International Research Journal of Earth Sciences E-ISSN 2321–2527
Vol. **4(2),** 9-14, February **(2016)** *Int. Res. J. Earth Sci.*

Ground Water Resource Estimation and Budgeting for Sustainable Growth of Agriculture in a Part of Drought Prone Sundargarh District, Odisha, India

P.C. Sahu[1*] and D.Nandi[2]
[1]Department of Geology, M.P.C. Autonomous College, Baripada, Orissa, India
[2]Department of Remote Sensing and G.I.S, North Orissa University, Baripada, Orissa, India
pcsahugeol@gmail.com

Available online at: www.isca.in, www.isca.me
Received 21st December 2015, revised 2nd January 2016, accepted 6th February 2016

Abstract

The study area, a part of the drought prone Sundargarh district is underlain predominantly by hard crystalline rocks of pre-cambrian age. The district often suffers from severe drought condition which causes major crop losses and scarcity of drinking water. The systematic and logical estimation of ground water resources is needed for sustainable utilisation of ground water. In the present study, ground water resource estimation and budgeting has been carried out for sustainable growth of agriculture in a part of drought prone Sundargarh district, using the inputs derived from the satellite data and ground hydro-geological surveys. The present study reveals that the stage of ground water development in the area is very low (5%). All the blocks come under White/ Safe categories. The total ground water balance of the study is as on december 2014 is 15,367 HM, out of which 13,810 HM can be utilized for additional irrigation purpose. It has been estimated that a total additional area of 17,287 hect. and 10,372 hect. can be irrigated during Kharif and Rabi seasons respectively. Hence, this area requires vast development of ground water through suitable structures to combat drought. The development of balance ground water resources will certainly provide irrigational facility round the year. In the study area, the ground water can be developed through dug wells, dug-cum-bore wells and bore wells. In low lying area, the ground water development is feasible through dug wells with depth range 8-10 m. The recommended diameter of the well is 4 to 6 m. Each dug well can have command area of 0.75 to 1 hect. In case of moderately elevated area, ground water can be developed through dug wells and dug-cum-bore wells. In the high land areas, the suitable structures for ground water development are bore wells having a depth range or 50-70 m. Each bore well can have command area up to 8 hect.

Keywords: Aquifer, Draft, Hydrogeology, Specific yield, Sustainable.

Introduction

During the last few years, the demand for ground water has increased manifold in India to enhance agricultural production and for meeting the domestic need. The importance of the role of groundwater to meet water supply requirements for domestic, industrial and agricultural use needs no emphasis[1]. Even in areas where surface water irrigation facilities exist, necessity of ground water exploitation is realized for supplementary irrigational and other uses. Therefore, the optimum utilization of water resources is vital for integrated and intensive development of the agro-economy of the area. This necessitates quantification of ground water resources as an essential pre-requisite for sustainable micro-level and macro-level area planning. The ground water potential of a region can be optimally harnessed to address several need based programme like assured irrigation, safe drinking water etc[2]. The systematic and logical estimation of ground water resources is needed to guard against the over exploitation of the available ground water resources[3]. Groundwater budgeting for a particular basin can be very useful for efficient management of groundwater resources[4]. In the present study, ground water resource estimation and budgeting has been carried out for sustainable growth of agriculture in a part of drought prone Sundargarh district, Orissa, using the inputs derived from the satellite data interpretation and ground hydro-geological survey.

The ground water potential in the state is very high[5]. There is a great scope for utilizing the degraded land for productive use by proper land and ground water management in Orissa. The available ground water is sufficient to grow intensive agricultural crops, pulses and cereals in addition to tree and orchard crops.The hydro geomorphic units like alluvial plains, intermontane valleys and deeply weathered buried pediplains have good ground water potential and suitable ground water structures can be constructed to harness ground water for sustainable growth of agriculture and mitigating drinking water problem in tribal dominated drought prone Bonai area of Sundargarh District, Orissa[6]. Only 10% ground water resources has so far been utilized in Bolangir district indicating a vast scope of future ground water development in the district[7]. Ground water resource estimation and budgeting has been carried out by many workers in different parts of Odisha[8-10].

Study Area: The study area occupies the eastern part of the Sundargarh district, lying towards the northern extremity of

Orissa. It is bounded by the north latitudes 210 35' – 220 10' and east longitudes 840 30' – 850 25' and falls in the Survey of India Toposheet Nos. 73B/12, 73B/16, 73C/9, 73C/10, 73C/13, 73C/14, 73F/4, 73G/1, 73G/2 and 73G/5. It is delimited by the state of Jharkhand in the northeast, Keonjhar district of Orissa in the east, Deogarh and Angul districts in the south, Sambalpur district in the west and Panposh subdivision of Sundargarh district in the north. The total geographical area of the study area is around 2200 sq.km. The area experiences mild to normal drought frequently. Physiographically the area is marked by hills with intervening narrow intermontane valleys, isolated hillocks and flat to gentle undulating plains. The area is underlain by crystalline rocks[11]. The lithological assemblage comprises of Banded Hematite Quartzite (BHQ), Banded Hematite Jasper (BHJ), Quartzite, Phyllite, Slate, Mica-Schist, Staurolite-Schists and Granite, which are intruded by dolerite dykes. These rocks are intensely folded, fractured and have been weathered to varying degree at different places. The occurrence and movement of groundwater depends mainly on secondary porosity. The dolerite dykes form barrier for movement of groundwater resulting in compartmentalization of the groundwater regime. Lateritic soils of considerable thickness is a good repository of groundwater due to their high porosity and permeability. The groundwater potential of alluvium is very good.

Methodology

In the study area, the ground water resource estimation has been carried out block wise for the year 2014 using "Water Table Fluctuation Method" recommended by the Ground Water Estimation Committee (GEC-97) constituted by the Government of India. In this method, the thickness of aquifer (T) is determined based on water table fluctuation recorded from the observation wells. Specific yield(s) of each aquifer/ formation is taken from the pumping test data. By multiplying the aquifer thickness (T) with specific yield(s) and rechargeable area (A), the gross ground water is worked out[12]. For the calculation of rechargeable area (A), satellite data have been used. In the present study, data of the hydro geo morphological map prepared from IRS-IA (LISS II) have been used. The other data include Survey of India Toposheets, geological maps and reports published. The various data collected from dug wells during the well inventory includes location, diameter and depth of wells, depth to water table during pre-monsoon and post-monsoon (2014) and use of ground water etc. Table-1 shows the yield potential of different Litho-Units in the study area[13]. For the estimation of ground water draft, unit draft method based on 100% well inventory is used. The ground water balance has been computed by subtracting the net groundwater draft from the net utilizable resources. The stage of groundwater development is calculated by using the following formulae.

$$\text{Stage of ground water development (\%)} = \frac{\text{Net ground water draft X 100}}{\text{Net utilisable ground water resources}}$$

Results and Discussion

The ground water resource estimation, draft estimation and budgeting (block-wise) for the year 2014 are presented in tabular form (Table-2 to 5).

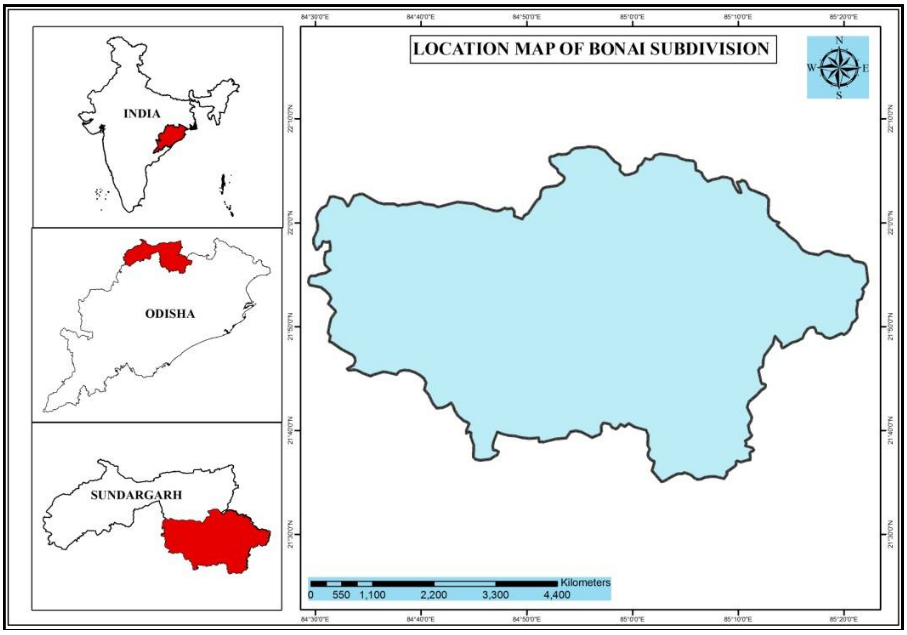

Figure-1
Location map of the study area

Table-1
Yield potential of different Litho-Units

Lithounits	**Depth range of saturated fracture (mbgl)**	**No. of saturated fractures occurring at different depth ranges**				**Yield (lps)**	
		Up to 60m depth	**60 – 100m depth**	**100 – 150m depth**	**150 – 200m depth**	**Range**	**Avg.**
Granitic rocks	11 – 200.0	1 to 3 sets, Very common	Mostly 1 set Very common	Mostly 1 Set less common	1 set, only in one well	Negligible - 20	3 - 10
Mica schist	3.2 – 178.9	1 to 4 sets Very common	1 set less frequent	1 set less frequent	--	Negligible - 11	1 - 2
Phyllite	18 – 99.5	1 to 4 sets Very common	1 set very rare	--	--	Negligible - 8	1 - 2
Basic meta-volcanics	19 - 87	1 to 4 sets common	1 to 2 sets	--	--	2 - 12	3 - 5

Table-2
Groundwater Resource Estimation and Budgeting (Bonai Block)

Resource

1. Gross Groundwater Resource	5034.62 HM
2. Net Utilisable Resource (70% of Gross)	3524.23 HM

Draft (Based on Well Census)

1. Gross Groundwater Draft (Annual)	361.00 HM
2. Net Groundwater Draft (70% of Gross)	252.70 HM
Groundwater Balance	3271.53 HM
Stage of Development	7.17%
Category	**WHITE / SAFE**
Allocation	
1.Domestic and drinking (10% of balance)	327.15 HM
2. Available for irrigation	2944.38 HM

Table-3
Groundwater Resource Estimation and Budgeting (Gurundia Block)

Resource

1. Gross Groundwater Resource	5621.62 HM
2. Net Utilisable Resource (70% of Gross)	3935.13 HM

Draft (Based on well census)

1. Gross Groundwater Draft (Annual)	430.00m HM
2. Net Groundwater Draft (70% of Gross)	301.00 HM
Groundwater Balance	3634.13 HM
Stage of Development	7.65 %
Category	**White / Safe**
Allocation	
1. Domestic and drinking (10% of balance)	363.41
2. Available for irrigation	3270.72 HM

Table-4
Groundwater Resource Estimation and Budgeting (Koira Block)

Resource		
1.	Gross Groundwater Resource	5081.97 HM
2.	Net Utilizable Resource (70% of Gross)	3557.37 HM
Draft (Based on well census)		
1.	Gross Groundwater draft (Annual)	163.00 HM
2.	Net Groundwater Draft (70% of Gross)	114.10 HM
Groundwater Balance		3443.27 HM
Stage of Development		3.20%
Category		**White / Safe**
Allocation		
1.	Domestic and drinking (10% of balance)	344.32 HM
2.	Available for irrigation	3098.95 HM

Table-5
Groundwater Resource Estimation and Budgeting (Lahunipada Block)

Resource		
1.	Grouses Ground water Resource	7493.81 HM
2.	Net Utilisable Resource (70% of Gross)	5245.66 HM
Draft (Based on well census)		
1.	Gross GW Draft (Annual)	325.00 HM
2.	Net GW Draft (70% of Gross)	227.50 HM
Groundwater Balance		5018.16 HM
Stage of Development		4.34%
Category		**White / Safe**
Allocation		
1.	Domestic and drinking (10% of balance)	501.81 HM
2.	Available for irrigation	4516.35 HM

Ground Water Potential: The study reveals that the net annual utilizable ground water resource of Bonai, Gurundia, Koira and Lahunipada blocks are 3,524.23 HM, 3,935.13 HM, 3,557.37 HM and 5,245.66 HM respectively. These findings are in accordance with the findings of Paul and Sahu (2000) who reported that the groundwater potential in the state is high. The maximum annual utilizable ground water resource is in Lahunipada block and minimum is in Bonai block. The net ground water draft of Bonai, Gurundia, Koira and Lahunipada blocks are 252.70 HM, 301..00 HM. 114.10 HM and 227.50 HM respectively. The maximum ground water draft is in Gurundia block and minimum is in Koira block. The groundwater balance as on December 2014 of Bonai, Gurundia, Koira and Lahunipada blocks are 3,271.53 HM, 3,634.13 HM, 3,443:27 HM and 5,018.16 HM respectively. The total ground water balance of the study area is 15367.09 HM out of which 13830.39 HM can be utilized for additional irrigation purpose. The stage of ground water development of Bonai. Gurundia. Koira and Lahunipada blocks are only 7.17%, 7.65%, 3.20% and 4.34% respectively. All the blocks come under *White/ Safe* categories. The ground water development in the study area is abysmally low which need further development through suitable ground water structure to combat drought.

Prospects for Ground Water Development: As the present level of ground water development in the study area is low (5%) and the total irrigated area from all sources is also very less. The development of balance ground water resources will certainly provide irrigational facility round the year. In the study area, the ground water can be developed through dug wells, dug-cum-bore wells and bore wells. But deep bore wells appear to be advantageous structure for ground water exploitation due to their high yields, and continuous discharge throughout the year and utilization of deeper storage ground water. In low lying area, the ground water development is feasible through dug wells with depth range 8-10 m. The recommended diameter of the well is 4 to 6 m. Each dug well can have command area of 0.75 to 1 ha. In case of moderately elevated area, ground water can be developed through dug wells and dug-cum-bore wells. In the high land areas, the suitable structures for ground water development are bore wells having a depth range or 50-70 m, since the potential fracture zones are restricted within a depth of 70m. Each bore well can have command area up to 8 ha.

The intensity and spacing of different ground water structures has been worked out basing on the utilizable ground water potential available for each block of the study area. In the Precambrian crystalline areas, optimum spacing between two adjacent wells should be 150 m to 380m and intensity should be 3 to 4 per sq.km. and 11 to 40 per sq.km. for standard dug well with pump set and tenda respectively. Table 6 shows the feasibility of groundwater structures in different geomorphic Units in the study area[13].

Irrigation Potential: The balance ground water resources that can be safely used for irrigation purpose in the area has been estimated to be 13,830 HM. This quantity of ground water can safely sustain installation of 13,830 numbers of additional standard dug wells with pump sets in addition to the existing ground water structures. It has been estimated that a standard dug well with pump set can irrigate an average area of 1.25 ha. for Kharif crops and 0.75 ha. for Rabi crops. Therefore, a total additional area of 17287 ha and 10372 ha. can be irrigated during Kharif and Rabi season respectively. With the ground water development in the Bonai area the cultivable wastelands can be managed scientifically. Table 7 shows the block wise existing groundwater structures and further feasible groundwater structure and additional irrigation potential in the stydy area[13].

Conclusion

Since the state of development of ground water in the area is very low, there is a vast scope for ground water development through suitable structures to face drought condition. A large scale intensive ground water development programme needs to be launched on a scientific basis. Large scale planning for ground water development should be done by intensive hydro geological and geophysical survey aided by remote sensing and GIS. The combination of applied geophysics, hydro geology, remote sensing and GIS show a tremendous promise for groundwater exploration, exploitation development all over the world[14]. The most suitable planning for the assured source of supply round the year can be achieved by different type of site specific ground water structures such as dug wells, dug-cum-bore wells and bore wells. The change in cropping pattern and adoption of modern irrigation practices like sprinkler and drip irrigation system is the need of the hour. The farmers should be educated through agricultural extension services to adopt suitable cropping pattern especially drought tolerant crops for optimum utilization of available ground water resources. Artificial recharge techniques should be adopted for conservation and augmentation of ground water as it holds the key for sustainable growth of agriculture in a drought prone area.

Table-6
Feasibility of Groundwater Structures in different Geomorphic Units

Geomorphic Units	Type of Structures	Depth Range (m)	Diameter (m)	Yields (lps)	Command Area (Hect)
Low lying Areas	Dug well	8 - 10	4 - 6	< 5	0.75 - 1
Moderately elevated areas	Dug well	10 - 15	4.5 - 6	< 3	0.5 - 0.75
	Dug-cum-bore well	10 – 15(DW)+30m (BW)	4.5 - 6 (DW) 100mm(BW)	Upto 5	1 to 1.5
High land areas	Bore well	50 - 100	150mm	< 10	Upto 8

Table-7
Groundwater Structure and Additional Irrigation Potential (hect)

Name of the Block	Existing Groundwater Structure			Further feasible Groundwater structure dug wells with pump sets	Additional Irrigation Potential (Hect)		
	Dug well with Tenda	Dug well with pump sets	Bore wells		Kharif	Rabi	Total
Bonai	613	155	11	2944	3680.00	2208.00	5888
Gurundia	549	263	01	3271	4088.75	2453.25	6542
Koira	287	77	--	3099	3873.75	2324.25	6198
Lahunipada	602	138	03	4516	5645.00	3387.00	9032
TOTAL	**2051**	**633**	**15**	**13830**	**17287.50**	**10372.50**	**27660**

References

1. Karanth K.R. (2008). Groundwater Assessment, Development, and Management, Tata McGraw-Hill Publishing Company, New Delhi.

2. Mahapatra S. (2000). Ground water Resource Assessment based on GEC (1997) Norms, A case study of sample blocks. Proceeding from CGWB: W*orkshop on prospect of Ground water Development and Management in Orissa*. Bhubaneswar, Orissa, India.

3. Ballukraya P.N. (1997). Ground Water Over-exploitation- A case study from Moje-Anepura, Kolar District, Karnatak. *J. Geol. Soc. India, 50*, 227-282.

4. Rajora R. (2002*).* Integrated Watershed Management, Rawat Publishers, Jaipur.

5. Paul J.C. and Sahu A.P. (2000) Wasteland Development and Management through exploitation of Ground Water in Orissa. *Yojana, Feb*. 29-30.

6. Sahu P.C. and Sahoo H.K. (2006). Pollution of drinking water by iron in tribal area of Sundargarh district Odisha: A guide to community health workers and non government organization. *Eco biology of Polluted waters*. Daya Publishing House, New Delhi. (6) 64-70.

7. Kar A.J. (2000). Climatic Aberration and role of ground water in sustainable growth of Agriculture and mitigating Drinking water need in drought prone Bolangir district, Orissa*:* Proceeding from CGWB*: Seminar on Ground Water resources of Orissa for 2020*. Bhubaneswar, Orissa, India.

8. D. Nandi, I. Mohanta and S. Mishra (2015). Delineation of Groundwater Prospective Zones by Schlumberger electrode array in Bangriposi block of Odisha. *International Research Journal of Earth Sciences, 3(4*), 5-11.

9. D. Nandi, J. Kant, C.K. Sahum (2015) Integrated Approach Using Remote Sensing And GIS For Hydrogeology Of Moroda Block InMayurbhanj District, Odisha, India, *International Journal of Conservation Scienc*e, *6(3)*, 383-390.

10. Nandi D Sahu P.C. and Mondal S. (2015) Ground Water Potential Studies Using Geo-Spatial Technique A Case Study In Karanjia Block of Odisha, India, *International Journal of Recent Scientific Research,* (6)11, 7380-7384.

11. Mahalik N.K. and Nanda J.K. (2006). *Geology and Mineral Resources of Orissa*. SGAT Publication, Bhubaneswar, Odisha, India.

12. Reddy P.R. (1999). Remote Sensing in Ground Water Studies. In: DP Rao(Ed.). *Remote Sensing for Earth Resources (2nd Edition).* Hyderabad: Asso. Expl. Geophysicists, 183-203.

13. Sahu P.C. (2004). Hydrogeological Studies in the Bonai subdivision of Sundargarh district, Orissa, India, (Unpublished doctoral dissertation). Sambalpur University, Burla.

14. Nath S.K., Patra H.P. and Shahid S., (2000). *Geophysical Prospecting for Groundwater*, Oxford and IBH Pub. Co. Pvt. Ltd. New Delhi, 152.