73RD INTERNATIONAL EXECUTIVE COUNCIL MEETING

24th ICID
INTERNATIONAL CONGRESS
73rd IEC MEETING
3rd OCT - 10th OCT 2022
ADELAIDE | SOUTH AUSTRALIA

Theme: Innovation and research in agriculture water management to achieve sustainable development goals

24th International Congress on Irrigation and Drainage & 73rd IEC Meeting
3-10 October 2022, Adelaide, Australia

INTERNATIONAL WORKSHOP ON "THE WATER ENERGY FOOD NEXUS: IMPLEMENTATION AND EXAMPLES OF APPLICATIONS"

04 October 2022: 08:45-10:30 and 11:15 to 13:00 Hours
Adelaide, Australia

24th International Congress on Irrigation and Drainage & 73rd IEC Meeting
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WELCOME

INTERBASIN WATER TRANSFER FOR SUSTAINABLE AGRICULTURAL PRODUCTION SYSTEMS – A CASE STUDY OF PATTISEEMA LIFT IRRIGATION SCHEME (PLIS) OF ANDHRA PRADESH, INDIA

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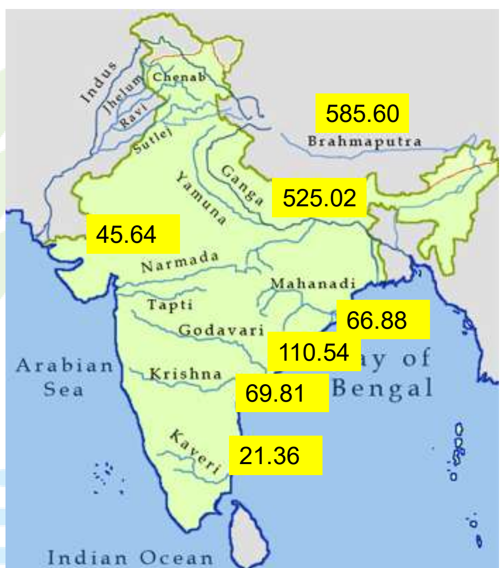
SURFACE WATER RESOURCES OF INDIA

Annual yield : 1953 km^3/year
Utilizable yield : 690 km^3/year

River	Average annual flow, km^3/year	Utilizable flow km^3/year	Live storage km^3
Ganga	525.02	250.00	56.32
Brahmaputra	585.60	24.00	2.51
Godavari	110.54	76.30	45.14
Krishna	69.81	58.00	54.80

National River Linking Project, 1982
Himalayan rivers : 14
Peninsular rivers : 16



Index map of Krishna basin

Index map of Krishna delta system

Table 1 Allocation of water from Bachawat Tribunal award in 1973

Type of use		Allocation MCM
Irrigation needs in Kharif	Krishna Delta system	4582
	a) Krishna Eastern Delta (KED)	2580
	b) Krishna Western Delta (KWD)	2002
Irrigation needs in rabi and domestic and industrial water supply		433
Evaporation losses at Prakasam barrage		113
		5128

Kharif : June-November; Rabi: December -April

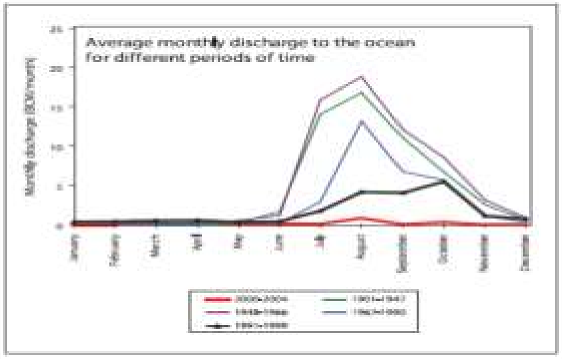
Revised allocation is **4279 MCM**

Irrigation development in Krishna basin

During last 50 years,

a) a decrease by more than half of the surface water inflow into the lower basin (~25.8 billion cubic meters (BCM) a year in 1996-2000) due to water development in the upper basin;

b) By 1996-2000, 2012-2015, 77% of the Lower Krishna Basin net inflow was depleted and discharge to the ocean amounted minimal defining a moderately modified ecosystem



Venot *et al.* (2007)

Irrigation development in Krishna basin

c) an uncontrolled irrigation development in excess of existing formal allocation procedures in the Lower Krishna Basin itself. (cropping intensity in the Krishna delta increased from 0.52 to 1.3 million acres and 108 to 160% during 1955 to 2015, respectively)

d) Cultivating during the dry season became more common as irrigation expanded utilizing the residual moisture in the field after kharif harvest.

e) Ground water irrigated area also increased by 14 times (45% of all irrigated area when compared to 8% during 1955).

f) At the irrigation project level (notably in Nagarjuna Sagar), governmental decisions and recommendations of the World Bank have led to changes in the design and practices of protective irrigation that have resulted in increased water use.

Consequences to Krishna Delta & Need for Trans-basin water transfer from Godavari basin to Krishna basin

- Delayed canal releases (July - August)
- Harvest season coincides with cyclones during October –November
- Economic loss of Produce
- Delayed sowings for second crop
- Water shortage during critical stages of rabi crop
- Polavaram Irrigation project is contemplated to transfer 2265 mM^3 for stabilizing Krishna delta command area of 0.53 Mha
- To reap immediate benefit, Pattiseema Lift Irrigation Project (PLIS) is contemplated.
- Present study aims to understand water-food – energy nexus in context of sustainability of agricultural production systems in Krishna delta

Methodology – Study area

Godavari - Krishna Delta and interlinking – Polavaram Project

2265 mM^3

Schematic view of PLIS

Cost of construction of PLIS : 210 mUSD

Table 2. Salient features of Pattiseema Lift Irrigation Project

Total Discharge	: 240 m^3/s
Pump House	: 221 x 36 m
Diaphram Panels	: 189 No's, 1.20 m thick
Delivery Cisterns	: 90 x 74 m
No. of Pumps	: 24
Type of Pumps	: Vertical Turbine Pumps
Type of Motors	: Synchronous motors
Discharge of each pump	: 10 m^3/s
Head	: 33 m
Capacity of each pump	: 3.95 MW
Capacity of each motor	: 4.70 MW
Total power required	: 113 MW

Study Methodology

- Collection of meteorological data from 2000-2015 (RARS, Lam, Guntur, India)
- Estimation of multiple uses of water in Krishna delta using CRIWAR 3.0
- Collection of river inflows, river discharges, canal releases to delta from 2000-2015 (Water Resources Dept., Govt. of Andhra Pradesh, India)
- Water releases, Pumping energy details from Pattiseema Lift Irrigation Scheme from 2015-2020) (Water Resources Dept., Govt. of Andhra Pradesh, India)
- Crop coverage, Production details from 2015-2020 (Agriculture Dept., Govt. of AP, India)
- Computation of Water-Food –Energy Nexus indicators
- Computation of Greenhouse Gas emissions (GHGs)
- Computation of Benefit-cost ratio of the PLIS during its operational period (2015-2020)

Evaluation indicators used in water-energy-food nexus approach (El-Gafy,2017)

Indicator	Equation	Notation
Water mass productivity (W_p)	$\frac{Yc}{Wc}$	Y_c= Yield (MT/ha) W_c=Water consumption (Mm^3/ha)
Energy mass productivity (E_p)	$\frac{Yc}{Ec}$	Y_c= yield (MT/ha) E_c = Energy consumption (MW/ha)
Water economic productivity (WEP)	$\frac{Nc}{Wc}$	Nc = Economic production advantage (mUSD) W_c=Water consumption (Mm^3/ha)
Energy economic productivity (EEP)	$\frac{Nc}{Ec}$	Nc = Economic production advantage (mUSD) E_c= Energy consumption (MW/ha)

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Table 3: Gross Irrigation requirement in Krishna Delta region

S.No	Name of the Crop /Multiple uses	Registered Ayacut (ha)	Crop Wise Registered Ayacut (ha)		Net Irrigation Requirement (m)	Net Irrigation Requirement (Mm^3)
			KED	KWD		
1	Paddy	460911	229595	231316	0.572	2636.41
2	Sugarcane	6685	6685	0	1.849	123.60
3	Maize	538	538	0	0.215	1.15
4	Pulses	538	538	0	0.259	1.39
5	Aquaculture	60835	60835		1.000	608.35
6	Domestic water	Computed @ 55 lpcd				110.00
7	Water to livestock	Computed @ 25 lpcd for big headed livestock, @5 lpcd medium headed and @0.3 lpcd for small headed livestock (Renwick *et al.*, 2007)				94.32
8	Water to industries					184.41
					Total (Mm^3)	3759.64
	Gross Irrigation Requirement considering field application efficiency @60% (Brouwer *et al.*, 1989; Srinivasulu, *et al.*, 2003; Gupta *et al.*, 2021)					**6266.00**

Accounting for water consumption for animals according to their category (Renwick et al., 2007)

Animals -Water consumption	Type of animal	liters/head /day	m^3/head /annual
Big size	Cattle, Buffaloes	25	9.125
Medium	Goats-Sheeps-pigs	5	1.825
small	Poultry	0.3	0.109

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Table 4. Comparison of average demand and canal releases in Krishna delta

Year	Canal releases (Kharif +Rabi) (Mm^3)			Average Demand (Mm^3)	Excess or Deficient water supplies (Mm^3)	% Excess or Deficient water
	KED	KWD	Total (KDS)	KDS	KDS	KDS (%)
2000-01	3865.802	2485.644	6351.446	6266	85.45	1.36
2001-02	3219.614	2037.107	5256.721	6266	-1009.28	-16.11
2002-03	1895.806	1549.209	3445.015	6266	-2820.98	-45.02
2003-04	1360.053	1119.078	2479.131	6266	-3786.87	-60.44
2004-05	2130.835	1848.234	3979.069	6266	-2286.93	-36.50
2005-06	3220.747	2184.071	5404.817	6266	-861.18	-13.74
2006-07	3947.354	2909.263	6856.617	6266	590.62	9.43
2007-08	3894.119	2321.407	6215.526	6266	-50.47	-0.81
2008-09	3728.466	2698.303	6426.769	6266	160.77	2.57
2009-10	3884.774	2749.273	6634.047	6266	368.05	5.87
2010-11	2514.244	1593.383	4107.627	6266	-2158.37	-34.45
2011-12	3197.244	2657.527	5854.771	6266	-411.23	-6.56
2012-13	1317.578	984.5733	2302.151	6266	-3963.85	-63.26
2013-14	3754.234	2109.314	5863.549	6266	-402.45	-6.42
2014-15	3099.834	2232.209	5332.043	6266	-933.96	-14.91
2015-16	715.281	471.757	1187.038	6266	-5078.96	-81.06

Table 5. Inflows from Pattiseema and others before and after the construction of PLIS

S. No	Year	Inflows					Total water utilisation	Surplus	Percent of water utilized supplied by PLIS
		Outflow at Pattiseema head work	NSP/PP Dam/ Wazinepalli	Right main canal (Budameru)	Keesara/ Others	Total Inflows			
1	2009-10	0	19051.22	0	2124.04	21175.26	6634.04	14541.22	
2	2010-11	0	9554.35	0	7261.26	16815.62	4107.62	12707.99	
3	2011-12	0	9863.57	0	2692.64	12556.21	5854.48	6701.72	
4	2012-13	0	1551.19	0	3256.99	4808.18	2302.15	2506.03	
5	2013-14	0	10086.43	0	7419.84	17506.26	5863.54	11642.71	
6	2014-15	0	6759.21	0	627.78	7386.99	5332.32	2054.66	
7	2015-16	0	797.97	254.57	938.98	1991.52	1187.03	804.48	
8	2016-17	1591.85	4162.84	1372.51	979.19	6514.55	3622.27	2892.27	**43.92**
9	2017-18	2996.06	1711.75	2553.89	786.92	5052.56	4444.31	608.24	**67.41**
10	2018-19	2744.62	1898.64	2304.70	1775.46	5978.80	4330.76	1648.03	**63.33**
11	2019-20	1217.53	2679.04	755.77	1656.24	5091.07	5091.06	0.00	**23.90**
12	2020-21	1176.98	1272.83	936.71	2957.68	5167.24	5167.23	0.00	**22.77**

Table 6. Estimation of Gross value addition on net production advantage due to inter basin water transfer

Crop	Kharif		Rabi		Kharif Production scenario in case of no inflows from PLIS (MT)	Net production advantage due to PLIS (MT)	Minimum Support Price/MT (USD)	GVA (Million USD)	Cropping Intensity (%)	Remarks
	Area (ha)	Production (MT)	Area (ha)	Production (MT)						
2016-17										
Paddy	364768	1468252.07	45088	219948.71	1174601.65	293650.41	201.33	59.12	216.0	20% yield reduction
Pulses	2325	1939.18	262686	133056.98						
Maize	225	1029.84	37623	313294.77						
Sugarcane	10053	974372.96								
Total	377371	2445594.05	345037							
2017-18										
Paddy	384454	2434800.11	28750	204768.45	1217400.06	1217400.06	212.00	258.08	185.10	50%yield reduction
Pulses	752	734.14	224126	251771.17						
Maize	207	1229.90	41393	107218.41						
Sugarcane	9742	905862.12								
	395155	3342626.27	336282							
2018-19										
Paddy	394745	2363708.44	39282	255615.42	1300039.64	1063668.80	236.00	251.02	164.75	45%yield reduction
Pulses	447	539.79	155992	191320.23						
Maize	227	826.23	11884	83630.08						
Sugarcane	12983	1289888.42								

Table 6. Estimation of Gross value addition on net production advantage due to inter basin water transfer

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	Area (ha)	Production (MT)	Area (ha)	Production (MT)						
2019-20										
Paddy	397357	2544155.25	73810	538806.60	2162531.96	381623.29	244.66	93.36	167.07	10% yield reduction
Pulses	486	664.91	135849	189148.20						
Maize	123	767.16	14315	100512.42						
Sugarcane	8916	852707.98								
	406882	3398295.30	272893							
2020-21										
Paddy	403990	2596491	73810	538806.60	2207018	389473.	244.66	93.36	167.10	10% yield reduction
Pulses			187811	241789.29						
Maize	440	2728	8198							
Sugarcane	4294	389251.1								
Grand total	403990	2988470.1	269819					**754.97**		
*Kharif (June-November); Rabi (December-April)	Net benefit has been calculated only on paddy production in kharif season only									

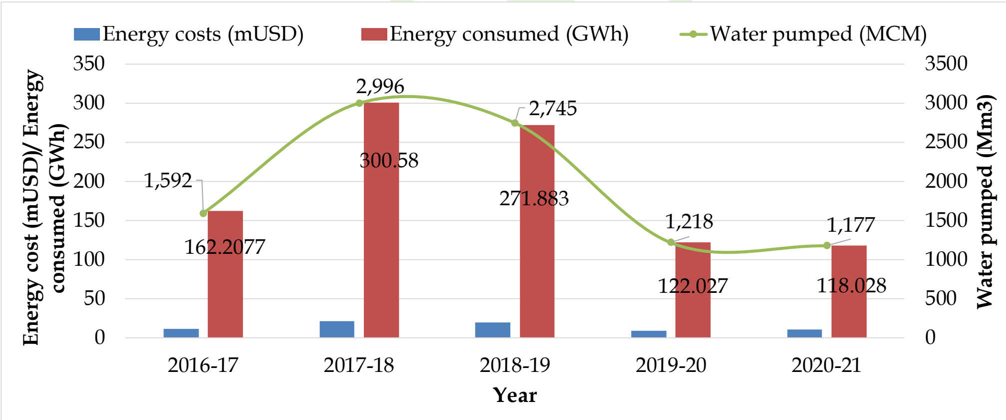

Fig 4. Year wise Energy consumed, associated energy costs and water pumped from PLIS

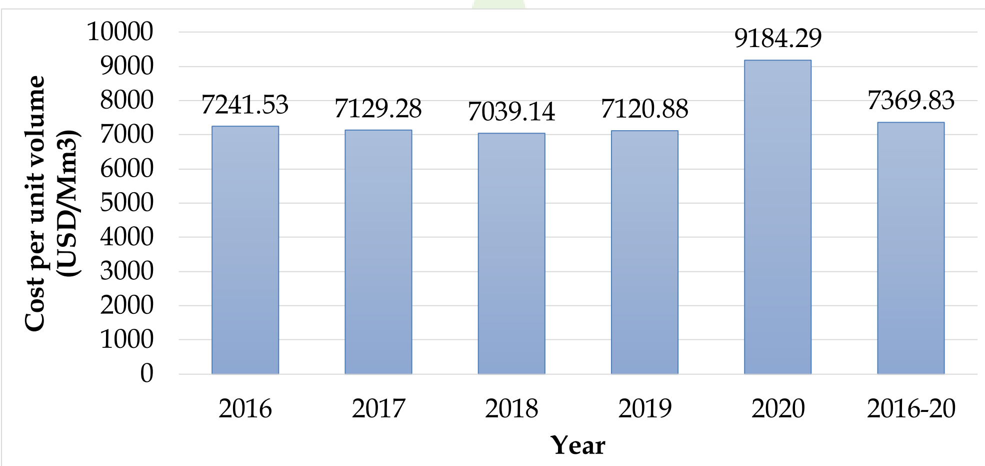

Fig 5. Associated energy cost for lifting one *Mm³* of water during different years of operation

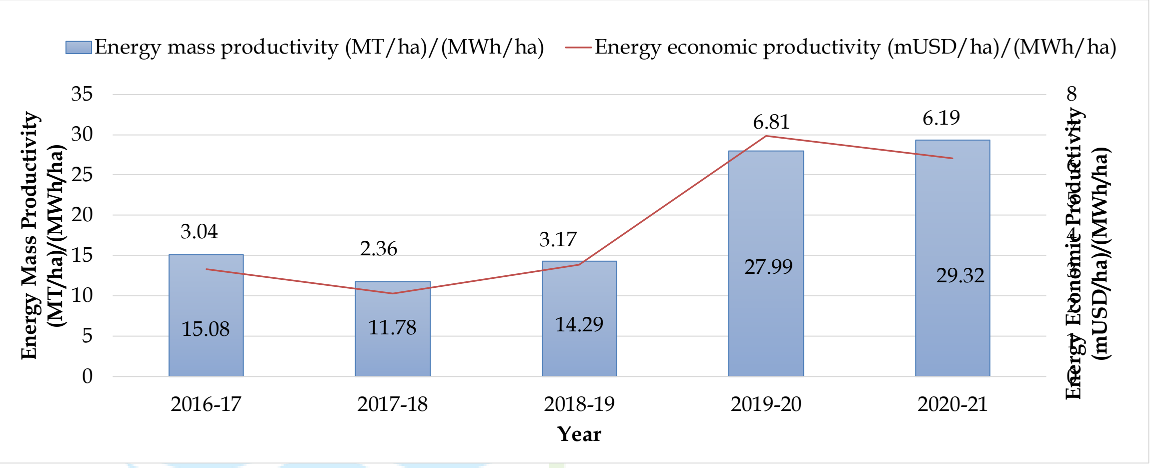

Fig 6. Computed energy mass productivity and energy economic productivity due to trans basin water transfer during different years

Table 7. Greenhouse gas emissions from PLIS during 2016-2020

Year	Electrical Energy (kWh)	Greenhouse gas emissions (MT)			
		*CO_2	**SO_2	N_2O	Total
2016-17	162207700	137876.55	136254.47	645.59	274776.60
2017-18	300580000	255493.00	252487.20	1196.31	509176.51
2018-19	271883000	231100.55	228381.72	1082.09	460564.36
2019-20	122027000	103722.95	102502.68	485.67	206711.30
2020-21	101913000	86626.05	85606.92	405.61	172638.58
Total	958610700	814819.10	805232.99	3815.27	1623867.35
CO_2 eq	-	814819.10	-	1136950.46	1951769.46

**CO_2 equivalent factors for GHG gases: CO_2 -1; N_2O – 298 (IPCC, 2007)*

***SO_2 is not a direct greenhouse gas as it does not absorb and trap infrared radiation*

Emission of GHGs from 1 kwh electrical power generated using thermal energy : (Mittal et al., 2012).

0.85 kg of CO_2,

0.84 kg of SO_2, and

0.00398 kg of N_2O

Table 8. Computation of Benefit-Cost, B/C ratio of PLIS for its 5 yrs of operation (2016-2020)

Description	Amount (mUSD)
Capital expenditure (mUSD$)	221.33
Life	10 years
Interest rate	7%
Depreciation	10 years
Capital recovery factor	0.142
Annual costs for 5 years of operation	
Depreciation (mUSD)	110.67
Annual payment (mUSD)	157.56
Housing cost@1% (mUSD)	11.07
Insurance@1% (mUSD)	11.07
Taxes @ 1% (mUSD)	11.07
Total annual cost (mUSD)……(1)	301.43
Operating costs for 5 years of operation	
Operating cost for 5 years (mUSD)	18.70
Man power (mUSD)	12.80
Repairs and maintenance@6% (mUSD)	66.40
Total operating cost (mUSD)….(2)	97.90
Total cost (mUSD) (1)+(2)	399.33
Total benefit (mUSD)	760.00
B-C ratio	1.90

Performance indicators

- *Energy intensity per hectare of irrigated area was estimated as 459.81 kWh/ha*
- *Energy productivity and water productivity on production advantage was estimated as 3.63 kg/kwh and 345.52 kg/ha-MCM.*
- *Benefit cost ratio of the project was estimated as 1.9.*

Conclusions

- The study suggested that seasonal pressure on water demand for various sectors could be effectively addressed by water resources management in the region through inter basin water transfer from Godavari River by a lift irrigation system.
- The agricultural production sustainability in the Krishna delta region was ensured through water transfer. Without the water transfer, production in the Krishna delta would have fallen by 10-40%.
- Net production advantage during 5 years of operation has been 760 million USD
- Careful integrated planning and analysis is necessary to ensure that the proposed high investment schemes are able to operate as planned and can deliver the expected long-term benefits and basin transfer should not result in increased water deficits during Rabi and summer months in Godavari delta

Conclusions (Contd..)

- There has been environmental concern that need attention due to lift irrigation schemes that utilize thermal powered electrical energy, as it has potential to emit greenhouse gases.
- Care must be taken to follow CO2 mitigation strategies to absorb GHG releases through use of clean coal technologies, improving efficiency of thermal power plants, disposal of CO_2 in to biosphere sinks through afforestation, carbon sequestration and storage in aquifers etc.,

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