Adaptation Technologies to Minimize the Impact of Climate Change on Crop Yield, Income and Water Use in Major River Basins in India



K.Palanisami

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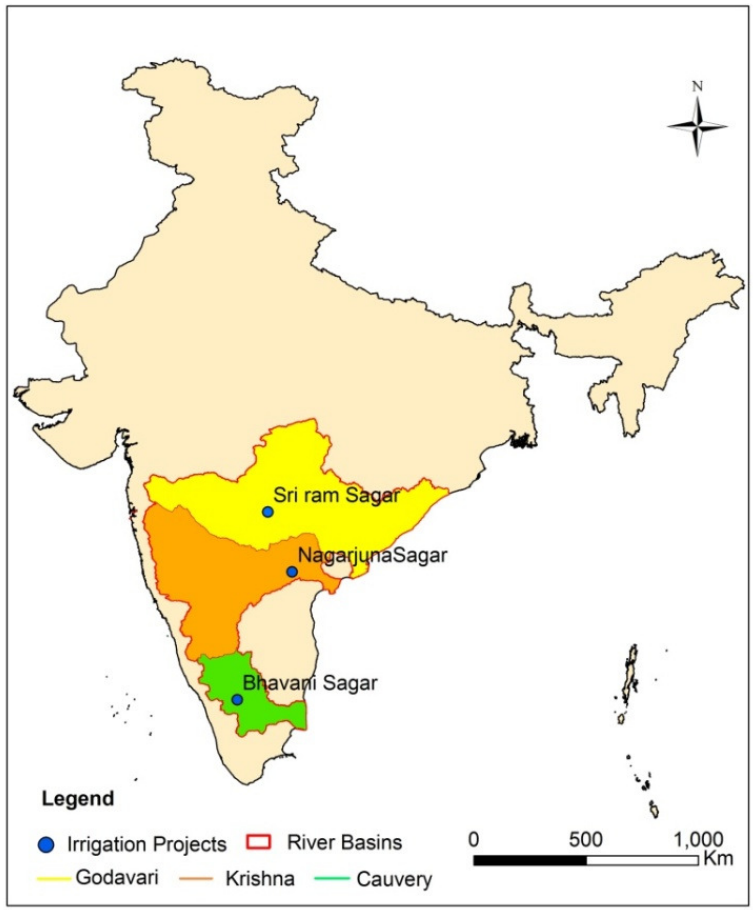
1.Background

- Agricultural sector is highly vulnerable to climate change in many parts of the world
- CC not only effects the yield but also variability (Barnwal and Kotani, 2010)
- CC is a complex subject and requires interdisciplinary approach to assess impacts and develop adaptation measures
- No clear cut procedures to characterise the human coping and adaptation mechanisms as they vary from place to place (Elisabeth et al., 2010)
- Economics of CC impacts as well as adaptation to CC through optimisation of the available resources is challenging

2.Objective

- Assess the impact of climate change on yield and yield variability
- Optimal allocation of resources viz., land, labour and water to the changing climatic conditions in major river basins of India

3.River Basins for study



- Godavari Basin (Sri Ram Sagar Project)
- Krishna River Basin (Nagarjuna Sagar Project)
- Cauvery River Basin (Lower Bhavani project)

Basin information

Particulars	Godavari	Krishna	Cauvery
No. of states covered	6	3	3
Catchment area (Km^2)	312812	258948	81155
Length (Km)	1465	1400	800
Annual rainfall (mm)	1000-3000	784	956
Average water resource potential (MCM)	110540	78120	21358
Utilizable surface water resource (MCM)	76300	58000	19000
No. of hydrological observation stations	17	53	34
No. of flood forecasting stations	77	9	0
Major crops	Paddy, wheat, maize, sugarcane, cotton	Paddy, cotton, chillie, maize, Sugarcane, groundnut, millets and horticultural crops	Paddy, sugarcane, maize, groundnut, banana, turmeric, gingelly etc

Irrigation project from Godavari, Krishna and Cauvery

Particulars	Sri Ram Sagar project	Nagarjuna Sagar project	Lower Bhavani Project
Name of the basin	Godavari	Krishna	Cauvery-sub bason
No. of districts covered	4	5	12
Catchment area (Km^2)	91751	215185	4200
Protect type	Multipurpose	Multipurpose	Multipurpose
Project Capacity (TMC)	112	408	70
Length (Km)	364.5	382	200
Command area (ha)	387456	896000	88000
Annual rainfall (mm)	878	785	730
On farm application efficiency-wet crops (%)	34.5	33.10	35
Average on farm application efficiency (%)	57.28	38.93	48
Overall project efficiency	44.66	21.8	52
Soil type	Black clay to red soils	Black clay to red chalka soils	Red loamy soils
Major crops	Paddy, maize and groundnut	Paddy, cotton, chillie, maize, groundnut and pulses	Paddy, maize, gingelly, turmeric, cholam and pulses

4.Impact of CC on agriculture

- CC has impact not only on mean yield but also on variability in yield
- Just-Pope (JP) Production function simultaneously estimates both
- JP production function has the form

$$y_{it} = f(x_{it};\beta) + \omega_{it} h(x_{it};\delta)^{0.5}$$



Optimum land and water use-MGLP

- Obj: Max production, income & min water use
- Management options (8) and scenarios (4):

M1.current management

M2.SRI

M3. SRI+MT+15% less L use in rice

M4. AWD+10% less W use in rice

M5. AWD+MT+ 10% less W & 15% less L use in rice

M6. MWM+less 10% less W use in maize

M7.AWD+MT+MWM+less 15% less W use in rice

M8.SRI+MT+MWM+less 15% less L use in rice

S1.current levels of Y,W, L

S2: Current Y, 10% Less W and 5% less L

S3:MC Y, 10% Less W and 5% less L

S4:EC Y, 10% Less W and 5% less L



- Constraints in the model
  - Area should not exceed the available crop area
  - Water required for all crops in the season-districts less than or equal to total water available
  - Crop labour use same
  - Credit requirement same as cost of cultivation
  - Assumed ratio of area under crops (rice, maize, cotton, chilly, g.nut) in the project area will continue



5. Results: Impact of CC on yield and variability in yield (Just and Pope production Function for Rice) – Godavari River basin

Mean Yield	Sri Ram Sagar Project (Godavari) - Kharif		
	Rice	Maize	Groundnut
Precipitation(R) (in mm)	7.210**	1.458***	-0.140
Temperature (T) (in °C)	2245.915**	-1684.180**	4621.546**
Trend(year)	42.436***	73.988***	20.096***
R^2	-0.001***	-0.001	0.000
T^2	-40.172	29.238***	-86.010***
R*T	-0.151	-0.005	-0.002
Adilabad/Nalgonda	-710.666	-443.900***	-237.896***
Karimnagar/Khammmam	119.036**	317.455***	-40.902
Nizamabad/Krishna	5.293	168.429	78.230
Guntur			
Constant	-31671.7	24377.590	-61385.950
Variability in Yield			
Precipitation (R)	-0.001**	-0.001	0.000
Temperature (T)	0.629**	0.133*	0.281**
Trend	0.026**	0.035**	0.029
Adilabad/Nalgonda	1.074**	0.443	0.656
Karimnagar/Khammam	0.854**	-0.136	0.347
Nizamabad/Krishna	1.922***	0.368	1.576
Guntur			
Constant	-6.100	8.376	2.566
Likelihood function	-1096.8	-1182.2	-1081.3

Nagarjuna sagar project Krishna Basin-Rice crop

	Rice -Kharif		Rice-Rabi	
Mean Yield:	**Coefficient**	**Std.Error**	**Coefficient Coefficient**	**Std.Error**
Precipitation (R)(in mm)	**7.1311**	**6.032**	**-5.7188**	**7.147**
Temperature (T)(in °C)	**517.5655*****	**225.373**	**1147.8960*****	**486.368**
Trend(year)	**38.6787*****	**3.319**	**36.7467*****	**2.938**
R^2	**-0.0011*****	**0.0004**	**-0.0004**	**0.000**
T^2	**-9.4077*****	**3.9.008**	**-28.5299*****	**9.514**
R*T	**-0.1676**	**0.209**	**0.2072**	**0.253**
Nalgonda	**-138.3995**	**107.165**	**4230.1310*****	**368.958**
Khammam	**-563.7501*****	**85.862**	**2664.9620*****	**290.266**
Krishna	**-155.2506**	**92.389**	**2055.1350*****	**209.861**
Guntur	**206.0429*****	**77.016**	**1203.9800*****	**128.111**
Constant	**-6141.2110**	**32079.720**	**-13809.6100**	**45671.940**
Variability in Yield:				
Precipitation (R)	**-0.0021****	**0.001**	**-0.0016***	**0.001**
Temperature (T)	**0.4219**	**0.286**	**-0.1711**	**0.269**
Trend	**0.0227****	**0.017**	**0.0260***	**0.015**
Nalgonda	**0.0307**	**0.569**	**1.7290**	**1.907**
Khammam	**0.2897**	**0.457**	**1.9084**	**1.459**
Krishna	**0.7685***	**0.443**	**1.7103**	**1.032**
Guntur	**-0.0555**	**0.396**	**0.5187**	**0.671**
Constant	**0.5013**	**8.318**	**14.0842**	**10.851**
Likelihood Fun.	**-1059.3**		**-1056.2**	

Lower Bhavani Project, Cauvery basin

Rice Mean Yield	Coefficient	Std. Error
Precipitation (R)(in mm)	-0.2329	0.148
Temperature (T)(in ^{o}C)	-190.3851***	46.692
Trend(year)	42.0260***	7.652
R^2	0.0003	0.001
T^2	0.7508	1.338
R*T	-0.0400*	0.023
Constant	7933.15	1559.928
Variability in Yield		
Precipitation (R)	0.0073**	0.004
Temperature (T)	2.8463**	1.442
Trend	-0.0522	0.051
Constant	-75.6846	40.853
Likelihood Fun.	-280.5	



Impact of CC on yield & variability in yield, SRSP- Godavari basin

CC Scenarios	Particulars	Rice	Maize	G.nut
	Normal Yield (kg/ha)	2,972	3922	1556
Mid-Century (MC) 1.93°C/13.6 per cent	MC-Predicted Yield (kg/ha)	2,747	3708	1254
	Loss (%)	7.6	5.5	19.4
	Standard Deviation	575	696	383
End-Century (EC) 4.03°C/17.8 per cent	EC-Predicted Yield (kg/ha)	2,065	3778	338
	Loss (%)	30.5	3.7	78.3
	Standard Deviation	1086	789	507

Impact of CC on rice yield & variability in yield, NSP-Krishna basin

Season	CC-Scenario	Particulars	Nalgonda	Khammam	Krishna	Guntur	Prakasam	Overall
Kharif		Normal Yield (kg/ha)	2883	2773	2814	3111	3139	2944
	Mid-Century 1.93°C/13.6%	MC-Predicted Yield	3068	2458	2855	3174	2980	2923
		Loss (%)	-6.4	11.4	-1.5	-2.0	5.1	0.7
		Standard Deviation	370	420	586	446	474	452
	End-Century 4.03°C/17.8%	EC-Predicted Yield	2658	1912	2335	2687	2520	2439
		Loss (%)	7.8	31.1	17.0	13.6	19.7	17.1
		Standard Deviation	558	628	879	671	715	680
Rabi		Normal Yield (kg/ha)	3074	3060	3440	3368	3346	3258
	Mid-Century 2.22°C/13.6%	MC-Predicted Yield	1837	2437	2634	2053	2159	1472
		Loss (%)	40.2	20.3	23.4	39.0	35.5	34.8
		Standard Deviation	326	269	237	174	88	201
	End-Century 4.28°C/17.8%	EC-Predicted Yield	1289	1983	2180	1483	1987	935
		Loss (%)	58.1	35.2	36.6	56.0	40.6	45.3
		Standard Deviation	434	358	317	232	117	268

Impact of CC on rice yield & Variability in yield, Lower Bhavani Project, Cauvery basin

Season	CC-Scenario	Particulars	Overall district
Kharif		Normal Yield (kg/ha)	3994
	Mid-Century 1.93°C/13.6%	MC-Predicted Yield	3469
		Loss (%)	13.2
		Standard Deviation	225
	End-Century 4.03°C/17.8%	EC-Predicted Yield	3033
		Loss (%)	24.1
		Standard Deviation	987

Technologies and adoption

Technologies	Adoption %		
	Godavari basin	Krishna basin	Cauvery basin
System of rice intensification (SRI)	6	7	11
Direct seed sowing in rice (DSR)	0	6	0
Subsurface drainage (SSD)	0	6	0
Supplemental well irrigation (WI)	8	-	30
Alternate wetting and drying (AWD)	7	8	10

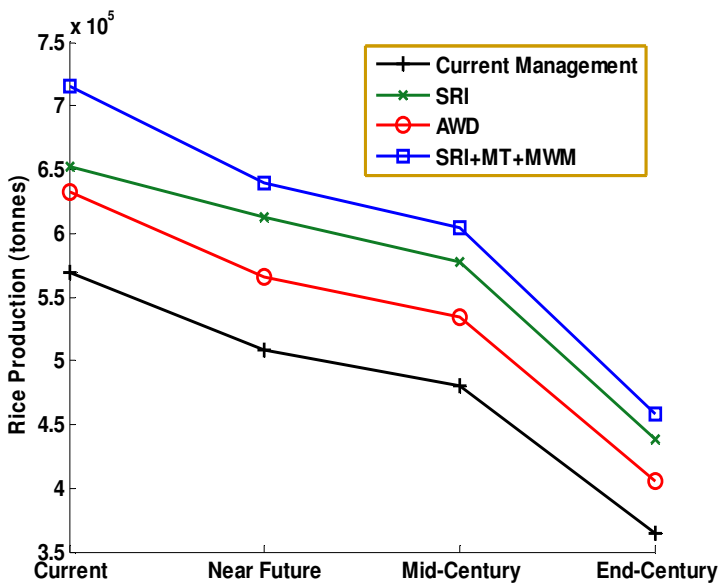
No. of farmers surveyed = 670

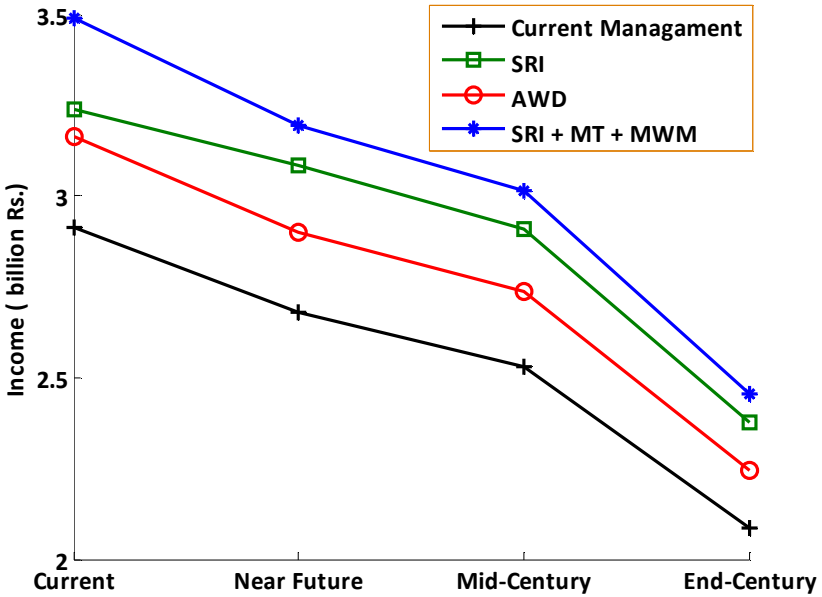
Reasons for low adoption

Technologies	Reasons (% farmers)		
	High cost	Too technical	Not suitable
System of rice intensification (SRI)	12	47	9
Direct seed sowing in rice (DSR)	0	4	40
Machine transplanting (MT)	10	6	5
Supplemental well irrigation (WI)	8	5	30
Alternate wetting and drying (AWD)	3	12	4

No. of farmers surveyed = 670

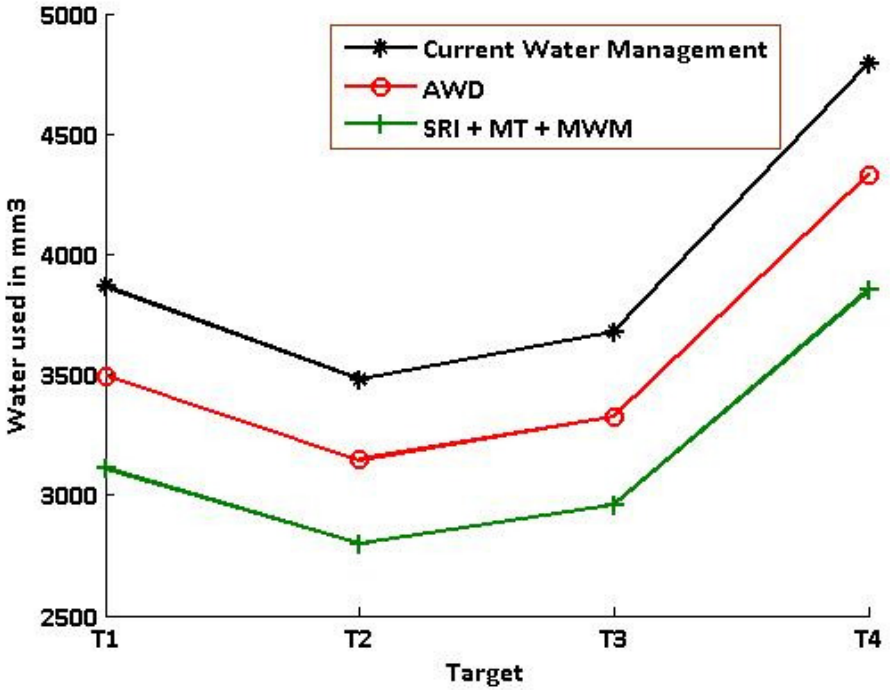
Maximize production & income- SRSP, Godavari





Rice production & income under different scenarios and management options during Kharif season

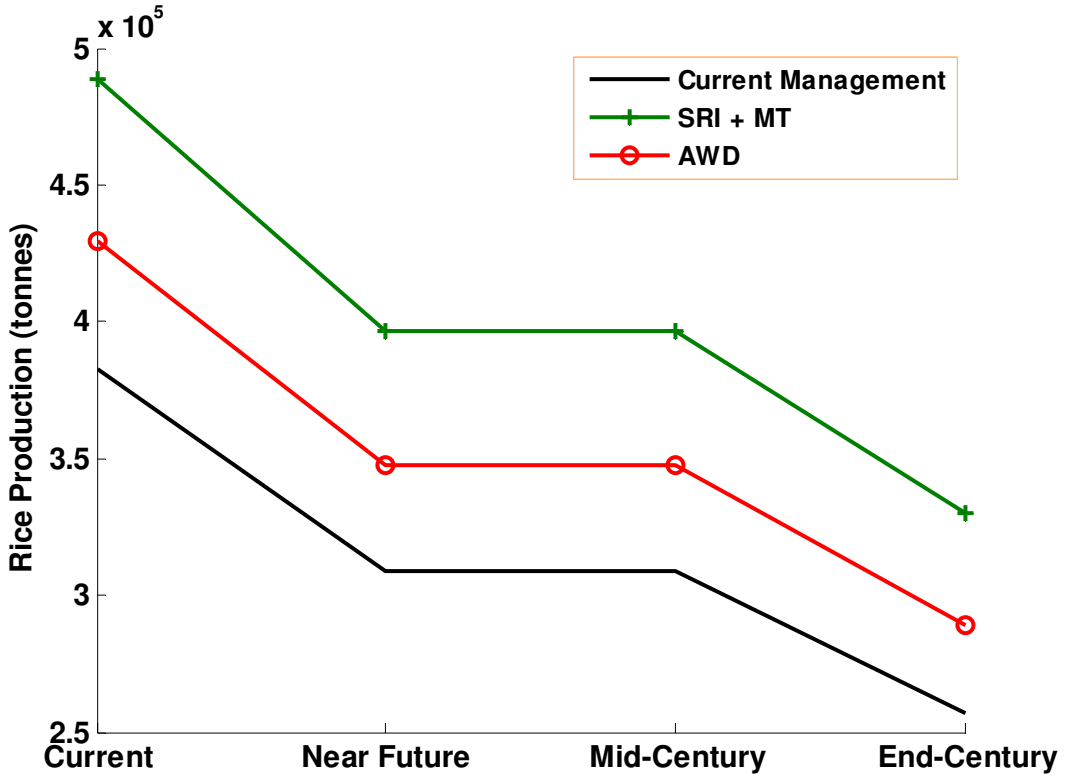
Minimize water use – SRSP, Godavari



Water use under different scenarios and management options - Kharif season

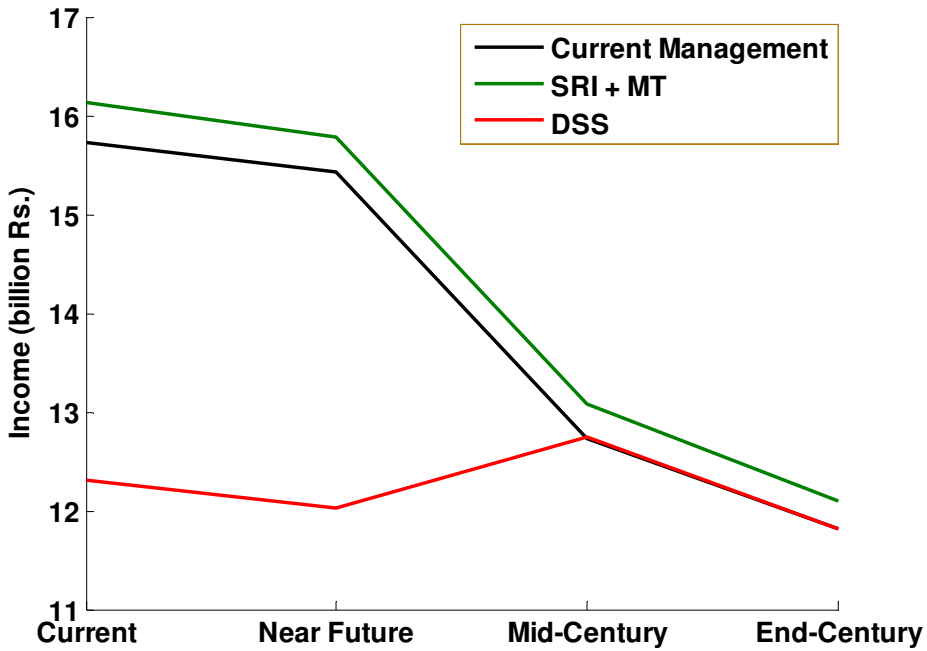
Rice production
Nagarjuna Sagar Project, Krishna basin

Rice production under different scenarios and management options during Kharif Season



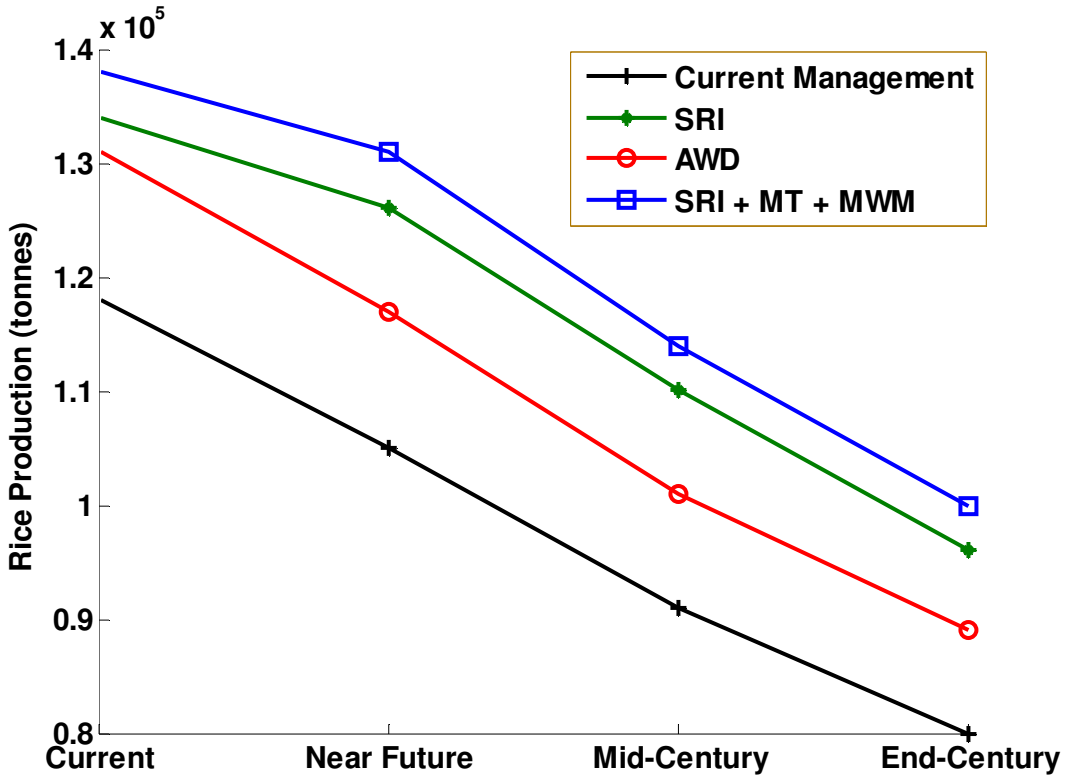
Total income
Nagarjuna Sagar Project, Krishna basin

Income under different scenarios and management options - Kharif Season



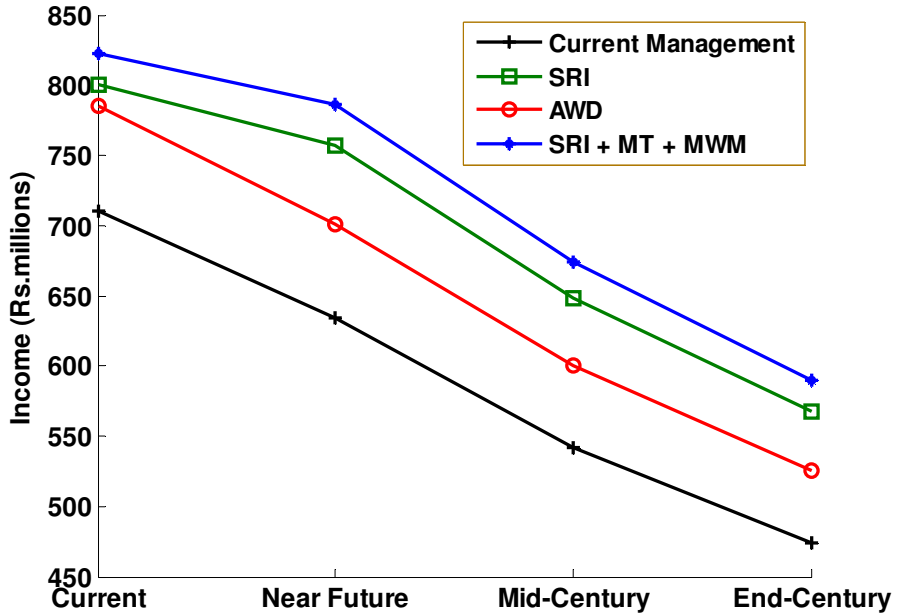
Rice production
Lower Bhavani Project, Cauvery basin

Rice production under different scenarios and management options during Kharif Season



Total income
Lower Bhavani Project, Cauvery basin

Income under different scenarios and management options during Kharif Season



Water use-Lower Bhavani Project, Cauvery basin

Water use under different scenarios and management options during Kharif Season

Management Option	Target: Rice Prod.= 1.18 lakh tonnes Income = Rs.709.8 millions Water available=480Mm^3	Target: Rice Prod.= 1.05 lakh tonnes Income = Rs.633.7 millions Water available=432Mm^3	Target: Rice Prod.= 1.05 lakh tonnes Income = Rs.633.7 millions Water available=432Mm^3 and mid-century projected crop productivities	Target: Rice Prod.= 1.05 lakh tonnes Income = Rs.633.7 millions Water available=432Mm^3 and end-century projected crop productivities.
	Water Required (Mm^3)			
Current Management	480.0(0.0)	432.0(0.0)	493.1(-61.1)	557.0(-125.0)
SRI	394.2(+85.8)	355.8(+76.2)	405.3(+26.7)	456.6(-24.6)
AWD	437.1(+42.9)	393.9(+38.1)	449.2(-17.2)	506.8(-74.8)
SRI + MT + MWM	393.7(+86.3)	355.3(+76.7)	377.9(+54.1)	450.6(18.6)

Note: +sign indicates excess water availability and – sign indicates deficit

6. Cost of adaptation

Cost of Uncertainty (CU): It is a long-term benefit foregone because of non-adoption of the adaptation strategies

- Joint probability of rainfall events & prices

$$p(X_{ij}) = p(X_1 = X_{1i}, X_2 = X_{2j}) = p(X_1 = X_{1i})p(X_2 = X_{2j})\; i = 1,2,3;\; j = 1,2,3,4$$

- Cost of Uncertainty (eg., supplemental irrigation, Subsurface drainage)

$$E(N) = \sum_{i=1}^{i=4}\sum_{j=1}^{j=3} N_{ij}\, p(X_{ij})$$

$$E(Cu) = \sum_{i=1}^{i=4}\sum_{j=1}^{j=3} Rn_{ij}\, p(X_{ij})$$



CU due to non-adoption of the climate change adaptation strategies – Godavari basin

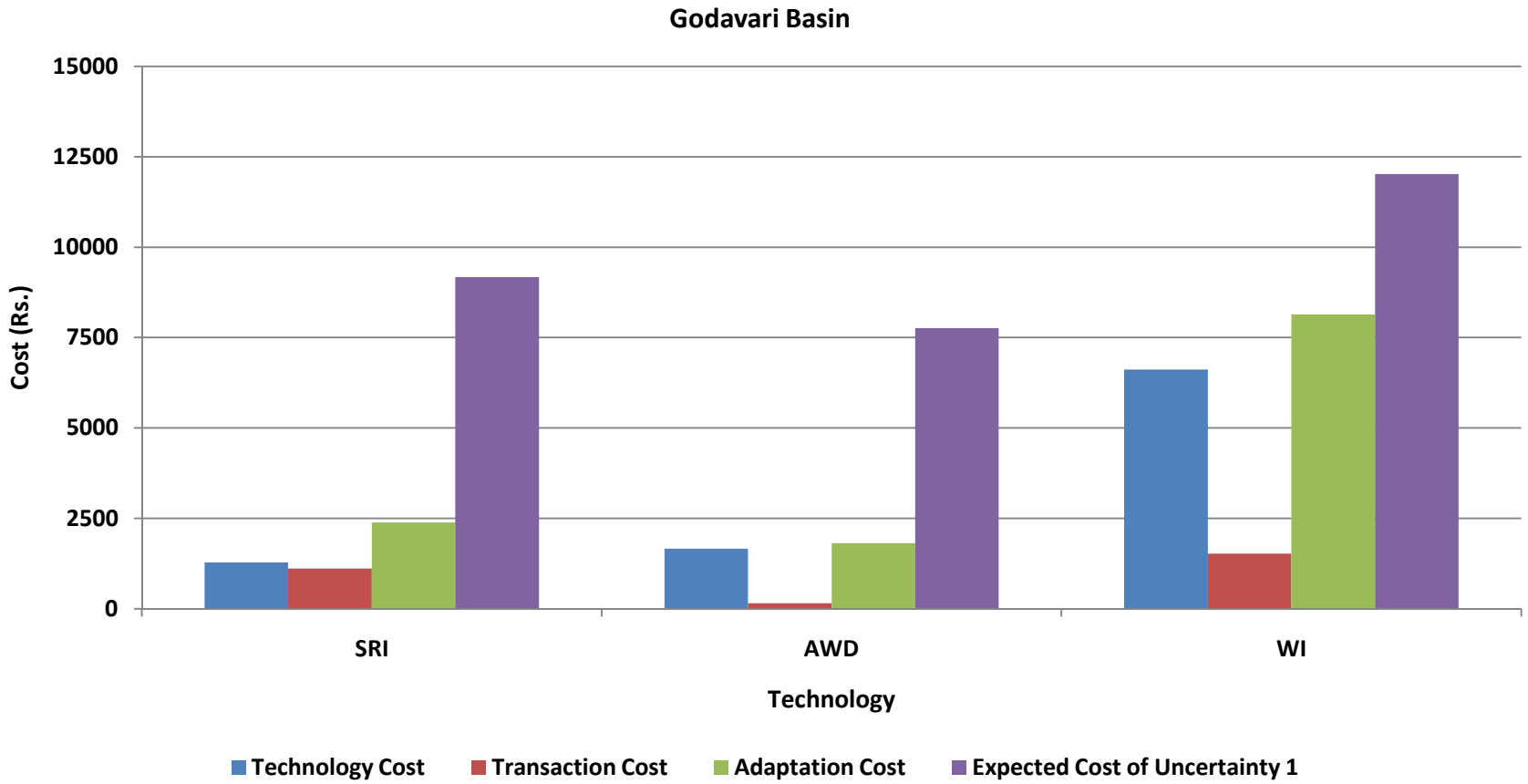
Event	JP	SRI	AWD	OPTD
1	0.24	8389	7324	8389
2	0.32	9660	5900	9660
3	0.24	9320	8350	9320
4	0.06	8840	13170	13170
5	0.08	8895	8330	8895
6	0.06	9810	10954	10954
	EMV (ECU1)	9172	7764	**9500***
	ECU2	**328****	1736	--

OPTD = optimum decision. * denotes EPwPI; ** denotes EVPI, JP=joint probability

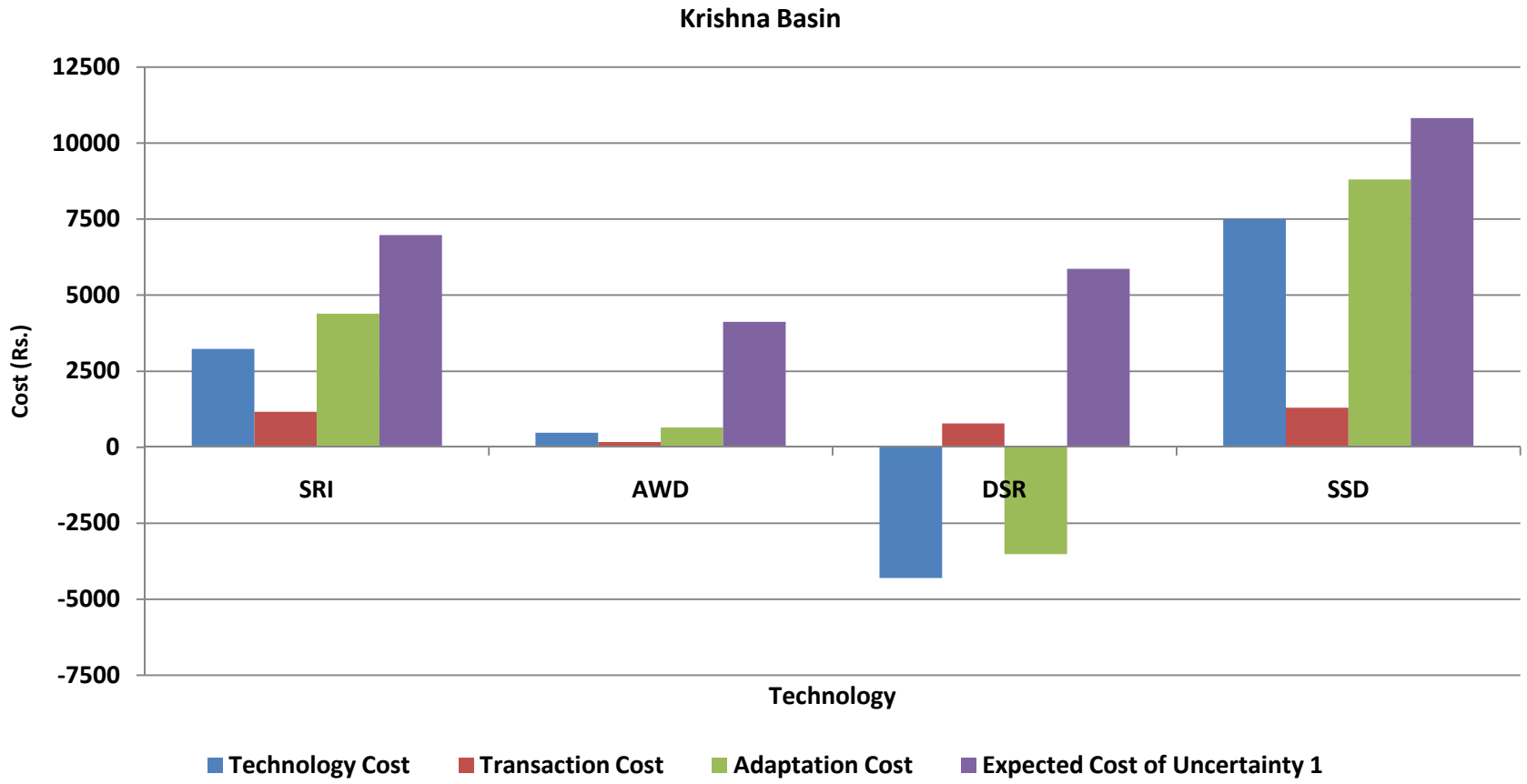
CU due to non-adoption of the CC adaptation strategies – Krishna basin

Event	JP	SRI	AWD	DSR	OPTD
1	0.24	6000	3900	4926	6000
2	0.32	7400	3750	6167	7400
3	0.24	6900	3750	6197	6900
4	0.06	6500	5050	5230	6500
5	0.08	7650	5300	6300	7650
6	0.06	8500	6000	6450	8500
	EMV (ECU1)	6976	4123	5848	**6976***
	ECU2	**0****	2853	1128	--

Adaptation cost & expected cost of uncertainty (CU)



Adaptation cost & expected cost of uncertainty (CU)



7. Conclusion

- Climate change impacts will reduce rice production in the project areas by 25-30%, in the long run
- Implementing various water- and labour-saving technologies (MT, SRI, DSR and AWD), one can minimize the reduction in rice production by 20 to 25% during the mid- and end-century periods
- learnings from the three basins had shown that adaption of various water management technologies improves the water productivity and income
- The level of technology adoption is currently poor in all the basins due to poor access to the technologies
- the expected cost for not adopting the adaptation technologies in rice is significantly high compared to actual cost of the adaptations in the river basins

8. Recommendations

- Institutional support has to be given for supply of quality inputs and better training to farmers on technologies
- technologies need to be disseminated and up-scaled with a capacity-building framework considering their impacts on the production, income and conservation of water resources
- piloting the technologies on a cluster approach (covering a group of villages in a location for each technology) will be more useful in up-scaling the management technologies



Thank you

NORWEGIAN EMBASSY

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