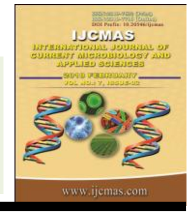
Int.J.Curr.Microbiol.App.Sci (2018) *7*(2): 1223-1232

EXCELLENT PUBLISHERS

International Journal of Current Microbiology and Applied Sciences
***ISSN: 2319-7706* Volume 7 Number 02 (2018)**
Journal homepage: http://www.ijcmas.com



Original Research Article https://doi.org/10.20546/ijcmas.2018.702.150

Assessment of Ground Water Resources for Irrigation in Nalanda District of South Bihar, India

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Keywords

Ganga alluvial plain, Ground water, GEC 97, Watertable Fluctuation technique, Groundwater draft

Article Info

Accepted:
10 January 2018
Available Online:
10 February 2018

A B S T R A C T

Ground Water remains the lifeline of socioeconomic development in the Ganga Alluvial Plain (GAP) since the down of civilization in the Indian subcontinent. Assessment of groundwater resources yields knowledge necessary for their informed management and governance. Keeping the importance of the above points a study was conducted for assessment of ground water resources in Nalanda district of south Bihar. The aim for the assessment of groundwater in Nalanda district was to compute a complete evaluation of groundwater resources and produce information that can be incorporated for future requirement. The study was undertaken based on the recommendation of groundwater estimation committee, 1997 (GEC-97). Methodology used the estimation of annual groundwater recharge from rainfall and other sources, including irrigation, water bodies and artificial recharge, determination of present status of groundwater utilization and categorization of assessment units based on the level of groundwater utilization and long-term water level trend. Water level fluctuation techniques and empirical norms were used for recharge estimation. The data collected for investigation were water table fluctuation data, rainfall data cropping pattern, number of groundwater structures, hydrogeology of area, specific yield, groundwater draft, pond area etc. The study revealed that total annual ground water recharge is 76898 ha-m for Nalanda district. The existing ground water draft for irrigation is 38226 ha-m for Nalanda district. The ground water draft for all uses is 42327 ha-m for Nalanda district. The net annual replenishable ground water resource is worked out to be 73054 ha-m for Nalanda district. The net annual ground water available for future irrigation development is 25100 ha-m for Nalanda district. The stage of ground water development is 58% for Nalanda district. According to definitions used by CGWB Nalanda district falls in safe category. The study recommended that there is a good scope for future groundwater development and keeping in view of rapid increase in groundwater draft, roof top rainwater harvesting needs to be taken up to recharge the aquifer in Patna and Gaya district particularly in urban areas.

Introduction

India Constitutes about 15 % of the world's Population, but only about 2 % and 4 % of World's land area and water resources, respectively. The gap between the availability of limited natural resources and the ever growing population are very crucial for addressing the sustainability issues in Indian context. Groundwater has an important role in the environment. It replenishes streams, rivers, and wetlands and helps to support wildlife habitat; it is used as primary source of drinking water and also in agricultural and industrial activities. Groundwater is the major source of drinking water in both urban and rural India. Besides, it is an important source of water for the agricultural and the industrial sector. Water utilization projections for 2000 put the groundwater usage at about 50%. Being an important and integral part of the hydrological cycle, its availability depends on the rainfall and recharge conditions. Till recently it had been considered a dependable source of uncontaminated water. Its importance as a precious natural resource in the Indian context can be gauged from the fact that more than 85 percent of India's rural domestic water requirements, 50 percent of its urban water requirements and more than 50 percent of its irrigation requirements are being met from ground water resources. The increasing dependence on ground water as a reliable source of water has resulted in its large-scale and often indiscriminate development in various parts of the country, without due regard to the recharging capacities of aquifers and other environmental factors.

Ground water remains the life line of socio-economic development in the Ganga alluvial plain (GAP) since the dawn of civilization in the Indian subcontinent. The quaternary sequence forming top layer of the thick unconsolidated sediments of the GAP, holds nearly 30% of the total annual replenishable ground water resources of India (Govt. of India, 2006). Increasing groundwater extraction from GAP has resulted in surfacing of aquifer stress symptoms like lowering of ground water levelled and ground water quality deterioration (World Banks, 1998).A recent assessment in the three states of North and East India, viz. U.P., Bihar and West Bengal covering nearly 80% of GAP, identified 37 community development blocks (Ground water resource assessment unit) under over exploited Category. Ground water extraction has exceeded the annual replenishable resource (Govt. of India, 2006).

A planned approach is therefore essential for sustainable development of this precious natural resource as dependence on ground water is likely to increase in future. For this the first task would be to make a realistic assessment of ground water resources and the plan their use in such a way that full crop water requirement are met and there is neither water logging nor excessive water lowering of ground water table. It is necessary to maintain the ground water reservoir in a state of dynamic equilibrium over a period of time and the water level fluctuations have to be kept within a particular range over the monsoon and non-monsoon seasons. The Bihar state forms a part of mid-Ganga plain. About 33% of the geographical area of the state in the south of the Ganga River is covered by alluvial deposits often referred to as marginal alluvial plain. Bihar is becoming very important state for pushing agriculture production of the country. The stage of ground water development in the state is only 39%. In light of the above mentioned points this study is taken up to assess the ground water situation of Nalanda district which is located in south of Bihar.

Materials and Methods

The methodology used for ground water resource assessment is based on the recommendation of ground water estimation committee, 1997 (GEC-97). The basic principle followed in this methodology is the estimation of annual groundwater recharge from rainfall and other sources, including irrigation, water bodies and artificial recharge, determination of present status of groundwater utilization and categorization of assessment units based on the level of groundwater utilization and long-term water level trend. These estimations are widely used in formulating various groundwater development and management plans.

Study area

This district falls within the geographical co-ordinates of 25°00' N to 25°30' N and 85°00'E to 86°00'E and its geographical area is 2367 sq. km. It is mainly plain land with Gangetic alluvial top soil. The district is surrounded by Patna in the north, Jehanabad in the west, Gaya in the South and Nawada and Lakhisarai in the East. About 82 per cent of the total area is cultivable land and of this 51.43 per cent is irrigated land. The area is intensively cultivated with wheat, pulse (gram, lentil, pea, khesari, green gram), vegetables (potato, onion, cabbage, cauliflower, brinjal) and sugarcane during the *rabi* season (November - March). Wheat is the main crop which is partly grown as irrigated and partly as rainfed crop within the district. Pulses occupy second place in this area, mainly broadcasted on vast flood plains taking the benefit of residual soil moisture and siltation by river during the previous monsoon season. In *kharif* season Paddy, pegionpea and vegetables are the major crops.

Nalanda district is popularly known as Biharsharif. The rivers Phalgu, and Mohane flows through the district of Nalanda. The various sub divisions of the district are Biharsharif, Rajgir, and Hilsa. The district is divided into blocks of Giriyak, Rahui, Noorsarai, Harnaut, Chandi, Islampur, Rajgir, Asthawan, Sarmera, Hilsa, Biharsharif, Ekangarsarai, Ben, Nagarnausa, Karaiparsurai, Silao, Parwalpur, Katrisarai, Bind, and Tharthari. It is spread over the area of 2,367 sq. km. The total population of the district is 2,87,523 (2011 census).

Soils

Nalanda district is characterized by four types of soil viz. Clay loam, fine loam, loam and course loam, mainly derived from alluvial deposit of southern Ganga Plain.

Hydrogeological condition

The study region (Nalanda district) is located in south Ganga plain, physiographic unit stretching between Precambrian Highlands in South and the Ganga River in the North. Out of 20 blocks of Nalanda district 18 blocks are having quaternary alluvium deposits, composed of multilayer sand, silt, clay, sandy clay and silty clay sequences. The Precambrian blocks are exposed as Rajgir hills (62 Km^2) and as a small in liner (1 $Km^{2)}$ near Biharsharif town. In Nawada district Quaternary alluvium and Precambrian Granite-Genesis rock formation are Present in combination. In almost 11 blocks of the district Quaternary alluvium and Precambrian Granite-Genesis rock formation are present in combination.

Climate and rainfall

The average annual rainfall of district is 1002.2 mm. About 92.55 % of the rainfall is received during June to October by south-west monsoon. The climate of the district is sub-tropical to sub-humid in nature. The district experiences severe cold during winter whereas on the other hand in summer it is very hot.

Irrigation structures

There are 20730 dug wells, 21038 shallow tube wells and 320 deep tube wells in Nalanda district.

Specific yield

It is defined as the actual volume of water that can be extracted by the force of gravity from a unit volume of aquifer material is known as the specific yield. It is expressed as

$$S_y = \frac{V_d}{V} \times 100 \quad \ldots (1)$$

Where,

V_d = Volume of water that can be extracted by the force of gravity,

V = Total volume

The value of specific yield for Nalanda district has been taken as 0.10.

Ground water draft

The amount of ground water extracted from the ground resources with the help of pumping unit is called ground water draft. The gross ground water draft would include the ground water extraction from all existing ground water structures. The ground water draft can be calculated by the number of wells of different types multiplied by unit draft. Norms for Bihar state for ground water draft for Bihar state as per GEC-97 are 0.6 ham for dugwell, 1.0 ham for shallow tubewell and 30 ham for deep tubwell.

Recharge from return flow from ground water irrigation

Recharge from return flow from ground water irrigation is considered to be 30% of annual ground water draft during monsoon season as per the GEC-97 norms.

Recharge from Ponds

It is taken as 1.4 mm/day for the period in which the pond has water, based on the average area of water spread as per GEC-97 norms.

Methodology

The present methodology used for resource assessment is known as ground water resource estimation methodology-1997 (GEC-97). Two approaches recommended are - Water level fluctuation method and Rain infiltration method.

Ground water recharge

Monsoon recharge (water table fluctuation method)

The recharge assessment during monsoon season is made as the sum total of the change in storage and gross draft. The change in storage is computed by multiplying water level fluctuation between pre and post monsoon periods with the area of assessment and specific yield. Monsoon recharge can be expressed as

$$R = S + DG = h \times S_y \times A + DG \quad \ldots \quad (2)$$

Where,

R= Recharge during monsoon, ha-m
S= Change in storage, m
DG=Gross draft during monsoon season, ha-m
h=Rise in water table during monsoon season, m
S_y=Specific yield and
A=Area of assessment. Ha

The monsoon ground water recharge has two components – (a). rainfall recharge and (b) recharge from other sources. The recharge calculated from equation (2) gives the available recharge from rainfall and other sources for the particular monsoon season. The recharge from rainfall is given by,

$$R_{rf} = R - R_{gw} - R_{wc} - R_t - R_c$$

Hence,

$$R_{rf} = h \times S_y \times A + DG - R_{gw} - R_{wc} - R_t - R_c \quad \ldots(3)$$

Where,

R_{rf}	=	Recharge from rainfall, ha-m
R_{gw}	=	Recharge from return flow from groundwater irrigation in the area, ha-m
R_{wc}	=	Recharge from water conservation structures, ha-m
R_t	=	Recharge from ponds, ha-m and
R_c	=	Recharge from canal system, ha-m

The recharge from rainfall estimated as per equation (3) is for the particular monsoon season. The procedure for normalisation of this recharge for estimating recharge corresponding to the normal monsoon rainfall is given in the coming section.

Estimation of normal recharge during monsoon season

The rainfall recharge obtained by using equation (3) provides the recharge in any particular monsoon season for the associated monsoon season rainfall. This estimate is to be normalised for the normal monsoon season rainfall which in turn is obtained as the average of the monsoon season rainfall for the recent 30 to 50 years. The rainfall recharge, $(R_{rf})_i$ for the i^{th} particular year is obtained as per the equation given below

$$(R_{rf})_i = R - R_{gw} - R_{wc} - R_t - R_c$$

$$(R_{rf})_i = h \times S_y \times A + DG - R_{gw} - R_{wc} - R_t - R_c \quad \ldots(4)$$

Where,

$(R_{rf})_i$=Rainfall recharge estimated for the i^{th} particular year, ha-m

h=Rise in water table during monsoon season for the i^{th} particular year, m

S_y =Specific yield,

A=Area of assessment, ha

DG=Gross ground water draft during monsoon season for the i^{th} particular year, ha-m

R_{gw}=Recharge from groundwater irrigation in the monsoon season for the i^{th} particular year, ha-m

R_{wc}=Recharge from water conservation structures, ha-m

R_t=Recharge from ponds, ha-m

R_c=Recharge from canal system, ha-m

Those values of $(R_{rf})_i$ obtained above which are negative or nearly zero should be omitted, and only the data in which $(R_{rf})_i$ is greater than zero should be considered for further computations in the normalisation procedure. It is also likely that all the $(R_{rf})_i$ values as obtained above are consistently negative or nearly zero. In such a case, the water table fluctuation method should be dispensed with, and the normal rainfall recharge during the monsoon season should be estimated by the rainfall infiltration factor method based on rainfall infiltration factors.

The computational procedure to be followed in the method is as given below

a) Each pair of $(R_{rf})_i$ and r_i are used to obtain $[R_{rf}\text{(normal)}]_i$, as

$$[R_{rf}\text{ (normal)}]_i = \frac{(R_{rf})_i \times r\text{ (normal)}}{r_a} \quad \ldots(5)$$

Where,

r(normal) = Normal rainfall value of 30 years (1980-2010) rainfall, mm

r_a = Annual rainfall, mm

$(R_{rf})_i$ = Rainfall recharge estimated for the i^{th} particular year, ha-m

b) The normal monsoon season rainfall recharge, R_{rf} (normal) is then

$$R_{rf}\text{ (normal)} = \frac{\sum_{i=1}^{N} [R_{rf}\text{ (normal)}]_i}{N} \quad \ldots(6)$$

Recharge from rainfall infiltration factor method

Recharge from rainfall in monsoon season by rainfall infiltration factor method based on rainfall infiltration factors which is given as

R_{rf} = f x A x Normal rainfall in monsoon season …(7)

Where,

f = Rainfall infiltration factor
(For Indo - Gangetic and Inland alluvial area, f= 0.22)

A = Area of computation for recharge, ha

The same recharge factor may be used for both monsoon and non-monsoon rainfall, with the condition that the recharge due to non-monsoon rainfall may be taken as zero, if the normal rainfall during the non-monsoon season is less than 10% of normal annual rainfall. In using the method based on the specified norms, recharge due to both monsoon and non-monsoon rainfall may be estimated for normal rainfall, based on recent 30 to 50 years of data. After the rainfall recharge for normal monsoon season rainfall using the water table fluctuation method has been estimated as described above, it is to be compared with the rainfall recharge estimated by rainfall infiltration factor method based on rainfall infiltration factors. For this a term percentage difference (PD) which is the difference between the two expressed as a percentage of the latter is computed as,

$$PD = \frac{R_{rf}(\text{normal, wtfm}) - R_{rf}(\text{normal, rifm})}{R_{rf}(\text{normal, rifm})} \times 100 \quad \ldots(8)$$

Where,

R_{rf} (normal, wlfm)=Rainfall recharge for normal monsoon season rainfall estimated by the water level fluctuation method

R_{rf} (normal, rifm)=Rainfall recharge for normal monsoon season rainfall estimated by the rainfall infiltration factor method

- If PD is within ± 20%, R_{rf} (normal) = R_{rf} (wlfm).
- If PD is <–20%, R_{rf} (normal) = 0.8 × R_{rf} (rifm).
- If PD is >20%, R_{rf} (normal) = 1.2 × R_{rf} (rifm).

The total recharge during the monsoon season for normal monsoon season rainfall condition is finally obtained as,

$$R(\text{normal}) = R_{rf}(\text{normal}) + R_{gw} + R_{wc} + R_t + R_c. \quad (9)$$

Where,

R (normal)=Total recharge during monsoon season, ha-m
R_{rf}(normal)=Rainfall recharge during monsoon season for normal monsoon season rainfall, ha-m
R_{gw}=Recharge from ground water irrigation in the monsoon season for the year of assessment, ha-m
R_{wc}=Recharge from water conservation structures in the monsoon season for the year of assessment, ha-m
R_t=Recharge from tanks/ponds in the monsoon season for the year of assessment, ha-m
R_c=Recharge from canal seepage in monsoon season for the year of assessment, ha-m

Estimation of normal recharge during non monsoon season

The recharge from rainfall during the non-monsoon season may be estimated based on the rainfall infiltration factor method, provided the normal rainfall in the non-monsoon season is greater than 10% of the normal annual rainfall. If the rainfall is less than this threshold value, the recharge due to rainfall in the non-monsoon season may be taken as zero. Recharge during the non-monsoon season from other sources, namely from ground water irrigation (R_{gw}), tanks (R_t) and from water conservation structures (R_{wc}) are to be estimated from the norms recommended in GEC-1997 or values obtained through field studies. The total recharge in the non-monsoon season is obtained as the sum of recharge from rainfall in the non-monsoon season and recharge from other sources in the non-monsoon season.

Total annual ground water recharge

The total annual ground water recharge of the assessment unit is the sum-total of monsoon and non monsoon recharge.

Annual recharge = Recharge during monsoon + Recharge during non-monsoon.

Net ground water availability

It is the difference of annual ground water recharge and natural discharge during non-monsoon season. An allowance is kept for natural discharge in the non monsoon season by deducting 5% of total annual ground water recharge, if water table fluctuation method is employed to compute rainfall recharge during monsoon season and 10% of the annual ground water recharge if rainfall infiltration method is employed. The balance ground water available accounts for existing ground water withdrawal for various uses and potential future development withdrawal for various uses and potential future development.

Net ground water availability is the difference of annual ground water recharge and natural discharge during non monsoon season.

Categorization of district

The assessment units are categorized for ground water development based on status of ground water utilisation and water level drain. The following four categories are – safe areas, which have ground water potential for development, semi critical areas, where cautious ground water development is recommended, critical areas and over exploited areas where there should be intensive monitoring and evaluation and future ground water development be linked with water conservation measures.

$$\text{Ground water development (\%)} = \frac{\text{Existing ground water draft for all uses}}{\text{Net annual ground water availability}} \times 100 \quad \text{...(10)}$$

Results and Discussion

Watertable fluctuation

The data of pre and post monsoon water level of Nalanda district for eleven years (1998-2008) where collected from Directorate of ground Water, Patna and based upon this water table fluctuation was calculated. The long term water table fluctuation in Nalanda district varies from -2.21 to 2.83 m with an average value of 2.56 m (Fig. 1). The annual rainfall varied from 499.8 mm to 1137.7 mm with an average value of 919.5 mm (Fig. 2).

Ground water resources

The evaluation of groundwater potential is done using the water level fluctuation approach. Measurements of water levels are taken at a point source and the change in levels in the time span is observed. Annually replenishable dynamic ground water resources of the district have been estimated (GEC-1997). The details of various components of ground water recharge in Nalanda district is depicted in Table 1. Data shows that total annual ground water recharge is 76898 ha-m for Nalanda district. The existing ground water draft for irrigation is 38226 ha-m for Nalanda district. The ground water draft for all uses is 42327 ha-m for Nalanda district. The net annual replenishable ground water resource is worked out to be 73054 ha-m for Nalanda district.

Table.1 Ground water resource and development potential of Nalanda district of Bihar (in ha-m)

S.No.	Component	
1.	Recharge from rainfall during Monsoon season	56328
2.	Recharge from other sources during monsoon season	9105
3.	Recharge from rainfall during non-monsoon season	6688
4	Recharge from other sources during non-monsoon season	4778
5.	Total Annual ground water recharge	76898
6.	Natural discharge during non-monsoon season	3845
7.	Net ground water availability (5-6)	73054
8.	Existing ground water draft for Irrigation	38226
9.	Existing ground water draft for domestic and Industrial water supply	4101
10.	Existing gross ground water draft for all uses	42327
11.	Allocation for domestic and industrial water requirement supply upto next 25 years	5627
12.	Net ground water availability for future irrigation development	25100
13.	Stage of ground water development (%)	**58**
14.	Category	**White**

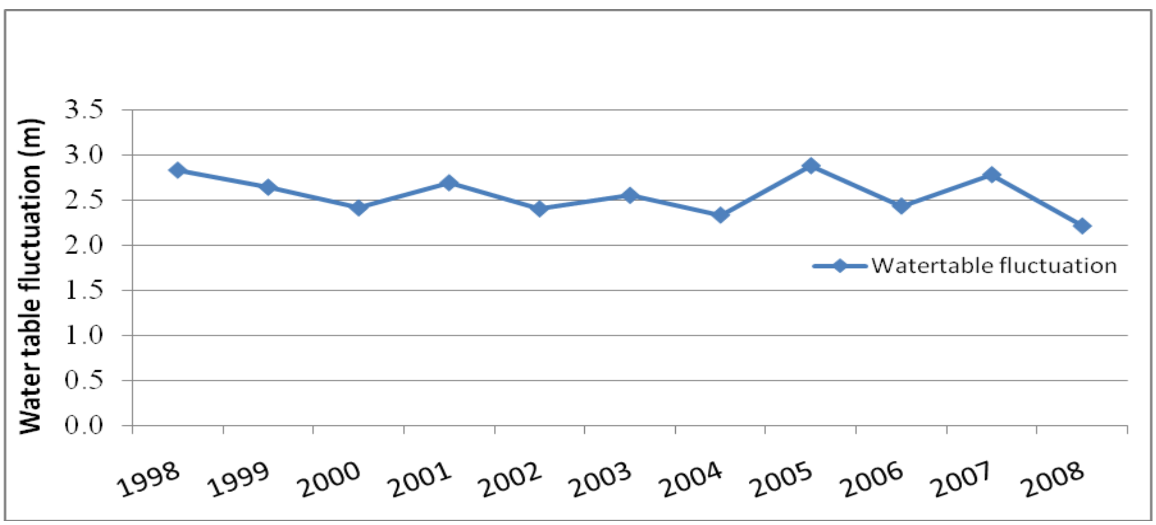

Fig.1 Average watertable fluctuation in Nalanda district

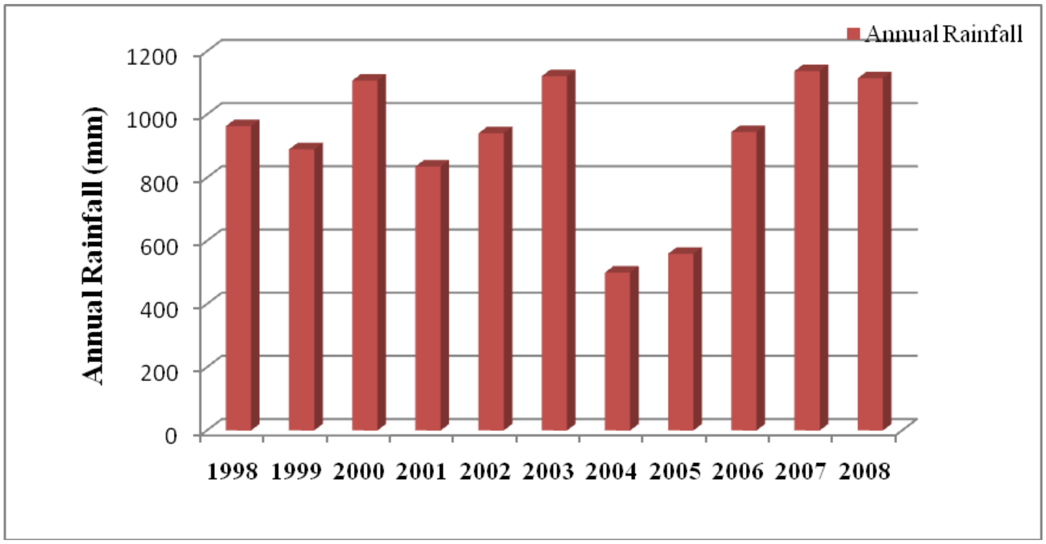

Fig.2 Annual rainfall of Nalanda district

The net annual ground water available for future irrigation development is 25100 ha-m for Nalanda district. The stage of ground water development is 58% for Nalanda district. According to definitions used by CGWB Nalanda district falls in safe category. The findings of the present study were in agreement with the other researchers (Kumar, 1989; Kaushal *et al.*, 1997; Kumar, 2004; Mane *et al.*, 2008; Ravi *et al.*, 2008; Chatterjee *et al.*, 2009; Patel *et al.*, 2013). The study recommended that there is a good scope for future groundwater development and keeping in view of rapid increase in groundwater draft, roof top rainwater harvesting needs to be taken up to recharge the aquifer in Nalanda district particularly in urban areas.

The total groundwater recharge through rainfall, water harvesting structures and return flow of irrigation water in the study area was estimated as 76898 ha m. The existing ground water draft for irrigation is 38226 ha-m for all uses is 42327 ha-m for Nalanda district. The net annual ground water available for future irrigation development is 25100 ha-m. The stage of ground water development is 58% for Nalanda district. According to definitions used by CGWB Nalanda district falls in safe category. The study recommended that there is a good scope for future groundwater development and keeping in view of rapid increase in groundwater draft, roof top rainwater harvesting needs to be taken up to recharge the aquifer in Nalanda district particularly in urban areas.

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How to cite this article:

Ravish Chandra, S.K. Jain and Singh, A.K. 2018. Assessment of Ground Water Resources for Irrigation in Nalanda District of South Bihar, India. *Int.J.Curr.Microbiol.App.Sci.* 7(02): 1223-1232. doi: https://doi.org/10.20546/ijcmas.2018.702.150