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WATER RESOURCES EVALUATION THROUGH WATER ACCOUNTING: A MEANS TO ACHIEVE SUSTAINABLE DEVELOPMENT

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ABSTRACT

This paper attempts to assess the water balance using water accounting in the undulating terrain region of Jharkhand and discusses the relevance of water accounting indicators. Various water accounting fractions have been assessed to identify the water status. Water accounting uses a water balance approach to quantify the amount of water entering a system through gross inflow, outflow and depletion. Results show that although the gross inflow is high (932 BCM) still the region is facing water crisis. Process depletion and non-process depletion are less compared to the available water. A major part of available water goes off as runoff. The present water resource assessment and the sectoral water resource demand of this state indicates that the demand is less than the net inflow. 68% of the gross inflow is being depleted due to process and non – process uses, 40% of the available water goes off as process and non process depletion, rest unutilized and goes off as runoff. According to the results obtained the region is water safe and should not face water crisis as the consumption is 15% of the total water available. Problem is not in the consumption pattern, so there is a need to study the geoenvironmental parameters of Jharkhand.

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INTRODUCTION

Water is becoming the limiting factor for development in almost all parts of the world. Availability of water is highly uneven in both space and time (National Water Policy, 2002). It is likely that 78% of the world's population will live in areas facing physical or economical water scarcity by 2025 (IWMI, 2000). The overexploitation of ground water has resulted in the depletion of water table (UNESCO, 2000). According to Baccini and Bader, 1996 the criteria's which are important for sustainability is that the extraction rate should not exceed the rate of renewal of the resources and the rate of waste generation should not exceed the assimilative capacity of the environment. A systematic approach is therefore needed to communicate how water is being used and how water resource developments will affect present use patterns (Peranginangina *et al.*, 2003). In physically water scarce region, there is simply not enough water to meet agricultural, industrial and domestic needs. In economically scarce region, there has been relatively little water development and substantial investment must be made to increase water supply by atleast 25% by 2025 to meet basic water needs. Increasing the productivity of water to obtain more value for each drop of water used can play a key role in mitigating scarcity (Molden *et al.,* 2001). To understand the water problem, it is important to understand the water balance of the region. It incorporates the relationship between geogenic (natural) recharge rates and anthropogenic demands (Binder *et al.,* 1997). Constructing a water balance is one of the first tasks in understanding the water regime of a specific area with special focus on consumption patterns and water diversions within a hydrological cycle (Wright, 1964). A water balance is a budgeting exercise that assesses the proportion of rainfall that becomes stream flow (runoff), evapotranspiration, drainage (ground water recharge) (Mehta *et al*., 2006) and various other water paths (Bos, 1979). India's water budget has been discussed by Gupta and Deshpande (2004), Kumar *et al.,* (2005) and Garg and Hassan (2007). Various scientists have proposed various terminologies for describing water within a basin (Keller and Keller, 1995 and Jensen, 1993) like Willardson *et al.,* in 1994 used the term fractions to define water within a basin. Special tools and directed actions are needed to most effectively utilize scarce water resources. This paper uses the concept of water accounting to assess the water resources of the region. Previously water accounting has been performed at irrigation level, basin level and field level (Molden *et al.,* 2001). In this paper the same approach is being used to account water at regional level.

A water-accounting procedure was introduced by Molden (1997) and developed by Molden and Sakthivadivel (1999) to address this need. The Molden and Sakthivadivel (M–S) procedure provides terminology and measures to describe the use and productivity of water resources. It has proven useful to identify means for improving water management and productivity while maintaining environmental integrity and is now being applied in The Philippines, Nepal, Pakistan, India, Sri Lanka, and China (IWMI, 1999; Molden *et al.,* 2001).

Study area

Jharkhand, the 28th state of India lies between latitude 21° 58'N and 25° 18'N and longitudes 83° 20'E and 87°57'E. The state covers an area of 79,714 sq km and is divided into twenty two administrative districts (RGNDWM, 2005). According to 2001 census the total population of Jharkhand is 26.90 million (26909428), the population shows a decennial increase of 23.19% between 1991 and 2001. Climatically the state falls in monsoon belt. The basic reason behind in considering our state is because of the presence of hilly terrain, steep slopes and undulating topography where most of the rainfall goes as waste as heavy run-off. The monsoon season is characterized by heavy average rainfall of 1300mm as an average. Most of the rainfall occurs due to the SW monsoon in this region. Physically Jharkhand is a plateau area which has turned into a peneplain with numerous hills, hillocks and residual mountain chains (Singh, 1998). This pleateau is a continuation of the plateau region of the peninsular India. The general slope is towards East and South East. The state of Jharkhand presents a complex geology starting from oldest Supra crustals of Archean age to recent alluviums. Physiographically the region is a rugged terrain, full of residual hilly ranges, rocky exposures and basins of hilly streams (Oraon, 2003). Physical elements like precipitation, temperature, wind, rivers, frosts etc. have fully eroded the original rocks of this area so the region has become a peneplain. In tertiary period during the upliftment of the Himalayas this region went through three successive block upliftment. Erosion, deposition, intrusion, eruption, faulting, uplifting, tilting, etc had controlled the final landscape of Jharkhand, which we see now. Thus whole of the state has plateaus, hills, valleys, scarps and rides. The drainage of Jharkhand is basically rainfed and there is hardly any other source of water. This region has considerable slope which allows quick run of rainwater and hardly allows water to penetrate below. According to CGWB groundwater is 21% utilized in Jharkhand and they are under safe category. Even then the state is facing water crisis. The colour of soils indicates their organic content. High content of ferric oxide and bauxite make the soil look red in colour. Soils vary in colour from laterite of plateaus to yellow grey loam and black and brown soil in valley beds. The degradation of forest and increase in built up area is also one reason for the emerging water scarcity in the region (Avishek *et al.,* 2008).

MATERIALS AND METHODS

The methodology adopted for the water resource assessment is based on water balance approach using water accounting parameters and indicators.

Water accounting uses a 'water balance' (Molden, 1997) approach to quantify the amount of water entering a system (through precipitation and river and groundwater flows) and the amount leaving a system (through evaporation, plant transpiration and river and groundwater flows). The amounts depleted within the basin/region are then classified according to use, whether or not the use is intended and whether or not it is beneficial.

The accounting procedure was given by Molden and Sakthivadiel (1999) to identify the reasons for water savings and increased productivity of water where water balance approach was used and the different water outflows and inflows were classified into water accounting categories. Generally for analyzing water basin is considered (Keller and Seckler, 1996; Seckler, 1996) which can be opened or closed. All the committed water in a closed basin can be utilized but any increase in depletive use of water in any part of the closed basin will lead to decrease use of the other part of the basin.

Water Accounting Definitions: According to Molden and Sakthivadivel, 1999, the following definitions were given for Water Accounting.

Water depletion: It is a use or removal of water from a water basin that renders it unavailable for further use.

Available water: It represents the amount of water available for use and includes process and non-process depletion, plus utilizable outflows.

Net inflow: It is the gross inflow plus any changes in storage.

Gross inflow: It is the total amount of water flowing into the river basin or defined area from precipitation, rivers and subsurface sources (groundwater).

Committed water: It is that part of outflow from the basin or defined domain that is committed to other uses such as downstream environmental requirements or downstream water rights.

Uncommitted outflow: It is the water that is neither depleted, nor committed and is therefore available for a use within the domain, but flows out of the basin due to lack of storage or sufficient operational measures.

Process depletion: It is that amount of water diverted for use that is depleted to produce a human-intended product.

Non-process depletion: It occurs when water is depleted, but not by a human-intended process. *Non-process depletion* can be either *beneficial* or *non-beneficial.* For example, evaporation from fallow land would generally be classified as non-beneficial while evaporation from forests would generally be considered beneficial.

Water Accounting Indicators: The indicators have been presented in the tables (Table 1), while the calculation of the indicators have been shown in table 2. Table 3 contains the results of calculated indicators with respective consequence.

Table 1: Indicators of water accounting

Indicators	Calculation
Gross Depletion Fraction	Depleted/ Gross Inflow
Available Depletion Fraction	Depleted/ Available
Available Process Fraction	Process Depletion/ Available Water
Beneficial Utilization	Beneficial Depletion/ Available water
Depleted Process Fraction	Process depletion/ total depletion
Process Productivity	Productivity / process Depletion

Table 2: Water accounting at regional/field level

S.N.	Parameters	Processes	Units in BCM	Grand Total in BCM
1	Gross Inflow	Precipitation	103	932
2		Surface Inflows	829	
3		Sub Surface Inflows	—	
4		Surface Diversions	—	
5	Storage Change	Surface	—	——
6		Sub Surface	—	
7	Net Inflow	Gross – Storage Change	932	932
8	Depletion	Non Process Depletion:		41.16+595.1=636.3
		Evaporation:	36	
		Crop Evapotranspiration:	5.16	
		Process Depletion:		
		Irrigation:	524	
		Domestic:	30	
		Industries:	30	
		Power:	9	
		Others:	2.1	
9.	Outflows	Uncommitted:	61.8	62.58
		Runoff:		
		Seepage	0.78	
10	Available Water			62.58+636.3+932= 1578.3

RESULTS

Table 2 shows the various components of water accounting for the state of Jharkhand. These values are based on the ground data provided by various governmental bodies of the state. The rainfall data, process and non process data were obtained from Ranchi Municipal Corporation, Central Ground water Division, Ranchi and Central ground water Directorate, Ranchi. These data were then put in the Table 2. According to Central Ground Water Board, New Delhi, 60% of annual rainfall in Jharkhand goes off as runoff due to its terrain characteristics.

Analysis

Based on the parameters of water accounting it is inferred that the region receives a good amount of water through gross inflow. Non-process depletion was very less 41.16 BCM as compared to process depletion of 595.1 BCM indicating that the total depletion of 636.3 BCM is less than the gross inflow. As compared to

Table 3: Water accounting indicators

S.N.	Indicators	Formula	Results	Comments
1	Depleted Fraction (gross)	Total Depletion/ Gross Inflow	0.68	A value of 0.68 is indicative of the fact that 68%of the gross inflow is being depleted due to process and non-process uses.
2	Process Fraction	Process depletion/ Total Depletion	0.93	It is indicative of the fact that almost 93% of the depletion is due to utilization of water in various sectors.
3	Depletion Fraction (Available)	Depletion/ Available Water	0.40	It indicates that only 40% of available water goes off as process and non-process depletion and rest 60% is unutilized and goes off as runoff.
4	Process fraction (available)	Process depletion/ Available Water	0.37	It indicates that only 37% of available water is the actual consumption in the region.

the gross inflow the total water utilized and depleted is very low.

The water loss due to evaporation and evapotranspiration is almost same as that required by different sectors and there has been no significant change in its values from 1970-2002. The uncommitted runoff comes out to be 62.5 indicating that the loss is very minor when in contrast with the gross inflow though it is 60% of the annual rainfall.

From the water accounting parameters various water accounting indicators were calculated (Table 3), taking into consideration total depletion or the process depletion to that of either the gross inflow or the available water. Depleted fraction (gross) indicates the fraction of total depletion by that of gross inflow. A value of 0.68 is indicative of the fact that 68%of the gross inflow is being depleted due to process and non-process uses. It is therefore surmised that that the region receives a good amount of precipitation and surface inflow of which 32% is unutilized. Process fraction is the process depletion by the total depletion, which is about 93% indication the depletion due to utilization of water in multifarious sectors. Depletion fraction (available) is 40% reflecting the amount of available water which goes off as process and non-process depletion and rest 60% which is unutilized and goes off as runoff. A value of 37% draws conclusion that it is the amount of available water that is the actual consumption in the region. According to the above fractions the region is water safe and should not face water crisis.

DISCUSSION

Water accounting is a procedure to identify the water entering and leaving the system. Clearly, water should not be depleted beyond the limit of the available water. The reliability of water availability estimates depends on the accuracy of individual water balance components. Process and non-process depletion is required for the final calculation of water accounting parameters. At regional level the depletion of water by non-agricultural process and return flow from that process is considered. Whenever the method of water accounting is adopted it assist in better understanding of the present status of water as well as allocation in various sectors for different uses. This finally results in saving the water resources as well as utilization of the same. This method has been found relevant even at regional level. The indicators of water accounting have shown the characteristic of the region correctly. Therefore accuracy can also be obtained if carried out at basin level. Though the calculations reflect that sufficient amount of water is entering the system still Jharkhand is declared drought prone mostly every year. The domain is not capable of holding the water resulting into water crisis.

Some methodologies like Methodology for Water Management Balance Assessments used for Autonomous Province of Vojvodina (1987), and Water Management Master Plan of Serbia (in Serbian, 2001) were not considered for the present study. Latest work and new methodology which was adopted by Molden (1997) of water balance approach was considered. The method relies on current datas and the present institutional and governmental organizations of Jharkhand.

Majkic *et al.,* (2001) considered parameters like amount of water vapour in the atmosphere, precipitation, evaporation, runoff. Some other parameters were also taken like variation in surface water and groundwater volume and groundwater flow during a specific time interval and unit vector perpendicular to the contour of the unit surface area was considered for their study. But due to unavailability of unit vector perpendicular to the contour of the unit surface area the above method was not feasible for the present study of Jharkhand.

The Water Cycle report, Barron Queensland which included urban treated effluent, irrigation drainage returns and irrigation channel outfalls returns. System gains for instance seepage from surface water features like dams, wetlands, etc. and seepage from streams to groundwater, inflow from aquifers outside the domain, aquifer reinjection groundwater discharge to springs were some of the parameters that were bifurcated for further accuracy. The present study consists of datas which was in combined form available from the Governmental institutions of Ranchi.

CONCLUSION

According to the fractions, it is inferred that the consumption of water is not a problem in the region. Infact the rainfall is really good and thus it brings good inflow into the region. The process of water accounting describes the components of inflow and outflows along with consumption pattern. This method has been found to relevant even at regional level. The indicators of water accounting have shown the characteristic of the region correctly. As per the fractions it is evident that it is not the consumption pattern of water that is leading to water crisis neither the region receives less rainfall. But the problem lies in the fact that huge volume of water goes off as runoff. It is due to the geoenvironmental parameters that must be affecting the water conditions. This is due to the terrain characteristic of the region. Secondly, rain water is not able to reach the permeable zone. Thus water management measures needs to taken for capturing the running water. This could be done through increasing the overall groundwater development and irrigation measures.

Audit is a study involving qualitative and quantitative analysis of water consumption, its reuse and recycling. Water audit is an effective management tool for minimizing losses, optimizing various uses and thus enabling considerable conservation of water not in irrigation sector alone but in other sectors of water use such as domestic, power and industrial as well (GOI, 2005). A water audit can identify the current status of water resources at different scales and trends in demand and use, provide information on access and entitlements to water and the trade-offs that have resulted or will result from different patterns of water use (Andhra Pradesh Rural Livelihoods Programme, 2003). The basic significance of water audit is identifying the Water Balance, identification of problem and water scarcity areas, better resource (water) management and reduced water degradation. The key indicators of sustainable water resource development should be considered when water accounting is done. They are water demand and forecasting, water quality, capacity of reservoirs, ground water fluctuations, precipitation and recharge. Water accounting has thus proved to be an effective mean to study the water balance of the region with an added advantage that it requires less field data as compared to other approaches.

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