© 2015 IJSRST | Volume 1 | Issue 2 | Print ISSN: 2395-6011 | Online ISSN: 2395-602X
Themed Section: Engineering and Technology

Study on Issues and Remedies of Waterlogging in Hirakud Command - Key to Enhance Crop and Water Productivity

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ABSTRACT

The present study deals with finding out the causes of rising groundwater table that creates waterlogging in the Hirakud command of Odisha. The study reveals that during the 55 years of construction of the project, the groundwater table in the command has risen by more than 5 m. In the head reach, the rise is more as compared to the lower reach. The main factors that contribute to the waterlogging are (i) faulty water management practice (ii) intensive rice-rice cultivation (iii) plot to plot irrigation in rice field instead of using field channel (iv) continuous canal flow etc. Some remedies to reclaim the waterlogged areas and decrease the groundwater table are also mentioned in this paper. Construction of parallel field surface drain at 10 m drain spacing is recommended in the ayacut to decline the rising groundwater table which may facilitate the farmers to grow even some non-rice crops in the ayacut and increase water productivity.

Keywords: waterlogging, alarming rate, evapptranspiration, waterlogging, percolation, Faulty water management practice, Intensive rice-rice cultivation, irrigation system, crop diversification, Drainage congestion, toposystem

I. INTRODUCTION

The populations of the world which was 250 crores in half a century ago has already crossed the 700 crores mark and is likely to cross the 900 crores mark in the next 25 years. In India, we have touched 126 crores population and is expected to touch 164 crores by 2050 A.D. To feed such a great population, about 450 million tons of food grain production is barely needed which requires about 100 percent increase in the total food grain production. This will be possible if we enhance the natural resources including both soil and water optimally in a very judicious manner. Irrigation development in India during the post-independence era has greatly facilitated enhancement of agricultural production by increasing the irrigation potential. However, in the wake of such phenomenal strides of irrigation development from 23 M ha (million hectare) in the early 1950's to nearly 109 M ha at present, twin problems of waterlogging and salinity have also come up in the irrigation commands due to hydrologic disturbances beyond the capacity of natural drainage systems. The abundant loss of water in the form of seepage in the conveyance systems is because of earthen canals/channel sections, badly damaged canal outlets etc. coupled with low water application efficiency in the crop field due to improper water management practice. This has resulted in waterlogging and salinization thus rendering vast areas to be unproductive. They not only threaten the capital investment but also the sustainability of irrigated agriculture and have become an environmental concern too. The waterlogged saline soils are found to occur all over the country; about 8.5 M ha area has been salt-affected, of this, 5.6 M ha is waterlogged saline area in the commands of irrigation projects and is commonly referred to as man-made or wet deserts (Balakrishnan et al., 2001). Based on the extrapolation of the data on individual schemes, it is estimated that irrigation induces salinization and waterlogging on an average of 10% of the net irrigated areas (Jain, 2002).

Recently in India, waterlogging in canal irrigated areas is increasing at an alarming rate. In Tungabhadra Project in Karnataka, more than 33000 ha has been reported to suffer from waterlogging and salinity and these areas are increasing at the rate of 600 ha/year. Large areas in Haryana have been rendered waterlogged after introduction of Bhakra canal irrigation. Rising water table in Gujarat has also been observed due to the flow of water in Mahi command.

Rice is the most important crop of India and the second most important crop of the world and is the staple food for nearly half of the world population. Among the rice growing countries, India has largest area under rice in the world (about 43.2 M ha) and ranks second in production, next to China. Rice in India consumes about 66% of irrigation water in the country. The water requirement of rice invariably is put 1000 to 2000 mm (for the irrigated transplanted crop) depending on soil type and climate. Rice is considered to be an inefficient water consumer. Unlike in other arable crops, seepage and percolation losses (SP losses) in rice greatly exceed the evapptranspiration (ET) demand. The SP losses are dependent on soil texture, irrigation practices and crop duration and could vary within 52-93% of the total water expenses (Pande and Mitra, 1992, Panigrahi, 2001). The SP losses in the rice field along with inadequate drainage facility are the major factor to cause waterlogging by raising the groundwater table. Research on drainage requirement of rice or management of the drainage water in India is a neglected component in water management, knowing fully well that when irrigation comes, drainage cannot be left behind. Drainage is an integral part of irrigation water management which provides desirable environment in the crop root zone for healthy growth of crops.

II. METHODS AND MATERIAL

Waterlogging in Hirakud Command

After the construction of the Hirakud dam (Figure 1) across the river Mahanadi in Odisha, there has been a gradual increase in irrigation potential in the pre-divided districts of Sambalpur and Bolangir of Odisha. This project now commands an area of 1.59 lakh ha in kharif and 1.12 lakh ha in rabi. The command area of Hirakud covers 5 blocks in Sambalpur, 6 blocks in Bargarh 2 blocks in Sonepur and 1 block in Bolangir through 4 canal systems i.e. Baragarh main canal, Sason main canal, Sambalpur distributary and Hirakud distributary. Basic details of canal systems of the command are presented in Table 1 (Anonymous, 2005).

Because of the introduction of the project, the average cropping intensity of the command has increased from 110 to 187% during the last 55 years of initiation of the project. The watershed of the command can be divided into 6 major streams which discharge water into the Mahanadi. The sub-watersheds are Ong, Jira, Jhan Jhor, Kuler Jhor, Harda and Malati. The topography of the ayacut is undulating marked by ridges and valleys. The land slope of the ayacut goes as high as 10%. The topography of the command is classified as att (unbunded upland), mal (bunded upland), berna (medium land) and bahal (low land). The major soil texture of the command area is sandy loam and clay loam. Climate is warm, sub humid characterized by hot dry summer and short and mild winter. The average rainfall of the command is 1419 mm. Average temperature varies from a minimum of 90C to a maximum of 45oC. The average groundwater table in the irrigated areas has come up by more than 5.8 m during the last 46 years. There are some pockets in the command where it lies only 0.15 m below the ground level. Commensuration of the project has caused about 20% of the total cultivated area waterlogged in the command where crop diversification is impossible or not cost effective (Behera et al., 2001).

Figure 1. Views of the Hirakud Dam across the river Mahanadi, Odisha

Table 1. Basic details of Hirakud Canal System

Types of canal	Length, km	Area irrigated, ha (*kharif*)	Discharge at canal head, cusec
Main canal (2)			
Bargarh main canal	88	6900	3800
Sason main canal	23	1900	680
Branch canal (2)	35	4070	506 - 906
Distributaries (35)	444.44		7.5 – 38.1
Minor canal (84)	293.64		5.6 – 96.8
Sub minors (32)	74.88	146,091	4.0 – 50.0
Sub sub minors (4)	12.60		3.0 – 10.0
Water courses (2985)	2433.70		1.0 – 3.0
Total	3406.66	158961	

Causes of Waterlogging in the Command

Farmers in the command, especially in the head end of the canal system cultivate rice-rice and grow them under shallow to deep submerged condition. About 97% of the total irrigated area in kharif season is cultivated with rice where 98% of the total irrigation water is consumed by rice. Similarly about 70% of the total irrigated area in rabi is grown with rice consuming about 91% irrigation water. Most of the farmers in the command, especially in head end maintain 15-25 cm ponded waster in the rice field. This has caused serious problems of waterlogging in the command especially in the head and mid reach of the command. In general the main causes of water logging in the command are as follows:

- Faulty water management practice
- Intensive rice-rice cultivation
- Absence of field channels to irrigate the fields
- No rotational irrigation system
- No control over flow i.e. absence of volumetric measurement device to measure and supply irrigation water
- No crop diversification
- Drainage congestion in outlets
- Unlined /badly maintained channels causing major seepage losses in canal system
- Mismatch between the demand and supply system
- Lack of land development and
- Inadequate drainage facilities

One of the most important problems of waterlogging and drainage in the command is the land locked toposystem. The canal that flows in the upland called locally as att land suffers from severe seepage loss. This seepage water continuously flow down and also laterally from the att land to the bahal land (low land) causing stagnation of water in the bahal land (Figure 2). Thus the att land suffers from moisture stress whereas the bahal land suffers from severe waterlogging. It is needless to mention here that both the deficit and excess moisture in the crop field are not congenial to crop growth.

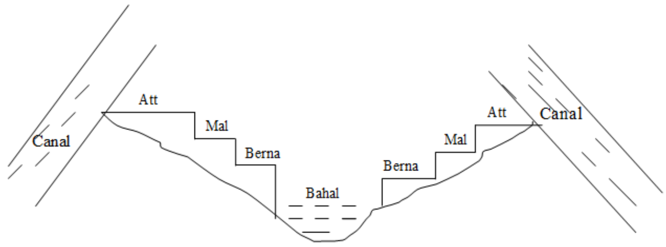

Figure 2. Land lay in Hirakud ayacut

Spatial Variation of Groundwater Table in the Command

Data on rise of groundwater table in the command were collected from different sources for 28 years (1985 – 2012). The four different sources from which data were collected are (i) irrigated area, (ii) areas near to canal (iii) uncultivated areas and (iv) dry farming areas). The depth of water table below the ground level was measured at weekly interval throughout the year for 28 years as mentioned above and the data are presented in Table 2 below.

Table 2. Fluctuation of groundwater table in different areas (average of 28 years, 1985-2012)

Week No.	Depth of groundwater table below ground level, m			
	Near canal	Irrigated area	Uncultivated area	Dry farming area
1	3.93	0.38	3.92	2.42
2	3.60	0.37	3.95	2.33
3	3.90	0.35	3.91	2.25
4	3.91	0.33	3.85	2.30
5	3.95	0.40	3.81	2.31
6	3.99	0.42	3.75	2.18
7	3.86	0.45	3.54	2.28
8	3.95	0.51	3.60	2.34
9	3.93	0.33	3.53	2.36
10	3.87	0.32	3.48	2.20
11	3.92	0.41	3.48	2.23
12	4.03	0.45	3.36	2.40

13	3.90	0.53	3.42	2.45
14	3.65	0.55	3.48	2.50
15	3.77	0.33	3.36	2.34
16	3.89	0.30	3.42	2.52
17	3.99	0.30	3.48	2.65
18	4.05	0.35	3.81	2.28
19	4.19	0.33	3.96	2.35
20	4.28	0.41	4.18	2.36
21	4.39	0.42	4.35	2.41
22	4.55	0.40	4.46	2.45
23	4.60	0.45	4.47	2.40
24	4.28	0.50	4.21	2.15
25	4.05	0.47	3.96	2.02
26	3.81	0.41	3.80	2.00
27	2.25	0.40	1.85	1.85
28	2.28	0.41	1.75	1.65
29	1.98	0.45	1.55	1.54
30	1.95	0.42	1.49	1.50
31	1.65	0.28	1.35	1.32
32	1.87	0.22	1.30	1.25
33	1.58	0.23	1.28	1.22
34	1.55	0.25	1.20	1.20
35	1.50	0.31	1.15	1.24
36	1.53	0.46	1.12	1.32
37	1.58	0.50	1.25	1.30
38	1.60	0.51	1.31	1.25
39	1.75	0.52	1.26	1.20
40	1.80	0.54	1.29	1.46
41	1.99	0.47	1.52	1.50
42	2.00	0.44	1.48	1.52
43	2.02	0.38	1.82	1.54
44	2.10	0.45	1.80	1.45
45	2.65	0.44	1.85	1.50
46	2.85	0.51	1.88	1.88
47	3.10	0.55	2.25	1.90
48	3.05	0.39	2.30	2.02
49	3.25	0.46	3.10	2.10
50	3.18	0.47	3.23	2.25
51	3.83	0.45	3.56	2.35
52	3.88	0.41	3.96	2.32

From the observed data, it is revealed that the water table data in the kharif (standard meteorological weeks 27 to 47 are higher i.e. near to the ground surface than the rabi season in all the places. The depth of water table near the canal varies from 1.50 to 4.60 m, whereas the water table in the irrigated areas, uncultivated areas and dry farming areas varies from 0.22 to 0.55 m, 1.12 to 4.47 m and 1.20 to 2.65 m, respectively. The rise of water table in the irrigated areas is found to be significant compared to other areas. The entire command areas receive water almost throughout the year. The canal operation schedule (mean of last 20 years data, 1990 to 2009) is presented in Table 3. From the table it is observed that the average duration of canal opening period is 278 days and only for 87 days, the canal remains closed. The rise of water table causing water logging and drainage problem in the command areas are mainly attributed to three points. They are (i) intensive rice-rice cultivation, (ii) faulty water management practice especially maintaining deep submergence in the rice field and (iii) high rainfall in the rainy season in conjunction with continuous canal flow. The water table remains at a shallow depth as compared to other areas in the irrigated areas due to continuous infiltration, seepage and deep percolation from the rice field and seepage from the unlined canal systems. The rise of water table is less in the summer months of May to June because of less rainfall in these months and

Table 3. Canal schedule data of the Hirakud command (mean of 20 years)

Sl. No.	Month	Canal opening period	Days
1	Jan	1st Jan - 31st Jan	31
2	Feb	1st Feb – 28th Feb	28
3	Mar	1st Mar – 31st Mar	31
4	Apr	1st Apr – 30th Apr	30
5	May	1st May – 11th May	11
6	June	21st Jun – 30th Jun	10
7	Jul	1st Jul – 31st Jul	31
8	Aug	1st Aug – 31st Aug	31
9	Sep	1st Sep – 30th Sep	30
10	Oct	1st Oct – 31st Oct	31
11	Nov	1st Nov – 8th Nov	8
12	Dec	25th Dec – 31st Dec	6
Total			278

also due to less number of days of canal opening periods. In dry farming areas, the rise of water table is found to be higher than the uncultivated areas because of field bunds raised around the fields to conserve maximum amount of rainfall. This has hastened up the infiltration of conserved rainwater in the field causing rise of the ground water table. It is interesting to note that in the dry farming areas, the rise of water table is higher in the months of rainy season than the winter and summer. The reason may be attributed to the high quantum of rainfall that is received in the rainy season as compared to winter and summer.

The rise of water table is found to be different for different reaches along a canal. In the up end (head reach) of the canal the rise of water table is found to be higher than that in the middle and tail end of the canal. Observations were taken to record the ground water table in 5 places along the canal reach of Baragarh distributary of Hirakud command. Out of these 5 places, two were in the head reach, and two in the middle and one was in the tail reach of the canal. The average groundwater table position in head, middle and tail reaches were recorded for fifty five years (1958 to 2012) and are presented in Table 4 below.

Table 4. Position of groundwater table in the different reaches in the canal in different years

Years	Average groundwater table (below ground), m		
	Head reach	Middle reach	Tail reach
1958	9.66	9.05	10.2
1963	7.01	7.77	8.67
1968	6.45	7.02	8.01
1973	5.02	5.55	7.78
1978	4.11	4.90	7.56
1983	3.78	4.43	7.01
1988	2.65	4.02	6.89

1983	2.11	3.03	6.45
1998	1.89	2.60	6.21
2003	1. 59	2.33	5.98
2007	1.35	2.12	5.78
2012	1.29	2.05	4.80

Data of Table 4 reveals that because of extensive irrigation and continuous water supply in the canal head end, the ground water table has risen up more compared to other two reaches. In the last 55 years, the water table in the head end has come up from 9.66 to 1.29 m whereas in the middle and tail reaches, the water table has come up from 9.05 to 2.05 m and 10.2 to 4.80 m. Thus the data reveals that the drainage and waterlogging problems are becoming severe in the head reach than the middle and tail reaches in the canal in the command. It is apprehended that if the present trend of the irrigation and cropping system (rice-rice) continues, then by 2030 AD, about 45% of the areas of the command would become waterlogged consequently affecting the crop yield severely. It, is hence, felt imperative to study the techno-economically feasible drainage system to reclaim the waterlogged areas or to arrest the upcoming waterlogging problem in canal commands.

III. RESULTS AND DISCUSSION

Affects of Waterlogging

Waterlogging has the following ill effects:

- It decreases soil health
- It decreases microbial activities
- Affects growth and yield of crops
- Increase chance of flooding
- Affects soil temperature
- Causes soil salinity
- Causes water and environmental pollution and
- Hampers in crop diversification

Figure3 shows the affects of waterlogging on stunted crop growth in a chronically waterlogged area.

Measures to Reduce Waterlogging

Waterlogging in the Hirakud command is an alarming situation and unless some tangible measures are taken then the situation will go beyond control and the fertile land will turn into fallow after some decades. In the following paragraph, some of the important remedial measures are mentioned.

- Irrigating rice fields through field channels instead of field to field to irrigation
- Irrigating the rice by intermittent irrigation method instead of maintaining standing water in field always
- Encouraging crop diversification instead of rice-rice cultivation

Figure 3. Affects of waterlogging on stunted growth of crop

- Using accurate irrigation scheduling including proper methods of irrigation
- Adopting water saving irrigation techniques in the crops
- Proper land smoothing and grading using appropriate farm machineries
- Using high tech irrigations like sprinkler and drip especially in fruits, orchards and vegetables which has high application efficiency
- Reduction of seepage and percolation in crop fields
- Using cost effective mulching in crops fields to check soil evaporation and reduce the frequency of irrigation in crop fields
- Decreasing the conveyance losses of canals by lining the canal systems
- Volumetric supply of water in canal commands

- Charging water rates on volumetric basis which will enforce the farmers to use right amount of water in the crop fields.

Surface and Sub-Surface Drainage System

Out of different drainage systems, surface drainage is the simplest and cheapest drainage system. Figure4 shows a surface drainage system for evacuation of excess water from crop field.

Figure 4. An open surface drain used to evacuate excess surface water

Parallel field surface drains are the widely adopted surface drain systems. In the design of parallel field surface drains, one of the most important design parameter is deciding the optimum drain spacing. The drain spacing would be optimum when it lowers down the groundwater table to the maximum amount and thereby facilitating to grow non-rice crops and at the same time it is economically viable. Experiments in the loamy soil at Regional Research and Technology Transfer Station, Chiplima in the command reveal that out of various drainage spacing, 10 m drain spacing works better in lowering down the water table and enables the farmers to grow rice based cropping systems like rice-wheat-mung and rice-mustard-sesamum in chronically waterlogged ecosystem. The six years experiments in the field revealed that the ground water level could be lowered down by 35.3, 32.6 and 29.4 cm below the ground level with 10, 15 and 20 m drain spacings, respectively (Panigrahi and Behera, 2008; Panigrahi, et al., 2007)). Figure 5 shows the fluctuation of groundwater table by different drain spacings by parallel filed surface drains. From the experimental data, it is recommended that in chronically waterlogged ecosystem, excess water from the soil surface as well as the groundwater from the soil sub surface should be evacuated by constructing 10 m parallel field surface drains. Groundwater table in the sub soil region can also be reduced by installing sub surface drains like tile and mole drains at suitable spacing and at suitable depth below the ground level. However, installation of sub surface drains is more costly than the surface drain methods but it has several advantages also. It does not hamper in conveyance of machineries and in farm operation. The costly agricultural lands are also not wasted towards construction of the drains.

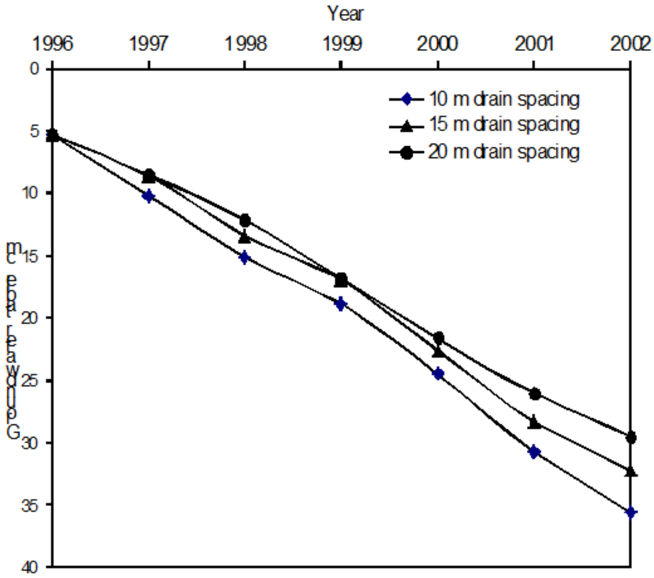

Figure 5. Fluctuation of groundwater table below ground surface

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