

WORK PACKAGE 5: INTERVENTION ANALYSIS

Intervention Analysis of the IGB Basin Focal Project



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Tasks and Schedule

- **Develop an inventory of the potential interventions (5 months)**
- **Conduct intervention analysis on potential interventions (7 months)**

Identification of WP Interventions

Resource Conservation Techniques (RCT)	Water and Watershed Management	Farming System	Multiple Use Water Scheme (MUS)	Climate Change and Environmental Flow	Institutional Interventions	Land Use
Mulching	Canal lining	Precision farming	Agri-aquaculture	Climate change	Subsidy	Urbanization
Land Levelling	Water harvesting structures	Organic farming	Hydroponic horticulture	Water use pattern	Loan waivers	Special economic zones (SEZ)
Surface Seeding	Pressurized irrigation system	Hybrid seeds	Reuse of urban effluent	Environmental flow requirement	Support price	Extent of land degradation
System of Rice Intensification	Surge irrigation	Horticultural systems			Other governmental policies	
Bed Planting	Irrigation scheduling	Crop diversification				
Zero Tillage	Deficit irrigation	Livestock system				
Reduced Tillage	Rain-water harvesting					
	Groundwater recharge methods					

Intervention Matrix

A. Location

Latitude/Longitude
State
District
Block
Others

B. Coverage

Area covered
No of farmers benefited
No of Villages benefited
Total irrigated area
Total reclaimed area
Others

C. Method Used

D. Primary Purpose

E. Financial Aspects

Cost of project
Economic benefit accrued
Funding source
Others

F. Stake-holder Linkages

Implementing agency
Involvement of local governance
Primary beneficiary
Maintenance responsibility
NGO/SHG/UG
Others

Intervention Matrix (contd...)

G. Specific Impact

i. Agricultural impact

Yield increase
 Quantity of water used (irrigation + rainfall)
 Cropping intensity
 Diversification (new crop)
 Herbicide use
 Improvement in nutrient use efficiency
 Weed control
 Others

ii. NR-Related impact

Available soil moisture
 Soil organic carbon content
 Groundwater recharge & quality
 Surface water replenishment & quality
 Impact on water use
 Soil temperature
 Pollutant load
 Sustainability

ii. NR-Related impact (contd...)

Land reclamation measures
 Others

iii. Livelihood-related impact

Food security
 Employment opportunity
 Decrease in poverty in the region
 Women drudgery
 Migration
 Impact on less-fortunate community
 Others

H. Any Other Information

I. Information Source

Literature Survey

● 70 Institutions/ Organizations

IIT Kharagpur: INTERVENTION ANALYSIS



Literature Survey

- **111 reports**

ICAR, IARI, IWMI, MoAgr, CARI, NIC, CPCB, CSSRI, IRRI, CWC, IIRS, CIFE, CPWF, GFCC, IITR, MoWR

- **289 research papers**

AWM, Agric Sys, WRM, Soil Till, Field Crop Res, etc.

- **9 PhD theses from IITKgp from 1995-08 having yield and water use data**

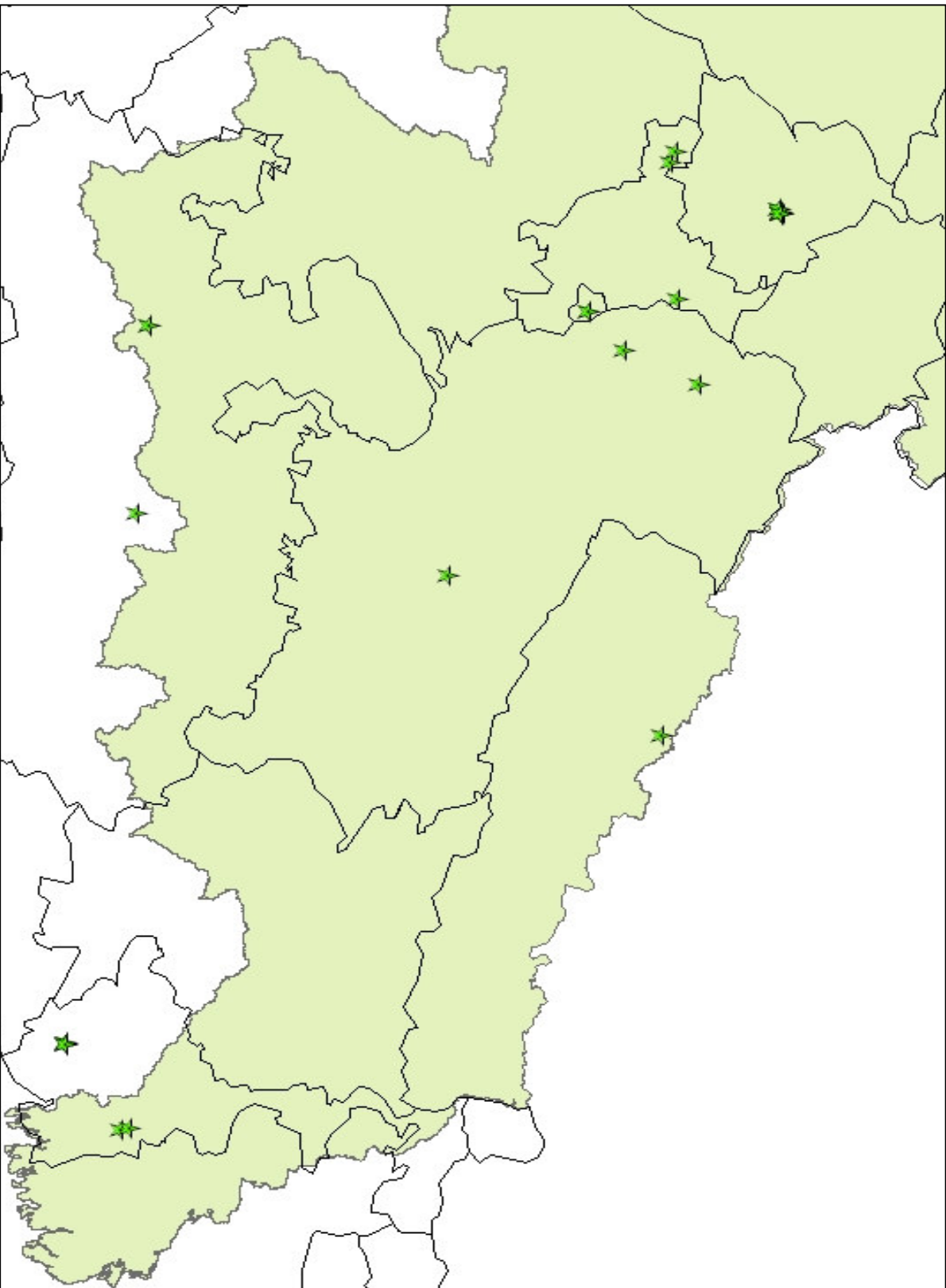
- **Book by Kijne et al. (2003)**

Water productivity in agriculture: Limits and opportunities for improvement

Literature Survey

Intervention Categories	Number of Studies
Farming Systems	23
RCTs	34
Water and Watershed Management	201
Multiple Water Use	2
Climate Change and Environmental Flow	29

Locations with WP Data



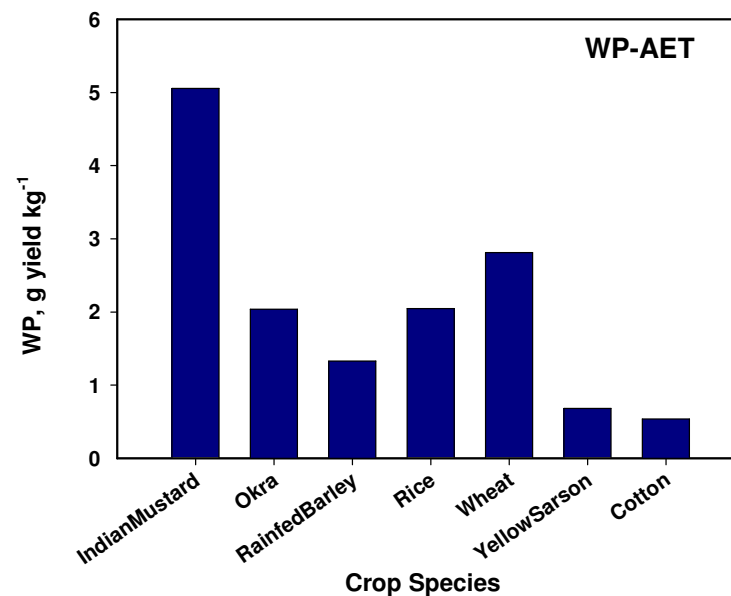
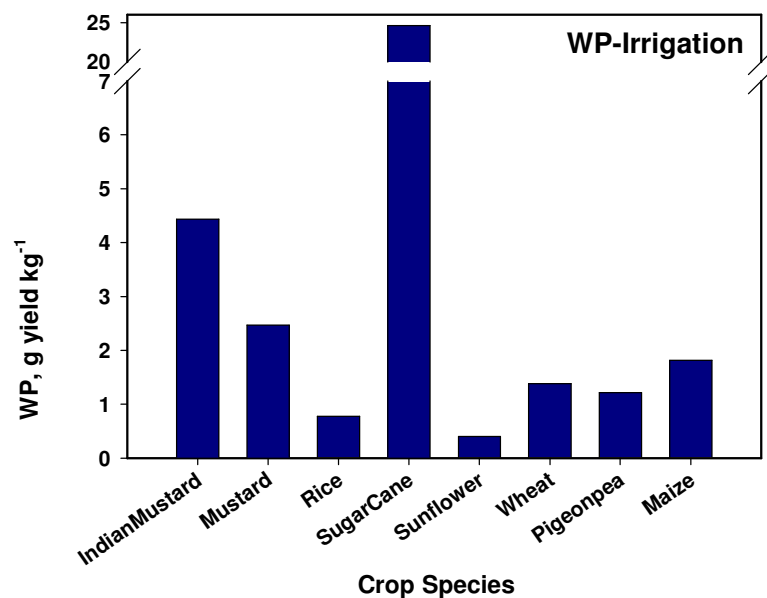
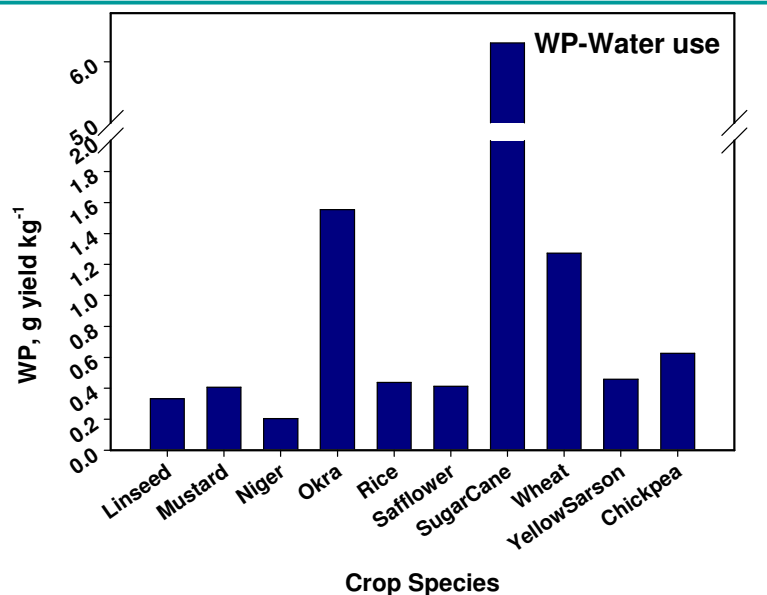
Estimated WP Values

Interventions	Crops	WP-Water use	WP-AET	WP-Irrigation
Tillage, Mulching	Yellow sarson		0.254-0.386	
Tillage, Mulching	Rainfed Barley		0.567-0.770	
Tillage, Nutrient management	Wheat			0.124-1.211
Tillage	Saflower, Niger, Mustard, Linseed, Yellow sarson	0.183-0.490		
Irrigation regime	Wheat	1.709-5.125		
Irrigation method, Irrigation scheduling	Okra		0.939-1.403	
Optimizing soil moisture regime	Sugarcane	5.23-7.74		9.17-38.13
Sizing on-farm reservoirs	Rice, Mustard			1.64-7.48
Tillage	Rice, Wheat		0.563-0.755	0.36-0.62
Irrigation and nutrient management	Indian mustard		1.756-3.422	1.79-8.01
Tillage, Mulching, Irri. regime, Soil type	Sunflower			0.24-0.68
Irrigation scheduling & method	Okra	1.32-2.09		
Irrigation regime, Tillage, Liming, N application method	Wheat	0.90-1.60		0.86-1.95
Tillage, Liming, Soil moisture regime	Rice, Wheat	0.46-1.51		

Estimated WP Values

Interventions	Crops	WP-Water use	WP-AET	WP-Irrigation
Irrigation levels, Irrigation scheduling	Rice			0.434-0.809
Tillage, Irrigation regime, Mulching, Season	Maize			0.044-6.133
Tillage, Irrigation regime, Nitrogen	Wheat			0.12-3.20
Tillage	Wheat, Rice	0.26-1.76		0.40-3.11
Raised bed, Crop Sequence	Chickpea, Linseed, Safflower	0.32-0.77		
Water productivity analysis (SWAP/SWAP-WOFOST)	Wheat, Rice, Cotton		0.22-2.23	
Cropping system, Nutrient management	Wheat, Rice, Pigeon pea			0.31-1.34
Model simulation (WTGROWS & Info Crop)	Wheat			0.67-3.80
Transplanting date, Cropping system	Rice, Wheat		0.80-1.39	0.18-0.31
Transplanting date, Variety	Rice	0.33-0.54		0.42-0.78
Variable Puddling intensity	Rice	0.32-0.43	0.95-1.05	
Puddling intensity, Irrigation regime	Rice	0.31-0.41		
Puddling intensity, Irrigation regime	Rice	0.21-0.55		
Drip Irrigation, Mulching	Okra	1.27-3.43		

Crop-wise Mean WP Indicators



- Develop an inventory of the potential interventions (5 months)
- **Conduct intervention analysis on potential interventions (7 months)**

The Analytic Hierarchy Process

- Decision Support Tool developed by Thomas L. Saaty
- A methodology for modeling problems in the economic, social and management sciences.
- A problem solving framework used for:
 - Determining the best of several alternatives
 - Setting Priorities
 - Allocating Resources
- Requires a “pair-wise” determination of the relative importance of each criteria.

➤ Saaty, Thomas L.: “The Analytic Hierarchy Process”, McGraw-Hill, Inc., New York, 1980.

The Process

- Break down an unstructured situation into its component parts.
- Arrange the parts or variables into a hierarchic order.
- Assign numerical values to subjective judgments on the relative importance of each variable.
- Synthesize the judgments to determine which variables have the highest priority and should be acted upon to influence the outcome of the situation.

Weight Assignment

AHP scale value meaning (Saaty, 1980; Laskar, 2003)

Scale Value	Meaning
1	Equal importance
3	Moderate Importance one over another
5	Essential or strong important
7	Very strong importance
9	Extreme importance
2, 4, 6, 8	Intermediate values between the two adjacent judgments
Reciprocals	For inverse judgment

Intervention Ranking Using Analytical Hierarchy Process (AHP)

- **Questionnaire Development:** Multiple interventions selected
- **Ranking by Experts:** Experts ranked interventions on a 10-point scale
- **Weight Assignments:** Assigned ranks converted to weights by reversing order, i.e., rank 1 reordered as weight 10, rank 2 reordered as weight 9 and so on....

Questionnaire on Intervention Analysis

Crop species	Interventions	Rank
		Rank (1-10)
Rice	Zero Tillage	
	Direct seeded Rice on raised bed	
	Transplanted Rice on raised bed (Bed planted system)	
	Direct Seeded Rice on flat bed	
	Crop diversification with legume-Extra Short Duration Pigeonpea with Furrow Irrigated Raised Bed planting technique	
	Crop diversification with legume-Chickpea with Furrow Irrigated Raised Bed planting technique in sequence and inter cropping	
	Irrigation scheduling and regime	
	Selection of short duration (early transplanting) and photoperiod sensitive (delayed transplanting) cultivars	
	Cultivars for Direct Seeded Rice	
	Co-cultured Sesbania with Direct seeded rice on raised beds	

Questionnaire

		Rank (1-10)
Wheat	Zero Tillage	
	Double no-Till practices	
	Crop diversification with legume-Extra Short Duration Pigeonpea with Furrow Irrigated Raised Bed planting technique	
	Crop diversification with Sugarcane	
	Conservation Tillage with raised bed	
	Direct seeding with raised bed	
	Timeliness in planting operation- Planting by 3rd week of Nov.	
	100% NP + FYM/Gypsum/Sulphitation pressmud	
	Irrigation scheduling and regime	
	Liming and Band placement of fertilizer N	

Questionnaire

		Rank (1-10)
Maize	Permanent raised bed planting system	
	No-Till flat bed system	
	Double no-Till practices	
	Zero Tillage - Direct seeding	
	Deep Tillage	
	Hybrid seeds	
	Crop diversification- Maize-Rice in Furrow Irrigated Raised Bed / Maize-Wheat	
	Irrigation scheduling and regime	
	Timeliness in planting operation- Planting by 2nd week of Nov.	
	Crop diversification- Inter cropping (Maize-Potato on raised bed)	

Questionnaire

		Rank (1-10)
Sugarcane	Trash mulching	
	Furrow Planting	
	Crop Diversification-Sugarcane on Furrow +Wheat/Chickpea on Raised bed planting	
	Crop Diversification-Rice-Wheat-Sugarcane-Ratoon-Wheat-Greengram/Blackgram	
	Crop Diversification-Rice-Autumncane+Wheat/-Ratoon-Greengram/Blackgram/Cowpea	
	Irrigation scheduling and Alternate or skip furrow method	
	Optimizing Soil moisture regime	
	Urea and K spray in 15 days interval to the standing crop	
	Furrow Irrigation	
	Timeliness in planting operation	

Questionnaire

		Rank (1-10)
Pulses	Zero Tillage	
	Laser leveling	
	Multi-Crop Zero-Till-Drill cum Bed planting	
	Crop Diversification-Chickpea and lentil in rotation with wheat	
	Crop Diversification-Short duration Mung bean as summer crop	
	Crop Diversification-Soyabean as rainy season crop	
	Crop Diversification-Chickpea after Soybean on raised bed	
	Crop Diversification-Pigeon pea in rotation with Rice	
	Crop Diversification-Extra Short Duration Pigeonpea + Rice/Wheat with Furrow Irrigated Raised Bed planting technique	
	Irrigation Scheduling	

Questionnaire

		Rank (1-10)
Oilseeds	Zero Tillage	
	Laser leveling	
	Deep Tillage	
	Raised bed planting system	
	Mulching	
	Furrow Irrigation	
	Selection of suitable cultivars and Hybrid seeds	
	Crop Diversification-Crop rotation-Mustard-Rice	
	Crop Diversification-Intercropping- Indian mustard+Sugarcane	
	Sulphur application	

Questionnaire

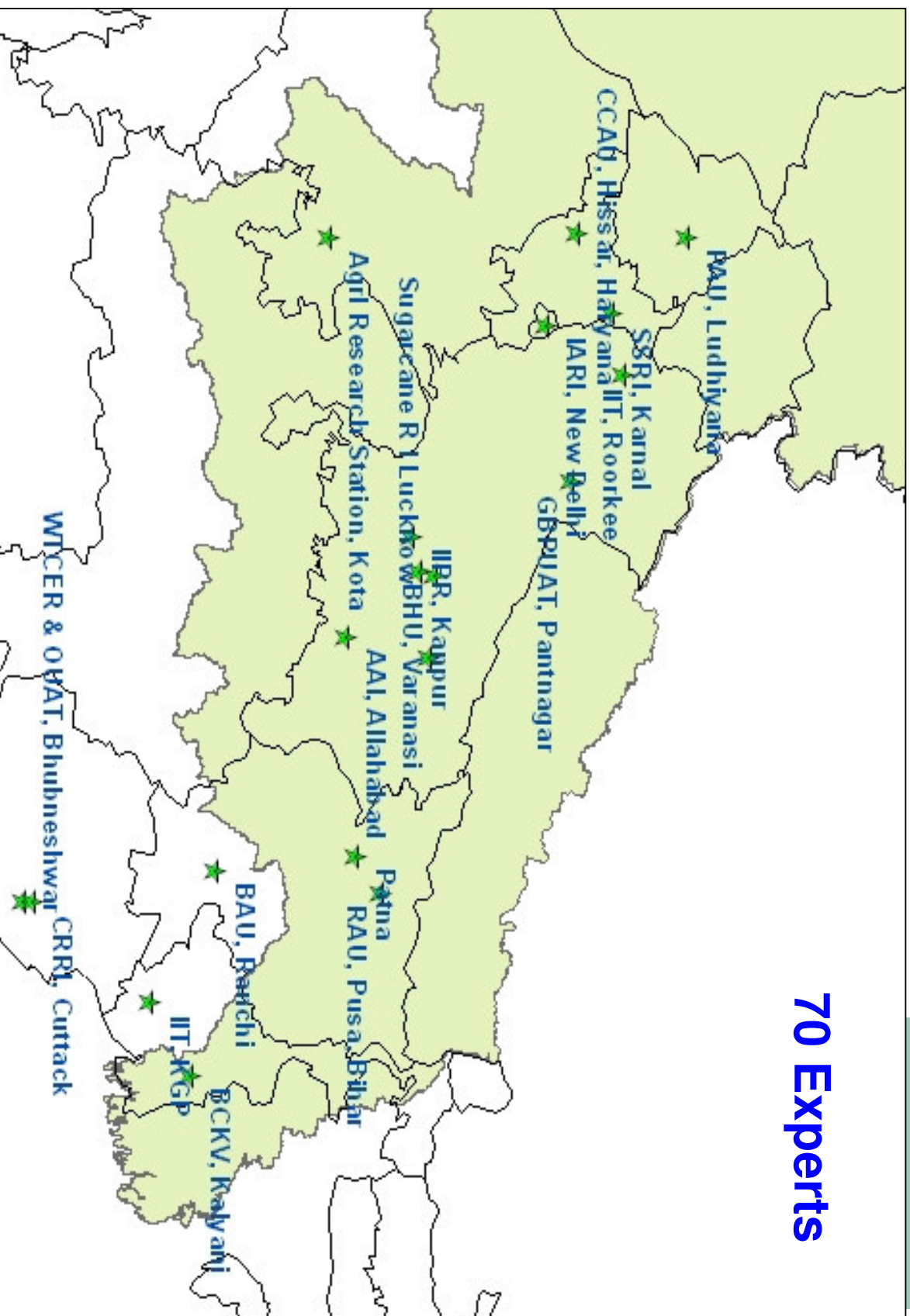
		Rank (1-10)
Potato	Crop Diversification-Crop rotation-Rice-Potato-Rice	
	Crop Diversification-Crop rotation-Jute-Potato-Rice	
	Crop Diversification-Crop rotation-Rice-Winter maize-Potato	
	Crop Diversification-Crop rotation-Potato-Black gram/ Mung bean	
	Irrigation Scheduling	
	Basal application of FYM	
	Integrated pest management	
	Integrated nutrient management	
	Planting method	
	Quality seed	

Questionnaire

		Rank (1-10)
Tomato	Laser leveling	
	Irrigation Scheduling	
	Basal application of FYM and N fertilization	
	Integrated pest management	
	Integrated nutrient management	
	Planting method	
	Quality seed	
	Plastic mulch	
	Raised bed planting system	
	Timeliness in planting operation	

Expert Locations

70 Experts



Sample Expert Opinion (1)

Weights assigned by expert to different intervention for Rice crop

Intervention	Weight
Zero Tillage (ZT)	1
Direct seeded Rice on raised bed (DSR)	5
Transplanted Rice on raised bed (Bed planted system) (TR)	9
Direct Seeded Rice on flat bed (DSF)	6
Crop diversification with legume-Extra Short Duration Pigeonpea with Furrow Irrigated Raised Bed planting technique (CLP)	7
Crop diversification with legume-Chickpea with Furrow Irrigated Raised Bed planting technique in sequence and inter cropping (CLC)	8
Irrigation scheduling and regime (ISR)	10
Selection of short duration (early transplanting) and photoperiod sensitive (delayed transplanting) cultivars (SD)	4
Cultivars for Direct Seeded Rice (CDSR)	3
Co-cultured Sesbania with Direct seeded rice on raised beds (CCS)	2

Saaty's Analytical Hierarchy Process

Pair-wise comparison matrix for Ten intervention practices of Rice

	ZT	DSR	TR	DSF	CLP	CLC	ISR	SD	CDSR	CCS
ZT	1/1	1/5	1/9	1/6	1/7	1/8	1/10	1/4	1/3	1/2
DSR	5/1	5/5	5/9	5/6	5/7	5/8	5/10	5/4	5/3	5/2
TR	9/1	9/5	9/9	9/6	9/7	9/8	9/10	9/4	9/3	9/2
DSF	6/1	6/5	6/9	6/6	6/7	6/8	6/10	6/4	6/3	6/2
CLP	7/1	7/5	7/9	7/6	7/7	7/8	7/10	7/4	7/3	7/2
CLC	8/1	8/5	8/9	8/6	8/7	8/8	8/10	8/4	8/3	8/2
ISR	10/1	10/5	10/9	10/6	10/7	10/8	10/10	10/4	10/3	10/2
SD	4/1	4/5	4/9	4/6	4/7	4/8	4/10	4/4	4/3	4/2
CDSR	3/1	3/5	3/9	3/6	3/7	3/8	3/10	3/4	3/3	3/2
CCS	2/1	2/5	2/9	2/6	2/7	2/8	2/10	2/4	2/3	2/2

Solving Pairwise Comparison Matrix by Eigenvector Method

Normalized weights of intervention obtained from Eigenvector method

	ZT	DSR	TR	DSF	CLP	CLC	ISR	SD	CDSR	CCS	Eigen vector	Norm. wt
ZT	1.00	0.20	0.11	0.17	0.14	0.13	0.10	0.25	0.33	0.50	0.10	0.02
DSR	5.00	1.00	0.56	0.83	0.71	0.63	0.50	1.25	1.67	2.50	0.50	0.09
TR	9.00	1.80	1.00	1.50	1.29	1.13	0.90	2.25	3.00	4.50	0.90	0.16
DSF	6.00	1.20	0.67	1.00	0.86	0.75	0.60	1.50	2.00	3.00	0.60	0.11
CLP	7.00	1.40	0.78	1.17	1.00	0.88	0.70	1.75	2.33	3.50	0.70	0.13
CLC	8.00	1.60	0.89	1.33	1.14	1.00	0.80	2.00	2.67	4.00	0.80	0.15
ISR	10.0	2.00	1.11	1.67	1.43	1.25	1.00	2.50	3.33	5.00	1.00	0.18
SD	4.00	0.80	0.44	0.67	0.57	0.50	0.40	1.00	1.33	2.00	0.40	0.07
CDSR	3.00	0.60	0.33	0.50	0.43	0.38	0.30	0.75	1.00	1.50	0.30	0.05
CCS	2.00	0.40	0.22	0.33	0.29	0.25	0.20	0.50	0.67	1.00	0.20	0.04
	Column Total											1.00

Principle Eigenvalue $\lambda_{\max} = 10.0492$ and CR Ratio = 0.00367

Sample Expert Opinion (2)

Weights assigned by expert to different intervention for Rice crop

Intervention	Weight
Zero Tillage (ZT)	1
Direct seeded Rice on raised bed (DSR)	9
Transplanted Rice on raised bed (Bed planted system) (TR)	10
Direct Seeded Rice on flat bed (DSF)	8
Crop diversification with legume-Extra Short Duration Pigeonpea with Furrow Irrigated Raised Bed planting technique (CLP)	4
Crop diversification with legume-Chickpea with Furrow Irrigated Raised Bed planting technique in sequence and inter cropping (CLC)	5
Irrigation scheduling and regime (ISR)	6
Selection of short duration (early transplanting) and photoperiod sensitive (delayed transplanting) cultivars (SD)	3
Cultivars for Direct Seeded Rice (CDSR)	7
Co-cultured Sesbania with Direct seeded rice on raised beds (CCS)	2

Saaty's Analytical Hierarchy Process

Pair-wise comparison matrix for Ten intervention practices of Rice

	ZT	DSR	TR	DSF	CLP	CLC	ISR	SD	CDSR	CCS
ZT	1/1	1/9	1/10	1/8	1/4	1/5	1/6	1/3	1/7	1/5
DSR	9/1	9/9	9/10	9/8	9/4	9/5	9/6	9/3	9/7	9/2
TR	10/1	10/9	10/10	10/8	10/4	10/5	10/6	10/3	10/7	10/2
DSF	8/1	8/9	8/10	8/8	8/4	8/5	8/6	8/3	8/7	8/2
CLP	4/1	4/9	4/10	4/8	4/4	4/5	4/6	4/3	4/7	4/2
CLC	5/1	5/9	5/10	5/8	5/4	5/5	5/6	5/3	5/7	5/2
ISR	6/1	6/9	6/10	6/8	6/4	6/5	6/6	6/3	6/7	6/2
SD	3/1	3/9	3/10	3/8	3/4	3/5	3/6	3/3	3/7	3/2
CDSR	7/1	7/9	7/10	7/8	7/4	7/5	7/6	7/3	7/7	7/2
CCS	2/1	2/9	2/10	2/8	2/4	2/5	2/6	2/3	2/7	2/2

Solving Pairwise Comparison Matrix by Eigenvector Method

Normalized weights of intervention obtained from Eigenvector method												
	ZT	DSR	TR	DSF	CLP	CLC	ISR	SD	CDSR	CCS	Eigen vector	Norm. wt
ZT	1.00	0.11	0.10	0.13	0.25	0.20	0.17	0.33	0.14	0.50	0.10	0.02
DSR	9.00	1.00	0.90	1.13	2.25	1.80	1.50	3.00	1.29	4.50	0.90	0.16
TR	10.0	1.11	1.00	1.25	2.50	2.00	1.67	3.33	1.43	5.00	1.00	0.18
DSF	8.00	0.89	0.80	1.00	2.00	1.60	1.33	2.67	1.14	4.00	0.80	0.15
CLP	4.00	0.44	0.40	0.50	1.00	0.80	0.67	1.33	0.57	2.00	0.44	0.07
CLC	5.00	0.56	0.50	0.63	1.25	1.00	0.83	1.67	0.71	2.50	0.50	0.09
ISR	6.00	0.67	0.60	0.75	1.50	1.20	1.00	2.00	0.86	3.00	0.62	0.11
SD	3.00	0.33	0.30	0.38	0.75	0.60	0.50	1.00	0.43	1.50	0.30	0.05
CDSR	7.00	0.78	0.70	0.88	1.75	1.40	1.17	2.33	1.00	3.50	0.70	0.13
CCS	2.00	0.22	0.20	0.25	0.50	0.40	0.33	0.67	0.29	1.00	0.20	0.04
	Column Total											1.00

Principal Eigenvalue $\lambda_{\max} = 10.0497$

Estimation of Consistency Ratio

- Consistency ratio was estimated to find out the bias and inconsistency of decision maker.
- Saaty (1980) suggested that if consistency ratio (CR) > 0.10 then weight should be re-evaluated.
- Steps followed to estimate consistency ratio:
 1. Calculate maximum Eigenvalue λ_{\max} by solving pair-wise comparison matrix.
 2. Calculate Consistency Index by using following formula

$$\text{Consistency Index (CI)} = \frac{\lambda_{\max} - n}{n - 1}$$

n is the number of factors

Estimation of Consistency Ratio

3. Calculate Consistency Ratio by using following formula:

$$\text{Consistency Ratio (CR)} = \frac{\text{Consistency Index (CI)}}{\text{Random Consistency Index (RI)}}$$

Random Consistency Index values (Saaty, 1980)										
n	1	2	3	4	5	6	7	8	9	10
Random Index	0	0	0.58	0.90	1.11	1.24	1.32	1.40	1.45	1.49

Consistency Ratio

Number of factors, $n = 10$,

$$\lambda_{\max} = 10.0497$$

Random Consistency Index, $RI = 1.49$

$$\text{Consistency Index (CI)} = \frac{10.0497 - 10}{10 - 1} = 0.0055$$

$$\text{Consistency Ratio (CR)} = \frac{0.0055}{1.49} = 0.0037 < 0.10$$

So, Weights assigned are consistent

Highest-Ranked Interventions for Different Crops

<u>Crop</u>	<u>Intervention</u>
Rice	Irrigation scheduling and water regime
Wheat	Irrigation scheduling and water regime
Maize	Hybrid seeds
Sugarcane	Irrigation scheduling and Alternate or skip furrow method
Pulses	Crop Diversification-Short duration Mung bean as summer crop
Oilseeds	Selection of suitable cultivars and Hybrid seeds
Potato	Quality seed
Tomato	Irrigation Scheduling

Ranked Interventions for Rice

Intervention	Rank
Irrigation scheduling and regime	1
Transplanted Rice on raised bed (Bed planted system)	2
Selection of short duration (early transplanting) and photoperiod sensitive (delayed transplanting) cultivars	3
Cultivars for Direct Seeded Rice	4
Direct seeded Rice on raised bed	5
Direct Seeded Rice on flat bed	6
Crop diversification with legume-Extra Short Duration Pigeonpea with Furrow Irrigated Raised Bed planting technique	7
Crop diversification with legume-Chickpea with Furrow Irrigated Raised Bed planting technique in sequence and inter cropping	8
Co-cultured Sesbania with Direct seeded rice on raised beds	9
Zero Tillage	10

Important Interventions for Selected Crops

Crop	Intervention	Rank
Rice	Irrigation scheduling and regime	1
	Transplanted Rice on raised bed (Bed planted system)	2
	Selection of short duration (early transplanting) and photoperiod sensitive (delayed transplanting) cultivars	3
Wheat	Irrigation scheduling and regime	1
	Timeliness in sowing operation- Sowing by 3rd week of Nov.	2
	Zero Tillage	3

Important Interventions for Selected Crops (Contd...)

Crop	Intervention	Rank
Potato	Quality seed	1
	Planting method	2
	Integrated nutrient management	3
Tomato	Irrigation scheduling	1
	Quality seed	2
	Basal application of FYM and N fertilization	3

Summary

- Identified important interventions under different intervention categories
- Developed matrices for different interventions
- Estimated WP for different interventions and crops from the available data
- Identified crop-specific interventions for ranking
- Identified potential interventions using AHP on expert opinions
- Irrigation scheduling and water regime appears to be a prominent intervention for major crops.

Road Ahead

- Strengthen the Expert Opinion Survey by involving various stake holders
- Analyse the data for different agro-ecological zones
- Superimpose the analysis on WP Maps to identify potential interventions in the High WP zones.



Thanks...