area Charge on volume of water delivered-charge per irrigation Charge based on number of waterings per season
D16	Agency entrusted with Revenue Collection	Irrigation Department Revenue Department WUA Others
D17	Land ownership	Government Private
Socio-economic		
D18	Gross Domestic Product (GDP)	
D19	Farming system	Cash crop Food grains crop Mixed cash/Food grains crop
D20	Marketing	Government marketing board Private traders Local market Regional/national market
D21	Pricing	Government controlled prices Local market prices
Water source and availability		
D22	Water source	Storage on river Run-of-the river including barrage/anicut Groundwater Conjunctive use of surface and groundwater
D23	Water availability	Abundant Sufficient Water scarcity

Guidelines for Benchmarking of Irrigation Systems in India (Table 2)
Indian National Committee on Irrigation and drainage, New Delhi (2002)

Code	Item	Possible options
D24	Number and duration of irrigation season(s)	Number of seasons Number of months per season: Season 1: Season 2: Season 3:
Size		
D25	Commanded (irrigation) area (ha)	-
D26	Total number of water users supplied	-
D27	Average farm size (ha)	-
D28	Average annual irrigated area (ha) Out of the above by Surface water (ha) Ground water (ha) In case of conjunctive use, please give weightage for the waterings from each source.	-
D29	Average annual cropping intensity (%)	-
Infrastructure – Irrigation		
D30	Method of water abstraction	Gravity diversion Pumped diversion Groundwater
D31	Water delivery infrastructure (length and %)	Lined channel Unlined Pipelines
D32	Location and type of water control equipment	Control structure at intake of the system/sub-system Type: None Fixed proportional division Gated – manual operation Gated – automatic local control
D33	Discharge measurement facilities, location and type	Location: None Type: Flow meter Fixed weir or flume Calibrated sections Calibrated gates

Guidelines for Benchmarking of Irrigation Systems in India (Table 2)
Indian National Committee on Irrigation and drainage, New Delhi (2002)

Table 2
Main Performance indicators for Benchmarking

Domain	**Performance indicator**
I. System Performance	1. Water delivery capacity Index 2. Total annual volume of irrigation water supplied/delivered (m^3/year) 3. Field application efficiency 4. Annual Relative Irrigation Supply Index 5. Annual irrigation water supply per unit command area (Cum/ha) 6. Annual irrigation water supply per unit irrigated area (Cum/ha)
II. Agricultural Productivity	7. Output per unit command area (Rs/ha) 8. Output per unit irrigated area – Tons/ha cropwise, Rs/ha 9. Output per unit irrigation supply (Rs/cum) 10. Output per unit crop water demand (Rs/cum)
III. Financial Aspects	11. Cost recovery ratio 12. Total O&M cost per unit area (Rs/ha) 13. Total cost per person employed on O&M works (Rs/person) 14. Revenue collection performance 15. Revenue per unit volume of irrigation water supplied (Rs/cum) 16. Maintenance cost to revenue ratio 17. Staff numbers for O&M per unit area (persons/ha) 18. Total O&M cost per unit of water supplied (Rs./cum)
IV. *Environmental Aspects*	19. (a) Average depth to watertable (m) 19. (b) Land Damage Index (a) Water quality: Ph/Salinity/Alkalinity Index 20. (b) Salt balance (tones)

Guidelines for Benchmarking of Irrigation Systems in India (Table 3)
Indian National Committee on Irrigation and drainage, New Delhi (2002)

Table 3
Data requirements pertaining to the system/sub-system

1. Current canal capacity of the system/sub-system at the diversion point
2. Designed Peak irrigation water demand for a month/fortnight
3. Total daily measured water at the intake of the system/sub-system
4. Total daily measured water delivery to the field head
5. Total daily measured water used by evapo-transpiration (for different crops if available)
6. Total daily measured rainfall over irrigated area
7. Total command area serviced by the irrigation system/sub-system
8. Total annual irrigated crop area
9. Total annual tonnage of each crop
10. Market price/Minimum Support Price (MSP) for the crops
11. Total volume of water consumed by the crops (Etc). For rice crop, percolation losses need to be included
12. Total revenue collected from water users
13. Total management, operation and maintenance (MOM) cost excluding capital expenditure and depreciation/renewals
14. Total cost of MOM personnel
15. Total number of MOM personnel employed
16. Total revenue due during the year
17. Periodic measurements of depth to water table
18. Waterlogged area in the command area after introduction of irrigation
19. Salinity/alkalinity affected area in the command area after introduction of irrigation
20. Electrical conductivity of periodically collected irrigation water samples in mmhos/cum
21. Electrical conductivity of periodically collected drainage water samples in mmhos/cum
22. Total daily measured drainage water outflow from the irrigation system
23. Periodic measurement of salt content of irrigation water
24. Periodic measurement of salt content of drainage water

THANK YOU

Plan wise expenditure incurred on Irrigation and Flood Control Sectors

(Rs in Crores)

Sl. No	Plan Period	Major & Medium Irrigation	MI/MI & CAD	Total Irrigation	Flood Control	Total Plan Expenditure All Sectors	Percentage expenditure on Irrigation
1.	First (1951-56)	376.2	65.6	441.8	13.2	1960	22.54
2.	Second (1956-61)	380.0	161.6	541.6	48.1	4672	11.59
3.	Third (1961-66)	576.0	443.1	1019.1	82.1	8577	11.89
4.	Annual (1966-69)	429.8	560.9	990.7	42	6625	15.04
5.	Fourth (1969-74)	1242.3	1173.4	2415.7	162	15779	15.31
6.	Fifth(1974-78	2516.2	1409.6	3925.8	298.6	28653	14.22
7.	Annual (1978-80)	2078.6	1344.9	3423.5	330	22950	14.27
8.	Sixth (1980-85)	7368.8	4159.9	11528.7	787	109292	10.55
9.	Seventh (1985-90)	11107.3	7626.8	18734.1	941.6	218730	8.56
10.	Annual (1990-92)	5459.2	3649.5	9108.7	460.6	123120	7.4
11.	Eighth (1992-97)	21071.9	13885.3	34957.2	1691.7	483060	7.59
12.	IX Plan(1997-02)	49289.0	13760	83049.0	3038	941041	6.7
13.	X Plan (2002-07)	83647.0	16458.9	100105.9	4344.18	1618460	6.19
14	XI Plan (2007-2012) Outlay (Projection)	165350	46350	211700	20100	3644718	5.81

Source: Report of the Working Group On Major & Medium Irrigation And Command Area Development For the XII Five Year Plan (2012-2017), Government of India Ministry Of Water Resources (2011)

Irrigation system performance

Conveyance efficiency

$$E_c = (V_f / V_t) \times 100$$

Application efficiency

$$E_a = (V_s / V_f) \times 100$$

Storage efficiency

$$E_s = [V_s / (V_{fc} - V_a)] \times 100$$

Where

V_f = Volume of irrigation water that reaches the farm or field

V_t = Volume of irrigation of water diverted from the water source

V_s = Volume of irrigation water stored in the root zone

V_{fc} = Volume capacity at field capacity in the crop root zone

V_a = Volume of water in the root zone prior to an irrigation event

Overall irrigation efficiency

$$E_o = (E_c \times E_a \times E_s) \times 100$$

Effective irrigation efficiency

$$E_e = [E_o + (FR) \times (1 - E_a)] \times 100$$

Where

FR = fraction of surface runoff , seepage, and deep percolation that is recovered

Uniformity of water application

Christiansen's Uniformity Coefficient (Sprinkler irrigation Systems)

$$Cu = [1- (\Sigma|X_1 – X_M|) / \Sigma X_1] \times 100$$

Emission uniformity (Micro irrigation System)

$$E_U = [1- 1.27 (C_{vm})] n^{-1/2} (q_{min}/q_{avg}) \times 100$$

Where

X_1 = measured depth water in equally spaced catch cans on a grid arrangement

X_M = mean depth of water of the catch in all cans

C_{vm} = manufacturer's coefficient of uniformity

n = number of emitters per plant

q_{min} = minimum discharge rate at minimum system pressure

q_{avg} = average emitter dicharge rate

Crop response to irrigation

Crop water Use Efficiency

$$CWUE = Y_g / ET$$

Transpiration Efficiency = Biomass/ Grain yield / Water transpired

Harvest index: grain yield/above ground biomass

Irrigation water use efficiency

$$IWUE = Y_g / IR$$

Where

Y_g = Economic yield

ET = crop water use

IR = irrigation water applied

Reasons for poor irrigation efficiency

- Non-stop flow of water to the field when the amount of water needed has been delivered
- Absence of volumetric supply of water from the water source to the field
- Non measurable soil moisture level at the time of irrigation

- Improper field levelling which cause poor water distribution across the field
- Excessive slopes which cause high runoff losses
- Application of water not based on intake characteristics of the soil

Improving irrigation efficiency

- **Modernization of Irrigation Projects**
- **Promotion of Efficient Irrigation Practices**
- **Promotion of Micro-Irrigation Systems**

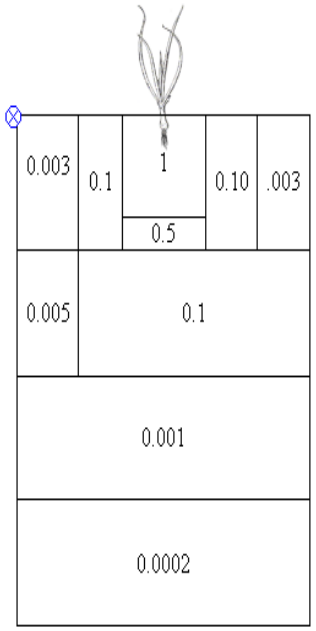
Improving irrigation efficiency

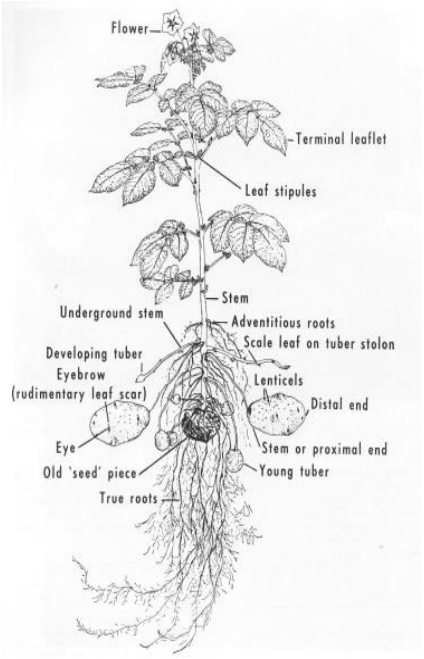
- **Crop Diversification**
- **Deficit Irrigation**
- **Conjunctive Use of Surface and Ground Water**

Key to Efficient On Farm Water Management

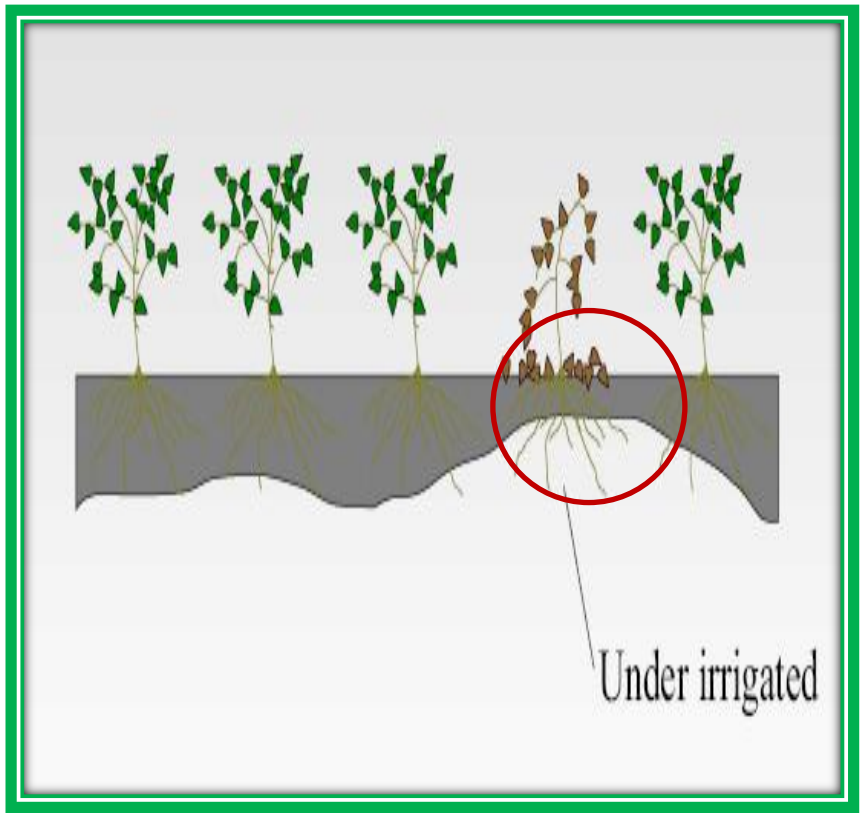
Maintaining adequate moisture in the active root zone (not more not less approach) to

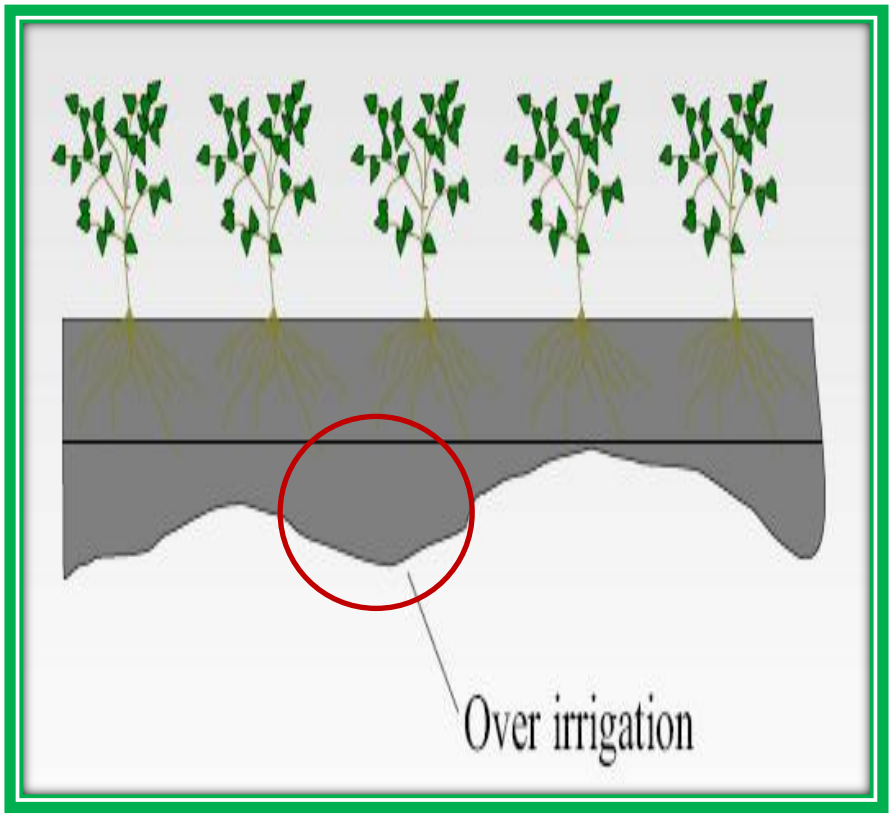
- **Facilitate adequate water and nutrient supply**
- **Avoid water loss**
- **Maximize the production per unit water used**





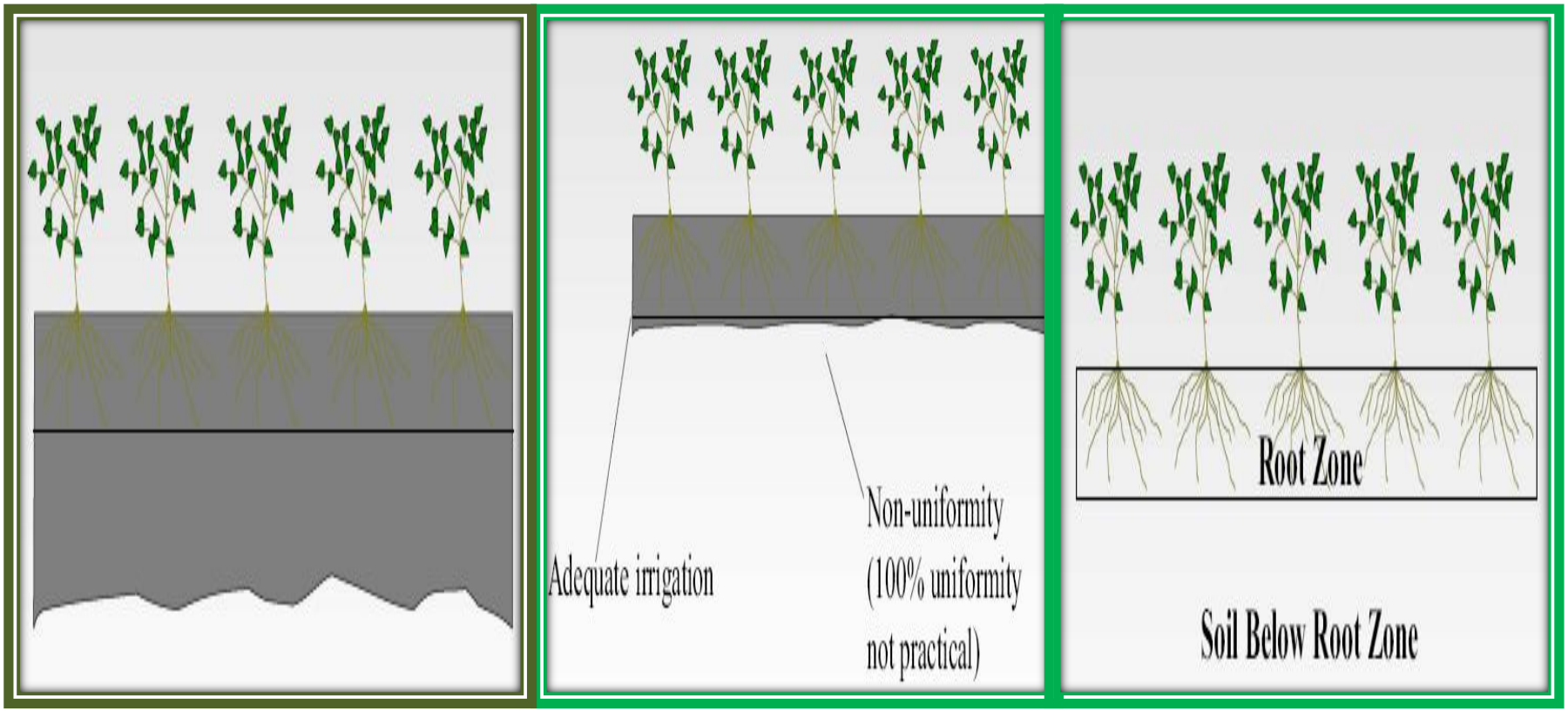
Non-uniformity of water application in the field





Non-uniform and inefficient

Uniformity of water application in the field



Uniform and inefficient

Uniform and efficient

Benchmarking of Irrigation Project: Potential