WATER USE EFFICIENCY OF UNDULATED COMMAND ENHANCED BY INTEGRATION OF TANKS: CASE STUDY

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ABSTRACT

Odisha a coastal State in east India having geographical area of 15.5 Million hectare (MHa) comprises of a western region, almost 500 Km. long and 250 Km. wide having undulated, hilly degraded terrain with large forest cover. The geographical area of this region is 11.3 MHa having arable land 3.5 MHa and irrigation coverage 1.4 MHa served by a few major and large number of medium and minor projects. The characteristics topographical feature of all irrigation projects is existence of large patches measuring 500 to 1000 hectare out of command upland within the command (GCA) and adjacent to the designated command, these lands are marginally above the command level (maximum 1 Mtr.) of the project.

Although the area receives an average of 1200 mm. of monsoon rain fall, the variability is in a range of 600 to 1700 mm. Invariably three to four dry years occur out of a ten year stretch, when no rain fall occurs continuously even up to fifteen days during the monsoon. The consequence is serious shortage to meet crop water demand as the reservoir/ pond as head works do not have enough storage. However, three to four storm spells in the monsoon precipitating to a maximum of 300 mm in three days is a regular pattern. At least two spells in July and August occur in dry years.

The project spills even up to 50% of the yield in above average years with nominal spill in dry years. To meet the deficiency of the evapo-transpiratory crop need during dry spells innovative interventions have been made by lining the main channels to increase their conveyance capacity. Further a large part of the spill during storms is conveyed to a series of new tanks built on valleys. These tanks essentially stabilise the designated command during dry spells and in addition provide deficit irrigation to specific out of command patches brought down to the command level by minimal cutting and levelling. In three typical projects Sunder, Saipala and Dumarbahal in Mahanadi basin, the modality of augmenting irrigation supplementation through identification and integration old/new tanks has led to increase of command area up to 23%.The consequential Water Use Efficiency (WUE) has increased from 32% to 43%.

The annual income of beneficiaries has significantly increased from Rs. 16000 per Ha to Rs. 28000 per Ha availing both monsoon and non-monsoon irrigation particularly adopting winter cash crops and horticulture in the tank command. The modalities of hydrological interventions and structural addition/ alteration to the conveyance system with tanks are detailed. Appropriate management technique for deficit irrigation are described for the three medium irrigation projects having designated command area of 4400 ha, 2752 ha and 2800 ha, which are now getting additional benefit 400, 700 and 850 ha respectively in both Kharif and Rabi season.

Keywords; Water use Efficiency, Undulated Command, Tank Integration, Management by Beneficiaries.

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1. INTRODUCTION

Odisha, a state in the east coast of India ***(Fig.-1)***, with geographical area of 15.5 Million Ha. (Mha), has an arable land of 6.3 Mha. Odisha supports a large rural population of 30 Million dependant on agriculture which is strongly linked with a good monsoon rainfall of 1300 mm which unfortunately becomes extremely erratic with long dry spells even upto ten days coupled with two or three severe storms spells which precipitates 200-300 mm in 2-3 days over large area upto15,000 Km^2. Odisha can be broadly classified two distinct geographical regions, a) **the coastal plain** with geographical area of 4.2 Mha and arable land of 2.7Mha, b) **the western region** with undulated and hilly terrain in the sub-mountainous region having geographical area of 11.3 Mha and arable land of 3.7Mha (OCC-SPARC, 2017).

The eastern region with large flat arable land has high irrigation coverage of 1.7 Mha(63%) and western region with undulated land has low irrigation coverage of 1.7 Mha (46%). However with a large number of medium projects (command area less than 10,000 ha.) and minor projects (command area less than 2000 ha.) in the western region with erratic rainfall, the water availability from the irrigation projects is undependable. The irrigation command in western region are fed by major projects to the tune of 35% whereas in the eastern region the major projects contribute to 65% of irrigation coverage. In the above background it has been a constant effort of the Water Resources Department of Odisha to maximise the water use efficiency (WUE) of the medium and minor projects with undulated command by appropriate intervention.

In the western region the average yield of water from a rainfall of 1300 mm is not more than 35% whereas it is as high as 60% in the flat eastern region. The effort so far have been not only to channelize more water into the head works of irrigation system but also to reduce the released irrigation water rapidly running out to valleys unutilised for irrigating the command of the small projects. The appropriate technology for such irrigation practices are detailed for few typical projects in western region, with objective of expanding the command area from the same source. Three medium projects in western tribal area Sundar, Saipala and Dumerbahal ***(Fig.-1)***, where additional storages in the command have been provided to enhance irrigation coverage. Intensity of irrigation increased even by 20% through such measures.

2. CLIMATE & METEOROLOGY

2.1 Climate

Orissa receives a decent annual average rainfall of about 150 cm. June ushers in the south-west monsoon and it's in mid-October that the rains bid adieu to the state. The rainfall has a key role to play in the climate of Orissa. As the temperature rises to 40-45^o in April-May and its cools down due to monsoon rain to 30^o. Monsoon retreats in mid-October thereafter the temperature is in the range 30^o to 10^o in the winter. The temperature influences evapotranspiration need of crops, the principal crop being paddy grown over 75% of the irrigated command. Light and medium duty crops like pulses, vegetables and oilseeds are grown in the winter.

2.2 Meteorology

Odisha lying in the tropics (17^o to 22^o N) receives an annual rainfall of 1462 mm on the average, which however ranges between 700 mm in worst drought years to 1800 mm in extremely good rainfall years. The monsoon rainfall generally ranges from 1000 to 1400 mm, averaging 1239 mm and the non-monsoon rainfall averaging 223 mm. The northern and north-western region receive a monsoon rainfall of 1300-1400 mm whereas the central and south-western region are relatively dry receiving monsoon rainfall of 900 to 1200 mm., which is more erratic with monsoon arriving too late (beyond July 1 against the normal onset of June 15 in the eastern region). The distribution of monsoon rainfall is also marked by long dry spells (non-rainy) of 15 to 20 days between storm spells.

Figure 1. Odisha showing river basins and location of three project studied in Mahanadi Basin

The impact of highly variable rainfall on the yield of the three typical medium projects are presented to elucidate how the storm spells yielding high runoff (60 to 70% of rainfall of 250-400 mm intensity in 2-3 days) can be utilised by technological intervention of building small storages across secondary and tertiary drains inside the command. Monthly rainfall data of a typical station that influences the studied projects is shown at ***Table-1****(SPARC-2009)*.The annual rainfall trend is shown graphically in ***Fig.-2***.

Table 1. Monthly rainfall in mm. for a typical station influencing the project

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1981			155		83	109	158	302	212	49			**1067**
1982		45	31	127	37	58	399	308	178	108	69		**1360**
1983		27	8	49	74	176	180	282	203	102	1	9	**1110**
1984	26			67	26	276	176	179	98	44			**891**
1985	31	26	16	2	29	101	129	299	221	78			**932**
1986	17	23		49	19	174	343	128	66	147	82	10	**1057**
1987	14		8	3	83	84	166	104	79	117	131		**788**
1988		34	0	43	48	146	288	176	150	47	21		**951**
1989			30	17	51	280	232	321	92	29	0	15	**1067**
1990		93	131	57	359	213	221	314	217	124	128	1	**1858**
1991	28	0	20	22	30	65	498	212	223	52	89	1	**1240**
1992	4	38		21	48	190	607	308	153	94			**1461**
1993				48	133	82	283	59	89	135	5		**832**
1994		35	25	44	24	185	311	311	391	116	13		**1454**
1995	12		16	66	423	66	269	325	85	186	98		**1545**
1996	64	9	24	50	2	206	192	276	93	44	2		**961**
1997	9	5	47	111	32	115	223	380	256	82	39	58	**1355**
1998		12	73	69	84	160	388	297	244	106	43		**1474**

1999				2	149	160	188	91	254	123	20		**986**
2000		134	3	13	164	83	252	406	86	78	13		**1231**
2001			39	33	52	421	258	213	168	123	26		**1332**
2002						99	146	281	97	138			**760**
2003						92	273	400	224	210			**1199**
2004						294	280	214	184	242			**1214**
2005						203	216	197	531	225			**1372**
2006			85		245	232	412	621	406	35	51		**2087**
2007						233	186	366	267	30	0	0	**1081**
Avg.	8	18	26	33	81	167	269	273	195	106	31	3	**1210**

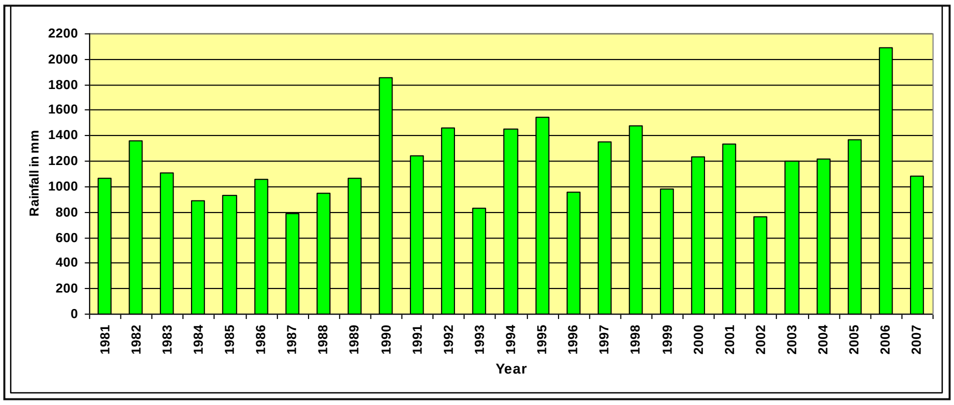

Figure 2. Annual Rainfall Trend of a typical Station

The data clearly establishes the occurrence of four drought years in the decade 1981 to 1990 and three drought years in the decade 1991 to 2000, when the annual rainfall was as low as 788 mm. An important feature is the occurrence of agricultural drought (erratic deficient rainfall with large number of dry days), although there is no meteorological drought which occurs when rainfall is deficient from the normal by 7%. The daily rainfall of a typical normal meteorological year 2003 is shown at ***Table-*** Illustrates the long dry spell of 28 days, September 7 through October 4. The benefit of storm rainfall of 164 mm on September 6 was harnessed due to impounding of tanks incorporated on secondary and tertiary drainage channels in the command.

Table 2. Daily Rainfall (mm) of a Typical Station

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1								36.00					
2							17.00	4.00	23.00				
3								12.00	3.00				
4							14.00	6.00					
5							5.00	9.00					
6								7.00	164.00	32.00			
7								34.00	11.00	89.00			
8								9.00		15.00			
9							12.00	4.00					
10							2.00	8.00					
11								20.00					
12							5.00						
13													

14							46.00	9.00					
15							1.00	50.00					
16								7.00	15.00				
17						30.00	11.00			2.00			
18						8.00	15.00	10.00	6.00				
19						16.00	25.00			3.00			
20						10.00	2.00			5.00			
21							5.00	8.00					
22							5.00	4.00					
23							8.00	32.00		14.00			
24							42.00			14.00			
25						12.00	33.00		2.00	27.00			
26							19.00	2.00					
27						2.00	10.00	13.00					
28						14.00	5.00	84.00					
29								12.00					
30								5.00		9.00			
31							18.00	15.00					
Total						**92.00**	**300.00**	**400.00**	**224.00**	**210.00**			**1226.00**

3. FEATURES FOR ENHANCING IRRIGATION COVERAGE & WATER USE EFFICIENCY

The studied medium projects Sundar, Saipala & Dumerbahal in the Mahanadi basin with largest area of 141000 Km^2 in Odisha and upstream basin state Chhattisgarh are in chronically drought prone western region. These projects have been operational from 1980. Hydrological review of the performance of these projects over a decade firmly indicated availability of surplus water in a 75% dependable yield (Q_{75}), which decides the design command area. Simulating the successes under the Q_{75} situation is carried out at the project formulation stage. Utilising the evapo-transpiration, Et data worked out in a research study (Reassessment of Design Energy, SPARC-2007, Doorenbos etal, 1977).The salient features of these projects are shown at ***Table-*** (Govt. of Odisha, DoWR, 2001).

Table 3. Salient features of three medium projects

Sl.	Name of Project	Catchment Area (Km²)	Live Storage in Ham.	Mean Annual Rainfall (mm)	Maximum Annual Rainfall (mm)	Minimum Annual Rainfall (mm)
1	Sundar	145	4440	1298	1791	702
2	Saipala	90	1834	1316	1628	774
3	Dumerbahal	96	1872	1276	1878	652

A typical presentation of the evapo-transpiration need of principal crops paddy and cotton grown in these projects is made at ***Table-4***.

Table 4. Evapotranspiration need and Normal Precipitation in the project area

Month	ETo	Kc (mm)		Kc x ETo (mm)	
		Paddy	Cotton	Paddy	Cotton
January	183	1.10	0.10	201.3	18.30
February	168	1.15	0.20	193.20	33.60
March	216	1.05	0.45	226.80	97.20
April	171	1.10	0.86	188.10	147.06
May	129	1.10	1.16	141.90	149.64
June	53	0.95	1.23	50.35	65.19
July	30		1.22		36.60
August	70		1.10		77.00
September	54		0.85		45.90
October	144		0.30		43.20
November	190		0.00		0.00
December	227		0.00		0.00
Total				**1001.65**	**713.69**

3.1 Examination of Yield and Utilisation Data

The annual basin yield, annual utilisation for irrigation and annual spill are presented in ***Table-5***.

Table 5. Yield, utilisation for irrigation and spill

Sl	Name of Project	Catchment Area (Km^2)	Command Area (Ha.)		Average Annual Yield in Ham.	Average Annual Utilisation in Ham.	Average Annual Spill in Ham.
			Design	Enhanced			
1	Sundar	145	4633	5030	6231	3628	2028
2	Saipala	90	2064	2752	3011	1947	1005
3	Dumerbahal	96	2800	3430	4139	2193	1799

The consumptive use for paddy contributed from irrigation supplementation is 0.6 m on the average (range 0.4 m in good years to 0.8 m in dry years), grown in the monsoon followed by cotton and medium / light duty cash crop in winter over 25 to 35% of the command. The extended command which is around 25 to 30 % of the design command in Kharif (monsoon) season became possible by structural addition of tanks in the valleys trapping both rain water and spill water from irrigation from uplands in the command area. In addition water spilled through escapes as well as water saving measures in managing irrigation helped better utilisation of canal water leading to increased water use efficiency.

The reservoir operation Table for Dumerbahal project for the period 1985 through 1994 is presented in ***Table-6***.

Table 6. Reservoir Operation data for Dumerbahal project

Sl.	Year	Inflow In Ham.	Irrigation Drawal In Ham.	Surplus In Ham.
1	1985	11259	2698 (Good Year)	9151
2	1986	6257	2772 (Good Year)	3854
3	1987	2206	1902 (Dry Year)	0
4	1988	2066	1706 (Dry Year)	0
5	1989	3091	2019	271
6	1990	6519	2534 (Good Year)	3944
7	1991	2198	2394	65
8	1992	5970	2034	3829
9	1993	2968	2714	296
10	1994	7126	2255	4526

Analysis of the above presentation and interventions is presented below;

- In good years the reservoirs spill almost 50% of their monsoon yield and this was occurring (in the decade following project completion).
- In average years (40% of the time) the consumption of water can be spread to an increased command area of 20% from the yield of good rainfall months July and August when there is scope for economising water supplementation. The irrigation practice is to stop supply when daily rainfall exceeds 30 mm or 50 mm in 2 consecutive days. The medium and low lands in hilly terrain receive substantial overland runoff from the uplands. A typical profile of irrigation command on either bank of a minor distribution channel is shown at ***Fig.-3***. Consumptive use of rain water and irrigation water is by utilising small additional storages of tanks totalling upto 25% of design live storage. These tanks, trap the July and August runoff surplus to the crop need. A typical extension and tank integration proposal for Dumerbahal project is shown at ***Fig.-4***.

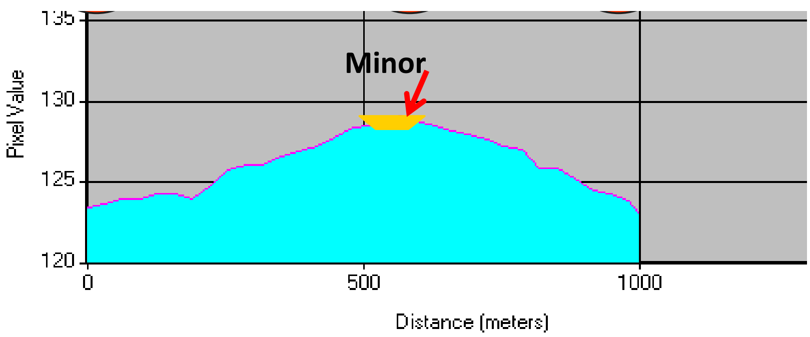

Fig. 3. Typical Terrain Profile of area served by a minor irrigation channel

Fig. 4. Command Area Extension of Dumerbahal Project

- Growing a cash crop over part of the upland (instead of rice) will necessarily save irrigation water from the upland which can be conserved and transmitted to the extended command. In every command high lands adjacent to irrigation channels (0.3 m above FSL) are being levelled and lowered (Patraetal, 1988& Priest, 2000) to receive irrigation as an extension of the command. In the summer (Kharif season) paddy is grown in these lands using deficit irrigation technique (Jurriens, etal 1996). Ponding of water over cropped land is avoided to save deep percolation loss of the order of 3 mm per day. Irrigation release is made after disappearance of ponded water, DAP (Rajkumar etal-1999).
- Escapes provided in the canal are so located that the spilled water during rains (when regulation at the reservoir cannot be instantaneously done) can be conveyed through an extension canal beyond the designated command or to feed marginally high uplands. This is specifically ideal for the steeply sloping terrain in the western region.
- Water use efficiency which was around 35% in all the projects has recorded an increase to 38%, 47% and 43% in Sundar, Saipala and Dumerbahal projects. For Sundar projects extension works are being continued.
- By tank integration and adopting water saving technique the per-capita income of beneficiaries has recorded a significant increase from Rs. 16,000 to 28,000 per ha. by increase productivity and coverage of cash crops.

4. CONCLUSION

Infrastructure of completed irrigation projects in drought prone Western Odisha serving highly undulating steep terrain is being altered / improve by creating additional small tanks 3 to 4 m deep of size 50 ha. or more, on secondary and tertiary drains inside the command. These tanks trap the surplus runoff from both rainfall received on upland and surplus irrigation water. The saving upland flow is enabling irrigation of 20 to 30% over the designated command by appropriate land levelling and shaping and efficient water management practice. Deficit irrigation and water saving techniques are being adopted for appropriate utilisation of the saved overland flow. Case study of three medium projects Sundar, Saipala and Dumerbahal with designated command of 4633 ha., 2064 ha. and 2800 ha., where 10 to 30% of additional area has been benefited by achieving increase of water use efficiency from 35% to as high as 47%.

5. ACKNOWLEDGEMENT

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