Evaluation of Groundwater Dynamics and Potential in Aligarh District

THESIS

Submitted in partial fulfilment of the requirement for

The award of degree of

Master of Technology

In

Agricultural Engineering

(Irrigation and Drainage Engineering)

VANDANA VARSHNEY

(ID NO. - 17MTAEID022)

DEPARTMENT OF IRRIGATION AND DRAINAGE ENGINEERING

VAUGH INSTITUTE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

SAM HIGGINBOTTOM UNIVERSITY OF AGRICULTURE,

TECHNOLOGY & SCIENCE

PRYAGRAJ – 211007

Sam Higginbottom University of Agriculture, Technology And Sciences
सैम हिग्गिनबॉटम कृषि, प्रौद्योगिकी एवं विज्ञान विश्वविद्यालय
(U.P. State Act No. 35 of 2016, as passed by the Uttar Pradesh Legislature)
Prayagraj (Allahabad) - 211 007, U.P., India
NAAC Accredited A
ISO 9001:2008 Certified
Office : 91-532-2684281, 2684781
Fax : 91-532-2684394
Website : www.shuats.edu.in
E-mail : info@shuats.edu.in

CERTIFICATE OF ACCEPTANCE OF EVALUATION COMMITTEE

This thesis entitled, **"EVALUATION OF GROUNDWATER DYNAMICS AND POTENTIAL IN ALIGARH DISTRICT"**, has been prepared and submitted by **Miss. Vandana Varshney, PId. No. 17MTAEID022** in partial fulfillment of the requirements for the award of degree of **Master of Technology in Agricultural Engineering**, of the College of Vaugh, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj - 211007 (U.P.).

	Name and Designation	Evaluation	Signature
1.	**Dr. Arpan Sherring** Professor and Dean P.G Department of I&DE,SHUATS **(Advisor)**	Satisfactory/ ~~Not satisfactory~~	
2.	**(Dr.) ir. Derrick Mario Denis** Professor & Head Department of I&DE,SHUATS **(Member)**	Satisfactory/ Not satisfactory	
3.	**Dr.Alex Thomas** Associate Professor, Department of SWLE,SHUATS **(Member)**	Satisfactory/ Not satisfactory	

This thesis is hereby accepted for the award of the degree of **Master of Technology** in **Agriculture Engineering.**

Place: Prayaraj
Date

Prof.Dr. (Mr.) R.K.Pandey
(Chairperson)

Sam Higginbottom University of Agriculture, Technology And Sciences
सैम हिग्गिनबॉटम कृषि, प्रौद्योगिकी एवं विज्ञान विश्वविद्यालय
(U.P. State Act No. 35 of 2016, as passed by the Uttar Pradesh Legislature)
Prayagraj (Allahabad) - 211 007, U.P., India
NAAC Accredited A
ISO 9001:2008 Certified
Office : 91-532-2684281, 2684781
Fax : 91-532-2684394
Website : www.shuats.edu.in
E-mail : info@shuats.edu.in

CERTIFICATE OF ORIGINAL WORK

This is to certify that the study conducted **VANDANA VARSHNEY** as reported in the present thesis was under my supervision. The results reported by her is genuine and the candidate has written the scripts of the thesis. Her entitled **"EVALUATION OF GROUNDWATER DYNAMICS AND POTENTIAL IN ALIAGRH DISTRICT"** is therefore being forwarded for the acceptance in the partial fulfilment of requirement for the award of the degree of MASTER OF TECHNOLOGY IN AGRICULTURAL ENGINEERING major in **IRRIGATION AND DRAINAGE ENGINEERING,** Vaugh Institute of Agricultural Engineering and Technology, Sam Higginbottom University of Agriculture Technology and Sciences, Pryagraj.

PLACE: SHUATS, Pryagraj

Date:

Dr. Arpan Sherring
(Advisor)
Department of Irrigation and Drainage Engineering
VIAET, SHUATS, Allahabad

SELF ATTESTATION

This is to certify that I have personally worked on the research thesis entitled **"Evaluation of Groundwater Potential in Aligarh District".** The data mentioned in this report were obtained during the unfeigned work done and collection by myself. Any other data or information in this report which has been collected or borrowed from outside agency has been duly acknowledged. None of the findings/information pertaining to work has been concealed. The result embodied in this project report have been submitted to any other universities or institute for the award of any degree or diploma.

Vandana

Date:- 30-July-2019

Place:-Prayagraj

VANDANA VARSHNEY

17MTAEID022

ACKNOWLEDGEMENT

All praises to Lord JESUS Almighty!

We express our sincere gratitude and thanks to our project advisor Dr. Arpan Sherring, Professor, Department of Irrigation and Drainage Engineering, Vaugh Institute of Agriculture Engineering and Technology, SHUATS, Allahabad, for his scholastic guidance, constructive criticism, constant encouragement, pertinent suggestion during every stage of my project work. It would be very difficult to complete this project work without his exceptional, analytical and outstanding supervision.

I have an immense pleasure in expressing our deepest sense of gratitude and humble indubitable towards our honourable Prof. (Dr) Alok Tripathi Dean, Vaugh Institute of Agriculture Engineering and Technology, SHUATS, Allahabad, for his steadfast inspiration expert guidance and dynamic support.

I also thank all the people who directly or indirectly helped us in my project work.

At last but not least, I think that words are in sufficient to express my deep sense of feeling and respect towards my parents without their love, blessing and benediction it would not have been possible for me to complete this study.

Date: 30-July-2019

Place: Allahabad

Vandana

(VANDANA VARSHNEY)

(17MTAEID022)

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

BCM	:	Billion cubic meter
CGWB	:	Central Groundwater Board
ET	:	Evapotranspiration
ET_0	:	Reference evapotranspiration
et al.	:	and others
FAO	:	Food and Agriculture Organization
Govt.	:	Government
ha	:	hectare
i.e.	:	that is
kmph	:	kilometre/hour
kms	:	kilometres
Mha	:	Million hectare meter
$m\ s^{-1}$	:	meter per second
PET	:	Potential Evapotranspiration
RH	:	Relative humidity
R_n	:	Net radiation
sq. km.	:	square kilometre
T_{max}	:	Maximum air temperature
T_{min}	:	Minimum air temperature

LIST OF SYMBOLS

<	:	less than
°	:	degree
/	:	division
>	:	greater than
≤	:	less than or equal to
≥	:	greater than or equal to
=	:	equal to
×	:	multiplication
%	:	percent
±	:	plus or minus
&	:	and
Δ	:	delta
∑	:	sigma

ABSTRACT

Groundwater potential of Aligarh district of Uttar Pradesh was assessed using water balance approach during the monsoon and non-monsoon season. Groundwater is basically a dynamic resource that may be expressed as the quantity of water measured by the difference between optimum and minimum water table within the aquifer, which is principally recharged from monsoon rainwater for the rest of the year. Exploitation or over withdrawal of groundwater resources imposes stress on groundwater regime distorting the aquifer recharge-withdrawal equilibrium and as a result, a continuous decline in water table may occur cause much adverse surface and subsurface environmental effect . The amount of this recharge depends upon the rate and duration of rainfall, the subsequent conditions at the upper boundary, the antecedent soil moisture conditions, the water table depth and the soil type. Evaluation of groundwater recharge from groundwater balance method essentially involves the quantitative estimation of two components – inflow to the groundwater and outflow from the groundwater. In order to evolve proper management strategies and development of recharge to and discharge from the groundwater reservoir to drive the component of recharge to and discharge from the groundwater reservoir to drive the groundwater balance.

In general, groundwater recharge in a particular area (having fixed hydro-geological situation) is dependent on rainfall – increases with rainfall, unless potential recharge occurs. Various methods, models and structure have been developed for excess use of excess rainfall by storing the rain water that is called water harvesting so that the groundwater strata to recharge the level of groundwater and to improve the quality of subsurface water. In some area it has become important to assess the groundwater recharge so that the use of quantity could be optimized and also the quantity of groundwater could be improved.

CHAPTER- I

INTRODUCTION

Groundwater is that the underground water that happens below the formation within the soils and geologic formations that are absolutely saturated **(Freeze & Cherry, 1979)**. Groundwater is among one of the key natural resources of the globe. Several major cities and little cities within the world rely on groundwater for water provides, principally thanks to its abundance, stable quality and additionally as a result of it's cheap to use **(Morris et al., 2003).** Groundwater use has elementary importance to satisfy the apace increasing urban, industrial and agricultural water demand, particularly in arid areas wherever surface waters are scarce and seasonal.

Uneven distribution of surface water resources resulted in an increased emphasis on the development of groundwater resources. An important objective of most groundwater studies is to make a quantitative assessment of the groundwater resources in terms of the total volume of water stored in an aquifer or long-term average recharge.Groundwater recharge is determined to a large extent as an imbalance at the land surface between precipitation and evaporative demand.

When precipitation exceeds phase change demand by AN quantity comfortable to refill soil water storage, any further excess flows deeper into the ground and arrives at the water table as recharge.Groundwater systems are studied by the employment of computer-based mathematical models **(Brassington, 1998).**

These essentially comprise a vast array of equations, which describe groundwater flow and the water balance in the aquifer. Finite difference method is a commonly used method to solve the equations.The equations are solved for each node and the movement of groundwater from one node to its neighbor is calculated. As discussed by **Scanlon et al.(2003),** numerical groundwater models square measure one among the most effective prophetical tools offered for managing water resources in aquifers.

These models may be accustomed to check or refine completely different abstract models, estimate hydraulic parameters and most importantly for water-resource management, predict how the aquifer might respond to changesin pumping and climate.Groundwater abstractions that exceed the typical recharge, ends up in a seamless depletion of formation storage and lowering of the groundwater table.Hence safe groundwater abstraction and proper groundwater management are crucial for the sustainability of the resource. Safe yield is the amount of naturally occurring groundwater that can be withdrawn from an aquifer on a sustained basis, economically and legally, without impairing the native groundwater qualityor making undesirable effects, such as environmental damage **(Fetter, 2001).**

As with most semi-arid areas, Ethiopia is also facing water scarcity, particularly in the dry season. Because of the poor permeability of the crystalline rocks and variable water table depths, the country has a limited supply of groundwater **(MacDonald, 2001).**The groundwater prevalence is especially ruled by earth science, degree of fracture and topography.Human activities, such as irrigation, groundwater pumping, cropping, and land clearance and too much use of groundwater are unbalancing the groundwater system. It can lead the problem of decreasing quality of groundwater, waterlogging, salinization and water shortage. Over-exploitation takes place when groundwater abstraction exceeds available groundwater recharge from surface water and rainfall contribution. Over-exploitation may result in a long-lasting depletion of the aquifer system and associated environmental consequences such as undesired changes in water quality, land subsidence and change in the surface drainage system. So, there is an urgent need for proper utilization and management of groundwater.

Unfortunately, the excessive use and continued mismanagement of water resources to supply ever-increasing water demands to profligate users have led to water shortages, increasing pollution of freshwater resources and degraded ecosystems worldwide **(e.g., Clarke, 1991; Falkenmark and Lundqvist, 1997; deVilliers, 2000; Tsakiris, 2004).**The recharge rate varies both spatially and temporally.

Factors influencing groundwater recharge embody characteristics of the recharge beds, like topography, land use, vegetation cover, existing soil wetness and also the ability of the recharge beds andaquifer materials to capture and transmit water **(Bureau of Rural Science, 2007).**Interest in quantifying recharge rate has increased because of concerns that land-use changes may reduce recharge and that groundwater resources in some areas may not be sustainable during drought periods **(Risser et al., 2005).**

The total geographical area of India is 328 million hectares (M ha) and the average annual rainfall of the country is 887 mm **(IMD, 2016).** Thus it receives water in the form of precipitation to the extent of about 290 million hectare meter (Mha-m). The entire water resources of a country can be separated as surface and subsurface water resources. The total annual replenishable groundwater resource is about 43 million hectare meter (M ha-m). After setting up the provision of 7 Mha-m groundwater for domestic, industrial and other uses, the available groundwater for irrigation is 36 Mha-m, out of this only 32.5 Mha-m is utilized. The utilizable irrigation potential is estimated as 64 Mha-m depending on water requirement of crop and cultivable land availability. From which, the potential due to recharge from natural rainfall is 50.8 Mha-m and augmentation from irrigation canal system is about 13.2 Mha-m. The irrigation potential created from groundwater was estimated to be 35.4 Mha-m until 1993 in the country (**Groundwater Resource Estimation Committee, 2009**).

Even though the groundwater availability has been favorable, there are several areas within the country which face scarcity of water. This is due to the non-uniform development of groundwater over different regions of the country. Groundwater extraction structures and wells are failing, due to a decrease in groundwater levels. According to the report of **Central Ground WaterBoard (2013),** in India, the availability of net annual groundwater is 447 billion cubic meters (bcm) and an annual draft of groundwater is 253 bcm (as on 31st March, 2013). The average groundwater development stage for the country is 62%. There are a total of 6584 assessment units (Blocks/ Mandals/ Talukas/Firkas) within the country. Out of total assessment units, 1034 units have been categorized as 'Over-exploited', 253 units as 'Critical', 681 units as 'Semi-critical' and 4520 units as 'Safe' in various States. Other than this, since a large part of groundwater is saline in phreatic aquifers, 96 assessment units have been categorized as 'Saline'.

It is well known, that there are a number of water-related challenges which would increase in the near future. To cope up with these challenges, computer-aided techniques can be very much helpful and can provide easy handling and calculation of various data related to assessing the groundwater recharge. Computer-aided techniques area unit versatile tools in its own towards the direction of precise and promptly resolution for varied technology and technology-based issues. Reasonability of computer-aided techniques has been confirmed in all streams of engineering and technology and fortunately, groundwater engineering is also one of the most significant users of such techniques for analysis, design, simulation, modeling, etc. Whatever the stream or problem domain for any engineering stream, the most important aspect is to conceptualization the logic which is to be analyzed, designed and accordingly coded in computer software language. The presentation of such conceptualization can be in the form of an algorithm, flow charts, UML charts, etc.

Aligarh district is situated on the western part of Uttar Pradesh occupying a small part of Ganga and Yamuna doab. It lies between latitude 27 0 35' and 28 0 10'N and longitudes 77 0 29'00" and 780 36'00" E falling in the survey of India Toposheet Nos. 53H, L & 54E. The northern boundary of the district is contiguous with that of Bulandshar district. Ganga river forms the natural boundary between Aligarh and Budaun in the northeastern corner of the district whereas the Yamuna in the northwest forms the state boundary between Uttar Pradesh & Haryana. Administratively the Aligarh district has an area of 3650 sq.km. which has been divided into five tehsils and 12 community development blocks (Plate-I). It has 122 Nyay Panchayats having 855 Gram Sabhas and 1210 villages.

Groundwater occurs in the pore spaces of unconsolidated alluvial material in the zone of saturation. In Aligarh district groundwater occurs under water table conditions at shallow depths while in the deeper aquifer, it is under a confined state of disposition, the confining layers are impermeable clay beds.

The groundwater level in the district is declining very fast and it is strongly recommended that exploitation of groundwater through private and shallow tube wells should be minimized in the 'Semi critical' blocks of Chandaus, Kahir, and Iglas blocks. Groundwater Regulation is recommended for Atrauli block which has been categorized as critical along with artificial recharge to groundwater at identified locations. The declining water level has caused an adverse effect on the ecological balance as minor drainage ways which used to have water are now almost dry. This obviously is the result of massive groundwater exploitation for irrigation as well as for industries needs.

OBJECTIVES

Keeping these points in view, the study has been planned to estimate the different component of groundwater inflow and outflow and thus to estimate groundwater recharge flux. The general objectives of the study are as under:

(i) To do the estimation of various inflow and outflow parameters of water balance equation in a different block of Aligarh district.

(ii) To appraise the groundwater draft, change in groundwater storage and water table fluctuation in different blocks.

(iii) To suggest a best strategy for proper groundwater management in the Aligarh area.

For estimating these components different type of required data has been collected from the respective government and non-government organization.

CHAPTER-II
REVIEW OF LITERATURE

2.1 General

Groundwater recharge may be outlined as "recharge is that the entry into the saturated zone of water created accessible at the groundwater level surface, in conjunction with the associated empty from the groundwater level at intervals the saturated zone". There square measure several studies and strategies to estimate the entry yet as the quantity of the water into the saturated zone so the groundwater can be charged and additionally case-studies square measure accessible to verify the precise analysis of groundwater recharge regionally and worldwide.

2.2 Groundwater Recharge Studies, Case-Studies, and Methods

Recently the haphazard exploitation of groundwater has compelled many researchers and scientists to measure the groundwater resources and to know the methods and the way how the groundwater could be charged so that the Indian agriculture remained same safe and optimized as groundwater is the best faith of Indian farmers for their agriculture production.

Since last 40 years lot of methods, models, and studies, in India and all over the world, are developed for quantification, measurement, and process to the groundwater recharge. Here the reviews of some of the methods, suitable for Indian perspective, are given worldwide and locally respectively.

2.2.1 Worldwide Studies for Groundwater Estimation

Cook and Kilty (1992) estimated groundwater recharge using unsaturated zone chloride methods at twenty sites located in western Murray Basin, Australia. A helicopter-borne electromagnetic survey was used for interpolation between drill sites. Correlations among recharge and apparent electric conductivity were significant (R2 = 0.65) only at the highest frequency (56,000 Hz). Using this single-frequency knowledge, variations in recharge were mapped over an area of 32 km2. Recharge, as inferred from the electromagnetic data, appeared to be log-normally distributed, and varied from less than 1 to greater than 50 mm / yr. It was found that spatially averaged recharge was estimated from the electromagnetic data, with an accuracy of approximately –60 % and +140 %. The estimation accuracy was comparable with the surface electromagnetic methods. It was concluded that aerial electromagnetic methods are useful for identifying regions of high and low recharge over large areas.

Cey*et. al.* (1998) studied the interaction between groundwater and surface water within a small agricultural watershed in southern Ontario, Canada. Four techniques were used to estimate the groundwater contribution to streamflow which was measured along a 450 m section of the stream during baseflow condition and rainfall event. Streamflow measurements using the velocity-area technique under baseflow condition indicated that the net groundwater flux to the stream during the summer months was 10 ml s-1 m-1. Hydrometric estimation using mini-piezometers installed in the sediment underneath the stream resulted in four to five times lower groundwater flux estimates were compared to velocity-area technique estimates. Seepage meters failed to give any estimation of water flux into or out of the stream. Therefore, based on these results, it was concluded that out of the above three techniques, the velocity- area technique was the best to estimate groundwater discharge. Hydrograph separations were conducted using 18O/16O isotopes ratios and electrical conductivity on two large rainfall events with different antecedent moisture conditions. Both events showed that pre-event water (generally thought of groundwater) dominated streamflow and tile drain flow with sixty-four nothing – eighty you look after the full discharge contributed by pre-event water.

Goes (1999) estimated groundwater recharge to the shallow aquifer in the Hadejia–Nguru Wetlands, Northeastern Nigeria. Wells records for the period of 1991 to 1997 and hydrogeological profile based on piezometers which were monitored for two years, had been used. It was observed that recharge through inundated flood plains was the source of rising groundwater. The wet-season groundwater recharge to the unconfined aquifer in the flood plain area between Hadejia and Nguru and in its vicinity was estimated to be 132 mm. The outflow from the unconfined flood-plain aquifer to the unconfined upland aquifer was estimated to be approximately 10 % of the wet-season flood-plain recharge.

Arnold *et al.* (2000) groundwater recharge and groundwater discharge estimates obtained using two different methods in the Upper Mississippi River basin were compared. The first method was a water balance components from the Soil and Water Assessment Tool Model (SWAT). The second method involved two procedures to estimate base flow and recharge from daily stream flow. The base flow was estimated using a digital recursive filter whole hydrograph recession curve displacement technique was used to estimate groundwater recharge. These procedures were applied to 283 stations with the area ranging from 50 to 1200 km2. To validate these methods (models) measured and simulated monthly stream flow at Alton were compared for the period w.e.f. 1981 to 1985. The value of the coefficient of determination R2 between measured and simulated monthly streamflow was found to be 0.65.

Ahmed *et al.* (2013) stated that the availability of groundwater, namely freshwater is too less. This situation provokes the scientific community to more analysis within the field groundwater exploration of H2O and natural recharge estimation, which are the most important components essential to formulate dependable groundwater management methods in scarceness, affected regions. Hydrochemical studies were conducted in Chinnaeru geographical area of Nalgonda District, Andhra Pradesh, India. Water samples from 28 locations were collected from bore wells during May 2011 and analyzed for different Physico-chemical parameters. Based on varied indices and water quality standards, the water is classified for safe drinking and irrigation uses. The concentration of halide in groundwater ranges from zero.4-2.9 mg/l. Piper diagram reflects that the water belongs to Ca+2 –Mg+2 –HCO3 - to Na+ –HCO3 - types. The Wilcox diagram suggests that almost all of the samples area unit inside the permissible limits which might be used for irrigation. High halide content in groundwater is often attributed to the continual water-rock interaction throughout the method of percolation with fluorspar bearing country rocks beneath arid, low precipitation and high evaporation conditions of the study area. The low metal content in rocks and soils and therefore the presence of high levels of bicarbonate in soils and waters area unit necessary factors favoring high levels of halide in waters. The basement rocks give abundant sources of halide within the sort of mineral, biotite, fluorite, and apatite. The high halide concentration area units are demarcated, and the de-fluoride plant was put in to treat the water for safe drinking functions.

Abdullahi*et al*. (2016) studied that the estimation of groundwater recharge is essential for efficient groundwater resources management, for domestic uses and irrigation purposes in the study area. The present analysis entails the assessment of natural groundwater recharge in Terengganu Asian nation. Estimation of recharge by no matter methodology is sometimes subjected to oversized uncertainties and errors. However, this analysis commits to derive AN empirical relationship to work out the groundwater recharge from precipitation supported seasonal groundwater balance study mistreatment the info obtained from 2000-2001 to 2011-2012. This empirical relationship almost like Chaturvedi formula was derived by fitting the calculable values of precipitation recharge and therefore the corresponding values of precipitation within the monsoon season through the non-linear regression techniques. The result shows that the proportion of variance explained was found to be eighty-nine .52 %, and the recharge of groundwater commences at P = 15.28 inches and the relative errors were found to range from 3.680 to 46.020%.

Govindu*et al.* (2016) studied that the issue of unsustainable groundwater utilization is becoming increasingly an evident problem and the key concern for many developing countries. One of the issues is that the absence of updated spatial info on the number and distribution of groundwater resource. Like the alternative developing countries, groundwater evaluation in Ethiopia has been usually conducted using field survey which is not feasible in terms of time and resource. This study was conducted in the Northern Federal Democratic Republic of Ethiopia, Wollo Zone, in Gerardo River Catchment district to spatially delineate the groundwater potential areas using geospatial and MCDA tools. To do so, eight major biophysical and environmental factors like geophysics, lithology, slope, rainfall, land use land cowl (LULC), soil, lineament density, and drainage density were considered. The sources of that information were satellite image, digital elevation model (DEM), existing thematic maps and metrological station data. Landsat image was used in ERDAS Imagine to drive the LULC of the area, while the geomorphology, soil, and lithology of the area were identified and classified through field survey and digitized from existing maps using the ArcGIS software. The slope, lineament and drain density of the realm were derived from DEM mistreatment spatial analysis tools. The rainfall surface map was generated using thissen polygon interpolation. Finally, on balance these thematic maps were organized, weighted value determination for each factor and its field value was computed using IDRSI software. At last, all the factors were integrated along and computed the model mistreatment the weighted overlay so potential groundwater areas were mapped. The findings pictured that the foremost potential groundwater square measures are found within the central and Japanese elements of the study space, while the northern and western parts of the Gerado River Catchment have the poor potential of groundwater availability. This is primarily because of the accumulative impact of steep geography and high drain density. At last, once the potential groundwater areas were identified, cross-validation of the resultant model was carefully carried out using existing data of dung wells and boreholes. The point data of dung wells and boreholes were overlaid on groundwater potential suitability map and coincide with the expected values. Generally, from this study, it may be ended that RS and GIS with the assistance of MCDA square measure necessary tools in observation and analysis of groundwater resource potential areas.

Khan and Adnan (2015) studied that the value of agricultural land is becoming valuable by increasing population with time. Some land is becoming Bad Land because of lack of water, whereas some are waterlogged due to the increasing water table. So, to calculate spring water balance is that the emergency of the time. For this reasons the ooze from a heap of rivers and canals flowing within the study space area unit calculated by completely different empirical equations victimization Nazir Ahmad Formula, Mortiz Formula, Molesworth and Yennidunia formula, Pakistanian Formula, Indian Formula, and Kostiakov A.N Formula. The total seepages into the study area are 3516447.5, m3 /day. The total area of the district is 1825.28 km2. For recharge, because of precipitations, merely the runoff ought to be excluded from total precipitation. To calculate runoff the curve variety is important, that is calculated from Land Use Map and comes bent be eighty-eight. The runoff by SCS-Curve variety methodology is calculated and comes bent be 570.4894 mm/year. The recharge from precipitation is calculated and comes bent be 200741, m3/day. The withdrawals from the study space area unit because of tube wells and hand pumps. The discharge by tube wells is calculated by the collected information from WAPDA and Irrigation Department that is 257105.016, m3/day. For pump discharge, a rough survey is conducted and statistically found the withdrawals that area unit 42818.25, m3/day. The flow and outflow are calculable 37820, m3/day and 199650.5, m3/day, respectively. The evaporation losses area unit calculable, which comes out to be 2957890, m3/day. The total flow and total outflow area unit calculable 3755008.5 m3/day and 3457463.766, m3/day, respectively. The net recharge to the realm is three.4438, money supply /sec that is fifty-nine.518, mm/year.

2.2.2 Local Studies of Groundwater Estimation

Kaushal *et al.* (1989) computed groundwater resources of the area bounded by Bhakra mainline canal, Ghaggar Branch, Sirhind Canal third Feeder and river Ghaggar for the period 1975-76 to 1985-86. Several components of groundwater recharge and discharge were estimated as per the norms adopted by the Groundwater Resource Estimation Committee. Recharge from rainfall, canal seepage and return flow from the irrigated areas were found to be 14.23, 18.0 and 67.66 percent of the total recharge, respectively. The total groundwater recharge in the area under study was estimated to be 52747 ha-m. It was observed that the groundwater resources in the study area were found overstressed which were causing a drop in the water table.

Hassan and Bhutta (1996) estimated recharge to groundwater reservoir by two methods, (i) water balance approach (ii) specific yield method, in Rechna Doab in the Punjab province of Pakistan. A water balance study was conducted on a seasonal basis (6 months) for an amount of thirty-one years. Recharge estimated by these two techniques was observed to be in good agreement with each other. During Kharif season, the average value of net groundwater recharge was observed as 60 mm. During rabi season no recharge occurred, rather during this season, there was a depletion of the groundwater reservoir. On the basis of the study, it was concluded that groundwater was being depleted on a regional basis, resulting in an average fall of 2.3 m in groundwater table over the period of 31 years (1960-1990).

Kumar and Seethapathi (2002) derived an empirical relationship to estimate groundwater recharge due to rainfall in Upper Ganga Canal command. The relationship was developed by performing non-linear regression between the estimates of rainfall recharge and the corresponding values of monsoon rainfall in Upper Ganga Canal commands. The empirical relationship could be expressed as:

$$Rr = 0.63 (P - 15.28)0.76 \qquad (2.8)$$

where Rr = Groundwater recharge from rainfall in monsoon season (inch); P = Mean rainfall in monsoon season (inch).

Naik and Awasthi (2003) estimated annual groundwater recharge and the annual specific yield on the basis of water table fluctuation method, in lower Koyna River basin, in the district of Satara, Maharashtra state, India. Total annual groundwater recharge into the study area was estimated as 57 MCM (million m3). The different components of this 57 MCM annual groundwater recharge were (i) 31 MCM infiltration of rainfall (ii) 3 MCM of seepage from the surface tank (iii) 23 MCM of return flow of irrigation. Recharge to deep aquifers was estimated as 1 MCM during the dry period (November–May). The annual safe yield was estimated as 58

MCM, it contained 16.50 MCM annual groundwater draft by wells for domestic, livestock, and irrigation needs. The natural losses from groundwater system comprising of base flow and spring discharges amounted to be 38 MCM, out of which 35 MCM was baseflow and 3 MCM was spring flow per year. Out of total draft by wells, 7 MCM was already pumped for irrigation requirement from the tributaries of the Koyna River. Thus, there remained a groundwater balance of 3.5 MCM of groundwater for further groundwater development.

Shivanna*et al.* (2004) used environmental isotopes and injected tracer methods were used to estimate the contribution of storms and annual rainfall to groundwater recharge in a semi-arid area of Bagepalli, Kolar district, Karnataka. To study the effect of storms to groundwater recharge 2H, 18O and 3H environmental isotopes were used, and contribution of storm component to groundwater was computed by isotope balance. Some of the groundwater samples collected during the periods of post-storm were depleted in stable isotope content with higher deuterium excess as compared to groundwater samples collected from the pre-storm periods. The estimated recharge component of a storm event of 600 mm to the groundwater was found to be in the range of 117–165 mm. An injected radiotracer 3H technique was also applied to estimate recharge due to total rainfall to the groundwater system. The estimated recharge to the groundwater was 33 mm of the 550 mm annual rainfall in 1992.

Reghunath*et al.* (2005) long-term trends of the water table fluctuations were calculated for Nethravathi River basin, in southern India through a time series approach. Statistical Package for Social Sciences (SPSS) was accustomed to performing the analysis. It was observed that this method was useful for differentiating the zones of recharge and discharge of an aquifer. In the study area, the alarming falling rate of the piezometric head indicated the high rate of pumping to which the deep aquifer was subjected, which ultimately ends up in the total drying up of the deep aquifers. It was suggested from the study that regulatory efforts could be taken immediately to promote the sustainable use of deep aquifers.

Adelana*et al*. (2006) estimated the groundwater recharge into the groundwater system in the Sokoto Basin using the empirical method, hydrochemical method (chloride mass balance) and climatic-hydrological balance method. The empirical method showed exaggerated values of groundwater recharge as compared to the other two methods. The chloride method estimated mean annual recharge of 19.6 mm/yr based on the mean annual rainfall of 670 mm during the period of 1916-1993.

Results showed that recharge around the Wurno and Goronyo zones was less than 1 % of annual rainfall while recharge outside of these zones was 3.2 % of annual rainfall.mm during the period of 1916-1993.It was observed that the chloride mass balance method was the most suitable method for estimation of groundwater recharge in the study area, but it was still limited by the lack of chloride measurements in rainwater in some areas.

Hoque*et al.* (2007) analyzed the causes of groundwater decline and dewatering of substantial aquifer in Dhaka, Bangladesh. The study area was completely dependent on the groundwater, which occurs below the area in an unconsolidated Plio-pleistocene sandy aquifer. It was analyzed that, the pattern of change in water level mainly replicated the pattern of change in the rate of groundwater abstraction. The abstraction of water from the aquifer storage was estimated to be more than 15 % in the year 2002. Dewatering of aquifer was estimated to be about 41 Mm3 (million cubic meters) in the year 1988, and it was increased very rapidly to 2,272 Mm3 in the year 2002. It was concluded that the groundwater abstraction from the storage could restrict the sustainability of the aquifer because the decline in water level was increased non-linearly due to limiting vertical recharge.

Tweed *et al.* (2007) developed a synergistic technique which applied a combination of geographic information system (GIS) and remote sensing method to map groundwater recharge and discharge regions. This method was used to an unconfined basalt aquifer, in a drought and salinity prone area of southeastern Australia. The basalt aquifer covers a region of approximately 11,500 km2 in an agricultural intense area. Groundwater discharge areas were identified by mapping the effects of discharge on surface features (vegetation), whereas preferential recharge areas were identified by mapping surface feature controls on recharge rates (infiltration). By mapping techniques, the resolution and extent of information were enhanced for the regional catchment and therefore, a new hydrogeological information system was provided for numerical modeling, water budget analysis, and salinity mitigation programs.

Umar *et al.* (2008) estimated water budget for the Kali–Hindon inter-stream region. Different groundwater recharge and discharge components were calculated. It was found that the total recharge into the groundwater system was 148.72 Mm3 (million cubic meters) and the total discharge was 161.06 Mm3 with a deficit balance of -12.34 Mm3. Depths of water level were shallow in the canal irrigated northern part and deeper in the southern part of the basin. The water level range was from 4.6 m to 17.7 m and 3.5 m to 16.5 m below ground level for pre-monsoon and post-monsoon respectively. It was concluded from the study that groundwater could further be pumped in the northern part of the basin while intense abstraction in the southern portion of the basin could lead to rapid falling of water table levels.

Unde*et al.* (2009) estimated groundwater potential in the Jalpaiguri district of West Bengal using a water balance approach. In this study, different components such as recharge from rainfall, recharge from irrigation water, recharge from canals and streams, groundwater draft, subsurface inflow-outflow, evapotranspiration losses, seepage to the streams and groundwater storage change were considered for the estimation of groundwater potential. The available annual groundwater potential was estimated to be 921.317 Mm3 in the study area. It was also estimated that groundwater withdrawals through different groundwater structures like shallow tube wells, deep tube wells and dug wells were to be 116.2 Mm3. Therefore, it was concluded that there was a scope for further utilization of groundwater for irrigating more area.

Nagaraju (2011) carried out the present study aims at the assessment of groundwater potential and an attempt was made to assess the groundwater balance using the water table fluctuation method in which all the components of the water balance equation are known and the only component which is considered unknown is the rainfall recharge. Most of the inputs were derived from the satellite remote sensing information. Twenty-eight rain gauge stations and fifty observation wells falling within and outside the periphery of the sub-basin were considered for groundwater assessment. The total annual recharge includes recharge form (i) Monsoon rainfall, (ii) Non-monsoon rainfall, (iii) Hilly areas (iv)Surface water-bodies (v) groundwater irrigation, (vi) Seepage from canals and (vii) Canal irrigation. The total annual draft consists of water applied to the crops and water consumed for domestic and industrial use. The difference in the annual draft and the net annual results compared to the other methods.

Kumar (2012) Water balance techniques are extensively accustomed create quantitative estimates of water resources and also the impact of man's activities on the hydrologic cycle. On the idea of the water balance approach, it's attainable to create a quantitative analysis of water resources and its dynamic behavior underneath the influence of man's activities. In this paper, a trial has been created to explain the methodologies to know and appraise the varied recharge and discharge elements of H2O balance equation and to establish the recharge coefficient with a view to working out the groundwater potential of an area.

Krishan *et al.* (2014) evaluated and analyzed the groundwater level monitoring has been carried out in 6 observation wells in 6 blocks namely Bhatinda, Maur, Nathana, Phul, Sangat, and Talwandi of Bhatinda district in southwest Punjab. Across these blocks, careful water level information sets have been generated consecutive on a monthly basis over the last eight years between Gregorian calendar month 2006 to December 2013 for assessing the patterns of groundwater level trends. The observed datasets point towards the declining and fluctuating groundwater levels in the Bhatinda district. Analysis of water table depth has shown that the groundwater depth shows variation from 7.63 to 10.58 m (bgl) in Bhatinda, 10.95 to 12.09 m (bgl) in Maur, 11.83 to 16.51 m (bgl) in Nathana, 11.71 to 18.64 m (bgl) in Phul, 6.77 to 7.86 m (bgl) in Sangat and 7.20 to 8.32 m (bgl) in Talwandi. Graphical statistics interpret a steep increase in water level depth of 6.92 m as observed in Phul block, followed by 4.69 m in Nathana and the least increase in water level depth was observed in Sangat block. Existence of freshwater zones up to deeper levels, as has been established in the current work in the Phul and Nathana blocks, reflect on the declining water table levels and the consequential difficulty of its extraction.

CHAPTER-III

MATERIAL AND METHOD

3.1Study Area

The Aligarh district, a segment of western Uttar Pradesh has been endowed with highly fertile soil. The district situated in the western part of Uttar Pradesh occupies a small part of the Ganga-Yamuna doab. It lies between latitude 27˚34'26" and 28˚10'46" N and longitudes 77˚ 28'17" and 78˚ 36'02" E falling in the survey of India Toposheet nos. 53H, L, 54E and I. The northern boundary of the district is contiguous with that of Bulandshahar and G B Nagar districts. Ganga River forms the natural boundary between Aligarh and Budaun in the north-eastern corner of the district. The southern part of the district is bounded by Hathras district.

The rest of the boundary is shared by Mathura and Kanshi Ram district is the western and eastern sides respectively.

The district is of a rectangular shape. It attains its maximum i.e. 112 kms along the northern border of the district between Yamuna and Ganga river. The maximum length from north to south is about 60 kms. The district encompasses a geographical about 3721 sq.km. The district headquarter is located at Aligarh which is about 130 kms South-East of the national capital New Delhi. It is well connected by rail and roads to Delhi and other important towns of the country. The district has a very good network of all-weather roads connective all the tehsils and blocks headquarters as well as the majority of village with its headquarter.

A is part of the Aligarh division and for the administrative convenience the Aligarh district has been divided into 05 (five) tehsils and 12 (twelve) Community development blocks (Fig3.1). It has 13 towns and 1210 villages (1170 inhabited and 40 uninhabited villages).The names of tehsils and blocks of the Aligarh district with their respective geographical areas & numbers of villages are given in Table-3.1

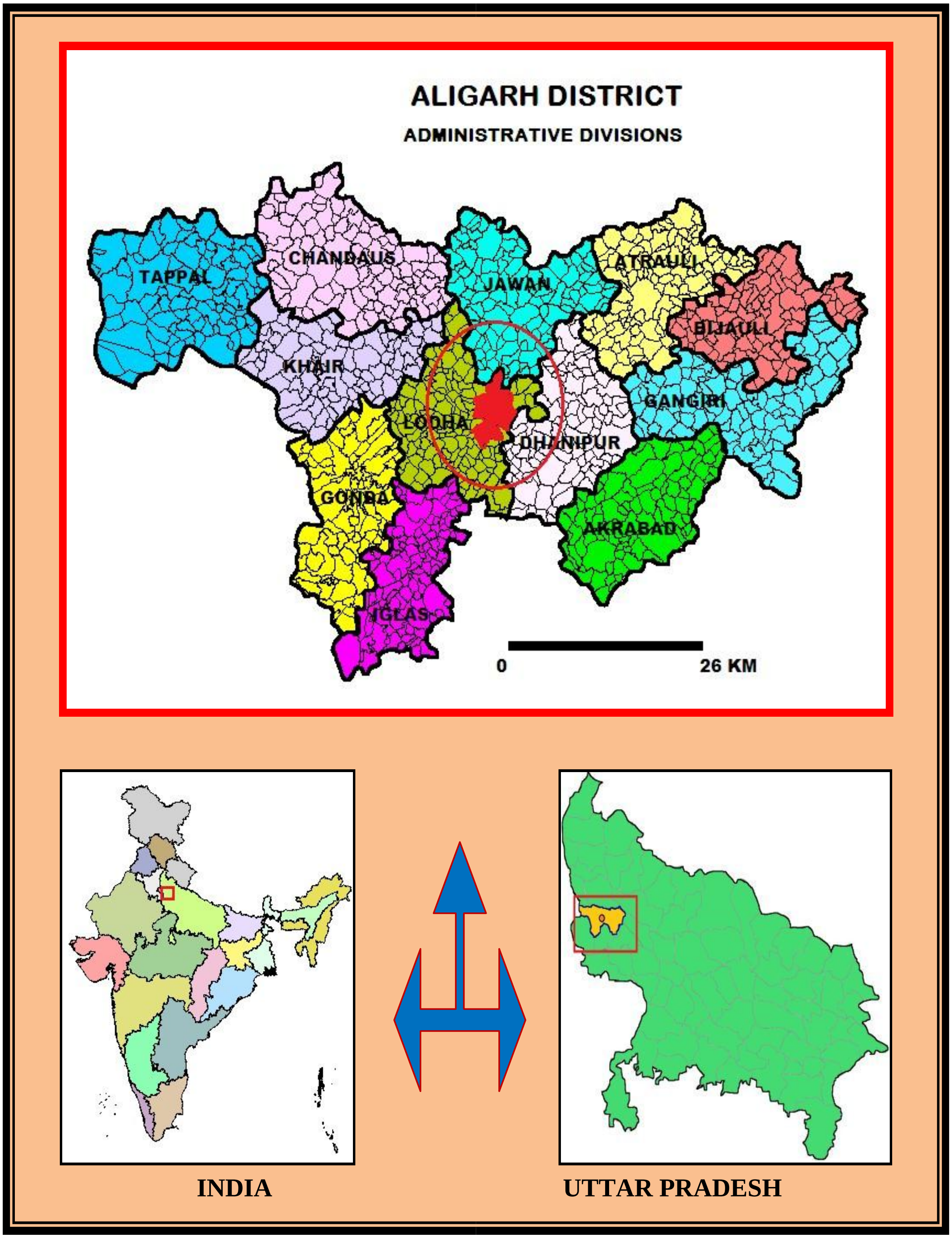


Fig. 3.1 Location Maps of the Study Area

Table-3.1 Number of Village Details Block wise Aligarh as on 31.3.2017 (Source: Statistical Diary, Directorate of Economics and Statistics, Govt. of U.P. -2017)

Sl. No.	**Blocks**	**Geographical area in sq.km.**	**Total No. of Villages**		**Total**
			Inhabited	*Uninhabited*	
I	**KHAIR TEHSIL**				
1.	Tappal	425.5	87	5	92
2.	Khair	305.7	96	0	90
II	**GABHANA TEHSIL**				
3.	Chandaus	362.5	92	2	94
4.	Jawan	286.7	104	5	109
III	**KOL TEHSIL**				
5.	Lodha	302.3	130	10	140
6.	Dhanipur	307.1	97	1	98
7.	Akrabad	276.4	86	3	89
IV	**IGLAS TEHSIL**				
8.	Gonda	323.3	83	0	83
9.	Iglas	234.1	103	0	103
V	**ATRAULI TEHSIL**				
10.	Atrauli	277.0	109	4	112
11.	Bijauli	256.6	84	8	91
12.	Gangiri	363.6	99	2	101
	Total	**3720.7**	**1170**	**40**	**1210**

3.1.1 DATA AVAILABILITY

The data pertaining to various attributes of ground water were collected from available literatures of Central Ground Water Board, State Departments and other agencies. The compiled data were plotted on 1:50,000 scale map. Data Requirement and Data Availability are summarized in Table-3.2.

Table 3.2: Data Requirement, Data Availability

Sl No	Study Aspect	Data Requirement	Data Availability
1	Rainfall and Other Climatic data	IMD Meteorological & 4 raingauage stations of Revenue Department in the area.	Rainfall data ofStudy area Available
2	Soil	Soil Map and Soil infiltration rate	Soil Map
3	Land Use	Latest Land use Pattern in Statistical department	Land Use available in StatisticsDepartment- 2016-17
4	Exploration	Data of Exploratory well	13 wells, Exploratory wells and Pz exist but theses tap Aquifer Group -I. No Aquifer parameters not available
5	Recharge Parameters	Recharge parameters of different soil and aquifer types based on field studies	Recharge parameters are available in GroundWater ResourceEstimation
6	Discharge Parameters	Discharge parameters for different Ground Water abstraction structure	Discharge parameters are available in GroundWater ResourceEstimation

3.1.2 LAND USE, IRRIGATION AND CROPPING PATTERN

- **Land Use:**

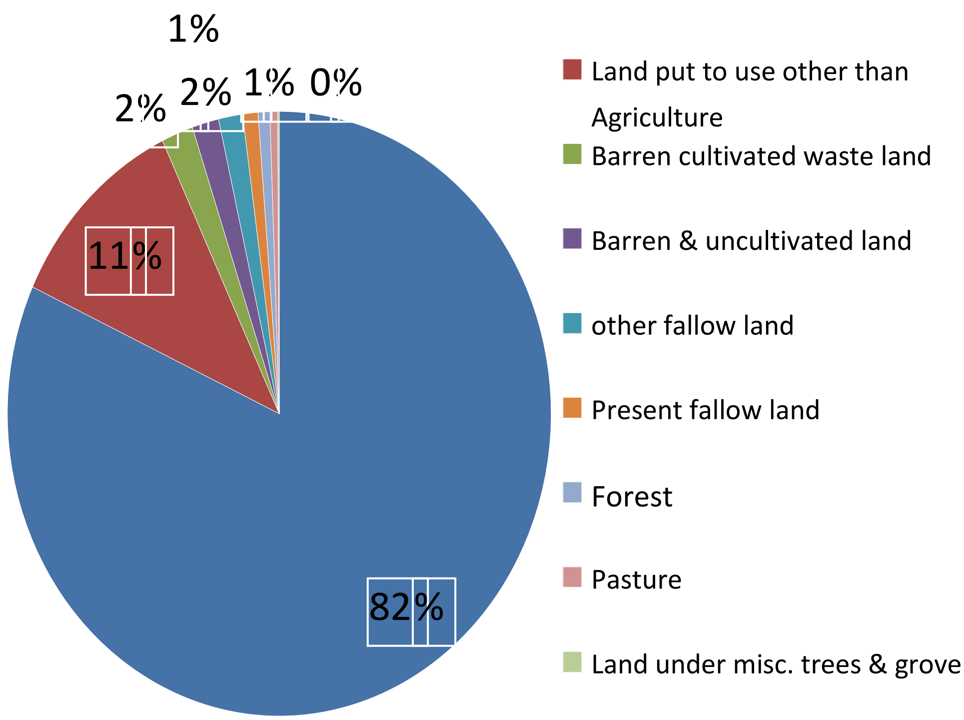
A major part of the land in the district is utilized for agriculture purpose. As per the latest statistical data available for the year 2016-17, following land utilization pattern has been observed in the district (Table 3.3). Land use distribution and map of Aligarh district is shown in Fig 3.2 and Fig 3.3. A perusal of the Table-3.3 and Fig 3.2 & 3.3 shows that 82% of land in the district is under active cultivation out of which in 68% of land, more than one crop is sown. The land under miscellaneous use is 3% and land other than agriculture use is 11% barren land is more than 2 % which is a sizeable amount. The block wise land utilization pattern indicates that of the total area sown is maximum in Tappal block followed by, Gangiri, Chandaus&Khair while in remaining blocks it is more or less evenly distributed where as in the Bijauli block it is minimum.

Rainfall:

The Annual normal rainfall of the District is 781.6 mm. Normal monsoon rainfall is 667.6 mm for the period i.e. June to September. August is the wettest month having the normal rainfall of 217.08 mm. followed by July with normal rainfall of 210.24 mm. Normal non monsoon rainfall is 113.6 mm. The normal rainy day of the district is 39.6. The average of annual rainfall of Iglas, Khair, Atrauli and Aligarh raingauge stations of the year 2008 to 2017 is presented in the Table 3.6. The annual rainfall for the year 2017 is 492.4mm. The departure of the monsoon rainfall from normal is computed and is given in Table-3.6 & Fig 3.6b. Monsoon rainfall within ± 19% of the normal monsoon rainfall is considered normal. Monsoon rainfall above 19% of the normal monsoon rainfall is considered excess and monsoon rainfall less than -19% and more than -59% of the normal monsoon rainfall is considered deficit and if the monsoon rainfall is less than -59% of the normal monsoon rainfall, it is considered scanty. Out of last 29 years, 14 years received deficient of rainfall, 1 year received scanty rainfall, 11years received normal and 3 years excess rainfall.

Table 3.3 Block wise Land use pattern of Aligarh District 2016-17

S No.	Block	Total area reported (ha)	forest	Barren cultivated waste land (ha)	Present fallow land (ha)	other fallow land (ha)	Barren & unculti vated land (ha)	Land put to use other than agriculture (ha)	Pasture (ha)	Land under misc. trees & grove (ha)	net area sown (ha)	Area sown more than once (ha)	gross area sown (ha)	Cropping Intensity %
1	Akrabad	25824	780	354	117	90	859	2130	29	59	21406	20537	41943	196
2	Atrauli	27282	210	218	128	248	234	2792	135	100	23217	19874	43091	186
3	Bijouli	24901	200	605	326	12	534	4249	148	38	18789	15450	34239	182
4	Chandaus	33346	131	758	225	394	439	2722	159	9	28509	21231	49740	174
5	Dhanipur	30067	50	988	312	502	906	3202	120	13	23974	16115	40089	167
6	Gangiri	34738	63	697	265	421	438	3264	157	16	29417	22180	51597	175
7	Gonda	29183	70	212	191	427	170	2922	78	5	25108	20649	45757	182
8	Iglas	25499	85	69	124	358	154	2800	104	10	21795	16788	38583	177
9	Jawa	31617	834	332	323	521	552	4239	192	44	24580	18930	43510	177
10	Khair	31968	44	647	201	300	378	2489	147	14	27748	21444	49192	177
11	Lodha	27364	49	457	438	1339	582	2657	231	8	21603	16830	38433	178
12	Tappal	37393	45	1048	219	308	354	4110	207	0	31102	26200	57302	184
	Total Rural	359182	2561	6385	2869	4920	5600	37576	1707	316	297248	236228	533476	179
	Total Urban	12079	16	628	498	397	305	3435	24	11	6765	6105	12870	190
	Total District	**371261**	**2577**	**7013**	**3367**	**5317**	**5905**	**41011**	**1731**	**327**	**304013**	**242333**	**546346**	**180**



. **Figure 3.2 Land Use Pattern of Aligarh district**

- **Irrigation:**

The development of irrigation potential in the district is remarkable. Block wise Irrigation facilities of district are presented in Table-3.4. Surface water irrigation through the network of upper Ganga and lower Ganga canal passes through the central parts of the district providing the irrigation facilities to the Jawan, Dhanipur, Akrabad and more parts of Lodha block while the lower Ganga canal irrigation the parts of Bijauli and Atrauli blocks in the eastern most part of Aligarh district. The Mat branch canal and its distributaries irrigates the parts of Tappal, Chandaus, Khair, Gonda and Iglas blocks located in the western parts of the distt. Total length of canal in the district is 1560 kms. These canals provide irrigation facilities in 25364 hectare which is about 8% of the total irrigation area of the district (Fig 3.4a). The major source of irrigation in the district is ground water irrigating 278196 ha contributing about 92% to the total irrigation potentials of the district. The Fig 3.4b shows block wise irrigated area by different sources.

Table 3.4 Block wise Area Irrigated by Different sources of Aligarh District 2017

S.N	**Block**	**Can-al (ha)**	**Tubewell (ha)**		well (ha)	pond (ha)	other (ha)	Net irrigated area (ha)	Surface water irrigated area (ha)	Ground water irrigated area (ha)	contricution of GW (ha)	Gross irrigated (ha)	Irrigation intensity
			Public	Private									
1	Akrabad	3967	356	16190	0	0	0	21004	4736	16268	77.4	37605	179
2	Atrauli	30	920	22891	0	0	0	23487	36	23451	99.8	37107	158
3	Bijouli	725	356	17974	0	0	0	18883	865	18018	95.4	24573	131
4	Chandaus	712	538	26282	0	0	0	27713	850	26863	97.0	41605	150
5	Dhanipur	4036	121	19002	0	0	0	23592	4818	18774	79.5	37149	257
6	Gonda	1935	44	23348	0	0	0	25264	150	22954	90.8	38103	125
7	Gangiri	126	1131	28591	0	0	0	29450	2310	29300	99.4	36757	151
8	Iglas	685	0	21280	0	0	0	21716	818	20898	96.2	33145	153
9	Jawa	2229	260	22025	0	0	0	24550	2661	21889	89.0	40268	164
10	Khair	3994	406	22651	0	0	0	27430	4768	22662	82.6	41408	151
11	Lodha	35	279	21939	0	0	0	21867	42	27433	94.4	30546	140
12	Tappal	1448	0	30258	0	0	0	31415	1729	29686	94.4	51999	166
	Urban Area	1323	117	5435	0	0	56	7189	1581	7189	82.0	11828	164
	Total	25364	4881	273259	0	0	56	303560	25364	278140	92.0	462093	180

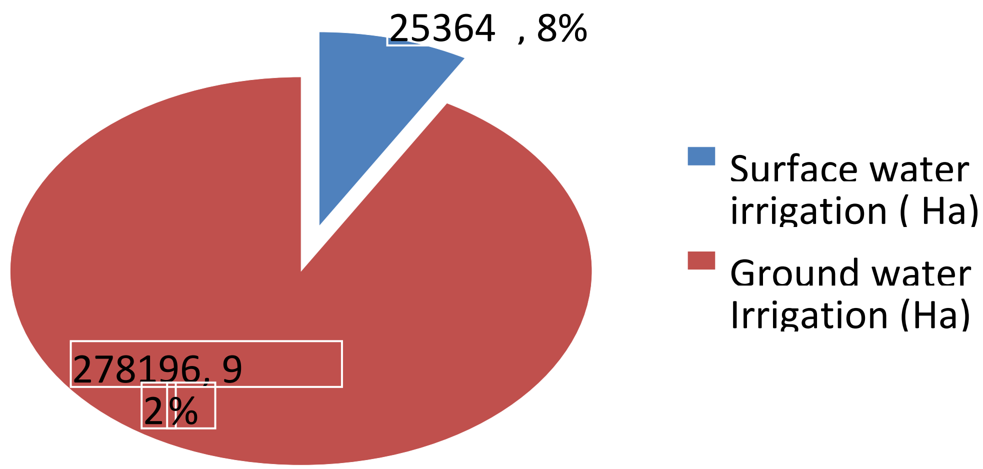


Fig: 3.3 Area Irrigated by Ground Water and Surface Water in Aligarh District-2017

Table 3.5 Block wise Number of Ground water Structures of Aligarh District 2017

S . No.	Block	Canal length	Govt. tube well	Pakka wells	Rahat	Shallow Tube well private				Ground pump set
						Electric	Diesel Run	Other	Total	
1	Akrabad	141	39	8	0	1023	4909	8	5940	0
2	Atrauli	149	119	10	0	2733	2346	10	5089	5
3	Bijouli	160	66	0	0	1018	4197	7	5222	5
4	Chandaus	61	57	0	0	2979	2317	12	5308	26
5	Dhanipur	115	31	12	0	1202	4263	10	5475	3
6	Gonda	130	9	12	0	1424	6638	10	8072	0
7	Gangiri	164	115	0	0	1133	5163	5	6301	45
8	Iglas	101	22	0	0	1999	4452	10	6461	
9	Jawa	123	49	10	0	1253	2972	10	4236	0
10	Khair	197	43	0	0	2518	4601	15	7134	5
11	Lodha	82	72	15	0	2264	832	17	3113	9
12	Tappal	121	17	0	0	2094	2195	10	4299	4
	Urban Area	**16**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	Total	**1560**	**641**	**67**	**0**	**21640**	**44885**	**124**	**66649**	**102**

- **CLIMATE**

Temperature:

One IMD meteorological observatory and four raingauge stations exist in Aligarh district. All Climatological variations are depicted in Table-3.5. Aligarh district experiences the sub-humid climate type of climate. The summers and winters are generally severe. The summer season starts from and March and continues till late June when the monsoon sets in over the area. The hottest month is June with average mean temperature of 33.65. The coldest month temperature is 10.9^{0}C in December followed by January with 14.02^{0}C.

Humidity:

The relative humidity remains high during the morning. Maximum relative humidity (85%) has been observed during the month of August and minimum (37%) in the month of May. The relative humidity falls to low during summer and increases during the active monsoon period. The average relative humidity at the morning is 64.25% and in the evening it is 50.25%. The relative humidity data of the district is given in Table-3.6

Wind Velocity:

During the month of summer hot strong dust blows during the day time thunder storm with a velocity of 50 to 70 km/hr. occurs during summers. In general used velocity is generally low during the winter season and high during the summer. The average of monthly the velocity over the district is shows in Table-3.6

Potential Evapotranspiration:

The annual normal potential evapotranspiration of the district is 1529.1 mm. The maximum P.E.T occurs in the month of May & June with 222 and 215mm. respectively whereas the minimum PET recorded in the month of December 51.5 mm. the average of monthly the P.E.T value the district is shown in Table-3.6

Table-3.6: Climatological Variations of Aligarh (Average Monthly)

Temp. in ^{0}C	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean/ Total
Max	21	25	30.7	37.2	41	39.6	34	32.8	33.4	32.9	28.3	12.9	30.68
Min	7.4	9.6	14.4	20.4	25	27.7	26	25.6	24.2	19.3	22.6	8.9	19.29
Avg.	14	17	22.6	28.8	33	33.7	30	29.2	28.8	26.1	25.5	10.9	24.99
Relative Humidity (%) Morning	78	71	58	39	37	54	78	85	77	66	54	74	64.25
Relative Humidity (%) Evening	54	44	66	22	24	39	67	74	62	48	48	55	50.25
Avg.	66	58	62	30.5	31	45.5	73	79.5	69.5	57	51	64.5	57.25
Monthly Rainfall (mm)	15	14	7.4	5.2	14	48.6	230	245	144	48.2	2.2	7.6	781.6
Potential Evapotranspiration (mm)	54	76	130	175	222	215	151	127	136	119.4	72.9	51.5	1529.1
Wind speed K mph	5.3	6.2	6.9	7.5	8	8.5	7.9	6.4	6.3	4.4	4	4.6	6.33
No. of Rainy Days	1.5	1.2	1	0.6	1.3	3.6	11	11.4	5.5	1.9	0.2	0.7	39.6
P.E. Value	0.9	0.7	0.29	0.17	0.4	1.75	11	11.9	6.64	2.12	0.07	0.48	36.16

3.2 Ground Water Balance Equation

The study of water balance is defined as the systematic presentation of data on the supply and use of water within a geographic region for a specified period. With water balance approach, it is possible to evaluate quantitatively individual contribution of sources of water in the system, over different time periods, and to establish the degree of variation in water regime due to changes in components of the system. The following groundwater equation of water balance was used for study.

Inflow to the system - outflow from the system = change in storage of the system (over a period of (time) **(3.1)**

Considering the various inflow and outflow components, the equation no. (3.1) can also be written as:

$$\mathbf{Ri + Rc + Rr + Rt + Si + Ig = Et + Tp + Se + Og + \Delta S} \quad \mathbf{(3.2)}$$

Where,

Ri = recharge from rainfall;

Rc = recharge from canal seepage;

Rr = recharge from field irrigation;

Rt = recharge from pond storage

Ig = inflow from other blocks;

Et = evapo-transpiration;

Tp = ground water discharge from tubewell;

Si, Se = influent and effluent seepage from rivers;

Og = outflow to other blocks; and

ΔS = change in ground water storage.

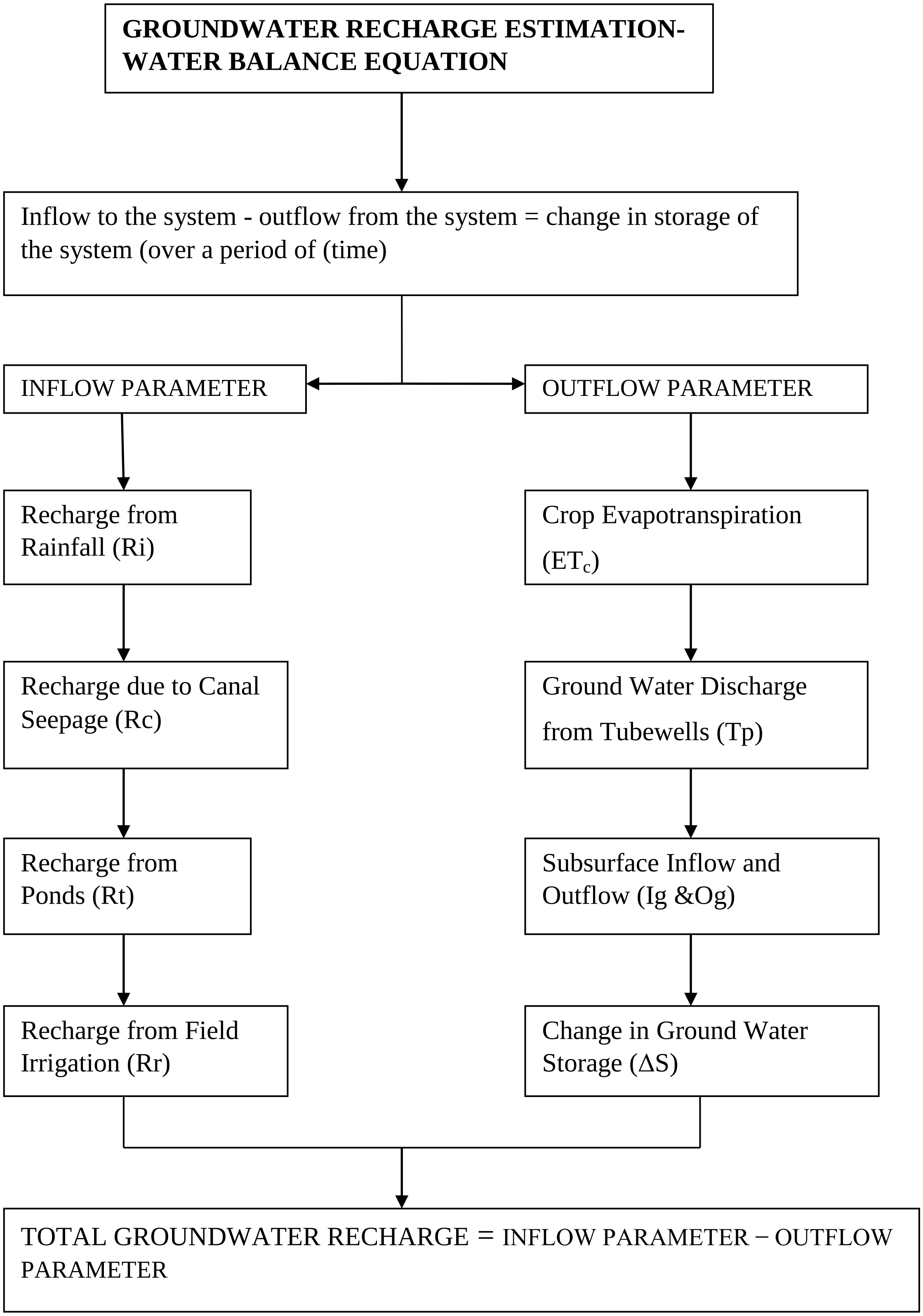
Equation (3.2) considers only one aquifer system and thus does not account for the interflows between the aquifers in a multi-aquifer system. However, if sufficient data related to water table and piezometric head fluctuations and conductivity of intervening layers are available, the additional terms for these interflows can be included in the governing equation. All elements of the water balance equation were computed using independent methods wherever possible. The water balance may be computed for any time interval and the complexity of computation of the water balance tends to increase with increase in area. This is due to a related increase in the technical difficulty of accurately computing the numerous important water balance components.

In this current study influent and effluent seepage from river was neglected as it would provide very small or no effect in recharge or draft. Thus the water balance equation can be re-written as

$$\mathbf{Ri + Rc + Rr + Rt + Ig = Et + Tp + Og + \Delta S} \qquad \mathbf{(3.3)}$$

3.3 Study Period

The periods for study depend from the time of maximum water table to the time of minimum water table elevation as the non-monsoon period and from the time of minimum water table to the time of maximum water table elevation as monsoon period. For northern India, the water year is taken as January 1 to December 31 same year. It is desirable to use the data of a number of years preferably covering one cycle of a dry and a wet period of year *(Kumar C.P.2004).* Thus the study periods are taken as monsoon period for the duration June to October and non-monsoon period for the duration of November to May.


GROUNDWATER RECHARGE ESTIMATION-WATER BALANCE EQUATION
Inflow to the system - outflow from the system = change in storage of the system (over a period of (time)
INFLOW PARAMETER
OUTFLOW PARAMETER
Recharge from Rainfall (Ri)
Recharge due to Canal Seepage (Rc)
Recharge from Ponds (Rt)
Recharge from Field Irrigation (Rr)
Crop Evapotranspiration (ET_c)
Ground Water Discharge from Tubewells (Tp)
Subsurface Inflow and Outflow (Ig &Og)
Change in Ground Water Storage (ΔS)
TOTAL GROUNDWATER RECHARGE = INFLOW PARAMETER − OUTFLOW PARAMETER

3.4 Estimation of Ground Water Balance Components

The estimation of the various inflow and outflow components of the ground water balance equation is discussed below.

3.4.1 Recharge from Rainfall (R_i)

The methods for estimation of rainfall recharge involve the empirical relationships established between recharge and rainfall developed for different regions. Based on the water level fluctuations and rainfall amounts the following formula was used to estimates the recharge from rainfall.

Some of these empirical relationships for different hydrogeological and climatological situations are:

3.4.1.1 Chaturvediformula (1936)

Based on the water level fluctuation and rainfall amounts in Ganga-Yamuna doab, Chaturvedi [24] derived an empirical relationship to arrive at the recharge as a function of annual precipitation (when rainfall exceeds 15.7 inch).

$$\mathbf{R = 2.0\ (P - 15)^{0.4}} \qquad \mathbf{(3.4)}$$

Where,

R = net recharge due to precipitation during the year, in inches

P = annual precipitation, in inches

The Chaturvedi formula has been widely used for preliminary estimation of ground water recharge from rainfall.

3.4.1.2 U.P.I.R.I. Formula (1954)

The formula given by Uttar Pradesh Irrigation Research Institute, Roorkee, 1954 is asfollows (Kumar, 1996),

$$\mathbf{Rg = 1.35\ (P-14)^{0.5}} \qquad \mathbf{(3.5)}$$

Where ,

Rg is net recharge, in inches

P is annual rainfall, in inches.

3.4.1.3Bhattacharjee Formula (1954)

Bhattacharjee, 1954 derived an empirical relationship for estimation of rainfall recharge (Annual report of AICRP on groundwater utilization.

$$\mathbf{R = 3.47\ (P-38)^{0.4}} \qquad \textbf{(3.6)}$$

Where,

R is groundwater recharge, cm

P is precipitation, cm

3.4.1.4 Sehgal formula (1973)

Using regression analysis for certain doabs in Punjab, Sehgal developed a formula in 1973 for Irrigation and Power Research Institute, Punjab (Cited by Baweja and Karanth, [25]). The formula was found to hold good for areas were rainfall was between 23.6 and 27.5 inches.

$$\mathbf{R = 2.5\ (P - 0.6)^{0.5}} \qquad \textbf{(3.7)}$$

Where,

R and P both are measured in inches.

This formula is not applicable for this study because the values are below the given range i.e (23.6 and 27.5).

3.4.1.5Modified Chaturvedi formula (1980)

The Chaturvedi formula was later modified by further work at the U.P. Irrigation Research Institute, Roorkee (Cited by Baweja and Karanth, [25]), and the modified form of the formula is:

$$\mathbf{R = 1.35\ (P-14)^{0.5}} \qquad \textbf{(3.8)}$$

Where,

R is groundwater recharge, (cm)

P is precipitation, (cm)

3.4.1.6Bhargava et al. (1983)

$$\mathbf{P = 3.24(R-30)^{0.49}} \qquad \textbf{(3.9)}$$

Where,

P and R in inches.

3.4.1.7Kumar and Seethapathi Formula (2002)

Kumar andSeethapathi, 2002 proposed the following relationship for estimation of recharge from rainfall in upper Ganga canal command area (Kumar and Seethapathiformula 2002),

$$Rg = 0.63\ (P-15.28)^{0.76} \qquad (3.10)$$

3.4.1.8 Bhattacharya Formula

$$P=1.35(R-14)^{0.5} \qquad (3.11)$$

Where,

P and R in inches.

3.4.1.9IPRI Formula

$$P= 3.98(R-40.6)^{0.5} \qquad (3.12)$$

Where,

P and R in inches.

3.4.2 Recharge due to Canal Seepage (Rc)

Seepage losses per million square meter of wetted area in unlined channels were taken as 3 cumecs . The following formula was adopted for computing the recharge from canal (Rc)

i). Mortiz Formula (USSR)

$$S = 0.2 * C * (Q/V)^{0.5} \qquad (3.13)$$

Where;

S: is the seepage losses in cubic foot per second per mile length of canal,

Q: is the discharge (ft3 /sec),

V: is the mean velocity (ft/sec),

C is a constant varies from 0.34 for clay and 1.1 for sand soil.

ii) Molesworth and Yennidunia (Egypt)

$$S = C * L * P * R^{0.5} \qquad (3.14)$$

Where,

S is the conveyance losses for a given canal length in m^3 /sec,

L is the length of the canal in km.

P is the wetted perimeter in m,

R is the hydraulic radius in m, and

C is the constant depends on soil types, for clay equal 0.0015 and for Sand equal 0.003

iii) Indian Formula

$$S=C*a*d \tag{3.15}$$

Where; S is the total seepage losses in ft^3 /sec;

a: the area of wetted perimeter in million ft;

d: the depth in ft; and

C: factor depends on soil types and varies from 1.1 to 1.8.

3.4.3Recharge from Field Irrigation (R_i)

The recharge due to irrigation return flow may also be estimated, based on the source of irrigation (groundwater or surface water), the type of crop (paddy, non -paddy) and the depth of water table below ground surface, using the norms provided by Groundwater Resource Estimation Committee (1997), as given below (as percentage of water application):

Source of Irrigation	Type of crop	Water table below ground surface		
		<10m	10-25m	>25m
Groundwater	Non-paddy	25	15	5
Surface water	Non-paddy	30	20	10
Groundswater	Paddy	45	35	20
Surface water	Paddy	50	40	25

3.4.4 Recharge from Tank (R_t)

Studies have indicated that seepage from tanks varies from 9 to 20 percent of their live storage capacity.

3.4.5 Influent and Effluent Seepage (S_i & S_e)

The discharge at the downstream end is expressed as:

$$\mathbf{Q_d \Delta t} = Q_u.\,\Delta t + Q_g.\,\Delta t + Q_t.\,\Delta t - Q_o.\,\Delta t - E.\,\Delta t \pm S_{rb} \qquad \mathbf{(3.17)}$$

Where,

Q_d=discharge at the downstream section;

Q_u=discharge at the upstream section;

Q_g = groundwater contribution (unknown quantity; -ve computed value indicates influent conditions);

Q_t =discharge of tributaries;

Q_o =discharge diverted from the river;

E = rate of evaporation from river water surface and flood plain (for extensive bodies of surface water and for long time periods, evaporation from open water surfaces can not be neglected);

Srb =change in bank storage (+ for decrease and - for increase); and

Δt=time period.

3.4.6 Inflow from and Outflow to Other Basins (I_g&O_g)

The inflow/outflow is determined as follows:

$$I_g \text{ or } O_g = \sum T\, I\, \Delta L \qquad \mathbf{(3.18)}$$

Where,

T is the transmissivity

I is the hydraulic gradient averaged over a length ΔL of contour line.

3.4.7 Evapotranspiration from Groundwater (E_t)

. The evapotranspiration can be estimated based on the following equations:

$E_t = PE_t * A$ if $h > h_s$

$E_t = 0$ if $h < (h_s - d)$

$E_t = PE_t * A (h - (h_s - d))/d$ if $(h_s - d) \le h \le h_s$

where,

E_t= evapotranspiration in volume of water per unit time[L^3 T^{-1}];

PE_t =maximum rate of evapotranspiration in volume of water per unit area per unit time [L^3 L^{-2} T^{-1}]

A= surface area [L^2];

H = water table elevation [L]

h_s =water table elevation at which the evapotranspiration loss reaches the maximum value;

d= extinction depth. When the distance between h_s and h exceeds d, evapotranspiration from groundwater ceases [L].

3.4.8Draft from Groundwater (T_p)

The groundwater draft represented as:-

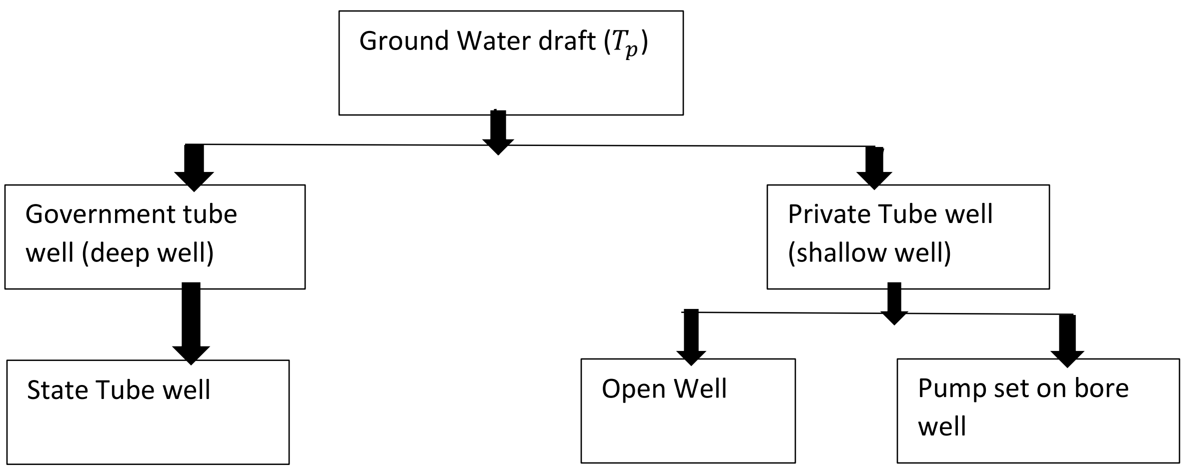


Fig.3.4 Flow chart of Groundwater Draft

3.5 Groundwater Recharge

The entire inflow component (i.e. recharge from rainfall, canal seepage, field irrigation, and tanks) and outflow component (i.e. crop water requirement, draft from tubewell, inflow and out flow of water from blocks and groundwater fluctuation) were estimated for each block separately and total groundwater recharge was estimated using equation 3.

CHAPTER-IV

RESULT AND DISCUSSION

The methodology for computing of each inflow and outflow component for groundwater recharge for Allahabad is given in previous chapter. The results of the study are discussed in this chapter under the following headings.

4.1Recharge from Rainfall (R_i)

For estimating this parameter there are various equation used, in which KUMAR AND SEETHAPTI equation is used for the area.The recharge from rainfall was appraised by using the results are given in Table and Fig. 4.1 and. Result manifest that utmost recharge due to the monsoon rainfall was estimated for Tappal block i.e. 22.93 Mm^3 followed by Gangiri block i.e. 18.57 Mm^3 and Chandos block i.e. 18.50 Mm^3. The minimal recharge due to monsoon rainfall was appraised for Iglas block i.e. 9.47 Mm^3 followed by Bijauli block i.e. 11.05 Mm^3 and Jawan block i.e. 13.16 Mm^3. The recharge during non-monsoon season was not found for any block because the rainfall occurred during non-monsoon season was found lesser. Total volume of water which bestow to the ground water in Aligarh during monsoon season is 177.70 Mm^3 and non-monsoon season is zero because there is lesser rainfall. Since the value of water recharge also depends on the rechargeable area of each block.Therefore rechargeable area and recharge from rainfall is highest for monsoon season in Tappal whereas Iglas block is having lowest rechargeable area and rainfall recharge is lowest.

Table 4.1Recharge from Rainfall during Monsoon season (Mm^3)

Recharge from Rainfall during Monsoon season (Mm^3)										
Blocks	**Area (Km^2)**	**UPIRI**	**IPRI**	**Bhattacharya**	**Bhargava *et al.***	**Kumar and Seethapathi**	**Bhattacharya Jee**	**Sehgal**	**Chaturvedi**	**Modified Chaturvedi**
Akrabad	276.40	30.90	44.03	27.31	44.72	12.44	30.90	81.75	31.09	27.30
Atrauli	277.00	30.97	44.13	27.37	44.82	12.48	30.97	81.93	31.16	27.36
Bijauli	256.60	28.69	40.88	25.35	41.52	11.05	28.69	75.89	28.86	25.34
Chandaus	362.50	40.53	57.75	35.82	58.65	18.50	40.52	107.22	40.77	35.80
Dhanipur	307.10	34.33	48.92	30.34	49.69	14.60	34.33	90.83	34.54	30.33
Gangiri	363.60	40.65	57.92	35.92	58.83	18.57	40.65	107.54	40.9	35.91
Gonda	323.30	36.14	51.50	31.94	52.31	15.74	36.14	95.62	36.37	31.93
Iglas	234.10	26.17	37.29	23.13	37.88	9.47	26.17	69.24	26.33	23.12
Jawan	286.70	32.05	45.67	28.33	46.39	13.16	32.05	84.8	32.25	28.31
Khair	305.70	34.18	48.70	30.2	49.46	14.50	34.18	90.42	34.39	30.19
Lodha	302.30	33.80	48.16	29.87	48.91	14.26	33.80	89.41	34.00	29.86
Tappal	425.50	47.57	67.78	42.04	68.85	22.93	47.57	125.85	47.86	42.02
Total	**3720.80**	**415.98**	**592.73**	**367.62**	**602.03**	**177.70**	**415.97**	**1100.50**	**418.52**	**367.47**

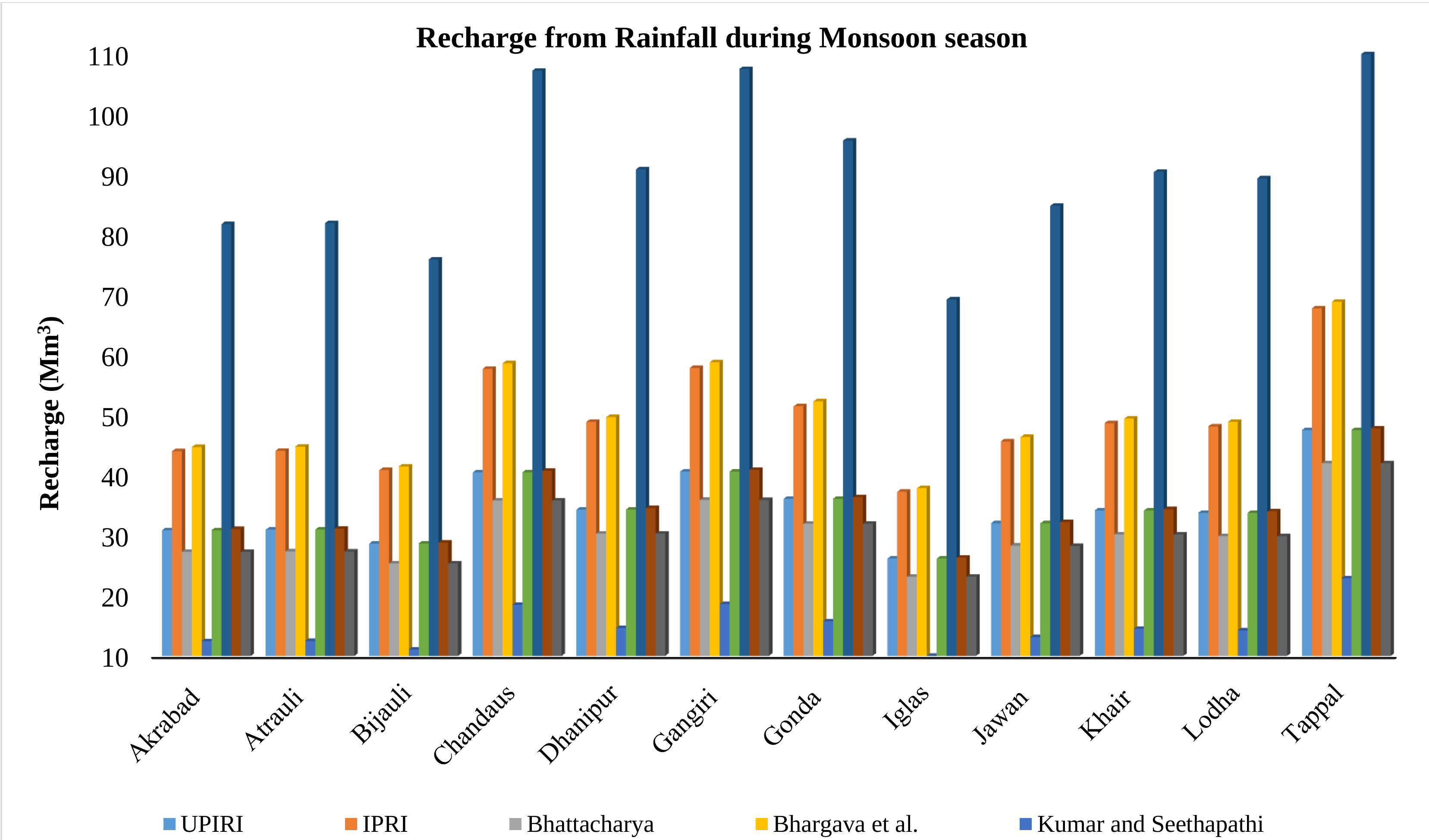


Fig. 4.1 Recharge due to Rainfall calculates using UPIRI, IPRI, Bhattacharya, Bhargava *et al.*,Kumar and Seethapati, Bhattacharya Jee, Sehgal, Chaturvedi,and Modified Chaturvedi during monsoon season.

4.2Recharge from Canal Seepage (R_c)

For estimating this parameter there are various equation used, in which INDIAN formula is used for the area The result of recharge from Canal Seepage are given in Table 4.2, Table 4.3 and Fig. 4.2. The appraised values shows that maximum recharge from canal seepage during monsoon period was appraised for Khair block i.e. 1.41Mm^3 followed by Gangiri block i.e. 1.18 Mm^3 and Bijauli block i.e.1.15 Mm^3. The minimal recharge from canal seepage during monsoon period was appraised for Chandaus block i.e. .44 Mm^3 followed by Lodha block i.e. .59 Mm^3 and Iglas block i.e. .79 Mm^3. The maximum recharge during non-monsoon canal seepage was also appraised for Khair block i.e. 2.55 Mm^3 followed Gangiri block i.e. 2.12 Mm^3 and Bijauli block i.e. 2.07 Mm^3. The minimal recharge from canal seepage during non-monsoon period was also appraised for Lodha block on i.e. 1.06 Mm^3 followed by Iglas i.e. 1.31 Mm^3 and Dhanipur block i.e. 1.49 Mm^3.The total cover up length of canal was highest in Khair block and lowest in Chandaus block. Thus the seepage from canal was observed highest in Khair block and lowest in Chandaus block. The resultant seepage from canal during monsoon and non- monsoon seasons were 11.09 Mm^3 and 19.7 Mm^3 respectively. Seepage from canal estimated by Ground Water Department Allahabad for monsoon and non-monsoon season was 83746600 m^3 and 91044700 m^3 respectively.

Table 4.2 Recharge from Canal during Monsoon Season (Mm^3)

Recharge from Canal during Monsoon Season (Mm^3)			
Block	**Mortiz Formula (USSR)**	**Molesworth and Yennidunia**	**Indian Formula**
Akrabad	0.04	3.17	1.01
Atrauli	0.04	3.35	1.07
Bijauli	0.04	3.6	1.15
Chandaus	0.04	1.37	0.44
Dhanipur	0.04	2.59	0.83
Gangiri	0.04	3.69	1.18
Gonda	0.04	2.92	0.93
Iglas	0.04	2.27	0.73
Jawan	0.04	2.77	0.88
Khair	0.04	4.43	1.41
Lodha	0.04	1.84	0.59
Tappal	0.04	2.72	0.87
Total	**0.48**	**34.72**	**11.09**

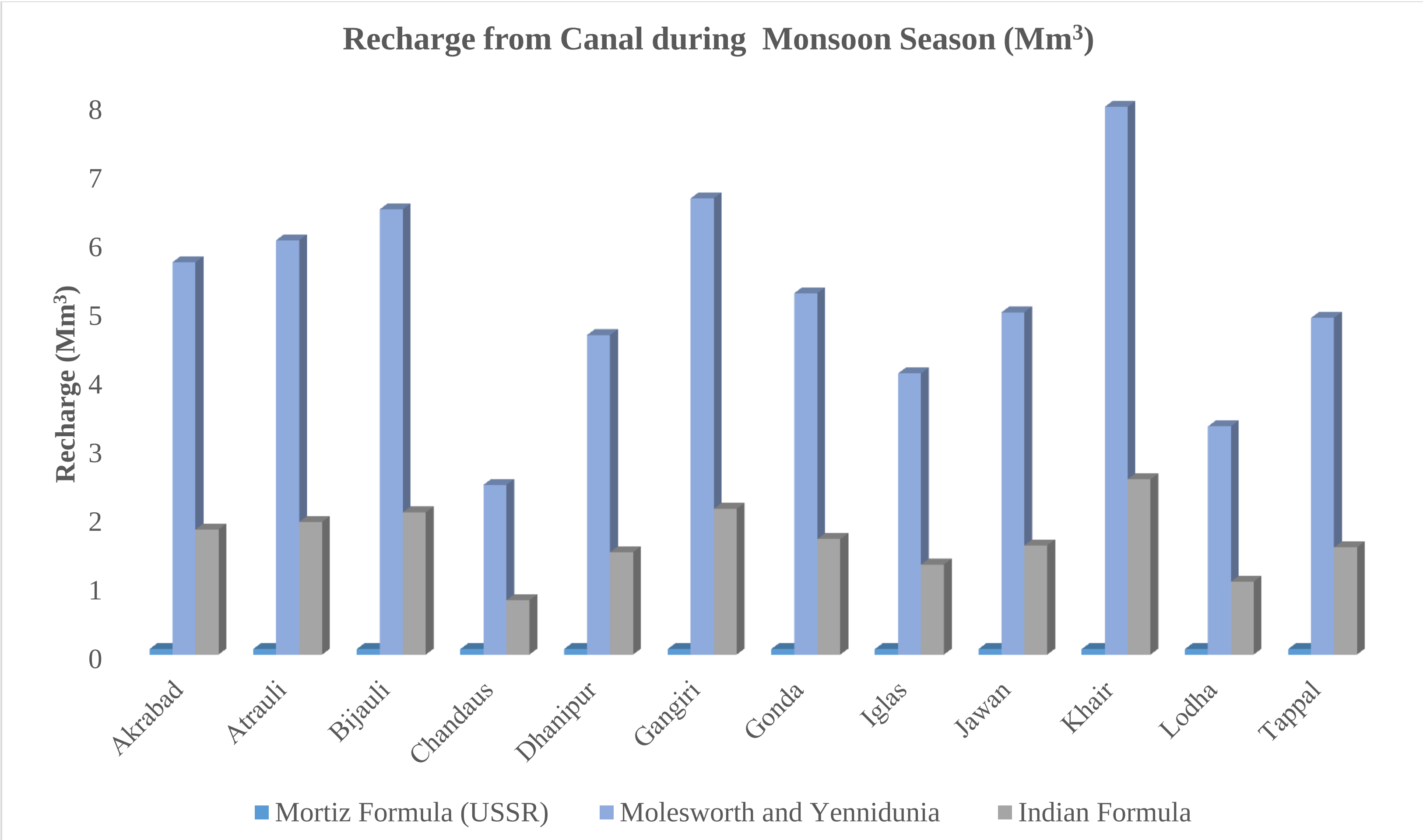


Fig. 4.2Recharge due to canal seepage calculates using Mortiz Formula (USSR), Molesworth and Yennidunia, and Indian Formula during monsoon season.

Table 4.3 Recharge from Canal during Non-Monsoon Season (Mm^3)

Recharge from Canal during Non-Monsoon Season (Mm^3)			
Block	**Mortiz Formula (USSR)**	**Molesworth and Yennidunia**	**Indian Formula**
Akrabad	0.08	5.71	1.82
Atrauli	0.08	6.03	1.93
Bijauli	0.08	6.48	2.07
Chandaus	0.08	2.47	0.79
Dhanipur	0.08	4.65	1.49
Gangiri	0.08	6.64	2.12
Gonda	0.08	5.26	1.68
Iglas	0.08	4.09	1.31
Jawan	0.08	4.98	1.59
Khair	0.08	7.97	2.55
Lodha	0.08	3.32	1.06
Tappal	0.08	4.90	1.56
Total	**0.96**	**62.5**	**19.97**

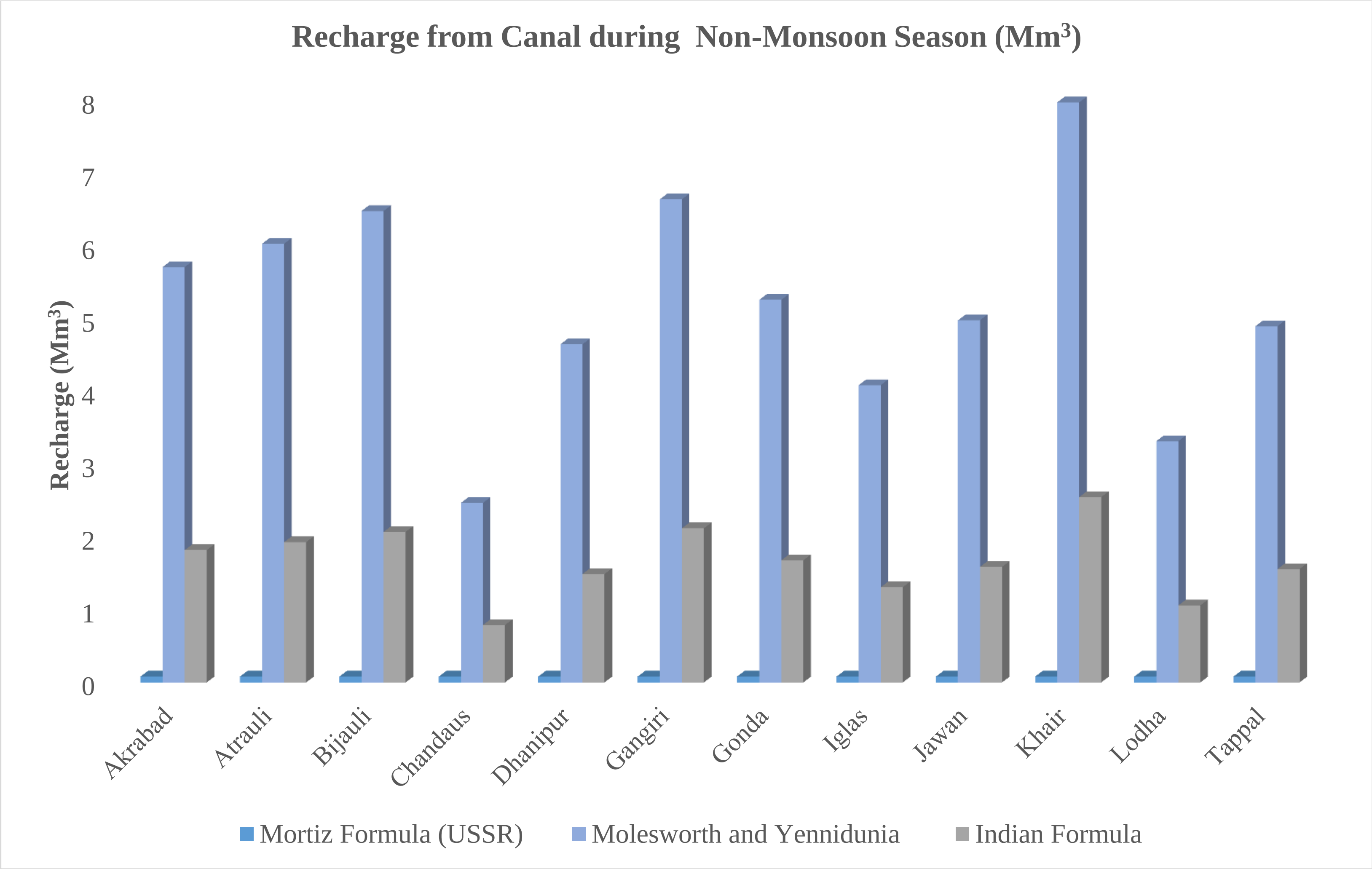


Fig. 4.3Recharge due to canal seepage calculates using Mortiz Formula (USSR), Molesworth and Yennidunia, and Indian Formula during non-monsoon season.

4.3Recharge from Field Irrigation (R_r)

To appraised recharge from field irrigation (R_r), the data for paddy and non-paddy crop area under surface and ground water irrigation and the water table for corresponding blocks as shown in Appendix A4. The recharge was estimated and the results are given in Table 4.4 and Fig. 4.4 and Fig. 4.5. Result shows that the maximum recharge from the field irrigation during monsoon season was estimated 10.17 Mm^3 for Tappal block followed by Gonda block (9.93 Mm^3) and Jawan block (7.29 Mm^3). The minimum recharge from the field irrigation during monsoon season was estimated 0.85 Mm^3 for Iglas block followed by Lodha block (1.12 Mm^3) and Chandaus block (1.21 Mm^3). The maximum recharge from the field irrigation during non-monsoon season was estimated 12.08 Mm^3 for Tappal block followed by Gonda block (10.54 Mm^3) and Jawan block (9.94 Mm^3). The minimum recharge from the field irrigation during non-monsoon season was estimated 1.84 Mm^3 for Iglas block followed by Lodha block (1.92 Mm^3) and Chandaus block (2.51 Mm^3). Tappal block is having the highest agricultural land so the seepage from the irrigation water is higher and secondly the percentage of recharge from surface irrigation is higher than that of ground water irrigation (Table 3.1), thus the seepage from irrigation was observed higher in Tappal block and lowest in Iglas block. The computed recharge during monsoon and non-monsoon season was 71.23 Mm^3 and 55.26 m^3 respectively. The similar results were reported by Ground Water Department of Aligarh where they computed recharge from field irrigation in Tappal and Iglas blocks. Recharge variation in monsoon season was much higher than that of non-monsoon season because of the higher depth of irrigation in paddy crop which contributed the recharge from field irrigation. Water depth for paddy was calculated 0.65 m whereas it was reported 0.30 m by Ground Water Department Aligarh (2008).

Table 4.4 Recharge from field irrigation (Mm^3)

Recharge from field irrigation (Mm^3)		
Blocks	**Non-Monsoon**	**Monsoon**
Akrabad	6.59	7.50
Atrauli	1.49	2.60
Bijauli	3.09	4.06
Chandaus	1.21	2.51
Dhanipur	7.11	8.79
Gangiri	4.36	6.05
Gonda	9.93	10.54
Iglas	0.85	1.84
Jawan	7.29	9.94
Khair	2.04	3.40
Lodha	1.12	1.92
Tappal	10.17	12.08
Total	**55.26**	**71.23**

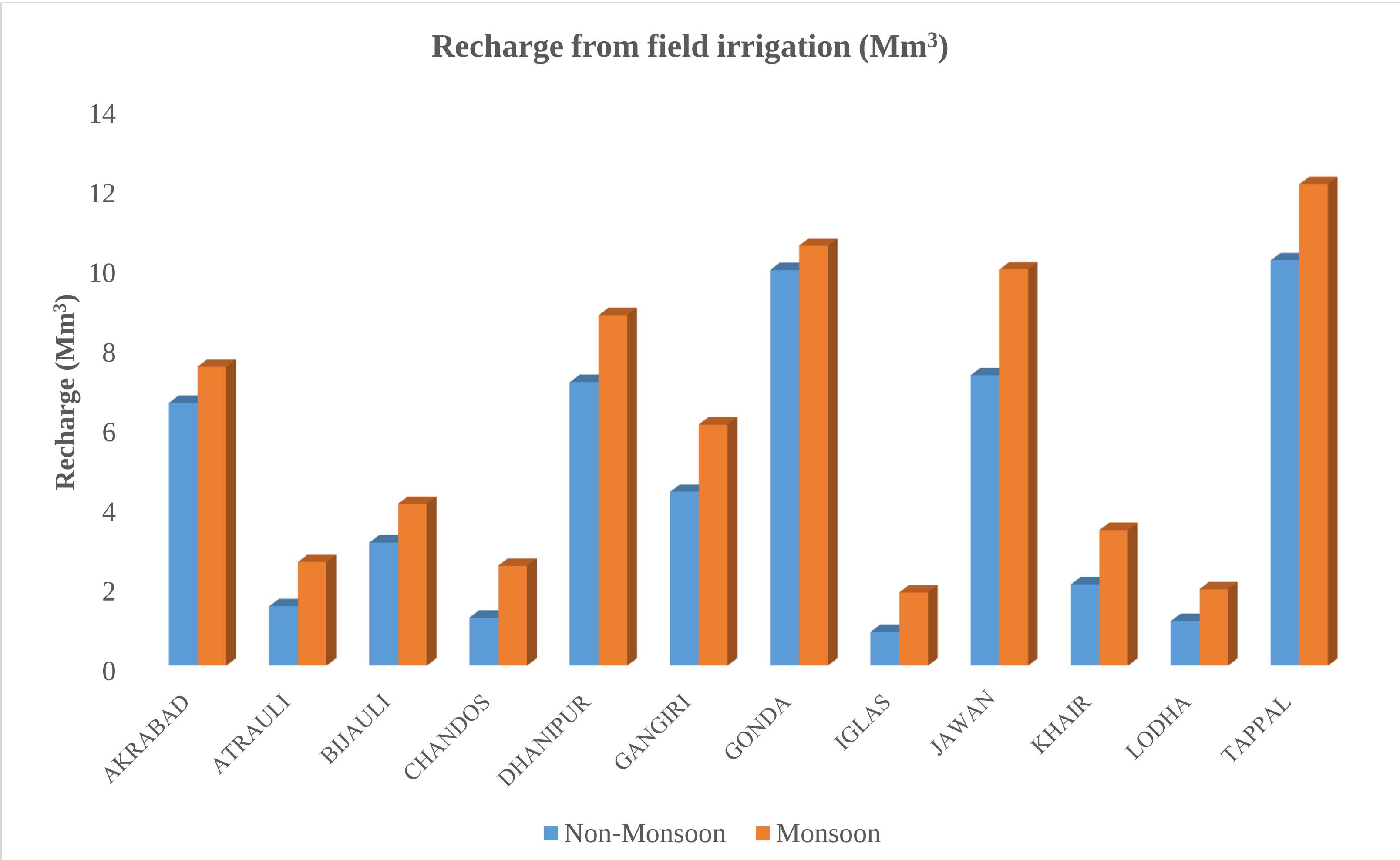


Fig. 4.4Recharge due to canal seepage calculates during non-monsoon season and monsoon season.

4.4 Recharge from Tank (R_t)

For the estimation of recharge from the tank, it is very necessary to have tanks with sufficient amount. Where as in Aligarh, there are no tanks .therefore the recharge through tanks is zero i.e. negligible.

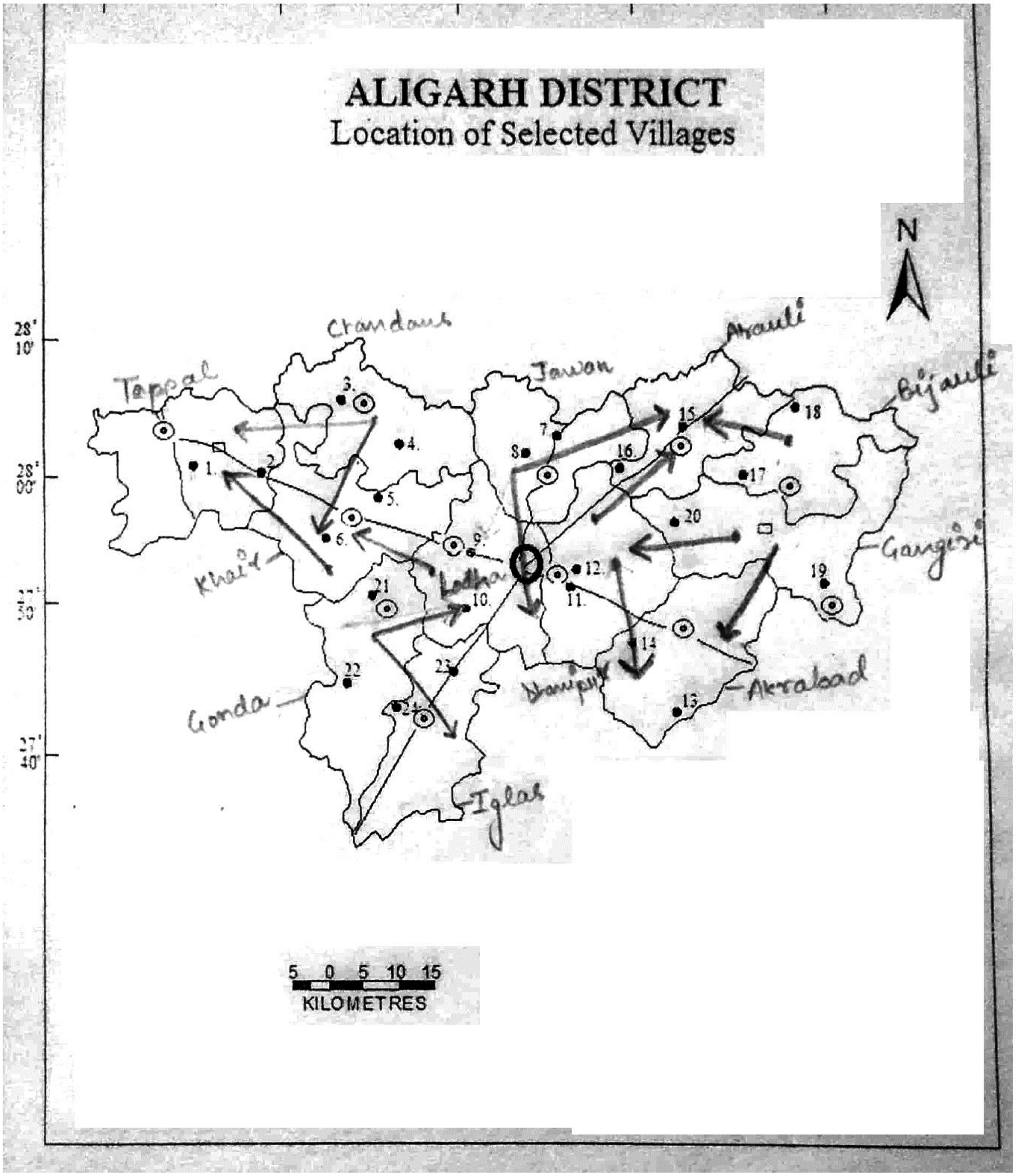
4.5Influent and Effluent Seepage (S_i and S_e)

For estimation of Influent and Effluent Seepage, a river which is directly connected with the groundwater is required. But at the area of study i.e. in Aligarh there is no such kind of river. Therefore, recharge through river is zero i.e. negligible.

4.6Subsurface Inflow and Outflow (Ig &Og)

To estimate the Subsurface inflow and outflow water level contour lines were sketched on the maps through the interpolation.Water level contour maps are shown in Fig. 4.6 and 4.7. Inflow and outflow from blocks during monsoon and non-monsoon season were estimated and presented in Table 4.4(a) and 4.4(b) respectively.

Table 4.5 and Table 4.6 show maximum water was in-flowed to Atrauli block i.e. 14.19m^3 followed by Tappal block (12.85m3) and out-flowed from Jawan block i.e.14.19m^3 followed by Chandos block (12.85m^3) during monsoon season. During non-monsoon season maximum water was also in-flowed to Atrauli block i.e. 6.80m^3 followed by Tappal block (6.50 m^3) and out-flowed from Jawan block i.e. 6.90 m^3 followed by Chandos block (6.50 m^3)in non-monsoon season.



Subsurface Inflow/Outflow to/from during mansoon season (Mm^3)

Table 4.5 Subsurface Inflow/Outflow to/from during mansoon season (Mm^3)

Subsurface Inflow/Outflow to/from during mansoon season (Mm^3)			
Blocks	**Inflow**	**Outflow**	**Total Inflow/Outflow**
AKRABAD	8.21	0.00	8.21
ATRAULI	14.19	0.00	14.19
BIJAULI	0.00	7.92	-7.92
CHANDOS	0.00	12.85	-12.85
DHANIPUR	0.00	8.21	-8.21
GANGIRI	0.00	6.60	-6.60
GONDA	0.00	6.39	-6.39
IGLAS	6.39	0.00	6.39
JAWAN	0.00	14.19	-14.19
KHAIR	3.42	0.00	3.42
LODHA	3.42	0.00	3.42
TAPPAL	12.85	0.00	12.85
Total	**48.48**	**56.16**	**-7.68**

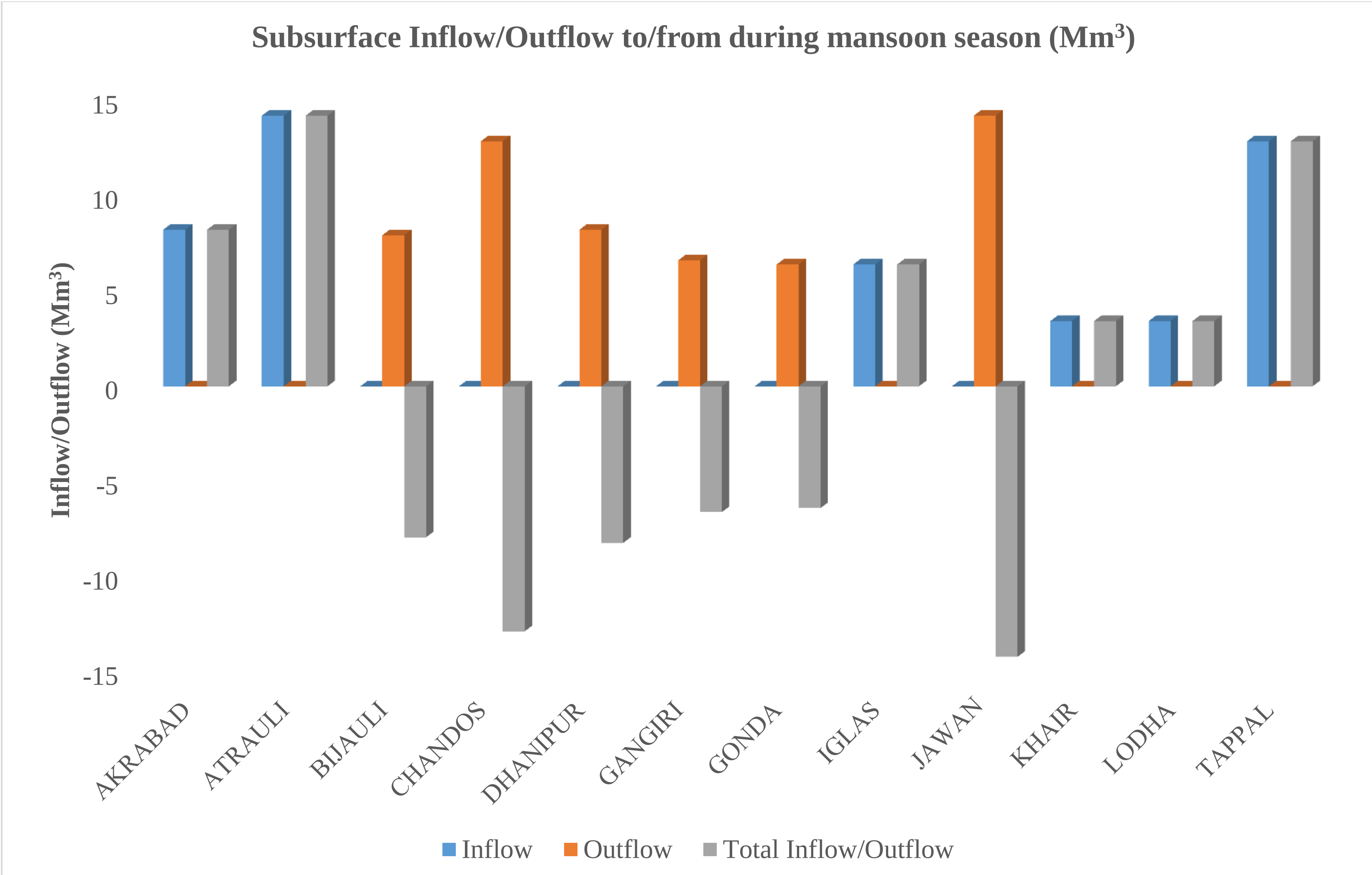
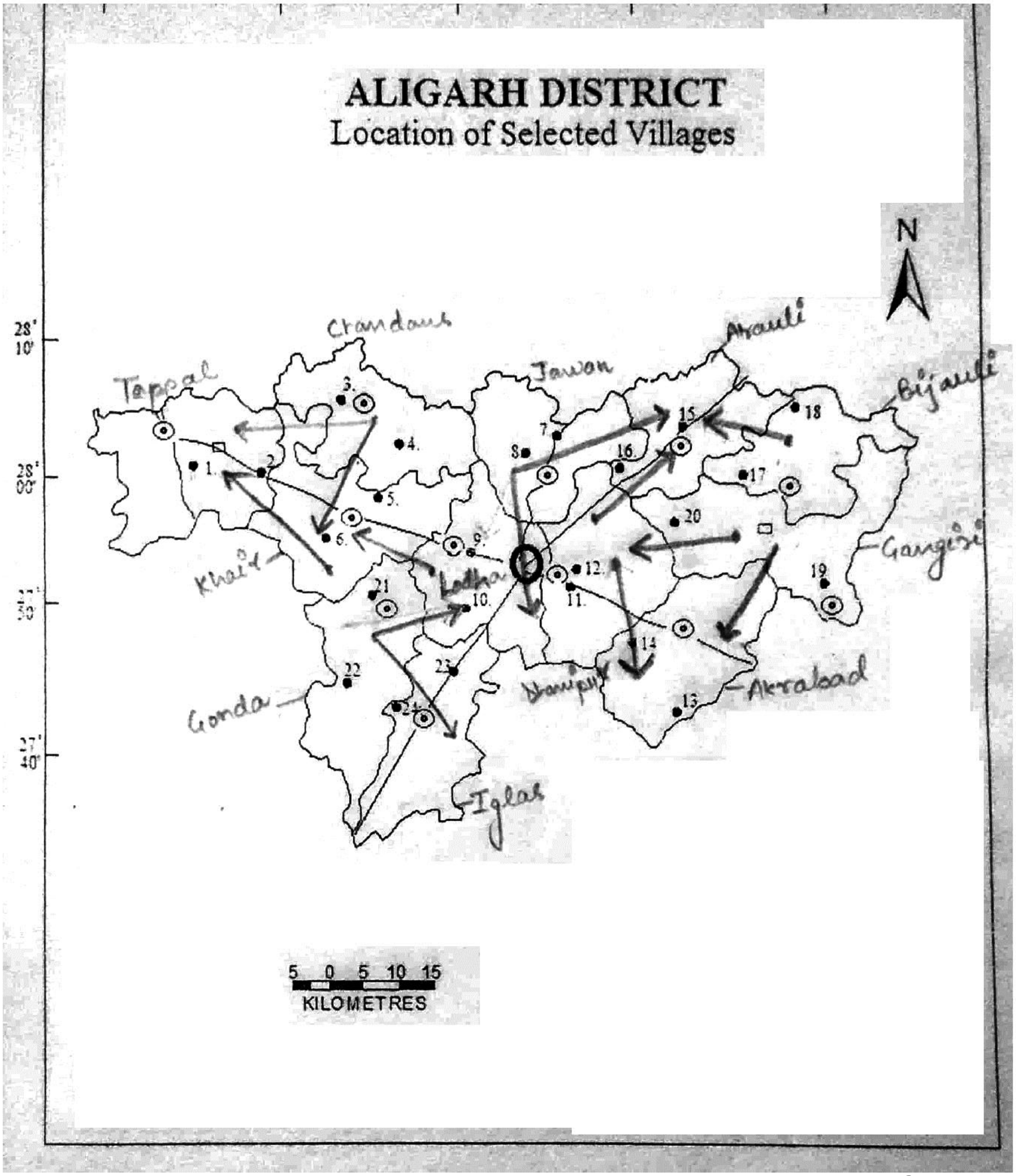


Fig. 4.5 Recharge due to Inflow/Outflow calculates during monsoon season.



Subsurface Inflow/Outflow to/from during non-mansoon season (Mm^3)

Table 4.6Subsurface Inflow/Outflow to/from during non-mansoon season (Mm^3)

Subsurface Inflow/Outflow to/from during non-mansoon season (Mm^3)			
Blocks	**Inflow**	**Outflow**	**Total Inflow/Outflow**
AKRABAD	4.11	0.00	4.11
ATRAULI	6.80	0.00	6.80
BIJAULI	0.00	4.20	-4.20
CHANDOS	0.00	6.50	-6.50
DHANIPUR	0.00	4.20	-4.20
GANGIRI	0.00	3.25	-3.25
GONDA	0.00	2.90	-2.90
IGLAS	5.30	0.00	5.30
JAWAN	0.00	6.90	-6.90
KHAIR	1.71	0.00	1.71
LODHA	1.80	0.00	1.80
TAPPAL	6.40	0.00	6.40
Total	**26.12**	**27.95**	**-1.83**

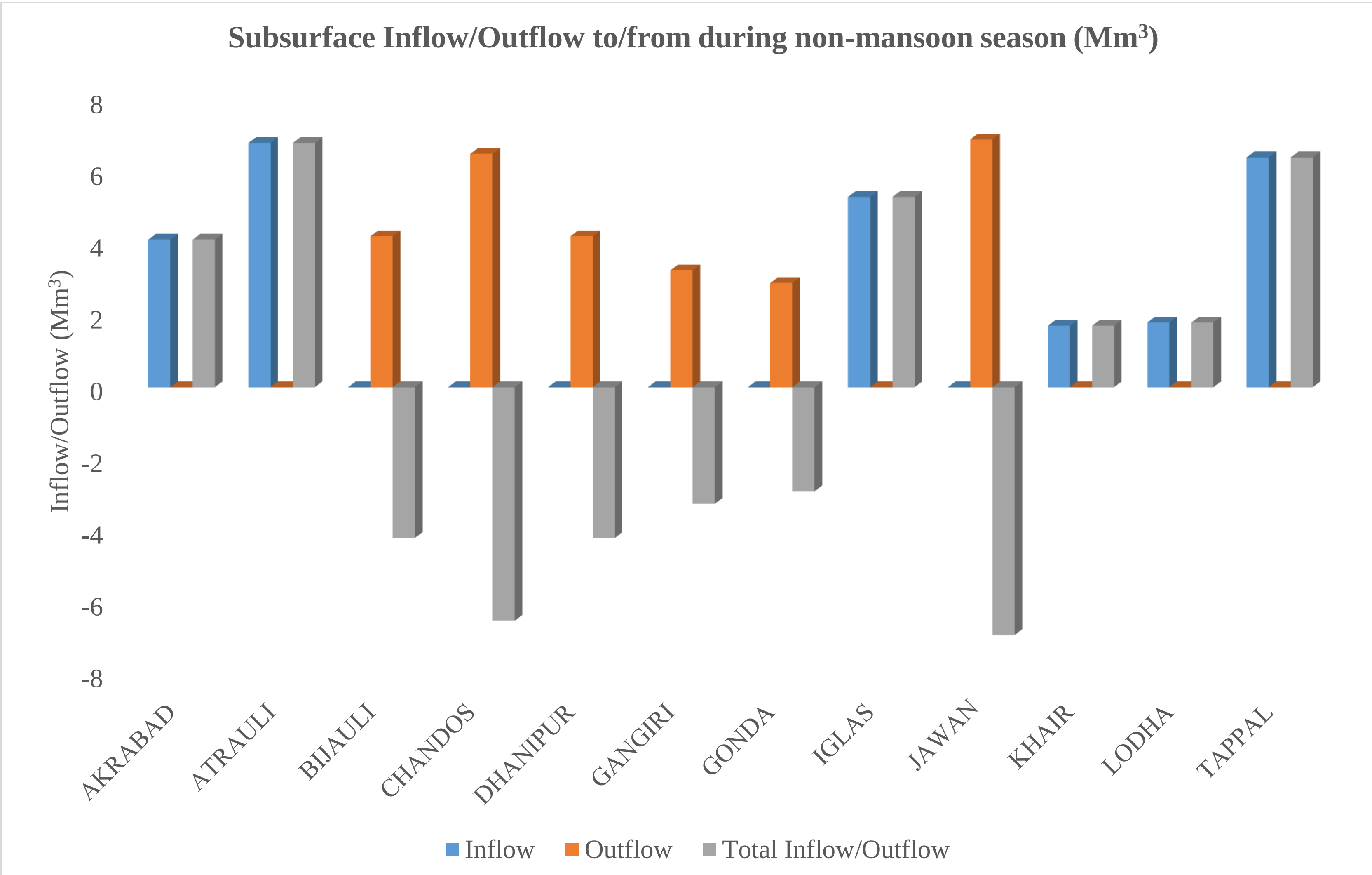


Fig. 4.6Recharge due to Inflow/Outflow calculates during non-monsoon season.

4.6 Evapotranspiration from Groundwater (E_t)

The Evapotranspiration from Groundwater always be calculated only when the groundwater is only 2 m from the surface. But in the Aligarh area the ground water is 4m or somewhere is 5 m below the surface area. So this parameter can not be calculated because of groundwater level. Therefore evapotranspiration from the groundwater may be negligible i.e. zero.

4.7 Groundwater Discharge from Tubewells (T_p)

To estimate the ground water discharge from Tubewells, input parameters such as the number of different tubewells (State Tubewells, Geostatic Tubewells, Private Tubewells, and Boring Pump Sets) in Aligarh for the year 2015 were listed in input file. Average discharge for all tubewells are given in (m^3/hr). Averaged working hour per day for all the tubewells in monsoon and non-monsoon season are also given in Appendix A11. Discharge of the Tubewells estimated for each block is given in Table 4.8 and Fig.4.9. The maximum groundwater discharge during monsoon season was estimated for Gangiri block i.e. 8.21 Mm^3 followed by Khair block (14.31 Mm^3). The minimum groundwater draft during monsoon season was estimated for Loadha block i.e. 11.20 Mm^3 followed by Tappal block (11.42 Mm^3). The maximum groundwater discharge during non-monsoon season was estimated for Gangiri block i.e. 16.39 Mm^3 followed by Atrauli block (15.00 Mm^3). The minimum groundwater draft during non-monsoon season was estimated for Tappal block i.e. 11.59 Mm^3 followed by Lodha block (11.83 Mm^3). Gangiri and Atrauli blocks higher groundwater discharge were observed because the number of all tubewells in these blocks was higher and lower for Tappal and Lodha blocks. The total groundwater discharge State Tubewells, Geostatic Tubewells, Private Tubewells, and Boring Pump Sets during monsoon and non-monsoon season was estimated 155.66 Mm^3 and 162.00 Mm^3 respectively. Results shows tubewells discharge during non-monsoon season was higher than that of monsoon season.

Table 4.6 Discharge from groundwater draft (Mm^3)

Discharge from groundwater draft (Mm^3)		
Blocks	**Non-Monsoon**	**Monsoon**
Akrabad	14.26	13.82
Atrauli	15.00	13.89
Bijauli	13.60	12.93
Chandaus	14.23	13.73
Dhanipur	12.51	12.16
Gangiri	16.39	15.21
Gonda	13.33	13.24
Iglas	12.31	12.12
Jawan	12.24	11.63
Khair	14.71	14.31
Lodha	11.83	11.20
Tappal	11.59	11.42
Total	**162.00**	**155.66**

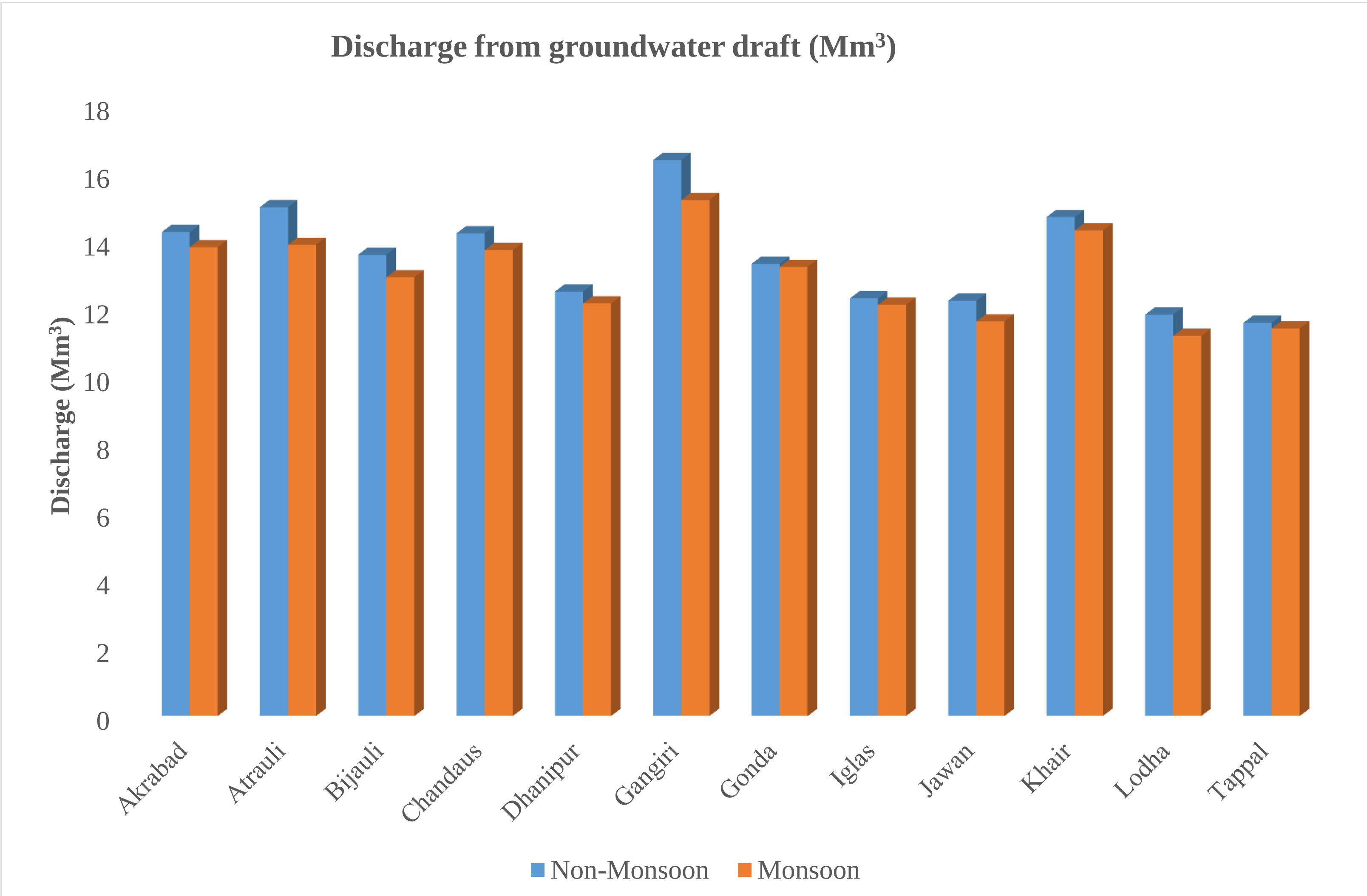


Fig. 4.8Groundwater draft calculates during non-monsoon and monsoon season.

4.8 Total Ground Water Recharge

Table 4.9, Table 4.10 and Fig.4.10, Fig.4.11show the total inflow, total outflow, and groundwater recharge (m^3 and cm/year) in different blocks of Aligarh during monsoon and non-monsoon periods.

The tabular data shows that in all the blocks over exploited of water is being practiced. The maximum water was exploited from Lodhablock i.e. 22.0Mm^3 and Gangiri 16.39Mm^3 during monsoon and non-monsoon season and there is need to take proper precautions. In monsoon season the discharge of water from the groundwater resources was lower than non-monsoon season.

Study also reveals that Atrauli, Akrabad, Bijauli and Chandaus blocks of Allahabad are at critical situation as the water is being over-exploited from these blocks and need to check the water use.

Table 4.9 Total Recharge during mansoon season

Total Recharge during mansoon season									
Blocks	Inflow Parameter				Outflow Parameter		Total Recharge	Area (Km2)	Total Recharge (cm)
	Recharge from Canal during Monsoon Season (Mm3)	Recharge from field irrigation (Mm3)	Subsurface Inflow/Outflow to/from during mansoon season (Mm3)	Recharge from rainfall during Monsoon season (Mm3)	Evapotranspiration from groundwater (Mm3)	Discharge from groundwater draft (Mm3)			
Akrabad	1.01	7.50	8.21	12.44	1.54	14.26	13.36	276.40	4.83
Atrauli	1.07	2.60	14.19	12.48	1.54	15.00	13.80	277.00	4.98
Bijauli	1.15	4.06	-7.92	11.05	1.43	13.60	-6.69	256.60	-2.61
Chandaus	0.44	2.51	-12.85	18.50	2.02	14.23	-7.65	362.50	-2.11
Dhanipur	0.83	8.79	-8.21	14.60	1.71	12.51	1.79	307.10	0.58
Gangiri	1.18	6.05	-6.60	18.57	2.02	16.39	0.79	363.60	0.22
Gonda	0.93	10.54	-6.39	15.74	1.80	13.33	5.69	323.30	1.76
Iglas	0.73	1.84	6.39	9.47	1.30	12.31	4.82	234.10	2.06
Jawan	0.88	9.94	-14.19	13.16	1.60	12.24	-4.05	286.70	-1.41
Khair	1.41	3.40	3.42	14.50	1.70	14.71	6.32	305.70	2.07
Lodha	0.59	1.92	3.42	14.26	1.68	22.00	-3.49	302.30	-1.15
Tappal	0.87	12.08	12.85	22.93	2.37	11.59	34.77	425.50	8.17
Total	**11.09**	**71.23**	**-7.68**	**177.70**	**20.71**	**172.17**	**59.46**	**3720.80**	**17.39**

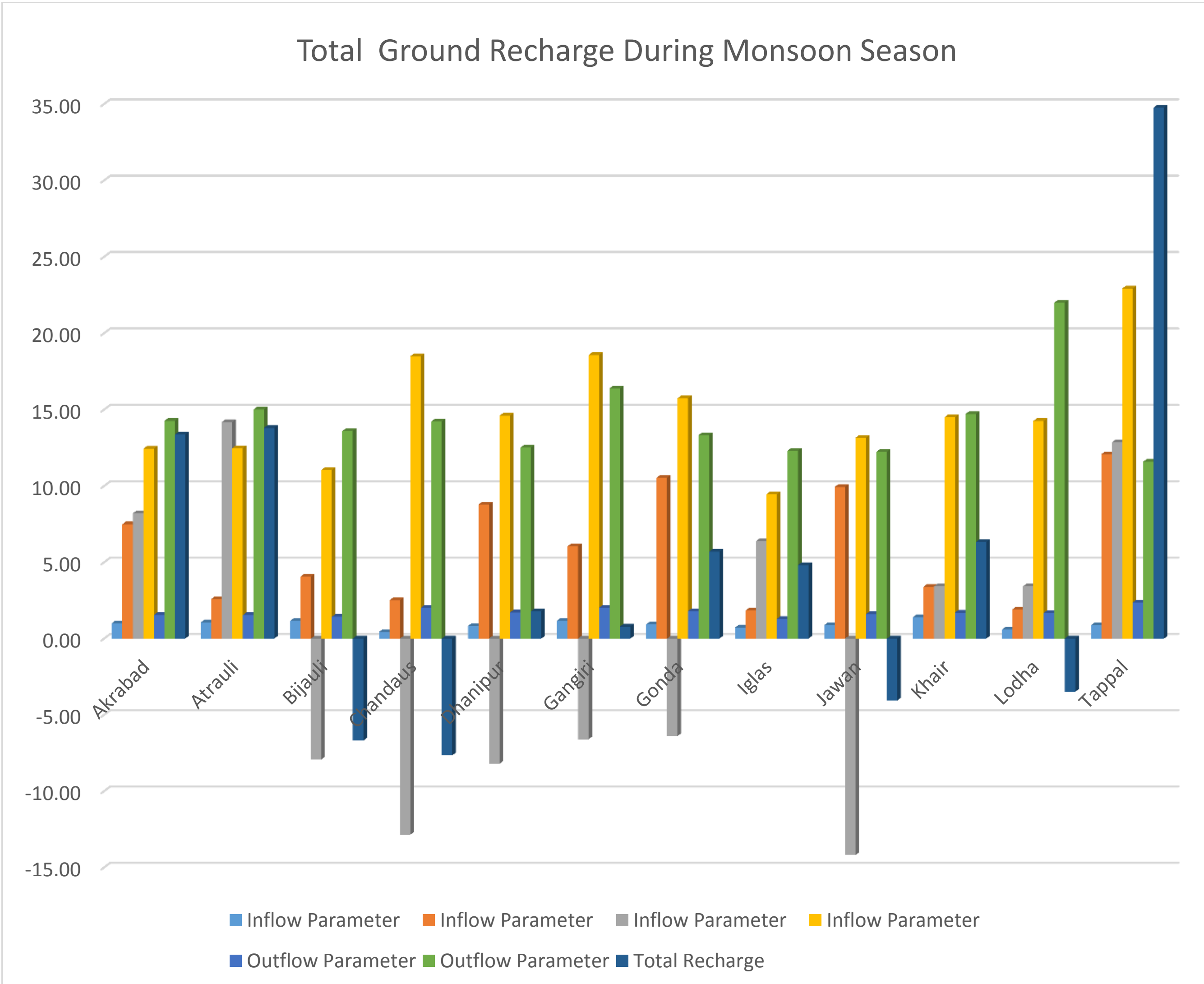


Fig. 4.9 Total Ground Recharge during mansoon season

Table 4.10Total Recharge during non-mansoon season

Total Recharge during non-mansoon season									
Blocks	Inflow Parameter				Outflow Paramter		Total Recharge (Mm3)	Area (Km2)	Total Recharge (cm)
	Recharge from Canal during non-Monsoon Season (Mm3)	Recharge from field irrigation (Mm3)	Subsurface Inflow/Outflow to/from during non-mansoon season (Mm3)	Recharge from rainfall during non-Monsoon season (Mm3)	Evapotranspiration from groundwater (Mm3)	Discharge from groundwater draft (Mm3)			
Akrabad	1.82	6.59	4.11	0.00	2.10	14.26	-3.84	276.40	-1.39
Atrauli	1.93	1.49	6.80	0.00	2.11	15.00	-6.89	277.00	-2.49
Bijauli	2.07	3.09	-4.20	0.00	1.95	13.60	-14.59	256.60	-5.69
Chandaus	0.79	1.21	-6.50	0.00	2.76	14.23	-21.49	362.50	-5.93
Dhanipur	1.49	7.11	-4.20	0.00	2.34	12.51	-10.45	307.10	-3.40
Gangiri	2.12	4.36	-3.25	0.00	2.77	16.39	-15.93	363.60	-4.38
Gonda	1.68	9.93	-2.90	0.00	2.46	13.33	-7.08	323.30	-2.19
Iglas	1.31	0.85	5.30	0.00	1.78	12.31	-6.63	234.10	-2.83
Jawan	1.59	7.29	-6.90	0.00	2.18	12.24	-12.44	286.70	-4.34
Khair	2.55	2.04	1.71	0.00	2.33	14.71	-10.74	305.70	-3.51
Lodha	1.06	1.12	1.80	0.00	2.30	11.83	-10.15	302.30	-3.36
Tappal	1.56	10.17	6.40	0.00	3.24	11.59	3.30	425.50	0.78
Total	**19.97**	**55.25**	**-1.83**	**0.00**	**28.32**	**162.00**	**-116.93**	**3720.80**	**-38.73**

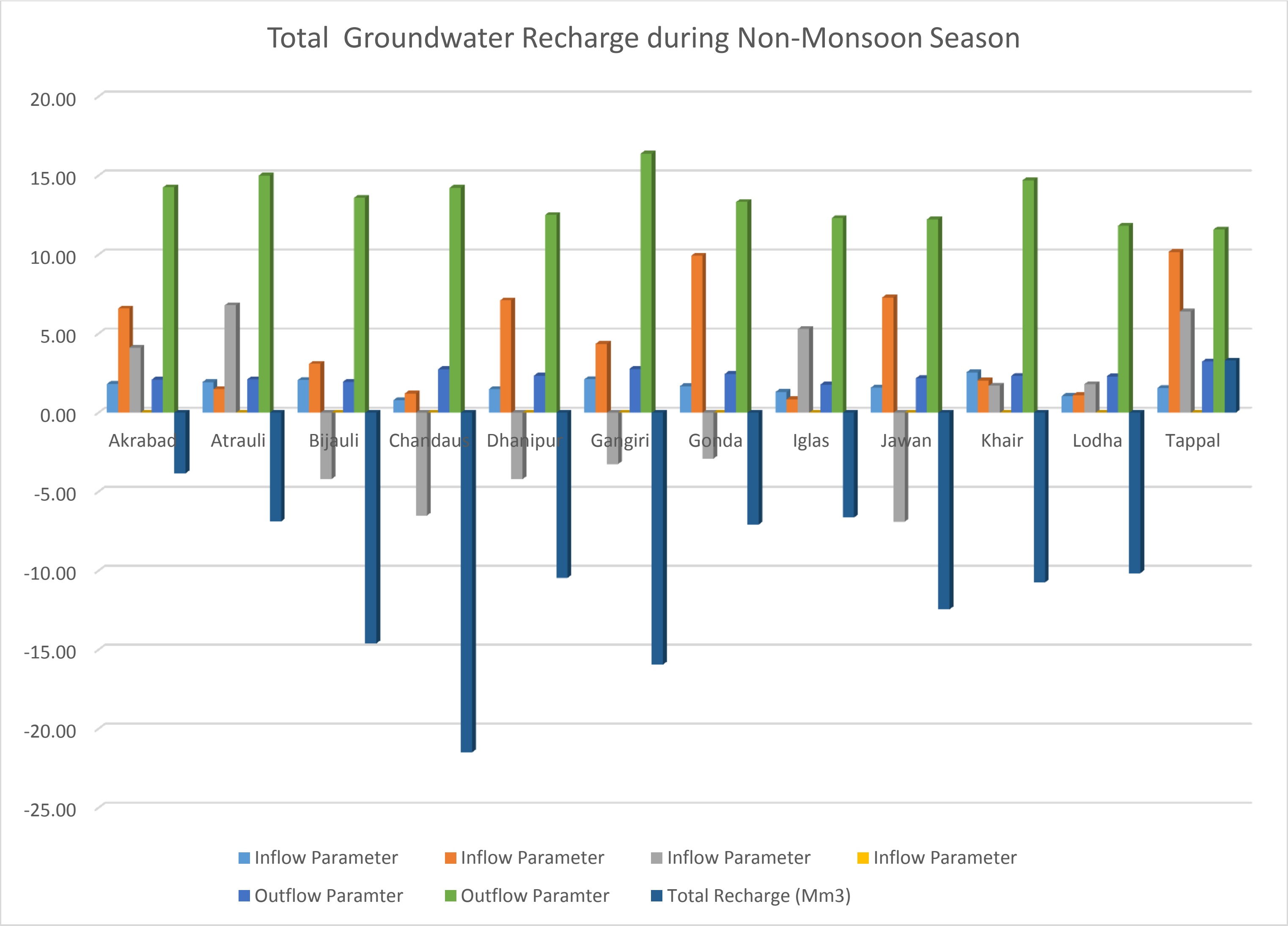


Fig. 4.10 Total Recharge during non-mansoon season

CHAPTER-V

SUMMARY AND CONCLUSION

Blockwise management plan is prepared considering the present water level, water level trend category of the block and further prioritized the blocks for interventions. Two blocks namely Bijauli and Chandaus are over exploited and declining trend of water level is recoded over the lastten years.Thus there is urgent need for taking up suitable water management interventions based on integrated approach, which on one hand include saugmentation of ground water resources through appropriate techniques, and on the other hand requires the adoption of suitable water conservation measures, such as ensuring water use efficiency through creation of additional water storage facility, maintenance/renovation of existing water bodies etc. Water awareness and capacity building of the stakeholders are also the important attributes of water management interventions as envisaged in the National Water Policy.

The following conclusions were drawn from the study:

- Ground water issues can be addressed mainly by focussing on measures to increasere charge and reducing the draft. It can be managed by amixing of measures such as supply side and demand side management. In view of it, the management plan is prepared and recommended for implementation two Over Exploited blocks namely Bijauli and Chandaus.
- In remaining ten blocks as such intervention is required for increasing the ground water availability and reducing draf texcept we need be little more vigilant. On farm activities and Water Use Efficiency practices may be recommended in the having higher stage of ground water development. The rooftop rain water harvesting is recommended in Lodha Block where Urban areas of Aligarh fall in this block.
- Artificial Ground Water recharge should be not taken where polluted surface water is available It is observed that the contribution of ground water for irrigation in this district is more than surface from 77.4% (Akrabadblock) to 99.6% (Gangiriblock). So surface water irrigation system should be planned and effectively be implemented in all blocks by increasing the canal network, which will help in reducing the stress on Ground Water withdraw directly as well as recharge of ground water.

- Blending with First and or second aquifer water is proposed for irrigation. Limited and controlled quantity of Saline ground water may be put in canal to enhance supply in canal so water can reach upto tail ends. It will just cause blending with out affecting EC of water beyond usable limit.
- Additional ground water development should have undertaken by supply side only replace slippage factors and in suitable areas water divides between two major canals and the tail end areas of the canal by appropriate with out structures to stabilize ground waterlevel.
- The present aquifer mapping is done based the existing data of CGWB in conjunction with the tubewells of State department such as Minor Irrigation ,Ground Water Department, U.P. Jal. As two drilled by CGWB are 300 mbgl and all wells are constructed upto 120 mbgl. Hence it recommended that proposed five number of exploratory wells be taken for refinement of the Aquifergroups, aquifer geometry ,and aquifer parameters, ground water resources and to as certain the quality of each aquifer.
- Further for refinemen t of aquifer disposition, the proposed 60 VES required & 2 D Line Imaging should be taken up.
- The data gap for soil infiltration is also observed. For soil infiltration rate study should be carried out.
- 10. National Monitoring wells optimization may be taken up in the district particularly in Jawan Block and duplicated wells showing similar trends and Wells very close to surface water bodies may be replaced and locatedat appropriate place. It is essential to bring out as genuine situation of ground water development.
- **Artificial Recharge to ground** Water conservation structures such as checkdams, farmponds, nalabunds etc resultin ground water recharge to the tune of about 50% of the storage capacity considering 4-6 annual fillings. Further construction of recharge trenches in the up stream side of the check dams is also proposed to enhance rate of infiltration by about 30 to 40%.
- The existing ponds and tanks lose their storage capacity as well as the natural ground water recharge due to siltation and encroachment by farmers for agriculture purposes.Through desilting, coupled with providing proper waste weir, the village tanks can be converted into recharge structure. The number of ponds are available for each

block surveyed Fisheries Department. On 70% of total ponds are taken for management planin Iglas and Chandauas blocks On FarmPractices

- Leveling of crop field is essential for uniform distribution o fwater. Laser leveling has been found very effective ensuring saving of 10 to 30% of applied irrigation.

  The insitu farm activities such as contourbunding, land leveling, bench terracing, water harvesting structures, afforestation and diversification of cropping pattern are other measures to increase recharge in theblock water Recharge / Water Conservation.

REFERENCES

A.R.D.C. (1979). Indian Agricultural Refinance and Development Corporation, Report of Ground Water over Exploitation Committee. A.R.D.C. Mumbai.

Arnold, J.G., Muttiah, R. S., Srinivasan, R. and Allen, P. M. (2000). Regional estimation of base flow and groundwater recharge in the Upper Mississippi River basin. *Journal of Hydrology*, 227: 21–40.

Adelana, S. M. A., Olasehinde, P. I. and Vrbka, P. (2006). A quantitative estimation of groundwater recharge in part of the Sokoto Basin, Nigeria. *Journal of Environmental Hydrology*, 14(5): 1-14.

Ahamed, A. J., Ananthakrishnan, S., Loganathan, K. and Manikandan, K. (2013). Assessment of groundwater quality for irrigation use in Alathur block, Perambalur district, Tamilnadu, South India. *Applied Water Science*, *3*(4), 763-771.

Abdullahi, M. G., Kamarudin, M. K. A., Toriman, M. E., Gasim, M. B., Endut, A. and Garba, I. (2016). Assessment of natural groundwater recharge in Terengganu, Malaysia. *International Journal on Advanced Science, Engineering and Information Technology*, *6*(5), 781-786.

Ali, M. H., Mubarak, S., Islam, M. A. and Biswas, P. (2017). Comparative evaluation of various empirical methods for estimating groundwater recharge. *Archives of Current Research International*, 1-10.

Baweja BK and Karanth KR. (2002). Groundwater recharge estimations in India. New Delhi: Central Groundwater Board; 1980. Ismail Award Paper, Montreal, 2002.

Chaturvedi, R.S. (1973). A Note on the Investigation of Ground Water Resources in Western Districts of Uttar Pradesh". Annual Report, U. P. Irrigation Research Institute, 1973, pp. 86-122

Chaturvedi. A note on the investigation o groundwater resources in western districts o Uttar Pradesh. In: Annual Report, U.P. Irri. Res. Insti. 1973;86-122.

Cook, P.G. and Kilty, S. (1992). A helicopter-borne electromagnetic survey to delineate groundwater recharge rates. *Water Resources Research,* 28(11): 2953-2961.

Cey, E. E., Rudolphb, D. L., Parkinc, G. W. and Aravenab, R. (1998). Quantifying groundwater discharge to a small perennial stream in southern Ontario, Canada. *Journal of Hydrology,* 210: 21–37.

CGWB, NR: Report on Status of Ground Water Exploration, Uttar Pradesh 2012

Freeze, R. A. and Cherry, J. A. (1979). Groundwater: Englewood Cliffs. *New Jersey:* Prentice-Hall.

Fetter, C. W. (2001). Applied hydrogeology + Visual Modflow, Flownet and Aqtesolv student version software on CD - ROM (Fourth edition ed.). Upper Saddle River: Prentice Hall

Goes, B.J. M. (1999). Estimate of shallow groundwater recharge in the Hadejia–Nguru Wetlands, semi-arid northeastern Nigeria. *Hydrogeology Journal*, 7: 294-304.

Gautam J.P. Ground Water Management Studies (Reappraisal Hydrogeological Studies) of Aligarh District, U.P 2005

GWD UP &CGWB Dynamic Ground Water Resources of Uttar Pradesh (As on March, 2004).

GWD UP &CGWB Dynamic Ground Water Resources of Uttar Pradesh (As on March, 2009).

GWD UP &CGWB Dynamic Ground Water Resources of Uttar Pradesh (As on March, 2011).

GWD UP &CGWB Dynamic Ground Water Resources of Uttar Pradesh (As on March, 2013exel sheet).

Hassan, G. Z. and Bhutta, M. N. (1996). A water balance model to estimate ground water recharge in the Rechana Doab, Pakistan. *Irrigation and Drainage Systems.* 10(4): 279-31.

Hoque, M. A., Hoque, M. M. and Ahmed, K. M. (2007). Declining groundwater level and aquifer dewatering in Dhaka, Bangladesh. *Hydrogeology Journal*,15: 1523–153.

I.P.R.I. formula, (1973). Groundwater resources of Panjab state-a recent study. *CBI and P Annual Research Session, May.*

IDWR. (2005). Augmenting Water Resources. Water in Rajasthan. Report of the Expert Committee on Integrated Development of Water Resources,India

Jal Nigam, U.P. Construction division U.P. Jal Nigam

Kaushal, M. P., Khepar, S. D. and Sondhi, S. K. (1989). Groundwater resources of a canal command area at Barna command. Proceedings of Silver Jubilee convention of ISAE, held at Udaipur on January 5-7, pp. 101-109.

Krishan, G., Rao, M. S., Lohani, A. K., Kumar, C. P., Takshi, K. S., Tuli, N. K. and Gill, G. S. (2014). Assessment of groundwater level in southwest Punjab, India. Hydraulics. *Water resources, Coastal & Environmental Engineering-Hydro*, 248-254.

Kumar, C.P. and P.V., Seethapathi. (2002). Assessment of natural ground water recharge in upper Ganga canal command area, Journal of Applied Hydrology, 15(4): pp. 13-20.

Kumar Arun& Bhargava A.K., Ground water Recourse & Development Potential of Aligarh, U.P.2002

Kumar, C. P. (2014). *Assessment of groundwater potential*. GRIN Publishing.

Michael, A. M., (1978). Irrigation: Theory and Practice, 2nd edition, Vikas Publishing House Pvt. Ltd. 768p.

Mahmood Kamal and Bharthawal Hydrogeology and Ground Water Potential of Aligarh District Uttar Pradesh, 1996

MacDonald, A. M. (2001). Ethiopia: water security and drought. BGS Technical Report WC/01/02.

Morris, B.L.; Lawrence, A.R.L.; Chilton, P.J.C.; Adams, B.; Calow, R.C. and Klinck, B.A. (2003). *Groundwater and its susceptibility to degradation: a global assessment of the problem and options for management.* United Nations Environment Programme, 126pp. (Eary warning and assessment report series, 03-3). Brassington, R. (1998). Field hydrogeology (2nd edition ed.). Chichester etc.: Wiley & Sons.

Naik, P. K. and Awasthi, A. K. (**2003).** Groundwater resources assessment of the Koyna River basin, India. *Hydrogeology Journal*, 11: 582–594.

Nagaraju, D., Siddalingamurthy, S. S., Mahadevaswamy, G., Subhanlone, M., Nagesh, P. C. and Rao, K. (2011). Assessment of groundwater potential in Chamarajanagar District, Karnataka, India. *International Journal of Earth Sciences and Engineering*, *4*(3), 462-466.

Nigam Neelam*et al.* A Report On Ground Water Quality Of Some Industrial Clusters of Uttar Pradesh June 2016

Nigam Neelam*etal.*Hydrochemical chemical report of Uttar Pradesh Jan 2017.

Natrajan P. S. V. Kottiswaran, A. Balasubramanian and Palanikumaran B. 2018 Groundwater recharge Estimation Using Comparision of methods in Sirumugai Area of Coimbatore, Tamil Nadu India Int. J. Curr. Microbiol. App. Sci. 7(6): 1433-1440.

Reghunath, R., Murthy, T.R.S. and Raghavan, B. R. (2005). Time series analysis to monitor and assess water resources by moving average approach. *Environmental Monitoring and Assessment*, 109: 65–72.

Risser, Dennis. W., Randall. W. Conger, James. E. Ulrich and Michael. P. Asmussen. (2005). Estimates of Ground Water Recharge Based on Stream Flow Hydrograph Method: Pennsylvania. http: //pubs.usgs.gov/of 2005/1333/s.

Scanlon, B. R., Mace, R. E., Barrett, M. E. and Smith, B. (2003). Can we simulate regional groundwater flow in a karst system using equivalent porous media models? Case study, Barton Springs Edwards aquifer, USA. Journal of Hydrology, 276(1-4), 137-158.

Shivanna, K., Kulkarni, U. P., Joseph, T. B. and Navada, S. V. (2004). Contribution ofstorms to groundwater recharge in the semi-arid region of Karnataka, India. *Hydrological Processes*, 473-485.

Tsakiris G (2004) Water resources management trends, prospects and limitations. Proceedings of the EWRA Symposium on Water Resources Management: Risks and Challenges for the 21st Century, 2–4 September 2004, Izmir, pp. 1–6

Trivedi B.B. and Chandra P.C., Inland Ground Water Salinity In Uttar Pradesh 2010.

Trivedi B.B. and Srivastava,M M and Bhowmic M.K U.P. State Geophysical Report ,2010

Tweed, S. O., Leblanc, M., Web, J. A. and Lubczynski, M. W. (2007). Remote sensing and GIS for mapping groundwater recharge and discharge areas in salinity prone catchments, southeastern Australia. *Hydrogeology Journal*, 15(1): 75-96.

Umar, R., Khan, M.M.A., Ahmed, I. and Ahmed, S. (2008). Implications of Kali–Hindoninter-stream aquifer water balance for groundwater management in western Uttar Pradesh. *Journal of Earth System Science*, 117(1): 69-78.

Unde, A.P., Mal1, B. C. and Chowdary, V.M. (2009). Assessment of groundwater potential in Jalpaiguri District of west Bengal. *Journal of Indian Water Resources*, 29(3): 34-39.

APPENDIX A1

Block wise Land use pattern of Aligarh District

Blocks	Total Agriculutre Land (ha)	Forest (ha)	Waste Land (ha)	Present fallow land (ha)	other fallow land (ha)	Barren cultivate d waste land (ha)	Land put to use other than agricultur e (ha)	Pasture (ha)	Land under misc. trees & grove (ha)
Akrabad	25871	780	344	98	80	853	2137	29	57
Atrauli	27325	210	212	107	221	232	2800	135	96
Bijauli	24914	200	589	273	11	530	4262	148	36
Chandaus	33367	131	737	188	351	436	2731	159	9
Dhanipur	30036	50	961	261	447	900	3212	120	13
Gangiri	34757	63	678	222	375	435	3274	157	16
Gonda	29210	70	206	160	381	169	2931	78	5
Iglas	25535	85	67	104	319	153	2809	104	10
Jawan	31605	834	323	270	464	548	4252	192	42
Khair	32002	44	629	168	267	375	2497	147	14
Lodha	27227	49	445	367	1993	578	2665	231	8
Tappal	37429	45	1020	183	275	351	4120	207	0
Total Area	**64656**	**94**	**1465**	**550**	**2268**	**929**	**6785**	**438**	**8**
Total Rural	**398063**	**1875**	**7332**	**2853**	**7372**	**5636**	**42338**	**2116**	**257**
Total Urban	**11983**	**16**	**612**	**418**	**355**	**303**	**3451**	**23**	**11**

APPENDIX A2
Block wise Area Irrigated by Different sources of Aligarh District

S. No.	Block	Canal (ha)	Tubewell (ha)		Well (ha)	Pond (ha)	Other (ha`	Net area irrigated(ha)	Area Irrigated by Surface water (ha)	Area Irrigated by Ground water (ha)	Contribution of GW	Gross area irrigated(ha)	Irrigation Intensity
			Public	Private									
1	Akrabad	4736	384	15884	0	0	0	21004	4736	16268	77.4	37605	179
2	Atrauli	36	993	22458	0	0	0	23487	36	23451	99.8	37107	158
3	Bijouli	865	384	17634	0	0	0	18883	865	18018	95.4	24573	131
4	Chandaus	850	581	26282	0	0	0	27713	850	26863	97.0	41605	150
5	Dhanipur	4818	131	18643	0	0	0	23592	4818	18774	79.5	37149	257
6	Gonda	2310	48	22906	0	0	0	25264	150	22954	90.8	38103	125
7	Gangiri	150	1222	28078	0	0	0	29450	2310	29300	99.4	36757	151
8	Iglas	818	0	20898	0	0	0	21716	818	20898	96.2	33145	153
9	Jawa	2661	281	21608	0	0	0	24550	2661	21889	89.0	40268	164
10	Khair	4768	439	22223	0	0	0	27430	4768	22662	82.6	41408	151
11	Lodha	42	301	21524	0	0	0	21867	42	27433	94.4	30546	140
12	Tappal	1729	0	29686	0	0	0	31415	1729	29686	94.4	51999	166
	Urban Area	1581	117	5435	0	0	56	7189	1581	7189	82.0	11828	164
	Total	25364	4881	273259	0	0	56	303560	25364	278140	92.0	462093	180

APPENDIX A3

Block wise Number of Ground water Structures of Aligarh District

S . No.	Block	Canal length	Govt. tube well	Pakka wells	Rahat	Shallow Tube well private				Ground pump set
						Electric	Diesel Run	Other	Total	
1	Akrabad	141	39	8	0	984	4784	8	5776	0
2	Atrauli	149	119	10	0	2654	2250	10	4914	5
3	Bijouli	160	66	0	0	980	4080	7	5067	5
4	Chandaus	61	57	0	0	2909	2291	12	5212	26
5	Dhanipur	115	31	12	0	1158	4138	10	5306	3
6	Gonda	130	9	12	0	1373	6494	10	7877	0
7	Gangiri	164	115	0	0	1090	5035	5	6130	45
8	Iglas	101	22	0	0	1952	4402	10	6364	
9	Jawa	123	49	10	0	1209	2832	10	4051	0
10	Khair	197	43	0	0	2458	4587	15	7060	5
11	Lodha	82	72	15	0	2215	823	17	3055	9
12	Tappal	121	17	0	0	2030	2100	10	4140	4
	Urban Area	**16**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	Total	**1560**	**641**	**67**	**0**	**21012**	**43816**	**124**	**64952**	**102**

APPENDIX A4

Block wise area under main crops of Aligarh District

S. No.	Block	Barley	Maize	Millet	Rice	Wheat	Pulses
		Area in ha					
1	**Akrabad**	417	881	5254	13054	18697	43006
2	**Atrauli**	798	3820	6506	5763	17491	37738
3	**Bijouli**	753	2107	8717	997	14745	29085
4	**Chandaus**	663	570	7790	10717	20985	45735
5	**Dhanipur**	397	814	5012	12653	17038	43012
6	**Gangiri**	1627	3729	14828	1132	21539	46106
7	**Gonda**	498	49	8672	9023	17633	38367
8	**Iglas**	271	30	7428	4060	10837	25866
9	**Jawa**	605	2716	3411	11682	18522	42408
10	**Khair**	637	300	5610	7560	20414	38104
11	**Lodha**	661	545	8787	3683	14719	32495
12	**Tappal**	528	479	5045	6960	26284	43048
	District Total	**7855**	**16040**	**87060**	**87284**	**218904**	**464970**

APPENDIX A5

Annual mean Rainfall (mm) of Aligarh District

Months	Standard Rainfall	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
January	15.60	0.00	0.00	0.92	0.00	20.80	6.40	44.28	30.48	0.00	16.80
February	16.20	0.00	0.28	9.06	27.02	0.00	36.58	10.24	0.00	0.00	0.00
March	10.60	0.00	1.32	0.00	1.68	0.00	0.40	14.56	47.80	5.40	17.20
April	6.70	14.32	3.56	0.20	6.48	3.80	3.28	2.00	23.40	0.00	0.00
May	9.00	64.76	24.56	1.36	22.32	0.40	2.74	18.00	4.40	18.96	16.20
June	64.80	124.14	3.88	7.14	99.36	8.84	73.20	40.00	31.80	44.20	159.00
July	190.00	228.34	68.64	143.50	261.10	128.00	133.68	97.93	115.76	290.00	55.40
August	193.00	165.56	146.68	168.32	180.98	253.92	266.32	33.10	189.88	124.02	71.40
September	118.50	77.00	52.10	322.04	45.80	78.32	50.00	80.52	18.76	31.80	156.40
October	17.70	0.00	21.92	0.00	0.00	2.40	41.04	13.00	13.52	3.40	0.00
November	1.60	0.80	22.02	10.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00
December	6.30	0.00	10.32	1.80	0.00	1.60	0.00	0.00	0.00	0.00	0.00
Total	**650.00**	**674.92**	**355.28**	**665.10**	**644.74**	**498.08**	**613.64**	**353.63**	**475.80**	**517.78**	**492.40**