Management of surface water resources
A case study of Indapur tahsil
district Pune

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Submitted By

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Under the Guidance of

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DECLARATION

I hereby declare that the thesis entitled **"Management of surface water resources: A case study of Indapur tahsil district Pune"** completed and written by me has not previously been formed as the basis for the award of any Degree or other similar title upon me of this or any other Vidyapeeth or examining body.

Gajanan Dhobale
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Place: Pune
Date: /01/2016

CERTIFICATE OF THE GUIDE

This is to certify that the thesis entitled, **“Management of surface water resources: A case study of Indapur tahsil district Pune”.** Which is being submitted herewith for the award of the Degree of Vidyavachaspati (Ph. D.) in Geography of Tilak Maharashtra Vidyapeeth, Pune is the result of original research work completed by Mr. Gajanan Krishna Dhobale under my supervision and guidance. To the best of my knowledge and belief the work incorporated in this thesis has not formed the basis for the award of any Degree or similar title of this or any other University or examining body upon him.

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(Gajanan Dhobale)

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ABBREVIATION

AET	- Actual Evapotranspiration
APRA	- Abolition of Proprietary Rights Act
BC	- Before Christ
BCM	- Billion Cubic Meters
BILT	- Ballarpur Industries Limited
C	- Centigrade
CGWB	- Central Ground Water Board
cm	- Centimetres
CN	- Curve Number
CPRs	- Common Property Resources
Cum	- Cubic Metres
CWC	- Central Water Commission
DEM	- Digital Elevation Model
DTM	- Digital Terrain Model
DPAP	- Drought Prone Area Programme
ET	- Evapotranspiration
FAO	- Food and Agriculture Organization
GDP	- Gross Domestic Product
GIS	- Geographical Information System
GSDA	- Groundwater Survey and Development Agency
ha	- Hectares
ham	- Hectare Metre
hr	- Hour
HYSIM	- Hydrological Simulation Model
ITCZ	- Inter Tropical Convergence Zone
IWRM	- Integrated water resources management
lpcd	- litres per capita per day
lps	- Litres per Second
LU/LC	- Landuse/Landcover
km	- Kilometres
LISS	- Linear Imaging and Self Scanning
MARDEF	- Mahabank Agricultural and Rural Development Foundation

mbgl	- meters below ground level
MCM	- Million Cubic Metres
MDGs	- Millennium Development Goals
Mha	- Million Hector
M km^3	- Million Cube kilometres
MLD	- Million Litres Peer Day
mm	- Millimetres
MPCB	- Maharashtra Pollution Control Board
MREGS	- Maharashtra Rural Employment Guaranteed Scheme
MRSAC	- Maharashtra Remote Sensing Applications centre
MSWSSD	- Maharashtra State Water Supply and Sanitary Department
NADS	- National Agricultural Development Scheme
NCIWRD	- National Commission on Integrated Water Resources Development
NGOs	- Non-Governmental Organizations
NRCS	- Natural Resources Conservation Service
NRDWP	- National Rural Drinking Water Programme
NSA	- Net Sown Area
PE	- Potential Evapotranspiration
PRIs	- Panchayat Raj Institutions
PWS	- Public Water Supply Scheme
RS	- Remote Sensing
RUSLE	- Revised Universal Soil Loss Equation
RWH	- Rainwater Harvesting
SCS	- Soil Conservation Services
SDSS	- Spatial Decision Support System
SWM	- Surface Water Management
TIN	- Triangular Irregular Network
UBB	- Upper Bhima Basin
UNCRC	- United Nations Convention on the Rights of the Child
UNEP	- United Nations Environment Programme
UNICEF	- United Nations International Children's Emergency Fund
USDA	- United States Department of Agriculture
USSR	- Union of the Soviet Socialist Republic
WBM	- Water Balance Model

WHO	- World Health Organisation
WMO	- World Metrological Organisation
WRIS	- Water Resources Information System
WRM	- Water Resources Management
WUA	- Water User Association
yr	- Year
/	- Per

Abstract

Preamble

Rain fed agriculture in India's semi-arid tropics is characterized by low productivity, degraded natural resources. Most of the people living in the Indian semiarid tropics depend on agriculture and natural resources. The temporal and spatial variation in availability of water was studied by many scholars, and it was observed that 71% of India's water resources are available to only 36% of area while the remaining 64% area has only 29% water resources are available (Verma and Phansalkar, 2007). Various estimates point out that there would be a widening gap between water demand and supply in future. The national per capita annual availability of water decreased to 1588 m^3 in 2010 from 5177 m^3 in 1951, due to the rise in population. Water scarcity issue is more complex, the factors like spatial and temporal variation in rainfall, climate change, rise in population, increased urbanisation, increased demand from various sectors, water pollution acts as catalyst.

Around 70% cultivated land falls under the rain-fed area in India. Surface water management is one of the critical factors for improving agricultural production. Almost 70% geographical area of the Maharashtra state's lies in semi-aird region depicting its vulnerability to water scarcity. There are148 tahsils of Maharashtra are in drought prone region. Every year, some part of the state is affected by drought conditions affecting availability of water for domestic use and irrigation. The state government spends huge amount on providing drinking water deploying water tankers and supply of fodder and establishing cattle camps and other relief measures. Taking permanent water scarcity proofing procedures is need of the hour.

The present study deals with some specific issues and strategies in the field of water management. Water resources in the Indapur tahsil have been seen as one of the development potentials for curtailing the high incidence of poverty by improving the standard of living of the people through improved smallholder irrigation techniques, livestock production and domestic as well as industrial uses. It focuses on suitable cropping pattern and estimates of availability of water resources, as well as assessing the feasibility of certain methods of harvesting water resources.

Study area

Indapur tahsil is one of the tahsils in the Pune district it is located between 17° 53´ 42" to 18° 19´ 58" North latitudes and 74° 39´ 16" to 75° 09´ 39" East longitudes.

Total geographical area of the tahsil is 1575.38km^2 (Census 2011), out of which Nira river catchment area compress about 586.8 km^2 and Bhima river catchment covers an area of 902.43km^2. The average annual rainfall in Indapur tahsil is 503.8 mm.

Major objectives of the present study

i) To ascertain the climatic variables in view of fluctuation in rainfall, temperature etc. which is helpful in understanding of prevailing drought conditions in the tahsil, as well as to analyses spatio temporal distribution of rainfall and available of surface water.

ii) To understand physiography, landuse pattern and socio-economic landscape of the study area.

iii) To get acquainted with the trend of water utilization, availability and requirement of water resources.

iv) To perform water budget estimation applying hydrological as well as Thornthwaite's method of water balance. Application of both the methods will be helpful to get unbiased and precise results.

v) To develop Composite Water Balance Index (CWBI) for entire study area using the principles of Map algebra, which can be helpful in giving a true picture of water balance of the study area.

vi) To prioritize villages according to CWBI for water resource planning and management of the Indapur tahsil.

vii) To suggest measures for WRM in the study area.

Methodology

The data collected from the field has been analysed using both quantitative and qualitative methods. . The data were processed by using the different GIS software's and statistical techniques. Grid wise data analysis has been carried out using MS Excel spreadsheet. The quantitative data has been analysed using statistical techniques. General water budget equation (Hydrological equation) has also been applied to estimate water budget of the Indapur tahsil as well as Thornthwaite's method has also been performed. Different thematic maps have been prepared using the base map. Combining the two methods development of CWBI (Composite Water Balance Index) has been done. Based on this index and erosion potential, runoff, aridity index finally villages require water management practices has been delineated and suggestions given accordingly.

Arrangement of the text

The present work deals with the seven chapters. **First chapter** deals with introductory section on the importance of water for human survival. The chapter provides the purpose of the study a brief history of the surface water management. The chapter provides the purpose of the study a brief history of the surface water management. The **second chapter** presents geographical profile of Indapur tahsil. **Third chapter** mainly focuses on spatial, temporal distribution of rainfall. The aim of this chapter is to analyze and determine the major sources of water. **Fourth chapter** presents utilization of water resources for domestic, agricultural and industrial. Further, calculate the water requirement for domestic, agricultural, livestock and industrial purpose in the study area. **Fifth chapter** mainly focuses on input and output of water resources in the study area. Further, it analyzes in order to understand the water stress, water utilization and put forward the water budget of Indapur tahsil. **Chapter six** presents a general overview of what is required in the surface water management. It also deals with the factors that determine the need of water resources management in Indapur Tahsil. The present study aims at solving the problem of domestic, agricultural and industrial water supply of study area. The final outcomes of this research work are arranged in **seven chapters**.

Major findings and conclusions

Following lines describes the Major findings and conclusions

1. The entire tahsil is characterised by basement of Deccan trap basaltic lava, which comprises mostly the prophylactic basalts with columnar joints inter trapped beds in the form of red boles at many places. The basalt flows of the Deccan Traps ranges in age from upper Cretaceous to lower Eocene. Local alluvial deposits of recent to sub recent are seen capping the basaltic flows along the major rivers courses no mineral of economic importance has encountered **(Fig. 2.3a)** in the study area
2. In the present study area around 394.79 km^2 (25.06%)area observed to be under groundwater level below 5 m below ground level(bgl),and between 5 to 15 m bgl around 553.12 km^2 (35.11%) area comprises this category. Maximum area i.e. above 15 m bgl has been observed to be 627.47 km^2 (39.83 %) of the total study area.

3. Aridity is high during the summer months due to increasing temperature. The diurnal variations in the aridity conditions during this period are low; water vapour gets condensed due to falling night time temperature, while the day time temperature is high. The duration of dryness is longer in the study area.
4. In the study area the annual evapotranspiration is increased from west to east especially, in the eastern part the climatic conditions are favourable to high level of evapotranspiration. In this area it is observed to be range between from 424 to 463 mm/yr.
5. Regional drainage pattern of stream is dendritic drainage pattern in which small streams join larger stream at an acute angle (less than 90 degrees) forming the dendrite drainage pattern. Drainage channels in most of the study area are narrow but shallow.
6. In the study area the literacy rate is 71.79 %, it is normal change than 2001(71.04). Literacy rate for males and females are 55.84% and 44.16% respectively according to 2011 census. It is evident that the levels of literacy changing very slowly.
7. The 'High' ground water potential areas are those having ground water table less than 5 m bgl, admeasures about 394.79 km^2 (25.06%). The 'Medium' areas are those having water table in the range of 5 to 15 m bgl this groundwater potential zone covers 553.12 km^2 (35.11%) of the total study area and the 'Low' ground water potential areas are those having water table more than 15 m bgl and under these having maximum area i.e. 627.47 km^2 (39.83%) of the total study area.
8. Ground water recharge potential map procured from the primary report – clearly indicates that there is very low to low ground water potential in the Indapur tahsil, may be probably due to hard compact basaltic terrain spreaded throughout the tahsil.
9. The total water use of Indapur tahsil is 3.894 MCM per year. The major portion of the water use of the study area is consumed by Indapur urban centre, Bhigwan, Palasdev, Lasurne and Kalamb. These five settlements are totally 1.205 MCM (30.95%) water use in the year and another 138 settlement 2.689 MCM (69.05%) water use the in the year.

10. Infiltration is relatively ineffective because of the rarity of rainfalls, low mean average precipitation and high potential evaporation. Furthermore, the high potential evaporation compared to precipitation in semi-arid environment results the low deep infiltration of rainwater.
11. In an exercise of water budget estimation, both the methods have been applied i.e. hydrological equation and Thornthwaite's method. It is observed that, although the entire area exhibiting water deficit. According to hydrological equation two classes have been determined, one class below '0' indicates more severity (50 villages' accounts to 35.98 % of the total geographical area) and 0-1 shows less severity (93 villages' accounts to 64.01 % of the total geographical area).According to Thornthwaite's method, it can be noticed that, around 49.08 % area (65 villages) facing very high water scarcity and rest of the villages (78 villages),50.92% area comparatively show low degree of water scarcity.
12. An attempt has also been made to develop a Composite Water Balance Index (CWBI), to prioritize the villages for water resource planning and management. It can be noticed that, central part of the tahsil almost remain same as like hydrological and Thornthwaite's method, showing the acute shortage of water, where as marginal areas have more or less fluctuating little bit. No doubt, the entire tahsil, by both the equations exhibiting more or less the same result, but composition of both the maps has certainly added a true picture of the tahsil in terms of water balance.
13. It can be observed from the composite water balance index map and Table no. 5.6 of Indapur tahsil that, VH (Very High) priority level in priority zone I, around 12 villages are accounted and contribute around 11.15% (175.77Km2) of the total area.46 villages throughout the area fall in priority zone II and at high level; it admeasures about 33.76% (531.78 Km2) of the total area of the tahsil. Medium and low level priority are confined to 53 and 32 villages, admeasuring about 33.04% (520.47Km2) and 22.05 % (347.36Km2) of the total study area respectively.
14. This overall statistics generated from the raster analysis through the principles of map algebra, clearly indicates that entire tahsil is in water deficit zone, within which different levels of priority have been delineated. Further an attempt has also been made to relate these villages with, the water tanker feed villages. It is

observed that, total tanker feed villages are 35 and out of which around eight villages falls in very high category, admeasures about 138.73 Km2 (8.8%) of the total geographical area of tahsil, 10 villages in high, 182.46 Km2 (11.58 %), 8 villages in medium 148.54 Km2 (9.42 %) and 9 villages 71.82 Km2 (4.55 %) in low category of the composite water balance index.

15. In an attempt to find out the present villages which are dependent on water supply through water tankers especially in summer months to CWBI - priority levels, it is observed that, in very high priority level (Zone I) there is a match about 22.86 % of the total number of villages dependent on water tankers. In high priority level it is about 28.57 % match (Zone II), in medium priority level it is about 20.00 % match (Zone III) and low priority level (Zone IV) it is about 28.57 % match. This matching exercise certainly adds a confirmation, that their villages are suffering from scarcity of water methodologically also, CWBI has thus been validated.
16. Out of the total 143, villages in Indapur Tahsil around 45 villages have been selected as sample villages opinions of around 685 respondents from these villages has been ascertained. It has been noticed, more or less from all the villages that there is a acute problem of water starts from the month of February and this condition persist for next 3 to 4 months. Month wise thematic map of water balance index also point out the same.
17. RS and GIS proved to be powerful tools in the assessment of water resources as well as in the planning and management of water resources.

Suggestions

In-depth analysis of parameters influencing the water budget scenario, potential erosion prone areas, runoff characteristics, aridity index and land use land cover of the study area various methods and techniques have been suggested for the villages having particular kind of problem of water scarcity. Table 7.1 shows major methods and techniques.

Villages have been classified according to criteria's mentioned above are displayed in table no.7.2.These variables moreover have been assigned weights according to their importance and final scores has been obtained then the villages are classified accordingly. Various techniques of WRM at village level suggested so far is as per the major problem and necessity of the village.

Chapter – I

Introduction

1.0 Introduction

1.1 Surface water resources scenario

- 1.1.1 Surface water resources scenario of India
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Chapter – I

Introduction

1.0 Introduction

Erratic and uneven distribution of rainfall, which leads to flood and droughts at various locations and during various periods, is one of the major concerns for the planning of water resources projects. Most of the people living in the Indian semiarid tropics depend on agriculture and natural resources. The temporal and spatial variation in availability of water was studied by many scholars, and it was observed that 71% of India's water resources are available to only 36% of area while the remaining 64% area has only 29% water resources are available (Verma and Phansalkar, 2007). Various estimates point out that there would be a widening gap between water demand and supply in future. The utilisable water resources of India are overestimated to the range of 66% to 88% (Garg and Hassan 2007). They estimated utilisable water resources as 668 km^3, which is much less than that of Central Water Commission (CWC), National Commission on Integrated Water Resources Development (NCIWRD) and National Water policy of India. The national per capita annual availability of water decreased to 1588 m^3 in 2010 from 5177 m^3 in 1951, due to the rise in population. It is estimated that in 2050, it will drop down to 1140 m^3 as a result of increase in population, which is expected to stabilise around 1640 million. NCIWRD estimated that in 2050, water demand for irrigation, domestic and industrial use will be 807 km^3, 111 km^3 and 262 km^3 respectively (Gov. of India, 1999). Thus, total water demand for all the uses is likely to be 1180 $km^3$and the water which will be available for use will be 1122 km^3. Water scarcity issue is more complex, the factors like spatial and temporal variation in rainfall, climate change, rise in population, increased urbanisation, increased demand from various sectors, water pollution acts as catalyst.

Around 70% cultivated land falls under the rain-fed area in India. Surface water management is one of the critical factors for improving agricultural production. The natural resource base on which existence of living beings depend soil, water and vegetation is under degradation. Most of the arid and semi-arid regions have concentrations of eroded and degraded natural resources. Loss of vegetal cover, followed by soil degradation through erosion, has resulted in lands lacking in water as well as solid nutrients. In India out of a total geographical area of 329 million hectares (Mha), 57% of it is suffering from soil degradation as a result of over-population, harsh climatic conditions, over exploitation, improper use of soil resources, deforestation etc (B. K. Kakade).

Almost 70% geographical area of the Maharashtra state's lies in semi-arid region depicting its vulnerability to water scarcity. There are148 tahsils of Maharashtra are in drought prone region. Every year, some part of the state is affected by drought conditions affecting availability of water for domestic use and irrigation. Forecasting of the droughts is linked with the forecasting of monsoon which is influenced by several global and regional factors such as the El Nino and Southern Oscillation (ENSO) events (Ropelewski and Halpert, 1986, Nicholls, 1993). The state government spends huge amount on providing drinking water deploying water tankers and supply of fodder and establishing cattle camps and other relief measures. Taking permanent water scarcity proofing procedures is need of the hour.

The present study deals with some specific issues and strategies in the field of water management. Water resources in the Indapur tahsil have been seen as one of the development potentials for curtailing the high incidence of poverty by improving the standard of living of the people through improved smallholder irrigation techniques, livestock production and domestic as well as industrial uses. It focuses on suitable cropping pattern and estimates of availability of water resources for domestic, agricultural and industrial purpose, as well as assessing the feasibility of certain methods of harvesting water resources.

1.1 Surface water resources scenario

According to the United Nations Environment Programme (UNEP 2002), has estimated the total volume of water on the earth is about 1400 km^3. Freshwater resources are estimated around 35 M km^3 (about 2.5 per cent). Further, around 10.5 M km^3 or 30 percent of the worlds freshwater is stored underground in the form of groundwater. Freshwater lakes and rivers contain an estimated 0.105 M km^3 or around 0.3 per cent of the world's freshwater. This statistics shows that even though water is available in ample quantity, it is not readily usable. Whether people save or waste water in one region is of no material consequence to those who live in other regions. People need sources of clean water close to their home.

1.1.1 Surface water scenario of India

India has 2.45% of worlds land and 17% of population but roughly 4% of the world's fresh water resources. The average annual rainfall in India is about 1170 mm and this may not be considered inadequate. Although the country receives about 4000 billion cubic meters (BCM) of rainfall and snowfall the average annual runoff is around 1869 BCM. Due to hydrological, geological and topographical constraints only 1122 BCM of this runoff is utilizable comprising of 690 BCM of surface water and 432 BCM of replenishable groundwater. By the year 2050 the demand for water has been projected as 1180 BCM (A. Sekhar 2003).

Water resources development which received high priority in the successive five years plan after independence has resulted in many achievements that are discernible. Many major, medium and minor water resources project has been constructed during the past five decades. All these projects have resulted in an increase in live storage capacity from 15.6 BCM at the time of independence to 177 BCM now (S. K. Das 2003). It is anticipated that utilizable surface water resources would be 69 million hector (Mha) which will be utilized by the year 2025. It is assessed that on full development, 76 Mha areas would be irrigated through surface water resources. In India water consumption is for industry power generation 1.50%, Livestock 1.40%, Municipal and rural water supplies 3.73% and Agriculture 93.27%.

1.1.2 Surface water scenario of Maharashtra

In Maharashtra total geographical area is divided into five major river basins, Godavari, Tapi, Narmada, Krishna and West flowing rivers of the Konkan region. The average annual availability of water in the above basin is anticipated as 163.82 BCM, out of which permissible use as per inter-state tribunal award is 125.94 BCM. The state has receives 1300 mm rainfall, it is highly uneven varies from 6000 mm to 400 mm. In Maharashtra 2, 23, 87,500 hectors are the gross cropped area; out of them 48, 08,100 hectors of land is under multiple cropping (Rucha Ghate). Owing to this feature, 40 percent of the state's cultivable land is drought prone, while 7 percent is flood prone. The estimated annual average availability of water resources consists of 164 Km^3 of surface water and 20.5 Km^3 of subsurface water. The total water used for domestic and industrial purposes has gone up from 18% in 1997-98 to 31% in 2003-04 i.e. 4790 million cubic meters (MCM). After diverting the water for domestic and industrial use, the average water available for irrigation is 112568 MCM. Out of the total non-irrigation water use, 64% is used for domestic purpose, while 34% is used for industrial and other uses put together. Agriculture has been the important occupation to supply food and fibre to the rising population of Maharashtra. The agricultural is a back bone of state as economy and irrigation facility is regarded as the key element of agriculture.

1.1.3 Surface water scenario of Pune District

Pune district is located in the western part of Maharashtra. It is spread over an area of 15,643 km^2 divided into 14 tahsils. The district is divided into two major river basins, *Bhima* and *Nira*. North-East, Eastern and Central part of the district comes under the *Bhima* river basin and the South-East and the Southern part of the district under the *Nira* river basin. The district has seven major rivers, namely *Bhima, Bhama, Ghod, Kukdi, Indrayani, Mula-Mutha,* and *Nira*. The average annual rainfall is 115 cms. The climate of the district differs according to the topography. River *Bhima* has its origin at `Bhimashankar' located in the Khed tahsil and it flows through the central part of the district towards the South-East. The *Ghod*, *Mula-Mutha* and *Nira* are tributaries of river *Bhima*. River *Ghod* is a perennial river and flows across the Northern region of the district. River *Kukdi* and *Mina* are the two tributaries of river *Ghod*. River *Ghod* originates in the Ambegaon tahsil. The confluence of the *Bhima* and *Nira* is at Nira-Narsingpur in Indapur Tahsil. East flowing river *Nira* flows along the Southern boundary of Pune district. The river *Karha* is a tributary of river *Nira*.

The normal annual rainfall over the district varies from about 500 mm to 4500 mm (CGWB 2009). All areas which are cultivated under purely rain-fed conditions are treated as unirrigated lands. In Pune district during the year 2003 -04, there was a severe drought situation and water scarcity. The uncontrolled extraction of ground water and its misuse caused its depletion. The level of ground water table decreased up to 1.17 m. (GSDA, GoM 2014). Because of this, the villages were supplied water through water tankers. It was observed that in the district 428 villages has over-exploited their water resources.

1.1.4 Surface water scenario of Indapur Tahsil

Indapur tahsil is one of the drought-prone areas in Pune district. It is always known as a region of scarce rainfall in Maharashtra. The average annual rainfall is 550 mm. There are two rivers of which the river Bhima is the main one. The other river Nira is a tributary of river Bhima. There is no adequate strategy for the management of water. Owing to lack of rainfall there is a need of restoring and maintaining water. In Indapur tahsil, out of 142 villages, around 73 villages (51% area of the total area) gets the benefit of Ujani Dam, Bhima river, Nira river, Nira Left canal and Khadakwasala right canal. The remaining 71 villages (49 % area of the total area) depend on uneven rainfall. All these villages fall under the drought-prone area. Nira and Bhima River are the main sources of water and many small or big flows join these rivers. The middle part of Indapur tahsil is the most water scarcity area. There is uncertainty and uneven distribution of rainfall in the study area. Owing to this situation surface water management become an important and indispensible for the entire Indapur tahsil.

1.2 Need of surface water management in drought prone area

Water resources management (WRM) is the process of decision-making on assessment, allocation, utilization, regulation, monitoring and improvement of surface and underground water sources (based on EC, 1998). WRM tasks and responsibilities are usually assigned to a government entity, which does not have a specific interest in water using sector and water users. The **S**urface **W**ater **M**anagement (SWM) plan seeks to: Contribute to the quality of life by preserving the high environmental quality of the community, Protect public investments and private property related to or affected by surface water, Balance environmental protection with community and economic needs and capabilities and meet regulatory requirements.

In the study area, agriculture is the major occupation and about 74.90% of the working population depends upon it for their livelihood. Irrigation facilities created so far are less than the potential and the total net sown area is 84.60%. As such, a large part of agricultural land depends on the monsoon and there is an uncertainty of rainfall. The study area comes under the rain-shadow region, due to which it is considered as a drought-prone area. The majority of small and marginal farmer and landless depends on agriculture, especially in the dry area. Further, due to soil erosion, over cutting of vegetation, unscientific methods of cultivation, land surface has been rendered barren. Therefore, water conservation and management is necessary due to following facts observed in the study area.

i) The availability of fresh water in many parts of study region is declining and these areas faces shortage of water.

ii) Water resources are unevenly distributed in the study area degraded.

iii) The demand of water is growing rapidly but its quality is getting lower by the human activities.

Another important aspect is water quality improvement in existing strategies to eliminate the pollution of surface and ground water resources. Demand for water for different uses is also increasing substantially. As a result, water, which is already a scare resource, will become even scarer in future. This underscores the need for the greatest efficiency in water utilization by creating community awareness. A number of issues and challenges have emerged in the development and management of the water resources, therefore, this kind of study may be very useful for environmental, communal and economic development of the study area.

1.3 Water scarcity and necessity of surface water management

Water scarcity has emerged as a prominent issue for communities across the study area. In fact, one of the most critical natural resources issues facing by communities today is managing the supply and availability of water. It emphasizes the need to modify the space and time availability of water to meet the demands. This concept also highlights the need for judicious use of water. There is a great potential for better conservation and management of water resources in its various uses. Since agriculture accounts for about 95.27% of water utilization, the greatest potential for conservation lies in increasing irrigation efficiencies. Just a 10% improvement in irrigation efficiency could conserve enough water to double the amount available for drinking.

In the study area use of sprinkler irrigation saves about 56% of water for the winter crops of bajra and jowar, while for maze; the saving is about 30% as compared to the traditional gravity irrigation. An important supplement to conservation is to minimize the wastage of water. In urban water supply, e.g. almost 30% of the water is wasted due to leakages, carelessness, etc. It is, therefore, imperative to prevent wastage of water. In industries also, there is a scope for reuse of water. In the study area 73 villages' get some amount of water resources from the Nira left canal, Khadakwasala canal, tanks, river Bhima and Nira K. T. Weirs. But remaining 71 villages depend only on rainfall. They are situated in the hilly area and central part of the study area. This area with uneven slope due to them could not derive much benefit from this canal and away from the river banks. To overcome this difficulty, the implementation of the concept of water-conservation is the only solution.

1.4 Review of literature

Review of literature in connection with surface water management, soil erosion intensity zones, computation of runoff, water availability, water demand, water scarcity, water management and watershed development etc has been carried out in order to bring together existing knowledge on the water resources management. The literature review draws upon both formal literature (journals, books, publications) and grey literature (unpublished project documents, internal reports) etc.

According to Pisharoty (1986), annual rainfall over the plains of India based on the data of 2800 stations is around 117 cms and this is the highest value anywhere in the world for a country of the same size of India. The seasonal and annual distribution of rainfall and its coefficient of variation using the data of 3000 stations for the period 1901 to 1960 have been prepared by India Meteorological Department (1971). The mean total volume of rainwater over India has been computed using the data of 306 rain gauges for the period 1871 to 1978 by Mooley et al. (1981) and found to be 3143 km^3 with a standard deviation of 300 km^3.

Investigations of Rao and Mishra (1971) have shown that annual rainfall of India is quite stable in general, but, it is most uncertain in the north-western parts of the country. The study on a sub divisional basis by Dhar and Kulkarni (1974) showed that, monsoon rainfall was highest in coastal Karnataka (289 cm) where it is about 87% of the mean annual rainfall and lowest in Tamil Nadu (35 cm) where it is only 19%. Various aspects of the rainfall of Kerala State have been studied by Ananthakrishnan et al. (1979b). They found that the actual duration of southwest monsoon rainfall 'is only 6% of the total duration of the monsoon season at Trivandrum, 12% at Cochin and 18% at Mangalore.

The ‘Run-off’ as expressed in terms of volume per unit of time and its generation largely depends on the amount of rain water that reaches the surface of earth (Rientjes, 2004; Shwab et al, 1981; Ward and Robinson, 1990).

The mathematical descriptions of all run-off models are simplification of the actual process of run-off in nature. Some models are more simplified than others but at the base of each model, there is a mathematical description that simplifies the factors that are being considered and that enables models to make quantitative predictions (Beven, 2000; Rienjtes, 2004). Factors involved in the process of run-off, such as soil characteristics, vary extensively over small distances. It is impossible to account for each variation in space in a mathematical model. For this reason, average values are taken for sets of variables that share similarities. All models weather empirical, physical or combinations of the two are therefore based in many assumptions (Beven, 2000).

According to Singh (1996) the availability of water does not match with demand in terms of quantity, quality, time and space. Currently, the main problem emerging in many parts of the world is water scarcity. Thus the conservation and optimum utilization of water as scare resource is extremely important for national economic development. The United Nations reports like Human Development Report (2006), Water for People, United Nations World Water Report (2003). Report by UNICEF and other organization and institutions reports published online also referred.

Calder et al. (1999) emphasised how to meet the sustainable requirements through watershed development in India. According to Chitale (2000), water availability in western Maharashtra ranges from $8000m^3$ per hectare which is normal to less than $1500m^3$ per hectare during highly deficit conditions. Local level water availability problem is also mentioned by Jog et al. (2003). Farrington J. and Lobo C. (1997) have discussed the issues related to watershed development in the western Maharashtra. Government of Maharashtra has given the water supply policy on his official website of the Maharashtra State Water Supply and Sanitary Department (MSWSSD).

According to Wolff (1999) worldwide water use has increased more than tenfold since the turn of the twentieth century. Water exploitation has risen sharply in the second half of the twentieth century. Further, unequal increases in water exploitation have taken place during this period in Asia and Europe (Wolff, 1999). The consumption level from these developing areas are much low as compared of the developing countries. The change in pattern of utilization multiply ever increasing population will result in an imaginable demand on water.

There has been substantial increase as demand for water, especially in arid countries where natural water resources are limited. On the global basis, the demand for fresh water has been increasing at fast rate since the beginning of the twentieth century and this demand is expected to double by the year 2050 (Biswas 1998). This means more water would be required for domestic and industrial use agricultural production and hydropower generation to meet the need of expanding population. Moreover, as more and more people attain higher standard of living, per capita water demand would continue increase as well. According to Jemma (1993) an increasing water demand needs a deep knowledge of the characteristics of water resources in order to offer a more rational water supply in terms of quality, quantity continuity and cost. In addition, it is necessary to have the assessment of both the real water demand in terms of actual and prevailing uses and the real water supply in terms of water quality and quantity. According to Kulshreshtha et al. (1996), the water demand assessment can be a good starting point for the identification of problems related to water resources management.

Many part of the world emerging the water scarcity problem. The optimum utilization and conservation of water as scare resource is extremely needed for national economic development. According to Olivier and McPherson (1993) innovative and dynamic policies are required best utilization of water resources. Verma & Phansalkar (2007) studied the temporal and spatial variation in availability of water and it was observed that 71 per cent of India’s water resources are available to only 36 per cent area while the remaining 64 per cent has 29 per cent available. Till the middle of the 20th century, the importance of water on life had not been particularly felt because of its moderate demand. But relentless increase in the demand of fresh water in recent years has lead to the scarcity of this basic resource in country. Such spurt in demand is caused by rapid growth of population, increase in urbanization and industrialization, high intake of fresh water in irrigation for additional food production, misuse and wastage of fresh water in miscellaneous other ways. These result in scarcity of water even for drinking in

India. Hence WRM issues are of vital concern to all to avoid any serious water crisis in the years to come with its rapidly rising population.

Runoff studies were advanced significantly in the 1940s by the work of C. W. Thornthwaite in the United States, H. L. Penman in England and M. I. Budyko in the USSR. Thornthwaite and Mather (1955), in the book keeping procedure of water balance, evaluated monthly runoff from surplus values. In the absence of detailed field investigations, they assumed that half of the water surplus appears as runoff in the same month and other half is detained in the soil as detention water and contributes to the next month's surplus. But this is valid only when the surface is flat, semi pervious and devoid of vegetation. Subrahmanyam and Pardhasaradhi (1980) and Subrahmanyam and Ali (1982) developed new runoff coefficients based on slope of the surface, soil type and vegetation pattern of the region. The runoff coefficient of a station is the product of slope, soil and vegetation factors and the detention coefficient is the complement of the runoff coefficient. Nair (1987) adopted the coefficients of Ali (1982) for studying the water resources of Western Ghats.

Medalye and Kundell (2008), viewed Integrated Water Resources Management as a comprehensive, participatory planning and implementation tool for managing and developing water resources by balancing social and economic needs, and ensuring the protection of ecosystems for future generations at the same time. Water management can be described as having the right amount of water available for a particular use at the right time and with the right quality (Mather 1984).

According to Biswas (1991), there has been increasing realization of the importance of water in the continuing well being and development of developing countries especially those located in the arid and semi-arid regions the last decade of the twentieth century. A number of traditional water harvesting systems still exist over India. Agarwal et al. (2001) pointed out that the Indians, depending on the resources available to them over centuries, developed a range of technique to harvest every possible form of water from rainwater to ground water, stream to river.

Drainage system design (Parker, T.K. 1980), a detailed description in both practical and theoretical terms of a drainage system designed in-house for a research farm. Pangare and Lokur (1996) elaborated importance of water in his book, *Pani*

Panchyat Model for sustainable management. Pani Panchyat is a voluntary activity of a group of farmers engaged in the collective management (harvesting and equitable distribution) of surface water and ground water (wells and percolation tanks).

Gleick et al. (2002) have discussed about water supply at subsidized prices or for free or make it available even to the poorest segments for the society. Jayraman (2003) opines inequities in availability are so severe in cities that the poor often make do with an average of sixteen litres per person a day. Juuti, P.S., & Katko, T.S. (July 2005) In this report the authors review historical patterns of decision-making relating to urban water supply and sanitation systems in Europe based upon future research to illustrate the interconnectedness of past, present and future.

The watershed development approach in India was first adopted in 1974 when the Govt., of India enforced the scheme for 'Soil Conservation in the watershed of river valley projects". In 1982 Govt. of India launched another ambitious programme for the development of dry land Agriculture on watershed basis under which 47 Model watersheds were identified under different Agro climatic zones all over the country. The important principles for success of watershed management program, the utilization of resource must be equitable, productive and sustainable development.

Worldwide several techniques of rainwater harvesting are used like in Israel, Japan, Sri Lanka and many parts of other countries. These are mentioned by different scholars like, Danesh (1997), Sheikh et al. (1995), Smet and Moriaty (2001). Sharma et al. (2000) have discussed various details of traditional and modern rainwater harvesting techniques in North West Himalayan region of India. Central Ground Water Board, Faridabad, (CGWB), has outlined different rainwater harvesting techniques to augment groundwater. Ghosh (2002) has discussed different issues related to water resources like, appropriate use of water, traditional ways of cleaning of water and water harvesting.

In India, evidence has been found of simple stone-rubble structures for impounding water that date back to the third millennium before Christ (BC) (Agarwal & Narain, 1997). There is evidence of the past utilisation of harvested rainwater in many areas around the world. In urban locations, rainwater catchment surfaces tend to be restricted to roofs (Hassell, 2005; Fewkes, 2006) although runoff can also be collected from other impermeable areas such as pavements, roads and car parks. Kadam et al

(2012) used SCS-CN method for identifying potential rainwater harvesting sites of a semi arid, basaltic region of western India. In this study, the rainwater harvesting structures deriving from thematic layers, such as land use/land cover, slope, soil, drainage and runoff from Land sat Thematic Mapper Imagery.

Biswas et al. (2002), performed morphometric analysis with parameters such as bifurcation ratio, drainage density, stream frequency, texture ratio, form factor, circularity ratio, and elongation ratio for a case study of a watershed in Midnapore District of West Bengal, India. Singh et al. (2009) analyzed 13 dimensionless parameters namely, average slope of the watershed, relief ratio, relative relief, main stream channel slope, elongation ratio, basin shape factor, length width ratio, stream length ratio, bifurcation ratio, hypsometric analysis, circulatory ratio, ruggedness number and drainage factor for 16 watersheds of Chambal catchment, Rajasthan, India. They applied principal component analysis for screening out the parameters of least significance. It was concluded that the study helped to regroup the remaining variables into physically significant factors. Other recent works include Chopra *et al.* (2005) on morphometric analysis of Bhagra Phungotri and Hara Maja sub watersheds of Gurdaspur district, Punjab. Shrinivas *et al.* (2004) morphometric analysis on sub watershed of Pawagada area, Tumkur district, Karnrtaka.

Prabhakar *et al.* (1991) observed that thematic maps so prepared facilitate in planning of different soil and water conservation measures like laying water harvesting structures in the watershed. Decisions regarding the use of land and water resources of a backward region depend mostly on their productive potential and local priorities. As integrated approach requires information about the topographic and terrain parameters, geomorphic process, water availability, land capability and socio-economic condition of the inhabitants, a database of Chandragiri watershed, Korapur district was generated by Mohanthy *et al.* (1994). The action plans prepared suggest alternate land use plan and sites for water harvesting structures, dug wells and tube wells. LU/LC, soil, hydro-geomorphology, drainage, slope and transportation network maps were integrated spatially by Uday Raj *et al.* (1995) to arrive at composite mapping units which are unique combination of various resources. This action plan comprising of alternate land use practices and a comprehensive plan for soil conservation and water harvesting structures like check dams, nala bunds, etc., was suggested to improve the productivity of Hirehalla watershed in Bijapur district. Lingaraju *et al.* (1996) reported that integration of different thematic maps like LU/LC, hydro geomorphology, soils, surface water bodies generated by the interpretation of remote sensing data, slope and drainage, the socio-economic and meteorological data enabled to generate developmental plans for land and water resources along with its sustainable development.

Chakraborthy *et al.* (2001) in Ballowal-Sounkhri Village in Hoshiarpur district of Punjab in a study conveyed an approach to water resource management through water harvesting structures. The study infers that if the excess rainwater is stored in the catchment and is conveyed through small channels to the field as per the agriculture requirements in different seasons of the year, it will not only help in attaining self sufficiency in agricultural production, but would also reduce soil loss and recharge aquifers. Field experiments were conducted by Jain and Kothari (2001) at ARS, Bhilwara and Rajasthan to evaluate the efficiency of recycling of harvested rainwater for rain fed crops. The study revealed that maximum water use efficiency of harvested water can be obtained by applying it in post monsoon period as partial irrigation to long duration crops in an intercropping system for improving crop production in dry land areas of Rajasthan.

Satellite based Remote Sensing (RS) technology meets both the requirements of reliability and speed and is an ideal tool for generating spatial information needs. It provides scientific inputs for planning, monitoring, management and impact assessment on natural resource development, environment, infrastructure planning etc. The Geographical Information Systems (GIS) technology provides suitable alternatives for efficient management of large and complex databases. Thus, blending of remote sensing and GIS technologies has proved to be an efficient tool and have been successfully used by various investigators for water resources development and management projects as well as for watershed characterization and prioritization. Nag (1998) carried out ‘Morphometric analysis using remote sensing techniques in the drought affected Chakra-river basin of West Bengal’: Using satellite imageries of LANDSAT and IRS, different hydro geomorphological units have been delineated. Drainage details have been prepared from toposheet and satellite imagery. Durbade and Purandara (2001) in their case study of "Estimation of surface runoff potential of a watershed in semi arid environment" analyzed the study area using IRS-IB LISS-II satellite imagery for estimating the runoff potential under geomorphic set-up. After the analysis of satellite imagery topographical maps, ground truth data verification and runoff calculation by SCS method. Tripati and Panda (2002) conducted a study for the Nagwan watershed of the Damodar valley Corporation, Bihar to prepare Runoff modelling. GIS is used to extract the hydrologic parameters of the watershed from the remote sensing and field data. Digital Elevation Model (DEM) for the preparation of Contour map and Easel Pace, GIS software was used to extract the topographic features and to delineate watershed and overland flow patterns from the DEM. Shrimali et al., (2001) have worked on Sukhana lake catchment in the Shiwalik hills for the delineation and prioritization of soil erosion areas by GIS and remote sensing. They prioritized the micro-watersheds using an elimination technique and considering factors like current vegetation cover, waste lands, soil type, erosion status, slope, scope for development, etc., Each of these factors are given weightages in spatial domain using ARC-Info GIS to arrive at very low, low, medium, high and very high priority micro-watersheds.

Y. Jantakat and S. Ongsom-wang, 2011, used spatial interpolation techniques based on 11 semi-variogram models of 4 main sub-types of co-kriging with 3 topographical variables: elevation, longitude and latitude. Physically based hydrological models have been generated topography based model ‘TOPOMODEL’, Digital Terrain Model (DTM) and DEM. Malik I. M. using Geographical Information System for Watershed Based Drainage Morphometric Analysis of stream frequency suggesting that there is an increase in stream population with respect to increasing drainage density and vice versa. World Metrological Organisation (WMO 1966) has suggested various powerful statistical techniques such as Mann-Kendall statistic, Students t-test and low pass filtering etc. to detect the presence and nature of trend in a climatic time series. The most likely alternative to randomness in the climatic time series is some form of trend which may be linear or non1inear. So the test of randomness is a good method to check the presence of trend. The Mann-Kendall statistic test is a very robust test in the sense that the distribution need not be of Gaussian normal type.

The variations in rainfall amounts in Africa and India had been of great concern during last two decades. Winstanley (1973a, b) reported that monsoon rains from Africa to India decreased by more than 50% from 1957 to 1970 and he predicted that the future monsoon seasonal rainfall, averaged over 5 to 10 years is likely to decrease to a minimum around 2030 A.D. and he arrived at a hypothesis that there is a southward movement of Sahelian and Rajasthan deserts.

There are large numbers of studies on trend and periodicity analysis of annual and seasonal rainfall of contiguous India, various sub-divisions and of various individual stations for differ end periods (Jagannathan and Parthasarathy, 1971, 1973, Jagannathan and Bhalme, 1973, Parthasarathy and Dhar, 1974, 1975a, b, 1976a, Parthasarathy and Mooley, 1978, Saha and Mooley, 1978, Mukherjee and Singh, 1978, Parthasarathy, 1984, 1985).

1.5 Problem Statement

Effective water resource management and development is central theme for optimum utilization and sustainable water resources conservation. The effects of lack of rainfall harvesting are already being felt on water resources availability, with impacts across many economic sectors. Changing climate has significant impacts on the availability of water, as well as the quality and quantity of water that is available and accessible. Pollution of water bodies through the use of toxic chemicals by agricultural activities, higher temperatures and other anthropogenic factors have negative effects on availability water resources thereby limited usable water resources are available in the study area. It is necessary to ensure that water resources are sustainably managed to avoid the water scarcity. With emerging water problems, it has become increasingly important that governments should develop and implement clear policy priorities and establish enabling framework in the water sector to address under-development, water shortages and pollution and to allow equitable and efficient access to water. It was in view of this that, the study seeks to delve into the extent to which water resources conservations are adhered to in the Indapur tahsil region.

1.6 Hypothesis

Surface water management will be useful for improving surface water availability in the study area. Latest water conservation techniques have demonstrated positive increase in the water resources. Sufficient surface water availability has improved the increase in cultivated area, crop yield. This has been proved in various parts of the world, especially, in drought-prone areas.

1.7 Major objectives of the present study

i) To ascertain the climatic variables in view of fluctuation in rainfall, temperature etc. which is helpful in understanding of prevailing drought conditions in the tahsil, as well as to analyses spatio temporal distribution of rainfall and available of surface water.

ii) To understand physiography, landuse pattern and socio-economic landscape of the study area.

iii) To get acquainted with the trend of water utilization, availability and requirement of water resources.

iv) To perform water budget estimation applying hydrological as well as Thornthwaite’s method of water balance. Application of both the methods will be helpful to get unbiased and precise results.

v) To develop Composite Water Balance Index (CWBI) for entire study area using the principles of Map algebra, which can be helpful in giving a true picture of water balance of the study area.

vi) To prioritize villages according to CWBI for water resource planning and management of the Indapur tahsil.

vii) To suggest measures for WRM in the study area.

1.8 Arrangement of the text

The present work deals with the ‘Management of Surface Water Resources: A Case Study of Indapur Tahsil, District Pune’ consist of seven chapters. A brief description of each chapter is given below:

Chapter one: Introduction

This chapter deals with introductory section on the importance of water for human survival. The chapter provides the purpose of the study a brief history of the surface water management and surface water resources scenario in India, Maharashtra, Pune district and Indapur tahsil. This chapter discusses the need of surface water management in drought prone area and water scarcity and necessity of surface water conservation. The chapter provides the purpose of the study a brief history of the surface water management in the country and study area as well. In addition to this, the chapter contains hypothesis and the major objectives of the study.

Chapter two: Study area and methodology

The second chapter begins with brief description of the study area. This chapter presents geographical profile of Indapur tahsil, namely, location, situation and site of study area, geology and geomorphology, climate, physiography, drainage network and water bodies, soil type, natural vegetation, demographic characteristics, occupational structure, database and sources of data, methodology and significance of work and sequencing of the study. The variables related to physiography are analyzed with the help of DEM and drainage network. The DEM map, geology map, geomorphology map and geohydrology map support the discussion.

Chapter three: Availability of water resources in the Indapur tahsil

This chapter mainly focuses on spatial, temporal distribution of rainfall. The aim of this chapter is to analyze and determine the major sources of water. However, this chapter deals with water resources available through existing conservation measures and amount of available water resources for domestic, agricultural and industrial use in the study area.

Chapter four: Water utilization in the Indapur tahsil

This chapter presents utilization of water resources for domestic, agricultural and industrial. Further, calculate the water requirement for domestic, agricultural, livestock and industrial purpose in the study area.

Chapter five: Water budget estimation of the Indapur tahsil

This chapter mainly focuses on input and output of water resources in the study area. Further, it analyzes in order to understand the water stress, water utilization and put forward the water budget of Indapur tahsil. However, this chapter deals with water surplus or deficit, optimum use of water resources and reuse of water resources. In brief, this chapter focused on data processing, analysis and presentation.

Chapter six: Management of water resources in the Indapur tahsil

This chapter presents a general overview of what is required in the surface water management. It also deals with the factors that determine the need of water resources management in Indapur Tahsil, present water supply system, assessment of potential rainwater harvesting, difficulties in surface water harvesting, managing of water requirement and prioritization.

Chapter seven: Major findings, conclusions and suggestions

The present study aims at solving the problem of domestic, agricultural and industrial water supply of study area. The final outcome of this research work are arranged this chapter. Major results and recommendations are given in detail. The final outcome of the research work in the form of action plan, program and participatory management of surface water present in this chapter.

Chapter – II
Study Area and Methodology

2.0 Introduction

2.1 Study area

- 2.1.1 Location
- 2.1.2 Geology
- 2.1.3 Climate
  - 2.1.3.1 Rainfall
  - 2.1.3.2 Temperature
  - 2.1.3.3 Aridity
  - 2.1.3.4 Evaporation
    - 2.1.3.4.1 Evapotranspiration
  - 2.1.3.5 Wind
  - 2.1.3.6 Sunshine
- 2.1.4 Physiography and geomorphology
  - 2.1.4.1 Physiography
  - 2.1.4.2 Digital Elevation Model (DEM)
  - 2.1.4.3 Slope
  - 2.1.4.4 Geomorphology
  - 2.1.4.5 Aspect
- 2.1.5 Drainage network and water bodies
  - 2.1.5.1 Surface reservoirs
  - 2.1.5.2 Surface water flow
  - 2.1.5.3 Geohydrology
- 2.1.6 Groundwater
- 2.1.7 Soils
  - 2.1.7.1 Soil type
  - 2.1.7.2 Soil productivity
- 2.1.8 Natural vegetation
- 2.1.9 Demographic characteristics
  - 2.1.9.1 Population size
  - 2.1.9.2 Population growth rates
  - 2.1.9.3 Population density

Chapter – II
Study Area and Methodology

2.0 Introduction

This chapter is divided into two main sections first section focusing on the geographical profile of the study area and the other on data base and methodology adopted for the present work. The study area comprises the semi arid track of Maharashtra plateau and exhibits very distinct nature of agriculture and landuse pattern. The study area is characterized by poor protective and degraded vegetative cover causing soil erosion and decline in the productivity of land. Groundwater over-exploitation is prevalent in the study area. Water supply options are unreliable and in the eastern part of Indapur tahsil, the quality of water in the principle aquifer is affected by pollution and saline intrusion. In the study area many aquifers are being depleted because of the heavy use of water for agriculture. The receding water table is causing shortage of water for irrigation as well as drinking purpose. More than 80% of the population of the study area depends on agriculture, animal husbandry and agro-industry for their livelihood.

2.1 Study area

2.1.1 Location

Indapur tahsil is one of the tahsils in the Pune district consisting of 142 villages along with one urban centre in the study area. There are eight revenue circles in the tahsil. Some of the main settlements in this area are Bhigwan, Indapur, Loni, Bawada, Kati, Nimgaon Ketki, Anthurne and Sansar. The area extends from 17° 53´ 42" to 18° 19´ 58" North latitudes and 74° 39´ 16" to 75° 09´ 39" East longitudes **(Fig. 2.1)**. The area is drained by the river Bhima on north and east both sides. Nira River flows south of Indapur tahsil. This area is surrounded by western boundary of Baramati tahsil, Daund tahsil lies to NW and Satara district to SW. Solapur district lies to the east, north-east and the south. The revenue circle wise villages are displayed in the **Fig. 2.2 and table 2.1.** Total geographical area of the tahsil is 1575.38km^2 (Census 2011), out of which Nira river catchment compress about 586.8 km^2 and Bhima river catchment covers an area of 902.43km^2. Nira River joins the Bhima River at famous tourist place i.e. Narsinhapur village after travelling a course of 209 Kms.

Fig. 2.1

Source: www.pune.gov.in **Fig. 2.2**

Table 2.1 Revenue circle wise villages in the study area.

Sr. No	Name of Revenue Circle	Name of Village	Sr. No	Name of Revenue Circle	Name of Village
1	Bhigwan	Bhigwan	41	Loni	Bandewadi
2		Diksal	42		Kalewadi
3		Takrarwadi	43		Dalaj No. 1
4		Madanwadi	44		Dalaj No. 2
5		Shetphalgadhe	45		Dalaj No. 3
6		Lamjewadi	46		Varkute Bk
7		Pimple	47		Karewadi
8		Nirgude	48		Gagargaon
9		Mhasobachiwadi	49		Rajwadi
10		Akole	50		Bijwadi
11		Vaysewadi	51		Vangali
12		Kumbhargaon	52		Pondkulwadi
13		Poundhawadi	53		Kalashi
14		Bhadalwadi	54		Gangavalan
15		Bandgarwadi	55		Agoti No. 1
16	Indapur	Indapur	56		Agoti No. 2
17		Tarangwadi	57		Chandgaon
18		Gokhali	58		Nhavi
19		Narutwadi	59	Bawada	Bawada
20		Galandwadi No. 1	60		Ganeshwadi
21		Galandwadi No. 2	61		Kacharewadi
22		Malwadi	62		Surwad
23		Sardewadi	63		Vakilvasti
24		Kalthan No. 1	64		Pithewadi
25		Kalthan No. 2	65		Lakhewadi
26		Padsthal	66		Bhodani
27		Shirsodi	67		Bhandgaon
28		Pimpri Kh	68		Nirnimgaon
29		Sugaon	69		Chakati
30		Ajoti	70		Sarati
31		Kandalgaon	71		Lumewadi
32		Shah	72		Gondi
33		Taratgaon	73		Ozare
34		Hingangaon	74		Pimpri Bk
35		Babhulgaon	75		Girvi
36	Loni	Loni	76		Narsingpur
37		Bhawadi	77		Tannu
38		Balpudi	78	Kati	Kati
39		Palasdeo	79		Jadhavwadi
40		Malewadi	80		Reda

Sr. No.	Name of Revenue Circle	Name of Village	Sr. No.	Name of Revenue Circle	Name of Village
81	Kati	Redni	113	Anthurne	Maradwadi
82		Khorachi	114		Nimsakhar
83		Boratwadi	115		Kalamb
84		Shetphal Haveli	116		Walchandnagar
85		Vadapuri	117		Ranmodwadi
86		Pandharwadi	118		Bori
87		Zagadewadi	119		Lasurne
88		Avasari	120		Jankshan
89		Bedshinge	121		Belwadi
90		Bhatnimgaon	122		Thoratwadi
91	Nimgaon Ketki	Nimgaon Ketki	123		Paritwadi
92		Kacharwadi	124		Chavanwadi
93		Gotandi	125		Kardanwadi
94		Varkute Kh	126	Sansar	Sansar
95		Vyahali	127		Bhavaninagar
96		Kauthali	128		Sapkalwadi
97		Nirwangi	129		Jachakvasti
98		Pitkeshwar	130		Hingnewadi
99		Ghorpadwadi	131		Nimbodi
100		Sarafwadi	132		Lakdi
101		Shelgaon	133		Kazad
102		Kadbanwadi	134		Shindewadi
103		Hangarwadi	135		Tawashi
104		Sirsatwadi	136		Udhat
105	Anthurne	Anthurne	137		Pawarwadi
106		Bharnewadi	138		Kuravali
107		Kalas	139		Jamb
108		Birgundwadi	140		Chikhali
109		Pilewadi	141		Mankarwadi
110		Gosaviwadi	142		Gholapwadi
111		Rui	143		Bambadwadi
112		Thoratwadi			

Source: Tahsil office, Indapur

The river Bhima, river Nira and their tributaries are draining the study area.

The study area experiences semi-arid climate. The month of March, April, May and June are the hottest months of where average temperature remains 32°C. Temperature gradually reduces in December up to 22.4°C. The average annual rainfall in Indapur tahsil is 503.8 mm. The medium black and deep black soil appears in the study area. These soils are useful for cultivation of grains, Sugarcane, Jowar, Bajara, Onion, Vegetables and Orchards. The area occupies less than 5 percent area under deciduous trees and observed to be scattered in the area. The irrigated land in the study area accounts to 54883 ha (37.39 %). According to 2011 Census the study area has 3, 83,183 population (1, 98,801 males and 1, 84,382 females). The average density of population is 240 per km^2. The region has eighteen weekly market centres. National highway, state highway, major district road and other roads are available in the Indapur tahsil for better connection. Indapur is a head quarter of the tahsil.

2.1.2: Geology

The entire tahsil is the basement of Deccan trap basaltic lava, which comprises mostly the prophylactic basalts with columnar joints inter trapped beds in the form of red boles at many places. The basalt flows of the Deccan Traps ranges in age from upper Cretaceous to lower Eocene. Local alluvial deposits of recent to sub recent are seen capping the basaltic flows along the major rivers courses no mineral of economic importance has encountered **(Fig. 2.3a)** in the study area.

Sr. No.	Geology	Area	
		sq km	%
1	5 "aa" Basaltic lava flow (55-180m)	19.22	1.22
2	5 "aa" & Compound pahochoc basaltic lava flow (55-220m)	55.61	3.53
3	10-15 "aa" and Simple basaltic lava flow (50-350m)	1500.55	95.25
	Total	1575.38	100

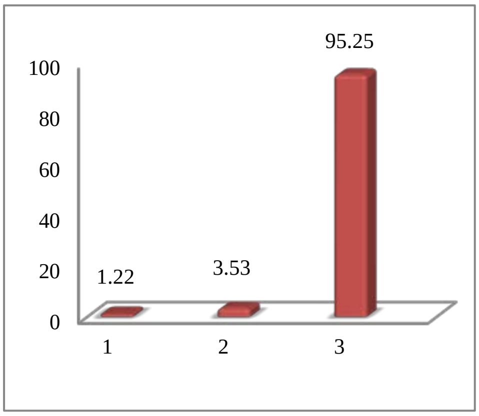


Fig. 2.3b Geological units (% area)

Area under various geological units are observed in the study area which mainly include 10-15 "aa" and simple basaltic lava flow (50-350 m) covering about 1500.55 km^2 (95.25% of the total area), 5 "aa" and compound pahochoc basaltic lava flow (55-220 m) covers 55.61 km^2 (3.53% of the total area) and 5 "aa" basaltic lava flow (55-180 m) covers only 19.22 km^2 (1.22% of the total study area) (Geological survey of India, Nagpur 2001) of the total study area **(Fig. 2.3a & Fig. 2.3b)**.The study area is underlain by the horizontal lava flows of the Deccan basalts, which makes up the ridges and plateaus over almost entire Maharashtra. Typically these rocks form the

‘Hard rock terrain’ and their physical properties such as porosity and permeability play an important role in the movement and accumulation of groundwater.

These lava flows are classified into two groups (considering the dominance of the two types in the area) viz., Compact Basalts (CB) and Compound Basalts (CpB). The Compact basalts show a brecciaed top and base with a dense compact core which exhibits vertical and/or horizontal joints. The Compact basalts often show a columnar structure. The Compound basalts are characterized by pipe amygdales at the base and a vesicular and amygdule zone at the top.

Within the study area, five Basaltic flows are exposed at various elevations ranging from 509m to 580m ASL. The lowermost flow, Compound flow II, is exposed in well sections at 509m and below, near the Bhadalwadi tank. This flow is highly vesicular and amygdaloidal in nature. Dense mineralization of silica minerals is observed throughout the flow. Overlying this is the Compact basalt III exhibiting a thickness of 10m. This flow has undergone weathering and shows exfoliated structure, with the presence of spherical weathering. Compound flow I **(Fig. 2.4)** over lie the Compact basalt III and exposed from 525m to 540m. Above this is the Compact basalt II which is relatively hard and shows widely spaced vertical fractures, which are observed across the entire thickness of the flow. The contact between Compact basalt II and Compound Flow II is seen at the base of Mutha right bank canal **(Fig. 2.5)**. The uppermost flow is the Compact basalt I which is exposed at an elevation of 560m to 580m exhibiting vertical fractures. Five Basaltic flows have

Fig. 2.4 Compound Flow I exposed in a road cutting near Bhigwan

Fig. 2.5 The compact basalt II is exposed on either bank of the Mutha canal and the contact with the lower compound flow is seen at the base of the canal.

Source: Geological Survey of India, central region, Nagpur. **Fig. 2.3a**

been identified in the study area. Out of these, the Compound flow II along with the deeper unclassified basalts forms the principle Aquifer system to the area. The Compound flow I and some part of the Compact basalt III constitute the secondary shallower aquifer system (Kaustubh Mahamuni et al.2009).

The study area is much gentler in relief than those from the Western Ghats in Maharashtra. The regional relief appears quite subtle, with the younger basalt outcrops standing out as ridges against the gently undulating and rolling landscape. The study area gradually slopes towards the southeast, the regional slope being towards the South.

2.1.3 Climate

The area is located in the eastern part of the western ghat ranges, on the western margin of the rain shadow region, and hence enjoys a semi-arid, subtropical climate. The climate of the study area is on the whole is agreeable. June to September is the south-west monsoon season, whereas October and November constitute the post-monsoon season. The climate of the study area is characterised by hot summer and generally dry throughout the year except during the southwest monsoon. The weather conditions throughout the year clearly demarcate three seasons i.e. summer, rainy (southwest monsoon and north-eastern retreating monsoon) and winter. The average annual rainfall for study area is of the order of 503.8 mm (Socio Economic Report 2011).The summer starts from the month of March, the maximum temperature is between the months of April and mid June, when the temperature shoots over to 32°C. The winter season is from December to about the middle of February followed by summer season which lasts upto May, during which the temperature falls to a minimum of 22.4°C.

2.1.3.1 Rainfall

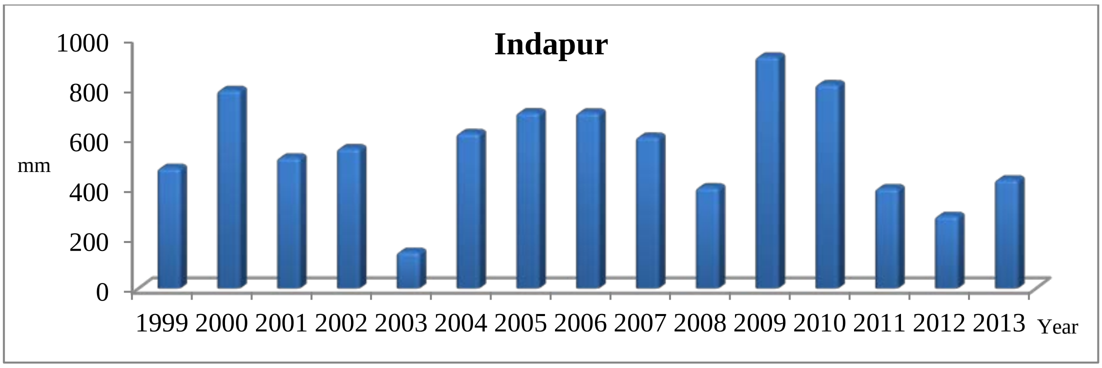
The Indapur tahsil being an semi arid and arid track incorporated under the Drought Prone Area Programme (DPAP) the area is characterized by scanty and uneven rainfall ranges from 450 to 550 mm. with and annual rainfall is 503.8 mm The Rainfall is mainly received from the south-west monsoon. Monsoon sets in the month of June and lasts up to the month of October. Monsoon onsets first week of June and having its peak period during the month of September and October. It is also characterizes by uneven and scanty rain with long dry spell during summer. The highest rainfall is observed in the in 2009 and it is recorded to be 1103 mm at Bawada and minimum at Sansar 85 mm in 2003. The rainfall data for the study area is

Table 2.2: Year wise and station wise rainfall variation in the study area (mm).

Sr. No.	Year	Indapur	Sansar	Anthurne	Nimgaon Ketki	Walchandnagar	Bawada	Shetphalgadhe	Bhigwan station
1	1999	485	647	315	NA	576	NA	420.5	339
2	2000	796.18	503	380	183	343	447	422	402.5
3	2001	526.83	377	349	452	248	643	503.5	370
4	2002	563.5	273	277	237	262	320	234.5	221.2
5	2003	148.9	85	107	98	111.5	154	188	132.56
6	2004	624.18	562.7	304	455	429.5	589	481	452.62
7	2005	706.9	597.6	298	323	412	568	674	224
8	2006	706.4	508.5	460.2	560	520	629	425	334.5
9	2007	609.5	460	409.2	468	510.5	770	588.25	536.75
10	2008	407.3	379	294	324	171	645	372	456
11	2009	929.7	890	815	946	591	1103	572.2	697
12	2010	819.3	803	654	713	181.5	863	289.5	783.8
13	2011	403.8	309	302.5	227.5	164	388	357	480
14	2012	293.2	163	189	271	465.2	459	171.9	356
15	2013	439.2	461	323	430	448.8	681	535.2	534.7

Source: Tahsil office and Agriculture office, Indapur

NA: Data not available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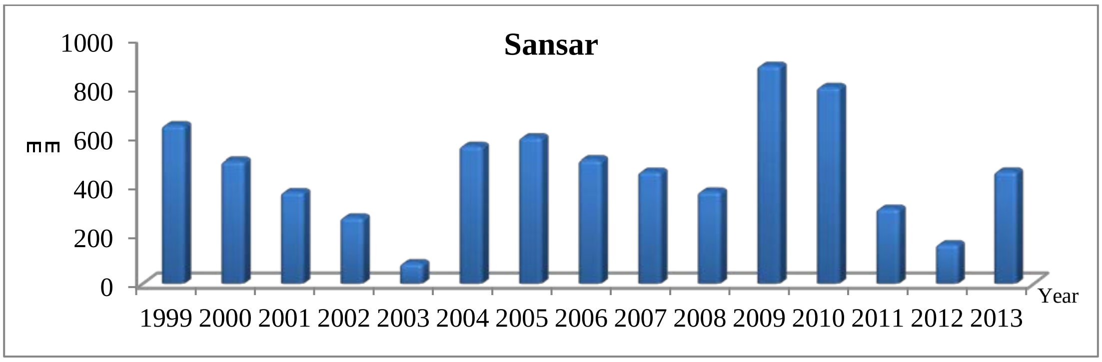
Year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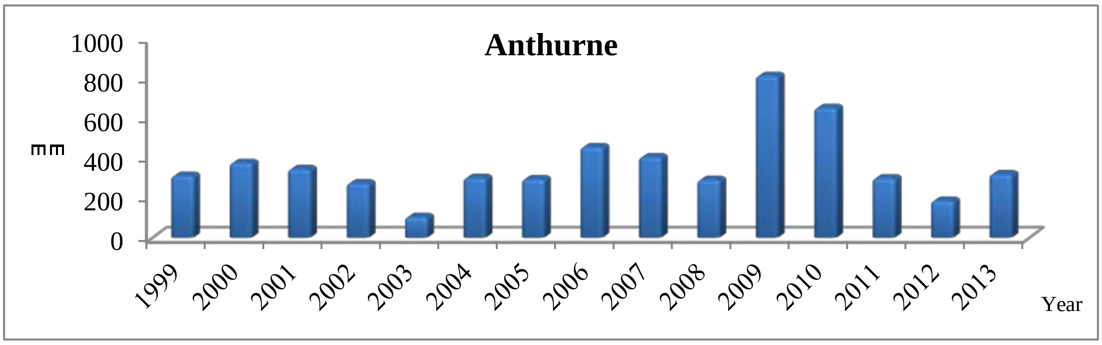
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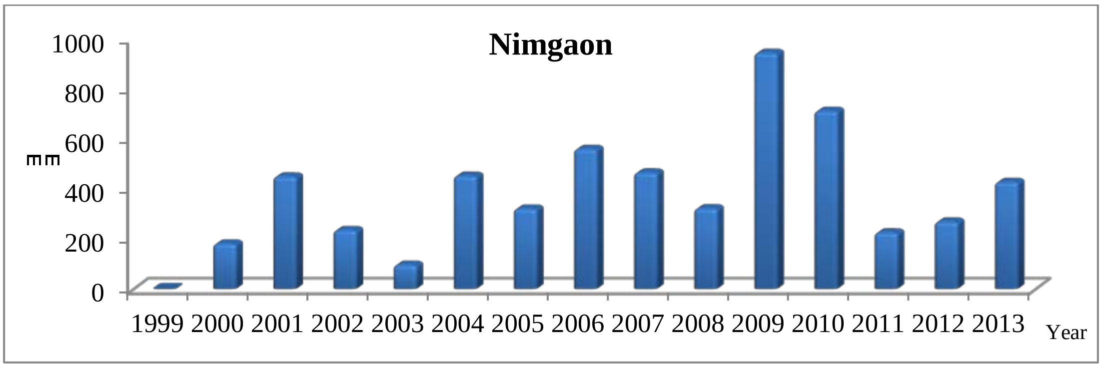
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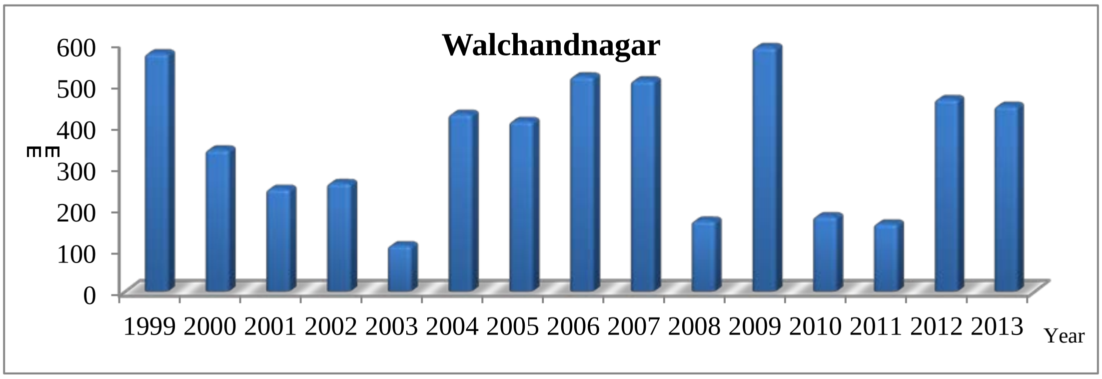
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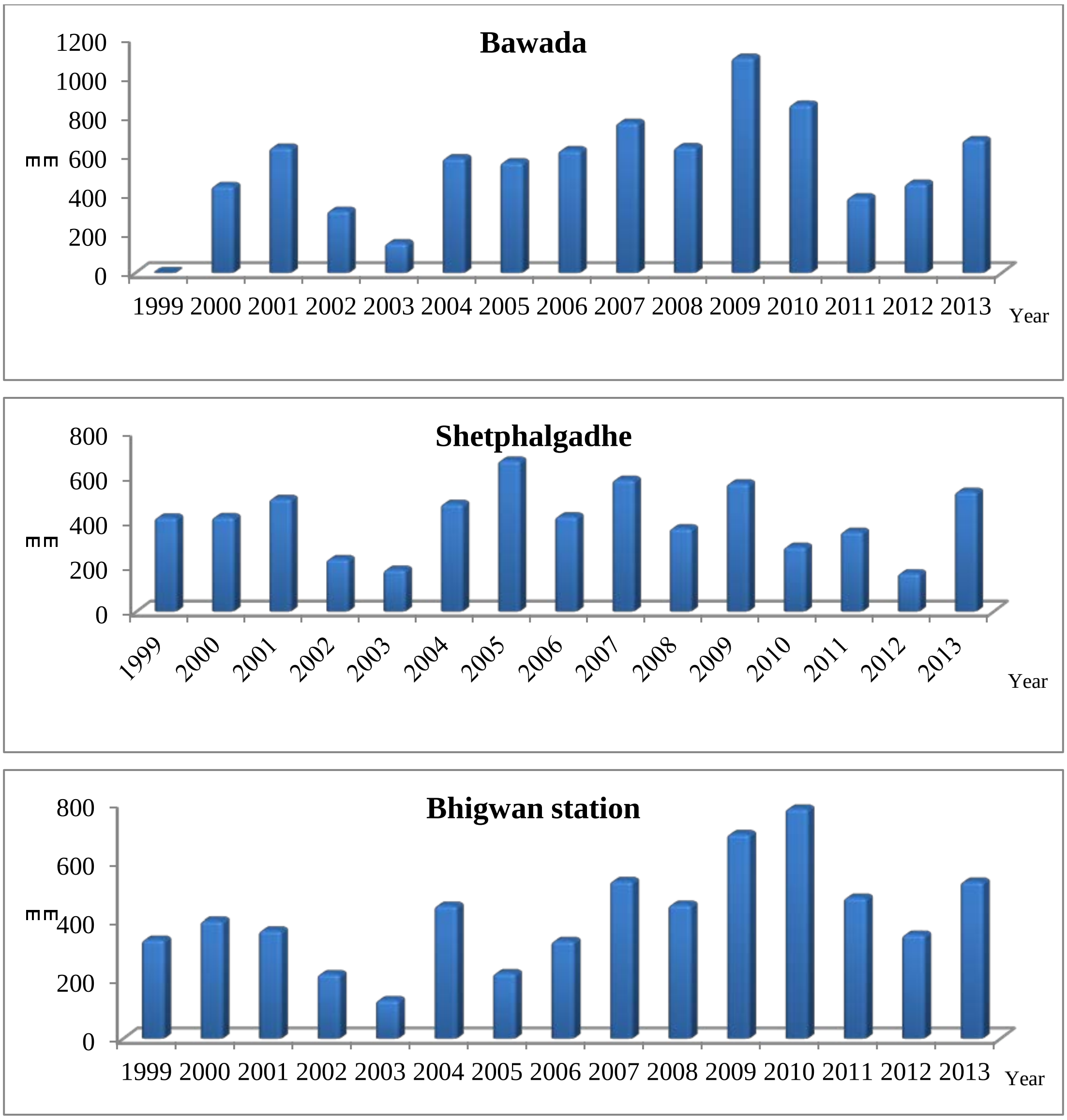


Fig. 2.6 Rainfall station wise variation in the study area (mm).

collected from the Tahsil Office and Agriculture Department Office, Indapur for the year 1999 to 2013 **(Table. 2.2 and Fig. 2.6)**.

Agro climatically, this study area belongs to scarcity zone of rainfall to about 80 to 90 percent received from southwest monsoon and remaining very less rainfall receives from retreat of monsoon. It can be clearly noticed that rainfall distribution decreases steadily from north-west to south-east direction.

The study area comes under the rain shadow region, hence rainfall is very irregular. The onset of monsoon, amount of rainfall and the variability of rain are very irregular in the study area.

2.1.3.2 Temperature

General climate of tahsil is dry climate exert monsoon season, due to limited latitudinal extent of the study area. The temperature does not change significantly. The climate of the study area is dry and hot. There are three seasons, namely, winter, rainy and summer in the study area experiences. The air temperature rises from the month of March up to May. The month of May is the hottest month in the year. The temperature rises to a maximum of 32ºC and in winter it drops down to 22.4ºC. Occasionally temperature goes up to 38ºC to 40ºC at the end of the month of May. The study area faces extreme variations in temperature conditions with very hot summers and very cold winters and a low relative humidity. The average maximum temperature is 32°C. The average minimum temperature is 22.4°C **(Table 2.3 Fig. 2.7a and 2.7b)**.

Table-2.3: Mean Monthly Temperature of Indapur Tahsil. (Temp. in°C)

Sr. No.	Months	Mean	Sr. No.	Months	Mean	Sr. No.	Months	Mean
1	January	22.8	5	May	32.0	9	September	26.4
2	February	24.9	6	June	28.8	10	October	26.2
3	March	28.3	7	July	26.7	11	November	23.8
4	April	31.0	8	August	26.1	12	December	22.4

Source: climate.geog.udel.edu

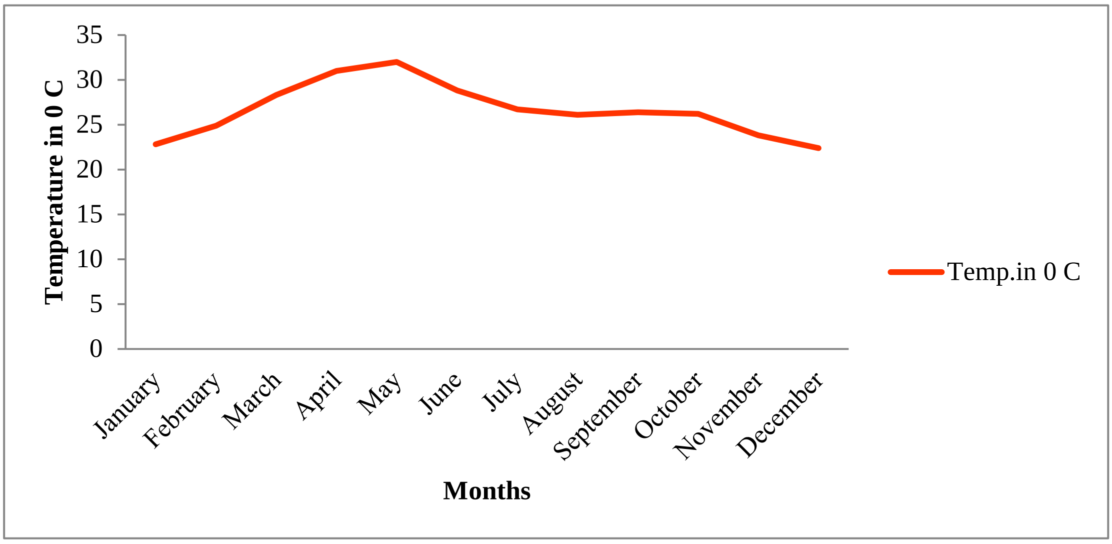


Fig. 2.7b Graph showing temperature

The mean annual maximum temperature is recorded in the month of May (32ºC) (Table-2.3), whereas the mean annual minimum temperature lies in December (22.4° C) **(Table. 2.3 Fig. 2.7a and 2.7b)**. The temperature increases in the study area

Source: worldclimate.org/tiles.php **Fig. 2.7a**

from January to April. The relative humidity is high in the month of July, August and September. The study area experiences high evaporation and high wind velocity in the months of March, April and May.

2.1.3.3 Aridity

Aridity is high during the summer months due to increasing temperature. The diurnal variations in the aridity conditions during this period are low; water vapour gets condensed due to falling night time temperature, while the day time temperature is high. The duration of dryness is longer in the study area. During the months of hot summer (March to May) and particularly at noon the average aridity is greater than 25%. The aridity falls at the end of May over the study area. It increases from North to South.

In the winter season, aridity varies but little than that in the hot weather period. The clear sky, fine and dry weather, low humidity and absence of rainfall become the general picture of the study area. The air is very humid during the south-west monsoon season and mostly dry in the rest of the year. It can be clearly noticed that aridity distribution decreases steadily from south -west to north -east direction except the Far east side of the study area. It is found more than 20% in the major part of the study area. Further, in the Northern and South Eastern part of the study area aridity found less than 20%.

2.1.3.4 Evaporation

The rate of evaporation is higher during the months of summer i.e. from March to May. The maximum evaporation rises up to 13.3 mm in the month of April and minimum evaporation is observed to be 3.9 mm in the month of August. An annual average of evaporation varies between is 8 mm to 9 mm throughout the year.

2.1.3.4.1 Evapotranspiration

In the study area the annual evapotranspiration increases from west to east especially, in the eastern part the climatic conditions are favourable to high level of evapotranspiration. In this area it is observed to be range between from 424 to 463 mm/yr. However, in the western and southern part comparatively low evapotranspiration prevails less than 430 mm/yr. Low evapotranspiration is observed from west side to the part of Shetphalgadhe, Tavshi, Kalamb and Khorachi villages and high evapotranspiration is found in the eastern part of study area i.e. Ganjewalan, Shirsodi, Padsthal, Pimpri Kh, Sugaon, Ajoti, Shah, Kandalgaon and Taratgaon.

Source: http://www.csi.cgiar.org **Fig 2.8**

In this area evapotranspiration is more than 460 mm/yr **(Fig. 2.8)**. In the remaining part of the study area the Actual Evapotranspiration is observed to range between 430 to 460 mm/yr.

2.1.3.5 Wind

The monsoon dominates the climates conditions during summer over the study area. The wind speed is greater at the end of summer and beginning of southwest monsoon. In the monsoon period they blow from southwest to northeast. After the southwest monsoon, the wind direction becomes opposite and blows from northeast to southwest. Stormy wind blows in the months of April and mostly associated with whirls. The averages of monthly wind velocity are greater in the month of May and recorded to be above the range of 6 Km/hr/days whereas in the month of November it is noticed to be below 3.5 km/hr/day.

2.1.3.6 Sunshine

In the study area, average annual sunshine hours are approximately 7 hours. Seasonally, the area receives more sunshine during post-monsoon and late pre-monsoon seasons because of the clear skies during span. However, the duration of sunshine decreases during the monsoon season due to the density of clouds.

2.1.4 Physiography and geomorphology

2.1.4.1 Physiography

Physiography of Indapur tahsil is divided by flat topped interfluves and flood plains. The study area is made up of sedimentary deposition. The northern and central parts cover by low hills and flat topped surface. The southern and south-east part is mostly flat with deep black soil. The amount of rainfall plays an important role in the evolution of the landscape (Datye, 1984). This area is with a rolling topography and the low hills sinking slowly in to the plains. Therefore, the physiography of the study area has given rise to two major characteristic land forms namely; (1) the foot hills and (2) the plains. Very small-elevated hills spread all over the middle and northern part of study area. It seems plateau basalt are extra ordinarily uniform in composition over wide area and have a considerable control on physiography and drainage system developed in the study area.

Altitude of this area ranges between 460 and 610 m. above mean sea level (MSL). The average height of study area is 544 meters from MSL. The direction of slope is eastwards. The narrow alluvial belt found along the major rivers has been classified as alluvial plains. These plains have a very gentle slope with considerable drainage density. The agriculture is a principal land use of the area and it is mostly cash cropped.

2.1.4.2 Digital Elevation Model (DEM)

Toposheets no. 47J/11, 47J/12, 47J/15, 47J/16, 47K/13, 47N/3, 47N/4 and 47O/1 on 1:50000 scales has been used for preparation of DEM model and to extract resultant study area basin parameters. DEM shows that, the central part of the study area is characterized by the highest elevation point .The first and very important method involves a map geo-referencing which has been achieved in Global Mapper software version 11.02. The systematic digitization work leads to the formation of line layers of each and every contour and then preparation of Triangular Irregular Network (TIN). Giving suitable arc spacing, this has been exported to arc ASCII grid to perform various operations in terms of grid format and subtraction of it. The small undulating hill ranges running in west to east direction. Water divide line of the study area is characterized by elevated topography. Altitudinal variation in the study area noticed to be from 460 M to 610M. There is a progressive increase in the altitude from east to west. The watershed divide line is also characterized by low heighted spurs end merging into plain topography in west to east direction. The Peneplain topography which shows altitudinal variation of river Bhima between 500 to 460 mts. (flowing north-west to south-east direction) and river Nira between 520 to 460 mts. (flowing west to east direction) mainly confined to valley floor regions of rivers. The rest of the river area of study area exhibits undulating nature of the relief watershed **(Fig. 2.9)**.

2.1.4.3 Slope

The slope map **(Fig. 2.10a)** has been prepared based on DEM. Based on slope intensity; the tahsil is classified into the 3 zones. The entire study area is characterized by gently to moderate gentle sloping ground. The area in between 420 to 520 m contour is plain area, which is characterized by the alluvial soil region. This part covered 712.77 km^2 (45.24%) area of the study area. The total area is gentle plain area. The area between 520 to 580 m contour intervals is moderate gentle sloping area. This part covered maximum area of the study area i.e. 814.94 km^2 (51.73%).The area more than 580 m contour intervals is covered very less i.e. 47.67 km^2 (3.03%) of the total study area. This area is water divide portion which is characterized by moderate sloping area **(Fig. 2.10a & Fig. 2.10b)**.

Source: Computed by author **Fig. 2.9**

Source: Author **Fig. 2.10a**

Sr. No.	Slope	Area	
		km^2.	%
1	Gentle plain	712.77	45.24
2	Moderate gentle	814.94	51.73
3	Moderate	47.67	3.03
	Total	1575.38	100

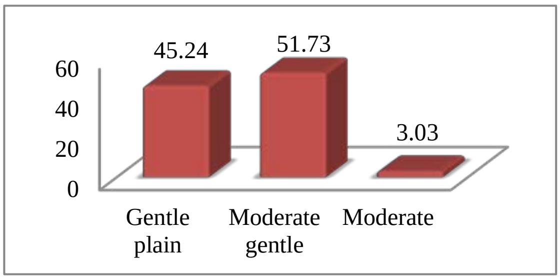


Fig. 2.10b Slope units (% area)

In the study area, the major area has a plain topography. Generally, it may be pointed out that maximum area of the study area is gently sloping area, having slope gradient between from 0.5^0 to 2^0. The small rills, streams sub-tributaries flow from south to north and north to south direction and finally meet to the rivers respectively river Bhima and Nira.

2.1.4.4 Geomorphology

The study area is drained by a part of the Bhima and Nira river system and its streams. The local morphology of the area comprises low lying spurs or ridges cover the west, central and the north-west part and slowly declining in elevation towards the northeast forming a relatively flat terrain. These ridges act as individual water divides thus forming various smaller watersheds In the present study area geomorphological area under various morphological units are observed which mainly include denudational origin on deccan trap 1032.66 km^2 (65.55%), older flood plain 539.14 km^2 (34.22%) and region of middle level plateaus (550-900m) only 3.58 km^2 (0.23%) of the total study area **(Fig. 2.11a & Fig. 2.11b)**.

Sr. No.	Geomorph-ology	Area	
		km^2.	%
1	Denudational origin	1032.66	65.55
2	Older flood plain	539.14	34.22
3	Middle level plateau	3.58	0.23
	Total	1575.38	100.00

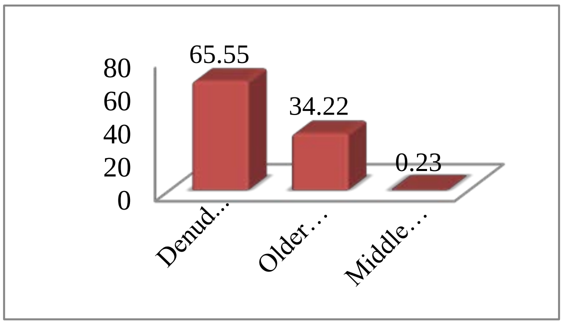


Fig. 2.11b Geomorphological units (% area)

Source: Reproduced by author **Fig. 2.11a**

2.1.4.5 Aspect

An aspect map appears solar orientations of slopes with different direction. The south facing slopes indicate the direct shaded sunlight and north-facing slope shown less sunlight shaded with darker colour. Since the basins of Roti nala, Kurje nala, Amir Amla nala, Kalas nala, Bhadalwadi nala, Ruin nala, Nhavi nala, Khar nala, Tel nala, Kavthicha Nala, Redni nala, and other rills and odhas are also clear shown in the map. These aspect map also shows the length of above nala and there rills **(Fig. 2.12)**.

2.1.5 Drainage network and water bodies

The general elevation of tahsil ranges from 420 to 610 m above the MSL. The general slope is from South to North in the upper part and from North to South in the lower half of the tahsil. There is clear cut water divide from West to East. The study area is divided into two major River basins, Bhima and Nira. The drainage in the study area is mainly dominated by river Bhima and Nira and other tributary streams **(Fig. 2.13)**. The river Bhima originates near Bhimashankar on the crest of Sahyadri range located in Khed tahsil (700 meters). The river Bhima is the main river of this tahsil and it flows on the northern boundary in the direction from north-west to south-east and forms natural boundaries of the tahsil on this side. This river receives water from Bhama, Indrayani, Vel, Mula-Mutha, Ghod and Nira rivers. River Nira originates near Shirgaon village in Bhor tahsil in Pune district. The confluence of the river Bhima and Nira is at Narsingpur village in the south-east part in Indapur tahsil. The total length of Bhima and Nira rivers are 103 and 64 kms respectively in the study area. Both rivers bring water during rainy season and shrink during summer. River Bhima located in the northern and north-eastern parts in the study region. There are 21 settlements situated on the bank of the Nira in Indapur tahsil.

Regional drainage pattern of stream is dendritic drainage pattern in which small streams join larger stream at an acute angle (less than 90 degrees) forming the dendrite drainage pattern. Drainage channels in most of the study area are narrow but shallow.

2.1.5.1 Surface reservoirs

The total area of tahsil Indapur 1.48 lacks ha and is the catchment of river Bhima and Nira basin. According to Ground Water Survey and Development Agency (GSDA), the watershed of Indapur tahsil divided into 288 micro watersheds. Indapur

Source: Author **Fig. 2.12**

Source: S.O.I. Toposheet and mpcb.gov.in **Fig. 2.13**

tahsil has one Dam, ten minor irrigation tanks, five percolation tanks and other surface reservoirs **(Table 2.4 & Fig. 2.14a & 2.14b)**.

Table: 2.4 Types of surface water reservoirs

Sr. No.	Type of surface reservoir	Quantity	Sr. No.	Type of surface reservoir	Quantity
1	Dam	1	8	Percolation Tank	5
2	M.I. Tank	10	9	Underground Band	6
3	K. T. Weir	16	10	Cement Nalabandh	89
4	Valan Bandhara	18	11	Soil Nalabandh	1911
5	L.B. Structure	476	12	Earthen Structure	498
6	Vanraie Band	560	13	Continuous Counter Trench	1020 ha.
7	Farm Tank	536	14	Compartment Banding	8957 ha.

Source: Government of Maharashtra, Agriculture Office, Indapur 2012.

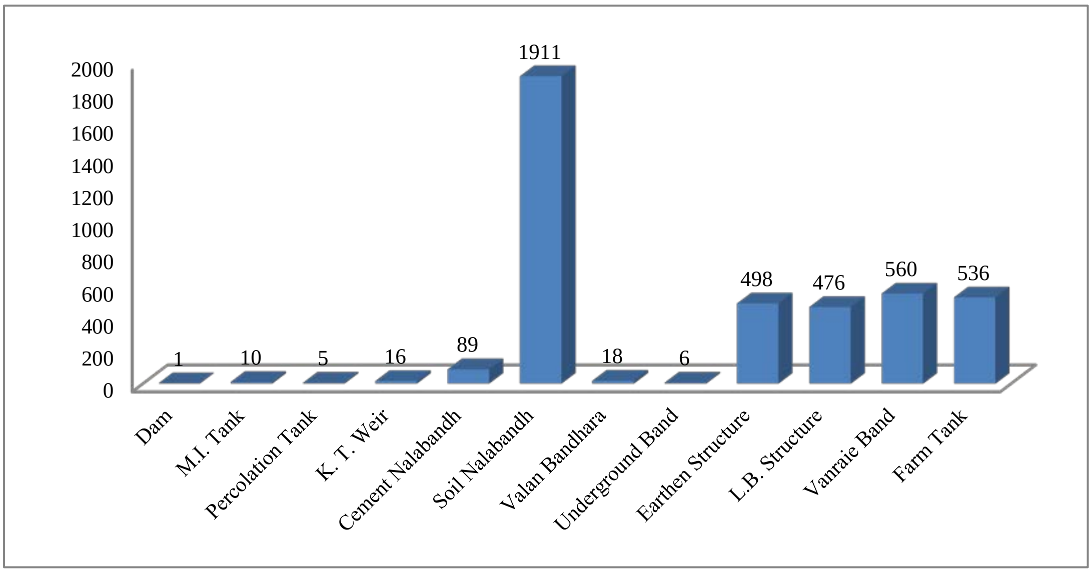


Fig. 2.14b

2.1.5.2 Surface water flow

The flow rate available in a river helps in determining the dilution factor available for effluents and in self-purification. Depending upon the flow, the drains are divided into two flow categories i.e. high and low relative to each other. Area wise distribution of the 'high' and 'low' surface water flow is depicted in the surface water flow map **(Fig. 2.15a)**. High flow areas include rivers or drainages with high flow and a buffer of 5 km to these drainages (River Bhima and Nira). Low flow areas include the seasonal streams and remaining watersheds. In the present study area observed 1009.51 km^2 (64.08%) high flow surface water area and 565.87 km^2 (35.92%) low flow surface water areas **(Fig. 2.15b)**.

Source: Google image and mpcb.gov.in **Fig. 2.14a**

Source: mpcb.gov.in/ DEA Pune maps **Fig. 2.15a**

Sr. No.	Surface water flow category	Area	
		km^2.	%
1	High	1009.51	64.08
2	Low	565.87	35.92
	Total	1575.38	100.00

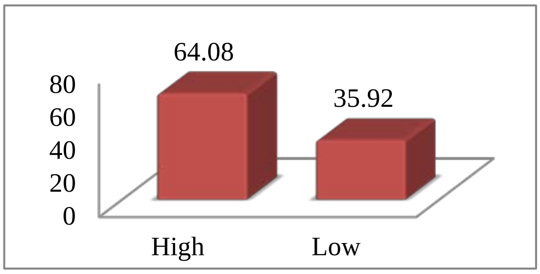


Fig. 2.15b Surface water flow (% area)

2.1.5.3 Geohydrology

The entire area of the tahsil is underlain by the basaltic lava flows of upper Cretaceous to lower Eocene age. The shallow alluvial formation of recent age also occurs as narrow stretch along the major Rivers flowing in the area **(Fig. 2.16a)**. There is only 74.67 km^2 (4.74%) area recommended for groundwater development in the study area. This is found in the patches in SW and NE part of the study area. Remaining 1500.71 km^2 (95.26%) area is characterised by Deccan trap and is notable as a constraint for groundwater development **(Fig. 2.16b)**.

Sr. No.	Geohydrology	Area	
		km^2	%
1	Deccan trap	1500.71	95.26
2	Recommended for GW development	74.67	4.74
	Total	1575.38	100

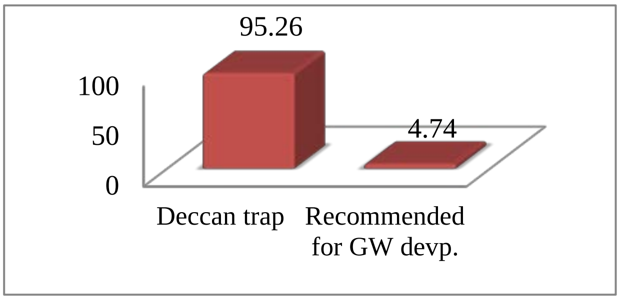


Fig 2.16b Geohydrological units (% area)

2.1.6 Groundwater

The Central Ground Water Board and Ground Water Survey and Development Agency have jointly estimated the ground water resources of study area based on GEC–97 methodology. The net annual ground water availability comes to be 261.86 MCM out of which 207.26 MCM is under command and 54.60 MCM is non command (GoM Groundwater Surveys and Development Agency, Pune 2014). The depth of ground water table plays an important role in determining the risk due to contamination to groundwater. Depending on the groundwater occurrence (as per MRSAC), the study area is divided into three zones ‘high’, ‘medium’ and ‘low’.

The map shows the depth of ground water table in the Indapur tahsil **(Fig. 2.17a)**. Three categories have been made based on the level of ground water table. Less than 5.0 meters below ground level (m bgl) located in the Middle Western part, Kalamb and its adjacent area, part of Bawada and Girvi, northern side of Indapur and

Source: Geological Survey of India, central region, Nagpur. **Fig. 2.16a**

Source: Reproduced from mpcb.gov.in/ DEA Pune maps **Fig. 2.17a**

part of Loni, Palasdev and Kalashi. The small patches are scattered in this area. It can be observed from the ground water table that, more than 15 m bgl found in side of Bhima River bank, southern part of study area and some places in northern side and remaining part of study area ground water table found 5-15 m bgl (MPCB). A major portion of the study area is covered by this water level. In the present study area found the 394.79 km^2 (25.06%)areas groundwater level is 5 m below groundwater level (m bgl), 553.12 km^2 (35.11%) areas water table 5 to 15 m bgl and maximum area water table found more than 15 m bgl i.e. 627.47 km^2 (39.83 %) area covered of the study area **(Fig. 2.17b)**.

Sr. No.	Groundwater table	Area	
		km^2.	%
1	More than 15 m bgl	627.47	39.83
2	5-15 m bgl	553.12	35.11
3	Less than 5 m bgl	394.79	25.06
	Total	1575.38	100

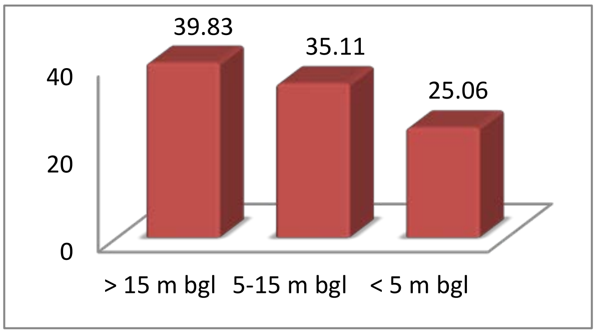


Fig. 2.17b Groundwater table units (% area)

2.1.7 Soils

2.1.7.1 Soil type

Soil plays a key role in crop cultivation and production in Indapur tahsil. Physiography, drainage and climate exert influence on the growth of plants. The organic, inorganic matter and water are essential for crop growth therefore, it is essential to study the soil types. On the basis of soil depth, drain, soil characteristics, slope etc. the following soil types are identified in the tahsil and shown in the **Fig. 2.18a**.

The black deep calcareous soil has high capacity moisture holding soil. This type of soil is only 136.42 km^2 (8.66%) are available in the study area. Whereas the slightly deep fine calcareous soil covers 512 km^2 (32.50%) area. It is found in the southern region between river Nira and Nira left canal. Besides this it found around in patches in the northern part of study area. The maximum area covered of the study area by this type soil. Along the deep black soil and slightly deep black soil found the shallow clayey soil is found. The Shallow clayey and slight stony soil is found in the Western and middle part of the study area that is higher relief and has coarser in texture and shallow in depth. These soils are covered 440.80 km^2 (27.98%) and 486.16 km^2 (30.86%) area respectively **(Fig. 2.18b)**.

Source: Reproduced from mpcb.gov.in/ DEA Pune maps **Fig. 2.18a**

Sr. No.	Soil types	Area	
		km^2.	%
1	Deep calcareous	136.42	8.66
2	Slightly deep calcareous	512.00	32.50
3	Shallow clayey	440.80	27.98
4	clayey slight stony	486.16	30.86
	Total	1575.38	100.00

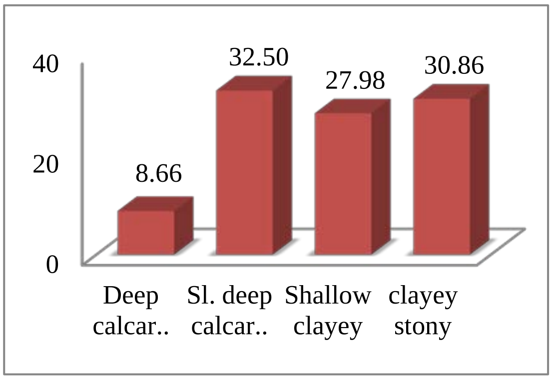


Fig. 2.18b Extent of soil type (%area)

2.1.7.2 Soil productivity

In the study area it is observed that the maximum 579.43 km^2 (36.78 %) area under high productivity and only 399.36 km^2 (25.35%) area under low productivity soil. High productivity soil area found along the river bank and low productivity soil spread over middle part of the study area **(Fig 2.19a & 2.19b)** along the water divide.

Sr. No.	Soil Productivity	Area	
		km^2.	%
1	High Productivity	579.43	36.78
2	Moderately productivity	515.46	32.72
3	Moderately low productivity	81.13	05.15
4	Low	399.36	25.35
	Total	1575.38	100.00

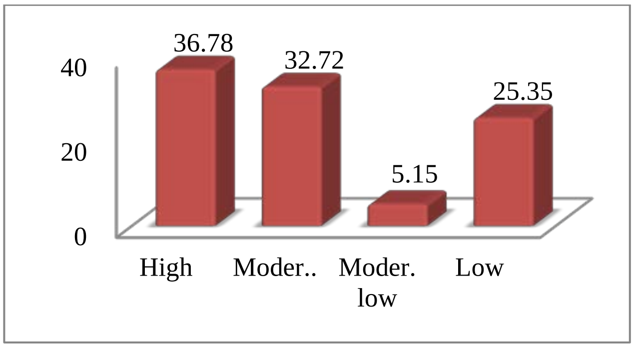


Fig 2.19b Soil productivity (% area)

2.1.8 Natural vegetation

Rainfall, soil types and availability of ground water level influence on the types and occurrence of natural vegetation in study region. The natural vegetation occupies 7864 hectares area accounting 5.28 % of the total geographical areas. The small patches of forest land are also found. It is negligible vegetation cover. Tropical dry deciduous trees are common in study region. Thorny bush, leaf shedding trees, stunted grass and mixed scanty vegetation are mostly appeared trees, namely, mango (Magnifera India), *Jambhul* (Syzygium Cummi), *Neem* (Azadiracta India), *chinch* (Tamarinds India) *Babhul* (Acacia Arabica) and *Bor* (Zizaphus Juju bal) are observed sparsely throughout the study region. *Babhul* trees are found in patches on soil moisture retaining area. Shrubs like *Ghaneri*, *Tarwad*, *Rui* and *Ghayapat* are

Source: Reproduced from mpcb.gov.in/ DEA Pune maps **Fig. 2.19a**

associated with cultivable wastelands. *Harali*, *Kusali* and *Gajar* grass appeared found on open space near '*gaothan*' and along the bunds of agricultural fields in the study area.

2.1.9 Demographic characteristics

2.1.9.1 Population size

The population of the Indapur tahsil has its own unique features. It has always experienced growth in numbers over the years and has a large youth population which is male dominant. Population is an important factor for the development of any region. Indapur tahsil has is 3, 83, 183 persons in 2011 Census having a population density of 240 persons per square kilometre (/km^2). Indapur has recorded the highest population 25,515 person followed by Kalamb (16,338), Nimgaon-ketki (12,397) and Bawada (10,734) and the lowest is noticed at Taratgaon of 288 persons.

2.1.9.2 Population growth rates

The growth of population of any area is an index of the size of a settlement. The growth of population is related to economic and social developments, if it is higher, then population gets increased very high. The last phase of 20^{th} century, i.e., the period between census years 1971 and 2001 is known as the period of high growth with definite signs of slowing down. The population of the study area is 196204 in 1971 and it is reached up to 383183 in 2011. Although the rate of growth was still very high, it is doubled in 40 years period. After 2001 it started to decline, it remains as 21 and 9.96 percent in 2011.

This trend of population growth has a negative effect on environment since arable lands are being reduced and degraded for settlements. The Forest Department and other stakeholders therefore need to be supported to effectively monitor and sensitize the people to protect our natural resources from the ravages of population pressure.

2.1.9.3 Population density

The term population density refers to the number of persons /km^2. The density depends on many natural and human factors, such as soil, rainfall, climate, economic resources, stage of economic growth and so on.

In the study area, there are thirty-one villages which have density of less than 150 persons /km^2. These villages are located on the Bhima River bank and western part of the study area. Around 75 villages population density are various between 150 to 300 persons /km^2 in the study area. The high density is observed in irrigated and

Source: Census of India 2011 **Fig. 2.20**

industrially developed area in the study area i.e. Bhavaninagar, Kalamb, Bhigvan, Junction and Indapur. The average population density was 240 persons /km^2 during 2001 to 2011**(Fig. 2.20)**. It is observed from this figure that the highest density has been recorded at Bhavaninagar 2,134 persons /km^2 followed by Junction (1613 persons) and Takrarwadi (808 persons), while the lowest population density is found at Sugaon (36 persons) followed by Kadbanwadi (59 persons) and Kalthan No.2 (68 persons). In Bhavaninagar and Junction villages have found more than 1000 persons because there found sugar industry and small scale industries respectively and occupy small area. This trend could be attributed to the availability of economic opportunities and social services in the two villages

2.1.9.4 Sex ratio

According to the 2011 Population Census, the Indapur tahsil has a relatively more male population compared to that of female. The sex ratio is usually defined as the number of females per thousand males. It is observed that there has been a dominance of male population over female population throughout the past 4 decades. The sex ratio observed at all the time is low i.e. 939 females to 1000 males in 1981, decline this sex ratio up to 923 females in 2011. The child sex ratio is very low. It is decreased up to 858 girls to per 1000 boys in 2011, but it is 891 in 2001. The male population is high, with a continuous drop in the decadal sex ratio during 1961-2011.

2.1.9.5 Age structure

More than 11.95 % (45787) population of the study area is below 6 years of age. The rural urban trend shows almost similar distribution of the age groups. It is further evident that the rural population below the age of 6years is 42760 (93.39%) and 3027 (6.61%) urban areas child population. However, in the 20- 60 age group which also forms 181791 (47.44%) population. There are more than half of the population is a dependant population.

2.1.9.6 Household composition

The composition and structure of the households reflects the general social structure of the society. The study area having total 79683 households, out of them 74455 rural households and only 5228 urban households according to census 2011. There are 12.62% households increased in the 2001 to 2011 period. More than 72 % houses are used for residential, 11% houses are vacant and less than 17% are used for the other non-residential purposes.

2.1.9.7 Rural / urban split

The population of the Indapur tahsil is basically rural. According to the 2011 census, the total urban population of the tahsil is 25515 and the rural population is 357668. Higher population density found in the rural industrial are and urban area, i.e. 2134 and 460 respectively and against 36 population density in the rural area. It is because of employment opportunities in the secondary sector, which includes the manufacturing, processing, servicing and the construction sector. The urban to rural population ratio in the district is highly imbalanced of the total population; urban population is 6.64%, which is spread over on only 3.77% geographical area. Whereas, remaining 93.36% rural population is spread over on 96.23% geographical area of the study area. The urban population density indicates the degree of urbanization in the study area.

2.1.9.8 Literacy and educational attainment

Literacy is a qualitative attribute of population which is fairly reliable index of the socio-economic development of an area. Thus the literacy is essential for the socio-economic development and demographic growth of the study area. A literate person is able ‘both to read and write a letter’ according to Indian census. In the study area the literacy rate is 71.79 %, it is normal change than 2001(71.04%). Literacy rate for males and females are 55.84% and 44.16% respectively according to 2011 census. It is evident that the levels of literacy changing very slowly.

2.1.9.9 Migration of the people and its trend

The movement of people into and out of the tahsil is very low. Out-migration is very low due to the fact that about 77019 of the total population is cultivators who have access to fertile lands and water bodies for farming, therefore, there is 54883 ha (37.39%) area under irrigation. Hence, there is very low out migration. The moderate in-migration has made labour cost cheaper and promoted economic activities, especially farming, fishing and trading. However, the outcome is much to be tahsil limited resources and social amenities are under pressure.

2.1.10 Occupational structure

Overall economic development depends on natural resources, agriculture practice and farmer’s decision and agriculture labours. The planning Commission of India in 1951 has classified population into three occupational structures, namely, main workers, non-workers and marginal workers. These workers have been further classified into three categories, namely, cultivators, agricultural labours and other workers. According to 2011 Census the population engaged in various occupations is shown from 1981 to 2011 in study area. **(Table 2.5 & Fig. 2.21)**.

Table 2.5: Occupational structure in Indapur Tahsil

Sr. No.	Years	Cultivators	Agricultural labors	Other workers	Marginal workers
1	1981	45.90	25.11	16.82	12.17
2	1991	40.56	27.55	19.97	11.92
3	2001	34.90	27.02	20.92	17.16
4	2011	42.37	32.53	18.83	06.27

Source: Pune District Census Handbook and CD. Note: Figures in percent

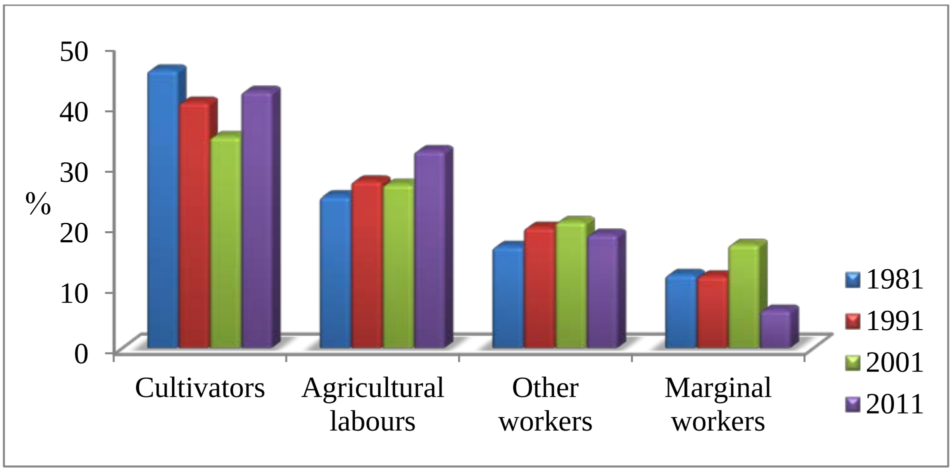


Fig. 2.21 Occupational structure

It is clear from this figure that cultivators have declined from 45.90% to 42.37% and agricultural labours have increased 25.11% to 32.53% from 1981 to 2011 years respectively. Other workers and marginal workers show a steady increase during 1981 to 2001 and decreasing in 2001 to 2011. The other workers decreased by 2.09% and marginal work increased to 10.89% in study area in the last decade.

2.1.11 Landuse

2.1.11.1 General landuse

The concept of landuse is related to the use of land which is used for certain activity for a given period of time. Land use depicts the use and pattern of land in the Indapur tahsil. Hence the land use map acts as the most important map for planning and site allocation. The land use pattern in different villages of study area has been shown in **table 2.6, Fig. 2.22** the land area in the study area was classified into five categories known as the five-fold land-utilization classification.

Table: 2.6 Land utilization trend in Indapur Tahsil

Sr. No.	Classification	Area in ha.	Percentage
1.	Total cultivable land	122411.00	77.70
2.	Area under forest	7443.74	04.73
3.	Area not available for cultivation	13170.17	08.36
4.	Area under fallow land	3419.79	02.17
5.	Other uncultivable land exclusive fallow land	11093.30	07.04
	Total	157538.00	100.00

Source: Census of India 2011

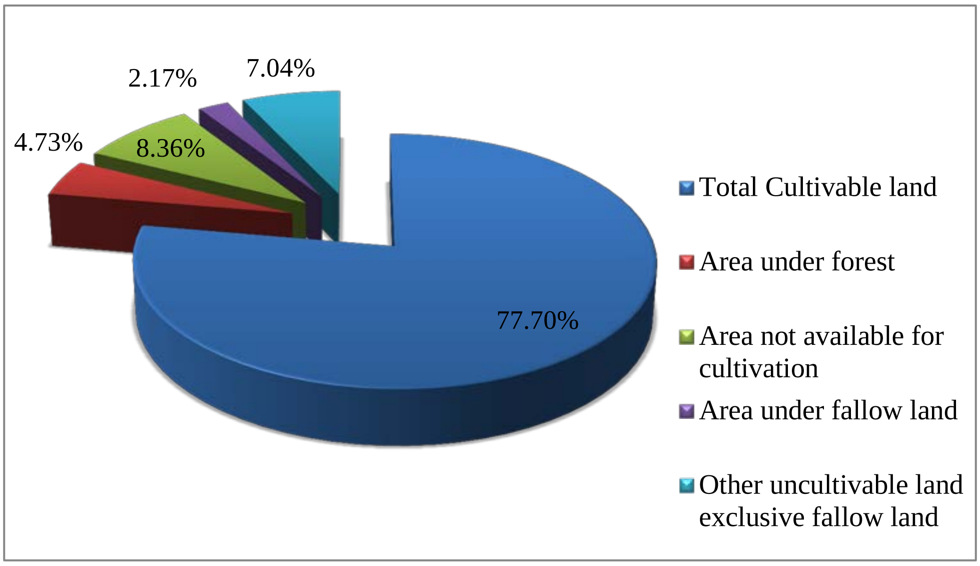


Fig. 2.22 Landuse land cover area occupy

As per the land utilization statistics of Indian census report 2011 out of the total 157538 hectors (ha) geographical area or the Indapur tahsil out of which 122411 ha (77.70%) area lie net cultivated, the recorded under forest area is 7443.74 ha (4.73%), area not under agricultural uses 13170.17 ha (8.36%). This category includes all lands occupied by buildings, roads or railways or water bodies and other lands put to used other than agricultural. The area under fallow lands near about 3419.79 ha (2.17%) in this area including under permanent pastures, grazing lands and without fallow land but uncultivated land is 11093.30 ha (7.04%). Generally, the maximum area found under cultivation (77.70%).

2.1.11.2 Agricultural landuse

Agricultural and allied activities sector has been the backbone of the Indian economy, especially the rural economy which is largely driven by this sector. Availability of agricultural land is abundant, quality of land and rain fed agricultural has restricted the scope for increase in agricultural production. The major part of Indapur tahsil is rain fed. According to soil and water distribution area under crop differential in Indapur tahsil. These are given below **(Table 2.7 and Fig. 2.23)**.

Table 2.7 Agricultural land use in Indapur tahsil.

Sr. No.	Name of the crop	Area in Hectors	%	Sr. No.	Name of the crop	Area in Hectors	%
1	Cereals	77832	68.22	7	Spice substance	367	0.32
2	Pulses	6326	5.54	8	Medicinal	81	0.07
3	Sugarcane	8935	7.83	9	Faber crop	173	0.15
4	Oil seeds	4861	4.26	10	Fodder crop	7549	6.62
5	Fruits	3171	2.78	11	Non-eatable	579	0.51
6	Vegetable	4218	3.7		Total	114092	100

Source: District Socio-economic report 2012.

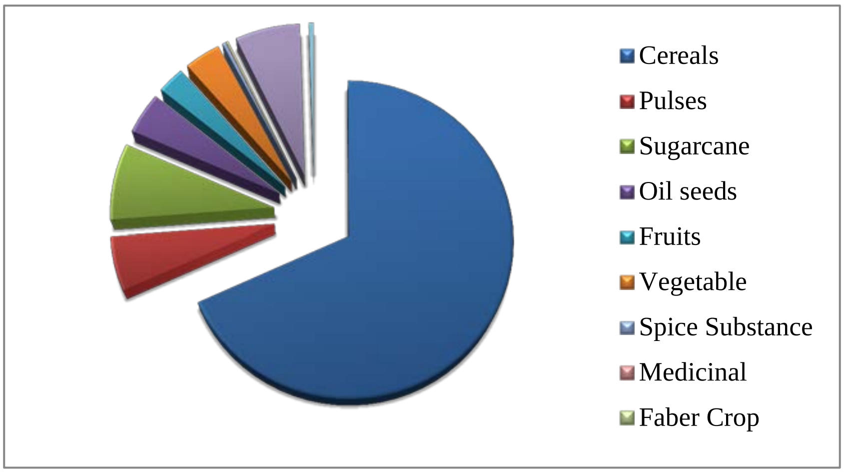


Fig. 2.23 Agricultural landuse

The prospects of agricultural land use in 2002-03 are considered reasonable bright due to more than normal rainfall in the Indapur tahsil. During this year 68.22% area under food grains out of total cultivated land and only 0.07% area medicinal. According to above data, it shows more than 84.82% land under eatable substance in Indapur tahsil and near about 15.18%, land under non eatable crop.

2.2 Database and sources of data

For the present research work both primary and secondary data source are used. This research work is to develop digital database at large scale using spatial and attribute data. The spatial data comprise of all the thematic and topographic maps and the attribute or non-spatial data is created mainly population details, agricultural details and water details utilities information etc.

Attributes are the characteristics of the map features and hold the descriptive information about the geographic features. Attributes are the non spatial data associated with time and area entities; collect this information of the study area by field survey.

Table 2.8 Data type and source of acquisition

Type of data	Source of data
Toposheets (1:50,000 scale)	Survey of India, Pune. (Toposheet No. 47J/11, 47J/12, 47J/15, 47J/16, 47K/13, 47N/3, 47N/4 and 47O/1)
Village utility information	Revenue office, Mandal office and panchayat samiti office, Indapur.
Census data	District census handbook and statistics department (Year 2011).
Meteorological data	Tahsil office & agricultural department, Indapur.
Agricultural and water resources data	Jalsampda Vibhaga Baramati, Patbandhare vibhaga, Baramati. Khadakwasala Patbandhare sub division No. 1, Daund and agricultural office, Indapur.
Individual house and utility wise database	Field survey with questionnaire, GPS and interviews of the people.
Land use/Land cover map	Google image (SPOT) Year (2012)
Other data	Geological survey of India, central region, Nagpur, Google image, Pune district collector office, MPCB, department of state government etc.

The attribute data composed of field data and collateral data. The field data is acquired through field survey by collecting detailed water consumption and socio-economic data from concerned villagers. These data base converted to Microsoft access format to suit to the link up for processing through software. The source or collected data are listed in **table 2.8**.

2.2.1 Primary data sources

The primary data is generated mainly from the field surveys. There are 142 settlements in Indapur tahsil. All the settlements from the Indapur tahsil are grouped into eight revenue circles viz. Bhigwan, Indapur, Loni, Bawada, Kati, Nimgaon Ketki, Anthurne and Sansar. The primary data was collected through observation, interviews and focus group discussions. Out of the total 143, villages in Indapur Tahsil around 45 villages have been selected as sample villages opinions of around 685 respondents from these villages has been ascertained. It has been noticed, more or less from all the villages that there is a acute problem of water starts from the month of February and this condition persist for next 3 to 4 months. Month wise thematic map of water balance index also pointed the same. The researcher personally contacted to 45 villagers and farmers with the help of the structured questions for this study. It is done for following aspects.

1. Assessment of the daily need of water and understanding of existing pattern or water utilization in Indapur tahsil.
2. Interviews of local people to know the utility, site suitability, construction and maintenance or rainwater harvesting.

2.2.2 Secondary data sources

Secondary data collected from different government offices. A list of the tanker supply villages from Panchyat Samiti office, Indapur. Similarly, the data collected is related to agricultural and industrial. Secondary data was however, drawn from published and unpublished reports, journals, magazines and district medium term plans and this helped underscore issues under study. All the supported data is collected from survey of India, Maharashtra State Gazetteer Pune District, socio economic report of Pune district 2011, 2012 and 2013, economic survey of Maharashtra 2012-13, Maharashtra Governments department of irrigation, department of agriculture, department of water conservation, Panchayat Samiti, Indapur-2013 and Municipality Indapur -2013.

2.2.2.1 Meteorological data

Rainfall data from 1991 to 2013 has been collected from the Agriculture department and Tahsil office of Indapur.

2.2.2.2 Soil survey data

Soil properties data has been collected from the Mahabank Sujala Soil Testing Centre, Bhigwan Tahsil Indapur Dist. Pune. This centre has been operated by together under the auspices of Mahabank Agricultural and Rural Development Foundation (MARDEF) and National Chemicals and Fertilizers Limited.

2.2.2.3 Spatial data

The spatial data is generated on the basis of sequential manner. First of all the satellite data is generated by processing the software image. Further, geoprocessing and Georeferencing are applied to the satellite data. Later on, the data is digitally enhanced. Then, the hard copy of the data is generated which resulted into the thematic maps. Thus, through step by step procedure the creation of the data is generated for the analysis.

2.2.2.3.1 Satellite data

Digital remote sensing data of resource sat is an advanced satellite built by Indian space research organization. It's SPOT Google image will be used for identifying demarking the watershed area. The land use/ land cover analysis of the area and processed to know the general trend of land utilization of the study area.

2.2.2.3.2 SOI toposheets

In the present study, the SOI toposheets manually scanned and added to the data. These SOI toposheets are further Georeferenced and rectified. From these SOI toposheets the spatial data is separated on the basis of topographical layers and the base map, drainage map, watershed map and other maps are generated for the sake of convenience. In addition to this, the attribute and collateral data is also used. The attribute and collateral data which is obtained and collected during fieldwork and the data used in GIS software are the basis of the maps generated. The flow chart 2.1 shows the overall methodology and the step-by-step procedure for develop the interactive.

2.3 Methodology

2.3.1 Data analysis

First, scoring of some of the items in the schedule was done after the field work was completed. The data collected from the field was analysed using both quantitative and qualitative methods. There was some sorting of the data, compilation, tabulation, computation, analysis and interpretation. The data were processed by using the different GIS software and statistical techniques. Grid wise data analysis has been carried out using MS Excel spreadsheet. The quantitative data was analysed using statistical techniques. The qualitative data analysis rested on comprehensive and analytical descriptions to responses by respondents with the aim of obtaining more insight to support results from quantitative data. The analysis of the data provided answers to the research questions and research objectives.

2.3.2 Water budget estimation

General water budget equation (Hydrological equation) has also been applied to estimate water budget of the Indapur tahsil as well as Thornthwaite's method has also been performed.

2.3.3 Development of CWBI and Geostatistical analysis

The various Geostatistical techniques used in this study for testing hypotheses. Grid operations have been performed for various thematic data layers; especially zonal grid operation has been performed in rainfall, runoff, soil moisture, evapotranspiration vornoii diagram etc.

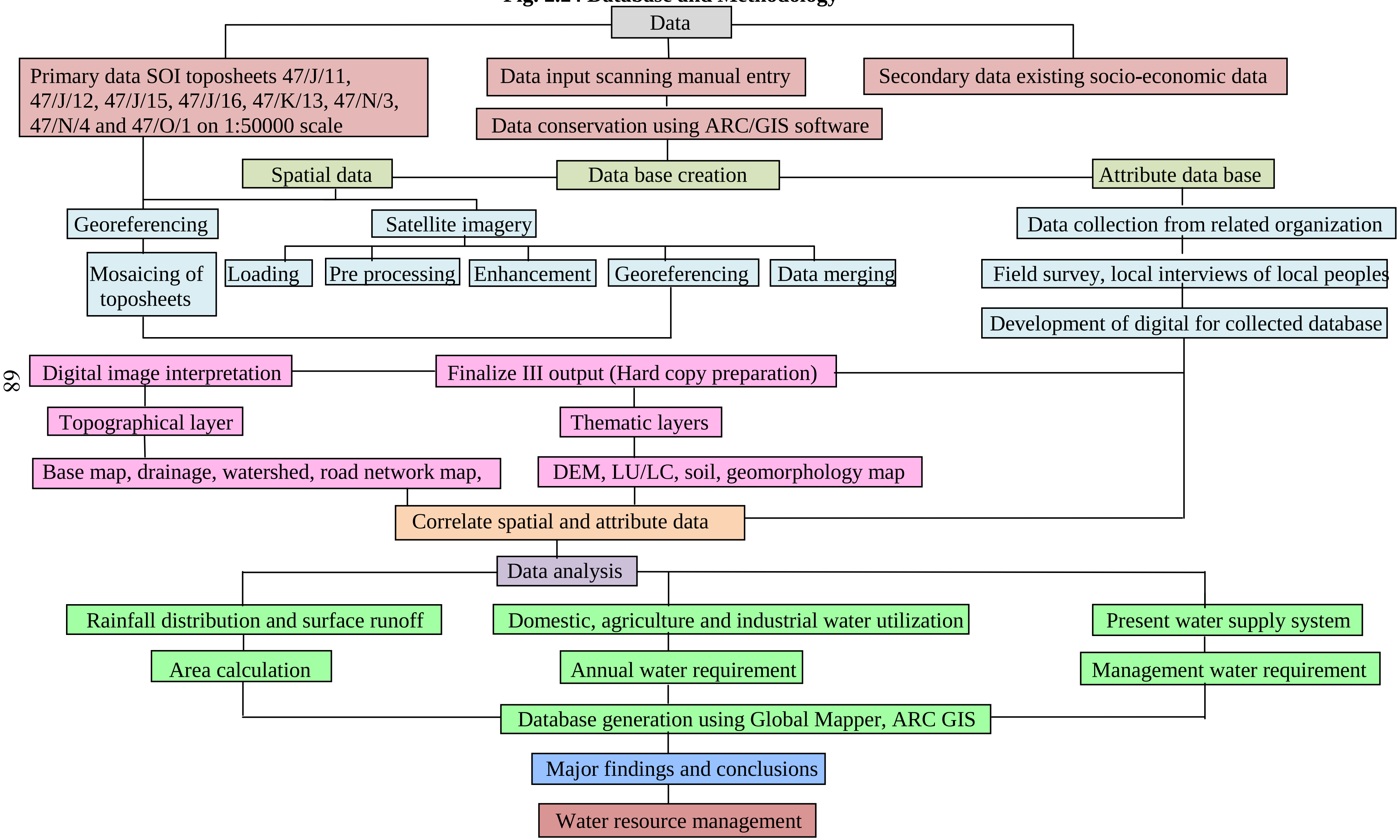
In an attempt to quantify water budget prepared by and Thornthwaite's method of water balance using water balance ISBH v0.3 software, a composite index has been developed to understand and simplify the water surplus and deficit areas of Indapur tahsil using principles of map algebra.

Raster analysis has been performed using multiple grid layer operation adopting addition function and then reclassifying it to get the average of both the grids. Focal grid operations (neighborhood cells) used to get the **C**omposite **W**ater **B**alance **I**ndex **(CWBI).**Global Mapper version 16, and Diva GIS V.7.5 software's have been used and graphing work has been performed in Arc GIS.

2.3.4 Thematic mapping

Different thematic maps have been prepared using the base map. Along with these maps different maps, of the area related to the overall physiography of the region has been prepared. These include contour map, slope map. DEM (Digital Elevation Model) has been prepared using Arc View 9.3, Surfer version 10, Global Mapper version 11, Diva GIS version software and Saga GIS, to get the perspective view of the study area. In addition to this various topographic indices have been performed using DiGem software.

Fig. 2.24 Database and Methodology



Chapter – III

Availability of Water Resources in the Indapur Tahsil

Chapter – III

Availability of Surface Water Resources in the Indapur Tahsil

3.0 Introduction

Present chapter deals with the assessment of the surface water availability in the study area. In addition to this detail, spread of average annual rainfall which has been analysed for more than 90 years of data has also been considered for interpretation.

3.1 Availability of water resources in the study area

There are around 142 villages and one urban centre which are spread over the Indapur tahsil. The source of water in each village clearly indicates its dependence on ground water for domestic water requirement. Some of the villages however rest upon two or more resources. The villages can be grouped into two categories: such as ground water dependent i.e. wells, tube wells, hand pumps and springs and surface water dependent it includes river, tank, lake and canal. Considering this scenario of the water supply in the study area it is thought appropriate to conduct sample survey for understanding the pattern of water utilization in the villages. For this purpose about 45 villages have been selected considering different geographical conditions. The **Table 3.1 and Fig 3.1** shows sample villages' distribution along with mean sea level. Out of them 9 villages are found below 480 m. high, 7 villages found between 480 to 500 met., 13 villages are found between 500 to 520 m. high, 9 villages are found 520 to 540 met. high and 7 villages are found more than 540 m. high from mean sea level. In rural sectors where agriculture is the main activity, domestic water requirement need to be taken into consideration along with the livestock also.

Source: Author **Fig. 3.1**

Table: 3.1 Sample villages height from mean sea level

Sr. No.	Village height from mean sea level in m				
	< 480	480 - 500	500 - 520	520 - 540	> 540
1	Hingangaon	Bhodani	Kandalgaon	Vangali	Vyahali
2	Avasari	Reda	Vadapuri	Loni	Rui
3	Bawada	Khorachi	Sarafwadi	Belwadi	Kalas
4	Chakati	Nimsakhar	Gokhali	Lasurne	Vaysewadi
5	Sarati	Sugaon	Shirsodi	Bori	Nimbodi
6	Gondi	Galandwadi No.2	Kalthan No. 2	Nimgaon Ketki	Mhasobachiwadi
7	Pimpri Bk.	Ganjewalan	Bijwadi	Hingnewadi	Lamjewadi
8	Narsingpur		Agoti No.1	Bhadalwadi	
9	Girvi		Palasdev	Pimple	
10			Diksal		
11			Takrarwadi		
12			Gholapwadi		
13			Kurwali		

Source: Author

3.1.1 Rainfall distribution and its variation

The rainfall is varied from season to season. Monsoon is the main rainy season in the study area. The monsoon starts as early in June and continues up to September, sometimes continues till the month of October as noted from the rainfall records during the years (1999-2013). Data recorded at the different rainfall stations of the study area form the main source of information for surface water resources. However, the data are still inadequate for planning and integrated management of the water resources. In general a few rainfall stations have continuous records. However, in some cases the continuity is not maintained. As far as rainfall record frequency is concerned, the study area is lacking in daily rainfall data. On the other hand, the monthly records are available for a period of 15 years (1999-2013) from 8 stations in the study area. Mean annual rainfall increases from east to west part of the study area. The average annual rainfall recorded at Bawada, Indapur and Sansar station is more than 550 mm and at Anthurne, Walchandnagar, Nimgaon, Bhigwan and Shetphalgadhe rainfall receives less than 470 mm over a period of 15 years. Average annual rainfall distribution over the Indapur tahsil is shown in **table 3.2 and fig. 3.2**.

Table 3.2 Annual Average Rainfall of Indapur tahsil in mm (1999 – 2013)

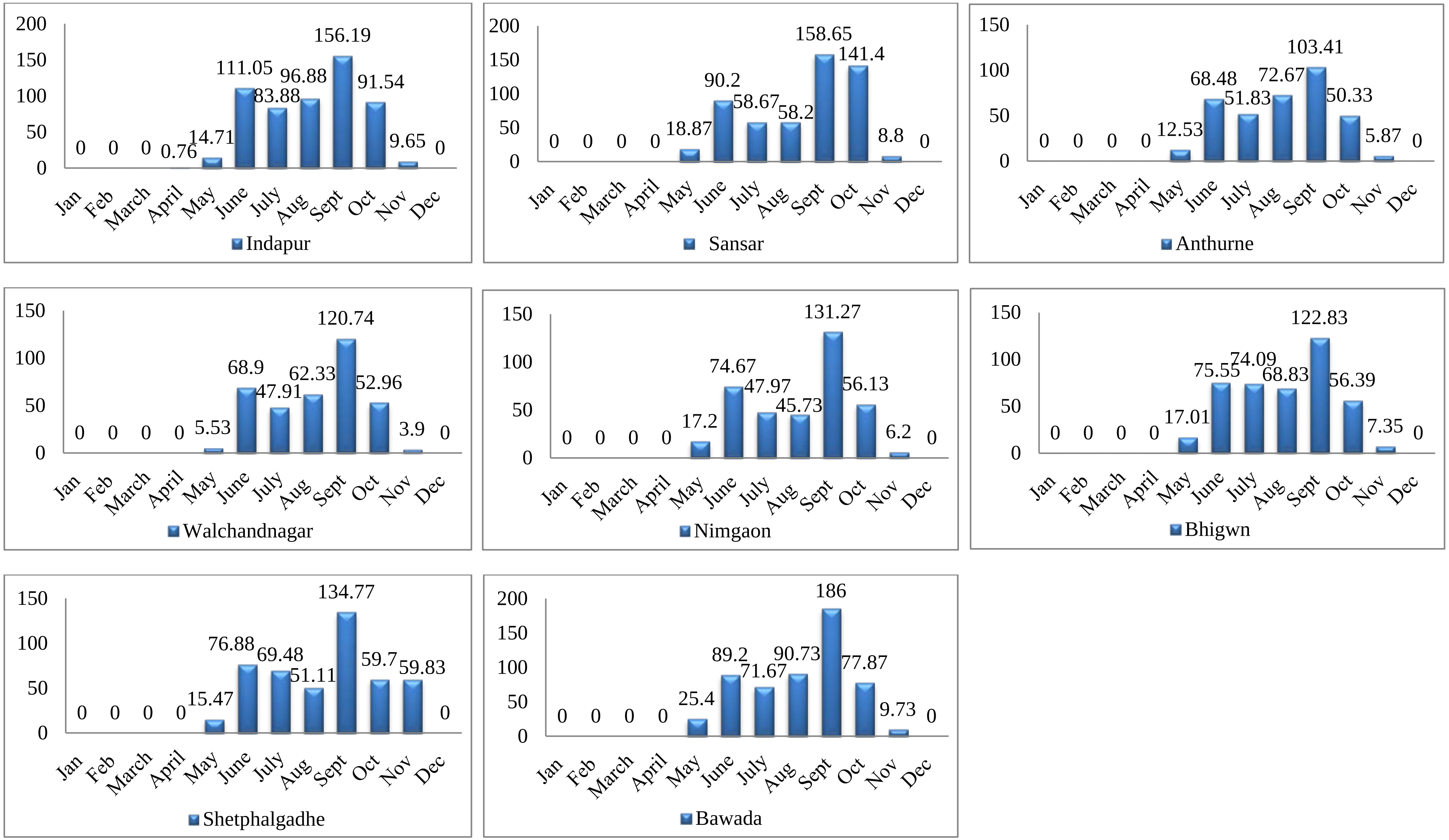
Sr. No.	Month/Name of rainfall station	Indapur	Sansar	Anthurne	Walchad-nagar	Nimgaon	Bhigwan	Shetphlgadhe	Bawada
1	January	0	0	0	0	0	0	0	0
2	February	0	0	0	0	0	0	0	0
3	March	0	0	0	0	0	0	0	0
4	April	0.76	0	0	0	0	0	0	0
5	May	14.71	18.87	12.53	5.53	17.2	17.01	15.47	25.4
6	June	111.05	90.2	68.48	68.9	74.67	75.55	76.88	89.2
7	July	83.88	58.67	51.83	47.91	47.97	74.09	69.48	71.67
8	August	96.88	58.2	72.67	62.33	45.73	68.83	51.11	90.73
9	September	156.19	158.65	103.41	120.74	131.27	122.83	134.77	186
10	October	91.54	141.4	50.33	52.96	56.13	56.39	59.7	77.87
11	November	9.65	8.8	5.87	3.9	6.2	7.35	59.83	9.73
12	December	0	0	0	0	0	0	0	0
	Total	564.66	534.79	365.12	362.27	379.17	422.05	467.24	550.6

Source: Agriculture and Tahsil office, Indapur (2014).

The study area receives nearly 75% mean annual rainfall by south –west monsoon, that blows from Arabian Sea and remaining rainfall receives from retreating monsoon. The rainfall is low in the central part of the study area due to the topographic effects. Monthly maximum rainfall occurs in June to September. The highest monthly mean rainfall occurs at Bawada station in the month of September (457 mm). The rainfall records of the five stations (Anthurne, Nimgaon, Shetphalgadhe, Bhigwan and Walchandnagar) situated in the eastern and central part of the study area which receives less rainfall than the remaining part of the study area.

However, the lowest mean monthly average rainfall occurred in the month of May and November with values reaching between 15mm to 10 mm. It can be concluded that the monsoon season is the only important rainy season in the study area. During the south west monsoon, the study area receives high amount of rainfall. Retreating monsoon contributes around 15% of the mean seasonal totals. Whereas pre monsoon season contributes about 10% of the total mean seasonal rainfall.

Fig 3.2 Station wise annual average rainfall (mm) distribution in the study area



Source: Agriculture and Tahsil office, Indapur (2014).

On the basis of 79 years average rainfall it is observed that and the actual rainfall received in the study area is highly uncertain. Which is shown in the **Fig. 3.3a** for the year of 1999 and **Fig. 3.3b** for the year of 2012. The actual rainfall receives greater than the average rainfall in 1999 and vice a versa condition in the year 2012.

Fig. 3.3 a & b Average and actual rainfall in the study area in mm

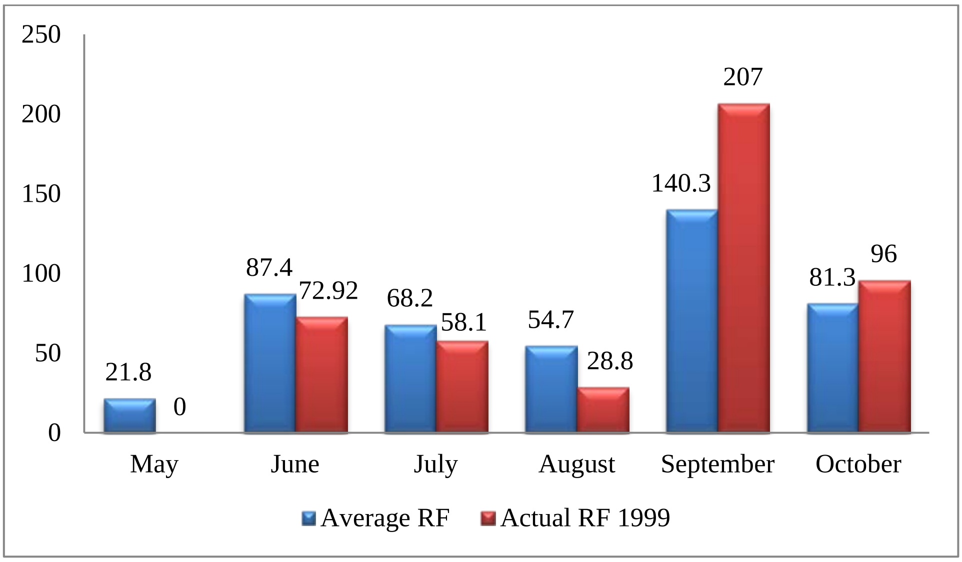


Fig. 3.3a

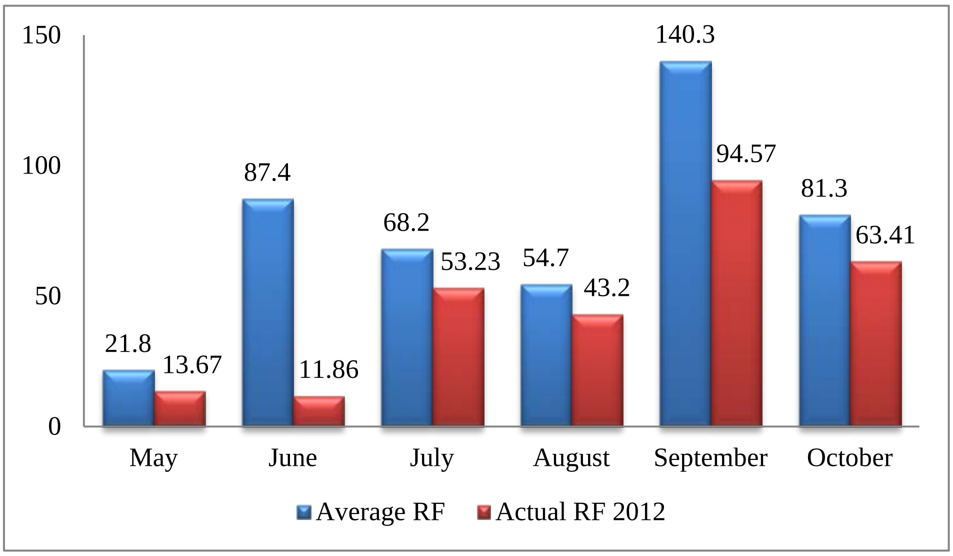


Fig. 3.3b

Source: Mahaagri.gov.in/rainfall/ntest2.asp and Agriculture and Tahsil office, Indapur

3.1.2 Rainfall volume computation

In the study area, the uncertainty of rainfall is a routine picture which has been reflected on total landuse pattern as well. Moreover, the irrigation is provided through canals, wells etc. to support irrigated crops up to some extent. Database on rainfall has been made available from variety of sources i.e. **F**ood and **A**griculture **O**rganization (FAO) grid of climate data, **W**ater **R**esources **I**nformation **S**ystem (WRIS) from river atlas of India (2014). The data obtained is of a longer period around hundred years or more and therefore considered as a final data set for present analysis.

3.1.2.1 Grid operations

Average rainfall distribution spread over the entire study area thus produced in grid format has been used for volumetric analysis. The area of tahsil segmented into sub basins has been used for the analysis and the volume of total rainfall has been computed accordingly.

3.1.2.2 Total volume average of rainfall

Sub basin wise total volume of rainfall thus computed is displayed in **table 3.3 Fig. 3.4a & 3.4b** clearly indicates that, the average annual volume of rainfall is 1052.46 MCM. The very low rainfall volume is observed to the northern side sub basin of the tahsil (BM-61) accounts 16.43 MCM i.e. 1.56% and very high rainfall volume is observed to the eastern side sub basins of Indapur tahsil (BM-78) accounts 247.95 MCM which covers around 23.56% of the total study area.

Table 3.3 and Fig. 3.4b Watershed wise computation of volume of rainfall

Sr. No.	Name of area	Surface area in		Rainfall volume	
		Km^2	%	M^3	in %
1	Bhigwan-BM61	24.72	1.57	16434626513	01.56
2	Loni-BM66	193.87	12.31	130769925147	12.43
3	Palaasdev-BM67	241.88	15.35	161222847818	15.32
4	Akole-BM68	124.42	7.90	83873429156	07.97
5	Sansar-BM76	337.28	21.41	224940004744	21.37
6	Nimgaon-BM77	281.58	17.87	187270276730	17.79
7	Indapur-BM78	371.63	23.59	247957793057	23.56
	Total	1575.38	100.00	1052468903164	100.00

Source: By author

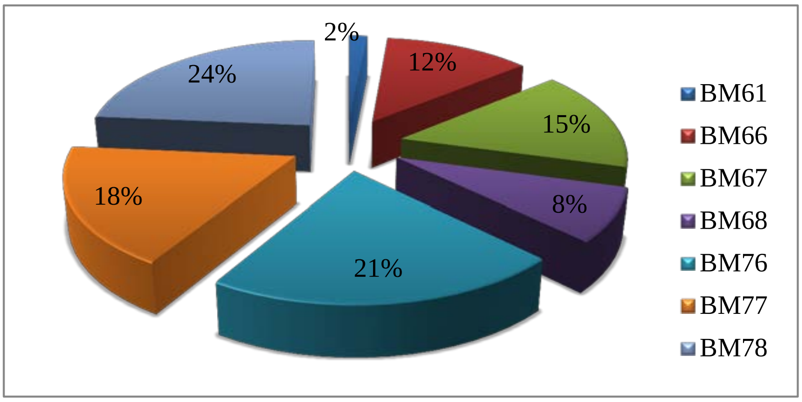


Fig. 3.4b

Source: www.india.wris.nrsc.gov.in **Fig. 3.4a**

3.1.2 Soil Moisture

The soils hold water (moisture) due to their colloidal properties and aggregation qualities. The approximate amount of moisture stored in the soil is calculated for the top 150 cm (common rooting zone) of the soil. Soil moisture includes free water as well as capillary water, hygroscopic water and water vapour. Approximately, 50% of the soil is made of pore space. In an average soil the pore space is occupied by 25% air and 25% water. Of course when it rains or during a drought, the proportion changes drastically. In the study area soil moisture declined from east to west. It can clearly notice from the map of percentage distribution of moisture in the area which ranges between 40 - 46 % all over the study area. Except the far eastern area have the moisture variation between 40 - 42 %. Chakati to Narsingpur village area shows reduction in moisture below 42 %. North south strip area of western side found high soil moisture ranges more than 45%. Remaining part of the study area has presented the medium soil moisture i.e. between from 42.1 45%.

3.1.3 Ground water availability

In the study area groundwater recharges from rainfall which is about 85.59 MCM and from other sources it is accounting to 190.05 MCM. There are 275.65 MCM is total groundwater recharge. The natural discharge is to the tune of 13.78 MCM and thus net ground water availability in the study area is 261.86 MCM (GoM Groundwater Survey and Development Agency, GSDA Pune 2014).

Depending on the groundwater occurrence as per Maharashtra Remote Sensing Applications Centre (MRSAC), the study area is divided into three zones, i.e. ‘high’, ‘medium’ and ‘low’ (**Fig. no. 2.18a)**. The ‘High’ ground water potential areas are those having ground water table less than 5 m bgl, admeasures about 394.79 km^2 (25.06%). The ‘Medium’ areas are those having water table in the range of 5 to 15 mbgl this groundwater potential zone covers 553.12 km^2 (35.11%) of the total study area and the ‘Low’ ground water potential areas are those having water table more than 15 mbgl and under these having maximum area i.e. 627.47 km^2 (39.83%) of the total study area (**Table 3.4 and Fig. no. 3.5)**. The High groundwater potential covers middle part like a strip from west to east in the study area, medium groundwater level is scattered in all villages in the tahsil and low groundwater level appears in small patches and are mainly found in the eastern part of the study area.

Table 3.4 Groundwater potential and covered area

Sr. No.	Zone	GW Potential	Area	
			km^2	%
1	Less than 5.0m below ground level	High	394.79	25.06
2	5 - 15m below ground level	Medium	553.12	35.11
3	More than 15m below ground level	Low	627.47	39.83
	Total		1575.38	100.00

Source: GSDA Pune 2014 – Author

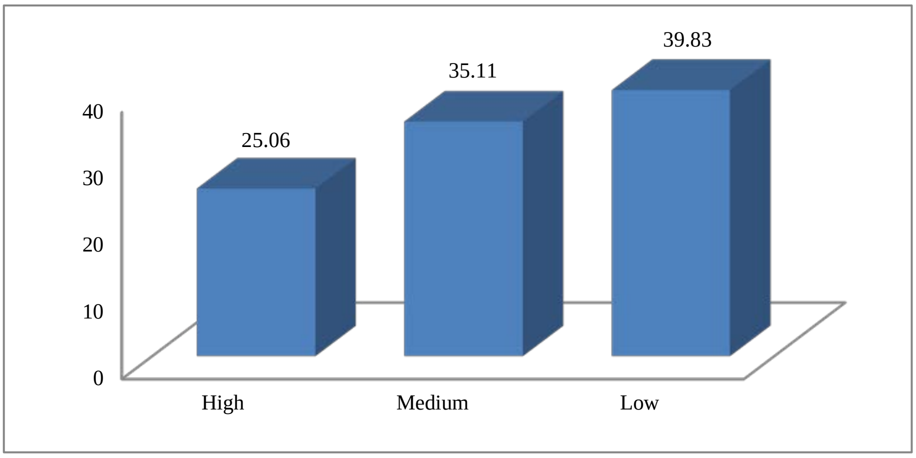


Fig. 3.5 Groundwater potential

3.1.3.1 Fluctuations in ground water

The average pre monsoon water level is 7.98 mbgl and average post monsoon water level is 3.8 mbgl observed in the study area. The average fluctuation of groundwater level in the study area is 4.19 m.

3.1.4 River water volume

There are two main rivers, River Bhima and Nira drain in the study area. Bhima is the main river in the study area and Nira is a tributary of river Bhima. Both the rivers sharing the drainage system of the entire study area. The total length of Bhima and Nira rivers are 103 and 64 kms respectively in the study area. Both rivers bring water during rainy season and shrink during summer. Out of the total 142 villages, 34 villages are lying on the boundary of river Bhima located in the eastern and north eastern parts of the study area; whereas 19 villages are situated on the bank of the river Nira in the study area. Although in the rainy season they vary in water volume, the river system of both the rivers play a significant role in economy of the Indapur tahsil. The large part of surface water is found in the Bhima and Nira rivers. There are 327.706 MCM volume of water found in the river. About 20% of the total surface water found into two rivers of the study area.

3.1.5 Water resources available through existing conservation measures

Water resources are available through canal, reservoir, K.T. weirs, farm tanks, tanks and other sources in the study area. Nira Left Bank Canal (NLBC) is distributed in the southern and Khadakwasala canal is distributed in the northern part of the study area. Reservoirs and K.T. weirs are located on the main channel network. Different type's reservoirs are available in the study area and it is displayed in **table 3.5 and Fig. 3.6a and 3.6b**.

Table 3.5 and Fig. 3.6a and 3.6b Reservoir types and quantity

Sr. No.	Reservoir types	Quantity	Sr. No.	Reservoir types	Quantity
1	Dam	1	8	Percolation Tank	5
2	M.I. Tank	10	9	Underground Band	6
3	K. T. Weir	16	10	Cement Nalabandh	89
4	Valan Bandhara	18	11	Soil Nalabandh	1911
5	L.B. Structure	476	12	Earthen Structure	498
6	Vanraie Band	560	13	Continuous Counter Trench	1020ha.
7	Farm Tank	536	14	Compartment Banding	8957ha.

Source: Agriculture Department, Indapur 2013

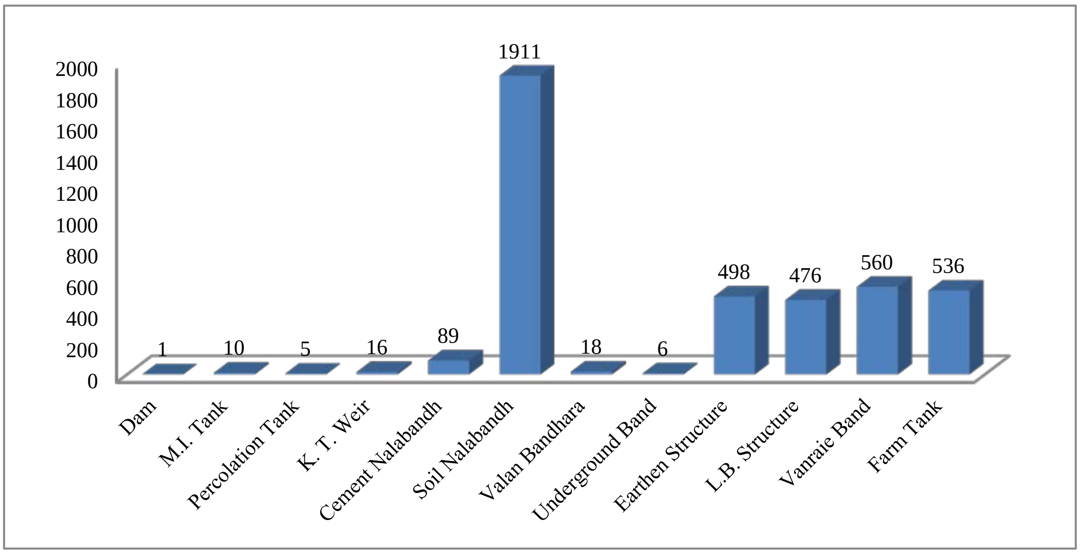


Fig. 3.6b

3.1.5.1 Canal

There are two canals in the Indapur tahsil. The canal which flows from southern part is known as Nira Left Bank Canal (NLBC) and that which flows from the northern part is known as Khadakwasala canal. These two canals supply the water for the purpose of domestic, agriculture and industrial use. From the Nira canal total 57.14 MCM water is made available for Indapur tahsil and around 36.823 MCM from Khadakwasala canal total of which 93.963 MCM**.**

Source: Reproduced from mpcb.gov.in/ DEA Pune map **Fig. 3.6a**.

Table 3.6 Reservoir type and water available for use

Sr. No.	Type of surface reservoir	Water available in MCM	Sr. No.	Type of surface reservoir	Water available in MCM
1	Dam	120.624	11	Varangali tank	0.56
2	Canal	93.963	12	Tarangwadi tank	1.75
3	Shetphal tank	5.85	13	Percolation tank	0.95025
4	Varkute tank	1.43	14	Valan bandhara	2.14735
5	Madanwadi tank	5.64	15	Farm Tank	1.45
6	Pondavadi tank	1.49	16	KT Weir 0-100 ha.	0.08355
7	Bhadalwadi tank	4.57	17	KT Weir 101-250 ha.	0.97963
8	Palasdeo tank	2.7	18	KT Weir >250 ha.	22.1103
9	Gagargaon tank	1.31	19	Other structure	5.48
10	Balpudi tank	0.72		Total	273.80808

Source: *Khadakwasala Patbandhare Sub Division No. 1, Daund, Nira Patbandhare Vibhag, Baramati, Bhima Patbandhare Vibhag, Pandharpur,* Ujani Dam Management Division, Bhimanagar, Irrigation Office, Indapur and Minor Irrigation Department Baramati and Indapur 2013.

3.1.5.2 Reservoir

The Ujani reservoir is located in the study area, aimed at increasing area under irrigated agriculture in the drought prone areas. Ujani reservoir Impounded in 1980, Ujani is the terminal reservoir in the intensively developed Upper Bhima Basin (UBB) and the source of water for irrigated agriculture, domestic use and generation of hydro-electricity. It is considered as the boon for water scarce and drought prone plains of the study area. The Ujani reservoir is an important source of water for Indapur tahsil. It is the major and reliable water source to meet the water demand. The actual live storage of Ujani reservoir is 117.25 TMC (3283MCM) out of them 53.58 TMC (1500.24 MCM) is usable water and rest of the water 63.67 TMC (1782.76 MCM) remains as a dead storage (Government of Maharashtra, Irrigation Department, Shwetpatrica - 2012, Vol. 2). However, in the last few years, the Ujani reservoir is facing the problems associated with eutrophication and the water quality has undergone significant deterioration. Permitted water for Indapur tahsil for irrigation is 120.624 MCM.

3.1.5.3 K. T. Weir

K. T. weirs are built up where there is flow or depth in the river and where there is strong base rock. Many minor irrigation systems are built on Nira and Bhima rivers in Indapur tahsil. Bhima is the largest river in the study area which flows in northern and eastern side of Indapur tahsil and which has fully irrigated the eastern part of Indapur tahsil. There are 3 K. T. weirs built on Bhima River through the Minor Irrigation Department. From these K. T. weirs around 9.0286 MCM water resources are made available and 1859 ha area is irrigated in the study area. Owing to the K. T. weirs, 6 villages are under irrigation.

Nira River is a tributary of river Bhima which flows in the southern parts of Indapur tahsil. The K. T. weirs built on Nira river helped to a small extent, to eradicate famine from some drought-prone villages. On Nira river around 13 K. T. weirs are built and 13.0816 MCM water resources are made available in the study area. Around 3845 ha area under 17 villages is thus irrigated in the study area, herewith two below 250 ha irrigation capacity K.T. weirs are built in Kurwali and Chavanwadi Villages. These two K. T. weirs storage capacities are 1.06 MCM. The K. T. weirs gross 23.1703 MCM available the water resources in the study area.

3.1.5.4 Farm tanks

In the study area 340 farm tanks are observed. These farm tanks are constructed the size of 30 X 30 X 3 m. There are 140 farm tanks are built by the grant of Maharashtra Rural Employment Guaranteed Scheme (MREGS), while 200 farm tanks, they are built by the grant of National Agricultural Development Scheme (NADS). These entire farm tanks avail 1.45 (0.449 as per Agri. Office -2012) MCM water resources in the study area.

3.1.5.5 Tank and other sources

In Indapur tahsil around 5.05% agricultural area is irrigated through tank water. The northern region, southern region and some central parts water supply is made through the tanks. In Indapur tahsil there are 10 Minor Irrigation tanks, 5 percolation tanks and 18 *valan bandhara* are available in the study area. All these tanks gross capacity is 4.16077 MCM and all other types of water conservation i.e. compartment bunding, soil nalabunding, cement nalabunding, earthen structure, underground bund and *Vanraie bund* stores around 5.48 MCM water resources. Totally 9.64077 MCM water resources are available in the study area. Through tank and other resources and around 5711 ha land has been irrigated.

Ground water recharge potential map procured from the primary report clearly indicates that there is very low to low ground water potential in the Indapur tahsil, may be probably due to hard compact basaltic terrain spreaded throughout the tahsil. Therefore in the computation of total water availability for the tahsil only actual evapotranspiration and runoff values have been considered and infiltration has not been considered. it is observed that in the **table 3.7**.

Table 3.7 Village wise water availability

Sr. No.	Village Name	Rainfall in MCM	Runoff in MCM	Actual ET in MCM	Water Available for utilization
1	Shetphalgadhe	14.81801	1.48022	4.135	9.20246
2	Pimple	6.06263	1.11811	1.579	3.36588
3	Madanwadi	14.55789	0.91855	6.522	7.11777
4	Takrarwadi	4.56422	0.18815	3.559	0.81707
5	Bhigvan	9.66548	0.80879	8.629	0.22728
6	Bhigvanstaion				
7	Diksal	4.53829	0.17865	5.605	-1.24564
8	Kumbhargaon	5.65782	0.09124	5.497	0.06989
9	Bandgarwadi	3.19668	0.41722	2.178	0.60141
10	Poundhawadi	6.94240	2.13462	3.155	1.65303
11	Lamjewadi	3.30024	0.00678	0.677	2.61628
12	Nirgude	23.29236	8.86251	5.905	8.52440
13	Mhasobachiwadi	5.19661	1.07683	0.638	3.48212
14	Vaysewadi	2.32898	0.72314	1.342	0.26374
15	Akole	12.16831	4.75912	8.928	-1.51919
16	Bhadalwadi	9.10164	2.94831	6.494	-0.34080
17	Dalaj No.1	5.83298	0.01998	5.719	0.09429
18	Dalaj No.2				
19	Dalaj No.3	12.36995	0.37145	7.258	4.74030
20	Kalewadi	11.33558	0.31562	9.575	1.44449
21	Bandewadi	2.57522	0.22109	1.565	0.78869
22	Palasdeo	11.83181	0.98479	11.475	-0.62818
23	Malewadi	5.76114	0.59654	4.681	0.48407
24	Bhawadi	6.59158	0.56943	6.401	-0.37862
25	Loni	11.37376	1.33494	4.686	5.35330
26	Varkute Bk.	17.88854	2.53134	13.157	2.19981
27	Balpudi	5.20488	0.35424	0.978	3.87222
28	Karewadi	3.31139	0.25198	0.492	2.56769
29	Lakdi	9.69886	3.91186	1.502	4.28487
30	Shindewadi	3.85505	2.96205	1.596	-0.70289
31	Kazad	14.49669	4.25671	8.450	1.79026
32	Nimbodi	6.35594	1.01702	1.505	3.83401
33	Bori	14.40153	3.61265	10.528	0.26116
34	Sansar	14.16169	0.17355	10.584	3.40460
35	Bhavaninagar				
36	Jachakvasti				
37	Sapkalwadi				
38	Kardanwadi	2.47902	0.05644	1.937	0.48558

Sr. No.	Village Name	Rainfall in MCM	Runoff in MCM	Actual ET in MCM	Water Available for utilization
39	Lasurne				
40	Junction	19.19739	1.57782	13.526	4.09345
41	Thoratwadi				
42	Pawarwadi	2.30461	0.12584	1.404	0.77513
43	Belwadi	1.92380	0.07662	1.891	-0.04356
44	Hingnewadi	1.53933	0.07764	1.496	-0.03446
45	Udhat	3.77528	0.27272	3.384	0.11823
46	Paritwadi	3.22521	0.24387	1.386	1.59507
47	Chavhanwadi	1.73346	0.09285	0.846	0.79487
48	Bambadwadi	0.60112	0.03904	0.251	0.31148
49	Mankarwadi	0.98420	0.07635	0.483	0.42473
50	Gholapwadi	2.30957	0.1725	2.559	-0.42181
51	Tawashi	4.06195	0.25968	4.709	-0.90642
52	Jamb	4.36038	0.1488	4.191	0.02079
53	Kurwali	6.30593	0.27357	3.996	2.03648
54	Chikhali	4.82223	0.1338	2.705	1.98378
55	Pilewadi	2.95322	1.0283	1.318	0.60668
56	Maradwadi	4.49369	0.25033	1.729	2.51436
57	Nhavi	17.78324	1.55266	5.218	11.01283
58	Rui	9.24601	0.61499	2.760	5.87089
59	Gosaviwadi	2.10448	0.00842	0.537	1.55932
60	Kalas	36.54562	34.9951	13.201	-11.65052
61	Thoratwadi	6.07275	0.62532	1.281	4.16621
62	Birgundwadi	4.73074	4.66279	2.477	-2.40895
63	Shelgaon	34.52249	3.58683	8.229	22.70697
64	Bharnewadi	0.45448	0.02776	0.188	0.23898
65	Anthurne	18.35361	1.68597	8.752	7.91553
66	Sirsatwadi	7.37823	0.2146	5.851	1.31262
67	Kadbanwadi				
68	Hangarwadi	4.10937	0.32781	1.988	1.79358
69	Pitkeshwar	6.68872	1.40322	2.693	2.59280
70	Sarafwadi	2.32802	0.34764	1.365	0.61553
71	Ghorpadwadi	4.31144	0.25943	3.102	0.95023
72	Ranmodwadi	3.88470	0.26933	2.875	0.74086
73	Kalamb	15.08938	1.06081	12.200	1.82888
74	Nimsakhar	15.98948	0.70208	14.437	0.85058
75	Nirwangi	12.11726	1.39368	9.323	1.40089
76	Kauthali	7.98153	0.70357	0.801	6.47730
77	Vyahali	9.11388	0.95909	1.097	7.05730
78	Kacharewadi	1.99811	0.15392	0.392	1.45191

Sr. No.	Village Name	Rainfall in MCM	Runoff in MCM	Actual ET in MCM	Water Available for utilization
79	Gotandi	15.08712	1.23513	8.012	5.83986
80	Nimgaon Ketki	23.18602	2.45278	3.892	16.84108
81	Varkute Kh.	11.32642	2.91436	3.587	4.82467
82	Kati	13.71074	5.26344	6.090	2.35756
83	Jadhavwadi	1.01159	0.3489	0.575	0.08762
84	Reda	3.89903	1.25973	1.960	0.67973
85	Redni	7.41048	1.40171	5.466	0.54267
86	Khorochi	9.42288	0.8981	9.049	-0.52380
87	Boratwadi	5.58000	0.19453	5.430	-0.04454
88	Chandgaon	4.99758	0.28502	7.271	-2.55870
89	Agoti No.1	3.74137	0.21972	4.473	-0.95159
90	Agoti No.2	3.60123	0.19207	4.675	-1.26569
91	Ganjewalan	5.85874	0.27312	10.654	-5.06847
92	Kalashi	6.81878	0.45226	9.117	-2.75074
93	Kalthan No.1	7.73769	0.73021	10.181	-3.17342
94	Shirsodi	8.54409	0.71300	14.056	-6.22519
95	Padsthal	14.13609	0.74934	26.078	-12.69078
96	Ajoti	5.69839	0.37721	11.196	-5.87472
97	Sugaon	6.04612	0.43251	10.933	-5.31954
98	Pimpri Kh.	3.82274	0.42071	6.809	-3.40674
99	Malwadi	7.73690	1.12034	11.612	-4.99553
100	Galandwadi No.1	2.48909	0.5366	2.799	-0.84694
101	Narutwadi	2.66008	0.57764	3.437	-1.35435
102	Kalthan No.2	1.67403	0.27709	2.196	-0.79947
103	Gagargaon	6.72687	0.48249	5.226	1.01840
104	Bijwadi	3.55509	0.21866	1.294	2.04238
105	Rajwadi	2.38601	0.29058	1.858	0.23754
106	Vangali	4.61908	0.95643	4.599	-0.93593
107	Pondkulwadi	5.42760	0.44878	1.023	3.95619
108	Shaha	7.45967	0.54472	9.965	-3.04975
109	Kandalgaon	12.18468	0.35163	21.117	-9.28411
110	Taratgaon	2.94234	0.11074	3.763	-0.93091
111	Hingangaon	6.57923	0.64199	7.022	-1.08499
112	Sardewadi	3.09254	0.43394	2.804	-0.14531
113	Galandwadi No.2	15.97769	3.01804	5.637	7.32222
114	Gokhali	3.14965	0.52888	0.636	1.98478
115	Tarangwadi	8.01859	0.52888	1.317	6.17241
116	Zagadewadi	7.48937	1.2878	2.319	3.88277

Sr. No.	Village Name	Rainfall in MCM	Runoff in MCM	Actual ET in MCM	Water Available for utilization
117 118	Pandharwadi Vadapuri	11.21699	2.33298	5.478	3.40633
119	Bedshinge	3.37314	0.50917	0.970	1.89363
120	Babhulgaon	9.66129	1.8714	7.196	0.59373
121	Avasari	8.15368	0.69991	3.174	4.27942
122	Bhat Nimgaon	6.20559	1.04102	3.809	1.35515
123	Shetphal Haveli	11.51689	2.0621	10.018	-0.56286
124	Surwad	4.81507	0.18405	4.801	-0.17026
125	Bhandgaon	9.01321	0.40387	7.809	0.80001
126	Vakilvasti	1.49749	0.03486	1.551	-0.08833
127	Bawada	34.01338	1.83074	35.095	-2.91227
128	Bhodani	4.18716	0.59111	3.261	0.33541
129	Lakhewadi	3.29444	0.32808	2.211	0.75580
130	Chakati	11.49621	1.30945	8.848	1.33904
131	Pithewadi	3.32841	0.14579	2.898	0.28509
132	Nirnimgaon	4.21659	0.24768	3.856	0.11288
133	Kacharewadi	3.58920	0.20807	2.672	0.70951
134	Sarati	5.08266	0.4374	4.814	-0.16835
135	Lumewadi	5.27952	0.98636	6.044	-1.75063
136	Gondi	3.74407	0.94871	4.423	-1.62762
137	Ganeshwadi	4.00060	0.66647	4.781	-1.44707
138	Pimpri Bk.	6.44301	1.04895	8.124	-2.72985
139	Tannu	5.48150	2.17685	7.149	-3.84481
140	Narsingpur	6.06391	1.1783	8.092	-3.20639
141	Giravi	8.39197	3.03964	11.117	-5.76514
142	Ozare	3.12298	1.29626	3.756	-1.92975
143	Indapur	39.16227	7.36475	29.885	1.91251
	Total	1052.46890	327.151	751.529	-26.21179

Source: Remote Sensing and Hydrological Modelling of the Upper Bhima Catchment (2006) www.india.wris.nrsc.gov.in and computed by author.

Thus, the major amount of availability of water resources through rainfall and existing conservation measures. It is observed that the wells and canals are major source of water supply in the study area.

Chapter – IV

Water Utilization and Requirement in the Indapur Tahsil

Chapter – IV

Water Utilization and Requirement in the Indapur Tahsil

4.0 Introduction

Water is life and it is universally acclamation as the most important natural resource. The end use of water is essential for every inhabitant and for a wide range of economic and informal sector activities. It is vital for agriculture, industry, health and hydropower. Water is also an integral part of the natural environment and the habitat for many forms of life; it may be human, animal and plant (Opoku-Agyemang, 2005). The household wise water utilization statistics has also been worked out through personal interviews conducted during the field visits. For this purpose a questionnaire was framed (Appendix-A). Questions are related to domestic, agriculture, livestock and industrial water use and requirement has also been incorporated accordingly.

4.1 Present water utilization of the study area

Water use includes all individual and collective activities of human society which affect water resources and change their quality and quantity. The beneficial utilization of water depends, as does its natural functions, on the water properties. The method of water use and distribution depends especially on the degree of development and organization of the social system. It becomes systematic as a consequence of agricultural, social and industrial development. From the beginning water has been the basic need and precondition of human existence, but gradually it has also become a raw material which has been turned into a means of development in it.

On the global scale the quantity of water is fixed and sufficiently large, at regional and local scale the water availability becomes a cause of concern and hence it needs to be managed. World Health Organization (WHO) has estimated that about 200 litres / capita / day (lpcd) water is required for these purposes. It is estimated that 200 lpcd would be sufficient for living in towns and only 70 lpcd living in villages without flush latrines. This chapter has been attempt has been made to quantify the water budget of the study area. The proportion of water utilization is in three different activities in the study area **(Table 4.1 and Fig.4.1)**.

Table 4.1 Proportion of water utilized in three different activities in the study area.

Sr. No.	Water utilization type	Use in MCM	In %
1	Domestic utilization	3.89	0.84
2	Agricultural utilization	451.59	97.01
3	Industrial utilization	10.02	2.15
	Total	465.50	100.00

Source: Nira irrigation office Baramati, Khadakwasala irrigation office Daund, Panchyat Samiti and Agriculture office, Indapur 2012.

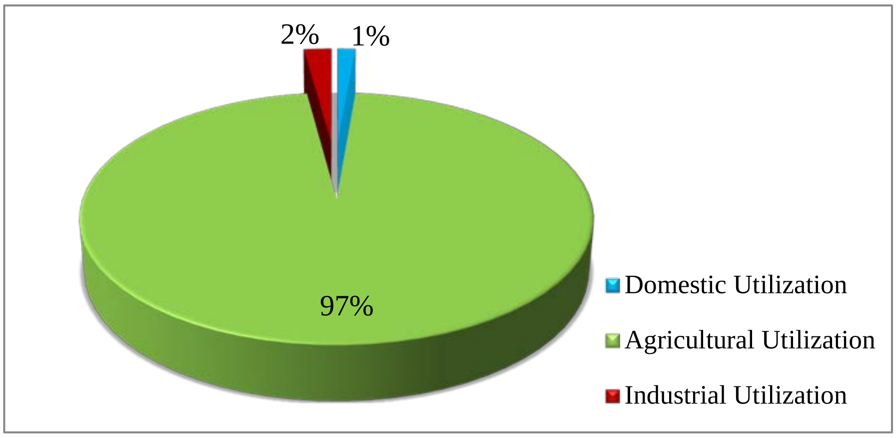


Fig. 4.1 Proportion of water utilized in the study area.

It is clear from the table that the total water utilization for agriculture claims 451.59 MCM (97.01%), it is large proportion. In the industrial sector 10.02 MCM (2.15%) utilized water, it is considerably low and only 3.89 MCM (0.84%) water utilized for domestic purposes. The water utilization increases in the municipal water requirements.

For the present analysis the quantification of the surface water availability has been worked out. Certainly the surface water availability falls short the total water requirements. The area being in monsoon climatic conditions it is subject to high variability conditions hence there is a requirement of supplementing the water from ground water storage for domestic and agricultural requirements. Ground water play important role; however, in the present study only the surface water conditions are being dealt with. The ground water hydrology is separate discipline. So the scope of the present work is confined to surface water conditions as input and water requirement on the demand side.

4.1.1 Present domestic water utilization

For survival of every human life water is an essential element. Man use water for different purposes in which direct consumption of water is of the fore most use. For the present work domestic water utilization pattern is studied on the basis of collected primary data. It was found that in Vaysewadi, Karewadi, Mhasobachiwadi, Lakdi, Nimbodi, Kauthali, Balpudi and Kacharwadi villages people follow the traditional method for water uses i.e. dug wells. It is main source of domestic water supply. In villages contemporary water supply systems are of tap system, hand pumps or dug wells. In case of tap water supply system water is available from the remote source like dam reservoir or from the public dug well in the village area. In most of the system ground water is used as a source for domestic water demand. Expect for on bank of river Bhima villages which use reservoir water and other village's water supply schemes are dependent on canal water and ground water. Ground water is used at a large scale in all the sectors of water use. As discussed by Deolankar (1980) and Sarbhukan (2001) ground water recharge rates are very slow in the basalt rock region of Maharashtra. In such areas further dependence on ground water sources for water supply schemes will be very difficult.

The total water use of Indapur tahsil is 3.894 MCM per year. The major portion of the water use of the study area is consumed by Indapur urban centre, Bhigwan, Palasdev, Lasurne and Kalamb. These five settlements are totally 1.205 MCM (30.95%) water use in the year and another 138 settlement 2.689 MCM (69.05%) water use the in the year. The following **table no. 4.2 and fig. no. 4.2** shows the village wise domestic water use in the study area.

Out of 142 villages and 1 urban center, 122 (85.31%) villages have a supply through tap water are the main source of the drinking water and remaining 21 (14.69%) villages supply through another mode. Supply through Nira canal 1.43 MCM, 0.12 MCM through Khadakwasala canal, take from Ujani reservoir 0.949 MCM and 1.395 MCM from groundwater, totally 3.894 MCM water use for domestic purposes in the study area. The villages which have using ground water sources are about 62%. Thus at least 38% are using one or more surface water sources. This clearly indicates that there is heavy dependence on the ground water is main source for domestic uses.

Table 4.2 Village wise domestic water use.

Sr. No.	Name	No. of household	Total Population	Water supply litres / day	Water in MCM	Sr. No.	Name	No. of household	Total Population	Water supply litres / day	Water in MCM
1	Shetphalgadhe	851	4123	144000	0.053	24	Bhawadi	225	907	48000	0.018
2	Pimple	264	1337	20000	0.007	25	Loni	560	2667	48000	0.018
3	Madanwadi	1204	5954	35000	0.013	26	Varkute Bk.	641	2915	80000	0.029
4	Takrarwadi	493	2166	100800	0.037	27	Balpudi	148	743	20000	0.007
5	Bhigvan	1576	7673	300000	0.110	28	Karewadi	302	1466	NA	NA
6	Bhigvanstaion	567	2858	32000	0.012	29	Lakdi	526	2547	20000	0.007
7	Diksal	339	1710	60000	0.022	30	Shindewadi	375	1883	20000	0.007
8	Kumbhargaon	293	1330	76000	0.028	31	Kazad	576	3139	72000	0.026
9	Bandgarwadi	117	622	19200	0.007	32	Nimbodi	383	1922	60000	0.022
10	Poundhawadi	355	1792	85000	0.031	33	Bori	1237	5861	80000	0.029
11	Lamjewadi	142	662	64000	0.023	34	Sansar	1339	6632	144000	0.053
12	Nirgude	433	2095	42400	0.015	35	Bhavaninagar	896	4011	100000	0.037
13	Mhasobachiwadi	397	2000	55000	0.020	36	Jachakvasti	247	1300	52000	0.019
14	Vaysewadi	126	577	NA	NA	37	Kardanwadi	212	917	40000	0.015
15	Akole	678	3273	70000	0.026	38	Jankshan	1081	4855	144000	0.053
16	Bhadalwadi	622	2628	24000	0.009	39	Lasurne	1780	8803	180000	0.066
17	Dalaj No.1	262	1204	40000	0.015	40	Pawarwadi	405	2202	48000	0.018
18	Dalaj No.2	298	1455	60000	0.022	41	Belwadi	1022	5056	90000	0.03285
19	Dalaj No.3	196	895	80000	0.029	42	Sapkalwadi	280	1305	25000	0.009
20	Kalewadi	307	1477	28000	0.010	43	Hingnewadi	243	1218	23000	0.008
21	Bandewadi	72	342	16000	0.006	44	Udhat	428	2023	40000	0.015
22	Palasdeo	793	3621	192000	0.070	45	Paritwadi	260	1245	28000	0.010
23	Malewadi	377	1818	36800	0.013	46	Thoratwadi	156	812	24000	0.009

Continued…..

Sr. No.	Name	No. of household	Total Population	Water supply litres / day	Water in MCM	Sr. No.	Name	No. of household	Total Population	Water supply litres / day	Water in MCM
47	Chavhanwadi	83	396	16000	0.006	72	Ranmodwadi	725	3468	80000	0.029
48	Bambadwadi	154	688	20000	0.007	73	Kalamb	3576	16338	180000	0.066
49	Mankarwadi	190	986	24000	0.009	74	Nimsakhar	1284	6000	64000	0.023
50	Gholapwadi	322	1407	40000	0.015	75	Nirwangi	753	3601	68000	0.025
51	Tawashi	639	3046	57600	0.021	76	Kauthali	543	2764	40000	0.015
52	Jamb	342	1459	56000	0.020	77	Vyahali	366	1698	33600	0.012
53	Kuravali	535	2925	80000	0.029	78	Kacharewadi	163	829	40000	0.015
54	Chikhali	283	1426	40000	0.015	79	Gotandi	877	4650	80000	0.029
55	Pilewadi	215	1150	40000	0.015	80	Nimgaon Ketki	2450	12397	144000	0.053
56	Maradwadi	139	571	20000	0.007	81	Varkute Kh.	980	4811	44000	0.016
57	Nhavi	695	3222	100000	0.037	82	Kati	1149	5353	144000	0.053
58	Rui	710	3232	95000	0.035	83	Jadhavwadi	101	472	40000	0.0146
59	Gosaviwadi	215	1157	25000	0.009	84	Reda	534	2415	80000	0.029
60	Kalas	855	4141	100000	0.037	85	Redni	795	3938	42400	0.015
61	Thoratwadi	86	473	20000	0.007	86	Khorochi	786	3637	34400	0.013
62	Birgundwadi	162	792	40000	0.015	87	Boratwadi	340	1715	48000	0.018
63	Shelgaon	1825	8215	100000	0.037	88	Chandgaon	185	797	40000	0.015
64	Bharnewadi	847	4358	NA	NA	89	Agoti No.1	282	1261	64000	0.023
65	Anthurne	1245	6100	144000	0.053	90	Agoti No.2	149	719	44800	0.016
66	Kadbanwadi	425	1636	40000	0.015	91	Ganjewalan	193	840	40000	0.015
67	Hangarwadi	376	1807	40000	0.015	92	Kalashi	384	1819	56000	0.020
68	Pitkeshwar	427	2065	68000	0.025	93	Kalthan No.1	483	2135	90000	0.033
69	Sarafwadi	413	2038	120000	0.044	94	Shirsodi	383	1938	34400	0.013
70	Ghorpadwadi	304	1401	16000	0.006	95	Padsthal	291	1405	45000	0.016
71	Sirsatwadi	433	2100	64000	0.023	96	Ajoti	204	864	NA	NA

Continued…..

Sr. No.	Name	No. of household	Total Population	Water supply litres / day	Water in MCM	Sr. No.	Name	No. of household	Total Population	Water supply litres / day	Water in MCM
97	Sugaon	72	301	17500	0.006	121	Avasari	496	2011	45600	0.017
98	Pimpri Kh.	242	1380	66000	0.024	122	Bhat Nimgaon	337	1547	67200	0.025
99	Malwadi	848	4263	32000	0.012	123	Shetphal Haveli	652	3006	64000	0.023
100	Galandwadi No.1	370	1873	80000	0.029	124	Surwad	587	2639	48000	0.018
101	Narutwadi	224	1331	NA	NA	125	Bhandgaon	632	2993	76000	0.028
102	Kalthan No.2	256	1188	100000	0.037	126	Vakilvasti	435	2144	40000	0.015
103	Gagargaon	152	709	40000	0.015	127	Bawada	2347	10734	144000	0.053
104	Bijwadi	755	3369	60000	0.022	128	Bhodani	545	2488	64000	0.023
105	Rajwadi	104	508	32000	0.012	129	Lakhewadi	946	4540	35600	0.013
106	Vangali	265	1251	32000	0.012	130	Chakati	247	1316	40000	0.015
107	Pondkulwadi	249	1330	17600	0.006	131	Pithewadi	219	1080	56000	0.020
108	Shaha	390	2364	41600	0.015	132	Nirnimgaon	585	2863	60000	0.022
109	Kandalgaon	416	2069	52000	0.019	133	Kacharewadi	219	1141	NA	NA
110	Taratgaon	63	288	40000	0.015	134	Sarati	414	2160	64000	0.023
111	Hingangaon	381	1846	32000	0.012	135	Lumewadi	620	3067	72000	0.026
112	Sardewadi	604	3187	48000	0.018	136	Gondi	232	1116	68000	0.025
113	Galandwadi No.2	470	2299	27200	0.010	137	Ganeshwadi	243	1346	56000	0.020
114	Gokhali	373	1608	NA	NA	138	Pimpri Bk.	463	2251	100000	0.037
115	Tarangwadi	513	2557	33600	0.012	139	Tannu	433	2117	16000	0.006
116	Zagadewadi	231	1193	30000	0.011	140	Narsingpur	468	2231	80000	0.029
117	Pandharwadi	235	1198	72000	0.026	141	Giravi	308	1766	61200	0.022
118	Vadapuri	919	4401	80000	0.029	142	Ozare	124	639	40000	0.015
119	Bedshinge	183	759	32000	0.012	143	Indapur Urban	5228	25515	2450000	0.894
120	Babhulgaon	608	2505	48000	0.018		Total	79683	383183		3.894

Source: Panchyat Samiti Indapur, Municipal Corporation, Indapur 2012 and Census of India 2011.

Source: Author **Fig. 4.2**

From the some villages use ground water for manage daily needs. Which water supply use the ground water, these central and western part located villages faces stress or sometimes fail in summer months. The remote water sources supply systems face the problem of water pump, power supply and maintenance of pipeline. These central and western part located villages have difficulties in summer when water is pumped alternate days or totally stop the supply. This is because they cannot afford storage facilities, and supply them by tankers; some poorer households take from their neighbours. However, all agreed this posed no difficulty as neighbours were always willing to assist.

Drinking water facilities are exists in almost all villages and towns in the study area, but do not supply water through in a year. In the study area not a single village have found dependent on a single source whereas the rest have two sources available in the other 15 (10.49%) villages, 37 (25.87%) and 62 (43.36%) villages available the 3 and 4 sources respectively. More than 5 drinking water sources are available in Palasdeo, Kalas, Kadbanwadi, Kalamb, Vadapuri and Girvi villages **(Table 4.3)**.

Table 4.3 Sources of domestic water supply of the study area.

Sr. No.	Source type	No. of water supply sources					
		Single	Two	Three	Four	Five	Six
1	Tap	0	4	24	45	21	6
2	Well	0	14	35	60	22	6
3	Tank	0	0	3	9	8	5
4	Tube well	0	0	9	38	19	6
5	Hand pump	0	10	32	59	20	6
6	River/Canal	0	2	3	27	17	5
7	Spring	0	0	1	3	3	2
No. of village		0	15	37	62	23	6

Source: Census of India 2011

The main source of drinking water in rural area is un-covered well on that source 22645 (30.73%) households depend and in urban area main source is tap water from treated source, on that source 4990 (92.32%) households are depended. Other sources of drinking water of rural and urban households are given in the **Table 4.4 and Fig.4.3**. In this figure shows the different drinking water sources of rural and urban households. In rural and urban area found the different main sources. According to above data out of total rural households more than 75% households supply the untreated drinking water and less than 25% households supply the treated drinking water in rural area. Therefore, in urban area 92.32% households supply treated drinking water only 7.68% households not supply treated drinking water.

Table 4.4. Distribution of households by main source of drinking water

Sr. No.	Main source of drinking water	Rural	In %	Urban	In %	Total	In %
1	Tap water from treated source	17783	24.13	4990	92.3	22773	28.79
2	Tap water from un-treated source	9768	13.26	24	0.44	9792	12.38
3	Covered well	1287	1.75	18	0.33	1305	1.65
4	Un-covered well	22645	30.73	29	0.54	22674	28.67
5	Hand pump	13069	17.74	32	0.59	13101	16.56
6	Tube well/Bore well	8064	10.94	180	3.33	8244	10.42
7	Spring	62	0.08	1	0.02	63	0.08
8	River/ Canal	540	0.73	16	0.3	556	0.703
9	Tank/Pond/Lake	141	0.19	15	0.28	156	0.197
10	Other sources	325	0.44	100	1.85	425	0.537
	Total	73684	100.00	5405	100	79089	100

Source: Census of India 2011.

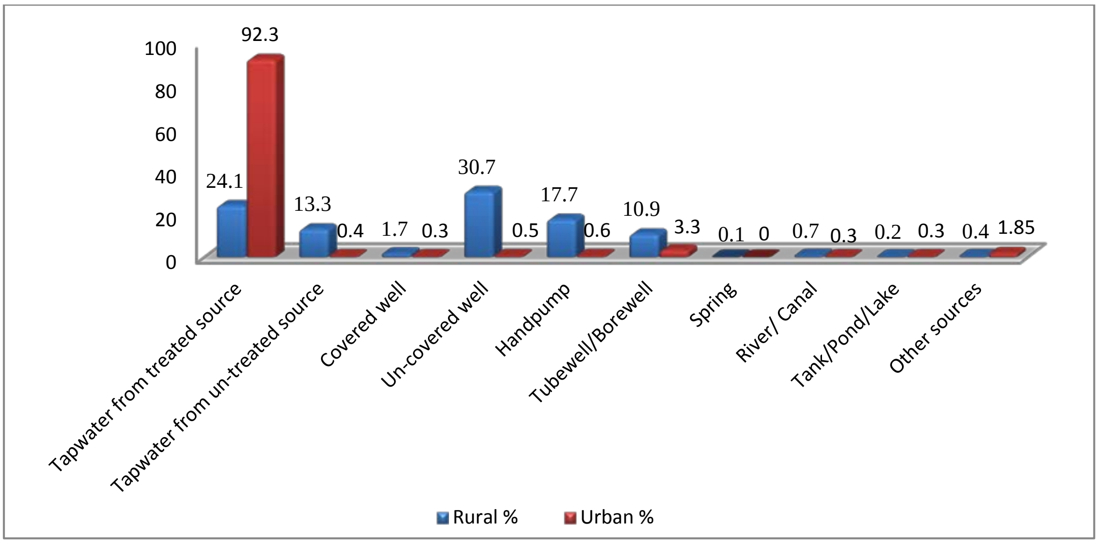


Fig. 4.3 Major sources of drinking water of rural and urban households

4.1.2 Present agricultural water utilization

The existing policy of water management therefore requires modifications and changes. The traditional system of irrigation results in mass wastage of water. Some amount of this water drains out as surface run-off, some increases the moisture level of the soil thus rendering it too wet and considerable amount is evaporated and returned to the atmosphere. The efficiency of the irrigation water use in farming still remains at the level of 35-40%.

The existing system of flooding the fields results in large scale wastage of water, without ensuring increase in agricultural productivity. Uses of sprinklers and drip irrigation have demonstrated on farm water efficiencies up to the range of 80-90% with concomitant increase in crop productivity to the tune of 20 to 100% depending on the crop. It is therefore necessary to adopt area specific, season specific, crop specific and source specific water resources management to ensure long term sustainability.

In the study area, under irrigated land by the different ways water sources are around 83067 ha (55.78%) **(Table 4.5, Fig. 4.4 and Fig. 4.5)**. The main source of irrigation water is farmer-owned wells, from that source 46.86% volume of water available in the study area. Out of total irrigated area, 42.45% area under irrigation with the help of Nira and Khadakwasala canals. Nira left canal was constructed in the year 1882, whose length was 60 Kms. in Indapur tahsil. Total irrigated area under Nira left canal area of Indapur tahsil is 18049 ha area. Khadakwasala Canal was constructed in the year 1956. The length of this canal is 61 Kms in Indapur tahsil. Total irrigated area under Khadakwasala canal of Indapur tahsil is 17209 ha and under small project 1036 ha, well irrigation 26469 (31.86%) ha.

Table .4.5 Area under different modes of irrigation

Sr. No.	Mode of irrigation	Area under irrigation in		Volume of water in	
		Hectares	%	MCM	%
1	Nira canal	18049	21.73	51.50	11.53
2	Khadakwasala canal	17209	20.72	35.94	8.05
3	Well	26469	31.86	209.13	46.84
4	Ujani reservoir	10052	12.10	120.62	27.02
5	K. T. weir	10252	12.34	24.97	5.59
6	PT and other	1036	1.25	4.31	0.97
	Total	83067	100.00	446.47	100.00

Source: Irrigation offices, Baramati and Daund, GSDA office, Pune and Socio-Economic Report, Pune 2012.

For the above area supply the water for irrigation by the different ways. Groundwater is a major source of irrigation through this way 209.13 MCM utilize water. The southern part of Indapur tahsil comes under plane area due to which it benefits from Nira left canal supply 51.5 MCM water 35.94 MCM through Khadakwasala canal.

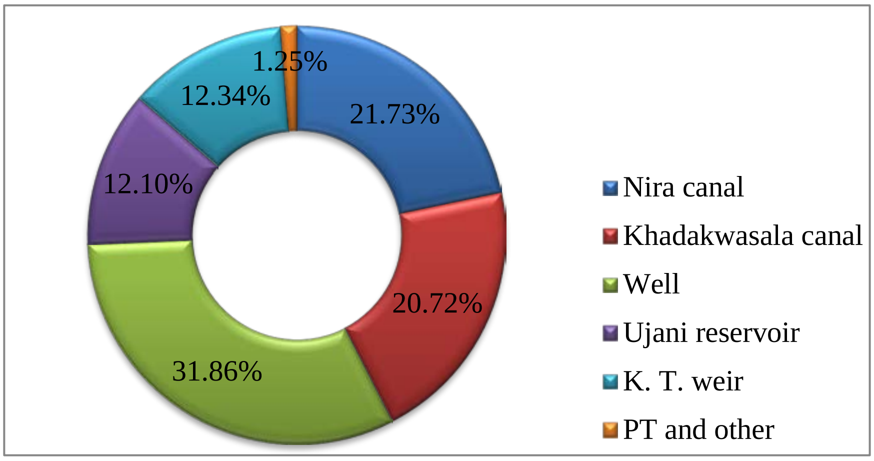


Fig. 4.4 Area under different modes of irrigation in the study area

Similarly, Ujani reservoir and K. T. Weir provide water respectively 120.62 MCM and 24.89 MCM, through percolation tank and other modes only 4.16 MCM supply water. There are 446.47 MCM water use for agriculture purposes **(Table No. 4.5 and Fig. 4.5)**.

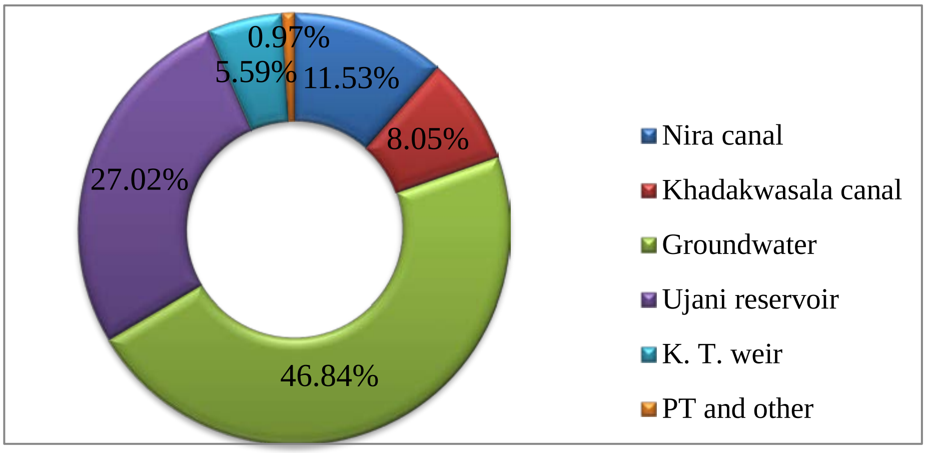


Fig. 4.5 Irrigation types volume of water utilized in the study area

Source: Irrigation office, Baramati and Daund and GSDA, Pune 2012

4.1.2.1 Agriculture water use estimation

Total water use of Indapur tahsil is approximately about 446.473 MCM per year. Estimation of total agriculture water use calculated as discussed in the methodology. The major portion of the water use of the Indapur tahsil is consumed by rabbi crop cultivation followed by kharif crop cultivation. The water utilized for each village for kharif and rabbi agriculture is shown in table **4.6 and fig 4.6**. The total cultivable land in the study area is 1,26,325 ha (84.82%) out of this kharif and rabbi crop cultivated area is only 23,391.94 ha (18.52%) and 47,995.6 ha (37.99%) of the total study area respectively in 2012-13.

Table 4.6 Village wise use of agriculture water for Kharif and Rabbi Season

Sr. No.	Name of village	Agricultural water use in MCM		
		Kharif season	Rabbi season	Total
1	Shetphalgadhe	1.204	4.512	5.716
2	Pimple	0.184	1.673	1.857
3	Madanwadi	0.343	3.843	4.186
4	Takrarwadi	0.094	0.358	0.452
5	Bhigvan	0.913	1.636	2.549
6	Bhigvanstaion	NA	NA	NA
7	Diksal	0.643	2.530	3.173
8	Kumbhargaon	0.117	1.412	1.529
9	Bandgarwadi	0.122	1.097	1.219
10	Poundhawadi	0.091	2.246	2.337
11	Lamjewadi	0.393	1.768	2.161
12	Nirgude	1.444	5.333	6.777
13	Mhasobachiwadi	0.566	4.556	5.122
14	Vaysewadi	0.487	1.226	1.713
15	Akole	4.694	5.049	9.743
16	Bhadalwadi	0.313	2.833	3.146
17	Dalaj No.1	0.239	0.927	1.166
18	Dalaj No.2	0.379	1.848	2.227
19	Dalaj No.3	0.194	1.169	1.363
20	Kalewadi	0.293	3.556	3.849
21	Bandewadi	0.198	3.180	3.378
22	Palasdeo	0.151	0.685	0.836
23	Malewadi	0.418	3.646	4.064
24	Bhawadi	0.915	1.323	2.238
25	Loni	1.159	1.868	3.027
26	Varkute Bk.	1.963	2.802	4.765
27	Balpudi	0.773	1.148	1.921
28	Karewadi	0.447	1.426	1.873
29	Lakdi	1.565	4.114	5.679
30	Shindewadi	2.054	3.049	5.103
31	Kazad	1.854	4.602	6.456
32	Nimbodi	1.512	1.995	3.507
33	Bori	3.117	5.537	8.654
34	Sansar	2.341	2.544	4.885
35	Bhavaninagar	1.171	1.383	2.554
36	Jachakvasti	1.848	2.007	3.855
37	Kardanwadi	0.725	0.929	1.654
38	Jankshan	0.183	0.675	0.858
39	Lasurne	0.995	2.688	3.683
40	Pawarwadi	0.516	0.700	1.216
41	Belwadi	0.800	1.790	2.590
42	Sapkalwadi	0.936	1.112	2.048
43	Hingnewadi	1.989	1.343	3.332
44	Udhat	1.365	1.698	3.063
45	Paritwadi	0.434	1.352	1.786
46	Thoratwadi	0.390	0.820	1.210
47	Chavhanwadi	0.804	0.464	1.268

Continued…..

Sr. No.	Name of village	Agricultural water use in MCM		
		Kharif season	Rabbi season	Total
48	Bambadwadi	0.312	0.561	0.873
49	Mankarwadi	0.336	0.525	0.861
50	Gholapwadi	0.557	0.707	1.264
51	Tawashi	2.118	2.853	4.971
52	Jamb	0.659	0.897	1.556
53	Kurwali	1.872	2.256	4.128
54	Chikhali	0.344	0.647	0.991
55	Pilewadi	0.397	1.669	2.066
56	Maradwadi	0.300	0.929	1.229
57	Nhavi	0.684	1.966	2.650
58	Rui	0.979	1.945	2.924
59	Gosaviwadi	0.511	3.015	3.526
60	Kalas	0.816	13.399	14.215
61	Thoratwadi	0.422	0.964	1.386
62	Birgundwadi	0.159	2.941	3.100
63	Shelgaon	6.430	3.871	10.301
64	Bharnewadi	2.649	3.900	6.549
65	Anthurne	0.554	1.397	1.951
66	Kadbanwadi	1.887	1.237	3.124
67	Hangarwadi	0.301	0.719	1.020
68	Pitkeshwar	1.268	1.351	2.619
69	Sarafwadi	0.849	1.051	1.900
70	Ghorpadwadi	0.468	0.816	1.284
71	Sirsatwadi	0.323	0.872	1.195
72	Ranmodwadi	0.243	0.512	0.755
73	Kalamb	0.979	1.407	2.386
74	Nimsakhar	1.553	4.044	5.597
75	Nirwangi	1.248	2.007	3.255
76	Kauthali	0.453	3.309	3.762
77	Vyahali	1.111	3.325	4.436
78	Kacharwadi	0.252	1.322	1.574
79	Gotandi	2.302	2.007	4.309
80	Nimgaon Ketki	3.192	9.868	13.060
81	Varkute Kh.	3.816	3.828	7.644
82	Kati	2.571	2.941	5.512
83	Jadhavwadi	0.337	0.873	1.210
84	Reda	0.616	2.262	2.878
85	Redni	1.504	1.589	3.093
86	Khorochi	1.447	2.006	3.453
87	Boratwadi	0.378	1.076	1.454
88	Chandgaon	0.934	1.165	2.099
89	Agoti No.1	0.795	0.933	1.728
90	Agoti No.2	0.645	0.790	1.435
91	Ganjewalan	0.609	0.736	1.345
92	Kalashi	1.280	1.747	3.027
93	Kalthan No.1	0.974	2.427	3.401
94	Shirsodi	0.440	2.216	2.656
95	Padsthal	1.091	2.409	3.500
96	Ajoti	0.085	0.146	0.231
97	Sugaon	0.054	0.163	0.217

Continued…..

Sr. No.	Name of village	Agricultural water use in MCM		
		Kharif season	Rabbi season	Total
98	Pimpri Kh.	0.709	1.625	2.334
99	Malwadi	0.958	4.813	5.771
100	Galandwadi No.1	0.562	1.700	2.262
101	Narutwadi	0.448	2.111	2.559
102	Kalthan No.2	0.533	1.517	2.050
103	Gagargaon	1.030	1.337	2.367
104	Bijwadi	0.364	1.111	1.475
105	Rajwadi	0.493	0.630	1.123
106	Vangali	0.662	0.940	1.602
107	Pondkulwadi	0.874	1.360	2.234
108	Shaha	0.799	1.272	2.071
109	Kandalgaon	0.598	1.270	1.868
110	Taratgaon	0.129	0.370	0.499
111	Hingangaon	0.852	1.816	2.668
112	Sardewadi	2.529	1.712	4.241
113	Galandwadi No.2	1.533	2.588	4.121
114	Gokhali	0.517	2.482	2.999
115	Tarangwadi	0.630	4.726	5.356
116	Zagadewadi	6.151	1.906	8.057
117	Pandharwadi	0.933	1.026	1.959
118	Vadapuri	1.499	1.768	3.267
119	Bedshinge	0.541	1.165	1.706
120	Babhulgaon	2.091	3.440	5.531
121	Avasari	1.579	2.132	3.711
122	Bhat Nimgaon	1.593	2.574	4.167
123	Shetphal Haveli	1.503	1.827	3.330
124	Surwad	0.785	1.505	2.290
125	Bhandgaon	2.076	3.012	5.088
126	Vakilvasti	0.525	1.242	1.767
127	Bawada	2.895	10.040	12.935
128	Bhodani	0.718	1.473	2.191
129	Lakhewadi	0.963	1.456	2.419
130	Chakati	0.610	1.046	1.656
131	Pithewadi	0.558	1.427	1.985
132	Nirnimgaon	0.547	1.176	1.723
133	Kacharewadi	0.589	1.577	2.166
134	Sarati	0.335	1.435	1.770
135	Lumewadi	0.690	1.402	2.092
136	Gondi	0.769	1.339	2.108
137	Ganeshwadi	1.042	1.519	2.561
138	Pimpri Bk.	1.501	1.821	3.322
139	Tannu	1.474	2.086	3.560
140	Narsingpur	1.329	1.976	3.305
141	Giravi	0.617	0.946	1.563
142	Ozare	0.659	1.156	1.815
143	Indapur	0.546	4.796	5.342
Total water use		146.778	299.695	446.473

Source: Agriculture office, Indapur 2012 and Author

NA: Not available

Source: Author **Fig. 4.6**

4.1.2.2 Livestock water use

Animals are important part of agriculture in the study area. Total animal population was 259980. Thus, total use of water for animal 5.11 MCM per annum. This estimate is presented in **table 4.7 and fig 4.7a and Fig. 4.7b**.

Table 4.7 and fig.4.7a shows population **and 4.7b** Shows water utilization of animal.

Sr. No.	Animal	Water use lpcd	Population	Total water use in	
				Litres per day	MCM per Year
1	Cattles	85	98357	8360345	3.05
2	Buffaloes	85	53962	4586770	1.67
3	Goat	10	83191	831910	0.30
4	Sheep	10	24470	244700	0.09
	Total	190	259980	14023725	5.11

Source: Frasier and Hyers, 1983 and Panchyat Samiti, Indapur 2012.

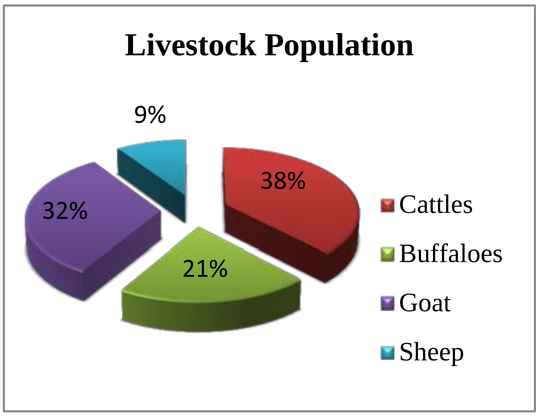


Fig. 4.7a

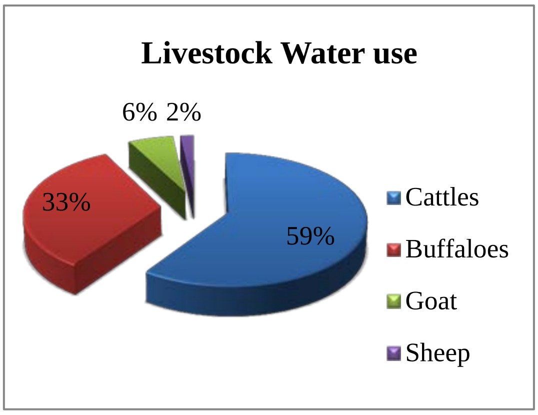


Fig. 4.7b

Agricultural water utilization is 446.473MCM and animal water utilization is 5.118 MCM totally 451.591 MCM (**Fig. 4.8**) water utilized for agriculture purpose in the study area.

4.1.3 Present Industrial water utilization

Industrial growth is a key driver of water demand both from industrial production perspective as well as the stimulation of service sectors. Water utilization for industries although insignificant compared for the demand for the agricultural uses. Industrial use is enabled by industrial water use and disposal systems, i.e. sets of structures, technological equipment such as measuring and controlling devices as well as waste water treatment and recycling, sludge disposal and the harmless discharge of polluted water into appropriate recipients. Sugar factory is the most successful

Source: Author **Fig. 4.8**

industries in the study area. There is 1 Ballarpur Industries Limited (BILT) paper mill are situated in the study area. It is an important activity using lot of water in Indapur tahsil. This BILT paper industry use the 8.6 MCM (85.83%) water and other industries use the only 1.42 MCM (14.17%) water. Other industrial activities that have implications for water demand include 4 sugar factories, 1 Jaggery factory and 1 milk product industries. These industries serve the needs of water through Nira canal 0.657 MCM, Khadakwasala canal 0.763 MCM and 8.6 MCM (23,571 m^3/day) fulfil by Ujani reservoir. There are total 10.02 MCM used in the industrial section. **(Table 4.8 and Fig. 4.9)**.

Table 4.8 Industrial water use by different industrial units

Sr. No.	Name of industry	Crushing capacity in MT	Daily use of water in M^3	Daily demand of water in M^3	Total use in season M^3	Use in %
1	Ballarpur Industries Ltd (BILT)	0	23571	23571.0	8603415	85.9
2	Chhatrapati Sahkari Sakhar Karkhana	3500	1750	1312.5	196875	1.97
3	Nira-Bhima Sahkari Sakhar Karkhana	3500	1750	1312.5	196875	1.97
4	Karmyogi Shankarrao Patil Sahkari Sakhar Karkhana	8000	4000	3000.0	450000	4.49
5	Baramati Agro Sakhar Karkhana	3500	1750	1312.5	196875	1.97
6	Sonaie Jaggery Industry	500	20	20.00	3000	0.03
7	Sonaie dairy	0	1300	600.0	219000	2.19
8	Other industrious	0	410.96	410.96	150000	1.50
	Total	19000	34552	31539.5	10016040	100.00

Source: Pune District Socio-Economic Report 2012 and 2013

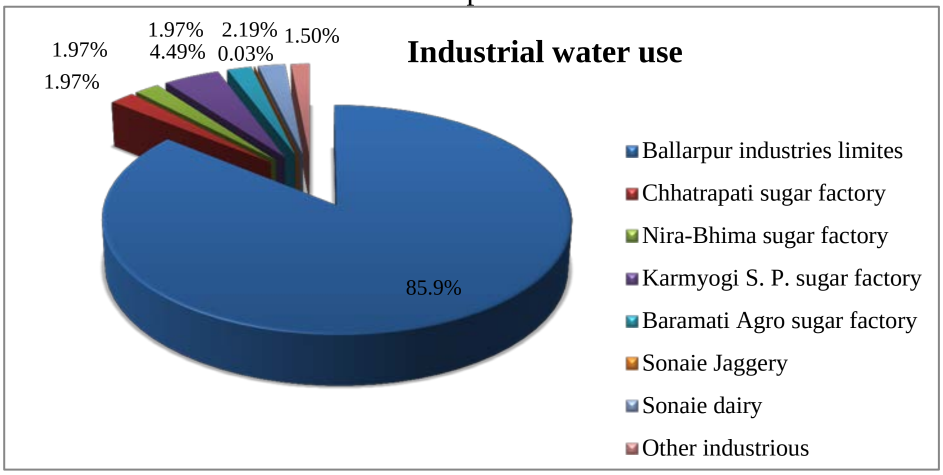


Fig. 4.9 Schematic diagram of use of industrial water by different industrial units

4.2 Water requirement

A given water requirement is the amount of water which is necessary for the undisturbed course of any natural or technological process. It includes water consumption (consumed flow), i. e. the difference between water withdrawal and the net return flow that consists of consumptive use and losses. The water loss represents that part of the water requirement, water consumption, water withdrawal or water resource which returns into the hydrologic cycle in the form of seepage, leakage, percolation, evaporation etc. losses may be either ways.

Water requirements and water consumption in the course of agricultural and industrial processes may be distinguished as

(a) Minimum,

(b) Optimum,

(c) Non-Economic.

Minimum water requirement or minimum water consumption during a specific production process can be achieved under special conditions, e.g. in laboratories. The water saving technology which achieves the minimum water requirements may differ from the technology which achieves the minimum consumption of water, and both can be unsuitable from the point of view of the total production cost. An optimum water requirement and optimum water consumption are attained when industrial processes may be distinguished as the product of desired quality is produced under the conditions of minimum total social effort, i.e. from the point of view of the national economy, by applying an optimum technology. The non-economic water requirements and water consumption exceed this optimum value. Low losses and optimum water consumption are indispensable preconditions for any efficient industrial technology. Low water requirements depend primarily on the degree of recirculation. An efficient water resources management policy is based on a decrease in water consumption and an improvement in the waste water quality. The requirement of society largely depends on its size, the spectrum of activities the society is engaged in and also the lifestyle of the individuals. It may generally be said that greater the concentration of population the more need for the resources. The amount of water required by a group of persons does not depend on only the size of the group but also the need arising out of concentration such as maintenance of hygienic conditions. Hence, the water requirement of rural areas and urban areas differ significantly. UNESCO estimates that the world demand for water will double between 1964 and 1984, but the natural supply will remain same (Batisse, 1964). By the large, water requirements are grouped as domestic requirements, agricultural requirements and industrial requirements.

The total quantity of water required for each village was quantified. The amount of water required for a village is the sum of different water uses like domestic water requirements, Livestock water consumption, cultivation and industrial sectors. The water requirement is primarily dependent on the water use of a village domestic, livestock and cultivation. The proportion of water requirement in three different activities in the study area is given in the following **table no 4.9 and Fig. 4.10**.

Table 4.9 Proportion of water requirement in Indapur tahsil

Sr. No.	Water requirement type	Requirement in MCM	In %
1	Domestic requirement	11.00	1.83
2	Agricultural requirement	580.36	96.50
3	Industrial requirement	10.02	1.67
	Total	601.38	100.00

Source: District Socio Economic Report 2012, Census 2011 and data analysis.

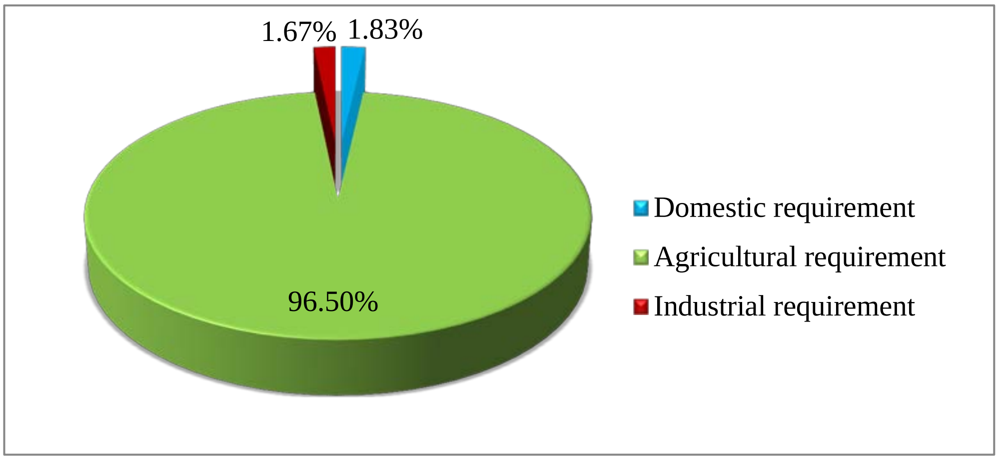


Fig. 4.10 Proportion of water requirement in the study area

It is clear from the above table and figure that the total water requirement for agricultural claims to 580.36 MCM (96.50%), it is a large proportion. In the industrial sector 10.02 MCM (1.67%) required water, it is considerably low and only 11 MCM (1.83%) water required for domestic purposes. Thus agricultural water required to the only major water consumption sector in the study area.

4.2.1 Domestic requirement

The amount and quality of water used in human settlements influenced the social development of the society concerned and affects the biological development of the individual human beings. The quality and quantity of drinking water supplied to organisms has a direct effect on health. Water demand in households, workshops and public services has different quality requirements for drinking, cooking and other domestic uses for washing, showering, bathing, dish washing, laundry, house cleaning, car washing, yard and park watering, street cleaning, sewer flushing, toilet rinsing, fire extinguishing, heating and air conditioning.

The requirement for drinking and domestic water depends on physical as well as level of socio-economic development. However, World Health Organization (WHO) has estimated that about 200 litres per capita per day (lpcd) water is required for these purposes. It is estimated that 200 lpcd would be sufficient for one person per day living in towns and only 70 lpcd living in villages without flush latrines. The quantity of water required for each village per day, for domestic per annum was estimated as follows.

Quantity of water required per day, QH1= Total population of the village * 70 liter/day

Quantity of water required per annum for each village, QH= 365 * QH1

Taking this average requirement of water for domestic purposes, it has been estimated on the basis of rural and urban population of 2011. It is shown in **table no. 4.10 and fig no. 4.11**. Total population of the study area is 3, 83,183 persons out of them total rural population is 3, 57,668 and urban population is 25515. Thus, a total requirement of rural people per annum arrives at 9.14 MCM and for urban people,
it is 1.86 MCM and thus total 11 MCM water requirements for domestic use in the study area has been estimated.

There is a wide regional variation in the requirement, which is the size of the rural and urban population. Rural necessity ranges from 0.007 MCM in Taratgaon village to 0.42 MCM in Kalamb village of study area. It is simply a reflection of the number of people living in these villages. The report of Panchyat Samiti 2010 mentions that the per capita water requirement for rural population is around 50 lpcd. This is on the basis of assumption that the rural water requirement is one third of the urban requirements.

Table 4.10 Village wise domestic water requirement and availability of water (MCM)

Sr. No.	Name of Village	Water Required	Water Available	Sr. No.	Name of village	Water Required	Water Available	Sr. No.	Name of Village	Water Required	Water Available
1	Shetphalgadhe	0.11	14.82	25	Loni	0.07	11.37	49	Mankarwadi	0.03	0.98
2	Pimple	0.03	6.06	26	Varkute Bk.	0.07	17.89	50	Gholapwadi	0.04	2.31
3	Madanwadi	0.15	14.56	27	Balpudi	0.02	5.20	51	Tawashi	0.08	4.06
4	Takrarwadi	0.06	4.56	28	Karewadi	0.04	3.31	52	Jamb	0.04	4.36
5	Bhigvan	0.20	9.67	29	Lakdi	0.07	9.70	53	Kurwali	0.07	6.31
6	Bhigvanstaion	0.07	NA	30	Shindewadi	0.05	3.86	54	Chikhali	0.04	4.82
7	Diksal	0.04	4.54	31	Kazad	0.08	14.50	55	Pilewadi	0.03	2.95
8	Kumbhargaon	0.03	5.66	32	Nimbodi	0.05	6.36	56	Maradwadi	0.01	4.49
9	Bandgarwadi	0.02	3.20	33	Bori	0.15	14.40	57	Nhavi	0.08	17.78
10	Poundhawadi	0.05	6.94	34	Sansar	0.17	14.16	58	Rui	0.08	9.25
11	Lamjewadi	0.02	3.30	35	Bhavaninagar	0.10	NA	59	Gosaviwadi	0.03	2.10
12	Nirgude	0.05	23.29	36	Jachakvasti	0.03	NA	60	Kalas	0.11	36.55
13	Mhasobachiwadi	0.05	5.20	37	Kardanwadi	0.02	2.48	61	Thoratwadi	0.01	6.07
14	Vaysewadi	0.01	2.33	38	Jankshan	0.12	0.00	62	Birgundwadi	0.02	4.73
15	Akole	0.08	12.17	39	Lasurne	0.22	19.20	63	Shelgaon	0.21	34.52
16	Bhadalwadi	0.07	9.10	40	Pawarwadi	0.06	2.30	64	Bharnewadi	0.11	0.45
17	Dalaj No.1	0.03	5.83	41	Belwadi	0.13	1.92	65	Anthurne	0.16	18.81
18	Dalaj No.2	0.04	NA	42	Sapkalwadi	0.03	NA	66	Kadbanwadi	0.04	7.38
19	Dalaj No.3	0.02	12.37	43	Hingnewadi	0.03	1.54	67	Hangarwadi	0.05	4.11
20	Kalewadi	0.04	11.34	44	Udhat	0.05	3.78	68	Pitkeshwar	0.05	6.69
21	Bandewadi	0.01	2.58	45	Paritwadi	0.03	3.23	69	Sarafwadi	0.05	2.33
22	Palasdeo	0.09	11.83	46	Thoratwadi	0.02	NA	70	Ghorpadwadi	0.04	4.31
23	Malewadi	0.05	5.76	47	Chavhanwadi	0.01	1.73	71	Sirsatwadi	0.05	NA
24	Bhawadi	0.02	6.59	48	Bambadwadi	0.02	0.60	72	Ranmodwadi	0.09	3.88

Continued…..

Sr. No.	Name of Village	Water Required	Water Available	Sr. No.	Name of Village	Water Required	Water Available	Sr. No.	Name of Village	Water Required	Water Available
73	Kalamb	0.42	15.09	97	Sugaon	0.01	6.05	121	Avasari	0.05	8.15
74	Nimsakhar	0.15	15.99	98	Pimpri Kh.	0.04	3.82	122	Bhat Nimgaon	0.04	6.21
75	Nirwangi	0.09	12.12	99	Malwadi	0.11	7.74	123	Shetphal Haveli	0.08	11.52
76	Kauthali	0.07	7.98	100	Galandwadi No.1	0.05	2.49	124	Surwad	0.07	4.82
77	Vyahali	0.04	9.11	101	Narutwadi	0.03	2.66	125	Bhandgaon	0.08	9.01
78	Kacharewadi	0.02	2.00	102	Kalthan No.2	0.03	1.67	126	Vakilvasti	0.05	1.50
79	Gotandi	0.12	15.09	103	Gagargaon	0.02	6.73	127	Bawada	0.27	34.01
80	Nimgaon Ketki	0.32	23.19	104	Bijwadi	0.09	3.56	128	Bhodani	0.06	4.19
81	Varkute Kh.	0.12	11.33	105	Rajwadi	0.01	2.39	129	Lakhewadi	0.12	3.29
82	Kati	0.14	13.71	106	Vangali	0.03	4.62	130	Chakati	0.03	11.50
83	Jadhavwadi	0.01	1.01	107	Pondkulwadi	0.03	5.43	131	Pithewadi	0.03	3.33
84	Reda	0.06	3.90	108	Shaha	0.06	7.46	132	Nirnimgaon	0.07	4.22
85	Redni	0.10	10.14	109	Kandalgaon	0.05	12.18	133	Kacharewadi	0.03	3.59
86	Khorochi	0.09	9.42	110	Taratgaon	0.01	2.94	134	Sarati	0.06	5.08
87	Boratwadi	0.04	2.85	111	Hingangaon	0.05	6.58	135	Lumewadi	0.08	5.28
88	Chandgaon	0.02	5.00	112	Sardewadi	0.08	3.09	136	Gondi	0.03	3.74
89	Agoti No.1	0.03	3.74	113	Galandwadi No.2	0.06	15.98	137	Ganeshwadi	0.03	4.00
90	Agoti No.2	0.02	3.60	114	Gokhali	0.04	3.15	138	Pimpri Bk.	0.06	6.44
91	Ganjewalan	0.02	5.86	115	Tarangwadi	0.07	8.02	139	Tannu	0.05	5.48
92	Kalashi	0.05	6.82	116	Zagadewadi	0.03	7.49	140	Narsingpur	0.06	6.06
93	Kalthan No.1	0.05	7.74	117	Pandharwadi	0.03	NA	141	Giravi	0.05	8.39
94	Shirsodi	0.05	8.54	118	Vadapuri	0.11	11.22	142	Ozare	0.02	3.12
95	Padsthal	0.04	7.81	119	Bedshinge	0.02	3.37	143	Indapur Urban	1.86	14.05
96	Ajoti	0.02	5.70	120	Babhulgaon	0.06	9.66		Total	11.00	1021.48

Source: Compiled and processed by author, NA: Not available, Water in MCM,

Fig. 4.11

Source: Author

4.2.2 Agricultural requirement

Agricultural water requirements are frequently satisfied by a combination of on-site and external supplies. The regulating function of water has to be achieved by an external water supply for regulating the soil moisture by means of irrigation and drainage, livestock and poultry breeding, fish and water poultry breeding, processing, boiling, cooling, heating, waste disposal, public uses in agricultural settlements.

With the modernization of agriculture, irrigation has become imperative. In fact the green revolution has started in areas where reliable sources of irrigation water existed. Total net sown area in the tahsil is 114092 hectors in the year 2012 and more than 83067 hectors (52.72 %) area under irrigation of the total study area. The irrigation department of Maharashtra has taken the data for estimation of water requirement for irrigation in this area. It is proposed to estimate for only half of the net sown area in the first instance. Water requirement for irrigation depends on several factors such as the characteristics of soil, season of cultivation, nature of crops and method of cropping. Agricultural water use of a village was estimated based on the quantity of water required for cultivation of different crops in a village during cropping seasons. The major crops cultivated during kharif (June to October) and rabbi (November to March) and their irrigation water requirements were used in the estimation of village wise agricultural water requirements. In this major crops assumed in agriculture water use estimation were Cereals, Pulses, Oil seeds, vegetables, Fruit's, Sugarcane, cotton, Fodder, Spice, Medicinal and Non-eatable. The total irrigation water requirements of different crops per ha in kharif and rabbi season are shown in **Table 4.11 and Fig 4.12.**

Quantity of water requirement for cultivation during Kharif and Rabbi season (QK) = Cereals water demand + Pulses water demand + Oil seeds water demand + vegetables water demand + Fruit's water demand + Sugarcane water demand + cotton water demand + Fodder water demand + Spice water demand + Medicinal water demand + Non-eatable water demand

QK = No of Acers * 450/100000 + No of Acers * 500/100000 + No of Acers * 506/100000 + No of Acers * 450/100000 + No of Acers * 600/100000 + No of Acers * 1200/100000 + No of Acers * 500/100000 + No of Acers * 225/100000 + No of Acers * 625/100000 + No of Acers * 625/100000 + No of Acers * 500/100000

Similarly, Rabbi season agriculture water requirement was estimated, based on the standard water consumption values.

Quantity of water requirement for cultivation during Rabbi season (QR) = water demand for cereals + Pulses water demand + water demand for oil seeds + water demand for vegetables + water demand for fruit's + water demand for sugarcane + water demand for cotton + water demand for fodder + water demand for spice + water demand for medicinal + water demand for non-eatable cultivation.

Table no. 4.11 Village wise net sown area under cereals crop and water requirement in MCM.

Sr. No.	Village Name	Cereals	Water Req.	Pulses	Water Req.	Sugar-cane	Water Req.	Oil-seeds	Water Req.	Fruits	Water Req.	Vege-table	Water Req.
1	Shetphalgadhe	948	4.27	94	0.47	112	1.34	63	0.32	83	0.50	23	0.10
2	Pimpale	608	2.74	78	0.39	9	0.11	14	0.07	9	0.05	7	0.03
3	Madanwadi	978	4.40	187	0.94	107	1.28	56	0.28	10	0.06	14	0.06
4	Takrarwadi	55	0.25	36	0.18	6	0.07	11	0.06	0	0.00	4	0.02
5	Bhigwan	368	1.66	92	0.46	112	1.34	36	0.18	11	0.07	41	0.18
6	Dikasal	397	1.79	32	0.16	52	0.62	23	0.12	6	0.04	16	0.07
7	Kumbhargaon	402	1.81	34	0.17	64	0.77	18	0.09	8	0.05	12	0.05
8	Bandgarwadi	76	0.34	12	0.06	9	0.11	6	0.03	6	0.04	7	0.03
9	Poundhawadi	443	1.99	113	0.57	132	1.58	14	0.07	12	0.07	24	0.11
10	Lamjewadi	182	0.82	14	0.07	21	0.25	9	0.05	3	0.02	12	0.05
11	Nirgude	531	2.39	143	0.72	62	0.74	17	0.09	56	0.34	47	0.21
12	Mhasobachiwadi	867	3.90	83	0.42	34	0.41	22	0.11	10	0.06	39	0.18
13	Vaysewadi	132	0.59	19	0.10	12	0.14	9	0.05	6	0.04	19	0.09
14	Akole	903	4.06	31	0.16	143	1.72	46	0.23	6	0.04	23	0.10
15	Bhadalwadi	849	3.82	48	0.24	53	0.64	69	0.35	45	0.27	28	0.13
16	Dalaj No. 1	134	0.60	19	0.10	14	0.17	12	0.06	8	0.05	2	0.01
17	Dalaj No. 2	278	1.25	13	0.07	81	0.97	11	0.06	15	0.09	6	0.03
18	Dalaj No. 3	258	1.16	2	0.01	83	1.00	3	0.02	7	0.04	12	0.05
19	Kalewadi	458	2.06	27	0.14	62	0.74	13	0.07	4	0.02	15	0.07
20	Bandewadi	33	0.15	12	0.06	8	0.10	6	0.03	3	0.02	7	0.03
21	Palasdeo	544	2.45	27	0.14	56	0.67	13	0.07	3	0.02	21	0.09
22	Malewadi	171	0.77	17	0.09	21	0.25	6	0.03	6	0.04	8	0.04
23	Bhawadi	496	2.23	31	0.16	63	0.76	23	0.12	5	0.03	20	0.09

Continued…..

Sr.No.	Village Name	Cereals	Water Req.	Pulses	Water Req.	Sugar-cane	Water Req.	Oil-seeds	Water Req.	Fruits	Water Req.	Vege-table	Water Req.
24	Loni	1164	5.24	24	0.12	89	1.07	13	0.07	11	0.07	32	0.14
25	Varkute kh	1286	5.79	92	0.46	124	1.49	44	0.22	16	0.10	39	0.18
26	Balpudi	643	2.89	34	0.17	31	0.37	12	0.06	10	0.06	18	0.08
27	Karewadi	262	1.18	11	0.06	32	0.38	8	0.04	18	0.11	17	0.08
28	Lakdi	476	2.14	63	0.32	42	0.50	12	0.06	63	0.38	39	0.18
29	Shindewadi	585	2.63	74	0.37	139	1.67	25	0.13	67	0.40	28	0.13
30	Kazad	657	2.96	25	0.13	152	1.82	9	0.05	77	0.46	12	0.05
31	Nimbodi	473	2.13	47	0.24	29	0.35	15	0.08	41	0.25	27	0.12
32	Bori	972	4.37	69	0.35	9	0.11	31	0.16	187	1.12	68	0.31
33	Sansar	614	2.76	32	0.16	39	0.47	68	0.34	60	0.36	31	0.14
34	Bhawaninagar	78	0.35	10	0.05	17	0.20	19	0.10	3	0.02	12	0.05
35	Jachakvasti	178	0.80	12	0.06	39	0.47	43	0.22	23	0.14	12	0.05
36	Kardanwadi	118	0.53	34	0.17	12	0.14	16	0.08	6	0.04	9	0.04
37	Jankshan	98	0.44	9	0.05	14	0.17	17	0.09	52	0.31	16	0.07
38	Lasurne	2248	10.12	281	1.41	237	2.84	156	0.79	159	0.95	92	0.41
39	Pawarwadi	278	1.25	11	0.06	37	0.44	19	0.10	4	0.02	12	0.05
40	Belewadi	254	1.14	19	0.10	51	0.61	26	0.13	41	0.25	43	0.19
41	Sapkalwadi	79	0.36	19	0.10	21	0.25	9	0.05	3	0.02	5	0.02
42	Hinganewadi	139	0.63	12	0.06	23	0.28	19	0.10	9	0.05	5	0.02
43	Udhat	215	0.97	9	0.05	24	0.29	12	0.06	15	0.09	21	0.09
44	Paritwadi	273	1.23	22	0.11	37	0.44	17	0.09	23	0.14	18	0.08
45	Thoratwadi	180	0.81	28	0.14	21	0.25	17	0.09	21	0.13	11	0.05
46	Chavhanwadi	261	1.17	9	0.05	16	0.19	18	0.09	11	0.07	5	0.02
47	Bambadwadi	46	0.21	0	0.00	4	0.05	4	0.02	16	0.10	1	0.00

Continued…..

Sr.No.	Village Name	Cereals	Water Req.	Pulses	Water Req.	Sugar-cane	Water Req.	Oil-seeds	Water Req.	Fruits	Water Req.	Vege-table	Water Req.
48	Mankarwadi	67	0.30	11	0.06	12	0.14	13	0.07	13	0.08	9	0.04
49	Gholapwadi	29	0.13	8	0.04	23	0.28	11	0.06	27	0.16	8	0.04
50	Tawashi	489	2.20	8	0.04	52	0.62	16	0.08	21	0.13	13	0.06
51	Jamb	124	0.56	13	0.07	18	0.22	15	0.08	16	0.10	19	0.09
52	Kurawali	307	1.38	72	0.36	82	0.98	48	0.24	14	0.08	12	0.05
53	Chikhali	183	0.82	11	0.06	27	0.32	9	0.05	12	0.07	7	0.03
54	Pilewadi	262	1.18	27	0.14	56	0.67	11	0.06	46	0.28	23	0.10
55	Maradwadi	68	0.31	13	0.07	11	0.13	6	0.03	33	0.20	3	0.01
56	Nhavi	778	3.50	87	0.44	103	1.24	31	0.16	15	0.09	41	0.18
57	Rui	873	3.93	62	0.31	87	1.04	28	0.14	46	0.28	66	0.30
58	Gosaviwadi	548	2.47	21	0.11	29	0.35	29	0.15	74	0.44	43	0.19
59	Kalas	1831	8.24	447	2.24	183	2.20	87	0.44	131	0.79	74	0.33
60	Thoratwadi	198	0.89	12	0.06	35	0.42	18	0.09	23	0.14	42	0.19
61	Birungwadi	287	1.29	29	0.15	53	0.64	12	0.06	89	0.53	12	0.05
62	Shelgaon	1961	8.82	117	0.59	343	4.12	187	0.95	88	0.53	72	0.32
63	Bharnewadi	636	2.86	59	0.30	21	0.25	32	0.16	10	0.06	13	0.06
64	Anthurne	517	2.33	68	0.34	107	1.28	76	0.38	8	0.05	43	0.19
65	Kadbanwadi	1146	5.16	57	0.29	203	2.44	62	0.31	12	0.07	64	0.29
66	Hangarwadi	403	1.81	28	0.14	18	0.22	18	0.09	14	0.08	32	0.14
67	Pitkeshwar	313	1.41	17	0.09	159	1.91	21	0.11	10	0.06	27	0.12
68	Sarafwadi	302	1.36	18	0.09	52	0.62	22	0.11	3	0.02	41	0.18
69	Ghorpadwadi	314	1.41	29	0.15	17	0.20	9	0.05	3	0.02	36	0.16
70	Sirsatwadi	589	2.65	27	0.14	24	0.29	16	0.08	12	0.07	23	0.10
71	Ranmodwadi	361	1.62	29	0.15	23	0.28	19	0.10	19	0.11	12	0.05

Continued…..

Sr.No.	Village Name	Cereals	Water Req.	Pulses	Water Req.	Sugar-cane	Water Req.	Oil-seeds	Water Req.	Fruits	Water Req.	Vege-table	Water Req.
72	Kalamb	1538	6.92	93	0.47	147	1.76	149	0.75	73	0.44	42	0.19
73	Nimsakhar	1341	6.03	63	0.32	148	1.78	79	0.40	62	0.37	78	0.35
74	Nirwangi	867	3.90	19	0.10	109	1.31	21	0.11	49	0.29	42	0.19
75	Kauthali	789	3.55	73	0.37	56	0.67	71	0.36	82	0.49	73	0.33
76	Vyahali	497	2.24	83	0.42	61	0.73	66	0.33	117	0.70	57	0.26
77	Kacharewadi	154	0.69	17	0.09	21	0.25	6	0.03	19	0.11	12	0.05
78	Gotandi	1174	5.28	56	0.28	102	1.22	48	0.24	36	0.22	141	0.63
79	Nimgaon Ketki	1243	5.59	197	0.99	131	1.57	390	1.97	142	0.85	224	1.01
80	Varkute Kh.	788	3.55	51	0.26	21	0.25	26	0.13	16	0.10	162	0.73
81	Kati	1173	5.28	93	0.47	19	0.23	51	0.26	28	0.17	143	0.64
82	Jadhavwadi	34	0.15	32	0.16	8	0.10	9	0.05	3	0.02	13	0.06
83	Reda	464	2.09	111	0.56	33	0.40	32	0.16	8	0.05	32	0.14
84	Redani	1057	4.76	97	0.49	62	0.74	49	0.25	17	0.10	41	0.18
85	Khorochi	868	3.91	23	0.12	51	0.61	56	0.28	0	0.00	12	0.05
86	Boratwadi	352	1.58	43	0.22	22	0.26	28	0.14	12	0.07	32	0.14
87	Chandgaon	249	1.12	11	0.06	33	0.40	17	0.09	8	0.05	8	0.04
88	Agoti No.1	348	1.57	27	0.14	17	0.20	39	0.20	2	0.01	13	0.06
89	Agoti No.2	106	0.48	11	0.06	11	0.13	11	0.06	3	0.02	4	0.02
90	Ganjewalan	349	1.57	12	0.06	67	0.80	12	0.06	11	0.07	9	0.04
91	Kalashi	613	2.76	23	0.12	82	0.98	118	0.60	3	0.02	8	0.04
92	Kalthan No.1	838	3.77	14	0.07	79	0.95	76	0.38	2	0.01	21	0.09
93	Shirsadi	283	1.27	19	0.10	51	0.61	24	0.12	3	0.02	10	0.05
94	Padasthal	456	2.05	21	0.11	41	0.49	36	0.18	4	0.02	8	0.04
95	Ajoti	48	0.22	2	0.01	17	0.20	7	0.04	2	0.01	6	0.03

Continued…..

Sr.No.	Village Name	Cereals	Water Req.	Pulses	Water Req.	Sugar-cane	Water Req.	Oil-seeds	Water Req.	Fruits	Water Req.	Vege-table	Water Req.
96	Sugaon	29	0.13	5	0.03	12	0.14	3	0.02	1	0.01	0	0.00
97	Pimpri Kh.	278	1.25	4	0.02	23	0.28	34	0.17	3	0.02	3	0.01
98	Malwadi	892	4.01	131	0.66	35	0.42	42	0.21	14	0.08	36	0.16
99	Galandwadi No.1	352	1.58	19	0.10	63	0.76	38	0.19	1	0.01	30	0.14
100	Narutwadi	492	2.21	96	0.48	47	0.56	18	0.09	6	0.04	15	0.07
101	Kalthan No.2	879	3.96	28	0.14	37	0.44	12	0.06	2	0.01	23	0.10
102	Gagargaon	389	1.75	27	0.14	21	0.25	15	0.08	9	0.05	14	0.06
103	Bijwadi	492	2.21	37	0.19	12	0.14	7	0.04	3	0.02	58	0.26
104	Rajwadi	134	0.60	4	0.02	11	0.13	6	0.03	3	0.02	9	0.04
105	Vangali	389	1.75	19	0.10	15	0.18	18	0.09	3	0.02	16	0.07
106	Pondkulwadi	52	0.23	24	0.12	9	0.11	6	0.03	5	0.03	12	0.05
107	Shaha	485	2.18	17	0.09	51	0.61	41	0.21	6	0.04	12	0.05
108	Kandalgaon	714	3.21	26	0.13	49	0.59	28	0.14	2	0.01	33	0.15
109	Taratgaon	146	0.66	16	0.08	3	0.04	3	0.02	0	0.00	5	0.02
110	Hingangaon	487	2.19	21	0.11	62	0.74	137	0.69	5	0.03	13	0.06
111	Sardewadi	587	2.64	34	0.17	39	0.47	18	0.09	0	0.00	16	0.07
112	Galandwadi No.2	488	2.20	89	0.45	37	0.44	32	0.16	2	0.01	16	0.07
113	Gokhali	366	1.65	29	0.15	18	0.22	11	0.06	7	0.04	17	0.08
114	Tarangwadi	796	3.58	57	0.29	58	0.70	29	0.15	37	0.22	89	0.40
115	Zagadewadi	282	1.27	41	0.21	42	0.50	23	0.12	29	0.17	77	0.35
116	Pandharwadi	551	2.48	28	0.14	41	0.49	21	0.11	15	0.09	39	0.18
117	Vadapuri	1278	5.75	44	0.22	49	0.59	37	0.19	9	0.05	64	0.29
118	Bedshinge	204	0.92	17	0.09	47	0.56	16	0.08	3	0.02	21	0.09
119	Babhulgaon	924	4.16	28	0.14	79	0.95	34	0.17	17	0.10	30	0.14

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Sr.No.	Village Name	Cereals	Water Req.	Pulses	Water Req.	Sugar-cane	Water Req.	Oil-seeds	Water Req.	Fruits	Water Req.	Vege-table	Water Req.
120	Awasari	774	3.48	12	0.06	39	0.47	14	0.07	8	0.05	27	0.12
121	Bhat Nimgaon	495	2.23	68	0.34	41	0.49	16	0.08	12	0.07	11	0.05
122	Shetphal Haveli	1163	5.23	87	0.44	62	0.74	21	0.11	41	0.25	42	0.19
123	Surwad	286	1.29	12	0.06	57	0.68	36	0.18	22	0.13	23	0.10
124	Bhandgaon	776	3.49	19	0.10	178	2.14	23	0.12	5	0.03	61	0.27
125	Vakilwasti	429	1.93	13	0.07	61	0.73	10	0.05	4	0.02	7	0.03
126	Bawada	3221	14.49	123	0.62	463	5.56	178	0.90	51	0.31	124	0.56
127	Bhodani	512	2.30	26	0.13	41	0.49	42	0.21	9	0.05	12	0.05
128	Lakhewadi	831	3.74	43	0.22	78	0.94	47	0.24	12	0.07	57	0.26
129	Chakati	552	2.48	13	0.07	24	0.29	16	0.08	14	0.08	16	0.07
130	Pithewadi	377	1.70	8	0.04	19	0.23	13	0.07	1	0.01	6	0.03
131	Nirnimgaon	428	1.93	30	0.15	57	0.68	23	0.12	9	0.05	4	0.02
132	Kacharewadi	312	1.40	31	0.16	76	0.91	23	0.12	1	0.01	3	0.01
312	Sarati	436	1.96	7	0.04	163	1.96	17	0.09	12	0.07	21	0.09
134	Lumewadi	468	2.11	7	0.04	123	1.48	19	0.10	0	0.00	10	0.05
135	Gondi	176	0.79	39	0.20	81	0.97	32	0.16	3	0.02	10	0.05
136	Ganeshwadi	315	1.42	8	0.04	102	1.22	19	0.10	15	0.09	12	0.05
137	Pimpri Bk.	489	2.20	63	0.32	142	1.70	28	0.14	9	0.05	9	0.04
138	Tannu	342	1.54	78	0.39	86	1.03	41	0.21	10	0.06	27	0.12
139	Narsingpur	478	2.15	51	0.26	96	1.15	36	0.18	4	0.02	9	0.04
140	Giravi	518	2.33	52	0.26	72	0.86	53	0.27	9	0.05	34	0.15
141	Ozare	189	0.85	6	0.03	43	0.52	12	0.06	3	0.02	5	0.02
142	Indapur	2676	12.04	118	0.59	289	3.47	167	0.85	36	0.22	134	0.60
	Total	77832	350.24	6326	31.63	8935	107.22	4861	24.60	3171	19.03	4218	18.98

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Sr.No.	Village Name	Spice	Water Req.	Medi-cinal	Water Req.	Faber Crop	Water Req.	Fodder	Water Req.	Non-eatable	Water Req.	Total NSA	Total Water
1	Shetphalgadhe	7	0.04	0	0.00	2	0.01	89.00	0.20	7	0.04	1428	7.29
2	Pimpale	3	0.02	2	0.01	1	0.01	28.00	0.06	2	0.01	761	3.50
3	Madanwadi	1	0.01	0	0.00	0	0.00	76.00	0.17	1	0.01	1430	7.21
4	Takrarwadi	0	0.00	0	0.00	0	0.00	12.00	0.03	0	0.00	124	0.60
5	Bhigvan	9	0.06	0	0.00	3	0.02	76.00	0.17	8	0.04	756	4.17
6	Dikasal	0	0.00	0	0.00	0	0.00	26.00	0.06	0	0.00	552	2.85
7	Kumbhargaon	0	0.00	0	0.00	0	0.00	15.00	0.03	0	0.00	553	2.97
8	Bandgarwadi	0	0.00	0	0.00	0	0.00	15.00	0.03	0	0.00	131	0.64
9	Poundhawadi	2	0.01	0	0.00	0	0.00	60.00	0.14	2	0.01	802	4.55
10	Lamjewadi	3	0.02	1	0.01	1	0.01	21.00	0.05	0	0.00	267	1.34
11	Nirgude	4	0.03	0	0.00	2	0.01	73.00	0.16	9	0.05	944	4.73
12	Mhasobachiwadi	2	0.01	1	0.01	1	0.01	59.00	0.13	5	0.03	1123	5.25
13	Vaysewadi	0	0.00	0	0.00	0	0.00	21.00	0.05	2	0.01	220	1.06
14	Akole	3	0.02	0	0.00	3	0.02	43.00	0.10	12	0.06	1213	6.50
15	Bhadalwadi	0	0.00	1	0.01	0	0.00	46.00	0.10	4	0.02	1143	5.57
16	Dalaj No.1	0	0.00	0	0.00	0	0.00	9.00	0.02	0	0.00	198	1.00
17	Dalaj No.2	0	0.00	0	0.00	0	0.00	45.00	0.10	2	0.01	451	2.57
18	Dalaj No.3	0	0.00	0	0.00	0	0.00	25.00	0.06	0	0.00	390	2.33
19	Kalewadi	0	0.00	0	0.00	0	0.00	64.00	0.14	0	0.00	643	3.24
20	Bandewadi	0	0.00	0	0.00	0	0.00	5.00	0.01	1	0.01	75	0.40
21	Palasdeo	0	0.00	0	0.00	0	0.00	26.00	0.06	3	0.02	693	3.51
22	Malewadi	0	0.00	0	0.00	0	0.00	25.00	0.06	5	0.03	259	1.29
23	Bhawadi	0	0.00	0	0.00	0	0.00	18.00	0.04	2	0.01	658	3.43

Continued…..

Sr.No.	Village Name	Spice	Water Req.	Medi-cinal	Water Req.	Faber Crop	Water Req.	Fodder	Water Req.	Non-eatable	Water Req.	Total NSA	Total Water
24	Loni	0	0.00	0	0.00	0	0.00	70.00	0.16	6	0.03	1409	6.89
25	Varkute Bk.	0	0.00	0	0.00	0	0.00	48.00	0.11	7	0.04	1656	8.37
26	Balpudi	0	0.00	0	0.00	1	0.01	16.00	0.04	2	0.01	767	3.69
27	Karewadi	0	0.00	0	0.00	1	0.01	29.00	0.07	0	0.00	378	1.91
28	Lakadi	1	0.01	1	0.01	3	0.02	58.00	0.13	13	0.07	771	3.80
29	Shindewadi	1	0.01	1	0.01	1	0.01	51.00	0.11	8	0.04	980	5.50
30	Kazad	1	0.01	0	0.00	0	0.00	13.00	0.03	7	0.04	953	5.54
31	Nimbodi	1	0.01	0	0.00	2	0.01	39.00	0.09	11	0.06	685	3.31
32	Bori	2	0.01	0	0.00	7	0.04	45.00	0.10	7	0.04	1397	6.60
33	Sansar	0	0.00	0	0.00	0	0.00	56.00	0.13	16	0.08	916	4.44
34	Bhawaninagar	0	0.00	0	0.00	0	0.00	15.00	0.03	0	0.00	154	0.81
35	Jachakvasti	0	0.00	0	0.00	0	0.00	16.00	0.04	6	0.03	329	1.80
36	Kardanwadi	0	0.00	0	0.00	0	0.00	12.00	0.03	1	0.01	208	1.03
37	Jankshan	4	0.03	0	0.00	0	0.00	11.00	0.02	0	0.00	221	1.17
38	Lasurne	7	0.04	1	0.01	2	0.01	136.00	0.31	11	0.06	3330	16.94
39	Pawarwadi	0	0.00	0	0.00	0	0.00	31.00	0.07	2	0.01	394	2.00
40	Belewadi	7	0.04	1	0.01	0	0.00	51.00	0.11	2	0.01	495	2.60
41	Sapkalwadi	0	0.00	0	0.00	0	0.00	13.00	0.03	0	0.00	149	0.82
42	Hinganewadi	0	0.00	0	0.00	0	0.00	19.00	0.04	0	0.00	226	1.18
43	Udhat	0	0.00	1	0.01	0	0.00	37.00	0.08	8	0.04	342	1.68
44	Paritwadi	1	0.01	0	0.00	0	0.00	29.00	0.07	2	0.01	422	2.17
45	Thoratwadi	0	0.00	0	0.00	0	0.00	20.00	0.05	0	0.00	298	1.51
46	Chavhanwadi	0	0.00	0	0.00	0	0.00	12.00	0.03	4	0.02	336	1.64
47	Bambadwadi	0	0.00	0	0.00	0	0.00	13.00	0.03	1	0.01	85	0.41

Continued…..

Sr.No.	Village Name	Spice	Water Req.	Medi-cinal	Water Req.	Faber Crop	Water Req.	Fodder	Water Req.	Non-eatable	Water Req.	Total NSA	Total Water
48	Mankarwadi	0	0.00	0	0.00	0	0.00	18.00	0.04	0	0.00	143	0.73
49	Gholapwadi	0	0.00	0	0.00	0	0.00	13.00	0.03	3	0.02	122	0.74
50	Tawashi	3	0.02	0	0.00	0	0.00	39.00	0.09	7	0.04	648	3.27
51	Jamb	0	0.00	0	0.00	0	0.00	48.00	0.11	4	0.02	257	1.22
52	Kurawali	2	0.01	0	0.00	0	0.00	25.00	0.06	1	0.01	563	3.18
53	Chikhali	0	0.00	0	0.00	3	0.02	34.00	0.08	3	0.02	289	1.46
54	Pilewadi	0	0.00	0	0.00	0	0.00	42.00	0.09	2	0.01	469	2.53
55	Maradwadi	0	0.00	0	0.00	1	0.01	15.00	0.03	0	0.00	150	0.78
56	Nhavi	0	0.00	1	0.01	3	0.02	56.00	0.13	9	0.05	1124	5.80
57	Rui	4	0.03	1	0.01	7	0.04	109.00	0.25	5	0.03	1288	6.33
58	Gosaviwadi	0	0.00	0	0.00	1	0.01	46.00	0.10	1	0.01	792	3.82
59	Kalas	2	0.01	1	0.01	9	0.05	218.00	0.49	16	0.08	2999	14.86
60	Thoratwadi	0	0.00	0	0.00	4	0.02	26.00	0.06	1	0.01	359	1.87
61	Birgundwadi	0	0.00	0	0.00	0	0.00	49.00	0.11	3	0.02	534	2.85
62	Shelgaon	21	0.13	3	0.02	0	0.00	203.00	0.46	13	0.07	3008	16.00
63	Bharnewadi	0	0.00	1	0.01	0	0.00	87.00	0.20	0	0.00	859	3.89
64	Anthurne	12	0.08	2	0.01	2	0.01	63.00	0.14	7	0.04	905	4.85
65	Kadbanwadi	9	0.06	1	0.01	0	0.00	73.00	0.16	0	0.00	1627	8.78
66	Hangarwadi	0	0.00	0	0.00	0	0.00	46.00	0.10	1	0.01	560	2.60
67	Pitkeshwar	7	0.04	3	0.02	1	0.01	35.00	0.08	0	0.00	593	3.84
68	Sarafwadi	4	0.03	1	0.01	0	0.00	46.00	0.10	1	0.01	490	2.53
69	Ghorpadwadi	3	0.02	1	0.01	0	0.00	17.00	0.04	0	0.00	429	2.05
70	Sirsatwadi	1	0.01	0	0.00	0	0.00	41.00	0.09	2	0.01	735	3.44
71	Ranmodwadi	3	0.02	0	0.00	0	0.00	39.00	0.09	3	0.02	508	2.43

Continued…..

Sr.No.	Village Name	Spice	Water Req.	Medi-cinal	Water Req.	Faber Crop	Water Req.	Fodder	Water Req.	Non-eatable	Water Req.	Total NSA	Total Water
72	Kalamb	7	0.04	2	0.01	4	0.02	196.00	0.44	14	0.07	2265	11.12
73	Nimsakhar	12	0.08	2	0.01	3	0.02	68.00	0.15	8	0.04	1864	9.54
74	Nirwangi	16	0.10	1	0.01	2	0.01	43.00	0.10	6	0.03	1175	6.14
75	Kauthali	7	0.04	1	0.01	3	0.02	99.00	0.22	1	0.01	1255	6.06
76	Vyahali	9	0.06	2	0.01	5	0.03	155.00	0.35	2	0.01	1054	5.13
77	Kacharewadi	8	0.05	0	0.00	9	0.05	24.00	0.05	0	0.00	270	1.38
78	Gotandi	12	0.08	0	0.00	2	0.01	21.00	0.05	2	0.01	1594	8.02
79	Nimgaon Ketki	24	0.15	3	0.02	1	0.01	189.00	0.43	3	0.02	2547	12.60
80	Varkute Kh.	11	0.07	2	0.01	2	0.01	86.00	0.19	2	0.01	1167	5.30
81	Kati	23	0.14	0	0.00	3	0.02	19.00	0.04	1	0.01	1553	7.25
82	Jadhavwadi	1	0.01	0	0.00	0	0.00	15.00	0.03	0	0.00	115	0.57
83	Reda	4	0.03	0	0.00	9	0.05	43.00	0.10	2	0.01	738	3.57
84	Redani	3	0.02	1	0.01	0	0.00	132.00	0.30	3	0.02	1462	6.86
85	Khorochi	0	0.00	0	0.00	4	0.02	78.00	0.18	8	0.04	1100	5.21
86	Boratwadi	2	0.01	2	0.01	1	0.01	64.00	0.14	11	0.06	569	2.65
87	Chandgaon	0	0.00	0	0.00	0	0.00	29.00	0.07	2	0.01	357	1.82
88	Agoti No.1	0	0.00	0	0.00	0	0.00	19.00	0.04	3	0.02	468	2.23
89	Agoti No.2	0	0.00	0	0.00	0	0.00	21.00	0.05	1	0.01	168	0.81
90	Ganjewalan	1	0.01	0	0.00	0	0.00	49.00	0.11	2	0.01	512	2.73
91	Kalashi	0	0.00	0	0.00	0	0.00	90.00	0.20	3	0.02	940	4.73
92	Kalthan No.1	0	0.00	0	0.00	0	0.00	63.00	0.14	5	0.03	1098	5.45
93	Shirsadi	0	0.00	0	0.00	0	0.00	46.00	0.10	2	0.01	438	2.28
94	Padasthal	0	0.00	0	0.00	0	0.00	17.00	0.04	3	0.02	586	2.94
95	Ajoti	0	0.00	0	0.00	0	0.00	11.00	0.02	2	0.01	95	0.54

Continued…..

Sr.No.	Village Name	Spice	Water Req.	Medi-cinal	Water Req.	Faber Crop	Water Req.	Fodder	Water Req.	Non-eatable	Water Req.	Total NSA	Total Water
96	Sugaon	0	0.00	0	0.00	0	0.00	4.00	0.01	1	0.01	55	0.33
97	Pimpri Kh.	0	0.00	0	0.00	0	0.00	15.00	0.03	6	0.03	366	1.81
98	Malwadi	0	0.00	0	0.00	0	0.00	143.00	0.32	2	0.01	1295	5.88
99	Galandwadi No.1	4	0.03	0	0.00	0	0.00	102.00	0.23	1	0.01	610	3.03
100	Narutwadi	1	0.01	0	0.00	0	0.00	85.00	0.19	0	0.00	760	3.65
101	Kalthan No.2	0	0.00	0	0.00	0	0.00	52.00	0.12	4	0.02	1037	4.85
102	Gagargaon	3	0.02	1	0.01	2	0.01	51.00	0.11	1	0.01	533	2.49
103	Bijwadi	5	0.03	0	0.00	0	0.00	54.00	0.12	0	0.00	668	3.01
104	Rajwadi	1	0.01	0	0.00	0	0.00	20.00	0.05	0	0.00	188	0.90
105	Vangali	0	0.00	0	0.00	0	0.00	15.00	0.03	0	0.00	475	2.24
106	Pondkulwadi	0	0.00	1	0.01	2	0.01	12.00	0.03	0	0.00	123	0.62
107	Shaha	0	0.00	0	0.00	0	0.00	51.00	0.11	2	0.01	665	3.30
108	Kandalgaon	0	0.00	0	0.00	3	0.02	24.00	0.05	6	0.03	885	4.33
109	Taratgaon	0	0.00	0	0.00	0	0.00	13.00	0.03	1	0.01	187	0.84
110	Hingangaon	0	0.00	0	0.00	0	0.00	21.00	0.05	1	0.01	747	3.87
111	Sardewadi	2	0.01	2	0.01	3	0.02	29.00	0.07	2	0.01	732	3.56
112	Galandwadi No.2	3	0.02	3	0.02	9	0.05	56.00	0.13	0	0.00	735	3.54
113	Gokhali	2	0.01	2	0.01	1	0.01	39.00	0.09	0	0.00	492	2.30
114	Tarangwadi	7	0.04	3	0.02	2	0.01	43.00	0.10	0	0.00	1121	5.50
115	Zagadewadi	9	0.06	3	0.02	3	0.02	26.00	0.06	1	0.01	536	2.77
116	Pandharwadi	4	0.03	0	0.00	3	0.02	75.00	0.17	0	0.00	777	3.69
117	Vadapuri	13	0.08	3	0.02	7	0.04	48.00	0.11	0	0.00	1552	7.33
118	Bedshinge	7	0.04	2	0.01	0	0.00	46.00	0.10	2	0.01	365	1.93
119	Babhulgaon	0	0.00	0	0.00	0	0.00	83.00	0.19	3	0.02	1198	5.86

Continued…..

Sr.No.	Village Name	Spice	Water Req.	Medi-cinal	Water Req.	Faber Crop	Water Req.	Fodder	Water Req.	Non-eatable	Water Req.	Total NSA	Total Water
120	Awasari	5	0.03	1	0.01	2	0.01	24.00	0.05	9	0.05	915	4.40
121	Bhat Nimgaon	0	0.00	2	0.01	0	0.00	54.00	0.12	12	0.06	711	3.46
122	Shetphal Haveli	7	0.04	0	0.00	6	0.03	83.00	0.19	16	0.08	1528	7.29
123	Surwad	0	0.00	1	0.01	0	0.00	42.00	0.09	10	0.05	489	2.60
124	Bhandgaon	7	0.04	3	0.02	0	0.00	62.00	0.14	14	0.07	1148	6.42
125	Vakilwasti	0	0.00	0	0.00	0	0.00	49.00	0.11	9	0.05	582	2.99
126	Bawada	6	0.04	4	0.03	7	0.04	278.00	0.63	19	0.10	4474	23.25
127	Bhodani	3	0.02	0	0.00	0	0.00	34.00	0.08	3	0.02	682	3.36
128	Lakhewadi	2	0.01	3	0.02	2	0.01	92.00	0.21	2	0.01	1169	5.72
129	Chakati	3	0.02	1	0.01	2	0.01	59.00	0.13	7	0.04	707	3.28
130	Pithewadi	0	0.00	0	0.00	0	0.00	46.00	0.10	5	0.03	475	2.19
131	Nirnimgaon	1	0.01	3	0.02	3	0.02	51.00	0.11	13	0.07	622	3.17
132	Kacharewadi	0	0.00	0	0.00	2	0.01	13.00	0.03	6	0.03	467	2.68
312	Sarati	0	0.00	0	0.00	0	0.00	96.00	0.22	9	0.05	761	4.47
134	Lumewadi	2	0.01	2	0.01	2	0.01	22.00	0.05	2	0.01	657	3.85
135	Gondi	0	0.00	0	0.00	0	0.00	72.00	0.16	4	0.02	417	2.37
136	Ganeshwadi	0	0.00	0	0.00	0	0.00	76.00	0.17	7	0.04	554	3.13
137	Pimpri Bk.	0	0.00	0	0.00	0	0.00	123.00	0.28	17	0.09	880	4.82
138	Tannu	0	0.00	0	0.00	0	0.00	96.00	0.22	9	0.05	689	3.61
139	Narsingpur	0	0.00	0	0.00	0	0.00	64.00	0.14	6	0.03	744	3.98
140	Giravi	0	0.00	0	0.00	0	0.00	67.00	0.15	11	0.06	816	4.14
141	Ozare	0	0.00	0	0.00	0	0.00	21.00	0.05	6	0.03	285	1.57
142	Indapur	0	0.00	0	0.00	3	0.02	236.00	0.53	3	0.02	3662	18.33
	Total	367	2.29	81	0.51	173	0.87	7549.00	16.99	579	2.90	114092	575.24

Source: Agriculture office, Indapur 2012 and Compiled by author

Source: Computed by author

Fig. 4.12

Table 4.12 and Fig.4.13a Shows area under crop and **Fig. 4.13b** shows water requirements

Sr. No.	Crop	Req. water in mm	Area under crop (ha)	Area in %	Water requirement in MCM	Water in %
1	Cereals	450	77832	68.22	350.24	60.89
2	Pulses	500	6326	5.54	31.63	5.50
3	Oil seeds	506	4861	4.26	24.60	4.27
4	Vegetable	450	4218	3.70	18.98	3.30
5	Fruit's	600	3171	2.78	19.03	3.31
6	Sugarcane	1200	8935	7.83	107.22	18.64
7	Cotton	500	173	0.15	0.86	0.15
8	Fodder	225	7549	6.62	16.98	2.95
9	Spice	625	367	0.32	2.29	0.40
10	Medicinal	625	81	0.07	0.51	0.09
11	Non-eatable	500	579	0.51	2.89	0.50
	Total		114092	100.00	575.24	100.00

Source: District Socio Economic Report 2012, Santosh Kumar Garg (2011) Irrigation Engineering and Hydraulic structures, Khanna publishers, New Delhi, 24th editions and data analysis.

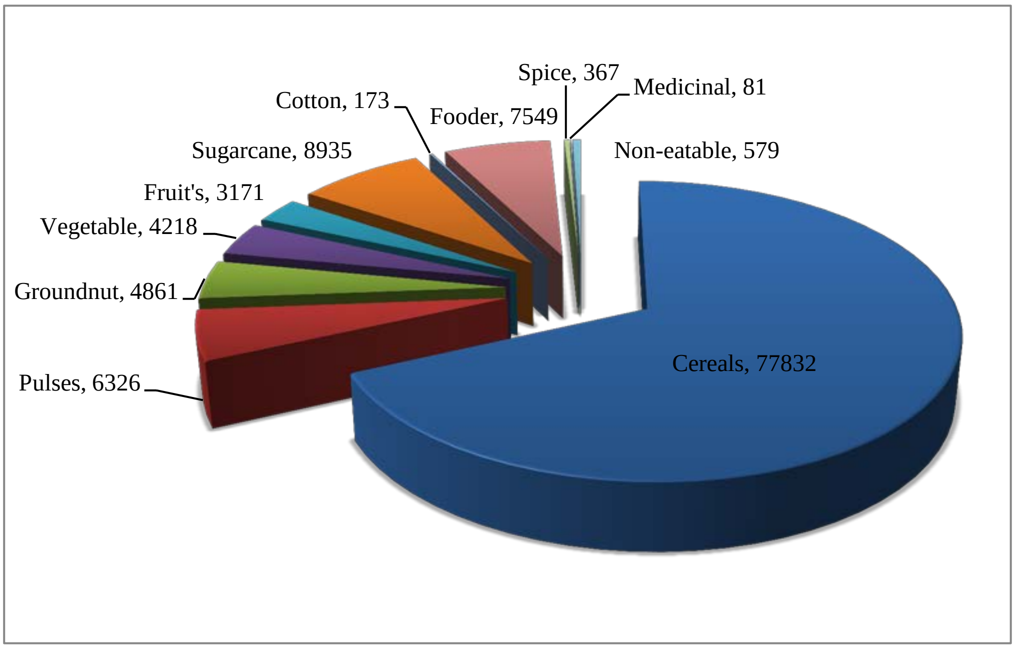


Fig. 4.13a Area under crop

More than 74% population in the study area is directly or indirectly connected to agricultural activity. The major crops of the study area are millets, wheat, maize, sugarcane and fodder etc. The impact of irrigated agriculture on water resources is significant since it uses 96.50% of the total water resources in the study area. There are 68.22% area under cereals and requires about 60.89% of water resources whereas around 7.83% area is under sugarcane and 18.64% water required for this crop. Below 1% area under cotton, spices, medicinal and non-eatable crop and less than 1% water required to cotton and medicinal crop.

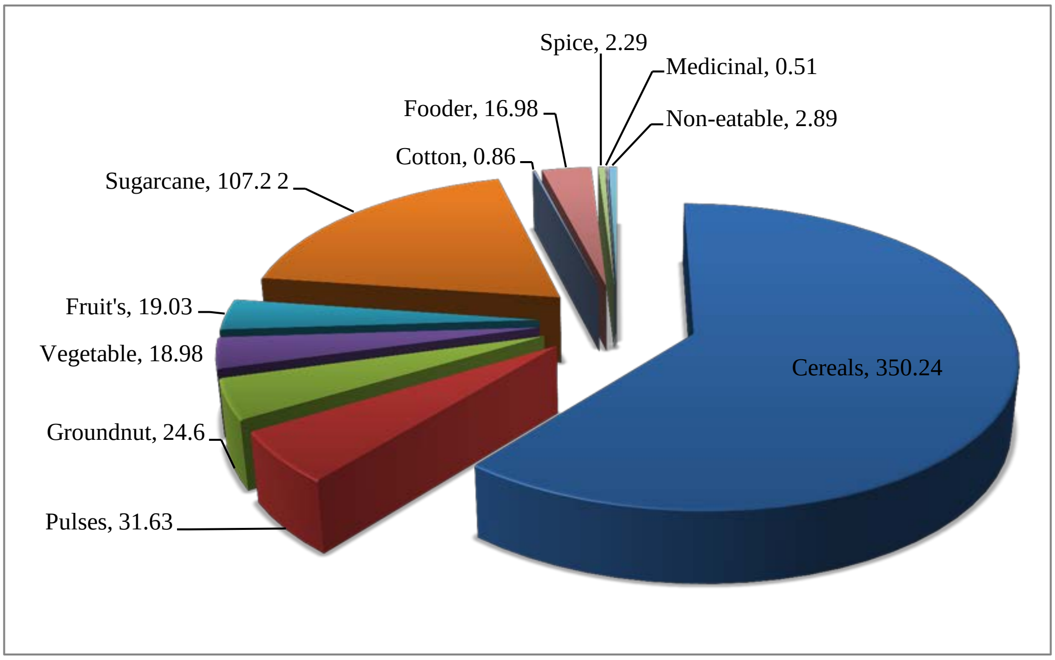


Fig. 4.13b water requirement for the crop

4.2.2.1 Livestock Water Requirement

Livestock are an integral part of farming in this area. Hence, it is essential to have an estimation of water required for provision of water for livestock rearing. Water requirement for livestock refers to the quantity of water required for drinking and water in feed to support livestock production (M. Blummel et al. 2009). The water required for livestock rearing depends on the number of animals and consumptive use per head (U. A. Amarsinghe et al. 2004). The total livestock water required for a village was assumed as the sum of water required for domestic animals like cattle, buffaloes, sheep and Goat. Approximate water required considered for different animals as recommended in Frasier and Hyers (1983) in litres per day (lpd) are shown in **table 4.13 fig. 4.14.** It is presumed that, on an average 85 to 10 litre of water required for one animal per day.

Quantity of water requirement for livestock consumption per day, QL1 = No. Of Cattle * 85 + No. of Buffaloes * 85 + No. of Goats * 10 + No. of Sheep * 10

Quantity of water requirement for livestock consumption per annum, QL = 365 * QL1

Table 4.13 Shows village wise animal population and water requirement.

Sr. No.	Village Name	Cattles	Water in lit.	Buffaloes	Water in lit.	Goat	Water in lit.	Sheep	Water in lit.	Total water use	
										Per day in lit	Per year in MCM
1	Shetphalgadhe	656	55760	118	10030	677	6770	338	3380	75940	0.0277
2	Pimple	558	47430	195	16575	549	5490	749	7490	76985	0.0281
3	Madanwadi	892	75820	424	36040	614	6140	1201	12010	130010	0.0475
4	Takrarwadi	158	13430	450	38250	121	1210	0	0	52890	0.0193
5	Bhigvan	225	19125	187	15895	259	2590	12	120	37730	0.0138
6	Bhigvanstaion	234	19890	96	8160	151	1510	51	510	30070	0.0110
7	Diksal	271	23035	272	23120	58	580	0	0	46735	0.0171
8	Kumbhargaon	291	24735	33	2805	446	4460	510	5100	37100	0.0135
9	Bandgarwadi	116	9860	160	13600	202	2020	193	1930	27410	0.0100
10	Poundhawadi	589	50065	201	17085	490	4900	228	2280	74330	0.0271
11	Lamjewadi	527	44795	52	4420	175	1750	0	0	50965	0.0186
12	Nirgude	786	66810	179	15215	1026	10260	355	3550	95835	0.0350
13	Mhasobachiwadi	476	40460	0	0	119	1190	0	0	41650	0.0152
14	Vaysewadi	103	8755	190	16150	100	1000	0	0	25905	0.0095
15	Akole	319	27115	171	14535	177	1770	157	1570	44990	0.0164
16	Bhadalwadi	568	48280	121	10285	314	3140	367	3670	65375	0.0239
17	Dalaj No.1	197	16745	346	29410	216	2160	304	3040	51355	0.0187
18	Dalaj No.2	281	23885	525	44625	189	1890	463	4630	75030	0.0274
19	Dalaj No.3	339	28815	184	15640	285	2850	69	690	47995	0.0175
20	Kalewadi	484	41140	66	5610	646	6460	292	2920	56130	0.0205
21	Bandewadi	188	15980	110	9350	144	1440	4	40	26810	0.0098
22	Palasdeo	280	23800	274	23290	416	4160	20	200	51450	0.0188
23	Malewadi	652	55420	402	34170	589	5890	85	850	96330	0.0352

Continued…..

Sr. No.	Village Name	Cattles	Water in lit.	Buffaloes	Water in lit.	Goat	Water in lit.	Sheep	Water in lit.	Total water use	
										Per day in lit	Per year in MCM
24	Bhawadi	331	28135	116	9860	241	2410	60	600	41005	0.0150
25	Loni	926	78710	441	37485	899	8990	4	40	125225	0.0457
26	Varkute Bk.	627	53295	230	19550	540	5400	170	1700	79945	0.0292
27	Balpudi	246	20910	66	5610	253	2530	134	1340	30390	0.0111
28	Karewadi	317	26945	151	12835	340	3400	142	1420	44600	0.0163
29	Lakdi	1662	141270	212	18020	708	7080	56	560	166930	0.0609
30	Shindewadi	562	47770	187	15895	544	5440	163	1630	70735	0.0258
31	Kazad	1240	105400	407	34595	1414	14140	567	5670	159805	0.0583
32	Nimbodi	1168	99280	195	16575	293	2930	28	280	119065	0.0435
33	Bori	532	45220	351	29835	1001	10010	431	4310	89375	0.0326
34	Sansar	690	58650	350	29750	833	8330	0	0	96730	0.0353
35	Bhavaninagar	274	23290	149	12665	245	2450	451	4510	42915	0.0157
36	Jachakvasti	442	37570	231	19635	206	2060	0	0	59265	0.0216
37	Kardanwadi	415	35275	95	8075	421	4210	70	700	48260	0.0176
38	Jankshan	218	18530	68	5780	532	5320	134	1340	30970	0.0113
39	Lasurne	652	55420	335	28475	642	6420	192	1920	92235	0.0337
40	Pawarwadi	180	15300	141	11985	205	2050	4	40	29375	0.0107
41	Belwadi	1197	101745	653	55505	1712	17120	200	2000	176370	0.0644
42	Sapkalwadi	255	21675	269	22865	358	3580	0	0	48120	0.0176
43	Hingnewadi	269	22865	74	6290	270	2700	16	160	32015	0.0117
44	Udhat	643	54655	166	14110	420	4200	67	670	73635	0.0269
45	Paritwadi	616	52360	239	20315	569	5690	48	480	78845	0.0288
46	Thoratwadi	162	13770	109	9265	148	1480	0	0	24515	0.0089

Continued…..

Sr. No.	Village Name	Cattles	Water in lit.	Buffaloes	Water in lit.	Goat	Water in lit.	Sheep	Water in lit.	Total water use	
										Per day in lit	Per year in MCM
47	Chavhanwadi	250	21250	43	3655	142	1420	2	20	26345	0.0096
48	Bambadwadi	168	14280	85	7225	323	3230	0	0	24735	0.0090
49	Mankarwadi	192	16320	116	9860	372	3720	0	0	29900	0.0109
50	Gholapwadi	243	20655	272	23120	198	1980	657	6570	52325	0.0191
51	Tawashi	512	43520	239	20315	701	7010	55	550	71395	0.0261
52	Jamb	343	29155	184	15640	410	4100	29	290	49185	0.0180
53	Kurwali	296	25160	246	20910	735	7350	36	360	53780	0.0196
54	Chikhali	491	41735	105	8925	228	2280	194	1940	54880	0.0200
55	Pilewadi	324	27540	139	11815	213	2130	202	2020	43505	0.0159
56	Maradwadi	346	29410	205	17425	315	3150	300	3000	52985	0.0193
57	Nhavi	1099	93415	548	46580	1853	18530	693	6930	165455	0.0604
58	Rui	1243	105655	61	5185	1300	13000	835	8350	132190	0.0482
59	Gosaviwadi	700	59500	63	5355	333	3330	300	3000	71185	0.0260
60	Kalas	2440	207400	379	32215	1064	10640	852	8520	258775	0.0945
61	Thoratwadi	267	22695	406	34510	492	4920	1868	18680	80805	0.0295
62	Birgundwadi	940	79900	0	0	535	5350	0	0	85250	0.0311
63	Shelgaon	1320	112200	764	64940	1766	17660	144	1440	196240	0.0716
64	Bharnewadi	1659	141015	1021	86785	1799	17990	1108	11080	256870	0.0938
65	Anthurne	601	51085	286	24310	890	8900	100	1000	85295	0.0311
66	Kadbanwadi	979	83215	139	11815	1109	11090	1300	13000	119120	0.0435
67	Hangarwadi	562	47770	183	15555	309	3090	0	0	66415	0.0242
68	Pitkeshwar	664	56440	253	21505	330	3300	58	580	81825	0.0299
69	Sarafwadi	641	54485	179	15215	401	4010	0	0	73710	0.0269

Continued…..

Sr. No.	Village Name	Cattles	Water in lit.	Buffaloes	Water in lit.	Goat	Water in lit.	Sheep	Water in lit.	Total water use	
										Per day in lit	Per year in MCM
70	Ghorpadwadi	625	53125	455	38675	369	3690	0	0	95490	0.0349
71	Sirsatwadi	1329	112965	727	61795	406	4060	0	0	178820	0.0653
72	Ranmodwadi	718	61030	448	38080	1390	13900	50	500	113510	0.0414
73	Kalamb	978	83130	979	83215	261	2610	232	2320	171275	0.0625
74	Nimsakhar	2630	223550	10347	879495	1896	18960	233	2330	1124335	0.4104
75	Nirwangi	902	76670	361	30685	863	8630	0	0	115985	0.0423
76	Kauthali	979	83215	144	12240	955	9550	0	0	105005	0.0383
77	Vyahali	248	21080	33	2805	284	2840	0	0	26725	0.0098
78	Kacharewadi	439	37315	117	9945	389	3890	344	3440	54590	0.0199
79	Gotandi	792	67320	489	41565	869	8690	263	2630	120205	0.0439
80	Nimgaon Ketki	812	69020	348	29580	340	3400	0	0	102000	0.0372
81	Varkute Kh.	1678	142630	168	14280	374	3740	169	1690	162340	0.0593
82	Kati	2354	200090	997	84745	1552	15520	789	7890	308245	0.1125
83	Jadhavwadi	282	23970	67	5695	217	2170	0	0	31835	0.0116
84	Reda	921	78285	646	54910	1093	10930	0	0	144125	0.0526
85	Redni	1364	115940	375	31875	1510	15100	48	480	163395	0.0596
86	Khorochi	1641	139485	566	48110	861	8610	333	3330	199535	0.0728
87	Boratwadi	248	21080	141	11985	1462	14620	122	1220	48905	0.0179
88	Chandgaon	231	19635	180	15300	84	840	0	0	35775	0.0131
89	Agoti No.1	550	46750	144	12240	350	3500	80	800	63290	0.0231
90	Agoti No.2	245	20825	130	11050	145	1450	3	30	33355	0.0122
91	Ganjewalan	264	22440	117	9945	225	2250	0	0	34635	0.0126
92	Kalashi	569	48365	180	15300	410	4100	87	870	68635	0.0251

Continued…..

Sr. No.	Village Name	Cattles	Water in lit.	Buffaloes	Water in lit.	Goat	Water in lit.	Sheep	Water in lit.	Total water use	
										Per day in lit	Per year in MCM
93	Kalthan No.1	90	7650	113	9605	292	2920	14	140	20315	0.0074
94	Shirsodi	475	40375	781	66385	774	7740	92	920	115420	0.0421
95	Padsthal	348	29580	519	44115	537	5370	23	230	79295	0.0289
96	Ajoti	84	7140	138	11730	227	2270	1	10	21150	0.0077
97	Sugaon	86	7310	104	8840	190	1900	0	0	18050	0.0066
98	Pimpri Kh.	234	19890	336	28560	510	5100	0	0	53550	0.0195
99	Malwadi	321	27285	40	3400	284	2840	0	0	33525	0.0122
100	Galandwadi No.1	387	32895	76	6460	182	1820	0	0	41175	0.0150
101	Narutwadi	412	35020	414	35190	586	5860	2	20	76090	0.0278
102	Kalthan No.2	220	18700	300	25500	318	3180	0	0	47380	0.0173
103	Gagargaon	265	22525	140	11900	340	3400	350	3500	41325	0.0151
104	Bijwadi	461	39185	349	29665	670	6700	533	5330	80880	0.0295
105	Rajwadi	217	18445	132	11220	209	2090	0	0	31755	0.0116
106	Vangali	180	15300	89	7565	187	1870	120	1200	25935	0.0095
107	Pondkulwadi	280	23800	99	8415	340	3400	88	880	36495	0.0133
108	Shaha	807	68595	534	45390	1026	10260	22	220	124465	0.0454
109	Kandalgaon	335	28475	384	32640	474	4740	10	100	65955	0.0241
110	Taratgaon	68	5780	86	7310	118	1180	0	0	14270	0.0052
111	Hingangaon	648	55080	358	30430	620	6200	1	10	91720	0.0335
112	Sardewadi	900	76500	625	53125	932	9320	27	270	139215	0.0508
113	Galandwadi No.2	423	35955	274	23290	504	5040	0	0	64285	0.0235
114	Gokhali	1157	98345	461	39185	948	9480	249	2490	149500	0.0546
115	Tarangwadi	497	42245	207	17595	620	6200	453	4530	70570	0.0258

Continued…..

Sr. No.	Village Name	Cattles	Water in lit.	Buffaloes	Water in lit.	Goat	Water in lit.	Sheep	Water in lit.	Total water use	
										Per day in lit	Per year in MCM
116	Zagadewadi	974	82790	583	49555	955	9550	0	0	141895	0.0518
117	Pandharwadi	1242	105570	310	26350	460	4600	76	760	137280	0.0501
118	Vadapuri	1824	155040	1364	115940	1361	13610	0	0	284590	0.1039
119	Bedshinge	365	31025	358	30430	569	5690	0	0	67145	0.0245
120	Babhulgaon	870	73950	459	39015	337	3370	0	0	116335	0.0425
121	Avasari	1280	108800	592	50320	1046	10460	365	3650	173230	0.0632
122	Bhat Nimgaon	549	46665	334	28390	456	4560	58	580	80195	0.0293
123	Shetphal Haveli	1982	168470	324	27540	1622	16220	206	2060	214290	0.0782
124	Surwad	1405	119425	1039	88315	1089	10890	0	0	218630	0.0798
125	Bhandgaon	1997	169745	837	71145	549	5490	749	7490	253870	0.0927
126	Vakilvasti	524	44540	322	27370	701	7010	55	550	79470	0.0290
127	Bawada	2167	184195	1401	119085	1952	19520	367	3670	326470	0.1192
128	Bhodani	1013	86105	168	14280	821	8210	0	0	108595	0.0396
129	Lakhewadi	2630	223550	436	37060	864	8640	0	0	269250	0.0983
130	Chakati	709	60265	302	25670	683	6830	0	0	92765	0.0339
131	Pithewadi	829	70465	0	0	627	6270	58	580	77315	0.0282
132	Nirnimgaon	2134	181390	684	58140	340	3400	350	3500	246430	0.0899
133	Kacharewadi	426	36210	244	20740	205	2050	4	40	59040	0.0215
134	Sarati	2626	223210	436	37060	556	5560	0	0	265830	0.09703
135	Lumewadi	351	29835	425	36125	990	9900	0	0	75860	0.0277
136	Gondi	264	22440	117	9945	208	2080	0	0	34465	0.0126
137	Ganeshwadi	414	35190	339	28815	303	3030	0	0	67035	0.0245
138	Pimpri Bk.	572	48620	248	21080	347	3470	0	0	73170	0.0267

Continued…..

Sr. No.	Village Name	Cattles	Water in lit.	Buffaloes	Water in lit.	Goat	Water in lit.	Sheep	Water in lit.	Total water use	
										Per day in lit	Per year in MCM
139	Tannu	558	47430	185	15725	501	5010	0	0	68165	0.0249
140	Narsingpur	659	56015	129	10965	225	2250	0	0	69230	0.0253
141	Giravi	641	54485	179	15215	277	2770	332	3320	75790	0.0277
142	Ozare	209	17765	97	8245	292	2920	0	0	28930	0.0106
143	Indapur Urban	252	21420	1164	98940	964	9640	44	440	130440	0.0476
144	Indapur Rural	103	8755	261	22185	123	1230	0	0	32170	0.0117
	Total	98357	8360345	53962	4586770	83191	831910	24470	244700	14023725	5.1187

Source: Frasier and Hyers, 1983 and Panchyat Samiti, Indapur 2012

Source: Author

Fig. 4.14

Total animal population was 259980 (Census 2012) in the year. Thus, total requirement of water for animal rearing arrives at 5118659625 litres (5.12 MCM) water required per annum are shown in **table 4.13 and fig no. 4.14**. Agricultural water requirement is 575.24MCM and animal water requirement is 5.12 MCM totally 580.36 MCM **(Fig. 4.15)** water required for agriculture purposes in the study area.

4.2.3 Industrial requirement

Industrial supply is enable by industrial water supply and disposal systems, i. e. sets of structures, technological equipment such as measuring and controlling devices with associated feedbacks which secure the withdrawal and treatment of water, its distribution and circulation, as well as waste water treatment and recycling, sludge disposal and the harmless discharge of polluted water into appropriate recipients. So supply of water is taken care of before establishing the industrial plants so that the industrial activities are not hampered by the scarcity of water. But there are several problems hindering the estimation of industrial requirement of water. First, distribution of industries by nature is a localized phenomenon. Secondly, requirements vary with size and nature of manufacturing. Therefore, requirements of industrial units cannot be generalized and estimated. There are 4 Sugar factories, 1 paper industry, 1 Jaggery mill, 1 Dairy industry and other small scale industries are located in the study area. Thus, at present about 10.02 MCM of water is required by industries located within this area, out of them paper industry requirement is on high amount i.e. 8.6 MCM (Science and Technology Park, University of Pune) it is 85.83% of the total industrial water requirements **(Table 4.14 & Fig. 4.16)**.

Source: Author **Fig. 4.15**

Table 4.14 and Fig. 4.16 Shows industrial water requirements.

Sr. No.	Name of industry	Crushing capacity in MT	Daily intake water (m^3)	Total yearly utilization (m^3)	Water requirement in MCM	Water use in %
1	Ballarpur Industries Ltd. (BILT)	-	23571.0	8603415	8.603	85.89
2	Chhatrapati Sahkari Sakhar Karkhana	3500	1312.5	196875	0.197	1.97
3	Nira-Bhima Sahkari Sakhar Karkhana	3500	1312.5	196875	0.197	1.97
4	Karmyogi Shankarrao Patil Sahkari Sakhar Karkhana	8000	3000.0	450000	0.450	4.48
5	Baramati Agro Sakhar Karkhana	3500	1312.5	196875	0.197	1.97
6	Sonaie Jaggery Industry	500	20.00	3000	0.003	0.03
7	Sonaie dairy	-	600.0	219700	0.220	2.19
8	Other industries	-	410.96	150000	0.150	1.50
	Total	19000	31539.5	10016740	10.017	100.00

Source: Socio-Economic report of Pune district 2012, 2013 and sugar factory reports.

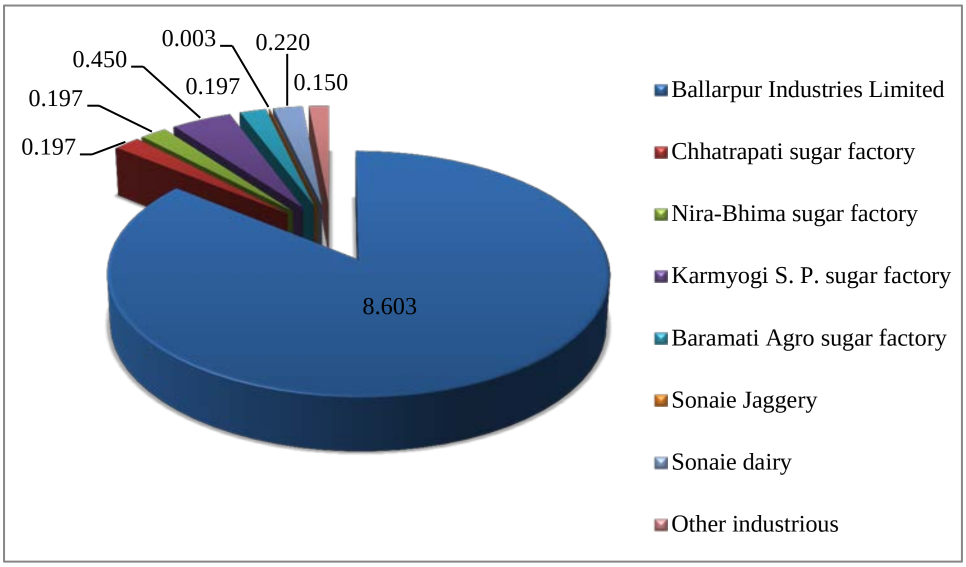


Fig. 4.16 Industrial water requirement

Thus, the amount of water use and requirement by different sectors i.e. domestic, agriculture and industrial it is observed that agricultural component in the study area requires a high amount of water.

Chapter – V

Water Budget Estimation of the Indapur Tahsil

5.0 Introduction

5.1 Water budget estimation using hydrological equation

5.1.1 Input

5.1.1.1 Rainfall

5.1.1.2 Canal and reservoir

5.1.13 Recharging of groundwater

5.1.2 Output

5.1.2.1 Runoff and computation of its volume

5.1.2.2 Distribution of surface runoff

5.1.2.3 Infiltration capacity of the soil

5.1.2.4 Village wise computation of runoff

5.1.2.5 Classification of villages based on hydrological equation

5.2. Rainfall station wise water budget estimation using ISBH water balance software

5.2.1 Input parameters

5.2.1.1 Rainfall

5.2.1.2 Evapotranspiration

5.2.1.2.1 Potential evapotranspiration

5.2.1.2.2 Actual evapotranspiration

5.2.1.3 Field capacity

5.2.2 Derived Parameters

5.2.2.1 Humidity index

5.2.2.2 Moisture index

5.2.2.3 Aridity Index

5.3 Water deficits

5.4 Classification of villages based on Thornthwaite's method

5.5 Water stress

5.6 Development of Composite water balance Index (CWBI) (Based on hydrological equation and Thornthwaite's method)

Chapter – V

Water Budget Estimation of the Indapur Tahsil

5.0 Introduction

A water budget is a basic tool that can be used to evaluate the occurrence and movement of water through the natural environment. Water budgets provide a foundation for evaluating its use in relationship to other important influencing conditions such as other ecological systems and features, as well as social and economic components – how much water is being used by agriculture, industry and residents etc. The water budget process can encompass various levels of assessment which start simple and grow more complex if there are concerns about how much water is available at any level. Water budgets commonly go well beyond how much water is available and where it is. They also include a detailed understanding of the flow dynamics. These flow dynamics include the origin and movement of groundwater and surface water as well as the interaction between the two systems. This overall interdependent understanding is necessary for sound water management. Water budget studies consider the volumes of water within the various reservoirs of the hydrologic cycle and the flow paths from recharge to discharge. Water budgets need to consider this information on a variety of spatial and temporal scales (Hazel Breton 2010).

The maximum water holding capacity of soils, rainfall and potential evapotranspiration are the basic controlling elements of water balance. The distribution of these elements decides droughts or water surplus condition. Therefore rainfall, potential evapotranspiration, aridity, humidity and soil moisture are become primary controlling factors of agriculture (Saikia 1994).

In the present study water balance technique is used to estimate the availability of rainwater resource in the study area. The nature and distribution of rainfall of the study area discussed earlier indicates that about 90 percent rainfall takes place during the short period of four months from June to September. There is a great variation in the number of rainy days also.

Water is available in sufficient quantity during rainy season. As the dry season sets in, there is a shortage of water. The reservoirs of surface and underground water are about 1542.695 MCM; Out of this only 601.38 MCM water is required for use. Present study deals with water budget estimation applying hydrological equation which considers rainfall recharging of ground water and as inputs and runoff actual evapotranspiration and infiltration as an output entities.

Water budgets are developed by measuring or estimating the inputs and outputs of a hydrologic system. Inputs are the processes that add water to the system; these include precipitation and inflow from surface water and groundwater. Outputs are the processes that remove water from the system; these include evapotranspiration, the various uses of water by humans, and outflow from surface water and groundwater. It is also observed that the critical examination of ground water recharge potential of the study area reveals that infiltration is negligible and hence not considered in the present computation of water budget. The components of a water budget are illustrated in **Table no. 5.1.** Many inputs and outputs can be measured directly or estimated using various techniques.

Table no. 5.1 The components of a water budget

Sr. No.	Inputs	Water in MCM	Outputs	Water in MCM
1	Rainfall	1052.468	Runoff	327.716
2	Canal and Reservoir	214.587	Actual evapotranspiration	771.212
3	Recharging of groundwater	275.64	Infiltration	*
	Total	1542.695		1098.918

Source: Tahsil office and agriculture office Indapur, Irrigation offices, Baramati and Daund 2013, GSDA office, Pune, 2014.

***** *Being too low ground water recharge potential Infiltration has not been considered in the present component.* Ref. **Fig. 5.3**

5.1 Water budget estimation using hydrological equation

General hydrological equation to compute Water balance used is

$$P = Q + E + \Delta S$$

Where,

P is precipitation,

Q is runoff,

E is evapotranspiration and

ΔS is the change in storage in soil or the bedrock.

5.1.1 Input

5.1.1.1 Rainfall

One of the fact that need to be emphasized here, is that the mean annual rainfall of the eight stations in the study area is above 362 mm for all of the stations receive more or less same rainfall throughout the year. The lowest rainfall in the study area, during the last 15 years period of time, the minimum value was around 128.12 mm in the year 2003 and maximum value was 817.99 mm in the year 2009 with this rainfall the volume of rainfall that is received is 188.06 MCM and 1200.73 MCM, respectively.

5.1.1.2 Canal and reservoir

The Nira left canal and Mutha (Khadakwasala) canal runs through the study area, hence the higher level of contribution to the irrigation. On the basis of the hydraulic data total 93.963 MCM water available from these two canals this is ultimately recharge the groundwater by canal through seepage and increase the level of groundwater.

Dam and reservoirs may largely regulate the hydrological regime of a catchment since they temporarily store surface water and hence, reduce storm water runoff downstream of structure. In terms of water budget, overall surface runoff may be significantly reduced due to evaporative losses from the reservoir and abstraction of stored water. These are shown in the **Fig. 3.7**.

There is only one dam namely Ujani, It is located in eastern side of the study area. The water storage capacity of Ujani dam is 117.25 TMC and covers 230 Km^2 areas (*Shwetpatrica*, Irrigation Department, Government of Maharashtra- 2012, Vol. 2). The stored water is mainly used for irrigation purposes. Similarly minor irrigation tank, percolation tank, K. T. Weir, *Nalabandh*, *valan bandhara*, earthen structure and farm ponds are build. Thereby 34.97 MCM water resources are thus made available in the study area.

5.1.1.3 Recharging of ground water

Entire study area has been considered as a moderate infiltration zone as a groundwater recharge area. The area characterised by lineaments and joint / fractured zones in the tahsil have been marked as ground water recharge areas. In these areas the infiltration rate is high with high ground water potential. The locations with high infiltration rate (Lineaments) occur in small narrow strips in the northern part of tahsil. The infiltration rate is low in those areas which are having unconsolidated, semi-consolidated, sedimentary beds and having shell formation. The lineaments are found in northern portion of Indapur tahsil may be considered as high potential recharge zone, whereas remaining tahsil sharing moderate and low infiltration rate and thereby low potential.

In the study area the total rechargeable fresh groundwater is computed as 275.64 MCM and the net ground water availability is to the tune of 261.86 MCM. The present gross groundwater draft for all purposes is 221.15MCM. The Stage of groundwater development for the study area, as whole, is 84.45%. This indicates that on an average 84.45% of yearly replenishable groundwater is being used in the study area. Considering the domestic and industrial requirement the allocation of groundwater for next 25 years comes out to be 18.79 MCM. Leaving this allocation, the groundwater available for irrigation in future is around 53.33 MCM. The canals and reservoirs are other main sources of groundwater recharge in the study area.

5.1.2 Output

5.1.2.1 Runoff estimation and computation of its volume

An effective watershed management programme for the conservation and development of natural resource management requires reliable hydrological data especially the runoff. The hydrologic behaviour of a watershed plays an important role in water resources planning and management (Shin-Min et al., 2002). Predicting runoff is important to assess the hydrologic response of land use changes. By knowing the future land uses, it is possible to predict its effects on runoff. Thus, the management of watershed can be improved from time to time. Predicting runoff is particularly important for an urban or urbanizing watershed because development in watershed can alter the volume and peak discharge of surface runoff. Large scale changes in land use, such as modifying rural land to urban land can significantly change the water yield (Abdul Rahim, 1988; Walesh, 1989; Kim et al., 2002).

There are several rainfall-runoff models available in the study of hydrological field. In this study, the following empirical formulae have been used and runoff has been estimated by the three methods. Design flood for Indapur tahsil has been worked out by empirical formulae are given below;

1. Dickens formula

$$Q = CA^{3/4}$$

Where Q = flood discharge in cumecs

C = constant depending upon the rainfall depth which may be taken as 13.9 to 19.5 for central India basins

A = catchment area in sq.km.

2. Inglis formula

$Q = 124A/ (A+10.4)^{0.5}$

Where Q = flood discharge in cumecs

A = catchment area in sq.km.

3. Nawab Ali Jung Bahadur formula

$Q = C\ (0.386A)^{\{0.925 - (1/14) \log 0.386A\}}$

Where Q = flood discharge in cumecs

C = coefficient varies from 49 to 60 with maximum value 86

A = catchment area in sq.km.

5.1.2.2 Distribution of surface runoff

Runoff is that portion of rainfall, which enters the stream immediately after the rainfall. It occurs when all losses are satisfied and if rain is still continued, with the rate greater than in-filtration rate, at this stage water starts flowing over the land as overland flow. For the design of any soil and water conservation structures and waterways or channels, runoff volume and peak rate of runoff are required to be estimated. Runoff rate is expressed in cubic meter per seconds and runoff volume or water yield from watershed is generally expressed as m^3 **Fig. 5.1a**. The study area is characterised by undulating terrain land in western part and eastern part is a plain area.

In the study area it is observed that the maximum 402.25 km^2 (25.57 %) area under more than 125 cumecs runoff and 235.51 km^2 (14.95%) area under less than 25 cumecs. More than 125 cumecs area found western high altitudinal area, eastern side strip between river Bhima and Nira and two patches are found at around Nimgaon Ketki and Indapur settlement. Low runoff (< 25) has found in the Northern area, besides this it found around in patches in the middle and Eastern part of the study area. Besides this 25-50, 50-75, 75-100 and 100-125 cumecs runoff found in patches all over in the study area **(Fig 5.1a & Fig 5.1b)**.

Fig. 5.1a watershed wise runoff

Sr. No.	Runoff in cumecs	Area		Description
		Km^2	%	
1	< 25	235.51	14.95	Very low
2	25-50	334.86	21.25	Low
3	50-75	357.76	22.71	Medium
4	75-100	149.32	9.48	High
5	100-125	95.08	6.04	Very high
6	> 125	402.25	25.57	
	Total	1575.38	100.00	

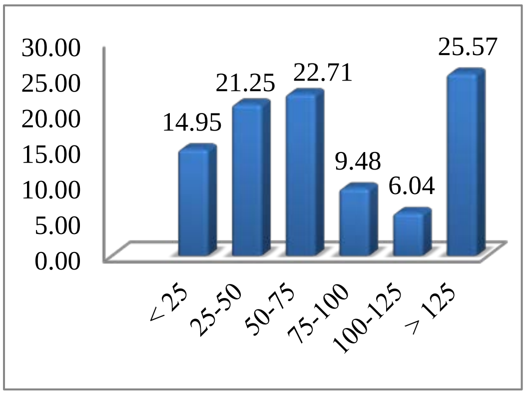


Fig 5.1b Average surface water runoff (% area)

The average surface water runoff of the catchment is estimated to 327.72 MCM/year **(Table 5.2 & Fig. 5.2)**. This is about 31.14% of the total volume of rainfall for the entire study area. There is great deal of variations in terms of volume of runoff by different watersheds. The maximum contribution of runoff in the watershed no. BM67 area that is amounting 46.08% and lowest contribution can obviously be expected from BM61 Bhigwan area which is only 0.37%. From the following **table no. 5.2** it becomes clear that, due to variation in rainfall and size of considerable amount of rainfall volume does not get converted in to runoff.

Table 5.2 and Fig. 5.2 Watershed wise area and runoff of Indapur tahsil

Sr. No.	Name of Watershed Area	Surface Area in		Runoff in	
		Km^2	%	MCM	in %
1	Bhigwan-BM61	24.53	1.56	1.20	0.37
2	Loni-BM66	194.93	12.37	12.07	3.68
3	Palasdev-BM67	238.97	15.17	150.99	46.08
4	Akole-BM68	125.67	7.98	50.57	15.43
5	Sansar-BM76	337.88	21.45	49.33	15.05
6	Nimgaon-BM77	281.63	17.88	29.98	9.15
7	Indapur-BM78	371.77	23.59	33.57	10.24
	Total	1575.38	100.00	327.71	100.00

Source: Author.

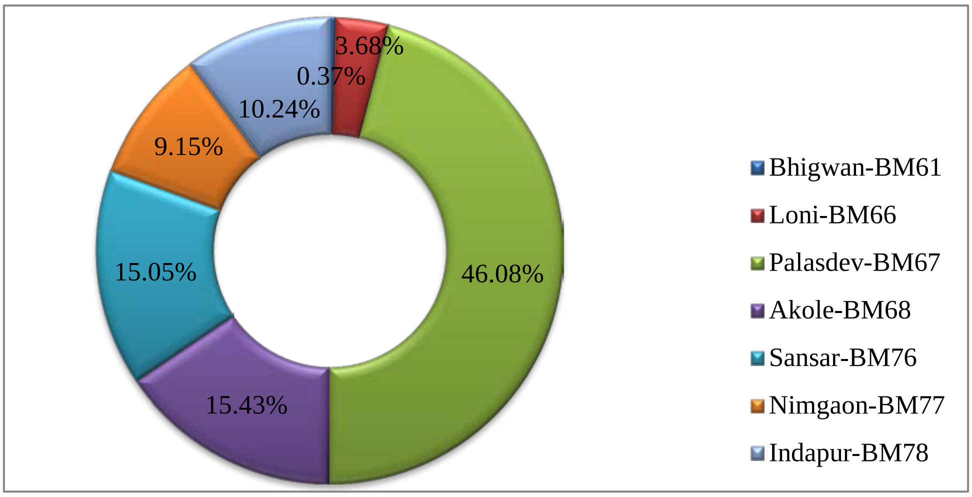


Fig. 5.2 Variation in watershed wise runoff

5.1.2.3 Infiltration capacity of the soil

The study area is in the rain shadow and semi-arid climatic condition. In this climatic condition the direct infiltration is relatively ineffective because of the rarity of rainfalls, low mean average precipitation and high potential evaporation. Furthermore, the high potential evaporation compared to precipitation in semi-arid environment results the low deep infiltration of rainwater. The entire tahsil is the basement of Deccan trap basaltic lava. Typically these rocks form the 'Hard rock terrain' and their physical properties such as porosity and permeability play an important role in the movement and accumulation of groundwater.Therefore, in the study area, ground water of acceptable quality and quantity usually lies very low. There are more than 95% area of the study area shows very low ground water recharge, along the Ujani back water and near the confluence of river Bhima and Nira low recharge the ground water (**Fig. 5.3**). There are only 74.67 km^2 (4.74%) area recommended for groundwater development in the study area. These are found in the patches in SW and NE part of the study area. Another 1500.71 km^2 (95.26%) area is notable for groundwater development (**Fig. 2.17a**).

Source: National rain fed area authority planning commission New Delhi 2011 **Fig. 5.3**

5.1.2.4 Village wise computation of runoff volume

The average surface water village wise runoff of the study area is estimated to 327.72 MCM/year **(Table 5.3 & Fig. 5.4)**, this is about 31.14% of the total volume of rainfall for the entire study area. There is great deal of variations in terms of volume of runoff by different villages. The maximum contribution of runoff in the Akole area that is amounting 79.889 MCM and lowest contribution can obviously be expected from Lamjewadi village that is amounting 0.007 MCM. From the following **Table no. 5.3** it becomes clear that, due to variation in rainfall, considerable amount of rainfall volume does not get converted in to runoff.

Source: Author

Fig. 5.4

Table 5.3 and Fig 5.4 Village wise runoff of Indapur tahsil

Sr. No.	Longitude	Latitude	Village Name	Runoff in MCM	Sr. No.	Longitude	Latitude	Village Name	Runoff in MCM
1	74.6893	18.2561	Shetphalgadhe	1.480	19	74.8232	18.2302	Dalaj No.3	0.371
2	74.7192	18.2582	Pimple	1.118	20	74.8530	18.2256	Kalewadi	0.316
3	74.7513	18.2807	Madanwadi	0.919	21	74.8864	18.2281	Bandewadi	0.221
4	74.7618	18.2939	Takrarwadi	0.188	22	74.8888	18.2158	Palasdeo	0.985
5	74.7577	18.2978	Bhigwan	0.809	23	74.8965	18.2306	Malewadi	2.120
6			Bhigvanstaion		24	74.9306	18.2278	Bhawadi	0.569
7	74.7926	18.3120	Diksal	0.179	25	74.9222	18.2013	Loni	1.335
8	74.7980	18.2697	Kumbhargaon	0.091	26	74.9567	18.1987	Varkute Bk.	1.049
9	74.7666	18.2661	Bandgarwadi	0.417	27	74.9387	18.1706	Balpudi	0.354
10	74.7493	18.2490	Poundhawadi	10.763	28	74.9392	18.1338	Karewadi	0.252
11	74.6675	18.2299	Lamjewadi	0.007	29	74.6915	18.1723	Lakdi	3.912
12	74.7069	18.2274	Nirgude	34.851	30	74.7139	18.1562	Shindewadi	2.962
13	74.6814	18.1988	Mhasobachiwadi	1.077	31	74.7286	18.1501	Kazad	21.876
14	74.7276	18.1872	Vaysewadi	11.031	32	74.6914	18.1479	Nimbodi	1.017
15	74.7580	18.2077	Akole	79.889	33	74.7456	18.1254	Bori	3.613
16	74.7788	18.2272	Bhadalwadi	14.012	34	74.7043	18.1138	Sansar	0.174
17	74.8039	18.2325	Dalaj No.1	1.371	35	74.6897	18.1189	Bhavaninagar	0.042
18	74.8310	18.2246	Dalaj No.2	0.020	36	74.7244	18.1050	Jachakvasti	0.076

Continued.....

Sr. No.	Longitude	Latitude	Village Name	Runoff in MCM	Sr. No.	Longitude	Latitude	Village Name	Runoff in MCM
37	74.6926	18.0960	Sapkalwadi	1.174	55	74.8016	18.2216	Pilewadi	3.360
38	74.7509	18.0747	Kardanwadi	0.056	56	74.8564	18.1946	Maradwadi	0.250
39			Lasurne		57	74.8827	18.1777	Nhavi	1.553
40	74.7676	18.0853	Junkshan	2.156	58	74.8589	18.1754	Rui	0.615
41			Thoratwadi		59	74.8255	18.1760	Gosaviwadi	0.008
42	74.7087	18.0669	Pawarwadi	0.126	60	74.7935	18.1696	Kalas	34.310
43	74.7294	18.0935	Belwadi	0.077	61	74.7327	18.0796	Thoratwadi	0.625
44	74.7055	18.0940	Hingnewadi	0.078	62	74.7747	18.1418	Birgundwadi	4.663
45	74.6955	18.0601	Udhat	0.273	63	74.8450	18.1039	Shelgaon	3.587
46	74.7579	18.0464	Paritwadi	0.244	64	74.8130	18.0868	Bharnewadi	0.028
47	74.7461	18.0536	Chavanwadi	0.093	65	74.8013	18.0841	Anthurne	1.686
48	74.7401	18.0711	Bambadwadi	0.039	66	74.8219	18.0567	Sirsatwadi	0.215
49	74.7197	18.0609	Mankarwadi	0.076	67	74.8340	18.0738	Kadbanwadi	0.215
50	74.6907	18.0839	Gholapwadi	0.172	68	74.8513	18.0688	Hangarwadi	0.328
51	74.6745	18.0716	Tawashi	0.260	69	74.9031	18.0458	Pitkeshwar	1.403
52	74.7096	18.0381	Jamb	0.149	70	74.8922	18.0269	Sarafwadi	0.348
53	74.7325	18.0318	Kurwali	0.274	71	74.8703	18.0361	Ghorpadwadi	0.259
54	74.7502	18.0246	Chikhali	0.134	72	74.8079	18.0505	Ranmodwadi	0.269

Continued......

Sr. No.	Longitude	Latitude	Village Name	Runoff in MCM	Sr. No.	Longitude	Latitude	Village Name	Runoff in MCM
73	74.7727	18.0251	Kalamb	1.061	91	75.0305	18.2506	Ganjewalan	0.273
74	74.8283	18.0147	Nimsakhar	0.702	92	75.0036	18.2197	Kalashi	0.452
75	74.8706	17.9931	Nirwangi	1.394	93	75.0036	18.1916	Kalthan No.1	0.730
76	74.9129	18.1456	Kauthali	0.704	94	75.0356	18.1648	Shirsodi	0.713
77	74.8868	18.1235	Vyahali	0.959	95	75.0733	18.1871	Padsthal	0.749
78	74.9020	18.0946	Kacharewadi	0.154	96	75.0687	18.1677	Ajoti	0.377
79	74.8762	18.0714	Gotandi	1.235	97	75.0777	18.1641	Sugaon	0.433
80	74.9206	18.0804	Nimgaon Ketki	2.453	98	75.0683	18.1566	Pimpri Kh.	0.421
81	74.9338	18.0607	Varkute Kh.	2.914	99	75.0218	18.1682	Malwadi	1.120
82	74.9463	18.0259	Kati	5.263	100	75.0043	18.1432	Galandwadi No.1	0.537
83	74.9457	18.0086	Jadhavwadi	0.349	101	75.0172	18.1482	Narutwadi	0.578
84	74.9236	18.0001	Reda	1.260	102	74.9710	18.1752	Kalthan No.2	0.277
85	74.9127	17.9830	Redni	1.402	103	74.9675	18.1605	Gagargaon	0.482
86	74.8662	17.9680	Khorochi	0.898	104	74.9621	18.1494	Bijwadi	0.219
87	74.8941	17.9406	Boratwadi	0.195	105	74.9766	18.1555	Rajwadi	0.291
88	74.9446	18.2570	Chandgaon	0.285	106	74.9957	18.1414	Vangali	0.956
89	74.9685	18.2335	Agoti No.1	0.220	107	74.9576	18.1217	Pondkulwadi	0.449
90	74.9787	18.2246	Agoti No.2	0.192	108	75.0948	18.1075	Shaha	0.545

Continued......

Sr. No.	Longitude	Latitude	Village Name	Runoff in MCM	Sr. No.	Longitude	Latitude	Village Name	Runoff in MCM
109	75.1129	18.1000	Kandalgaon	0.352	127	75.0010	17.9636	Bawada	1.831
110	75.1026	18.0787	Taratgaon	0.111	128	74.9729	17.9939	Bhodani	0.591
111	75.0906	18.0636	Hingangaon	0.642	129	74.9474	17.9723	Lakhewadi	0.328
112	75.0728	18.0945	Sardewadi	0.434	130	74.9250	17.9466	Chakati	1.309
113	75.0584	18.0751	Galandwadi No.2	3.018	131	74.9469	17.9445	Pithewadi	0.146
114	74.9844	18.0916	Gokhali	0.529	132	74.9558	17.9319	Nirnimgaon	0.248
115	74.9784	18.0990	Tarangwadi	1.288	133	74.9776	17.9198	Kacharwadi	0.208
116	74.9706	18.0787	Zagadewadi	1.288	134	75.0015	17.9230	Sarati	0.437
117	74.9816	18.0460	Pandharwadi	1.173	135	75.0414	17.9049	Lumewadi	0.986
118	74.9974	18.0580	Vadapuri	1.160	136	75.0520	17.9244	Gondi	0.949
119	75.0470	18.0536	Bedshing	0.509	137	75.0388	17.9447	Ganeshwadi	0.666
120	75.0884	18.0550	Babhulgaon	1.871	138	75.0642	17.9455	Pimpri BK.	2.531
121	75.0370	18.0400	Avasari	0.700	139	75.1007	17.9688	Tannu	2.177
122	75.0631	18.0302	Bhatnimgaon	1.041	140	75.1332	17.9704	Narsingpur	1.178
123	74.9739	18.0160	Shetphal Haveli	2.062	141	75.1084	17.9419	Giravi	3.040
124	74.9983	18.0107	Surwad	0.184	142	75.0795	17.9165	Ozare	1.296
125	75.0396	18.0005	Bhandgaon	0.404	143	75.0338	18.1095	Indapur	2.958
126	74.9990	17.9914	Vakilvasti	0.035				Total	327.716

Source: Author

5.1.2.5 Classification of villages based on hydrological equation

It can be deduced from the figure no. 5.5 that, hydrological equation implied for water budget assessment clearly demonstrates that, the entire tahsil is drought prone and faces the problem of water scarcity throughout the year. In order to make the differences again to find out the villages facing very high shortage of water. By adopting the grid operation, reclassification has been achieved and two classes have been determined. One class below '0' indicates more severity covered 566.92 km^2 (35.99%) area (50 villages) and 0-1 shows less severity 1008.46 km^2 (64.01%) area covered (93 villages) of the problem in a comparison list of these both the classes have been displayed in **Table 5.4** and shows in **Fig. 5.5.**

Source: Author **Fig. 5.5**

Table 5.4 Average water deficit of Indapur tahsil based on hydrological equation.

Sr. No.	Below '0'	Area in		Sr. No.	Below '0'	Area in	
	Name of Village	km^2	%		Name of Village	km^2	%
1	Shetphalgadhe	18.95	1.20	39	Kati	18.13	1.15
2	Pimple	8.87	0.56	40	Jadhavwadi	1.88	0.12
3	Madanwadi	22.46	1.43	41	Bhodani	8.05	0.51
4	Lamjewadi	3.73	0.24	42	Lakhewadi	14.92	0.95
5	Nirgude	25.22	1.60	43	Pithewadi	6.62	0.42
6	Mhasobachiwadi	14.72	0.93	44	Bijwadi	12.57	0.80
7	Dalaj No.1	6.32	0.40	45	Pondkulwadi	2.84	0.18
8	Dalaj No.3	6.53	0.41	46	Tarangwadi	15.66	0.99
9	Lakdi	13.10	0.83	47	Zagadewadi	6.66	0.42
10	Nimbodi	8.45	0.54	48	Galandwadi No.2	8.50	0.54
11	Paritwadi	4.75	0.30	49	Bedshinge	4.72	0.30
12	Thoratwadi	3.16	0.20	50	Bhat Nimgaon	8.30	0.53
13	Chavhanwadi	2.20	0.14		Total	566.92	35.99
14	Bambadwadi	0.00	0.00		0 - 1		
15	Jamb	4.28	0.27	1	Takrarwadi	2.69	0.17
16	Kurwali	7.29	0.46	2	Bhigvan	12.77	0.81
17	Chikhali	3.99	0.25	3	Bhigvanstaion	13.69	0.87
18	Kalamb	25.53	1.62	4	Diksal	8.08	0.51
19	Ranmodwadi	6.17	0.39	5	Kumbhargaon	11.73	0.74
20	Nhavi	21.57	1.37	6	Bandgarwadi	2.81	0.18
21	Rui	25.60	1.63	7	Poundhawadi	14.35	0.91
22	Thoratwadi	5.33	0.34	8	Vaysewadi	2.71	0.17
23	Shelgaon	39.96	2.54	9	Akole	16.55	1.05
24	Bharnewadi	17.23	1.09	10	Bhadalwadi	13.55	0.86
25	Hangarwadi	7.06	0.45	11	Dalaj No.2	8.67	0.55
26	Gotandi	17.81	1.13	12	Kalewadi	17.87	1.13
27	Pitkeshwar	9.64	0.61	13	Bandewadi	4.69	0.30
28	Sarafwadi	8.41	0.53	14	Palasdeo	17.76	1.13
29	Ghorpadwadi	5.21	0.33	15	Malewadi	4.42	0.28
30	Nirwangi	13.00	0.83	16	Bhawadi	7.80	0.50
31	Reda	9.65	0.61	17	Loni	15.74	1.00
32	Balpudi	8.36	0.53	18	Varkute Bk.	18.40	1.17
33	Karewadi	4.44	0.28	19	Shindewadi	11.06	0.70
34	Kauthali	15.01	0.95	20	Kazad	15.65	0.99
35	Vyahali	13.07	0.83	21	Bori	18.65	1.18
36	Kacharewadi	3.47	0.22	22	Sansar	12.21	0.78
37	Nimgaon Ketki	31.96	2.03	23	Bhavaninagar	2.13	0.13
38	Varkute Kh.	15.58	0.99	24	Jachakvasti	3.94	0.25

Continued.....

Sr. No.	0 - 1	Area in		Sr. No.	0 - 1	Area in	
	Name of Village	km^2	%		Name of Village	km^2	%
25	Kardanwadi	2.38	0.15	60	Galandwadi No.1	7.10	0.45
26	Jankshan	3.01	0.19	61	Narutwadi	9.05	0.57
27	Lasurne	38.11	2.42	62	Kalthan No.2	17.48	1.11
28	Pawarwadi	4.39	0.28	63	Gagargaon	7.70	0.49
29	Belwadi	6.40	0.41	64	Rajwadi	2.42	0.15
30	Sapkalwadi	2.18	0.14	65	Vangali	7.29	0.46
31	Hingnewadi	3.18	0.20	66	Shaha	10.07	0.64
32	Udhat	3.65	0.23	67	Kandalgaon	15.39	0.98
33	Mankarwadi	1.85	0.12	68	Taratgaon	3.23	0.21
34	Gholapwadi	1.28	0.08	69	Hingangaon	9.60	0.61
35	Tawashi	6.78	0.43	70	Sardewadi	9.96	0.63
36	Pilewadi	8.13	0.52	71	Gokhali	9.89	0.63
37	Maradwadi	2.01	0.13	72	Pandharwadi	11.76	0.75
38	Gosaviwadi	10.44	0.66	73	Vadapuri	26.43	1.68
39	Kalas	37.69	2.39	74	Babhulgaon	13.27	0.84
40	Birgundwadi	7.68	0.49	75	Avasari	10.62	0.67
41	Anthurne	12.30	0.78	76	Shetphal Haveli	16.21	1.03
42	Kadbanwadi	27.66	1.76	77	Surwad	6.42	0.41
43	Sirsatwadi	7.54	0.48	78	Bhandgaon	13.34	0.85
44	Nimsakhar	22.67	1.44	79	Vakilvasti	6.38	0.41
45	Redni	18.57	1.18	80	Bawada	80.97	5.14
46	Khorochi	13.59	0.86	81	Chakati	8.27	0.52
47	Boratwadi	8.02	0.51	82	Nirnimgaon	6.60	0.42
48	Chandgaon	5.90	0.37	83	Kacharewadi	5.96	0.38
49	Agoti No.1	10.44	0.66	84	Sarati	7.80	0.50
50	Agoti No.2	4.25	0.27	85	Lumewadi	6.98	0.44
51	Ganjewalan	7.20	0.46	86	Gondi	4.76	0.30
52	Kalashi	10.39	0.66	87	Ganeshwadi	6.22	0.39
53	Kalthan No.1	18.19	1.15	88	Pimpri Bk.	10.37	0.66
54	Shirsodi	11.13	0.71	89	Tannu	8.33	0.53
55	Padsthal	10.13	0.64	90	Narsingpur	8.04	0.51
56	Ajoti	7.53	0.48	91	Giravi	9.62	0.61
57	Sugaon	8.46	0.54	92	Ozare	3.13	0.20
58	Pimpri Kh.	5.29	0.34	93	Indapur Urban	5.62	0.36
59	Malwadi	15.82	1.00		Total	1008.46	64.01

Source: Census of India 2011 and author.

5.2 Rainfall station wise water budget estimation using water balance (Using ISBH v0.3 software)

An attempt has also been made to compute water budget considering the actual rainfall over a period of 15 years by traditional Thornthwaite's method. Software namely ISBH v0.3 has been used for the same and rainfall measuring stations wise, water budget has been obtained for the entire tahsil. Interpolation technique of nearest neighbour used for this exercise and village wise spread of water surplus or deficit has been determined. This has helped to understand month wise variation of the availability or non availability of water resources in the study area.

5.2.1 Input parameters

5.2.1.1 Rainfall

The rainfall data used for this work during the period from 1999 to 2013. Data recorded at the different rainfall stations of the study area form the main source of information in the assessment of surface water resources. The monthly average rainfall data are used for a period of 15 years (1999-2013) for 8 stations in the study area **(Fig 3.2)**.

5.2.1.2 Evapotranspiration

Evapotranspiration data are important input in water budgets. Evapotranspiration varies with space and time depending on land cover, precipitation and other climatic variables. Evapotranspiration data for the study area obtained form 2006 year. It can be noted that, the estimates for evapotranspiration vary from 423 to 463 mm/yr in the study area. Very high evapotranspiration varies between 450 to 463 mm/yr confined to far eastern part of the tahsil, along the bank of river Bhima namely Palasdeo to Babhulgaon village and on the bank of river Nira from Sarati to Tavshi and Sansar, Bhavaninagar, Lakdi, Nimbodi, Nirgude, Mhasobachiwadi, Lamjewadi and Shetphalgadhe have very low evapotranspiration i.e. less than 430 mm/yr and remaining part of the study area it ranges between 430 to 449 mm/yr. The distribution of evapotranspiration has shown in the **Fig. 2.9**.

5.2.1.2.1 Potential evapotranspiration

The potential evapotranspiration is defined as the evaporation from a large vegetation cover land surface with adequate soil moisture at all times. The advantage of Thornthwaite's method is that potential evapotranspiration can be estimated if data of mean temperature is available. Potential evapotranspiration data obtained from 2006 year.

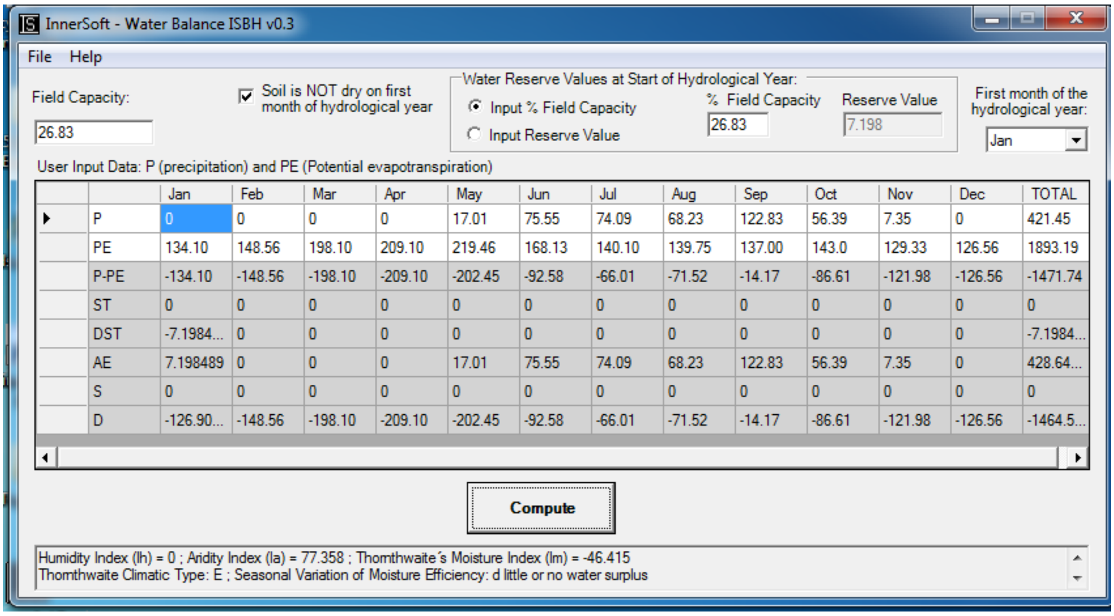
The distribution of potential evapotranspiration over the study area is shown in **Fig. 5.6**. Generally potential evapotranspiration increases from west to east in the study area. Distributions of potential evapotranspiration values are uniform along the bank of the Bhima river bank. While there exist a low values near the western boundary and central eastern part of the study area which is noted to be about 336 mm to 375 mm. Eastern part of the study area have comparatively high potential evapotranspiration values i.e. range between 800 mm to 1175 mm. Middle part of the tahsil experienced moderate evapotranspiration. The annual PE distribution values shows more than 500 mm over the middle land and the highest value of more than 1160 mm occurs over the area of Kalashi and Girvi village. The lowest value of annual potential evapotranspiration (less than 338 mm) has been observed over the village Zagadewadi.

5.2.1.2 2 Actual evapotranspiration

Actual evaporation is a major component in the water balance of a catchment, reservoir or lake, irrigated area. Compared with precipitation and stream flow, the magnitude of actual evaporation over the long term is more difficult to estimate than either precipitation or stream flow. The actual evapotranspiration data obtained from 2006 year has been used for the present study. The spatial distribution pattern of actual evapotranspiration (AE) is shown in the **Fig. 5.7.** It has distinct to that of PE distribution. But in this case, highest values are observed in the eastern side area and decreasing from east to middle portion of the study area. The highest value of 1500 mm is at the village Ganjewalan, Ajoti and Kandalgaon; where the area experiences very heavy rainfall comparatively rest of the study area and in the area of Ujani dam. An increasing trend towards east has been observed in actual evapotranspiration, this is seen in the case of annual potential evapotranspiration. This is because of the dependence of actual evapotranspiration on rainfall. The lowest values of actual evapotranspiration are over the places Nirgude, Mhasobachiwadi, Lakdi, Vyahali, Kauthali, Karewadi, Nimgaon-ketki, Tarangwadi, Zagadewadi, Gokhali, Vadapuri and Galandwadi No.2, which is already discussed, is the lowest rainfall part of the study area. In this area actual evapotranspiration has been observed between 56 mm to 113mm.

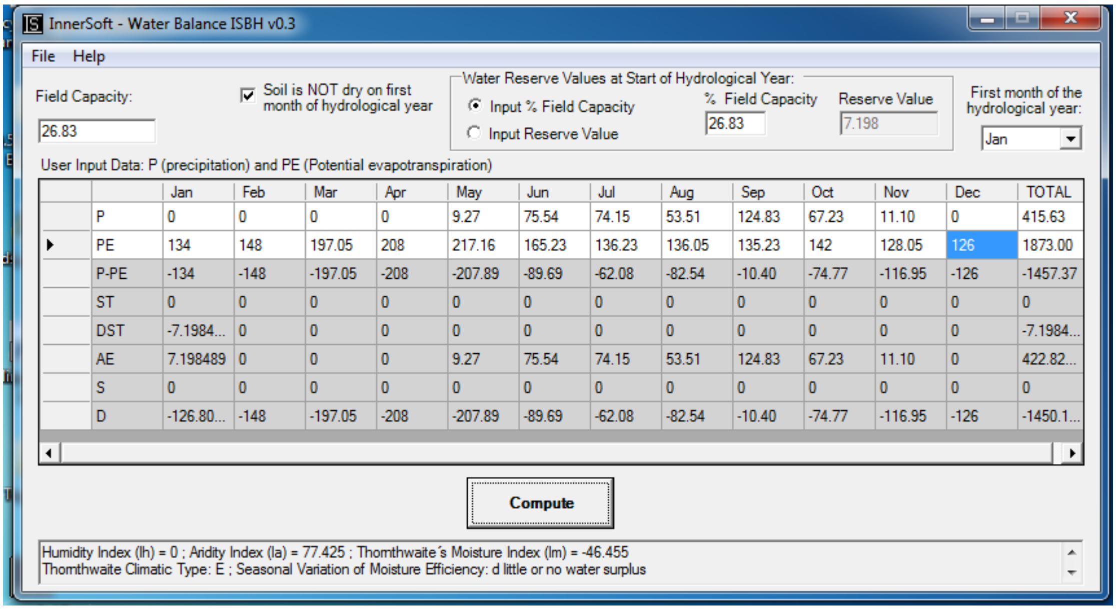
Source: Remote Sensing and Hydrological Modelling of the Upper Bhima Catchment (2006) **Fig. 5.6**

Source: Remote Sensing and Hydrological Modelling of the Upper Bhima Catchment (2006) **Fig. 5.7**



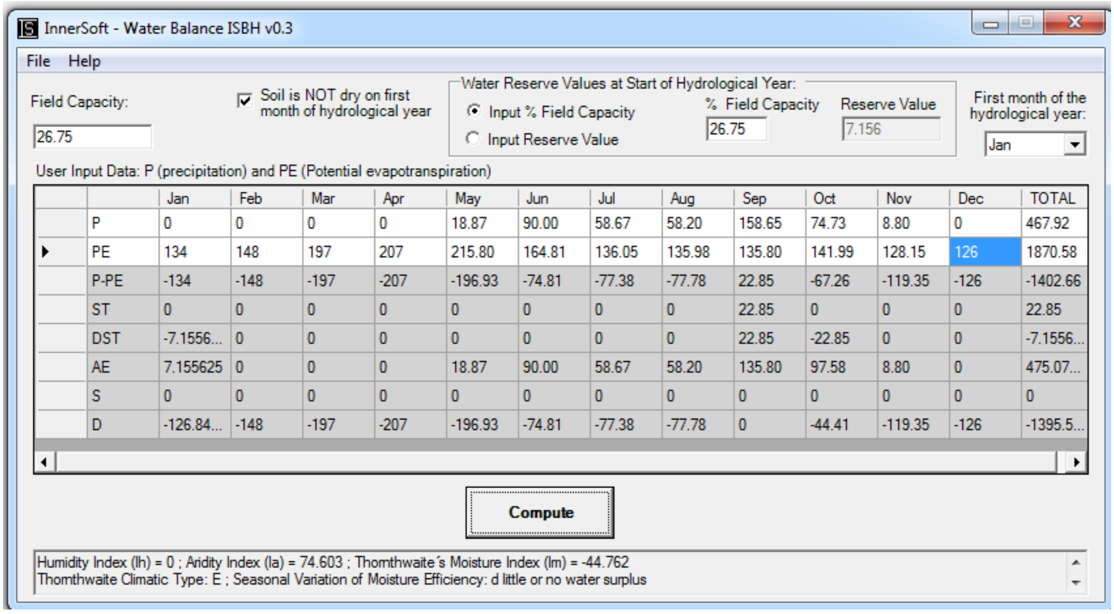
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
P	0	0	0	0	17.01	75.55	74.09	68.23	122.83	56.39	7.35	0	421.45
PE	134.10	148.56	198.10	209.10	219.46	168.13	140.10	139.75	137.00	143.0	129.33	126.56	1893.19
P-PE	-134.10	-148.56	-198.10	-209.10	-202.45	-92.58	-66.01	-71.52	-14.17	-86.61	-121.98	-126.56	-1471.74
ST	0	0	0	0	0	0	0	0	0	0	0	0	0
DST	-7.1984...	0	0	0	0	0	0	0	0	0	0	0	-7.1984...
AE	7.198489	0	0	0	17.01	75.55	74.09	68.23	122.83	56.39	7.35	0	428.64...
S	0	0	0	0	0	0	0	0	0	0	0	0	0
D	-126.90...	-148.56	-198.10	-209.10	-202.45	-92.58	-66.01	-71.52	-14.17	-86.61	-121.98	-126.56	-1464.5...

Water budget estimation using water balance for Bhigwan **Fig. 5.8a**



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
P	0	0	0	0	9.27	75.54	74.15	53.51	124.83	67.23	11.10	0	415.63
PE	134	148	197.05	208	217.16	165.23	136.23	136.05	135.23	142	128.05	126	1873.00
P-PE	-134	-148	-197.05	-208	-207.89	-89.69	-62.08	-82.54	-10.40	-74.77	-116.95	-126	-1457.37
ST	0	0	0	0	0	0	0	0	0	0	0	0	0
DST	-7.1984...	0	0	0	0	0	0	0	0	0	0	0	-7.1984...
AE	7.198489	0	0	0	9.27	75.54	74.15	53.51	124.83	67.23	11.10	0	422.82...
S	0	0	0	0	0	0	0	0	0	0	0	0	0
D	-126.80...	-148	-197.05	-208	-207.89	-89.69	-62.08	-82.54	-10.40	-74.77	-116.95	-126	-1450.1...

Water budget estimation using water balance for Shetphalgadhe **Fig. 5.8b**



InnerSoft - Water Balance ISBH v0.3

File Help

Field Capacity: 26.75

☑ Soil is NOT dry on first month of hydrological year

Water Reserve Values at Start of Hydrological Year:
◉ Input % Field Capacity ○ Input Reserve Value
% Field Capacity: 26.75 Reserve Value: 7.156

First month of the hydrological year: Jan

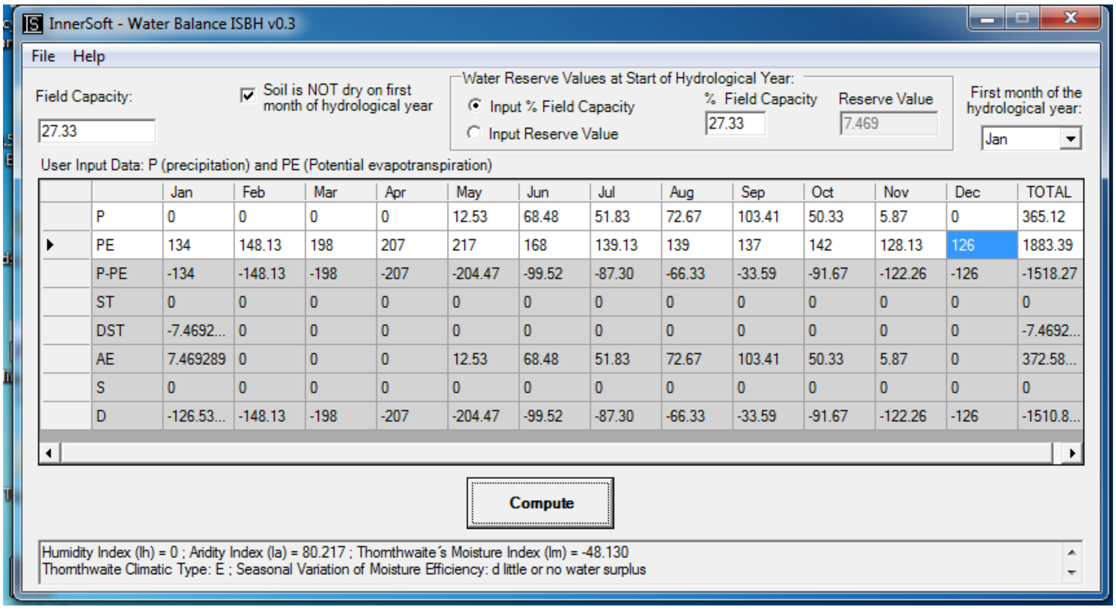
User Input Data: P (precipitation) and PE (Potential evapotranspiration)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
P	0	0	0	0	18.87	90.00	58.67	58.20	158.65	74.73	8.80	0	467.92
PE	134	148	197	207	215.80	164.81	136.05	135.98	135.80	141.99	128.15	126	1870.58
P-PE	-134	-148	-197	-207	-196.93	-74.81	-77.38	-77.78	22.85	-67.26	-119.35	-126	-1402.66
ST	0	0	0	0	0	0	0	0	22.85	0	0	0	22.85
DST	-7.1556...	0	0	0	0	0	0	0	22.85	-22.85	0	0	-7.1556...
AE	7.155625	0	0	0	18.87	90.00	58.67	58.20	135.80	97.58	8.80	0	475.07...
S	0	0	0	0	0	0	0	0	0	0	0	0	0
D	-126.84...	-148	-197	-207	-196.93	-74.81	-77.38	-77.78	0	-44.41	-119.35	-126	-1395.5...

Compute

Humidity Index (Ih) = 0 ; Aridity Index (Ia) = 74.603 ; Thornthwaite´s Moisture Index (Im) = -44.762
Thornthwaite Climatic Type: E ; Seasonal Variation of Moisture Efficiency: d little or no water surplus

Water budget estimation using water balance for Sansar **Fig. 5.8c**



InnerSoft - Water Balance ISBH v0.3

File Help

Field Capacity: 27.33

☑ Soil is NOT dry on first month of hydrological year

Water Reserve Values at Start of Hydrological Year:
◉ Input % Field Capacity ○ Input Reserve Value
% Field Capacity: 27.33 Reserve Value: 7.469

First month of the hydrological year: Jan

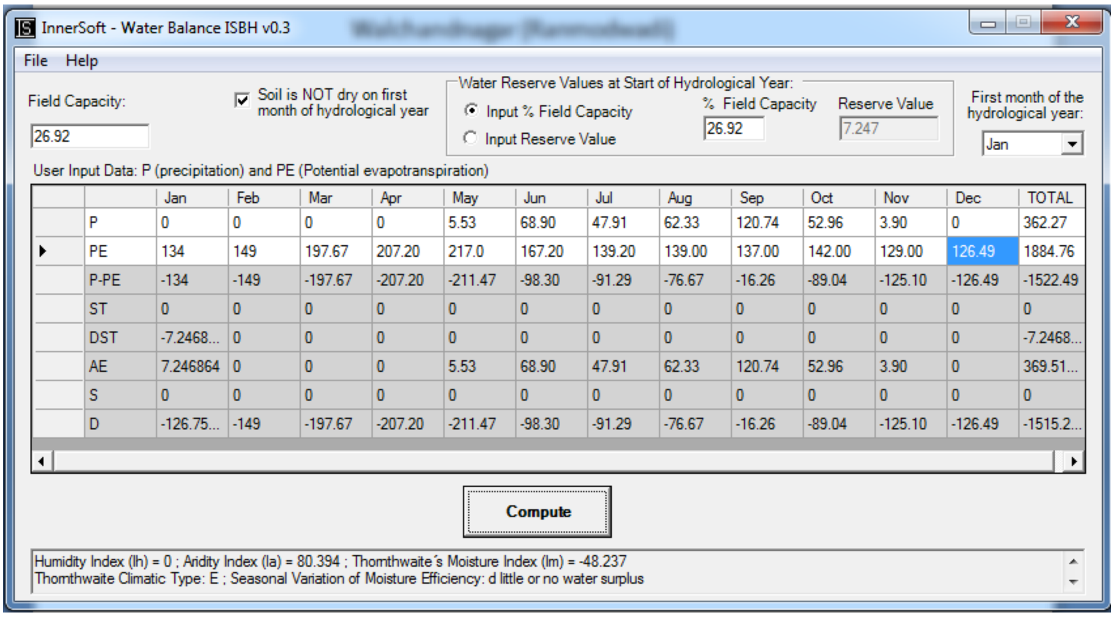
User Input Data: P (precipitation) and PE (Potential evapotranspiration)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
P	0	0	0	0	12.53	68.48	51.83	72.67	103.41	50.33	5.87	0	365.12
PE	134	148.13	198	207	217	168	139.13	139	137	142	128.13	126	1883.39
P-PE	-134	-148.13	-198	-207	-204.47	-99.52	-87.30	-66.33	-33.59	-91.67	-122.26	-126	-1518.27
ST	0	0	0	0	0	0	0	0	0	0	0	0	0
DST	-7.4692...	0	0	0	0	0	0	0	0	0	0	0	-7.4692...
AE	7.469289	0	0	0	12.53	68.48	51.83	72.67	103.41	50.33	5.87	0	372.58...
S	0	0	0	0	0	0	0	0	0	0	0	0	0
D	-126.53...	-148.13	-198	-207	-204.47	-99.52	-87.30	-66.33	-33.59	-91.67	-122.26	-126	-1510.8...

Compute

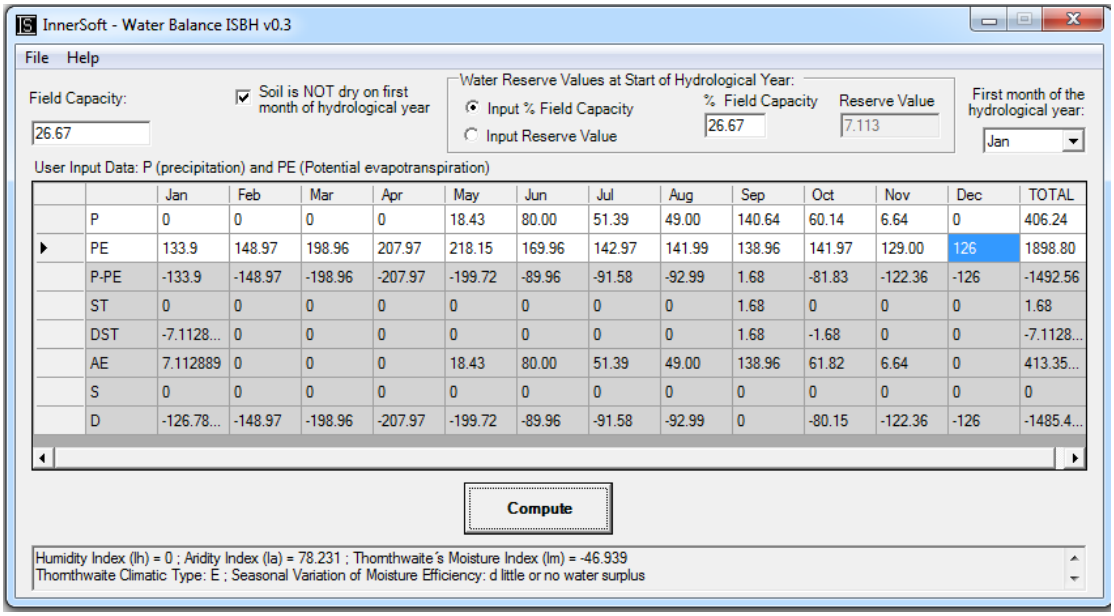
Humidity Index (Ih) = 0 ; Aridity Index (Ia) = 80.217 ; Thornthwaite´s Moisture Index (Im) = -48.130
Thornthwaite Climatic Type: E ; Seasonal Variation of Moisture Efficiency: d little or no water surplus

Water budget estimation using water balance for Anthurne **Fig. 5.8d**



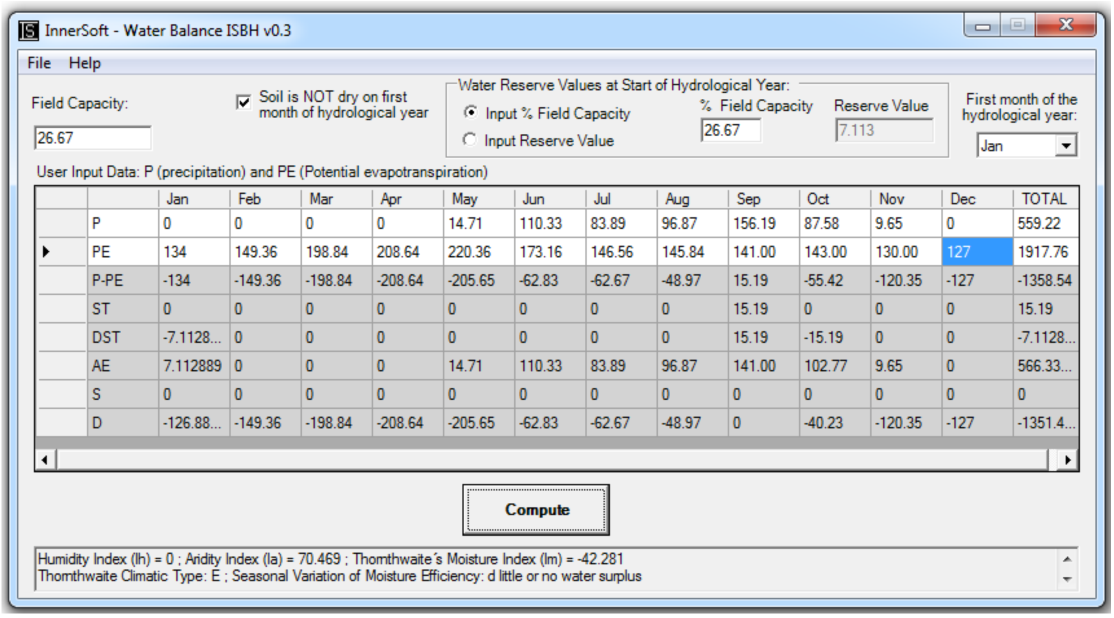
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
P	0	0	0	0	5.53	68.90	47.91	62.33	120.74	52.96	3.90	0	362.27
PE	134	149	197.67	207.20	217.0	167.20	139.20	139.00	137.00	142.00	129.00	126.49	1884.76
P-PE	-134	-149	-197.67	-207.20	-211.47	-98.30	-91.29	-76.67	-16.26	-89.04	-125.10	-126.49	-1522.49
ST	0	0	0	0	0	0	0	0	0	0	0	0	0
DST	-7.2468...	0	0	0	0	0	0	0	0	0	0	0	-7.2468...
AE	7.246864	0	0	0	5.53	68.90	47.91	62.33	120.74	52.96	3.90	0	369.51...
S	0	0	0	0	0	0	0	0	0	0	0	0	0
D	-126.75...	-149	-197.67	-207.20	-211.47	-98.30	-91.29	-76.67	-16.26	-89.04	-125.10	-126.49	-1515.2...

Water budget estimation using water balance for Walchandnagar **Fig. 5.8e**



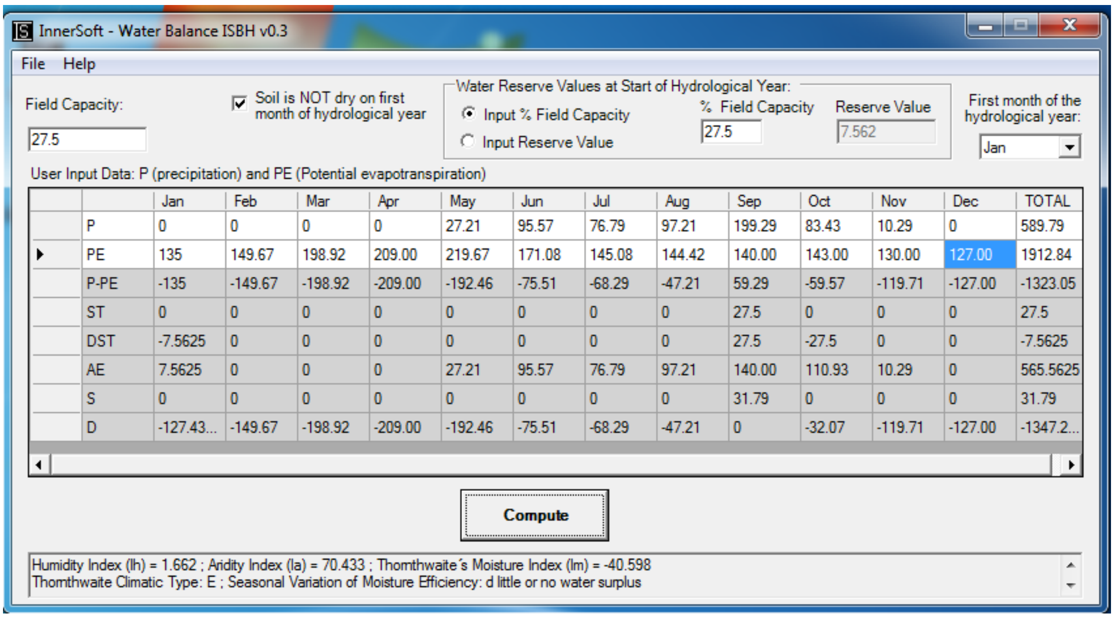
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
P	0	0	0	0	18.43	80.00	51.39	49.00	140.64	60.14	6.64	0	406.24
PE	133.9	148.97	198.96	207.97	218.15	169.96	142.97	141.99	138.96	141.97	129.00	126	1898.80
P-PE	-133.9	-148.97	-198.96	-207.97	-199.72	-89.96	-91.58	-92.99	1.68	-81.83	-122.36	-126	-1492.56
ST	0	0	0	0	0	0	0	0	1.68	0	0	0	1.68
DST	-7.1128...	0	0	0	0	0	0	0	1.68	-1.68	0	0	-7.1128...
AE	7.112889	0	0	0	18.43	80.00	51.39	49.00	138.96	61.82	6.64	0	413.35...
S	0	0	0	0	0	0	0	0	0	0	0	0	0
D	-126.78...	-148.97	-198.96	-207.97	-199.72	-89.96	-91.58	-92.99	0	-80.15	-122.36	-126	-1485.4...

Water budget estimation using water balance for Nimgaon Ketki **Fig. 5.8f**



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
P	0	0	0	0	14.71	110.33	83.89	96.87	156.19	87.58	9.65	0	559.22
PE	134	149.36	198.84	208.64	220.36	173.16	146.56	145.84	141.00	143.00	130.00	127	1917.76
P-PE	-134	-149.36	-198.84	-208.64	-205.65	-62.83	-62.67	-48.97	15.19	-55.42	-120.35	-127	-1358.54
ST	0	0	0	0	0	0	0	0	15.19	0	0	0	15.19
DST	-7.1128...	0	0	0	0	0	0	0	15.19	-15.19	0	0	-7.1128...
AE	7.112889	0	0	0	14.71	110.33	83.89	96.87	141.00	102.77	9.65	0	566.33...
S	0	0	0	0	0	0	0	0	0	0	0	0	0
D	-126.88...	-149.36	-198.84	-208.64	-205.65	-62.83	-62.67	-48.97	0	-40.23	-120.35	-127	-1351.4...

Water budget estimation using water balance for Indapur **Fig. 5.8g**



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
P	0	0	0	0	27.21	95.57	76.79	97.21	199.29	83.43	10.29	0	589.79
PE	135	149.67	198.92	209.00	219.67	171.08	145.08	144.42	140.00	143.00	130.00	127.00	1912.84
P-PE	-135	-149.67	-198.92	-209.00	-192.46	-75.51	-68.29	-47.21	59.29	-59.57	-119.71	-127.00	-1323.05
ST	0	0	0	0	0	0	0	0	27.5	0	0	0	27.5
DST	-7.5625	0	0	0	0	0	0	0	27.5	-27.5	0	0	-7.5625
AE	7.5625	0	0	0	27.21	95.57	76.79	97.21	140.00	110.93	10.29	0	565.5625
S	0	0	0	0	0	0	0	0	31.79	0	0	0	31.79
D	-127.43...	-149.67	-198.92	-209.00	-192.46	-75.51	-68.29	-47.21	0	-32.07	-119.71	-127.00	-1347.2...

Water budget estimation using water balance for Bawada **Fig. 5.8h**

5.2.1.3 Field Capacity

Field capacity of the study area obtained from 2009. The field capacity shows diverse volume in the different months. The high volume is found in the month of September which is between 0.38 to 0.40 m^3/m^3 in the study area. The low volume is found in the month of March which is around 0.17 m^3/m^3. Generally, the high field capacity area is found in the eastern part of the study area and remaining part is low field capacity area. The villages Tawashi, Sansar, Lakdi, Nimbodi, Sapkalwadi, Belwadi, Udhat and Gholapwadi have very low field capacity area. It is recorded 26.75m^3/m^3 field capacity volume and more than 27.50 m^3/m^3 volume in Nimgaon-ketki, Zagadewadi, Tarangwadi, Gokhali, Indapur, Gagargaon, Bijwadi, Kandalgaon, Shah, Galandwadi No.2, Babhulgaon, Hingangaon, Taratgaon, Sardewadi, Avasari, Bedshing and Bhandgaon village **Fig. 5.9**.

5.2. 2 Derived parameters

5.2.2.1 Humidity Index

In the study area, a very low humidity is found in all the villages less than 1mm humidity except the south east part of the study area. In the eastern part particularly, Bawada, Narsingpur, Girvi, Tannu, Gondi, Lumewadi, Sarati, Pimpri Bk, Ganeshwadi, Kacharewadi and Nirnimgaon have recorded more than 1mm humidity. Maximum part of the study area has experienced zero humidity index which is found in the northern and western side of the study area **Fig. 5.10**.

5.2.2.2 Moisture Index

All over the year, near about 46% moisture index is found in the study area. Maximum moisture found in the villages Anthurne, Rangaon, Bharnewadi, Kadbanwadi, Shirsatwadi, Hangarwadi, Gotandi, Kacharwadi, Vyahali, Shelgaon, Kalamb and Nimsakhar. There is near about 48% moisture index. Low moisture index (40.5%) is found at Bawada, Narsingpur, Girvi, Tannu, Gondi, Lumewadi, Sarati, Pimpri Bk, and Ganeshwadi. The percentage of moisture is decreased from the west towards the east side in the study area **Fig. 5.11**.

Source: http://www.csi.cgiar.org **Fig. 5.9**

Source: Author

Fig. 5.10

Source: Author **Fig. 5.11**

5.2.2.3 Aridity Index

On yearly average, the study area has experience drought, although drought took place in February, March, April, May and Jun, it is still in the category of heavy drought. It is peak period. The average aridity index of study area is 75%. The western and middle part of the study area which experience the most severe drought with index up to 80%. Aridity index is high in the study area. It is found approximately between 70.43% to 80.39%. At the same time, the villages Anthurne, Rangaon, Bharnewadi, Kadbanwadi, Shirsatwadi, Hangarwadi, Gotandi, Kacharwadi, Vyahali, Shelgaon, Kalamb and Nimsakhar have the aridity above 80%. However, in the eastern part of the study area the villages experienced comparatively low aridity around the year i.e. 70%. The villages namely, Narsingpur, Girvi, Tannu, Gondi, Lumewadi, Sarati, Pimpri Bk, Ganeshwadi, Babhulgaon, Hingangaon, Taratgaon, Sardewadi, Kandalgaon, Shah, and eastern parts of Indapur, Galandwadi No.2, Avasari, Bedshing, Bhandgaon and Bawada. The remaining part of the study area is found medium aridity **Fig. 5.12**.

Source: Author **Fig. 5.12**

5.3 Water deficits

It is observed that the entire study area shows a deficit of water. As all the values of surplus comes to zero and deficit is to the larger degree. Therefore, in order to identify the higher degree of deficit classes have been made accordingly.

In the study area a very high deficit of water has been observed mainly in the month of February, March, April and May. These four months have recorded between -211 to -148 mm. On the other hand, a very low water deficit is found in the month of September that is up to -33mm. In this study area, southern part the villages namely Nimsakhar, Kalamb, Kuravali, Rangaon, Shirsatwadi, Lasurne, Junction, Anthurne, Shelgaon, Gotandi, Ghorpadwadi, north east part the included villages from Shah upto Palasdev recorded very high deficit of water in the month of May. However, in the north western part Shetphalgade, Lamjewadi, Pimple, Madanwadi and the Western and Northern part of Bhigwan experience high deficit of water. Generally, from the month of December to April, the eastern part of the study area particularly, the villages on the bank of Bhima river experience high water deficit. The south central part of the study area experience high water deficit from the month of May to November **Fig. 5.13a, 5.13b** and **5.13c**.

Low water deficit found between - 48.97 to - 7.08 mm in the month of September at the eastern part in the study area namely, Narsingpur, Tannu, Girvi, the eastern part of Bawada, Bhandgaon, Bhatnimgaon, Avasari, Vakilvasti, the south east part of Babhulgaon, Galandwadi No. 2, and Pimpri Bk. In the eastern part of the study area, low water deficit is recorded in the month of July, August, September and October.

5.4 Classification of villages based on Thornthwaite’s method/ equation

An attempt has also been made to get the average of water deficit for twelve months for this exercise map algebra techniques have been used simply by adopting multilayer operation in GIS environment. Grids of the respective months have been added from January to December by overlaying to each other and average of the entire year have been obtained and displayed in **Fig 5.14** Average water deficit of Indapur tahsil based on Thornthwaite’s equation.

It is observed that, although the entire area exhibiting water deficit, two classes could have been made to find the villages facing acute water shortages. Somewhat villages in the central part of the tahsil faces very high shortage of water for different uses and remaining are also faces the same problem but with lower degree of severity (**Table 5.5**). It can be noticed that around 49.08 % area (65 villages) facing very high water scarcity and rest of the 50.92% area (78 villages) comparatively low degree of water scarcity.

Source: Represented from http://www.csi.cgiar.org **Fig. 5.13a**

Source: Represented from http://www.csi.cgiar.org **Fig. 5.13b**

Source: Represented from http://www.csi.cgiar.org **Fig. 5.13c**

Source: Author **Fig. 5.14**

Table 5.5 Average water deficit of Indapur tahsil based on Thornthwaite's equation**.**

Sr. No.	Less than -117	Area in		Sr. No.	Less than -117	Area in	
	Name of Village	km^2	%		Name of Village	km^2	%
1	Chikhali	3.99	0.25	39	Pondkulwadi	2.84	0.18
2	Kuravali	7.29	0.46	40	Vyahali	13.06	0.83
3	Chavanwadi	2.2	0.14	41	Kauthali	15.1	0.96
4	Mankarwadi	1.84	0.12	42	Kacharwadi	3.46	0.22
5	Paritwadi	4.75	0.30	43	Nimgaon Ketki	31.96	2.03
6	Bambadwadi	N. A.	N. A.	44	Varkute Kh	15.58	0.99
7	Lasurne	38.11	2.42	45	Pitkeshwar	9.64	0.61
8	Thoratwadi	3.15	0.20	46	Gotandi	17.81	1.13
9	Junction	3.01	0.19	47	Hangarwadi	7.06	0.45
10	Bori	18.65	1.18	48	Kadbanwadi	27.66	1.76
11	Pilewadi	8.13	0.52	49	Shirsatwadi	7.54	0.48
12	Kalas	37.69	2.39	50	Anthurne	12.3	0.78
13	Birgundwadi	7.68	0.49	51	Bharnewadi	17.23	1.09
14	Maradwadi	2.01	0.13	52	Ranmodwadi	6.17	0.39
15	Gosaviwadi	10.44	0.66	53	Kalamb	25.53	1.62
16	Bhadalwadi	13.55	0.86	54	Nimsakhar	22.67	1.44
17	Bandgarwadi	2.81	0.18	55	Nirwangi	13	0.83
18	Takrarwadi	2.69	0.17	56	Ghorpadwadi	5.21	0.33
19	Bhigwan	12.77	0.81	57	Sarafwadi	7.54	0.48
20	Bhigvanstaion	13.69	0.87	58	Kati	18.13	1.15
21	Diksal	8.08	0.51	59	Jadhavwadi	1.88	0.12
22	Kumbhargaon	11.73	0.74	60	Reda	9.65	0.61
23	Dalaj No.1	6.32	0.40	61	Redni	18.57	1.18
24	Dalaj No2	5.67	0.36	62	Khorachi	13.59	0.86
25	Dalaj No.3	6.53	0.41	63	Boratwadi	8.03	0.51
26	Kalewadi	17.87	1.13	64	Chakati	8.27	0.52
27	Palasdev	17.76	1.13	65	Lakhewadi	14.92	0.95
28	Bandewadi	4.69	0.30		Total	773.27	49.08
29	Malewadi	4.42	0.28		-117 To -115		
30	Bhawadi	7.8	0.50	1	Jamb	4.28	0.27
31	Rui	25.6	1.63	2	Gholapwadi	1.28	0.08
32	Nhavi	21.57	1.37	3	Udhat	3.65	0.23
33	Thoratwadi	5.33	0.34	4	Tawashi	6.78	0.43
34	Shelgaon	39.96	2.54	5	Pawarwadi	4.38	0.28
35	Loni	15.73	1.00	6	Kardanwadi	2.38	0.15
36	Balpudi	8.35	0.53	7	Hingnewadi	3.18	0.20
37	Karewadi	4.44	0.28	8	Sapkalwadi	2.18	0.14
38	Bijwadi	12.57	0.80	9	Sansar	12.21	0.78

Continued.....

Sr. No.	-117-115 Name of Village	Area in km²	%	Sr. No.	-117-115 Name of Village	Area in km²	%
10	Bhavaninagar	2.12	0.13	45	Gokhali	9.89	0.63
11	Belwadi	6.4	0.41	46	Tarangwadi	15.66	0.99
12	Jachakvasti	3.94	0.25	47	Zagadewadi	6.66	0.42
13	Shindewadi	11.05	0.70	48	Vadapuri	26.43	1.68
14	Kazad	15.64	0.99	49	Pandharwadi	11.77	0.75
15	Lakdi	13.09	0.83	50	Indapur Urban	5.62	0.36
16	Nimbodi	8.45	0.54	51	Galandwadi No. 2	8.49	0.54
17	Mhasobachiwadi	14.72	0.93	52	Sardewadi	9.96	0.63
18	Vaysewadi	2.7	0.17	53	Shaha	10.07	0.64
19	Akole	16.55	1.05	54	Kandalgaon	15.38	0.98
20	Nirgude	25.22	1.60	55	Taratgaon	3.23	0.21
21	Lamjewadi	3.73	0.24	56	Hingangaon	9.6	0.61
22	Pimple	8.86	0.56	57	Babhulgaon	13.27	0.84
23	Shetphalgadhe	18.95	1.20	58	Bedshing	4.72	0.30
24	Pondkulwadi	14.35	0.91	59	Bhatnimgaon	8.29	0.53
25	Madanwadi	22.46	1.43	60	Avasari	10.62	0.67
26	Chandgaon	5.89	0.37	61	Bhandgaon	13.34	0.85
27	Agoti No.1	10.44	0.66	62	Surwad	6.42	0.41
28	Agoti No.2	4.24	0.27	63	Vakilvasti	6.38	0.40
29	Ganjewalan	7.2	0.46	64	Bawada	80.97	5.14
30	Kalashi	10.39	0.66	65	Bhodani	8.05	0.51
31	Kalthan No.1	18.19	1.15	66	Shetphal haveli	16.21	1.03
32	Kalthan No.2	17.48	1.11	67	Pithewadi	6.62	0.42
33	Malwadi	15.81	1.00	68	Nirnimgaon	6.6	0.42
34	Shirsodi	11.13	0.71	69	Kacharewadi	5.96	0.38
35	Padsthal	11.25	0.71	70	Sarati	7.8	0.50
36	Ajoti	7.53	0.48	71	Lumewadi	6.98	0.44
37	Sugaon	8.45	0.54	72	Gondhi	4.76	0.30
38	Pimpri Kh.	5.28	0.34	73	Ganeshwadi	6.22	0.39
39	Varkute Bk	18.4	1.17	74	Pimpri Bk.	10.37	0.66
40	Gagargaon	7.69	0.49	75	Tannu	8.33	0.53
41	Rajwadi	2.41	0.15	76	Girvi	9.62	0.61
42	Vangali	7.29	0.46	77	Ozare	3.13	0.20
43	Narutwadi	9.04	0.57	78	Narsingpur	8.04	0.51
44	Galandwadi No.1	7.1	0.45		Total	802.11	50.92

Source: Census of India 2011 and author.

5.5 Water stress

In the year 2011, 36.89% of the study area experienced water stress due to uncertainty of monsoon increased demand of water by industry, municipalities and agriculture. The symptoms of water stress include: decreasing groundwater levels, desiccation of rivers and the drying of inland water bodies. The population of study area has doubled over the past 40 years (1971 to 2011). This rapid population growth, combined with changing lifestyle, has led to an even more rapid increase in water consumption and use in many areas. At the same time clean fresh water remains essential to sustain life, support a healthy environment and enable economic development. Economic growth drives increases in water demand for household, industrial and agricultural uses. Due to this condition creating pressure from inadequate water supplies in the study area, while the functioning and quality of watersheds and irrigated lands are deteriorating and ground and surface water pollution is increasing. An irregularity of monsoon rain is a further threat to future water availability.

Today, many parts in the study area already experienced water stress due to population and economic growth. About 32.95% of the study area, population lives in water scare zone. Being ‘closed’ river basins, i.e., basins in which the river’s water is heavily used and much needed. The irrigation of almost 83 thousand hectares of agricultural land requires over 14% of the river water, mainly for the cultivation of water-intensive crops, like sugarcane.

Scarcity Programme is implemented every year from the months of March to June in villages and *wadis* facing water scarcity. During 2011-12, due to uneven rainfall, scarcity programme was extended up to July, 2012. Additionally, water demands from other stakeholders and sectors are increasing, namely, the growing urban population of Indapur and other villages that require water for drinking and household purposes besides industrial users. Being completely dependent on the monsoon for replenishment, the amount of water can provide to myriads of users varies with the fluctuating strength of the monsoon rainfall.

The improving water productivity and water management practices to produce more with less water. This includes greater awareness; higher level of water reuse by all users of water; improvements and evolution of water technology; water and wastewater infrastructure improvements; extension of services to rural and urban poor population and greater energy efficiency along with increased use of renewable energy. Most freshwater resources are depleted for use by the agriculture sector and therefore, the potential for water productivity in agriculture is generally largest. However that productivity improvement in domestic and industrial sectors can also make significant contribution in reducing the share of the population.

However, alternative, sustainable development pathways, such as the blue scenario described here, are feasible and would help shift river basins and the study area toward a more sustainable development path. Such a Blue scenario would require rethinking among all water users, including agriculture, industries, and domestic water supply. That will need to move toward water conservation and efficiency improvements, coupled with aggressive but feasible investments and policy reform focused on increased water productivity. Thus, "going Blue" should be a part of the study area development agendas to help ensure that all people have an opportunity to enjoy productive and healthy lives.

5.6 Development of Composite water balance Index (CWBI) (Based on hydrological equation and Thornthwaite's method)

In an attempt to quantify water budget prepared by and Thornthwaite's method of water balance using water balance ISBH v0.3 software, a composite index has been developed to understand and simplify the water surplus and deficit areas of Indapur tahsil using principles of map algebra.

Raster analysis has been performed using multiple grid layer operation adopting addition function and then reclassifying it to get the average of both the grids. Focal grid operations (neighbourhood cells) used to get the composite water balance index. Global Mapper version 16, and Diva GIS V.7.5 software's have been used and graphing work has been performed in Arc GIS. This exercise produced a final grid of combining these two grids and displayed in **Fig. 5.15**.

It can be seen from the figure that, central part of the tahsil almost remain same as like hydrological and Thornthwaite's method, showing the acute shortage of water, where as marginal areas have more or less fluctuating little bit. No doubt, the entire tahsil, by both the equations exhibiting more or less the same result, but composition of both the maps has certainly added a true picture of the tahsil in terms of water balance.

Based on this exercise finally villages have been classified accordingly for water resource management. They are shown in **table 5.6**.

Source: Author **Fig. 5.15**

Table 5.6 Prioritization of villages for water resources management

Sr. No.	Priority level Very high	Area in km^2	Area in %	Sr. No.	Priority level High	Area in km^2	Area in %
1	Kalamb	25.53	1.62	26	Bandewadi	4.69	0.30
2	Ranmodwadi	6.17	0.39	27	Malewadi	4.42	0.28
3	Anthurne	12.3	0.78	28	Bhawadi	7.8	0.50
4	Bharnewadi	17.23	1.09	29	Loni	15.73	1.00
5	Shirsatwadi	7.54	0.48	30	Agoti No.2	4.24	0.27
6	Kadbanwadi	27.66	1.76	31	Ganjewalan	7.2	0.46
7	Hangarwadi	7.06	0.45	32	Kalashi	10.39	0.66
8	Gotandi	17.81	1.13	33	Nhavi	21.57	1.37
9	Ghorpadwadi	5.21	0.33	34	Thoratwadi	5.33	0.34
10	Nimsakhar	22.67	1.44	35	Shelgaon	39.96	2.54
11	Nirwangi	13	0.83	36	Vyahali	13.06	0.83
12	Khorachi	13.59	0.86	37	Kacharwadi	3.46	0.22
	Total	175.77	11.15	38	Nimgaon Ketki	31.96	2.03
	Priority level High			39	Pitkeshwar	9.64	0.61
1	Chikhali	3.99	0.25	40	Sarafwadi	7.54	0.48
2	Chavanwadi	2.2	0.14	41	Kati	18.13	1.15
3	Lasurne	38.11	2.42	42	Reda	9.65	0.61
4	Thoratwadi	3.15	0.20	43	Redni	18.57	1.18
5	Junction	3.01	0.19	44	Boratwadi	8.03	0.51
6	Kardanwadi	2.38	0.15	45	Chakati	8.27	0.52
7	Bori	18.65	1.18	46	Mankarwadi	1.84	0.12
8	Pilewadi	8.13	0.52		Total	531.78	33.76
9	Kalas	37.69	2.39		Priority level Medium		
10	Birgundwadi	7.68	0.49	1	Kuravali	7.29	0.46
11	Maradwadi	2.01	0.13	2	Jamb	4.28	0.27
12	Gosaviwadi	10.44	0.66	3	Gholapwadi	1.28	0.08
13	Bhadalwadi	13.55	0.86	4	Udhat	3.65	0.23
14	Bandgarwadi	2.81	0.18	5	Tawashi	6.78	0.43
15	Poundhawadi	14.35	0.91	6	Hingnewadi	3.18	0.20
16	Takrarwadi	2.69	0.17	7	Sapkalwadi	2.18	0.14
17	Bhigwan	12.77	0.81	8	Sansar	12.21	0.78
18	Bhigvanstaion	13.69	0.87	9	Belwadi	6.4	0.41
19	Diksal	8.08	0.51	10	Jachakvasti	3.94	0.25
20	Kumbhargaon	11.73	0.74	11	Shindewadi	11.05	0.70
21	Dalaj No.1	6.32	0.40	12	Kazad	15.64	0.99
22	Dalaj No2	5.67	0.36	13	Vaysewadi	2.7	0.17
23	Kalewadi	17.87	1.13	14	Akole	16.55	1.05
24	Varkute Kh	15.58	0.99	15	Nirgude	25.22	1.60
25	Palasdev	17.76	1.13	16	Pondkulwadi	14.35	0.91

Continued.....

Sr. No.	Priority level Medium	Area in	
		km^2	%
17	Madanwadi	22.46	1.43
18	Dalaj No.3	6.53	0.41
19	Agoti No.1	10.44	0.66
20	Chandgaon	5.89	0.37
21	Ruie	25.6	1.63
22	Varkute Bk	18.4	1.17
23	Balpudi	8.35	0.53
24	Kauthali	15.1	0.96
25	Karewadi	4.44	0.28
26	Gagargaon	7.69	0.49
27	Bijwadi	12.57	0.80
28	Vangali	7.29	0.46
29	Pondkulwadi	2.84	0.18
30	Narutwadi	9.04	0.57
31	Gokhali	9.89	0.63
32	Vadapuri	26.43	1.68
33	Pandharwadi	11.77	0.75
34	Shetphal haveli	16.21	1.03
35	Bhodani	8.05	0.51
36	Lakhewadi	14.92	0.95
37	Nirnimgaon	6.6	0.42
38	Kacharewadi	5.96	0.38
39	Girvi	9.62	0.61
40	Ozare	3.13	0.20
41	Kalthan No.1	18.19	1.15
42	Kalthan No.2	17.48	1.11
43	Malwadi	15.81	1.00
44	Shirsodi	11.13	0.71
45	Ajoti	7.53	0.48
46	Sugaon	8.45	0.54
47	Pimpri Kh.	5.28	0.34
48	Shaha	10.07	0.64
49	Hingangaon	9.6	0.61
50	Pawarwadi	4.38	0.28
51	Paritwadi	4.75	0.30
52	Bambadwadi	N. A.	N. A.
53	Jadhavwadi	1.88	0.12
	Total	520.47	33.04

Sr. No.	Priority level Low	Area in	
		km^2	%
1	Bhavaninagar	2.12	0.13
2	Nimbodi	8.45	0.54
3	Lakdi	13.09	0.83
4	Mhasobachiwadi	14.72	0.93
5	Lamjewadi	3.73	0.24
6	Pimple	8.86	0.56
7	Shetphalgadhe	18.95	1.20
8	Tarangwadi	15.66	0.99
9	Zagadewadi	6.66	0.42
10	Pithewadi	6.62	0.42
11	Galandwadi No. 1	7.1	0.45
12	Indapur Urban	5.62	0.36
13	Galandwadi No. 2	8.49	0.54
14	Sardewadi	9.96	0.63
15	Padsthal	11.25	0.71
16	Kandalgaon	15.38	0.98
17	Taratgaon	3.23	0.21
18	Babhulgaon	13.27	0.84
19	Bedshing	4.72	0.30
20	Bhatnimgaon	8.29	0.53
21	Avasari	10.62	0.67
22	Bhandgaon	13.34	0.85
23	Surwad	6.42	0.41
24	Vakilvasti	6.38	0.40
25	Bawada	80.97	5.14
26	Sarati	7.8	0.50
27	Lumewadi	6.98	0.44
28	Gondhi	4.76	0.30
29	Ganeshwadi	6.22	0.39
30	Pimpri Bk.	10.37	0.66
31	Tannu	8.33	0.53
32	Narsingpur	8.04	0.51
	Total	347.36	22.05

Source: Census of India 2011 and author.

Chapter – VI

Management of Water Resources in the Indapur Tahsil

6.0 Introduction

6.1 Need of water resources management in Indapur tahsil

6.2 Management of water resources in Indapur tahsil

- 6.2.1 Prioritization of villages for water resources management based on CWBI
- 6.2.2 Management of surface water resources for domestic purposes
  - 6.2.2.1 Water tanker feed villages
  - 6.2.2.2 Matching of priority villages and water tanker feed villages
  - 6.2.2.3 Multiple regression analysis
  - 6.2.2.4 Methods / techniques suggested for WRM for domestic purposes
    - 6.2.2.4.1 Roof top RWH
    - 6.2.2.4.2 Area requirement for RWH for domestic
- 6.2.3 Management of surface water resources for agriculture purposes
  - 6.2.3.1 Bhima and Nira
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  - 6.2.3.3 Methods / techniques suggested for WRM for agriculture purposes
    - 6.2.3.3.1 Integrated water resources management of Indapur tahsil
    - 6.2.3.3.1a) Soil resource management
    - 6.2.3.3.1b) Water resource management
- 6.2.4 Management of surface water resources for industrial purposes
  - 6.2.4.1 Methods / techniques suggested for WRM for industrial purposes

6.3 Assessment of potential RWH

- 6.3.1 Water availability through RWH
- 6.3.2 Area requirement for RWH

6.4 Difficulties in surface water harvesting

Chapter –VI

Management of Water Resources in the Indapur Tahsil

6.0 Introduction

Water resources management is the integrating concept for a number of water sub-sectors. The use of an integrated water resources perspective ensures that social, economical, environmental and technical dimensions are taken into account in the management and development of surface waters (rivers, lakes, and wetlands) and groundwater. This integrated approach requires water management to understand not only the water cycle (including rainfall, distribution, ecosystem interactions and natural environment and land-use changes) but also the diverse intersectoral development needs for water resources.

Where water is unavailable in most rural communities or even in many urban communities, people find it convenient to live along the rivers or the places where access of water is guaranteed. The tendency for communities to locate around water bodies is indicative of how important water is for life (Daily Graphic, 7th September, 2010). Water is indispensable to life and essential for food cultivation, household use, and industry and to sustaining the ecosystem. The availability and access to water is therefore, a fundamental right which should be considered as an integral part of any sustainable livelihood and poverty reduction programmes. The millennium development goals (MDGs) are important in their definition of a clear international agenda for focusing effort on poverty reduction. One of the goals is to stop the unsustainable exploitation of natural resources and to halve it by 2050 (Desai and Potter, 2008). This clearly relates to water and must be focus to improve the role of water in poverty reduction. The role of water in achieving the MDGs is not confined to this issue, however, as water management can contribute to realizing all of the MDGs and is of particular significance for MDGs related to promoting health, reducing hunger, increasing income and improving the living conditions of the poor. Considering the current trend of population growth and increasing demands of both in quantity and quality of population, the issue of water resource management is becoming more sensitive. Water resources in the study area have been seen as one of the development potentials for curtailing the high incidence of poverty by improving the standard of living of the people through improved irrigation techniques, livestock production and domestic as well as industrial uses.

6.1 Need of water resources management in Indapur Tahsil

In India National Water Policy had been adopted in September 1987, which recognizes water as one of the crucial element in development planning. Water Resource planning, has to be done for hydrological unit, such as the drainage basin as a whole or for a sub-basins. National Commission on Integrated Water Resources Development Plan, the Government of India (1996), under the Chairmanship of Dr. S. R. Hashim, Planning Commission member, has submitted its report in December (1999) with its recommendations on various important issues viz., irrigation, flood control, hydro-power, industrial uses of water, institutional aspects, inter-basin transfers, international dimensions, legal issues, local water resources development and management, navigation, research and development needs and water quality and environmental aspects.

Water is vital to life, without which no living being can survive. It is indispensable for economic prosperity and overall development. Therefore, water is considered prime natural resources, a basic human need and a valuable national asset. Though fresh water is available in abundance, it is not equally distributed. Till the middle of the 20^{th} century the importance of water on life had not been particularly felt because of its moderate demand. But relentless increase in the demand of fresh water in recent years has led to the scarcity of this basic resource in many parts of the study area. Such sudden endeavour on demand is caused by rapid growth of population, increasing in urbanization and industrialization, high intake of fresh water in irrigation for additional food production and misuse and wastage of fresh water in miscellaneous other ways. This is evident from the fact that annual availability of fresh water per capita has decreased.

More than 60% cultivated land of the study area fall under the rain-fed areas; Water management is one of the critical factors for improving agricultural production. The natural resource base on which existence of living beings depend-soil, water and vegetation is under degradation. Most of the regions have concentrations of eroded and degraded natural resources. Loss of vegetal cover, followed by soil degradation through erosion, has resulted in lands lacking in water as well as solid nutrients. In the study area out of a total geographical area of 157538 hectares, 50.59% of the area is suffering from soil degradation as a result of wrong and incorrect agricultural practices, over exploitation of ground water, improper use of soil resources, deforestation etc.

It is important to recognize both the positive and negative aspects of water. On the one hand, water is essential to human, animal and plant life. Water supports productive activities, agriculture, hydropower generation, industries, fishing, tourism and transport. On the other hand, water can be extremely destructive, carrying diseases and flooding vast areas. Insufficient water or prolonged drought can result in widespread death and economic decline. We also need to understand the ways in which society uses and pollutes water, or modifies the hydro morphology of water courses. These change the quantity and quality of water in ecosystems. In many areas there is ongoing degradation of freshwater resources in terms of both quantity and quality of aquatic ecosystems.

In the study area, agriculture is the predominant occupation and about 74.9% of the working population depends upon it for their livelihood (District Census 2011). Irrigation facilities created 83067 ha (52.73%) so far are less than the potential and the total net sown area is 114092 ha (72.42%) (Pune District Socio-Economic Report, 2012). As such, a large portion of agricultural land depends upon the monsoon. The majority of small and marginal farmer and landless depend on agriculture, especially in the dry region. Further because of soil erosion, over cutting of vegetation, unscientific methods of cultivation, a large area of land has been rendered barren.

Clearly, factors such as population growth, demographic changes, economic development and climate change have a critical impact on water resources. Equally, water resources have a significant impact on production and economic growth, on health and livelihoods. From west to east central part area of the study area, managing water has always been a major problem because of the low rainfall and other sources of water are not available the other source of water. This certainly provokes to find smarter ways to develop and manage water resources. The study area also has to address pollution. As villages spread along river banks, water pollution from domestic and industrial waste increases. Advances in agriculture mean that farmers use more fertilizers and pesticides, which also increase pollution. These polluted waters direct effect on community and agricultural production.

A sensible combination of the two can be applicable both in water surplus and water deficit areas. In between the two extremes, varieties of crops are grown in the canvas of partially dry and partially wet areas. This is manifested in the introduction of high water loving crops with help of canal irrigation and exploitation of ground water resources.

6.2 Management of water resources in Indapur tahsil

Water resources are the basis of sustainable development of society and economy. It is recognized from the present situation that the key issue is the management. The strategies for water conservation may be demand oriented or supply oriented and/or management oriented. The strategies may vary depending upon the field of water use domestic, irrigation or industrial. The study area receives an average rainfall equivalent of 807.35 MCM but faces serious temporal and spatial water shortages. Most of the rainwater is lost in the form of runoff, due to lack of resources for RWH and infiltration into the ground due to geological constraint. These shortages have exerted with rising demand of water particularly for irrigation. Thus water management plays crucial role both for increase the ground and surface water availability and for the control soil erosion. Contributing to the scenario is inefficient water management and use. The efficiency of surface water irrigation is estimated as low as 39.44% and although overall groundwater exploitation is only about 59.66%, resource-threatening exploitation levels have been reached in several locations. Subsidies for canal irrigation and power have encouraged inefficient resource use. The present situation has been traced to a variety of reasons, of which the most crucial are:

(a) Traditional policy and institutional focus on resource utilisation rather than management and

(b) Lack of regulation (including self-regulation) on inefficient water use. Government agencies, often uncoordinated, unsystematic and trapped in resource utilisation modes, have been largely unsuccessful in addressing the situation.

Water management at the local level offers opportunities for community involvement in analysing, planning, negotiating and managing the resource. This can correct the unsustainable and iniquitous use patterns arising from the earlier focus on resource utilisation and development. Most villages suffering water shortages are found in the central parts of study area. In these areas, small water harvesting structures are considered the most appropriate and viable. These can potentially offer benefits of:

(a) Water availability during the end of the monsoons to protect against crop failure,

(b) Groundwater recharge for improved drinking water availability during summer,

(c) Protective irrigation for rabbi crops. Such local management systems have existed in several parts of the study area but have been rendered ineffective over time by the dominant 'resource exploitation' mode of working. At the local level, their resurrection (though challenging), offers opportunity to demonstrate innovative approaches, engage with Panchayat Raj Institutions (PRIs) and other related community institutions with fewer institutional complexities and resource demands.

6.2.1 Prioritization of villages for water resources management based on CWBI

Composite **W**ater **B**alance **I**ndex (CWBI) is an outcome of the combination of water budget estimation by hydrological equation and Thornthwaite's method of water balance. The methodology adopted is discussed length in earlier lines. This index is developed to find out the villages facing acute problem of water scarcity. The results of both the methods are indicative of the prevailing drought conditions throughout the Indapur tahsil. In fact this is a known drought prone area in western Maharashtra. Within this drought prone tahsil, villages have been classified according to developed **C**omposite **W**ater **B**alance **I**ndex (CWBI).

It can be observed from the composite water balance index map and **Table no. 5.6** of Indapur tahsil that, VH (Very High) priority level in priority zone I, around 12 villages are accounted and contribute around 11.15% (175.77Km^2) of the total area, 46 villages throughout the area fall in priority zone II and at high level it admeasures about 33.76% (531.78 Km^2) of the total area of the tahsil.

Medium and low level priority are confined to 53 and 32 villages, admeasuring about 33.04% (520.47Km^2) and 22.05 % (347.36Km^2) of the total study area respectively. This overall statistics generated from the raster analysis through the principles of map algebra, clearly indicates that entire tahsil is in water deficit zone, within which different levels of priority have been delineated. Further an attempt has also been made to relate these villages with, the water tanker feed villages. It is observed that, total tanker feed villages are 35 and out of which around eight villages falls in very high category, admeasures about 138.73 Km^2 (8.8%) of the total geographical area of tahsil, 10 villages in high, 182.46 Km^2 (11.58 %), 8 villages in medium 148.54 Km^2 (9.42 %) and 9 villages 71.82 Km^2 (4.55 %) in low category of the composite water balance index.

6.2.2 Management of surface water resources for domestic purposes

The surface water is absolutely renewable, however, within the limits of its natural unpredictability. In order to manage the surface water resources, it is necessary to take into account the nature of rainfall occurrences, its spatio-temporal variability and quantity of water that becomes available. The water received in the form of rainfall is subjected to a multiplicity of factors associated to the land and soil conditions, before it becomes available for utilization. Therefore particulars of land conditions, mainly those related to slope and relief becomes an invariable component of the study of water resources management. Considering this certain details of physiography mainly related to lithology, relief drainage and slope are covered. The availability of water in the form of rainfall and its volume as well as runoff has been worked out in chapter III. The runoff estimates attempted in chapter III appear to be on higher side as compared to earlier estimates available in the literature. However if the estimates are obtained on the local level and rainwater is harvested within reasonable distances it is more than likely to have higher yield can be realised.

At the village level water security planning should start with knowledge of water resources management in the village, aquifer or watershed. A water budgeting exercise should consist of understanding water resources available, and methods of increasing the utilisation of available water resources, water requirements of different sectors like domestic, agriculture and industry. Monitoring of ground water levels and rainfall with rain gauges will lead to knowledge of availability of water resources. Understanding of water conservation and recharge should lead to planning of water harvesting and groundwater recharge structures which maximise recharge and minimise evaporation losses. Demand management of water by the irrigation sector would focus on use of less water intensive crops, efficient irrigation methods like drip and sprinkler, reuse and recycling of water, and regulation of groundwater over-abstraction. This collective approach requires considerable work with by trained persons with the villagers.

In the preceding chapter, the requirements of water for domestic use have been quantified. From the discussion it is clear that for the water requirement no single source can prove to be adequate to fulfil the total need. The only two sources are by and large commonly available and they are the rainwater and the groundwater. With all its inherent variability either spatial or temporal, rainfall is the only source, which is renewable within the limits of variation. Estimates of the volume of surface and groundwater used for domestic consumption relate to the study area as a whole and that too only for a few years. These are based on systematic comprehensive surveys of actual consumption. Domestic consumption is based on assumptions of desirable levels of water availability to ensure healthy living in rural and urban areas. The Government of India, through the Department of Drinking Water and Sanitation, has already taken significant steps to meet this challenge through the National Rural Drinking Water Programme (NRDWP) launched in April 2009. NRDWP provides grants for construction of rural water supply schemes with special focus on water-stressed and water quality affected areas, rainwater harvesting and groundwater recharge measures, and for operation and maintenance including minor repairs.

As far as the domestic water requirement is concerned, which has been estimated to be 11 MCM for whole Indapur tahsil, it may be stated that the water in adequate quantity is available provided that it is collected and utilized at places when it is received or in its immediate vicinity. Depending of the size of the village in terms of its population the area requirement is most of the villages in Indapur tahsil is differential (Appendix D). It may be observed that the minimum and maximum area requirement villages for domestic use 1.30 ha and 114.33 ha respectively, other villages required area for this purpose between this range. However, Indapur urban area required for domestic purpose 330.29 ha such areas which are to be reserved for the rainwater harvesting, should be as far as possible close to the village settlement, so that the water thus collected can be utilized without incurring transporting cost.

These water can be safely be used for all other domestic needs accepts for the consumptive water utilization by human being. For consumptive utilization it may need some processing in terms of purifications; however the total requirement of consumptive utilization is of the order of 25-30% of the total utilization. Thus by this method over 70-75% of the dependence on ground water for domestic need will be reduced and it can then be utilized for other needs.

In the previous chapter while quantifying the water requirement for domestic needs the area requirement for collecting the amount of water necessary for fulfilling the annual requirement of the population have been computed and are recorded. The area requirement values for villages are given as average area required per village. It is obvious that this value will be greater for villages with greater population and also those located in the areas where the rainfall is low. In such cases water from larger area may have to be collected at more than one place according to the area requirements as per the size of the population as well as the terrain conditions.

Such areas, which are to be reserved for the rainwater harvesting, should be as far as possible close to the village settlement, so that the water thus collected can be utilized without incurring transportation cost. These water can safely be used for all other domestic needs accepts for the consumptive water utilization by human beings.

6.2.2.1 Water tanker feed villages

There is 24.65% villages experience water scarcity in the study area which includes around 35 villages and concerned to about 32.95% population according to 2011 census .Hence in the Indapur tahsil water management has become an essential task. The villages that have single sources of drinking and agriculture water have been frequently required water tankers for longer duration in a year, which should be consider at priority level for water management. According to Panchayat Samiti, Indapur **Table no. 6.1** incorporated a list of 35 villages of Indapur tahsil which face a acute problem of drinking water requires water tankers during the summer season. Hence it suggested that the larger number of tankers frequency, higher the requirement of water management. The sequence of these villages given in this table according to scarcity period from high to low. Water Tanker firstly started in the Nimgaon Ketki and then started in other villages by a sequence these are shown in **table no 6.1**. However, which villages are located at low rainfall zone should be treated at the next priority level. Then which villages with poor accessibility where even the tanker supply becomes difficult be given higher priority.

6.2.2.2 Matching of priority villages and water tanker feed villages

In an attempt to find out the present villages which are dependent on water supply through water tankers especially in summer months to CWBI - priority levels, it is observed that in very high priority level (Zone I) there is a match about 22.86 % of the total number of villages dependent on water tankers. In high priority level it is about 28.57 % match (Zone II), in medium priority level it is about 20.00 % match (Zone III) and low priority level (Zone IV) it is about 28.57 % match. This matching exercise certainly adds a confirmation, that their villages are suffering from scarcity of water methodologically also, CWBI has thus been validated.

Table 6.1 Tanker feeds water in respected villages as water scarcity started in 2012 and their population in 2011

Sr. No.	Name of Village	Area in km^2	Population	Tanker period in days	Sr. No.	Name of Village	Area in km^2	Population	Tanker period in days
1	Nimgaon Ketki	31.96	12397	120	19	Kazad	15.21	3139	30
2	Nirgude	25.22	2095	101	20	Akole	16.55	3273	30
3	Vyahali	13.05	1698	85	21	Tarangwadi	15.66	2557	27
4	Mhasobachiwadi	14.72	2000	82	22	Gokhali	9.89	1608	27
5	Kacharwadi	3.47	829	80	23	Varkute Kh.	15.58	4811	26
6	Lakdi	12.93	2547	71	24	Kadbanwadi	27.66	1636	26
7	Nimsakhar	22.67	6000	68	25	Rangaon	6.17	3468	26
8	Vadapuri	26.43	4401	68	26	Zagadewadi	6.64	1193	23
9	Kalas	37.69	4141	66	27	Lakhewadi	14.92	4540	23
10	Galandwadi No.2	8.76	2299	66	28	Nirwangi	13	3601	22
11	Kalamb	25.53	16338	51	29	Gotandi	17.81	4650	21
12	Pithewadi	6.62	1080	50	30	Pitkeshwar	9.71	2065	19
13	Vakilvasti	6.32	435	48	31	Surwad	6.42	2639	17
14	Lamjewadi	3.73	662	41	32	Redni	17.96	3938	11
15	Thoratwadi	5.33	473	40	33	Lasurne	26.14	8803	11
16	Rui	25.6	3232	40	34	Anthurne	12.3	6100	11
17	Bedshinge	4.74	759	30	35	Nhavi	21.57	3222	2
18	Khorachi	13.59	3637	30		Total	541.55	126266	

Source: Census 2011 and Panchayat Samiti, Indapur 2012

6.2.2.3Multiple regression analysis

Regression analysis is a tool that is only as good as the underlying data used in the analysis and as good as the person using it. Ultimately, there is no substitute for a better understanding of the underlying cause-and-effect that the regression is meant to analyze as well as a better understanding of the real world elements being modelled in the regression. Linear regression analysis with multiple variables: When the dependent variable is a function of multiple independent variables the problem is called *multiple regressions*. Multiple linear regression attempts to model the relationship between two or more explanatory variables and a response variable by fitting a linear equation to observed data. This is from the Excel application provide a sense of continuity between the variables. The general purpose of multiple regressions (the term was first used by Pearson, 1908) is to learn more about the relationship between several independent or predictor variables and a dependent or criterion variable.

A trend line shows the trend in a data set and is typically associated with regression analysis. Creating a trend line and calculating its coefficients allows for the quantitative analysis of the underlying data and the ability to both interpolate and extrapolate the data for forecast purposes. In the present study, population and area of the villages shows somewhat similar trend that is as the area increases proportionately population also increases and vice versa e. g. highest population of Nimgaon Ketki and Kalamb villages are 12397 and 16338 respectively whereas its area is also larger like 31.96 Km^2 and 25.53 Km^2 respectively. While lowest population observed in Vakilvasti and Thoratwadi i.e. 435 and 473 respectively whereas its area is also smaller like 6.32 Km^2 and 5.33 Km^2. This indicates that there is a direct relationship between population and area.

But there is no any relationship between frequency of tankers and population along with frequency of tankers and area e. g. in the case of Nimgaon Ketki the population is higher (12397) and frequency of tankers is also higher (120) in the year 2011, whereas Nhavi village population is about 3222 but its frequency of tankers is only 2, this indicate there is no any relationship between population and frequency of tankers. Hence it is concluded with this analysis that the aridity the only reason for the frequency of tankers in any village of the study area shown in **Fig 6.1**.

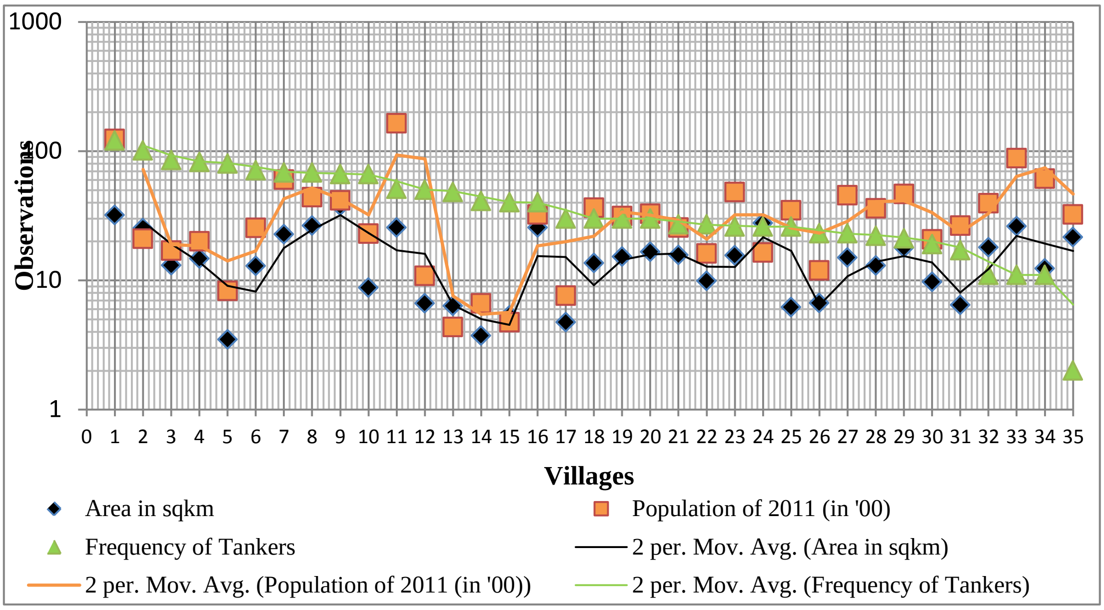

Fig. 6.1 Moving Average Graph showing village wise area, population and frequency of tankers

6.2.2.4 Methods/Techniques suggested for WRM –Domestic purposes

6.2.2.4.1 Roof top RWH

Domestic rain water harvesting or roof top RWH is the technique through which rain water is capture from roof catchments and stored in tanks/reservoirs/ ground water aquifers. It consists of conservation of roof top rain water in urban areas and utilizing it to augment ground water storage by artificial recharge. It requires connecting the outlet pipe from roof top to divert collected water to existing well/tube well/bore well or a spatial designed well.

Water harvesting is the deliberate collection and storage of rainwater that runs off on natural or manmade catchment areas. Catchment includes roof tops, compounds, rocky surface or hill slopes or artificially prepared impervious/ semi-pervious land surface. The amount of water harvested depends on the frequency and intensity of rainfall, catchment characteristics, water demands and how much runoff occurs and how quickly or how easy it is for the water to infiltrate through the subsoil and percolate down to recharge the aquifers. Moreover, in urban areas, adequate space for surface storage is not available, water levels are deep enough to accommodate additional rainwater to recharge the aquifers, rooftop and runoff RWH is ideal solution to solve the water supply problems. The main objective of such RWH is to make water available for future use. The methods of ground water recharge mainly are in urban areas roof top RWH through recharge pit, recharge trench, tube well and

Table 6.2 Availability of rain water through roof top rain water harvesting

Rainfall in mm	100	200	300	400	500	600	800	1000	1200	1400
Roof Top Area in m^2	Harvested Water from Roof Top in cum									
20	1.6	3.2	4.8	6.4	8	9.6	12.8	16	19.2	22.4
30	2.4	4.8	7.2	9.6	12	14.4	19.2	24	28.8	33.6
40	3.2	6.4	9.6	12.8	16	19.2	25.6	32	38.4	44.8
50	4	8	12	16	20	24	32	40	48	56
60	4.8	9.6	14.4	19.2	24	28.8	38.4	48	57.6	67.2
70	5.6	11.2	16.8	22.4	28	33.6	44.8	56	67.2	78.4
80	6.4	12.8	19.2	25.6	32	38.4	51.2	64	76.8	89.6
90	7.2	14.4	21.6	28.8	36	43.2	57.6	72	86.4	100.8
100	8	16	24	32	40	48	64	80	96	112
150	12	24	36	48	60	72	96	120	144	168
200	16	32	48	64	80	96	128	160	192	224
250	20	40	60	80	100	120	160	200	240	280
300	24	48	72	96	120	144	192	240	288	336
400	32	64	96	128	160	192	256	320	384	448
500	40	80	120	160	200	240	320	400	480	560
1000	80	160	240	320	400	480	640	800	960	1120
2000	160	320	480	640	800	960	1280	1600	1920	2240
3000	240	480	720	960	1200	1440	1920	2400	2880	3360

Source: Central ground water board, Delhi 2003.

recharge well. The approximate volume of water available for harvesting with respect to roof top and annual rainfall of that area has been shown in **table 6.2**.

In urban areas, rain water available from roof tops of buildings, paved and unpaved areas goes waste. This water can be recharged to aquifer and can be utilized gainfully at the time of need. The RWH system needs to be designed in a way that it does not occupy large space for collection and recharge system.

6.2.2.4.2 Area requirement for RWH for domestic purpose

The per capita water requirements proposed for different circles are used for calculating the area required. World Health Organization (WHO) has estimated that 200 litres would be sufficient for lpcd living in towns and only 70 lpcd living in villages without flush latrines. This value gives the number of persons, which can be supported for their annual water requirements with the collection of water from 1 hectare with a given amount of rainfall. The details of population, water requirement and area requirement of each circle are given below (**Table 6.3 and Fig. 6.2)**.

Table 6.3 Revenue circle wise water and area requirements

Sr. No.	Name of revenue circles	Population	Revenue circle area in ha	Water requirement in TCM	Area requirement to collect water in ha.	% area of total revenue circle
1	Bhigwan	40800	19288.39	1040	250.31	1.30
2	Indapur	60916	21136.55	2770	275.64	1.30
3	Loni	35335	21357.54	900	N. A.	N. A.
4	Bawada	48631	22278.23	1240	226.19	1.02
5	Kati	31645	15455.03	810	222.85	1.44
6	Nimgaon Ketki	50012	21537.73	1280	337.92	1.57
7	Anthurne	75725	25944.3	1930	529.55	2.04
8	Sansar	40119	10540.26	1030	219.23	2.08
Total		383183	157538	11000	2061.68	1.31

Source: Census of India 2011and analysed data N. A.: Not available

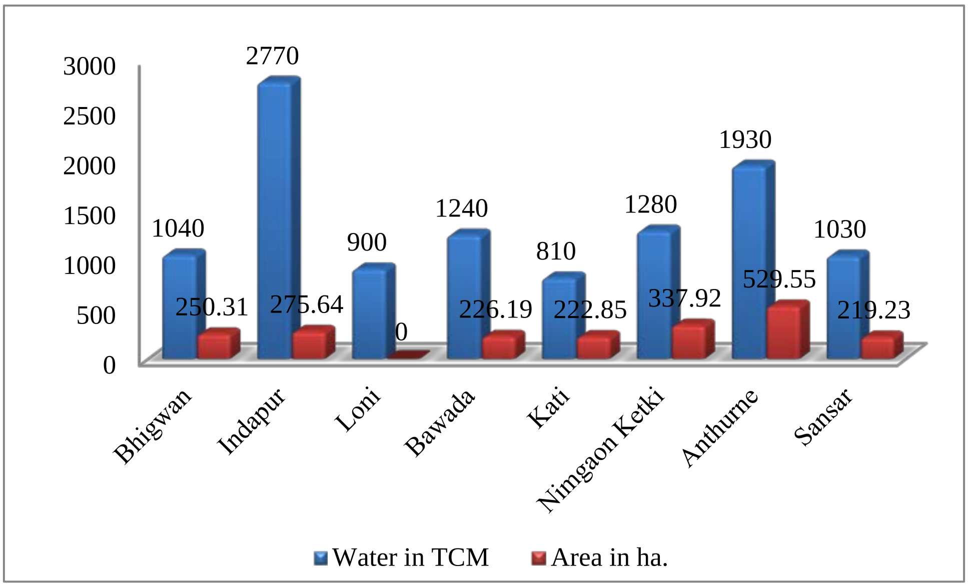

Fig. 6.2 Revenue circle wise water and area requirements

6.2.3 Management of surface water resources for agricultural purpose

There are several problems of water resources. These problems have to be taken into consideration particularly when surface water management programmes are to be worked out on micro level. Surface water development micro level the participation of people on the entire programme is essential. At this stage these details normally required at local level are not been taken into consideration. Instead, certain details of general guidelines at a regional level are being discussed here.

The study area is a part of drought prone area. Hence, there receive rainfall on a small scale. The irrigation area is mostly depending on canal, river and ground water. The total are under cultivation in Indapur tahsil as a whole is 77.72% and this also various from year to year. The actual area cultivated may vary considerably depending on the rainfall condition in a particular year. It may drop drastically to even one third of the in bad rainfall years and considering the level of variability one can clearly see that frequencies of low rainfall are much higher than that of high rainfall. Vast areas in different physiographical units are barren for one reason or the other. Most of the agriculture activity is confined to the regions, which have some prospects of getting water; either in the form of groundwater or through water irrigation. Some of the characteristics of region related to the problems pertaining to the water harvesting and utilization are discussed below.

6.2.3.1 Bhima and Nira

These areas are flat and fertile land with very high potentials of agriculture. This area suffers from low rainfall. However, it is fortunate to have canal, Ujani back water and groundwater resources to depend on for the agricultural activity. The increasing demand of food grains and other agricultural products is causing tremendous stress on the groundwater resources. The level of groundwater is lowering and alarming rate. The area away from the canals and Ujani back water has to depend only on the groundwater. Moreover, due to the peculiar arrangement of water rights of riparian population, the farmers in the far downstream areas generally suffer from insufficient water availability particularly in the years of low rainfall. The land being full of black soils, it should not be difficult for the farmers to attempt collection of rain water individually into the farm tanks and use it during the time of moisture stresses faced by the crops. Hence, if proper care water taken to collect and store rainwater in the farm tanks it would reduce the threat crop failure simply because of the non-availability of the water. Considering the high water requirement of the study area, the researcher is aware of the fact that such waters will not prove to be adequate to fulfil the entire irrigation needs of the given crops. Another problem regarding agricultures in Indapur tahsil relates to salinization of soils. Therefore considering the water requirement of crops Maharram (1997) has made provision for leaching water requirement.

For all un-irrigated crops (including forests and trees), the quantum of effective rainfall over the area covered by them gives the volume of rainfall available for their use. The total water availability for irrigated areas is the sum of the effective rainfall and supplies from irrigation sources. For irrigated areas, the total availability is the sum of the effective rainfall and the volume drawn by the canal systems adjusted for the return flows out of the commands, or the volume of water pumped from underground.

6.2.3.2 Hilly area

The northern and central east west hillock region is rather most difficult zone so far as the problems of water resources availability and management are concerned. By and large it can be described as an agrarian and barren zone. This region is high level region in the study area. This uncommand region covered 32699 ha land. It suffers from all the adverse aspects of high variability and sporadic nature comparatively other study region. The rainfall with high intensity has been .responsible for intense soil erosion and as a result most of the hillocks tract of this area bears a barren look and its sterile appearance. The drainage density is relatively low in this part of the area, slope are moderate to steep. At the base of hill slopes the runoff can be channelized to flow and collected in river Bhima and Nira.

6.2.3.3Methods/Techniques suggested for WRM-Agriculture purposes

6.2.3.3.1 Integrated water resources management of Indapur tahsil

IWRM means putting all of the pieces together. Social, environmental and technical aspects must be considered. Issues of concern include: providing the forums; reshaping planning processes; coordinating land and water resources management; recognizing water source and water quality linkages The challenge is to guide water management decision-making into flexible, holistic, and environmentally sound directions (Ballweber, 1995; Bulkley, 1995; Deyle, 1995; Viessman and Welty, 1985). IWRM is a process which promotes the co-ordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems. Therefore, IWRM should be inter-disciplinary in nature, applying knowledge from various disciplines as well as the insights from diverse stakeholders to devise and implement efficient, equitable and sustainable solutions to water and development problems.

IWRM approach invites integrated inputs derived from satellite imageries, data analysis and the quantity of sediment yield for the development of Indapur tahsil in accordance with as socio-economic data. This approach is the key to protect land, water and other natural resources to attain good crop yields and developing the area with limited funds by means of community's participation. The integrated management of surface water elicits broader information that aids in the planning of effective the study area development schemes. In the study area natural and human resources are inter-dependent. Hence, the land and water resources in conjunction with the socio-economic data serve as a tool for surface water management.

6.2.3.3.1 a) Soil resource management

When the soil erosion map shows **(Fig. 6.3)** that a particular village is less or moderately or easily susceptible to erosion it has to be compared with its sediment production and has to be checked out for any differences. These differences have to be re-examined by the overlay of landuse land cover map and slope map.

When the slope is strong and the land use is of degraded scrub land or fallow or sandy area or land with cohesion less material the area is said to be prone to moderate to severe erosion. Whereas for the same land use if the slope is gentles the erosion may be less and can be categorized under slight to moderate erosion. In some cases though the slope is strong, the erosion may be less due to the crop present in the areas with nearly level slope and crop land or pasture or forest. Severe erosion may be encountered near the foot of ridges. Further while making alternate recommendations for land use practice, futuristic considerations such as exploitation of groundwater, if presently not exploited and possibility of adopting more efficient system of irrigation and water management and other site improvements through soil and water conservation are also kept in view. In the study region proper harnessing, exploitation and development are important for their use and to prevent soil erosion are important. An unmanaged watershed posses serious hurdles like tank sedimentation, depletion of groundwater resources, lower agricultural outputs and finally affecting the inhabitants of the watershed. The streams of this watershed meet only limited water requirement of forming. Major portion of the agriculture land is rain fed. Therefore, management of water resources in the study area is important for agricultural development. As the rainfall pattern varies within this area, the water harvesting structures are required to bring such areas under irrigation. The water harvesting structures such as tanks can be

Source: Areas prone to soil erosion of Indapur tahsil **fig 6.3** built cheaply using stone-cement-motor lining and thick polythene sheets. Water harvesting shall allow an increasing in yield of important crops like food grain and pulses bringing additional area under this crop. Observations on drainage here suggest that the first order streams are still not disturbed and have good potential. Therefore, ideal conditions exist for water harvesting with suitable planning.

6.2.3.3.1 b) Water resource management

Water management affects related lands and land use practices affect related waters. Reservoir developments change land use patterns for better or worse; management of solid wastes may affect water quality; land treatment residues appear in runoff waters; channelizing streams affects their flood plains and wetlands; watershed management practices may affect the amount and quality of water available for use; attitudes of land owners are reflected in the impacts they may have on water quantity and/or quality; and facilities sitting can disrupt local hydrological regimes. These examples of ties between land-water management practices underscore the need to coordinate water resources planning and management with land use planning and regulation.

Agricultural production shows a significant difference before and after the development of the irrigation system according to the socio-economic report. Before the construction of Ujani dam only 11.51% of irrigated area to the total cultivable area, but today there are 41.19% of irrigated area to the total cultivable area in the study area. However, before the construction of an irrigation Ujani dam in Indapur tahsil, sugarcane production was only 4621 (Socio Economic Review of Pune District 1962-63) ha, but soon after the construction of the Ujani dam they are under sugarcane increased to 10900 (Socio Economic Report of Pune District 2012) ha. Correspondingly, production of maize and wheat also increased. Cropping pattern of jowar, wheat and maize as main crops, however, has changed Cropping pattern and cropping intensity has increased after irrigation scheme was constructed. This is evidenced from the increase in the use of chemical fertilizers, as reported by the respondent households in the study area.

Although water quality and water quantity (surface water and groundwater sources) are inextricably linked, these subjects have been treated too-long as if they soil erosion map shows were independent. Water quality deserves attention because of its implications for affecting the public health, the economy and the quality of ecosystems. The study area's waters continue to be damaged by pollution and misuse. Pollutants reach water bodies from point and nonpoint sources. Of special importance are the vestiges of toxic and hazardous materials disposal that are transported by surface and ground waters. In the future, groundwater and surface water resources must be managed holistically, with due consideration given to water quality aspects.

Water harvesting shall allow an increasing in and bringing additional area under the crop. Observations on drainage here suggest that the first order streams are still are not disturbed and have good potential. Therefore, ideal conditions exist for water harvesting with suitable planning. Hydrological budgeting is also important. In the study area activities such as Gully plug, Check dams, Percolation tank, Nalabunding, village ponds and tanks, Farm pond, Bore well, Dug well and Dug cum bore well etc. are recommended at particular sites are discussed below. These methods of water harvesting mainly are in rural areas.

6.2.3.3.1 b1) Gully plug

In the non-arable land, soil conservation is carried out by growing vegetative contour hedges with furrows and plugging of all gullies on the 1st order stream. Gully plugs are the smallest soil conservation structures built across small stream in hill slopes. Although, the gully plugs are soil conservation structures, they also help in maintaining the soil moisture with enhanced recharge to ground water storage. The average storage capacity of a gully plug is considered as 0.005 MCM.

6.2.3.3.1 b2) Check dams

Check dams and earth dams built across 2nd order or 3rd order streams with medium slope in which stored water is confined to stream courses. These structures also facilitate the recharge to groundwater storage and available surface water. They are proposed where water table fluctuation is very high land the stream is influent or intermittently effluent the watershed area varies widely. Check dams are 10 to 5 m long and 2 to 3m high, with width 1 to 3 m, constructed in a trapezoidal form. For the foundation of core wall a trench is dug 0.6 m wide in hard rock or 1.2 m in soft rock and cement wall is constructed 0.6 m wide to the height of at least 2.5 m above the streambed. The core wall is buttressed on both sides by a bund made up of local clays with stone pitching done on the upstream side. The average storage capacity of a check dam is 0.01 MCM but during monsoon due to multiple fillings, the gross storage capacity is considered as 0.03 MCM (Romani, 2000).

6.2.3.3.1 b3) Percolation tank

These are the tanks built in the watershed reaches to harvest rainwater through which water percolates into the ground and recharges aquifers in the downstream area. The artificially developed surface water body is the percolation tank, which facilitates the percolation of surface runoff or harvested rainwater into the ground water storage by submerging in its reservoir a highly permeable land area. A tank can be located either across small streams by creating low elevation. Where is the terrain with highly fractured and weathered rock for speedy recharge. Submergence area should be uncultivated as far as possible. Rainfall pattern based on long-term evaluation is to be studied so that the percolation tank gets filled up fully during monsoon (preferably more than once). Soils in the catchment area should preferably be of light sandy type to avoid silting up of the tank bed. The location of the tank should preferably be downstream of runoff zone or in the upper part of the transition zone, with a land slope gradient of 3 to 5%. The percolation tank should be constructed by earth material with masonry structure only for spillway. Normally the storage capacity of a percolation tank is 0.1 to 0.5 MCM. The average storage capacity is generally considered as 0.2 MCM.

6.2.3.3.1 b4) Nalabunding

Nala bunds can be constructed across bigger streams of second order in areas having gentle slopes. The rainfall in the catchments should be less than 1000 mm/annum. The soil downstream of the bund should not be prone to water logging. The Nala bunds should be preferably located in area where contour or graded bunding of lands have been carried out. The rock strata exposed in the pond area should be adequately permeable to cause ground water recharge through pond water.

6.2.3.3.1 b5) Village tanks

These are number tanks of tanks in or around the villages to collect the rainwater for domestic purpose throughout the year. Tanks also recharge the aquifer in many places, which in turn sustains the dug wells (Thomas, 1999). In the watershed, most of the tanks are either dry or dwindled due to silt deposition. The average recharge capacity through tanks is considered as 0.01 MCM.

6.2.3.3.1 b6) Farm tanks

In relatively flatter terrain with good soil cover, a farm tanks has an earth section with usually 3:1 side slopes on waterside and 2:1 side slopes on the downstream face. The drainage area above the pond should be large enough to fill the pond in 2 or 3 spells of good rainfall. The tanks should be located where it could serve a major purpose: e.g. for irrigation, it should be above the irrigated fields and for sediment control it should intercept the flow from the most erodible parts of the catchment. Junction of two drainage channels or large natural depressions should be preferred. The land surface should not have excessive seepage losses unless it is meant to serve as a percolation tank for ground water recharge.

6.2.3.3.1 b7) Bore wells

Where present land use is crop land or fallow land, slope is 0–10% and where major lineament intersects. These areas are suitable for bore wells.

6.2.3.3.1 b8) Dug well

Where land use is crop land or fallow or waste land, slope category 0–3% and minor lineaments intersect these area is appropriate for dug well. The abandoned dug wells can also be used for recharge of groundwater in the study area. There are many dug wells dry and abandoned due to declining of water table. If these abandoned dug wells in the study area are converted into recharge shafts.

6.2.3.3.1 b9) Underground tank (Bandhara)

In the study area where found the sandy soil with about 1 to 2 m depth underlained by clay, narrow nalla width and gentle slope of bed with clayey banks made the structure highly successful. This helped store under ground water and recharged the wells in the surrounding area.

6.2.3.3.1 b10) Rock fills dam

A Rock fill dam an embankment constructed across a waterway using variable sizes of stones or over burnt bricks is usually a permeable type of semi permanent structure, such as loose / stone checks are generally adopted for gully control. Rock fill dams are constructed in places where loose boulders are locally and cheaply available and gullies are not wider than 10m or so. Brick dams usually replace those dams if good quality bricks are cheaply available. In close foundation conditions are highly unstable; gabions are preferred in place of ordinary rock fill dams. By and large, rock fill dams require better foundation conditions then the earthen dams or earthen gully plugs.

6.2.4 Management of surface water resources for industrial purpose

The scope and basis of estimates of water consumption by industries are nowhere spelt out clearly. It is learnt that they are based on rather patchy data on consumption per unit of output in major industries. In the study area BILT paper industry use the 8.6 MCM (85.83%) water and other industries use the only 1.42 MCM (14.17%) water. Other industrial activities that have implications for water demand include 4 sugar factories, 1 Jaggery mill and 2 dairies. These industries are serve the needs through Nira canal 0.657 MCM, Khadakwasala canal 0.763 MCM and 8.6 MCM (23571m^3/day) fulfil by Ujani reservoir. There are total 10.02 MCM used in the industrial section. The need of water of the industries is fulfil by the canals and reservoirs.

The researcher firmly believes that though the problems are serious and complex in nature they are not insurmountable. With serious and committed efforts and through the participation of local people some remedial measures can be thought of, so as to initiate developmental efforts. So the first step in water management should be participatory resource appraisal and problem identification of the region. The next step in programme planning has to be in the form of the proper resource appraisal carried out by a team of technical experts who would understand the problem of villagers and will also be in the position to recommend strategies with minimum level of external inputs. These should be kept at minimal level and that to in the form of financial subsidies for the programmes as well technical knowledge that may not be locally available. People who are likely to be the beneficiaries of the programme shall take interest in the programme if are also the planner and the implements of the same. The absence of their participation not only hampers the progress but the whole programme may get stalled at times. Hence making people aware about the need of such programme and encouraging them to participate in the same is the first task. This can be performed by non-governmental organizations (NGOs).

The planning of the programme needs to be done with the help of some technical assistance has to be sought and therefore role of NGOs project implementing agencies becomes quite vital. With the participation of NGOs and people the issue like “what need to be done: and “what can be done”, preferably with local inputs can be sorted out.

6.2.4.1 Methods/Techniques suggested for WRM –Industrial purposes

This emphasis is to be given on harvesting of rainwater and its retention in the watershed. Appropriate measures for conservation and efficient utilization of rain water soil conservation are needed for this region. Low cost and small structures along with in-situ soil moisture conservation measures are needed. The amount of potential runoff available for harvesting in the watershed and number of structures across the toposequence is needed. In the study area open wells are functional and they must be used for RWH and recharging to improve the groundwater potential. This method not only solves conservation problems but also produces biomass and stabilizes the ground further by root system.

6.3 Assessment of potential RWH

The term water harvesting was probably used first by Geddes of the University of Sydney. He defined as the collection and storage of any form of water either runoff or creek flow for irrigation use. In India water harvesting means utilizing the erratic monsoon rain for raising good crops in dry tracks and conserve the excess runoff water for drinking and for recharging purposes. Rapid industrial development, urbanization and increase in agricultural production have led to freshwater abstraction in many parts of the study area. As the recharging of the groundwater is not adequate, there is a rapid decrease in groundwater level in several parts of the study area. In view of increasing demand of water for various purposes like agricultural, domestic and industrial etc., as well as unpredictable monsoon rainfall, a greater emphasis is being laid now-a-days for rainwater harvesting (RWH). It has become an urgent need of this century. All stakeholders should be involved using participatory approaches in the planning and implementation of RWH systems. Effective RWH systems can help supply water to beneficiaries throughout an entire year even with minimal rainfall. It is needed to use local knowledge and new technologies for RWH. RWH should also involve local resources, i.e. materials and labour, for the creation of or improvements to RWH systems. There are different / various system of water harvesting depending upon the source of water supply and places as classified below.

i) Surface water harvesting techniques

Bunding and terracing, Vegetative / stone contour barriers, Contour trenching, Contour stone walls, Contour farming, Micro catchments and Tie ridging methods Farm ponds.

ii) Direct surface runoff harvesting techniques

Roof water collection, Dug out ponds / storage tanks, Tanks, Kunds, Oranis, Temple tanks, Diversion bunds and Water spreading.

iii) Stream flow / runoff harvesting techniques

Nalabunding, Gully control structures, Check dams – Temporary, Permanent, Silt detention tanks and Percolation ponds.

iv) Sub surface flow harvesting techniques

Sub surface dams and Diaphragm dams,

v) Micro catchment's / watershed techniques

Inter terrace / inter plot water harvesting and Conservation bench terrace

vi) Runoff inducement by surface treatment

Roadbed catchments, Use of cover materials – Aluminium foils, Plastic sheet, intonate Rubber etc, using chemicals for water proofing, water repellent etc. to get more runoff water.

6.3.1 Water availability through RWH

Water can be made available in any region wherever rainfall as at least 10 to 20 mm/year. There are many water harvesting opportunities on developed sites and it can easily be planned into a new landscape during the design phase. Homes, schools, parks, parking lots, apartment complexes, commercial facilities and on ground surface area harvest the rainfall water. Water harvesting is the capture, diversion, and storage of rainwater for domestic use, plant irrigation and other uses. **R**ain **W**ater **H**arvesting (RWH) primarily consists of the collection, storage and subsequent use of captured rainwater as either the principal or as a supplementary source of water. Both potable and non-potable applications are possible (Fewkes, 2006).

There are many benefits to harvesting rainwater: Water harvesting not only reduces potable water use and related costs, but also reduces off-site flooding and erosion by holding rainwater on the site. If large amounts of water are held in pervious areas where water penetrates easily, some of the water may percolate to the water table. Rainwater is a clean, salt-free source of water for plants. RWH can reduce salt accumulation in the soil which can be harmful to root growth. When collected, rainwater percolates into the soil, forcing salts down and away from the root zone area. This allows for greater root growth and water uptake, which increases the drought tolerance of plants. Limitations of water harvesting are few and are easily met by good planning and design. RWH is a potential solution to address the water crisis in both rural and urban areas. Rainwater can be harvested in two types; 1) roof top RWH and 2) surface area RWH. RWH is estimated considering the areas where rainfall receives. Net water availability for utilization is calculated after considering the losses through evaporation and seepage. To estimate the water availability RWH runoff coefficient is also considered which varies from 0.7 to 0.9 while runoff coefficient varies from 0.5 to 0.8 for treated surface like concrete and brick pavement. For untreated surfaces it is less than 0.5 (C.S.E., 2000) and cf. Pacey and Cullis (1989) **(Table 6.4)**.

Table 6.4 Runoff Coefficients for different types of catchments and material used for Rain water harvesting.

Sr. No.	Types of Catchment	Type of Material Used	Runoff Coefficient
1.	Roof	Tiles	0.8 – 0.9
		Corrugated Metal Sheets	0.7 -0.9
2.	Covered Ground Surface	Concrete	0.6 – 0.8
		Brick Pavement	0.5 – 0.6
	Uncovered Ground Surface	Soil On Slopes Less Than 10 Percent	0.0 – 0.3
		Rocky Natural Catchments	0.2 – 0.5

Source: Modified from Pacey and Cullis (1989) And C.S.E., (2000).

6.3.2 Area requirement for RWH

The rainfall harvesting if is to be considered as a technique or approach to assure some of the water requirement then it will be necessary to think in terms of, the area from which harvesting can be done and what would be extant of such area, required for meeting the insist of an activity. The amount of water that can be collect size of region has been given in **table no. 6.5**.

Table 6.5 Quantity of water for unit areas at different levels

Sr. No.	Unit	Dimension in met.	Area	Rainfall	Water Collection	
					Litres	M^3
1.	m^2	1 X 1	1 m^2	1 mm	1	0.001
2.	Are	10 X 10	100 m^2	1 mm	100	0.1
3.	Hectare	100 (10 X 10)	10000 m^2	1 mm	10,000	10
4.	Km^2	1000 X 1000	10,00,000 m^2	1 mm	1,000,000	1,000

If the effective rainfall is of the order of 1 mm then the actual quantity of water that will get collected will be

$$VR = ER \times \text{Area in } m^2$$

Where, VR = Volume of Rainfall in Litres

ER = Effective Rainfall

Thus in case of Indapur tahsil with 550 mm of dependable rainfall (for average rainfall year) the quantity of water that can be collected in an area of 1 hectare (ha) shall be

$$VR = ER \times \text{Area in } m^2$$

$$= 550 \times 10{,}000$$

$$= 55,\ 00{,}000 \text{ litres } (5500\ m^3)$$

This quantity will be sufficient for the annual water necessity of an assured number of persons. The number will depend on the level of water necessity at a given point of time. Thus it may be clear that the number of persons which can be supported by the water collect in 1 ha of land will change with increasing water consumption level. With passage of time the level of water utilisation by people is expected to increase as result of change in life style. The total requirement will change in accordance with the number of persons but the individual requirements will change with the change in life style. The number of persons that can be supported from the study area with water collection in 1 hectare of land will vary from 89 to158 in rural area and urban area these value is 55 in 2011. This value of person is obtained in the following way:

$$\text{Persons per hectare} = \frac{\text{Water collected from 1 hectare of land in litres}}{\text{Annual water requirement per capita}}$$

The lowest areal unit for which population data were available is village. Hence the requirements are quantified for each village. For this quantification 2011 population figures have been used as based values **(Table 6.6 and Fig 6.4)**.

Table 6.6 and Fig 6.4 Circle wise number of persons supported by RWH in 1 hectare

Sr. No.	Name of revenue circles	Persons supported/ha			
		2001	2006	2011	Average RF
1.	Bhigwan	197	166	140	163
2.	Indapur	206	276	158	221
3.	Loni	N.A.	N.A.	N.A.	N.A.
4.	Bawada	252	246	152	215
5.	Kati	97	204	64	142
6.	Nimgaon	177	219	89	148
7.	Anthurne	137	180	118	143
8.	Sansar	258	199	121	183

Source: Based on data analysis RF: Rainfall N. A.: Not available

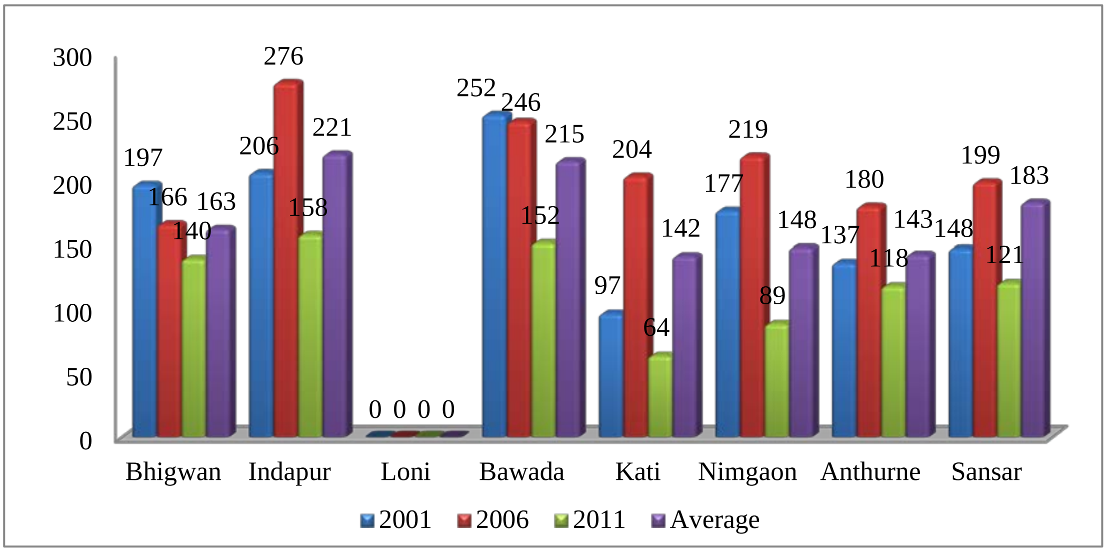

Fig 6.4

Source: Author.

It may clear from the above tables that the 1 ha area supported to different size of population in the study area. This has dependable on the rainfall distribution and life style of the people. In the Indapur circle as high as 403.8mm receives rainfall and supported 158 persons only in per ha area and in the fifteen years average rainfall is 563.99 mm receives and supported 221persons in per ha, but Kati circle 164 mm receives rainfall and in 64 persons supported population per ha and average rainfall is

362.267 mm receives and supported 142 persons in per ha. The total water requirement for domestic use in the study area for year 2011 computed to be 11000 TCM. Loni village rainfall station started recently hence data is absent.

6.4 Difficulties in surface water harvesting

i) Cost of RWH structure

The main problem in opting for the surface water harvesting for domestic and agricultural water supply is not the availability of the water but the cost of storing the water if harvested. As outlined below the cost of construction of a 30 X 30 X 3 size single tank, that can store 27, 00,000 litres water, but 25, 55, 000 litres water required for 100 people and supply 0.5 ha farm for a year. According to the rate of Government of Maharashtra Public Works Region, Pune, it is estimated to be Rs. 2932300.61 (**Table 6.7 and Fig. 6.5**). The expenditure on water storage tank construction per litre is only Rs. 1.14 and per person Rs. 29323 (per year Rs. 586.46) for the domestic water conservation. Moreover, each tank needs variable catchment areas depending on the rainfall condition, maintaining such areas wholly for collection of water may become a problem in conditions of availability of area.

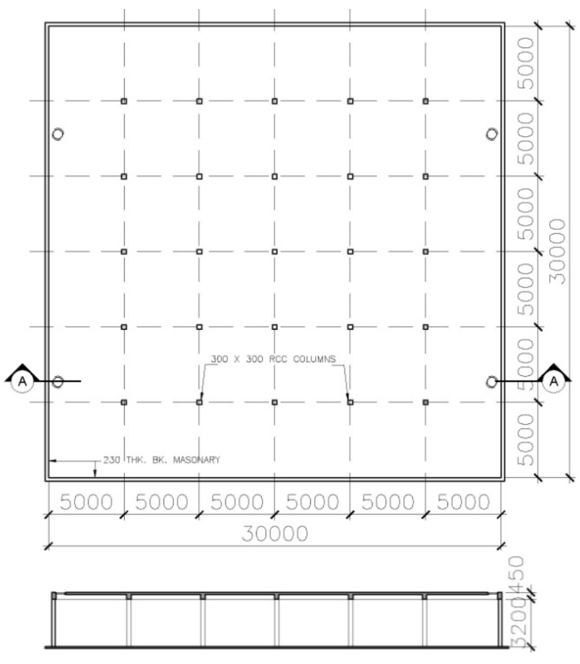

Fig. 6.5 Underground water storage tank plan design and section: AA

ii) Acceptability of the scheme

In this research work necessary primary data was collected through interviews, during the time of fieldwork an attempt was made to appreciate the response of villagers for the roof top and field harvesting. Moreover it was found that they were

Table 6.7 Storage tank measurement sheet and expenditure require

DSR No	Description of items	No.	Length	Breadth	Height	Quantity	Unit	Rate	Amount in Rs.
	Excavation								
1ia1/BDA-1	Excavation in all types of soil for tank up to 1.50 m.	1	31.36	31.36	1.5	1475.1744	CM	138	203574.0672
2iia/1-BDA2	Excavation in soft Murum for tank from 1.5 to 3.0 m.	1	31.36	31.36	1.5	1475.1744	CM	169	249304.4736
11/1 BDA-2	Providing and laying 200mm thk.dry rubble packing	1	30.76	30.76	0.15	141.92664	CM	950	134830.308
2i B /	P/Laying M:15 Grade PCC bed concrete	1	30.76	30.76	0.15	141.92664			
4 BDE2	for column footing	25	1	1	0.45	11.25			
	for column	25	0.3	0.3	1.95	4.3875			
	for beam	7	30.46	0.23	0.475	23.294285			
	for slab	1	30.46	30.46	0.125	115.97645			
	runner beam at 1.50 m.	2	30.46	0.23	0.3	4.20348			
		2	30	0.23	0.3	4.14			
						305.17836	CM	5294	1615614.211
8b/	230mm thick. Brick masonry for external walls of Tank	2	30.46	0.23	2.525	35.37929			
6-BDG-10		2	30	0.23	2.875	39.675			
						75.05429	CM	5115	383902.6934
2a/	P/Apply single coat plaster to internal surface of walls								
11- BDA-2	walls of U/G Tank	2	30.46		3	182.76			
		2	30		3	180			
	for columns	25	1.2		3	90			
	Beam sides	5	30		0.93	139.5			
						592.26	SQM	148	87654.48
1/	Damp proof water proofing over top slab 50mm thick.	1	30.46	30.46		927.8116	SQM	274	254220.3784
9 - BDJ-2	RCC Covers					4	Nos	800	3200
	Total Rs.……………………..								**2932300.612**

Source: Schedule of rates, Public Works Region, Pune 2014-15 not able to understand that the water stored from roof tops and fields can be used throughout the period of scarcity. For them it amounted to saved water and some of them also had misgivings if such water will remain usable after string it for more than 4-5 months. However, the youngsters and mainly the women did show awareness and had a number of queries about the RWH and understand that some such scheme providing a proper solution to the always occur again problem of the domestic and agricultural water supply should be make acquainted

iii) Social fabric of the rural population

The social partition of the rural population sometimes becomes a main difficulty for any kind of new schemes to be introduced. This will be more severe when a scheme interrelated to water supply is being thought of. There are number of villages, even today, where distinct water sources such as wells are maintained for separate communal groups.

Moreover the social separation a number of villages have small hamlets increase in dissimilar parts depending on the availability of arable land. These hamlets locally names as '*wadis*' are far from the main settlements. Moreover, some villages have settlements in the form of '*vasti*', which belong to migratory populations like shepherd '*vasti*' and temporary workers like sugarcane cutting workers are they considered to be portion of village by residents of major settlement.

iv) Overall inactivity to change

The main problems in foreword of any new scheme are always the inactivity that may also be coming through the propensity of jeopardy aversion. Though people face the problem of fetch water from the long distances during the period of scarcity the lack of interest to find permanent and dependable solution hinders the efforts of bringing about the changes.

v) Maintenance of catchment area

Absolutely such costs are beyond the potential of individuals or even the village panchayat. Hence, without the government supports such plan are not achievable. However the cost of implementing such plan for all the villages in an area will be completely complex

vi) Maintenance of water quality

The rainfall to be collect and stored into tanks will be to some amount vulnerable to contamination and therefore cost for maintaining it quality will have to be taken into consideration before such water is introduced for safe use. The major problem in opting for the surface water harvesting for dissimilar water supply is not the availability of the water but the cost of the storing the water, if harvested. Besides cost reason there are other difficulties that one may have to face if any effort is to be made to switch over to surface water harvesting.

Chapter-VII

Major Findings, Conclusions and Suggestions

Chapter-VII

Major Findings, Conclusions and Suggestions

7.0 Introduction

Indapur tahsil is one of the tahsils in the Pune district consisting of 142 villages along with one urban centre in the study area. There are eight revenue circles in the tahsil. Some of the main settlements in this area are Bhigwan, Indapur, Loni, Bawada, Kati, Nimgaon Ketki, Anthurne and Sansar. The area extends from 17° 53´ 42" to 18° 19´ 58" North latitudes and 74° 39´ 16" to 75° 09´ 39" East longitudes **(Fig. 2.1)**. The area is drained by the river Bhima on north and east both sides. Nira River flows south of Indapur tahsil. This area is surrounded by western boundary of Baramati tahsil, Daund tahsil lies to NW and Satara district to SW. Solapur district lies to the east, north-east and the south. There are eight revenue circles are found in Indapur tahsil. The revenue circle wise villages are displayed in the **Fig. 2.2 and table 2.1.** Total geographical area of the tahsil is 1575.38km^2 (Census 2011), out of which Nira river catchment area compress about 586.8 km^2 and Bhima river catchment covers an area of 902.43km^2. Nira River joins the Bhima River at famous tourist place i.e. Narsinhapur village after travelling a course of 209 Kms. The river Bhima, river Nira and their tributaries are draining the study area.

The river Bhima originates near Bhimashankar on the crest of Sahyadri range located in Khed tahsil (700 meters). The river Bhima is the main river of this tahsil and it flows on the northern boundary in the direction from north-west to south-east and forms natural boundaries of the tahsil on this side. This river receives water from Bhama, Indrayani, Vel, Mula-Mutha, Ghod and Nira rivers. River Nira originates near Shirgaon village in Bhor tahsil in Pune district. The confluence of the river Bhima and Nira is at Narsingpur village in the south-east part in Indapur tahsil. The total length of Bhima and Nira rivers are 103 and 64 kms respectively in the study area. Both rivers bring water during rainy season and shrink during summer. River Bhima located in the northern and north-eastern parts in the study region. There are 21 settlements situated along the bank of the river Nira in Indapur tahsil.

7.1 Major findings

Following lines describes the Major findings and conclusions.

1. The entire tahsil is characterised by basement of Deccan trap basaltic lava, which comprises mostly the prophylactic basalts with columnar joints inter trapped beds in the form of red boles at many places. The basalt flows of the Deccan Traps ranges in age from upper

Cretaceous to lower Eocene. Local alluvial deposits of recent to sub recent are seen capping the basaltic flows along the major rivers courses no mineral of economic importance has encountered **(Fig. 2.3a)** in the study area.

2. Within the study area, five Basaltic flows are exposed at various elevations ranging from 509m to 580m ASL. The lowermost flow, Compound flow II, is exposed in well sections at 509m and below, near the Bhadalwadi tank. This flow is highly vesicular and amygdaloidal in nature. Dense mineralization of silica minerals is observed throughout the flow. Overlying this is the Compact basalt III exhibiting a thickness of 10m. This flow has undergone weathering and shows exfoliated structure, with the presence of spherical weathering. Compound flow I **(Fig. 2.4)** over lie the Compact basalt III and exposed from 525m to 540m. Above this is the Compact basalt II which is relatively hard and shows widely spaced vertical fractures, which are observed across the entire thickness of the flow. The contact between Compact basalt II and Compound Flow II is seen at the base of Mutha right bank canal **(Fig. 2.5)**. The uppermost flow is the Compact basalt I which is exposed at an elevation of 560m to 580m exhibiting vertical fractures. Five Basaltic flows have been identified in the study area. Out of these, the Compound flow II along with the deeper unclassified basalts forms the principle Aquifer system to the area. The Compound flow I and some part of the Compact basalt III constitute the secondary shallower aquifer system (Kaustubh Mahamuni *et al.*2009).

3. The entire area of the tahsil is underlain by the basaltic lava flows of upper Cretaceous to lower Eocene age. The shallow alluvial formation of recent age also occurs as narrow stretch along the major Rivers flowing in the area **(Fig. 2.17a)**. There is only 74.67 km^2 (4.74%) area recommended for groundwater development in the study area. This is found in the patches in SW and NE part of the study area. Remaining 1500.71 km^2 (95.26%) area is characterised by Deccan trap and is notable as a constraint for groundwater development.

4. The Central Ground Water Board and Ground Water Survey and Development Agency have jointly estimated the ground water resources of study area based on GEC–97 methodology. The net annual ground water availability comes to be 261.86 MCM out of which 207.26 MCM is under command and 54.60 MCM is non command (GoM Groundwater Surveys and Development Agency, Pune 2014). The depth of ground water table plays an important role in determining the risk due to contamination to groundwater. Depending on the groundwater occurrence (as per MRSAC), the study area is divided into three zones ‘high’, ‘medium’ and ‘low’.

5. In the present study area around 394.79 km^2 (25.06%)area observed to be under groundwater level below 5 m below ground level(bgl),and between 5 to 15 m bgl around 553.12 km^2 (35.11%) area comprises this category. Maximum area i.e. above 15 m bgl has been observed to be 627.47 km^2 (39.83 %) of the total study area.

6. The entire study area is characterized by gently to moderate gentle sloping ground. The area in between 420 to 520 m contour is plain area, which is characterized by the alluvial soil region. This part covered 712.77 km^2 (45.24%) area of the study area. The total area is gentle plain area. The area between 520 to 580 m contour intervals is moderate gentle sloping area. This part covered maximum area of the study area i.e. 814.94 km^2 (51.73%).The area more than 580 m contour intervals is covered very less i.e. 47.67 km^2 (3.03%) of the total study area. This area is water divide portion which is characterized by moderate sloping area

7. In the present study area geomorphological area under various morphological units are observed which mainly include denudational origin on deccan trap 1032.66 km^2 (65.55%), older flood plain 539.14 km^2 (34.22%) and region of middle level plateaus (550-900m) only 3.58 km^2 (0.23%) of the total study area.

8. The shallow alluvial formation of recent age also occurs as narrow stretch along the major Rivers flowing in the area **(Fig. 2.17a)**. There is only 74.67 km^2 (4.74%) area recommended for groundwater development in the study area. This is found in the patches in SW and NE part of the study area.

9. On the basis of soil depth, drain, soil characteristics, slope etc. the following soil types are identified in the tahsil and shown in the **Fig. 2.19a**.

The black deep calcareous soil has high capacity moisture holding soil. This type of soil is only 136.42 km^2 (8.66%) are available in the study area. Whereas the slightly deep fine calcareous soil 512 km^2 (32.50%) covered area. It is found in the southern region between river Nira and Nira left canal. Besides this it found around in patches in the northern part of study area. The maximum area covered of the study area by this type soil. Along the deep black soil and slightly deep black soil found the shallow clayey soil is found. The Shallow clayey and slight stony soil is found in the Western and middle part of the study area that is higher relief and has coarser in texture and shallow in depth. These soils are covered 440.80 km^2 (27.98%) and 486.16 km^2 (30.86%) area respectively **(Fig. 2.19b)**.

10. The natural vegetation occupies 7864 hectares area accounting 5.28 % of the total geographical areas. The small patches of forest land are also found. It is negligible vegetation cover. Tropical dry deciduous trees are common in study region. Thorny bush, leaf shedding trees, stunted grass and mixed scanty vegetation are mostly appeared trees, namely, mango (Magnifera India), *Jambhul* (Syzygium Cummi), *Neem* (Azadiracta India), *chinch* (Tamarinds India) *Babhul* (Acacia Arabica) and *Bor* (Zizaphus Juju bal) are observed sparsely throughout the study region. *Babhul* trees are found in patches on soil moisture retaining area. Shrubs like *Ghaneri, Tarwad, Rui* and *Ghayapat* are associated with cultivable wastelands. *Harali, Kusali* and *Gajar* grass appeared found on open space near '*gaothan*' and along the bunds of agricultural fields in the study area.

11. The population of the study area is 196204 in 1971 and it is reached up to 383183 in 2011. Although the rate of growth was still very high, it is doubled in 40 years period. After 2001 it started to decline, it remains as 21 and 9.96 percent in 2011. This trend of population growth has a negative effect on environment since arable lands are being reduced and degraded for settlements. The Forestry Department and other stakeholders therefore need to be supported to effectively monitor and sensitize the people to protect our natural resources from the ravages of population pressure.

12. In the study area, there are thirty-one villages which have density of less than 150 persons /km^2. These villages are located on the Bhima River bank and western part of the study area. Around 75 villages population density are various between 150 to 300 persons /km^2 in the study area. The high density is observed in irrigated and industrially developed area in the study area i.e. Bhavaninagar, Kalamb, Bhigvan, Junction and Indapur. The average population density was 240 persons /km^2 during 2001 to 2011**(Fig. 2.21)**.

13. The sex ratio observed at all the time is low i.e. 939 females to 1000 males in 1981, decline this sex ratio up to 923 females in 2011. The child sex ratio is very low. It is decreased up to 858 girls to per 1000 boys in 2011, but it is 891 in 2001. The male population is high, with a continuous drop in the decadal sex ratio during 1961-2011.

14. According to census 2011, in the study area, out of the total 79683 households, around 74455 rural households and only 5228 urban households are on record. There are 12.62%

households increased in the period of 2001 to 2011. More than 72 % houses are used for residential, 11% houses are vacant and less than 17% are used for other non-residential purposes.

15. The urban to rural population ratio in the district is highly imbalanced of the total population; urban population is 6.64%, which is spread over on only 3.77% geographical area. Whereas, remaining 93.36% rural population is spread over on 96.23% geographical area of the study area. The urban population density indicates the degree of urbanization in the study area.

16. Cultivators have declined from 45.90% to 42.37% and agricultural labours have increased 25.11% to 32.53% from 1981 to 2011 years respectively. Other workers and marginal workers show a steady increase during 1981 to 2001 and decreasing in 2001 to 2011. The other workers decreased by 2.09% and marginal work increased to 10.89% in study area in the last decade.

17. As per the land utilization statistics of Indian census report 2011 out of the total 157538 hectors (ha) geographical area or the Indapur tahsil out of which 122411 ha (77.70%) area lie net cultivated, the recorded under forest area is 7443.74 ha (4.73%), area not under agricultural uses 13170.17 ha (8.36%). This category includes all lands occupied by buildings, roads or railways or water bodies and other lands put to used other than agricultural. The area under follow lands near about 3419.79 ha (2.17%) in this area including under permanent pastures, grazing lands and without fallow land but uncultivated land is 11093.30 ha (7.04%). Generally, the maximum area found under cultivation (77.70%).

18. Out of the total 143, villages in Indapur Tahsil around 45 villages have been selected as sample villages opinions of around 685 respondents from these villages has been ascertained. It has been noticed, more or less from all the villages that there is a acute problem of water starts from the month of February and this condition persist for next 3 to 4 months. Month wise thematic map of water balance index also pointed the same.

19. There are around 142 villages and one urban centre which are spread over the Indapur tahsil. The source of water in each village clearly indicates its dependence on ground water for domestic water requirement. Some of the villages however rest upon two or more resources. The villages can be grouped into two categories: such as ground water dependent i.e. wells, tube wells, hand pumps and springs and surface water dependent it includes river, tank, lake and canal. Considering this scenario of the water supply in the study area it is thought appropriate to conduct sample survey for understanding the pattern of water utilization in the villages. For this purpose about 45 villages have been selected considering different geographical conditions.

20. The average annual volume of rainfall is 1052.46 MCM. The very low rainfall volume is observed to the northern side sub basin of the tahsil (BM-61) accounts 16.43 MCM i.e. 1.56% and very high rainfall volume is observed to the eastern side sub basins of Indapur tahsil (BM-78) accounts 247.95 MCM which covers around 23.56% of the total study area.

21. The 'High' ground water potential areas are those having ground water table less than 5 m bgl, admeasures about 394.79 km^2 (25.06%). The 'Medium' areas are those having water table in the range of 5 to 15 m bgl this groundwater potential zone covers 553.12 km^2 (35.11%) of the total study area and the 'Low' ground water potential areas are those having water table more than 15 m bgl and under these having maximum area i.e. 627.47 km^2 (39.83%) of the total study area.

22. It is observed that the wells and canals are major source of water supply in the study area from the Nira canal total 57.14 MCM water is made available for Indapur tahsil and around 36.823 MCM from Khadakwasala canal total of which 93.963 MCM**.** The actual live storage of Ujani reservoir is 117.25 TMC (3283MCM) out of them 53.58 TMC (1500.24 MCM) is usable water and rest of the water 63.67 TMC (1782.76 MCM) remains as a dead storage (Government of Maharashtra, Irrigation Department, Shwetpatrica - 2012, Vol. 2).

23. There are 3 K. T. weirs built on Bhima River through the Minor Irrigation Department. From these K. T. weirs around 9.0286 MCM water resources are made available and 1859 ha area is irrigated in the study area. Owing to the K. T. weirs, 6 villages are under irrigation. K. T. weirs storage capacities are 1.06 MCM. The K. T. weirs gross 23.1703 MCM available the water resources in the study area.

24. In the study area 340 farm tanks are observed. These farm tanks are constructed the size of 30 X 30 X 3 m. There are 140 farm tanks are built by the grant of Maharashtra Rural Employment Guaranteed Scheme (MREGS), while 200 farm tanks, they are built by the grant of National Agricultural Development Scheme (NADS). These entire farm tanks avail 1.45 (0.449 as per Agri. Office -2012) MCM water resources in the study area.

25. Ground water recharge potential map procured from the primary report clearly indicates that there is very low to low ground water potential in the Indapur tahsil, may be probably due to hard compact basaltic terrain spread throughout the tahsil.

26. The total water use of Indapur tahsil is 3.894 MCM per year. The major portion of the water use of the study area is consumed by Indapur urban centre, Bhigwan, Palasdev, Lasurne and Kalamb. These five settlements are totally 1.205 MCM (30.95%) water use in the year and another 138 settlement 2.689 MCM (69.05%) water use the in the year.

27. Out of 142 villages and 1 urban center, 122 (85.31%) villages have a supply through tap water are the main source of the drinking water and remaining 21 (14.69%) villages supply through another mode. Supply through Nira canal 1.43 MCM, 0.12 MCM through Khadakwasala canal, take from Ujani reservoir 0.949 MCM and 1.395 MCM from groundwater, totally 3.894 MCM water use for domestic purposes in the study area. The villages which have using ground water sources are about 62%. Thus at least 38% are using one or more surface water sources. This clearly indicates that there is heavy dependence on the ground water is main source for domestic uses.

28. Drinking water facilities are exists in almost all villages and towns in the study area, but do not supply water throughout the year. In the study area not a single village have found dependent on a single source whereas the rest have two sources available in the other 15 (10.49%) villages, 37 (25.87%) and 62 (43.36%) villages available the 3 and 4 sources respectively. More than 5 drinking water sources are available in Palasdeo, Kalas, Kadbanwadi, Kalamb, Vadapuri and Girvi villages.

29. The main source of irrigation water is farmer-owned wells, from that source 46.86% volume of water available in the study area. Out of total irrigated area, 42.45% area under irrigation with the help of Nira and Khadakwasala canals. Nira left canal was constructed in the year 1882, whose length was 60 Kms. in Indapur tahsil. Total irrigated area under Nira left canal area of Indapur tahsil is 18049 ha area. Khadakwasala Canal was constructed in the year 1956. The length of this canal is 61 Kms in Indapur tahsil. Total irrigated area under Khadakwasala canal of Indapur tahsil is 17209 ha and under small project 1036 ha, well irrigation 26469 (31.86%) ha.

30. The major portion of the water use of the Indapur tahsil is consumed by rabbi crop cultivation followed by kharif crop cultivation. The water utilized for each village for kharif and rabbi agriculture is shown in table **4.6 and fig 4.6**. The total cultivable land in the study area is 126325 ha (84.82%) out of this kharif and rabbi crop cultivated area is only 23391.94 ha (18.52%) and 47995.6 ha (37.99%) of the total study area respectively in 2012-13.

31. Total animal population was 259980. Thus, total use of water for animal has been 5.11 MCM per annum.

32. Sugar factory is the most successful industries in the study area. There is 1 Ballarpur Industries Limited (BILT) paper mill are situated in the study area. It is an important activity using lot of water in Indapur tahsil. This BILT paper industry use the 8.6 MCM (85.83%) water and other industries use the only 1.42 MCM (14.17%) water. Other industrial activities that have implications for water demand include 4 sugar factories, 1 Jaggery factory and 1 milk product industries. These industries serve the needs of water through Nira canal 0.657 MCM, Khadakwasala canal 0.763 MCM and 8.6 MCM (23571 m^3/day) fulfill by Ujani reservoir. There are total 10.02 MCM used in the industrial section.

33. The total water requirement for agricultural claims to 580.36 MCM (96.50%), it is a large proportion. In the industrial sector 10.02 MCM (1.67%) required water, it is considerably low and only 11 MCM (1.83%) water required for domestic purposes. Thus agricultural water required to the only major water consumption sector in the study area.

34. Total population of the study area is 3, 83,183 persons out of them total rural population is 3, 57,668 and urban population is 25515. Thus, a total requirement of rural people per annum arrives at 9.14 MCM and for urban people, is 1.86 MCM and thus total 11 MCM water requirements for domestic use in the study area has been estimated.

35. In the study area the total rechargeable fresh groundwater is computed as 275.64 MCM and the net ground water availability is to the tune of 261.86 MCM. The present gross groundwater draft for all purposes is 221.15MCM. The Stage of groundwater development for the study area, as whole, is 84.45%. This indicates that on an average 84.45% of yearly replenishable groundwater is being used in the study area. Considering the domestic and industrial requirement the allocation of groundwater for next 25 years comes out to be 18.79 MCM. Leaving this allocation, the groundwater available for irrigation in future is around 53.33 MCM. The canals and reservoirs are other main sources of groundwater recharge in the study area.

36. RS and GIS proved to be powerful tools in the assessment of water resources as well as in the planning and management of water resources.

7.2 Conclusions

1. In the study area it is observed that, the maximum 402.25 km^2 (25.57 %) area under more than 125 cumecs runoff and 235.51 km^2 (14.95%) area under less than 25 cumecs. More than 125 cumecs area estimated for western high altitudinal area, eastern side strip between river Bhima and Nira and two patches are found at around Nimgaon Ketki and Indapur settlement. Low runoff (< 25) has estimated for Northern area, besides this it found around in patches in the middle and Eastern part of the study area. Besides this 25-50, 50-75, 75-100 and 100-125 cumecs runoff found in patches all over in the study area. The average surface water runoff of the catchment is estimated to 327.72 MCM/year.

2. In an exercise of water budget estimation, both the methods have been applied i.e. hydrological equation and Thornthwaite's method. It is observed that, although the entire area exhibiting water deficit. According to hydrological equation two classes have been determined, one class below '0' indicates more severity (50 villages' accounts to 35.98 % of the total geographical area) and 0-1 shows less severity (93 villages' accounts to 64.01 % of the total geographical area).According to Thornthwaite's method, it can be noticed that, around 49.08 % area (65 villages) facing very high water scarcity and rest of the villages (78 villages), 50.92% area comparatively show low degree of water scarcity.

3. An attempt has also been made to develop a **C**omposite **W**ater **B**alance **I**ndex (**CWBI**), to prioritize the villages for water resource planning and management. It can be noticed that, central part of the tahsil almost remain same as like hydrological and Thornthwaite's method, showing the acute shortage of water, where as marginal areas have more or less fluctuating little bit. No doubt, the entire tahsil, by both the equations exhibiting more or less the same result, but composition of both the maps has certainly added a true picture of the tahsil in terms of water balance.

4. It can be observed from the composite water balance index map and **Table no. 5.6** of Indapur tahsil that, VH (Very High) priority level in priority zone I, around 12 villages are accounted and contribute around 11.15% (175.77 Km^2) of the total area. 46 villages throughout the area fall in priority zone II and at high level; it admeasures about 33.76% (531.78 Km^2) of the total area of the tahsil. Medium and low level priority are confined to 53 and 32 villages, admeasuring about 33.04% (520.47Km^2) and 22.05 % (347.36Km^2) of the total study area respectively.

This overall statistics generated from the raster analysis through the principles of map algebra, clearly indicates that entire tahsil is in water deficit zone, within which different levels of priority have been delineated. Further an attempt has also been made to relate these villages with, the water tanker feed villages. It is observed that, total tanker feed villages are 35 and out of which around eight villages falls in very high category, admeasures about 138.73 Km^2 (8.8%) of the total geographical area of tahsil, 10 villages in high, 182.46 Km^2 (11.58 %), 8 villages in medium 148.54 Km^2 (9.42 %) and 9 villages 71.82 Km^2 (4.55 %) in low category of the composite water balance index.

5. In an attempt to find out the present villages which are dependent on water supply through water tankers especially in summer months to CWBI - priority levels, it is observed that, in very high priority level (Zone I) there is a match about 22.86 % of the total number of villages dependent on water tankers. In high priority level it is about 28.57 % match (Zone II), in medium priority level it is about 20.00 % match (Zone III) and low priority level (Zone IV) it is about 28.57 % match. This matching exercise certainly adds a confirmation, that their villages are suffering from scarcity of water methodologically also, CWBI has thus been validated.

7.3 Suggestions

In-depth analysis of parameters influencing the water budget scenario, potential erosion prone areas, runoff characteristics, aridity index and land use land cover **(Fig. 7.1)** of the study area various methods and techniques have been suggested for the villages having particular kind of problem of water scarcity. **Table 7.1** shows major methods and techniques as follows.

Fig. 7.1 Landuse land cover

Table 7.1: Suggested SWR Management Codes and Methods / Techniques codes for Surface Water Resource Management

SWR Management Code	Methods/Techniques codes	Description
SWRM 1	DPRT $_{\textbf{(RWH)}}$	Domestic Purpose Roof Top Rain Water Harvesting
SWRM 2	DPMLI $_{\textbf{(CANAL)}}$	Domestic Purpose Minor Lift Irrigation From Canal
SWRM 3	DPMLI $_{\textbf{(WELL)}}$	Domestic Purpose Minor Lift Irrigation From Well
SWRM 4	DPWS $_{\textbf{(TANKS)}}$	Domestic Purpose Water Supply Tanks
SWRM 5	DP $_{\textbf{(WELLS)}}$	Domestic Purpose Water Supply Wells
SWRM 6	APSW $_{\textbf{(RWH)}}$	Agricultural Purpose Surface Water Rain Water Harvesting – Through Integrated Soil and Water Conservation Measures.
SWRM 7	APF $_{\textbf{(PONDS)}}$	Agricultural Purpose Farm Ponds – Supply Through Canals and Wells.
SWRM 8	APMLI $_{\textbf{(CANAL)}}$	Agricultural Purpose Major Lift Irrigation Canal
SWRM 9	IPMLI $_{\textbf{(CANAL)}}$	Industrial Purpose Minor Lift Irrigation Canal
SWRM 10	IPRT $_{\textbf{(RHW)}}$	Industrial Purpose Roof Top Rain Water Harvesting
SWRM 11	IPMLI $_{\textbf{(WELLS)}}$	Industrial Purpose Minor Irrigation Wells
SWRM = Surface Water Resource Management.		

Source: Author

Villages have been classified according to criteria’s mentioned above are displayed in table no.7.2.These variables moreover have been assigned weights according to their importance and final scores obtained villages then classified accordingly.

Table 7.2: Village wise methods / techniques suggested for water resource management

Sr. No.	CWBI Index	Village	Area in Km2	Area in %	Status of Dominant LU/LC	Status of Runoff	Status of soil erosion % area	Aridity Index	Methods / Techniques suggested	Final score
I	**Very High Priority (VHP)**									
1	VHP	Kalamb	25.53	1.62	4	2	4	4	SWRM 6 SWRM 7 SWRM 8 SWRM 9	4
2		Ranmodwadi	6.17	0.39	4	1	4	4	SWRM 6 SWRM 7 SWRM 8 SWRM 9	4
3		Anthurne	12.3	0.78	1	2	2	4	SWRM 5 SWRM 10 SWRM 11	3
4		Bharnewadi	17.23	1.09	1	1	1	4	SWRM 2 SWRM 4	3
5		Shirsatwadi	7.54	0.48	1	1	4	4	SWRM 5 SWRM 10 SWRM 11	3
6		Kadbanwadi	27.66	1.76	1	1	1	4	SWRM 2 SWRM 4	3
7		Hangarwadi	7.06	0.45	1	1	1	4	SWRM 2 SWRM 4	3
8		Gotandi	17.81	1.13	1	2	3	4	SWRM 5 SWRM 10 SWRM 11	3
9		Ghorpadwadi	5.21	0.33	1	1	2	4	SWRM 2 SWRM 4	3
10		Nimsakhar	22.67	1.44	1	1	4	4	SWRM 5 SWRM 10 SWRM 11	3
11		Nirwangi	13	0.83	1	2	4	4	SWRM 5 SWRM 10 SWRM 11	4
12		Khorachi	13.59	0.86	1	1	4	4	SWRM 5 SWRM 10 SWRM 11	3
		Total	**175.77**	**11.15**						
II	**High Priority (HP)**									
1	HP	Chikhali	3.99	0.25	1	1	4	4	SWRM 5 SWRM 10 SWRM 11	3
2		Chavanwadi	2.2	0.14	1	1	2	4	SWRM 2 SWRM 4	3
3		Lasurne	38.11	2.42	1	3	2	4	SWRM 5 SWRM 10 SWRM 11	3
4		Thoratwadi	3.15	0.2	1	3	2	4	SWRM 5 SWRM 10 SWRM 11	3
5		Junction	3.01	0.19	3	3	2	4	SWRM 5 SWRM 10 SWRM 11	4

Sr. No.	CWBI Index	Village	Area in Km2	Area in %	Status of Dominant LU/LC	Status of Runoff	Status of soil erosion % area	Aridity Index	Methods / Techniques suggested	Final score
6	HP	Kardanwadi	2.38	0.15	1	1	2	4	SWRM 2 SWRM 4	3
7		Bori	18.65	1.18	1	4	1	4	SWRM 5 SWRM 10 SWRM 11	3
8		Pilewadi	8.13	0.52	1	4	4	4	SWRM 6 SWRM 7 SWRM 8 SWRM 9	4
9		Kalas	37.69	2.39	4	4	2	4	SWRM 6 SWRM 7 SWRM 8 SWRM 9	4
10		Birgundwadi	7.68	0.49	4	4	1	4	SWRM 6 SWRM 7 SWRM 8 SWRM 9	4
11		Maradwadi	2.01	0.13	1	1	1	4	SWRM 2 SWRM 4	3
12		Gosaviwadi	10.44	0.66	1	1	4	4	SWRM 5 SWRM 10 SWRM 11	3
13		Bhadalwadi	13.55	0.86	1	4	4	4	SWRM 6 SWRM 7 SWRM 8 SWRM 9	4
14		Bandgarwadi	2.81	0.18	1	1	2	4	SWRM 2 SWRM 4	3
15		Poundhawadi	14.35	0.91	4	4	2	4	SWRM 6 SWRM 7 SWRM 8 SWRM 9	4
16		Takrarwadi	2.69	0.17	4	1	2	4	SWRM 5 SWRM 10 SWRM 11	4
17		Bhigwan	12.77	0.81	4	1	2	4	SWRM 5 SWRM 10 SWRM 11	4
18		Bhigvanstaion	13.69	0.87	1		2	4	SWRM 2 SWRM 4	3
19		Diksal	8.08	0.51	1	1	1	4	SWRM 2 SWRM 4	3
20		Kumbhargaon	11.73	0.74	1	1	2	4	SWRM 2 SWRM 4	3
21		Dalaj No.1	6.32	0.4	4	2	2	4	SWRM 5 SWRM 10 SWRM 11	4
22		Dalaj No2	5.67	0.36	4	1	2	4	SWRM 5 SWRM 10 SWRM 11	4
23		Kalewadi	17.87	1.13	1	1	4	4	SWRM 5 SWRM 10 SWRM 11	3
24		Varkute Kh	15.58	0.99	1	2	4	3	SWRM 5 SWRM 10 SWRM 11	3
25		Palasdev	17.76	1.13	4	1	4	4	SWRM 6 SWRM 7 SWRM 8 SWRM 9	4
26		Bandewadi	4.69	0.3	4	1	4	4	SWRM 6 SWRM 7 SWRM 8 SWRM 9	4
27		Malewadi	4.42	0.28	1	3	4	4	SWRM 5 SWRM 10 SWRM 11	4

Sr. No.	CWBI Index	Village	Area in Km2	Area in %	Status of Dominant LU/LC	Status of Runoff	Status of soil erosion % area	Aridity Index	Methods / Techniques suggested	Final score
28	HP	Bhawadi	7.8	0.5	1	1	4	4	SWRM 5 SWRM 10 SWRM 11	3
29		Loni	15.73	1	1	2	4	4	SWRM 5 SWRM 10 SWRM 11	4
30		Agoti No.2	4.24	0.27	1	1	4	4	SWRM 5 SWRM 10 SWRM 11	3
31		Ganjewalan	7.2	0.46	1	1	4	2	SWRM 2 SWRM 4	3
32		Kalashi	10.39	0.66	1	1	3	2	SWRM 2 SWRM 4	3
33		Nhavi	21.57	1.37	1	2	3	4	SWRM 5 SWRM 10 SWRM 11	3
34		Thoratwadi	5.33	0.34	1	1	2	4	SWRM 2 SWRM 4	3
35		Shelgaon	39.96	2.54	4	4	2	4	SWRM 6 SWRM 7 SWRM 8 SWRM 9	4
36		Vyahali	13.06	0.83	1	1	1	4	SWRM 2 SWRM 4	3
37		Kacharwadi	3.46	0.22	1	1	2	4	SWRM 2 SWRM 4	3
38		Nimgaon Ketki	31.96	2.03	1	3	3	4	SWRM 5 SWRM 10 SWRM 11	4
39		Pitkeshwar	9.64	0.61	1	2	4	4	SWRM 5 SWRM 10 SWRM 11	4
40		Sarafwadi	7.54	0.48	1	1	3	4	SWRM 5 SWRM 10 SWRM 11	3
41		Kati	18.13	1.15	1	4	2	4	SWRM 5 SWRM 10 SWRM 11	4
42		Reda	9.65	0.61	1	2	2	4	SWRM 5 SWRM 10 SWRM 11	3
43		Redni	18.57	1.18	1	2	2	4	SWRM 5 SWRM 10 SWRM 11	3
44		Boratwadi	8.03	0.51	1	1	3	3	SWRM 2 SWRM 4	3
45		Chakati	8.27	0.52	1	2	4	2	SWRM 5 SWRM 10 SWRM 11	3
46		Mankarwadi	1.84	0.12	1	1	1	4	SWRM 2 SWRM 4	3
		Total	**531.78**	**33.76**						

Sr. No.	CWBI Index	Village	Area in Km2	Area in %	Status of Dominant LU/LC	Status of Runoff	Status of soil erosion % area	Aridity Index	Methods / Techniques suggested	Final score
III	**Medium Priority (MP)**									
1	MP	Kuravali	7.29	0.46	1	1	1	4	SWRM 2 SWRM 4	3
2		Jamb	4.28	0.27	1	1	1	4	SWRM 2 SWRM 4	3
3		Gholapwadi	1.28	0.08	1	1	2	4	SWRM 2 SWRM 4	3
4		Udhat	3.65	0.23	1	1	4	4	SWRM 5 SWRM 10 SWRM 11	3
5		Tawashi	6.78	0.43	1	1	2	4	SWRM 2 SWRM 4	3
6		Hingnewadi	3.18	0.2	1	1	4	4	SWRM 5 SWRM 10 SWRM 11	3
7		Sapkalwadi	2.18	0.14	1	2	2	4	SWRM 5 SWRM 10 SWRM 11	3
8		Sansar	12.21	0.78	1	1	2	4	SWRM 2 SWRM 4	3
9		Belwadi	6.4	0.41	1	1	4	4	SWRM 5 SWRM 10 SWRM 11	3
10		Jachakvasti	3.94	0.25	1	1	4	4	SWRM 5 SWRM 10 SWRM 11	3
11		Shindewadi	11.05	0.7	1	3	2	4	SWRM 5 SWRM 10 SWRM 11	3
12		Kazad	15.64	0.99	1	4	4	4	SWRM 6 SWRM 7 SWRM 8 SWRM 9	4
13		Vaysewadi	2.7	0.17	4	4	1	4	SWRM 6 SWRM 7 SWRM 8 SWRM 9	4
14		Akole	16.55	1.05	1	4	2	4	SWRM 5 SWRM 10 SWRM 11	4
15		Nirgude	25.22	1.6	1	4	2	4	SWRM 5 SWRM 10 SWRM 11	4
16		Poundhawadi	14.35	0.91	4	1	3	4	SWRM 5 SWRM 10 SWRM 11	4
17		Madanwadi	22.46	1.43	4	1	2	4	SWRM 5 SWRM 10 SWRM 11	4
18		Dalaj No.3	6.53	0.41	4	1	1	4	SWRM 5 SWRM 10 SWRM 11	3
19		Agoti No.1	10.44	0.66	1	1	2	4	SWRM 2 SWRM 4	3

Sr. No.	CWBI Index	Village	Area in Km2	Area in %	Status of Dominant LU/LC	Status of Runoff	Status of soil erosion % area	Aridity Index	Methods / Techniques suggested	Final score
20	MP	Chandgaon	5.89	0.37	1	1	2	4	SWRM 2 SWRM 4	3
21		Rui	25.6	1.63	1	1	2	4	SWRM 2 SWRM 4	3
22		Varkute Bk	18.4	1.17	1	2	2	4	SWRM 5 SWRM 10 SWRM 11	3
23		Balpudi	8.35	0.53	4	1	1	4	SWRM 5 SWRM 10 SWRM 11	3
24		Kauthali	15.1	0.96	4	1	2	4	SWRM 5 SWRM 10 SWRM 11	4
25		Karewadi	4.44	0.28	1	1	2	4	SWRM 2 SWRM 4	3
26		Gagargaon	7.69	0.49	1	1	4	3	SWRM 5 SWRM 10 SWRM 11	3
27		Bijwadi	12.57	0.8	1	1	2	3	SWRM 2 SWRM 4	3
28		Vangali	7.29	0.46	1	1	4	2	SWRM 2 SWRM 4	3
29		Pondkulwadi	2.84	0.18	1	1	4	4	SWRM 5 SWRM 10 SWRM 11	3
30		Narutwadi	9.04	0.57	1	1	4	2	SWRM 2 SWRM 4	3
31		Gokhali	9.89	0.63	1	1	4	3	SWRM 5 SWRM 10 SWRM 11	3
32		Vadapuri	26.43	1.68	1	2	4	2	SWRM 5 SWRM 10 SWRM 11	3
33		Pandharwadi	11.77	0.75	1	2	4	3	SWRM 5 SWRM 10 SWRM 11	3
34		Shetphal haveli	16.21	1.03	1	3	2	3	SWRM 5 SWRM 10 SWRM 11	3
35		Bhodani	8.05	0.51	1	1	4	3	SWRM 5 SWRM 10 SWRM 11	3
36		Lakhewadi	14.92	0.95	1	1	4	3	SWRM 5 SWRM 10 SWRM 11	3
37		Nirnimgaon	6.6	0.42	1	1	4	2	SWRM 2 SWRM 4	3
38		Kacharewadi	5.96	0.38	1	1	4	1	SWRM 2 SWRM 4	3
39		Girvi	9.62	0.61	1	4	4	1	SWRM 5 SWRM 10 SWRM 11	3

Sr. No.	CWBI Index	Village	Area in Km2	Area in %	Status of Dominant LU/LC	Status of Runoff	Status of soil erosion % area	Aridity Index	Methods / Techniques suggested	Final score
40	MP	Ozare	3.13	0.2	1	2	3	1	SWRM 2 SWRM 4	3
41		Kalthan No.1	18.19	1.15	1	1	4	3	SWRM 5 SWRM 10 SWRM 11	3
42		Kalthan No.2	17.48	1.11	1	1	4	3	SWRM 5 SWRM 10 SWRM 11	3
43		Malwadi	15.81	1	1	2	4	3	SWRM 5 SWRM 10 SWRM 11	3
44		Shirsodi	11.13	0.71	1	1	4	3	SWRM 5 SWRM 10 SWRM 11	3
45		Ajoti	7.53	0.48	1	1	4	2	SWRM 2 SWRM 4	3
46		Sugaon	8.45	0.54	1	1	4	2	SWRM 2 SWRM 4	3
47		Pimpri Kh.	5.28	0.34	1	1	3	2	SWRM 2 SWRM 4	3
48		Shaha	10.07	0.64	1	1	4	1	SWRM 2 SWRM 4	3
49		Hingangaon	9.6	0.61	1	1	3	1	SWRM 2 SWRM 4	3
50		Pawarwadi	4.38	0.28	1	1	4	4	SWRM 5 SWRM 10 SWRM 11	3
51		Paritwadi	4.75	0.3	1	1	4	4	SWRM 5 SWRM 10 SWRM 11	3
52		Bambadwadi	N. A.	N. A.	1	1	4	4	SWRM 5 SWRM 10 SWRM 11	3
53		Jadhavwadi	1.88	0.12	1	1	4	4	SWRM 5 SWRM 10 SWRM 11	3
		Total	**520.47**	**33.04**						
IV	**Low Priority (LP)**									
1	LP	Bhavaninagar	2.12	0.13	1	1	1	3	SWRM 2 SWRM 4	2
2		Nimbodi	8.45	0.54	1	2	2	4	SWRM 5 SWRM 10 SWRM 11	3
3		Lakdi	13.09	0.83	1	4	4	4	SWRM 6 SWRM 7 SWRM 8 SWRM 9	4
4		Mhasobachiwadi	14.72	0.93	1	2	1	4	SWRM 2 SWRM 4	3

Sr. No.	CWBI Index	Village	Area in		Status of Dominant LU/LC	Status of Runoff	Status of soil erosion % area	Aridity Index	Methods / Techniques suggested	Final score
			Km2	%						
5	LP	Lamjewadi	3.73	0.24	1	1	2	4	SWRM 2 SWRM 4	3
6		Pimple	8.86	0.56	1	2	3	4	SWRM 5 SWRM 10 SWRM 11	3
7		Shetphalgadhe	18.95	1.2	1	2	2	4	SWRM 5 SWRM 10 SWRM 11	3
8		Tarangwadi	15.66	0.99	1	2	4	4	SWRM 5 SWRM 10 SWRM 11	4
9		Zagadewadi	6.66	0.42	1	2	4	4	SWRM 5 SWRM 10 SWRM 11	4
10		Pithewadi	6.62	0.42	1	1	4	3	SWRM 5 SWRM 10 SWRM 11	3
11		Galandwadi No. 1	7.1	0.45	1	1	4	3	SWRM 5 SWRM 10 SWRM 11	3
12		Indapur Urban	5.62	0.36	3	3	4	1	SWRM 5 SWRM 10 SWRM 11	4
13		Galandwadi No. 2	8.49	0.54	1	4	4	1	SWRM 5 SWRM 10 SWRM 11	3
14		Sardewadi	9.96	0.63	1	1	4	1	SWRM 2 SWRM 4	3
15		Padsthal	11.25	0.71	1	1	4	2	SWRM 2 SWRM 4	3
16		Kandalgaon	15.38	0.98	1	1	4	1	SWRM 2 SWRM 4	3
17		Taratgaon	3.23	0.21	1	1	4	1	SWRM 2 SWRM 4	3
18		Babhulgaon	13.27	0.84	1	2	2	1	SWRM 2 SWRM 4	2
19		Bedshing	4.72	0.3	1	1	2	1	SWRM 2 SWRM 4	2
20		Bhatnimgaon	8.29	0.53	1	2	2	1	SWRM 2 SWRM 4	2
21		Avasari	10.62	0.67	1	1	2	1	SWRM 2 SWRM 4	2
22		Bhandgaon	13.34	0.85	1	2	3	1	SWRM 2 SWRM 4	3

Sr. No.	CWBI Index	Village	Area in Km2	Area in %	Status of Dominant LU/LC	Status of Runoff	Status of soil erosion % area	Aridity Index	Methods / Techniques suggested	Final score
23	LP	Surwad	6.42	0.41	1	1	1	2	SWRM 2 SWRM 4	2
24		Vakilvasti	6.38	0.4	1	1	4	1	SWRM 2 SWRM 4	3
25		Bawada	80.97	5.14	1	2	4	2	SWRM 5 SWRM 10 SWRM 11	3
26		Sarati	7.8	0.5	1	1	4	1	SWRM 2 SWRM 4	3
27		Lumewadi	6.98	0.44	1	1	4	1	SWRM 2 SWRM 4	3
28		Gondhi	4.76	0.3	1	1	4	1	SWRM 2 SWRM 4	3
29		Ganeshwadi	6.22	0.39	1	1	4	1	SWRM 2 SWRM 4	3
30		Pimpri Bk.	10.37	0.66	1	3	4	1	SWRM 5 SWRM 10 SWRM 11	3
31		Tannu	8.33	0.53	1	3	4	1	SWRM 5 SWRM 10 SWRM 11	3
32		Narsingpur	8.04	0.51	1	2	4	1	SWRM 2 SWRM 4	3
		Total	**347.36**	**22.05**						

Source: Author

Table7.3 Rating table for various parameters used to suggest conservation measures

Sr. No.	Rank	Status of dominant LU/LC	Status of Runoff MCM	Status of soil erosion % area	Status of Aridity index	Methods/ techniques suggest
1.	1	Agriculture	< 1	< 20	71	< 1
2.	2	Vegetation	1 – 2	20 – 40	72	1 – 1.5
3.	3	Settlement	2 – 3	40 – 60	73	1.5 – 2.5
4.	4	Fallow land	> 3	> 60	74	> 2.5

Source: Author

Source: Author **Fig. 7.2**

Appendix – A

Questionnaire for Fieldwork

Date of Survey:

1. Name of the village
2. Area of the Village
3. Latitude
4. Longitude
5. Height form sea level
6. Circle

7.Population

8. Total area of cropping

A. Irrigated area

B. Non-irrigated area

9. Information of watershed area:

River valley	Watershed Number	Area in Hectares	Large Watershed	Small Watershed	Micro Watershed

10. Nature of surface:

Plain	Steep slope	gentle slope	Valley	Type of rock	Type of soil

11. What are the irrigation facilities available? Give details.

Sr. No.	Type of irrigation	Total numbers	Total available water stock	Irrigated area
1.	River			
2.	Well			
3.	Borewell			
4.	Lake			
5.	Canal			
6.	Other			

Information related to water consumption considering Necules/large/literate/ animal herding families/ hotel/cold drink/ other professions

12. Name of Family head: 13. Occupation:

14. Details of the members of the family:

Individual	Male			Female			Boys			Girls		
	1	2	3	1	2	3	1	2	3	1	2	3
Age												
Education												
Occupation												

15. Facilities available in house:

A. Kitchen Otta –Yes/No B. Bathroom: In house/ Outside house

C. Toilet- Inside / Outside of house/ Public

16. Number of rooms in the house:

17. House Flooring: Smeared/ Shahabadi Floor/ Tiles/ Other

18. Domestic Water use:

	Drinking	Cooking	Bathroom	Other cleaning activities	Washing	Total
Buckets						
Water Pots/ *Hande*						

19. How water is provided in house?

20. What is the provision of stocking water in house?

21. What is tentative water stocking capacity?

22. Where and how long do you have access to water?

Where?	Distance	Required time for one trip	Number of persons involved		Number of trips	Quantity	
			Female	Male		Pots/ hande	Buckets

23. Is wastage water drainage system available in house? If yes, give details.

24. Is your house surrounded by garden? If not, Why not?

25. What are the types of trees?

26. Are clothes washed outside the house?

A. At what distance? B. And What is the facility available there?

27. From where do you avail water for domestic and public programmes?

28. Cattle rearing/ Live stock:

Types	Total	Milking	Required water		From where do you avail water for cattle?	What is the distance of it?	How many times in a day?
			Hande/pots	Bucket			
Bulloks							
Cows							

Buffalos							
Goats							
Sheep							
Other							

29. How much water is required for cleaning cattle shed?

30. After how many days the cattle shed is being cleaned?

Business:

31. What are occupations other than cultivation or agriculture?

Sr. No.	Occupation	Cooperative	Private	Quantity of water required?	
				Hande/Pots	Buckets
1	Dairy				
2	Rearing goats				
3	Poultry				
4	small scale industry				
5	Other traditional occupations				
6	Shops				
7	Hotels and alike				
8	Other occupations				

32. From where do you avail water for your business / or occupation?

33. During the days of scarcity of water, how much water is made available?

A. Hande/Pots B. Buckets

34. Is your business is affected due to water scarcity?

35. Public Places:

Public Places	Required Water		System of water storage	The place from where water is availed	Is there change in using water because of seasonal change?
	Hande/ pots	Buckets			

36. **Government Offices:**

Government office	Quantity of water required		Water storage system	Water availed from	Change of water use as the seasons change
	Water pots/*hande*	Buckets			

37. In above mentioned public offices, what is the wastage water drainage system available? Give details.

38. Sources of water:

Sources of water	Private	Public	Distance	Common	Locality wise	Duration of water availablity
Tap						
Wells						
Hand Pump						
Other						

39. Is the well water source is sufficient/ enough for a year?

40. How is public well maintained?

41. When does the silt excavated from the public well?

42. Are certain rules implemented regarding the public well water use? If yes, give details.

43. What is the provision made for wastage water drainage at the public well?

44. Well:

Number of Wells	Private	Public	Common	Locality wise
Village well				
Farm well				

45. River Course, Odha/Nallah/ Stream, spring:

Natural source	Distance from house	Duration of water available	Quality of water
River			
Stream			
Spring			

46. Are there rules formed for use of river, stream and brook water?

47. How the sources are maintained clean?

48. Is there sewage water management of river, stream or spring water?

49. What are the measures taken if the public water sources get polluted?

50. At what time of the year, the water gets polluted more?

51. What are the pollutants found?

52. What measures are implemented to avoid water pollution from the sources available?

Public Health:

53. Is drainage system available in the village?

54. What is the health situation/standard of the village?

Best/ general/ medium/ critical

55. When do the communicable diseases are spread in a year?

Sr, No.	Name disease	Point of time of infection of disease	Affected population in percent
1			
2			

56. When and for how many months is the scarcity of water experienced?

57. For how many years, scarcity of water is experienced?

58. How water is made available during the scarcity of water?

Means of water supply	Number of trips everyday	Availability of water for each family		Locality wise in the village	Source	Place	Distance
		Water pots/hande	Buckets				
Tanker							
Bullock Cart							
By walk/feet							
Other							

59. How many members or persons from your family are remain engage in making water availability?

A. Male B. Female C. Boys D. Girls

60. Do you demand water tanker for personal / individual use?

A. Number of trips B. After how many days?

61. Is it necessary for demanding water tankers for family functions? How many tankers are demanded?

62. Do you demand extra water tankers for public functions?

63. Do you change the way of water use on the basis of availability of water?

Appendix – B

Public water supply scheme

Sr. No .	Name of Grampan-chyat	Notified Habitation	Total water supplied with PWS in liters / day	Total water supplied by PWS in liter / capita / day
1	Agoti No. 1	Agoti No.1	64000	45
2	Agoti No.2	Agoti No.2	44800	54
3		Dhuke Wasti	0	54
4	Ajoti	Sugaon	17500	45
5	Akole	Akole	70000	26
6		Choudhari Wasti	0	0
7		Darade Wasti No 1	0	0
8		Darade Wasti No 2	0	0
9		Dhaigudewasti	0	0
10		Gaikwadwasti	0	0
11		Malwadi	0	0
12		Margal Wasti	0	0
13		Vaysewadi	0	0
14	Anthurne	Anthurne	1440000	53
15		Bhujbal Wasti	0	0
16		Boarate Wasti	0	0
17		Dalviwasti	0	0
18		Gaothan New	0	53
19		Sabalewasti	0	0
20		Sharad Nagar	0	53
21		Shinde Wasti	0	0
22		Ukalmala No.1,	0	0
23		Ukalmala No.2	0	0
24		Waghwasti	0	0
25	Awasari	Awasari	45600	40
26		Hanuman Nagar	0	0
27		Kate Magar Wasti	0	0
28		Kawitake Wasti	0	0
29		More Wasti	0	0
30		Shinde Wasti	0	0
31		Bedshinge	32000	67
32		Jadhavwasti	0	0
33		Kadam Deokarwasti	0	0
34		Yadav Vasti 2	0	0
35		Yadavwasti No 1	0	0
36	Babhulgaon	Babhulgaon	48000	20
37		Bhosale Wasti	0	0
38		Deokar Wasti	0	0

Sr. No .	Name of Grampan-chyat	Notified Habitation	Total water supplied with PWS in liters / day	Total water supplied by PWS in liter / capita / day
39	Babhulgaon	Gurgude Wasti	0	0
40		Jagtap Wasti	0	0
41		Londe Wasti	0	0
42		Pawar Wasti	0	0
43		Rakhunde Mala	0	0
44	Balpudi	Balpudi	20000	40
45		Chormale Wasti	0	0
46		Deokate Gadave Wasti	0	0
47		Holkar Dadas Wasti	0	0
48		Kalel Guruji Wasti	0	0
49		Kalel Wasti	0	0
50		Karande Bhujbal Wasti	0	0
51		Kathal Kale Wasti	0	0
52	Bawada	Bawada	144000	24
53		Aragade Wasti	0	0
54		Bagal Patta	0	0
55		Barawphata	0	0
56		Agalave Wasti	0	0
57		Bhurkunde Wasti	0	0
58		Damu Anna Wasti	0	0
59		Dhadage Wasti	0	0
60		Gaikwad Shinde Wasti	0	0
61		Gaikwad Wasti	0	0
62		Ghogare Ramrao Wasti	0	0
63		Kalokhe Wasti	0	0
64		Kambale Wasti	0	0
65		Kharat Wasti	0	0
66		Kudale Wasti	0	0
67		Mane Wasti	0	0
68		Naikude Wasti	0	0
69		Patil Wasti	0	24
70		Phadtare Wasti	0	0
71		Ramrao Wasti	0	0
72		Raut Wasti	0	0
73		Sawant Wasti	0	0
74		Shedge Wasti	0	0
75		Sherekar Wasti	0	0
76		Shete Wasti	0	0
77		Ganeshwadi	56000	24

Sr. No.	Name of Grampan-chyat	Notified Habitation	Total water supplied with PWS in liters / day	Total water supplied by PWS in liter / capita / day
78	Belwadi	Belwadi	90000	32
79		Gore Wasti	0	32
80		Jamdarwasti	0	32
81		Kadam Yadav Wasti	0	32
82		Khaire Wasti	0	32
83		Khillaremala M.I.D.C.	0	0
84		Khumbar Wasti	0	0
85		Mali Mane Wasti	0	0
86		Palakhi Tal	0	0
87		Pawar Mala	0	0
88		Shirkemala	0	0
89	Bhadalwadi	Bhadalwadi	24000	35
90		Bilt Company	0	35
91		Kuthalwasti	0	35
92	Bhandgaon	Bhandgaon	76000	31
93		Gaikwadwasti	0	31
94		Gawade Wasti	0	31
95		Jadhav Wasti	0	31
96		Parkale Wasti	0	0
97		Patilwasti	0	0
98	Bharanewadi	Birobawadi	64000	36
99		Awate Wasti	0	0
100		Deokulewasti	0	36
101		Dhapatewasti	0	36
102		Gaikwadi Wasti	0	0
103		Kale Borate Wasti	0	36
104		Mhaske Wasti	0	0
105		Musalmanwadi	0	36
106		Porewadi	0	36
107		Umbar Wadi	0	36
108	Bhatnimgaon	Bhatnimgaon	67200	61
109		Bhosale Tawade Wasti	0	61
110		Deokar Wasti	0	61
111		Kambale Chavan Wasti	0	61
112		Khabale Wasti	0	61
113		Magar Wasti	0	0
114		Nana Gavali Wasti	0	0
115		Pathan Wasti	0	0
116		Pawar Wasti	0	0
117		Varpe Dhone Wasti	0	0

Sr. No.	Name of Grampan-chyat	Notified Habitation	Total water supplied with PWS in liters / day	Total water supplied by PWS in liter / capita / day
118	Bhatnimgaon	Vetal Wasti	0	0
119	Bhavadi	Bhavadi	48000	52
120	Bhigvan	Bhigvan	300000	46
121		Atole Jadhav Wasti	0	46
122		Bhigvanstaion (N.V.)	32000	44
123		Matre Wagjkar Kokelar	0	0
124		Sontakke Wasti	0	0
125	Bhodani	Bhodani	64000	36
126		Bokudrada	0	0
127		Chavan Wasti	0	0
128		Deokar Wasti	0	0
129		Jagtap Wasti	0	0
130		Kambale Londe Wasti	0	0
131		Khandobachiwadi	0	0
132		Khote Wasti	0	0
133		Nimbalkar Wasti	0	0
134	Bijwadi	Bijwadi	60000	20
135		Butar Galli	0	0
136		Kale Wasti 2	32000	24
137		Kalel Wasti 1	0	0
138		Phule Nagar	0	0
139		S.B.Nikam Wasti	0	0
140		Garargaon	40000	34
141		Pondkul Wadi	17600	48
142		Dhuke Wasti	0	0
143		Gaikawadwasti	0	0
144		Rajawadi	0	0
145		Chavan Wasti	0	0
146		Nikam Wasti	0	0
147		Parekar Wasti	32000	39
148		Wangali	0	0
149	Boratwadi	Boratwadi	1040000	66
150		Chavan Wasti	0	0
151		Gaikwadi Wasti	0	0
152		Hegadkarwasti	0	0
153		Khadewasti	0	0
154		Sakhare Wasti	0	0
155		Sudrik Wasti	0	0
156	Bori	Bori	80000	20
157		Bhise Wasti	0	0

Sr. No.	Name of Grampan-chyat	Notified Habitation	Total water supplied with PWS in liters / day	Total water supplied by PWS in liter / capita / day
158	Bori	Deokate Wasti	0	0
159		Devade Wasti	0	0
160		Khandoba Nagar	0	0
161		Kharat Wasti	0	0
162		Kshatia Wasti	0	0
163		Malhar Wadi	0	0
164		Mali Wasti	0	0
165		Nagave Wasti	0	0
166		Nanavre Wasti	0	0
167		Waghmodewasti	0	0
168	Chakati	Chakati	40000	50
169		Markad Wasti	0	0
170		Pandhare Bandgar Wasti	0	0
171		Phadate Rupnawar Nikam	0	0
172		Tanpure Wasti	0	0
173	Chandgaon	Chandgaon	40000	54
174		Gole Wasti	0	0
175	Chikhali	Chikhali	40000	40
176		Arjun Wasti	0	0
177		Madane Wasti	0	0
178		Nikam Wasti	0	0
179		Ramoshi Wasti	0	0
180	Dalaj No.2	Dalaj No.2	60000	60
181		Chaufula	0	0
182		Jagtap Wasti	0	0
183		More Wasti	0	0
184		Nimkar Wasti	0	0
185		Pansare Wasti	0	0
186		Patil Wasti	0	0
187	Dalaj No.1	Dalaj No.1	40000	40
188		Ankush Bhosale Wasti	0	0
189		Mete Wasti	0	0
190		Subhash Jagtap Wasti	0	0
191	Dalaj No.3	Dalaj No.3	80000	57
192	Dikasal	Dikasal	60000	57
193		Hagare Pondkule Wasti	0	0
194		Jadhav Wasti	0	0
195		Mali Kumbhar Wasti	0	0
196		Pawar Wasti	0	0

Sr. No.	Name of Grampan-chyat	Notified Habitation	Total water supplied with PWS in liters / day	Total water supplied by PWS in liter / capita / day
197	Galandwadi No.1	Galandwadi No 1	80000	58
198		Warangali	0	0
199		Narutwadi	0	0
200	Galandwadi No.2	Galandwadi No.2	27200	39
201		Bhong Wasti	0	0
202		Bobade Wasti	0	0
203		Gadade Bhong Wasti	0	0
204		Bhagwan Galande Wasti	0	0
205		Kadam Wasti 1	0	0
206		Kadam Wasti 2	0	0
207		Mavare Jamdar Wasti	0	0
208		More Wasti	0	0
209		Pimpre Gade Wasti	0	0
210		Shende Wasti	0	0
211		Shindewasti	0	0
212		Tatewasti	0	0
213		Vitthalwadi	0	0
214	Gangavalan	Gangavalan	40000	29
215	Ghorpadwadi	Ghorpadwadi	16000	30
216	Giravi	Giravi	61200	45
217		Diisale Dhokalewasti	0	0
218		Khirsagar Shinde Wasti	0	0
219	Gondi	Gondi	68000	50
220		Deshmukh Wasti	0	0
221		Dushkali Bhag	0	0
222		Dange Wasti	0	0
223		Jadhav Wasti	0	0
224		Gaikwadi Wasti	0	0
225		Ozare	40000	60
226		Palave Wasti	0	0
227		Pawar Wasti	0	0
228		Rupnawar Wasti	0	0
229		Shinde Wasti	0	0
230		Solankar Wasti	0	0
231	Gotandi	Gotandi	80000	40
232	Hangarwadi	Hangarwadi	40000	45
233		Bormanwadi	0	0
234		Hanumanwadi	0	0
235		Mergalwasti	0	0

Sr. No.	Name of Grampan-chyat	Notified Habitation	Total water supplied with PWS in liters / day	Total water supplied by PWS in liter / capita / day
236	Higangoan	Higangoan	32000	40
237		Chormale Kokekar Wasti	0	0
238		Deokar Autade Wasti	0	0
239		Deokar Patil Wasti	0	0
240		Deokar Wasti	0	0
241		Hasbe Wasti	0	0
242		Autade Deokar Wasti	0	0
243		Jagtap Wasti	0	0
244		Javale Gaikawad Wasti	0	0
245		Kate Redekar Wasti	0	0
246		Kharde Pawar Wasti	0	0
247		Patole Kale Wasti	0	0
248		Tambili Jagtap Wasti	0	0
249		Tamibile Lawate Wasti	0	0
250	Jachakwasti	Jachakwasti	52000	42
251		Jamdar Wasti	0	0
252		Nanavarewasti	0	0
253		Nimbalkar Wasti No 1	0	0
254		Nimbalkar Wasti No 2	0	0
255		Parlekar Wasti	0	0
256		Pawar Mala	0	0
257		Ranaware Mala	0	0
258	Jadhavwadi	Jadhavwadi	40000	46
259		Arade Wasti	0	0
260		Musalman Wasti	0	0
261		Shivajinagar	0	0
262	Jamb	Jamb	56000	40
263		Dananewasti	0	0
264		Gaikwadi Wasti	0	0
265		Chavan Wasti	0	40
266		Kambale Wasti	0	0
267	Jankshan	Jankshan	144000	45
268		Bankarwasti	0	0
269		Anand Gana	0	0
270		Kale Wasti	0	0
271		Kharpad	0	0
272		Londe Wasti	0	0
273		Lorade Wasti	0	0
274		Sai Nagar	0	0
275		Salakhe Wasti	0	0

Sr. No.	Name of Grampan-chyat	Notified Habitation	Total water supplied with PWS in liters / day	Total water supplied by PWS in liter / capita / day
276	Jankshan	Wadekar Wasti	0	0
277		Zopadpatti	0	0
278	Kacharewadi	Kacharewadi	40000	48
279		Bhausaheb Nagar	0	0
280		Kachare Wasti	0	0
281		Bhagat Wasti	0	0
282		Misal Wasti	0	0
283		Yadav Wasti	0	0
284	Kadbanwadi	Kadbanwadi	40000	50
285		Domable Wasti	0	0
286		Gawade Vasye Wasti	0	0
287		Gawade Wasti	0	0
288		Hagare Wasti	0	0
289		Jadhav Vasti	0	0
290		Chaure Wasti	0	0
291		Kharde Wasti	0	0
292		Musalman Wasti	0	0
293		Ramoshi Wasti	0	0
294		Shingade Wasti	0	0
295		Tale Wasti	0	0
296		Ughada Maruti Wasti	0	0
297	Kalamb	Kalamb	180000	38
298		Ambedkar Colony	0	0
299		Ashok Nagar	0	0
300		Bhorakar Wadi	0	0
301		Dnyndip Society	0	0
302		Ghodake Wasti	0	0
303		Gulmohar Society	0	0
304		Jagtap Mala	0	0
305		Jankar Mala	0	0
306		Adhipuri	0	0
307		Kokare Wasti	0	0
308		Lalpuri	2800	35
309		Mohite Mala	0	0
310		Narlibhag	0	0
311		Naudare	32000	45
312		Pathan Wasti	0	0
313		Pawar Wasti	0	0
314		Phadtare Wasti	0	0
315		Ramwadi	0	0

Sr. No.	Name of Grampan-chyat	Notified Habitation	Total water supplied with PWS in liters / day	Total water supplied by PWS in liter / capita / day
316	Kalamb	Sandhachal	0	0
317		Sattawanchal	0	0
318		Sawantwasti	0	0
319		Shivajinagar	0	0
320		Solankar Wasti	0	0
321		Subhedhar Wasti	0	0
322	Kalas	Kalas	100000	38
323		Birungudi	40000	35
324		Bondre Sangale Wasti	0	0
325		Jambal Wasti	0	0
326		Lohar Wasti	0	0
327		Mahadeo Mandir Wasti	0	0
328		More Dadge Wasti	0	0
329		Patil Wasti	0	0
330		Sangale Wasti	0	0
331		Zagirdar Wasti	0	0
332		Gosaviwadi	0	0
333		Kharche Wasti	0	0
334		Khobaricha Mala	0	0
335		Vayal Wasti	32000	32
336		Vitthalwadi	0	0
337		Agalawe Wasti	0	0
338		Bagwadi	0	0
339		Chinchecha Mala	0	0
340		Don Motocha Mala	0	0
341		Gujgal Wasti	0	0
342		Bhagat Wasti	0	0
343		Khade Musalman Wasti	0	0
344		Mukadam Wasti	0	0
345		Pondakule Wasti	0	0
346		Postman Wasti	0	0
347		Bhandvalkar Wasti	0	0
348		Kambale Colony	0	0
349		Ogale Wayal Wasti	0	0
350		Pilewadi	40000	35
351	Kalashi	Kalashi	56000	28
352		Redake Wasti	0	0
353	Kalthan No.1	Kalthan No.1	90000	30
354		Jagtap Wasti	0	0
355		Gatkulwasti	0	0

Sr. No.	Name of Grampan-chyat	Notified Habitation	Total water supplied with PWS in liters / day	Total water supplied by PWS in liter / capita / day
356	Kalthan No.2	Kalthan No.2	100000	57
357		Padule Wasti	0	0
358		Redake Wasti	0	0
359	Kandalgoan	Kandalgoan	52000	30
360		Bhaskar Wasti	0	0
361		Bhange Wasti	0	0
362		Nanware Sarade Wasti	0	0
363		Phate Wasti	0	0
364	Kati	Kati	144000	54
365		Bharatwadi	0	0
366		Bhosale Wasti	0	0
367		Dattawadi	0	0
368		Daulat Barkade Wasti	0	0
369		Hanuman Nagar	0	0
370		Jadhavwadi	0	0
371		Kachare Wasti	0	0
372		Autade Wasti	0	0
373		Kisan Bhong Wasti	0	0
374		Laxmi Nagar	0	0
375		Masal Wasti	0	0
376		Mohitewasti	0	0
377		Mulani Bhosale Wasti	0	0
378		Parande Pise Wasti	0	0
379		Shelkewasti	0	0
380		Thorat Kachare Wasti	0	0
381		Yadavwadi	0	0
382	Kauthali	Kauthali	40000	35
383		Bhise Deokate Wasti	0	0
384		Chormale Wasti	0	0
385		Kalel Wasti	0	0
386		Bhandalkar Wasti	0	0
387		Khamgalwadi	0	0
388		Manewasti	0	0
389		Markad Wasti	0	0
390		Yamgar Wasti	0	0
391	Kazad	Kazad	72000	40
392		Jayavantwadi	0	0
393		Hanumanwadi	0	0
394		Kharat Wasti	0	0
395		Panmala	0	0

Sr. No.	Name of Grampan-chyat	Notified Habitation	Total water supplied with PWS in liters / day	Total water supplied by PWS in liter / capita / day
396	Kazad	Ranmala	0	0
397		Siddeshwar Mala	0	0
398		Wadacha Mala	0	0
399	Khorochi	Khorochi	34400	35
400		Deokar Wasti	0	0
401		Hegadkarwasti	0	0
402		Jadhav Kare Wasti	0	0
403		Jamdadewasti	0	0
404		Kadam Wasti	0	0
405		Khirsagar Wasti	0	0
406		Borade Hegdkar Wasti	0	0
407		Kokarewasti	0	0
408		Patilwasti	0	0
409		Phadtare Wasti	0	0
410		Sakhare Wasti	0	0
411		Waghmodewasti	0	0
412	Kumbhargaon	Kumbhargaon	76000	69
413		Dhumalwadi	0	0
414	Kuravali	Kuravali	80000	40
415		Chavan Wasti	0	0
416		Harijanwasti	0	40
417		Kadam Wasti	0	0
418		Khomane Wasti	0	0
419		Bambadwadi	0	0
420		Mane Tanpure Vasti	0	40
421		Matang Wasti	0	40
422		Phadtare Wasti	0	0
423	Lakadi	Lakadi	20000	46
424		Patilwasti	0	0
425		Vadaje Wasti	0	0
426		Wanve Wasti	0	0
427	Lakhewadi	Lakhewadi	35600	40
428	Lasurne	Lasurne	180000	40
429		Chavhanwadi	0	0
430		Kardanwadi	40000	25
431		Kardanwadi 2	0	0
432		Mohitewadi	0	0
433		Salunkhe Wasti	0	0
434		Athadare	0	0
435		Bajarang Wadi	0	0

Sr. No.	Name of Grampan-chyat	Notified Habitation	Total water supplied with PWS in liters / day	Total water supplied by PWS in liter / capita / day
436	Lasurne	Bambadwadi	128000	27
437		Rajiv Gandhi Nagar	0	0
438		Vaiduwasti	0	0
439		Jachakwasti	0	0
440		Kokare Wasti	0	0
441		Paritwadi	0	0
442		Patil Wasti	0	0
443	Loni Deokar	Loni Deokar	48000	37
444		Ghadage Wasti No.1	0	0
445		Ghadage Wasti No.2	0	0
446		Irrigation Bunglow	0	0
447		Deokar Dongare Wasti	0	0
448		Thorat Wasti	0	0
449		Thorave Kangude Wasti	0	0
450		Tonde Wasti	0	0
451	Lumewadi	Lumewadi	72000	32
452		Limbodi	16000	43
453	Madanwadi	Madanwadi	35000	30
454		Bhakas Wadi	0	0
455		Chaufula	0	0
456		Deokatewasti	0	0
457		Dhavale Wasti	0	0
458		Bandgarwasti	19200	31
459		Nikam Wasti	0	0
460		Virwadi No 1	25600	40
461		Virwadi No.2	0	0
462	Malwadi	Malwadi	36800	41
463		Gadade Wasti	0	0
464		Kshirsagarwasti	0	0
465		Bend Wasti	0	0
466		Malwadi No 2	32000	40
467		Mhetrewasti	0	0
468		Satputewasti	0	0
469		Shingade Wasti	0	0
470		Thakarwasti	0	0
471	Mankarwadi	Mankarwadi	20000	40
472		Kanse Wasti	0	0
473		Mankar Wasti	0	0
474		Charmkar Wasti	0	0
475		Morewasti	0	0

Sr. No.	Name of Grampanchyat	Notified Habitation	Total water supplied with PWS in liters / day	Total water supplied by PWS in liter / capita / day
476	Mankarwadi	Zopadpatti	0	0
477	Mhasobachi Wadi	Mhasobachi Wadi	55000	32
478		Kawadewasti	0	0
479		Dabhadewasti	0	0
480	Narsingpur	Narsingpur	80000	50
481		Laxmi Nagar	0	0
482		Adobawasti	0	0
483	Nhavi	Nhavi	120000	53
484		Dombalwadi	16000	33
485		Kalokhe Wasti	0	0
486		Kargal Wasti	0	0
487		Markadwasti	0	0
488		Mulani Raskarwasti	0	0
489		Boratwadi	48000	25
490		Shaikh Wasti	0	0
491		Shinde Wasti	0	0
492	Nimbodi	Nimbodi	60000	40
493		Gholave Wasti 1	0	0
494		Gholave Wasti 2	0	0
495		Nikamwasti	0	0
496		Bhoitewasti	0	0
497	Nimgaon Ketaki	Nimgaon Ketaki	144000	23
498		Baravkar Hewal Wasti	0	0
499		Bhiroba Mala	0	0
500		Bhogwadi	0	0
501		Bhosale Wasti	0	0
502		Chinchwadi	0	0
503		Dongare Wasti	0	0
504		Gadad Wasti	0	0
505		Hegade Wasti 1	0	0
506		Hegade Wasti 2	0	0
507		Irrgation Colony	0	0
508		Jadhavwadi	0	0
509		Kahndoba Mala	0	0
510		Kala Mala	0	0
511		Kauti Mala	0	0
512		Kharade Khore Wasti	0	0
513		Laxminagar	0	0
514		Mehtre Wasti	0	0
515		Nahau Mala	0	0

Sr. No.	Name of Grampan-chyat	Notified Habitation	Total water supplied with PWS in liters / day	Total water supplied by PWS in liter / capita / day
516	Nimgaon Ketaki	Nale Jadhavwasti	0	0
517		Nawamala	0	0
518		Adaling Mala	0	0
519		Patilwasti	0	0
520		Rautwadi	0	0
521		Shende Mala 1 To 3	0	0
522		Vadapure Wasti	0	0
523	Nimsakhar	Nimsakhar	64000	18
524		Karandewasti	0	0
525		Khandobanagar	24000	24
526		Lavatewasti	0	0
527		Bargewasti	0	0
528		Veerwasti	0	0
529	Nirgude	Nirgude	42400	30
530		Lakade Wasti	0	0
531		Kakan Sonwane Wasti	0	0
532		Pawarwasti	0	0
533		Vakil Wasti	0	0
534	Nirnimgaon	Nirnimgaon	60000	42
535		Indiranagar	0	0
536		Datta Nagar Wasti	0	0
537		Pamdin Wasti	0	0
538		Patil Wasti	0	0
539		Pawar Wasti	0	0
540		Wavare Wasti	0	0
541	Nirvangi	Nirvangi	68000	48
542		Jadhavwasti	0	0
543		Kambale Chavan Wasti	0	0
544		Kashid Shende Wasti	0	0
545		Khandobanagar	0	0
546		Mane Wasti	0	0
547		Gurav Mala	0	0
548		Raskar Wasti	0	0
549		Rode Wasti	0	0
550		Shine Davale Wasti	0	0
551	Padasthal	Padasthal	45000	50
552		Chindadevi	0	0
553		Zende Wasti	0	0

Sr. No.	Name of Grampan-chyat	Notified Habitation	Total water supplied with PWS in liters / day	Total water supplied by PWS in liter / capita / day
554	Palasdeo	Palasdeo	192000	52
555		Kalewadi	28000	50
556		Kalewadi No.2	32000	35
557		Yede Mehtre Wasti	0	0
558		Yedewasti No.2	0	0
559		Madalamala	60000	37
560		Malewadi	28800	40
561		Shelar Patta	0	0
562		Shindewasti	16000	40
563		Bandewadi	16000	30
564	Pandharwadi	Pandharwadi	72000	56
565		Mane Wasti	0	0
566		Ranware Wasti	0	0
567		Raut Wasti	0	0
568		Shike Pawar Wasti	0	0
569	Pawarwadi	Pawarwadi	48000	40
570		Gholapwadi	0	40
571		Udmai Wadi	0	40
572		Yadav Wadi	0	40
573	Pimpale	Pimpale	20000	28
574		Bhagat Dhavre Wasti	0	0
575		Chormale Wasti	0	0
576		Gaikawadwasti	0	0
577		Jadhav Wasti	0	0
578		Kate Patil Wasti	0	0
579		Khatkhale Wasti	0	0
580		Phadtare Wasti	0	0
581		Bagal Wasti	0	0
582	Pimpri Bk.	Pimpri Budruk	100000	56
583		Katkar Wasti	0	0
584		Narute Wasti	0	0
585		Padalkar Wasti	0	0
586		Bandalkar Wasti	0	0
587		Sul Wasti	0	0
588		Sutar Wasti	0	0
589	Pimpri Kh	Pimpri Kh	66000	50
590		Petkar Wasti	0	0
591		Wahayare Wasti	0	0
592		Bhui Wasti	0	0
593		Chindadevi	0	0

Sr. No.	Name of Grampan-chyat	Notified Habitation	Total water supplied with PWS in liters/day	Total water supplied by PWS in liter /capita / day
594	Pimpri Kh	Ghamgalwasti	0	0
595		Shingarewasti	0	0
596		Shirsodi	34400	40
597		Vyawahare Marakad Wasti	0	0
598	Pithewadi	Pithewadi	56000	64
599		Dadaj Wasti	0	0
600		Jadhav Wasti	0	0
601		Masal Wasti	0	0
602		Bungale Wasti	0	0
603		Pokane Wasti	0	0
604	Pitkeshwar	Pitkeshwar	68000	58
605		Bhise Wasti	0	0
606		Bhong Wasti	0	0
607		Iralkar Kirkat Wasti	0	0
608		Kambale Wasti	0	0
609		Maske Wasti	0	0
610		Abhang Wasti	0	0
611		Shende Wasti	0	0
612		Yadav Wasti	0	0
613	Poundhawadi	Poundhawadi	85000	37
614		Bhosale Wasti	0	0
615		Khartode Wasti	0	0
616		Pawar Wadi	0	0
617		Bandgarwadi	0	0
618	Ranmodwadi	Ranmodwadi	80000	40
619		Kaularu Chal	0	0
620		Pavo Wasti	0	0
621		Gosavi Salukhe Wasti	0	0
622		Ratnapuri	0	0
623		Shivajinagar	0	0
624	Reda	Reda	80000	40
625		Deokar Wasti	0	0
626		Gaikwad Wasti	0	0
627		Harijan Wasti	0	0
628		Jagdale Wasti	0	0
629		Kati Mala Mane Mandre Wasti	0	0
630		Kharkhana	0	0
631		Kharkhana Road Deokar Wasti	0	0
632		Mahadeo Nagar	0	0
633		Mane Wasti	0	0

Sr. No.	Name of Grampan-chyat	Notified Habitation	Total water supplied with PWS in liters / day	Total water supplied by PWS in liter / capita / day
634	Reda	Mohite Gaikwad Wasti	0	0
635		Pawar Wasti	0	0
636		Bhong Wasti	0	0
637		Sayyad Wasti	0	0
638		Yadav Wasti	0	0
639		Zadi Mala	0	0
640	Redani	Redani	42400	35
641		Bhosale Wasti	0	0
642		Chavan Chinchkar Wasti	0	0
643		Jadhav Vasti	0	0
644		Kadam Kade Wasti	0	0
645		Kale Gosavi Wasti	0	0
646		Kale Wasti	0	0
647		Khade Wasti	0	0
648		Lanka Wasti	0	0
649		Padalkar Wasti	0	0
650		Pati Wasti	0	0
651		Patil Wasti	0	0
652		Balu Kale Wasti	0	0
653		Tarange Wasti	0	0
654	Rui	Rui	120000	60
655		Kokare Gawade Wasti	0	0
656		Lawand Dhaigudewasti	0	0
657		Pimplacha Mala	0	0
658		Mankarwadi	0	0
659		Sonnawane Wasti	0	0
660		Tale Wasti	0	0
661		Thoratwadi	0	0
662		Unde Wasti	0	0
663		Vakilwasti	0	0
664	Sansar	Sansar	144000	32
665		Ashoknagar	0	0
666		Bhagyanagar	0	0
667		Bhawaninagar	100000	40
668		Hingangaon	0	0
669		Indiranagar	0	0
670		Kale Wasti	0	0
671		Kedar Mala	0	0
672		39 Phata	0	0
673		Irrigation Bunglow	0	0

Sr. No.	Name of Grampan-chyat	Notified Habitation	Total water supplied with PWS in liters / day	Total water supplied by PWS in liter / capita / day
674	Sansar	Khomane Wasti	0	0
675		Nare Wasti	0	0
676		Rayte Mala	0	0
677		Achanaknagar	0	0
678	Sapkalwadi	Sapkalwadi	48000	41
679	Sarafwadi	Sarafwadi	120000	60
680		Kale Shinde Wasti	0	0
681		Kautich Mala	0	0
682		Kazad Wasti	0	0
683		Khadappa Wasti	0	0
684		Raskar Mala	0	0
685		Ambrai Mala	0	0
686	Sarati	Sarati	64000	42
687		Bhosale Wasti	0	0
688		Kokate Wasti	0	0
689		Appaso Jagdale Wasti	0	0
690	Sardewadi	Sardewadi	48000	31
691		Gaikwad Wasti	0	0
692		Jadhav Bhagat Wasti	0	0
693		Jamdhade Wasti	0	0
694		Kolekar Kokare Wasti	0	0
695		Pathan Wasti	0	0
696		Reliance Company	0	0
697		Chitrao Wasti	0	0
698		Shinde Sarade Wasti	0	0
699		Shinde Wasti	0	0
700		Sidh Wasti	0	0
701		Tobare Wasti	0	0
702		Vith Batti Parisar	0	0
703	Shaha	Shaha	41600	42
704		Khabale Wasti	0	0
705		Mahadeo Nagar	0	0
706		Pandhare Wasti	0	0
707		Kadole Wasti	0	0
708		Yajgude Wasti	0	0
709	Shelgaon	Shelgaon	120000	52
710		Chawarewasti	0	0
711		Datta Wadi Nanware Wasti	0	0
712		Gauraimala	0	0
713		Mahadeonagar	0	0

Sr. No.	Name of Grampan-chyat	Notified Habitation	Total water supplied with PWS in liters / day	Total water supplied by PWS in liter / capita / day
714	Shelgaon	Mali Wasti	0	0
715		Raut Nanware Mala	0	0
716		Bhulbaj Nazarkarwasti	0	0
717		Tel Odha	0	0
718		Vaid Wadi	40000	39
719		Vayasemala	0	0
720		Vithoba Mal	0	0
721	Shetphal Ga.	Shetphal Gadhe	144000	37
722		Lamjewadi	64000	54
723		Mulik Bhosale Wasti	0	0
724		Nimboni Mal	0	0
725		Patil Wasti	0	0
726		Sawanewasti	0	0
727		Ambar Hol	0	0
728	Shetphal Ha.	Shetphal Haveli	64000	59
729		Borate Wasti	0	0
730		Chavan Wasti	0	0
731		Devidas Sawant	0	0
732		Jagtap Wasti	0	0
733		Kambale Wasti	0	0
734		Mulani Wasti	0	0
735		Nawale Wasti	0	0
736		Nirgude Wasti	0	0
737		Ranmala	0	0
738		Ambarwasti	0	0
739		Shinde Wasti	0	0
740		Sopan Thorat	0	0
741		Sutal Mala	0	0
742		Vithobamal	0	0
743	Shindewadi	Shindewadi	20000	35
744		Datta Mandir Wasti	0	0
745		Dinkar Shinde Wasti	0	0
746		Garpir Wasti	0	0
747		Jotibamala	0	0
748		Khandobacha Mal	0	0
749		Kharat Wasti	0	0
750		Malavarchi Wasti	0	0
751		Mehtre Wasti	0	0
752		Narute Wasti	0	0
753		Bankar Wasti	0	0

Sr. No.	Name of Grampan-chyat	Notified Habitation	Total water supplied with PWS in liters / day	Total water supplied by PWS in liter / capita / day
754	Shindewadi	Zagade Wasti	0	0
755	Shirsatwadi	Shirsatwadi	64000	40
756		Bhujbal Wasti	0	0
757		Chavan Wasti	0	0
758		Dange Wasti	0	0
759		Kadam Wasti	0	0
760		Pagale Wasti	0	0
761		Pathan Wasti	0	0
762		Ravan Wasti	0	0
763		Ajabe Wasti	0	0
764		Shirsatwadi	0	0
765	Surwad	Surwad	48000	23
766		Bhatekar Wasti	0	0
767		Jagtap Wasti	0	0
768		Kalokhe Wasti	0	0
769		Koratkar Wasti	0	0
770		Meherwasti	0	0
771		Phadtare Wasti	0	0
772		Shivajinagar	0	0
773		Surve Wasti	0	0
774		Bave Wasti	0	0
775		Todkar Wasti	0	0
776	Takrar Wadi	Takrar Wadi	100800	40
777	Tannu	Tannu	16000	35
778		Chavan Wasti	0	0
779		Jadhav Mohite Wasti	0	0
780		Adoba Wasti	0	0
781	Tarangwadi	Tarangwadi	33600	45
782		Bhosale Wasti	0	0
783		Bunge Wasti	0	0
784		Charewasti	0	0
785		Gawade Tarange Wasti	0	0
786		Heagadewasti	0	0
787		Jadhavwasti	0	0
788		Kare Wasti	0	0
789		Markadwasti	0	0
790		Saraswati Nagar	0	0
791		Satwai Mala	0	0
792		Ambe Mala	0	0
793		Tarangwadi	0	0

Sr. No.	Name of Grampan-chyat	Notified Habitation	Total water supplied with PWS in liters / day	Total water supplied by PWS in liter / capita / day
794	Taratgaon	Taratgaon	40000	32
795		Nanware Bhange Wasti	0	0
796	Tawashi	Tawashi	57600	40
797		Harijan Wasti	0	0
798		Mandlik Wasti	0	40
799		Matang Wasti	0	0
800		Pansare Wasti	0	0
801		Ramoshi Wasti No 1	0	0
802		Ramoshi Wasti No 2	0	0
803		Shirke Mala	0	40
804		Garmala	0	40
805		Thorat Otekar Wasti	0	0
806		Vharkate Wasti	0	0
807	Thoratwadi	Thoratwadi	24000	40
808	Udhat	Udhat	40000	40
809		Indalkar Wasti	0	0
810		Kale Pol Wasti	0	40
811		Thorat Wadi	0	0
812		Bhosale Wasti	0	40
813		Yadav Wasti	0	0
814	Vadapuri	Vadapuri	80000	51
815		Hanumanwadi	0	0
816		Jadhav Wasti	0	0
817		Kale Wasti	0	0
818		Katkar Wasti	0	0
819		Manewasti	0	0
820		Panchshilnagar	0	0
821		Pandharkarwasti	0	0
822		Pasage Wasti	0	0
823		Pawar Wasti	0	0
824		Phadate Shinde Wasti	0	0
825		Pingalewasti	0	0
826		Ramwadi	0	0
827		Shirke Wasti	0	0
828		Tobare Wasti	0	0
829		Gokhali	0	0
830	Vakil Wasti	Vakil Wasti	40000	36
831		Gogare Wasti	0	0
832		Koratkar Shete Wasti	0	0
833		Mahal Shikare Wasti	0	0

Sr. No.	Name of Grampan-chyat	Notified Habitation	Total water supplied with PWS in liters / day	Total water supplied by PWS in liter / capita / day
834	Vakil Wasti	Pandare Wasti	0	0
835		Pawar Wasti	0	0
836		Shete Wasti	0	0
837		Bokadara Gogare Wasti	0	0
838	Varkute Bk.	Varkute Budruk	80000	55
839		Aba Kare Wasti	0	0
840		Bankar Wadi	0	0
841		Bankar Wasti	0	0
842		Bujbal Wasti	0	0
843		Chitalkar Wadi	0	0
844		Satav Wasti	0	0
845		Karewadi	0	0
846	Varkute Kh	Varkute Kh	44000	42
847		Bosale Wasti	0	0
848		Dagade Wasti	0	0
849		Davarewasti	0	0
850		Hari Mala Misal Wasti	0	0
851		Hari Mala Shende Wasti	0	0
852		Hegade Wasti	0	0
853		Jagtap Wasti	0	0
854		Kudale Shinde Dagade Wasti	0	0
855		Misal Mashal Wasti	0	0
856		Misal Wasti	0	0
857		Mulani Shende Wasti	0	0
858		Muslim Wasti	0	0
859		Pawar More Wasti	0	0
860		Ramkund	0	0
861		Shende Patre Wasti	0	0
862		Shende Thavare Wasti	0	0
863		Vadapuri To Varkute Rasta	0	0
864		Varcha Mala	0	0
865		Bhogale Nogaba Mala	0	0
866		Yadav Wasti	0	0
867	Vyahali	Vyahali	33600	40
868		Shinde Pawar Wasti	0	0
869		Tanpure Wadi	0	0
870		Bharal Wasti	0	0
871	Zagadewadi	Zagadewadi	30000	40
872		More Wasti	0	0
873		Nalwadewasti	0	0
874		Abhang Wasti	0	0

Source: Panchyat Samiti, Indapur 2012. Total No. of public water supply schemes-146

Appendix - C

Rainfall data for 1999 – 2013

Sr. No.	Year	Month	Indapur	Sansar	Anthurne	Nimgaon	Walchand - nagar	Bawada	Shetphal-gade	Bhigwan St.
1	1999	April	0	0	0	0	0	0	0	0
2		May	0	0	0	0	0	0	0	0
3		June	95	66	126	NA	29	NA	91.5	30
4		July	83.6	57	86	NA	59	NA	30	33
5		August	7.8	110	3	NA	42	NA	10	10. 0
6		September	134	285	100	NA	352	NA	211	160
7		October	164.6	129	NA	NA	94	NA	78	116
8	2000	April	0	0	0	0	0	0	0	0
9		May	12.6	39	35	88	0	9	20	14
10		June	172.5	172	120	42	60	167	61	68
11		July	98.68	36	19	26	21	83	48	57
12		August	212.8	43	42	NA	76	116	91	116
13		September	43.6	155	72	NA	80	72	89	72.5
14		October	256	58	92	27	106	NA	113	75
15	2001	April	0	0	0	0	0	0	0	0
16		May	3.8	21	25	19	NA	17	40	5
17		June	81.2	4	10	84	14	42	10	80
18		July	8.9	NA	NA	NA	NA	3	NA	NA
19		August	180.2	56	67	29	55	62	141	85
20		September	103.7	111	87	173	84	271	174	45
21		October	118.23	185	160	128	95	246	138.5	155
22		November	30.8	NA	NA	19	NA	2	NA	NA

Sr. No.	Year	Month	Indapur	Sansar	Anthurne	Nimgaon	Walchand - nagar	Bawada	Shetphal-gade	Bhigwan St.
23	2002	April	11.4	0	0	0	0	0	0	0
24		May	16.4	0	0	12	0	14	0	0
25		June	175.3	88	91	61	83	108	54	14
26		July	12	12	11	NA	NA	NA	7	NA
27		August	73.2	25	28	32	7	27	24.5	37
28		September	127.6	41	37	47	43	27	35	54
29		October	132.2	99	102	64	121	127	104	102
30		November	15.4	8	8	21	8	17	10	14.2
31	2003	May	0	0	0	0	0	0	0	0
32		June	15.9	16	35	40	40	35	21	26.23
33		July	48.2	NA	NA	43	NA	50	16	25
34		August	55	44	46	15	46.5	38	91	35
35		September	26.2	11	12	NA	12	31	41	46
36		October	3.6	14	14	NA	13	NA	19	0.33
37	2004	April	0	0	0	0	0	0	0	0
38		May	121.48	176	73	51	41	216	93	101.62
39		June	135.8	222	72	146	146	63	113	96
40		July	78.8	18	13	29	39	31	43	46
41		August	29.6	8	10	10	22	5	7	10
42		September	195.5	73.7	106	217	143.5	199	156	156
43		October	63	65	30	2	38	75	69	43

Sr. No.	Year	Month	Indapur	Sansar	Anthurne	Nimgaon	Walchand - nagar	Bawada	Shetphal-gade	Bhigwan St.
44	2005	May	0	0	0	0	0	0	0	0
45		June	10	8	0	2	0	21	0	0
46		July	244.6	216	136	100	109	124	266	209
47		August	106.4	47	58	20	81	25	38	15
48		September	227.8	221.6	28	131	98	264	248	NA
49		October	118.1	104.98	76	70	124	134	122	NA
50	2006	April	0	0	0	0	0	0	0	0
51		May	47.4	28	53	83	42	98	79	83.5
52		June	153.8	125	117	159	127	134	139	111
53		July	151.6	129	117	159	128	140	139	69
54		August	54.7	8	27	12	28	34	NA	NA
55		September	191.2	138.5	114.2	76	157	167	68	33
56		October	107.7	80	32	71	38	56	NA	38
57	2007	May	0	0	0	0	0	0	0	0
58		June	197.7	186	111.2	262	216.5	173	258.25	217.75
59		July	69.6	31	21	13	52	39	69	62
60		August	149.2	24	210	43	73	263	82	75
61		September	193	219	67	150	169	295	179	182

Sr. No.	Year	Month	Indapur	Sansar	Anthurne	Nimgaon	Walchand - nagar	Bawada	Shetphal-gade	Bhigwan St.
62		May	0	0	0	0	0	0	0	0
63		June	4.4	3	0	0	0	23	5	7
64		July	30.2	4	2	2	10	48	29	32
65	2008	August	61.8	69	97	46	45	89	54	94
66		September	248.6	302	185	274	116	420	245	276
67		October	16.3	1	10	2	NA	65	39	47
68		November	46	NA	NA	NA	NA	NA	NA	NA
69		May	0	0	0	0	0	0	0	0
70		June	130.8	70	35	22	58	71	88	104
71		July	105.4	49	126	37	58	50	34.5	93
72	2009	August	151.7	220	256	170	184	286	60.5	69
73		September	366.6	300	245	476	191	457	144.7	190
74		October	151	164	89	205	57	179	157	157
75		November	24.2	87	64	36	43	60	87.5	84
76		May	0	0	0	0	0	0	0	0
77		June	286.2	329	264	206	127	305	171	224.5
78		July	103.1	97	82	129	3	127	76	147.3
79	2010	August	128	87	128	124	33	133	16.5	177
80		September	176.8	137	102	74	11	52	7	184
81		October	96.8	116	62	163	NA	179	19	39
82		November	28.4	37	16	17	7.5	67	NA	12

Sr. No.	Year	Month	Indapur	Sansar	Anthurne	Nimgaon	Walchand - nagar	Bawada	Shetphal- gade	Bhigwan St.
83	2011	May	0	0	0	0	0	0	0	0
84		June	57.2	36	19	18	7	33	60.2	58
85		July	79.8	109	95.5	40.5	36	131	147	203
86		August	185.6	73	62	91	83	161	80.3	154.5
87		September	44.4	17	83	43	21	63	25.5	17.5
88		October	36.8	74	43	35	17	NA	44	47
89	2012	April	0	0	0	0	0	0	0	0
90		May	19	19	2	5	NA	27	NA	51
91		June	32.2	NA	NA	NA	8	8	15.5	30
92		July	52.4	33	30	52	124.6	126	24.6	23.5
93		August	17.6	21	40	62	96	23	17	101
94		September	63.2	59	72	77	145.2	168	95.8	124
95		October	108.8	31	45	75	91.4	107	19	26.5
96	2013	May	0	0	0	0	0	0	0	0
97		June	107.8	25	27	78	118	155	65.7	66.7
98		July	91.4	89	39	89	79	123	113.1	111.6
99		August	39.4	38	16	32	63.4	99	53.9	53.9
100		September	200.6	309	241	231	188.4	304	302.5	302.5
101		October								

Source: Tahsil office and Irrigation office, Indapur.

Appendix – D

Village wise population, domestic water and area requirement for water conservation

Sr. No.	Name of city / village	Population	Domestic water requirement in MCM	Area required in ha.
1	Indapur	25515	1.863	331
2	Shetphalgadhe	4123	0.105	25.29
3	Pimple	1337	0.034	8.20
4	Madanwadi	5954	0.152	36.08
5	Takrarwadi	2166	0.055	13.13
6	Bhigvan	7673	0.196	46.50
7	Bhigvanstaion	2858	0.073	17.32
8	Diksal	1710	0.044	10.36
9	Kumbhargaon	1330	0.034	8.06
10	Bandgarwadi	622	0.016	3.77
11	Poundhawadi	1792	0.046	10.86
12	Lamjewadi	662	0.017	4.06
13	Nirgude	2095	0.054	12.85
14	Mhasobachiwadi	2000	0.051	12.27
15	Vaysewadi	577	0.015	3.54
16	Akole	3273	0.084	20.08
17	Bhadalwadi	2628	0.067	15.93
18	Dalaj No.1	1204	0.031	7.30
19	Dalaj No.2	1455	0.037	8.82
20	Dalaj No.3	895	0.023	5.42
21	Kalewadi	1477	0.038	8.95
22	Bandewadi	342	0.009	2.07
23	Palasdeo	3621	0.093	21.95
24	Malewadi	1818	0.046	11.02
25	Bhawadi	907	0.023	5.50
26	Loni	2667	0.068	12.07
27	Varkute Bk.	2915	0.074	13.19
28	Balpudi	743	0.019	3.36
29	Karewadi	1466	0.037	6.63
30	Lakdi	2547	0.065	13.92
31	Shindewadi	1883	0.048	10.29
32	Kazad	3139	0.080	17.15
33	Nimbodi	1922	0.049	10.50
34	Bori	5861	0.150	32.03

Sr. No.	Name of city / village	Population	Domestic water requirement in MCM	Area required in ha.
35	Sansar	6632	0.169	36.24
36	Bhavaninagar	4011	0.102	21.92
37	Jachakvasti	1300	0.033	7.10
38	Kardanwadi	917	0.023	5.01
39	Junkshan	4855	0.124	34.19
40	Lasurne	8803	0.225	61.99
41	Pawarwadi	2202	0.056	15.51
42	Belwadi	5056	0.129	35.61
43	Sapkalwadi	1305	0.033	9.19
44	Hingnewadi	1218	0.031	8.58
45	Udhat	2023	0.052	14.25
46	Paritwadi	1245	0.032	8.77
47	Thoratwadi	812	0.021	5.72
48	Chavhanwadi	396	0.010	2.79
49	Bambadwadi	688	0.018	4.85
50	Mankarwadi	986	0.025	6.94
51	Gholapwadi	1407	0.036	7.69
52	Tawashi	3046	0.078	16.64
53	Jamb	1459	0.037	7.97
54	Kurwali	2925	0.075	20.60
55	Chikhali	1426	0.036	10.04
56	Pilewadi	1150	0.029	8.04
57	Maradwadi	571	0.015	3.99
58	Nhavi	3222	0.082	22.53
59	Rui	3232	0.083	22.60
60	Gosaviwadi	1157	0.030	8.09
61	Kalas	4141	0.106	28.96
62	Thoratwadi	473	0.012	3.31
63	Birgundwadi	792	0.020	5.54
64	Shelgaon	8215	0.210	57.45
65	Bharnewadi	4358	0.111	30.48
66	Anthurne	6100	0.156	42.66
67	Kadbanwadi	1636	0.042	11.44
68	Hangarwadi	1807	0.046	12.64
69	Pitkeshwar	2065	0.053	14.44
70	Sarafwadi	2038	0.052	14.25
71	Ghorpadwadi	1401	0.036	9.87
72	Sirsatwadi	2100	0.054	14.79

Sr. No.	Name of city / village	Population	Domestic water requirement in MCM	Area required in ha.
73	Ranmodwadi	3468	0.089	24.42
74	Kalamb	16338	0.417	115.06
75	Nimsakhar	6000	0.153	42.25
76	Nirwangi	3601	0.092	25.36
77	Kauthali	2764	0.071	18.68
78	Vyahali	1698	0.043	11.47
79	Kacharewadi	829	0.021	5.60
80	Gotandi	4650	0.119	31.42
81	Nimgaon Ketki	12397	0.317	83.76
82	Varkute Kh.	4811	0.123	32.51
83	Kati	5353	0.137	36.17
84	Jadhavwadi	472	0.012	3.19
85	Reda	2415	0.062	16.32
86	Redni	3938	0.101	26.61
87	Khorochi	3637	0.093	24.57
88	Boratwadi	1715	0.044	11.59
89	Chandgaon	797	0.020	3.61
90	Agoti No.1	1261	0.032	5.71
91	Agoti No.2	719	0.018	3.25
92	Ganjewalan	840	0.021	3.80
93	Kalashi	1819	0.046	8.23
94	Kalthan No.1	2135	0.055	9.66
95	Shirsodi	1938	0.050	8.77
96	Padsthal	1405	0.036	6.36
97	Ajoti	864	0.022	3.91
98	Sugaon	301	0.008	1.36
99	Pimpri Kh.	1380	0.035	6.24
100	Malwadi	4263	0.109	19.29
101	Galand Wadi No.1	1873	0.048	8.48
102	Narutwadi	1331	0.034	6.02
103	Kalthan No.2	1188	0.030	5.38
104	Gagargaon	709	0.018	3.21
105	Bijwadi	3369	0.086	15.24
106	Rajwadi	508	0.013	2.30
107	Vangali	1251	0.032	5.66

Sr. No.	Name of city / village	Population	Domestic water requirement in MCM	Area required in ha.
108	Pondkulwadi	1330	0.034	6.02
109	Shaha	2364	0.060	10.70
110	Kandalgaon	2069	0.053	9.36
111	Taratgaon	288	0.007	1.30
112	Hingangaon	1846	0.047	8.35
113	Sardewadi	3187	0.081	14.42
114	Galand Wadi No.2	2299	0.059	10.40
115	Gokhali	1608	0.041	7.28
116	Tarangwadi	2557	0.065	11.57
117	Zagadewadi	1193	0.030	5.40
118	Pandharwadi	1198	0.031	5.42
119	Vadapuri	4401	0.112	19.91
120	Bedshinge	759	0.019	3.43
121	Babhulgaon	2505	0.064	11.33
122	Avasari	2011	0.051	9.35
123	Bhat Nimgaon	1547	0.040	7.20
124	Shetphal Haveli	3006	0.077	13.98
125	Surwad	2639	0.067	12.27
126	Bhandgaon	2993	0.076	13.92
127	Vakilvasti	2144	0.055	9.97
128	Bawada	10734	0.274	49.93
129	Bhodani	2488	0.064	11.57
130	Lakhewadi	4540	0.116	21.12
131	Chakati	1316	0.034	6.12
132	Pithewadi	1080	0.028	5.02
133	Nirnimgaon	2863	0.073	13.32
134	Kacharewadi	1141	0.029	5.31
135	Sarati	2160	0.055	10.05
136	Lumewadi	3067	0.078	14.27
137	Gondi	1116	0.029	5.19
138	Ganeshwadi	1346	0.034	6.26
139	Pimpri Bk.	2251	0.058	10.47
140	Tannu	2117	0.054	9.85
141	Narsingpur	2231	0.057	10.38
142	Giravi	1766	0.045	8.21
143	Ozare	639	0.016	2.97
144	Total	383183	11.001	2439.23

Source: Census 2011 and author

Appendix - E

Watershed wise runoff of Indapur tahsil

Sr. No.	Water-shed No.	Centroid Longitude	Centroid Latitude	Runoff in cumec			Average of the three methods runoff in MCM
				Dickens formula	Inglis formula	Nawab Ali formula	
1	1	74.788	18.341	73.78	213.28	149.88	0.012521642
2	2	74.728	18.324	384.50	930.16	858.91	0.96053293
3	3	74.788	18.312	138.50	398.12	302.27	0.225758714
4	4	74.819	18.300	127.73	369.23	276.90	0.020084087
5	5	74.837	18.261	21.66	50.84	33.77	0.003311214
6	6	74.805	18.274	148.14	423.42	324.96	0.035151564
7	7	74.774	18.275	15.39	32.95	21.63	0.000170613
8	8	74.736	18.289	169.22	476.95	374.39	0.896966701
9	9	74.664	18.286	199.61	550.30	445.13	0.053689842
10	10	74.677	18.249	186.43	519.00	414.53	0.896848106
11	11	74.695	18.232	126.39	365.58	273.73	2.663772396
12	12	74.696	18.212	226.42	611.75	506.94	38.79872875
13	13	74.642	18.188	120.91	350.55	260.79	0.002415172
14	14	74.679	18.155	197.79	546.03	440.92	4.33572631
15	15	74.668	18.114	126.52	365.93	274.03	0.006848477
16	16	74.658	18.081	43.40	118.12	80.24	0.013479115
17	17	74.659	18.070	19.73	45.21	29.94	0.000114727
18	18	74.684	18.068	183.44	511.79	407.57	0.688431007
19	19	74.706	18.045	74.31	214.92	151.13	0.121121151
20	20	74.732	18.028	93.06	271.21	195.11	0.090760364
21	21	74.754	18.016	19.60	44.83	29.68	0.002590488
22	22	74.749	18.029	27.10	67.14	44.88	0.027094107
23	23	74.763	18.079	158.89	451.00	350.19	1.383968937
24	24	74.725	18.067	174.42	489.82	386.55	0.98835611
25	25	74.754	18.124	250.37	664.42	561.65	8.270656815
26	26	74.702	18.100	96.93	282.56	204.23	0.128803837
27	27	74.730	18.151	217.60	591.86	486.68	24.16642039
28	28	74.787	18.189	226.73	612.46	507.66	32.97581903
29	29	74.750	18.208	5925.57	6189.63	7994.09	97.69529849
30	30	74.741	18.247	215.57	587.22	482.00	19.76245706
31	31	74.781	18.236	53.36	149.63	102.70	1.050081432
32	32	74.807	18.235	116.13	337.30	249.52	0.74416257
33	33	74.814	18.218	100.34	292.46	212.27	0.714145707
34	34	74.824	18.206	160.72	455.65	354.50	0.227717115
35	35	74.863	18.252	140.67	403.86	307.38	0.110168832
36	36	74.867	18.226	96.58	281.54	203.41	0.321441519
37	37	74.889	18.239	147.65	422.16	323.82	0.964467666
38	38	74.910	18.281	183.78	512.61	408.36	0.12855465
39	39	74.943	18.279	53.68	150.65	103.44	0.000015266
40	40	74.915	18.207	223.35	604.86	499.90	2.401162935

Sr. No.	Water-shed No.	Centroid Longitude	Centroid Latitude	Runoff in cumec			Average of the three methods runoff in MCM
				Dickens formula	Inglis formula	Nawab Ali formula	
41	41	74.848	18.177	197.40	545.11	440.01	1.401525816
42	42	74.882	18.179	156.03	443.73	343.49	1.215725715
43	43	74.935	18.177	127.54	368.71	276.44	0.684188957
44	44	74.967	18.167	33.55	87.09	58.59	0.085168182
45	45	74.928	18.142	181.00	505.89	401.89	1.311699688
46	46	74.839	18.116	235.90	632.83	528.65	2.618790941
47	47	74.806	18.115	126.58	366.10	274.18	1.009186862
48	48	74.791	18.088	171.94	483.71	380.76	1.525136284
49	49	74.774	18.021	185.64	517.11	412.69	0.736767721
50	50	74.810	18.003	51.60	144.09	98.72	0.043577429
51	51	74.814	18.040	159.54	452.66	351.72	0.813753373
52	52	74.817	18.067	55.00	154.83	106.47	0.112818589
53	53	74.847	18.082	142.45	408.57	311.59	0.855913882
54	54	74.832	18.055	65.33	187.21	130.25	0.141235673
55	55	74.833	17.997	152.61	434.98	335.47	0.280092459
56	56	74.859	18.014	68.11	195.82	136.68	0.231010214
57	57	74.857	17.986	206.45	566.24	460.95	1.730700596
58	58	74.833	17.928	70.46	203.07	142.14	0.002626742
59	59	74.872	17.949	143.01	410.02	312.89	0.56465245
60	60	74.853	17.939	22.70	53.92	35.86	0.046431006
61	61	74.926	17.941	46.59	128.22	87.38	0.025988896
62	62	74.938	17.967	97.63	284.60	205.88	0.488518931
63	63	74.925	18.027	445.28	1038.53	988.62	13.69043825
64	64	74.886	18.054	180.83	505.47	401.49	2.553164786
65	65	74.865	18.058	144.66	414.36	316.79	0.839992227
66	66	74.892	18.114	179.06	501.18	397.38	1.743686274
67	67	74.922	18.111	97.28	283.58	205.06	0.490108817
68	68	74.962	18.139	141.35	405.65	308.98	1.356229219
69	69	74.990	18.163	288.30	744.13	647.30	4.536184263
70	70	74.959	18.218	121.23	351.44	261.56	0.584823484
71	71	74.958	18.239	155.55	442.51	342.37	0.679907091
72	72	74.993	18.246	112.02	325.78	239.82	0.193894622
73	73	75.016	18.276	204.27	561.18	455.91	0.1517314
74	74	75.046	18.244	42.50	115.27	78.23	0.004677063
75	75	75.002	18.223	158.89	451.00	350.19	0.903330248
76	76	75.047	18.202	142.82	409.54	312.45	0.545828321
77	77	75.077	18.220	214.01	583.67	478.41	0.709387161
78	78	75.117	18.250	196.47	542.91	437.84	0.020891756
79	79	75.107	18.208	165.14	466.76	364.83	0.690546987
80	80	75.139	18.192	206.64	566.70	461.40	0.090063392
81	81	75.079	18.165	130.34	376.29	283.05	0.726043238

Sr. No.	Water-shed No.	Centroid Longitude	Centroid Latitude	Runoff in cumec			Average of the three methods runoff in MCM
				Dickens formula	Inglis formula	Nawab Ali formula	
82	82	75.050	18.143	142.82	409.54	312.45	3.116751214
83	83	75.091	18.131	129.07	372.86	280.05	0.598800087
84	84	75.104	18.120	55.46	156.27	107.51	0.070726815
85	85	75.124	18.132	137.32	394.98	299.49	0.137441745
86	86	75.164	18.120	98.33	286.62	207.52	0.047350065
87	87	75.164	18.120	98.33	286.62	207.52	0.116878337
88	88	75.146	18.087	117.44	340.96	252.62	0.041936385
89	89	75.113	18.076	121.62	352.52	262.48	0.257750492
90	90	75.048	18.102	272.24	710.89	611.19	5.376279741
91	91	74.989	18.093	253.83	671.87	569.52	4.573627406
92	92	74.988	18.063	161.55	457.74	356.43	1.843881436
93	93	75.027	18.044	162.85	461.01	359.47	1.571830355
94	94	75.091	18.039	297.45	762.74	667.76	2.601129812
95	95	75.033	18.007	110.48	321.45	236.19	0.221338849
96	96	74.978	18.028	192.64	533.84	428.96	2.411102655
97	97	74.972	17.997	119.60	346.95	257.72	0.981578071
98	98	75.000	17.999	100.62	293.26	212.92	0.163685736
99	99	75.028	17.979	63.33	180.96	125.61	0.017669334
100	100	74.984	17.965	137.13	394.48	299.04	0.537887103
101	101	74.949	17.938	165.14	466.76	364.83	0.545726691
102	102	74.955	17.891	135.94	391.33	296.25	0.000081485
103	103	74.980	17.928	109.34	318.22	233.50	0.329371873
104	104	75.011	17.894	172.93	486.13	383.05	0.905860719
105	105	75.085	17.918	440.05	1029.44	977.58	6.6534642
106	106	75.056	17.980	415.65	986.46	925.76	6.033873786
107	107	75.143	18.020	120.38	349.11	259.56	0.0000026
108	108	75.135	17.995	81.98	238.22	169.07	0.232961853
109	109	75.147	17.985	88.48	257.68	184.34	0.001154272
	Total	8163.896	1974.985	21791.70	49876.37	42648.40	327.716398

Source: Author

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PHOTO PLATES

View of terrain in the vicinity of village Rui and Thoratwadi

View of terrain in the vicinity of village Kalas note the canal on foreground

Water tanker
feed village -
RUI

View taken from Devstan Babir village temple – note the valley floors characterized by agriculture

View of terrain in the vicinity of village Nhavi and Thoratwadi-dry land agriculture

View of terrain in the vicinity of village Akole in dry land agriculture –plantation on well water

View of terrain in the vicinity of village Thoratwadi-dry land agriculture

View of terrain in the vicinity of village Pondhwadi well irrigation agriculture

View of terrain in the vicinity of village Kacharewadi dry land agriculture –plantation on well water

Kadabanwadi

Vyahali dry land and farm tank

View of terrain in the vicinity of village Kadabanwadi dry land agriculture –plantation on well water

View of terrain in the vicinity of village Vyahali And Kacharewad dry land agricultural fields-farm pond on the background

View of Village Vyahali And Kacharewadi -dry land agricultural fields-sheeps and goats in search of food

Village Vyahali no water –hand pumps in summer

Village Vyahali water tank

Village Vyahali –note the dryness of agricultural fields

Village Kuathali note the dryness of agricultural fields

Near village Nimgaon Ketki water tanker frequency is high

Village Nimgaon Ketki- dryness of agricultural fields

Dry area of Mhasobachiwadi

Scanty Vegetation in study area


Near Gokhali - EGS work in action


valan bandhara at village Kalas

Village Thoratwadi note the ground water level as well as quality of water

Village Lakdi note the ground water level

KALAS CANAL

EXPOSED BASALT NEAR
PALASDEO-UJJANI
BACKWATER

EXPOSED BASALT NEAR PALASDEO-UJJANI BACKWATER

DRY LAND NEAR NIMGAON KETKI

Sarati village

Nira river in monsoon

Sarati village

Nira river in pre monsoon

Bandhara near Narsingpur-Nira river

Narsingpur- River Nira and Bhima confluence

Narsingpur-Nira river erosion of river bank

Narsingpur River Nira and Bhima confluence -Bank erosion

Distant view of Narsingpur River Nira and Bhima confluence

Water meter recharge machine at village Takrarwadi

Distant view of Narsing Pur temple

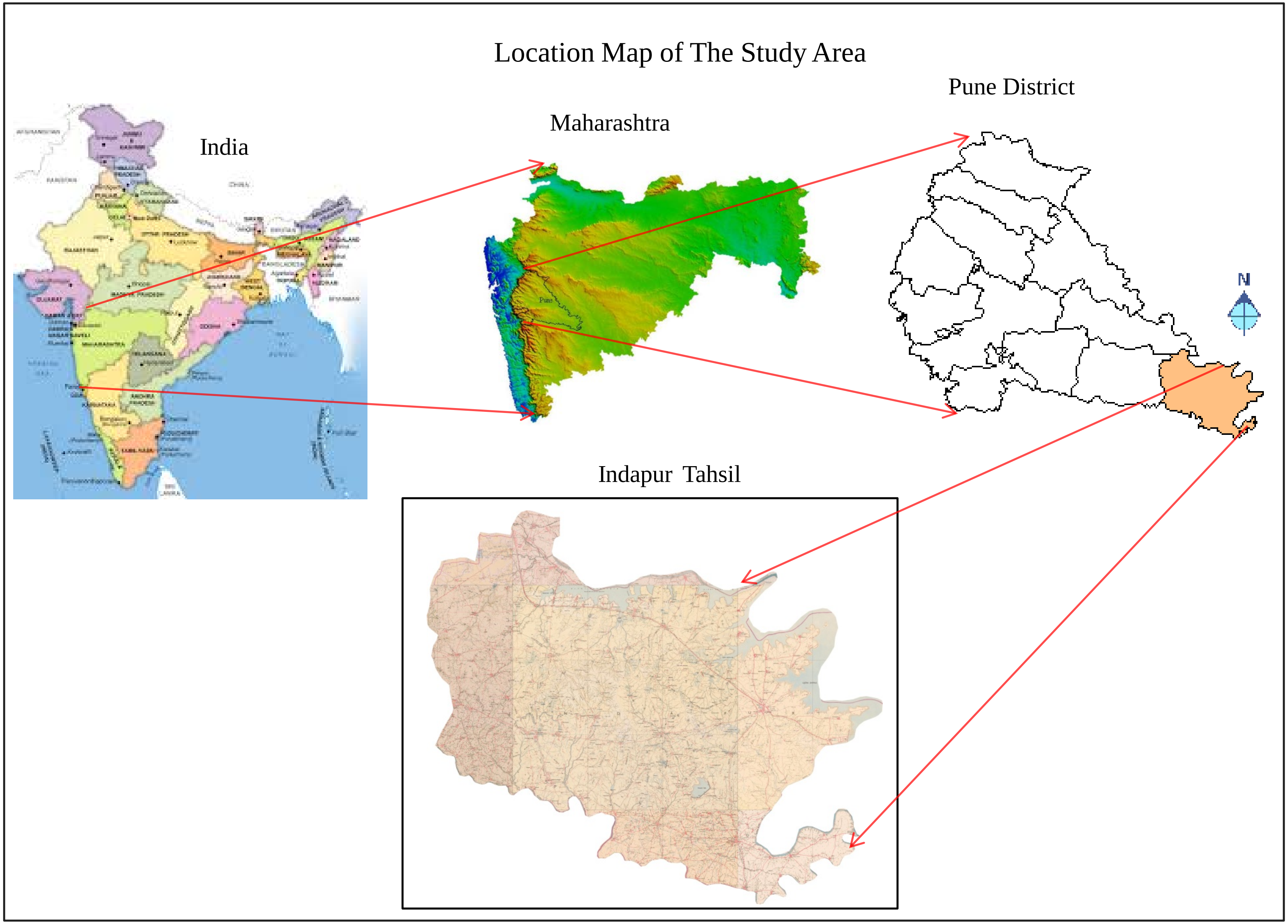
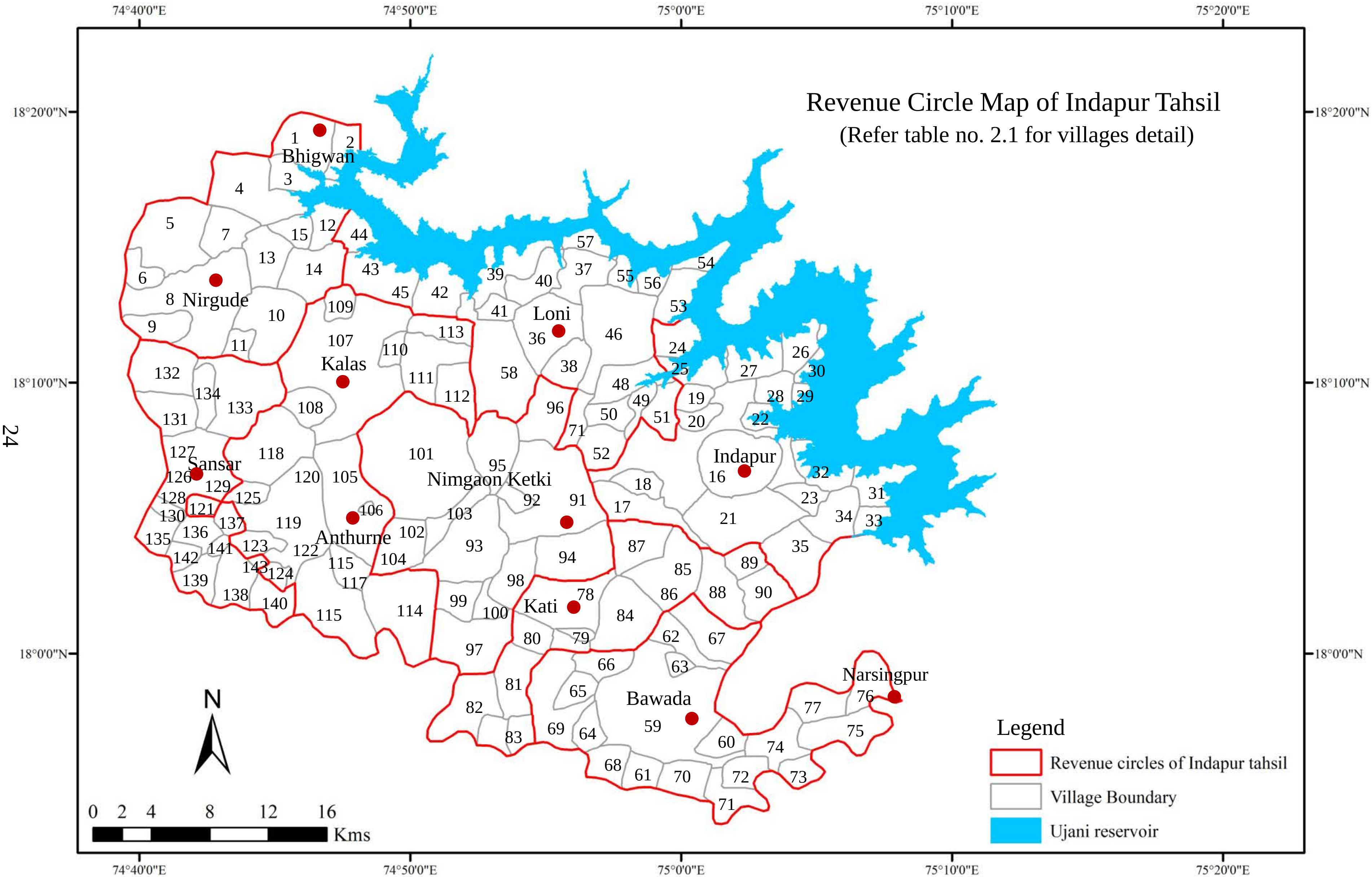
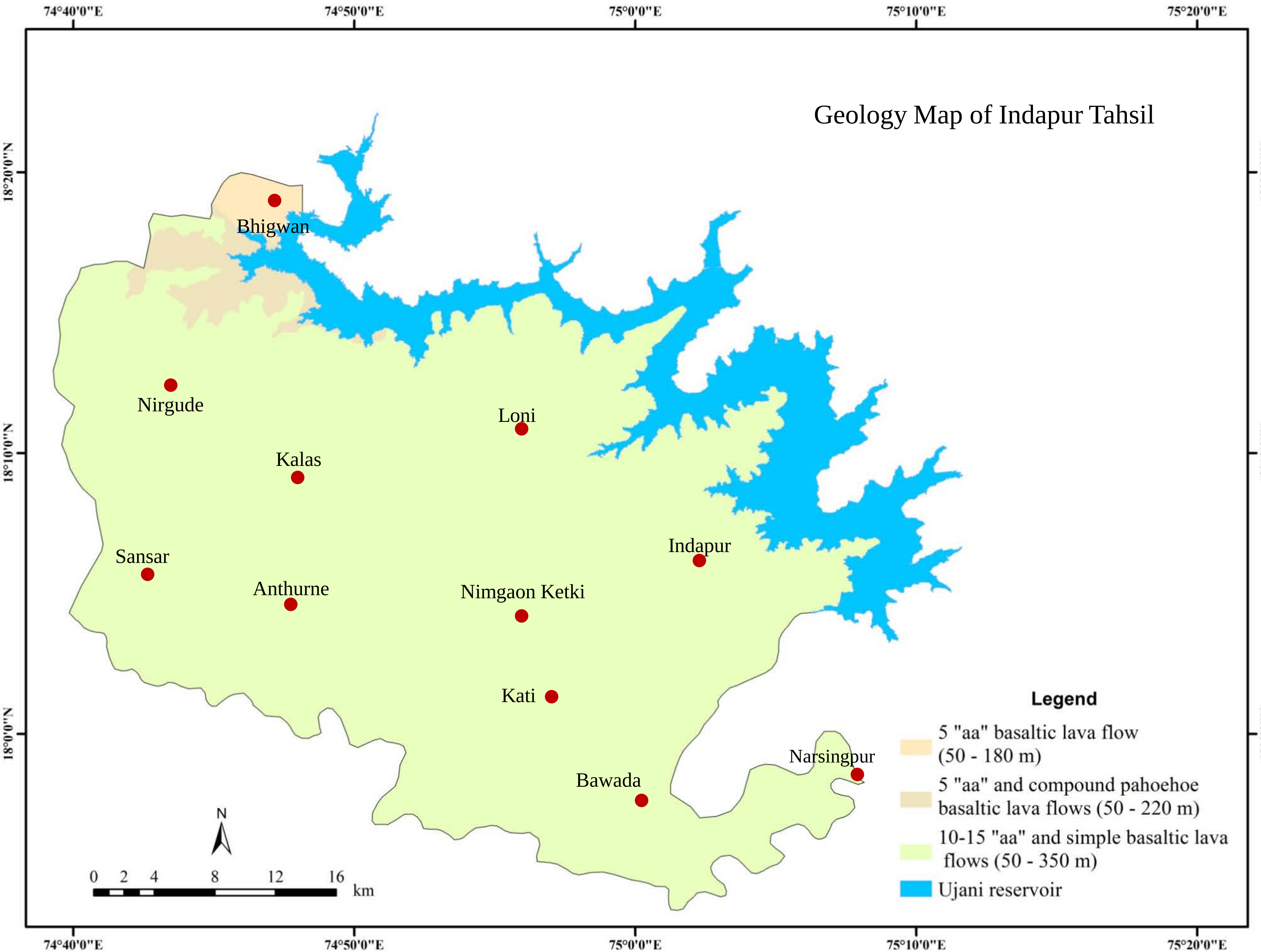

Location Map of The Study Area
India
Maharashtra
Pune District
N
Indapur Tahsil

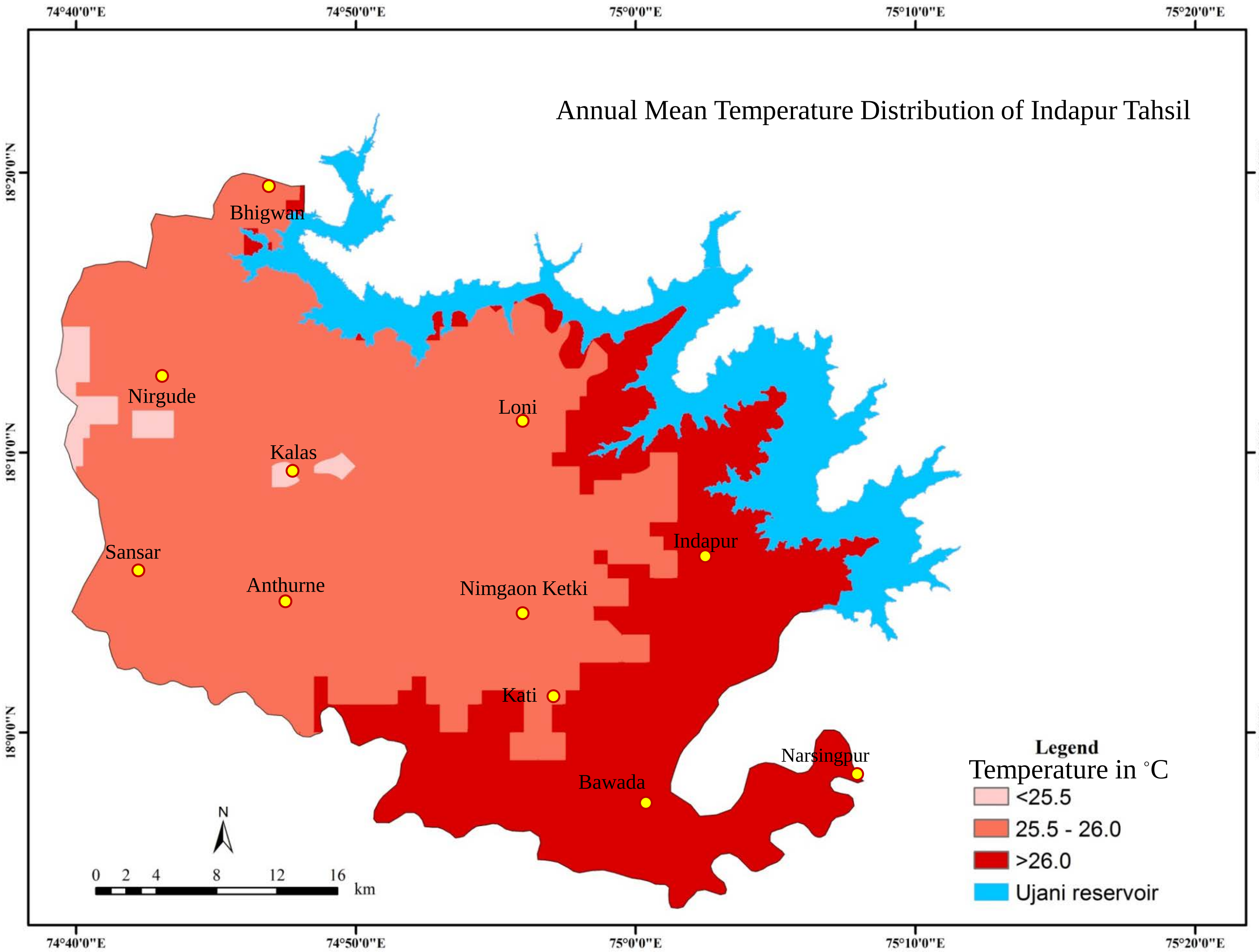
Fig. 2.1



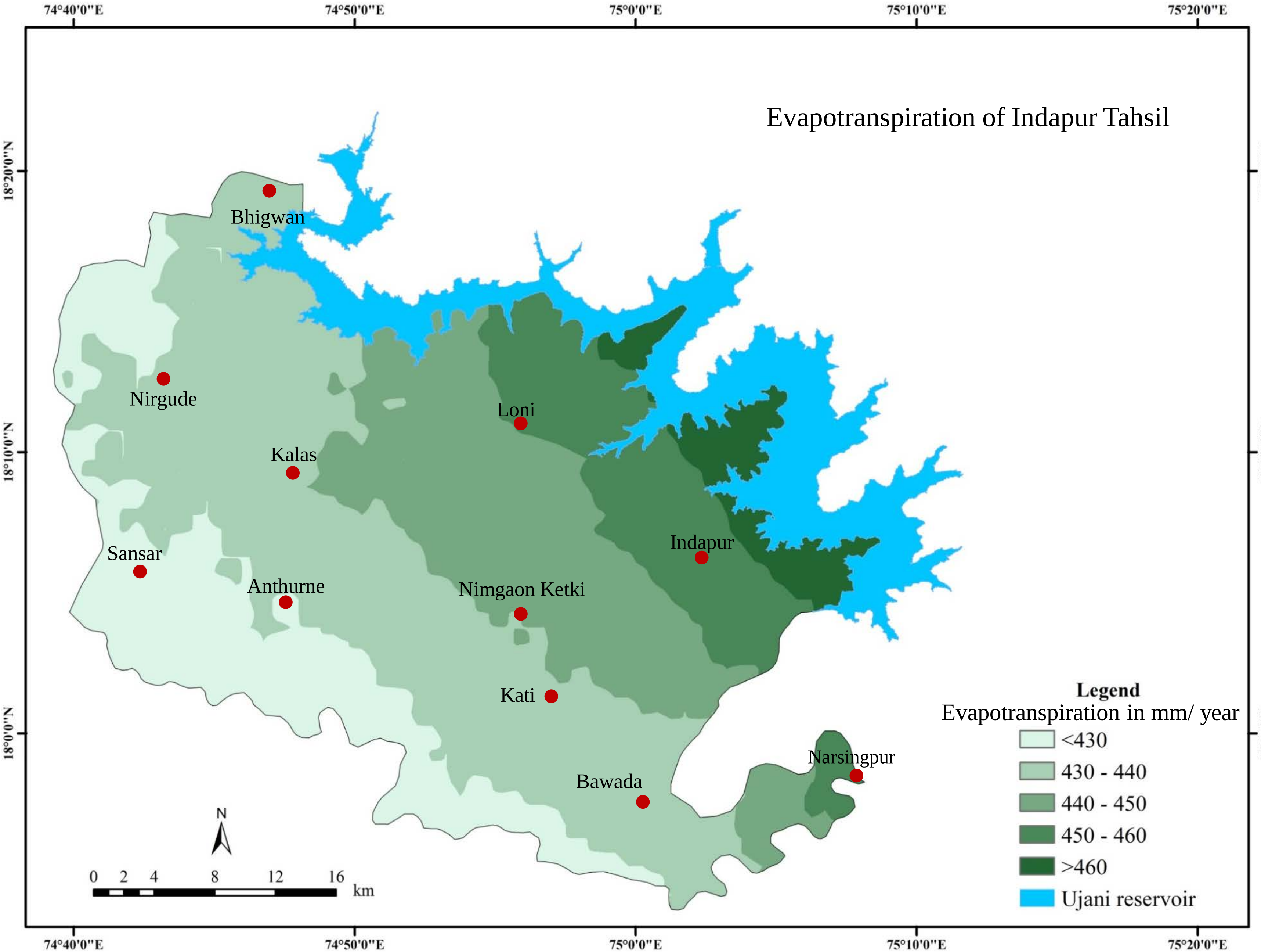
Source: Reproduced from www.pune.gov.in **Fig. 2.2**



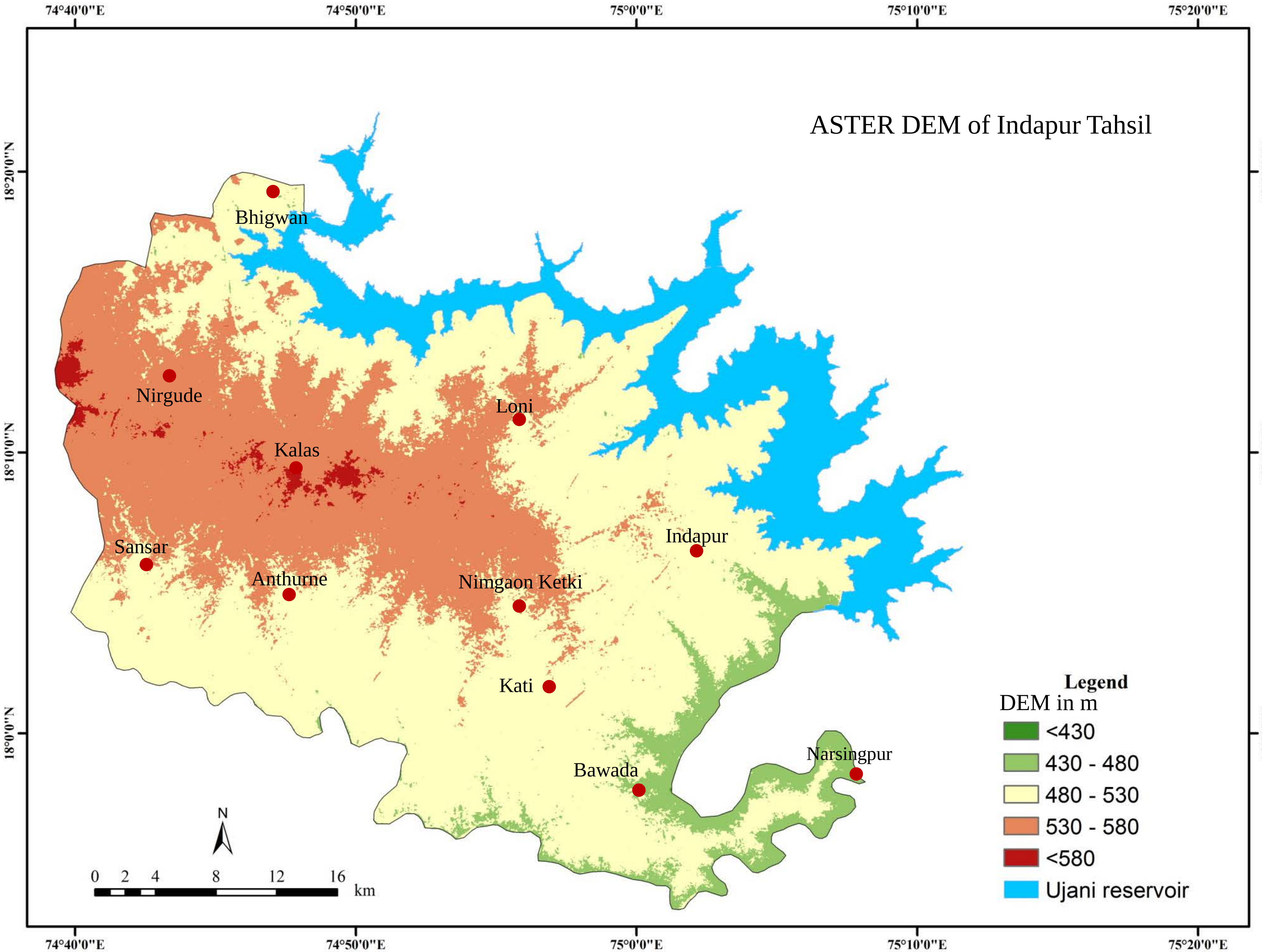
Source: Reproduced from Geological Survey of India, central region, Nagpur. **Fig. 2.3a**



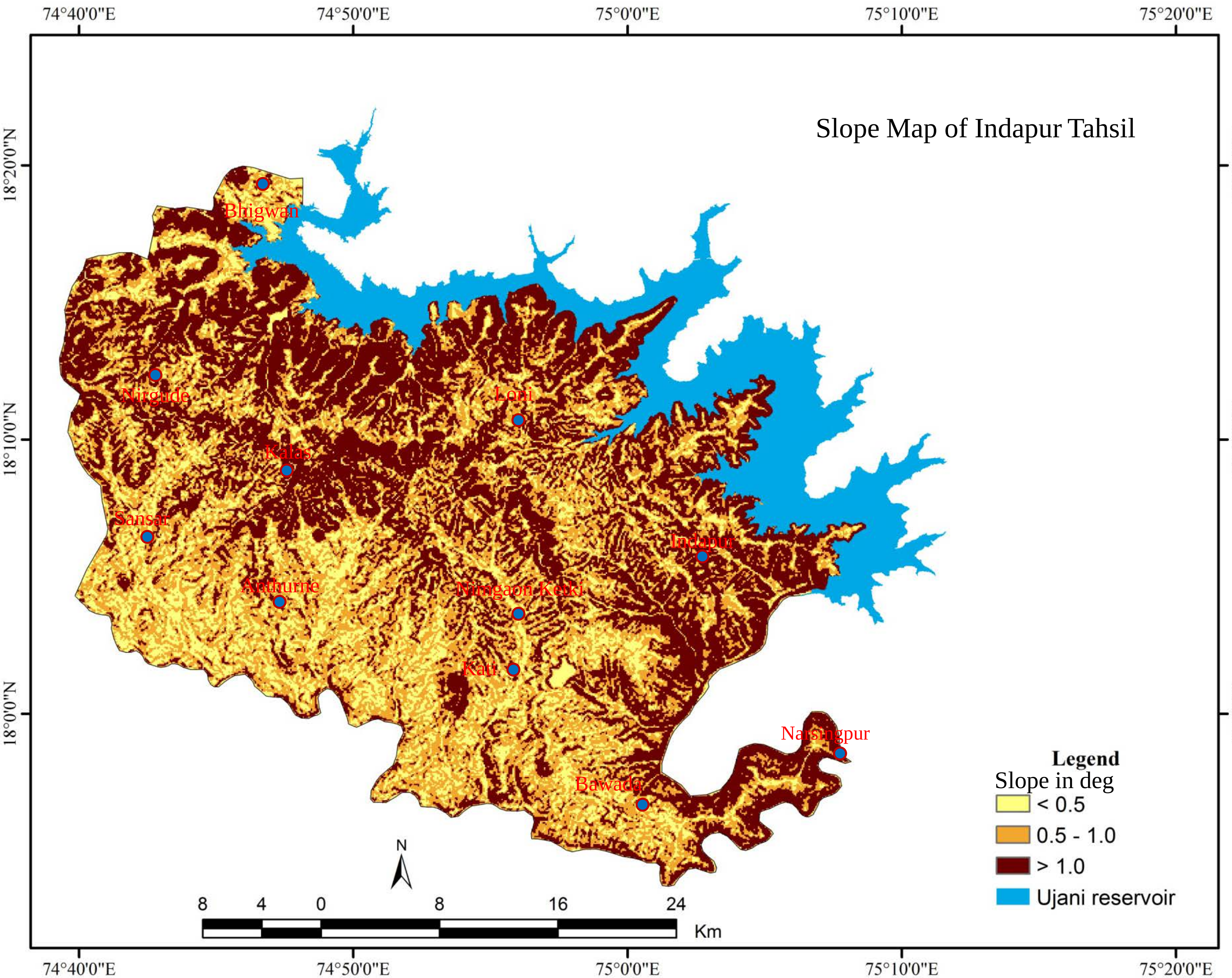
Source: Reproduced from worldclimate.org/tiles.php **Fig. 2.7a**



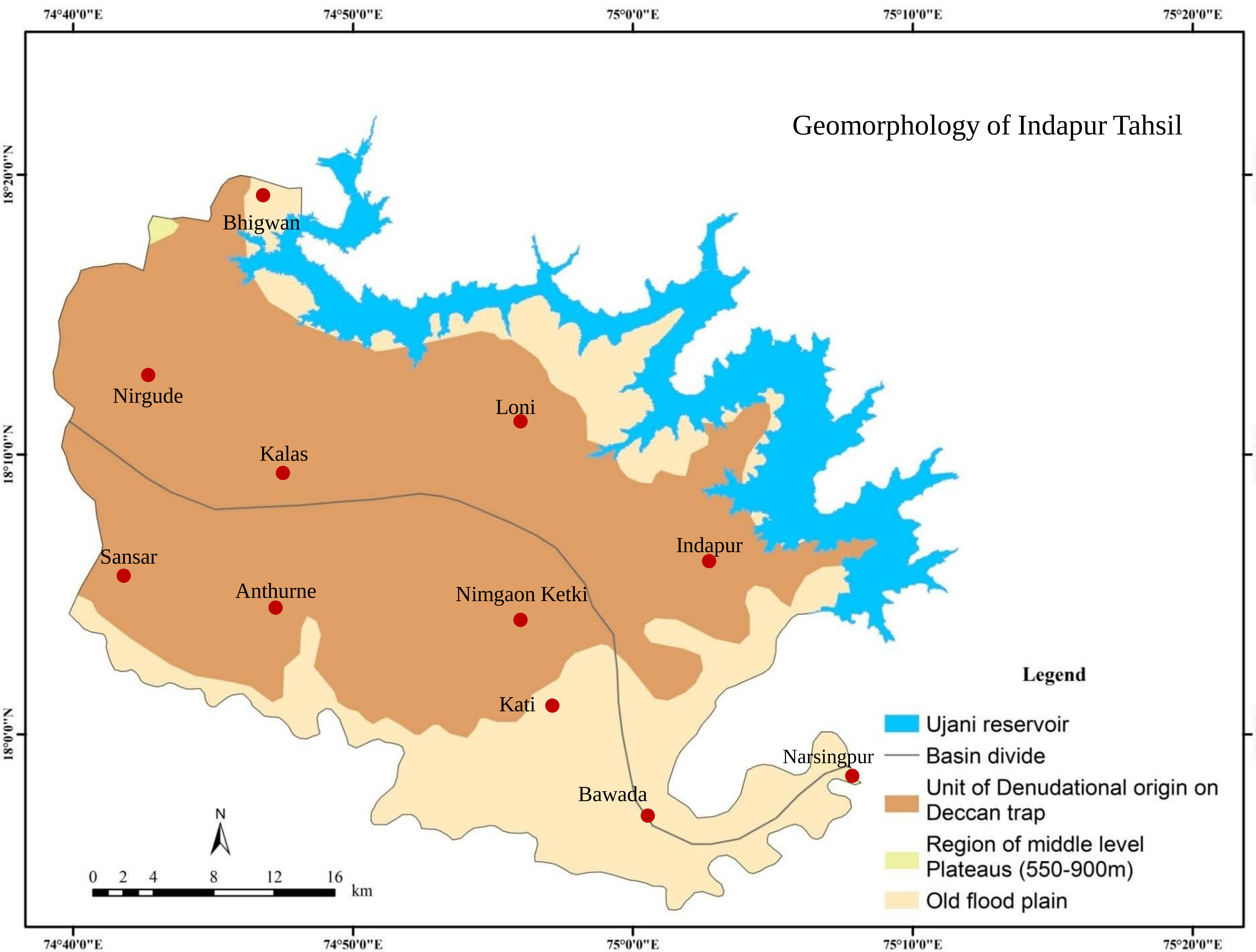
Source: Reproduced from http://www.csi.cgiar.org **Fig. 2.8**



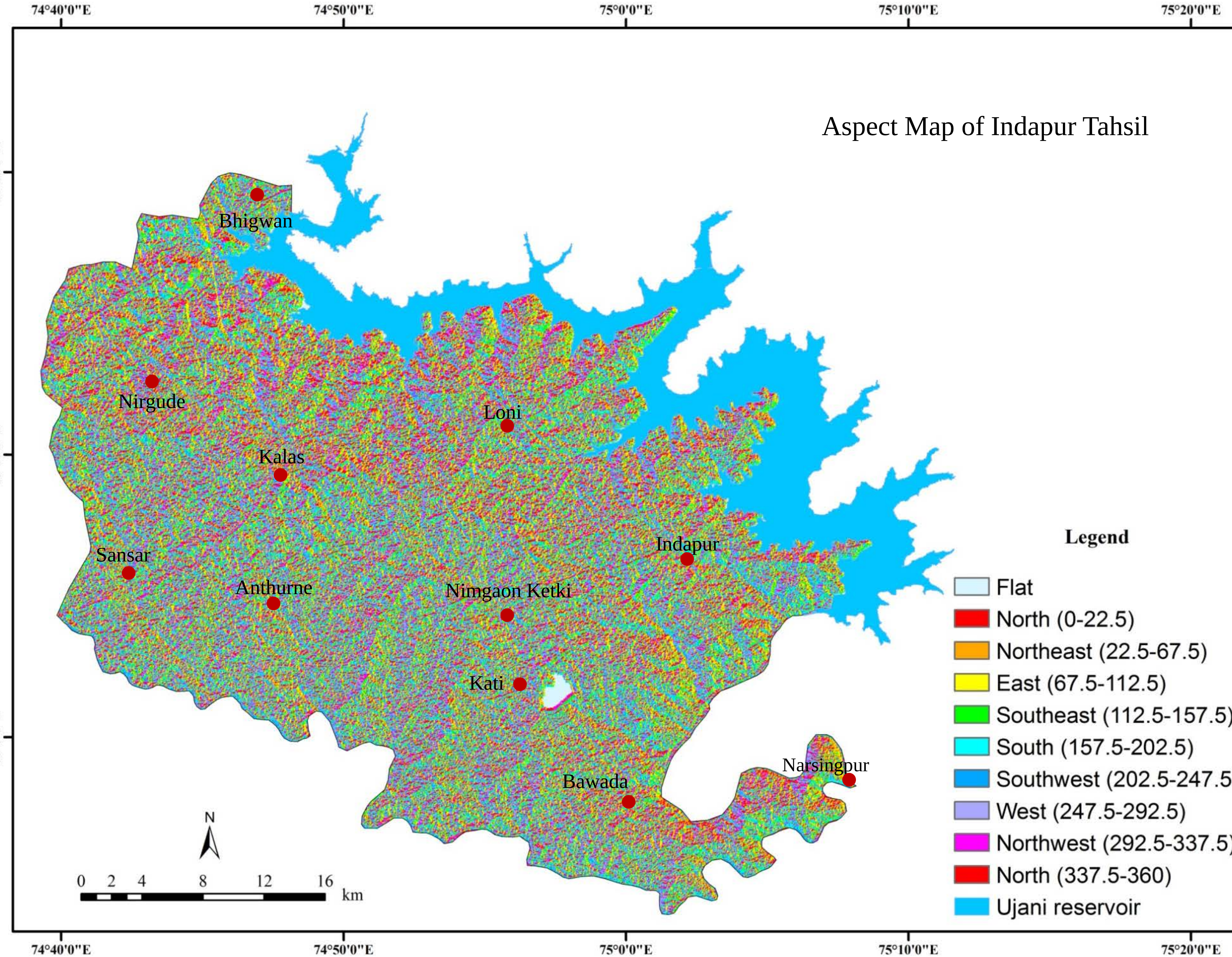
Source: Author **Fig. 2.9**



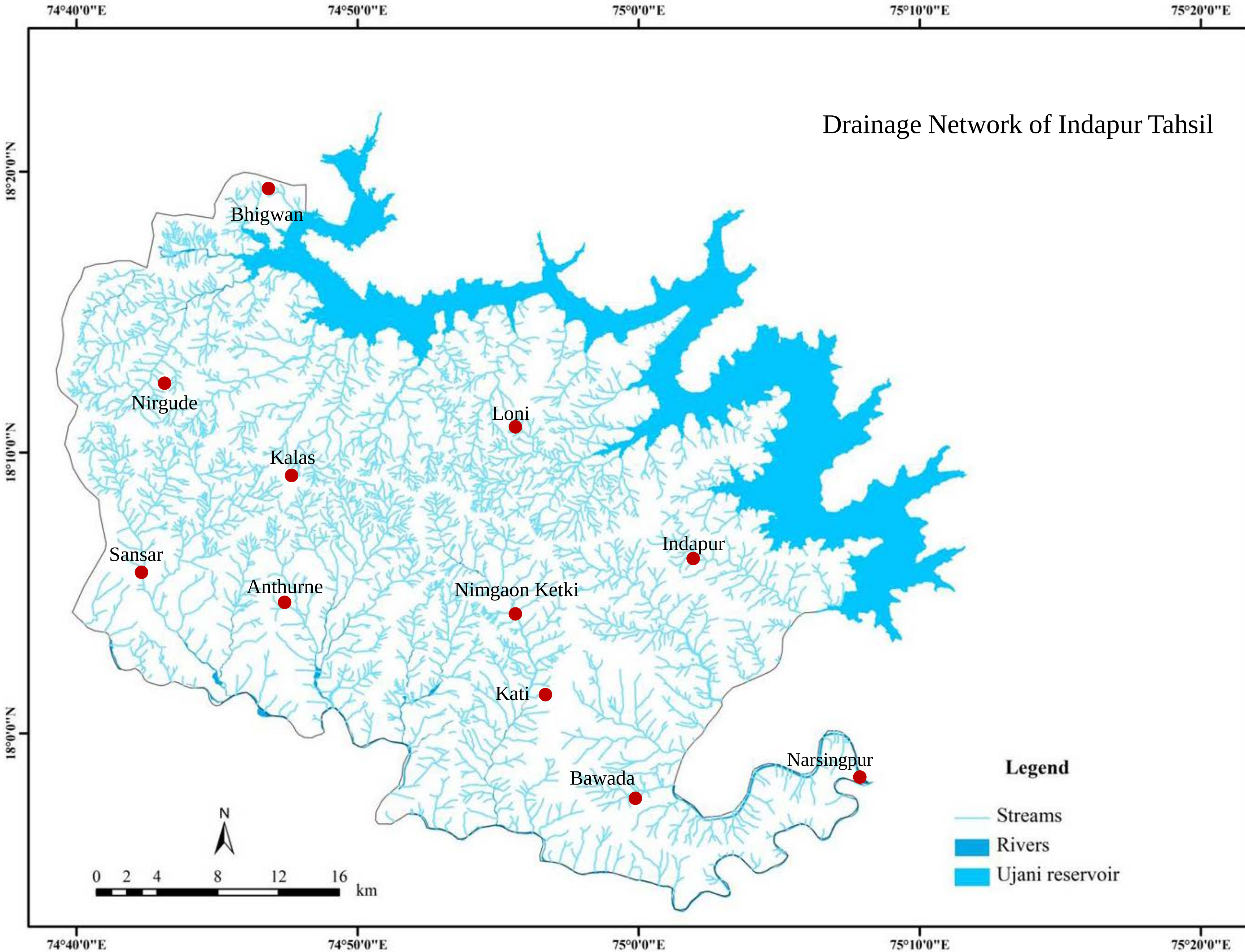
Source: Author **Fig. 2.10a**



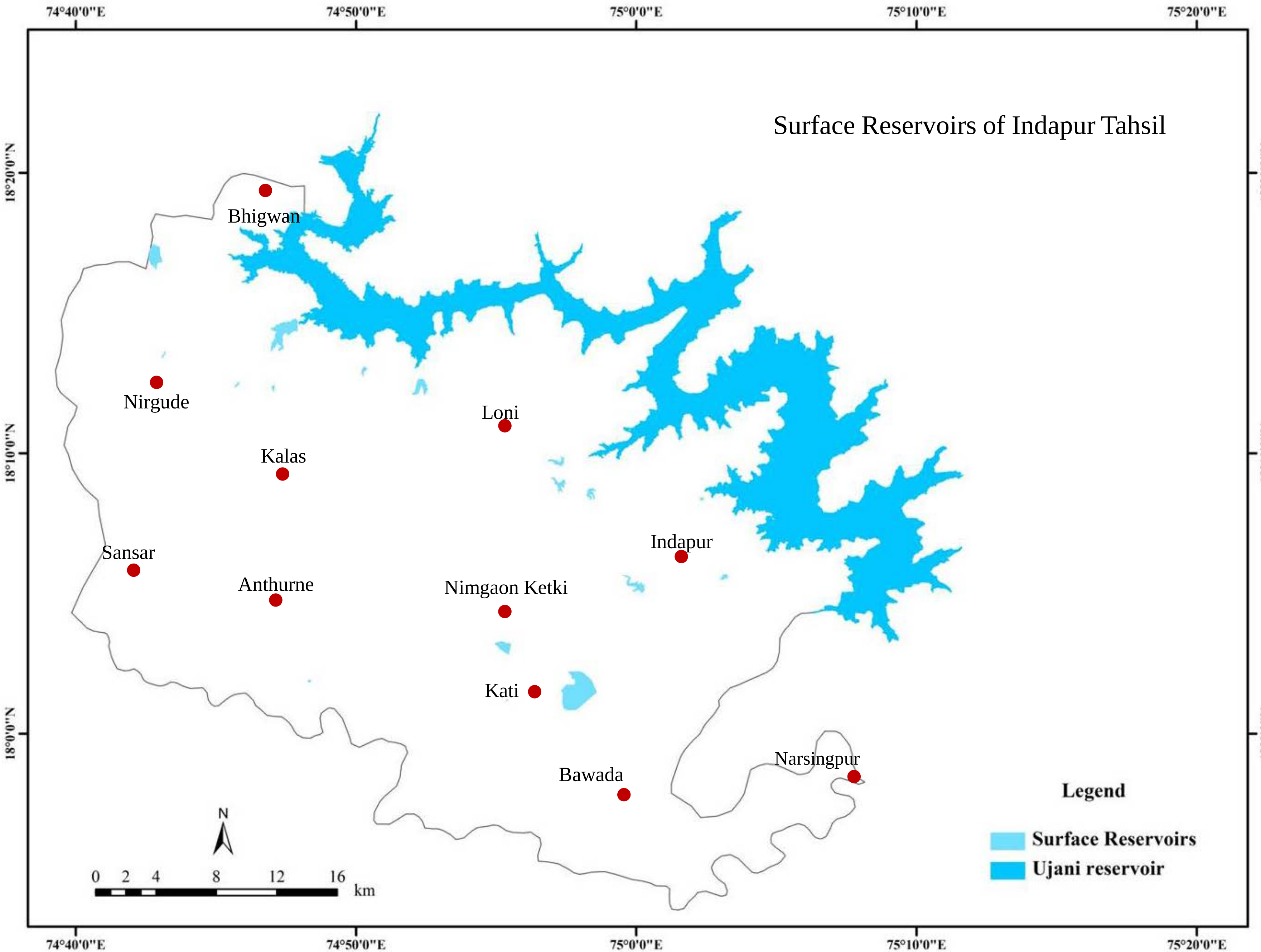
Source: Reproduced from mpcb.gov.in **Fig. 2.11a**



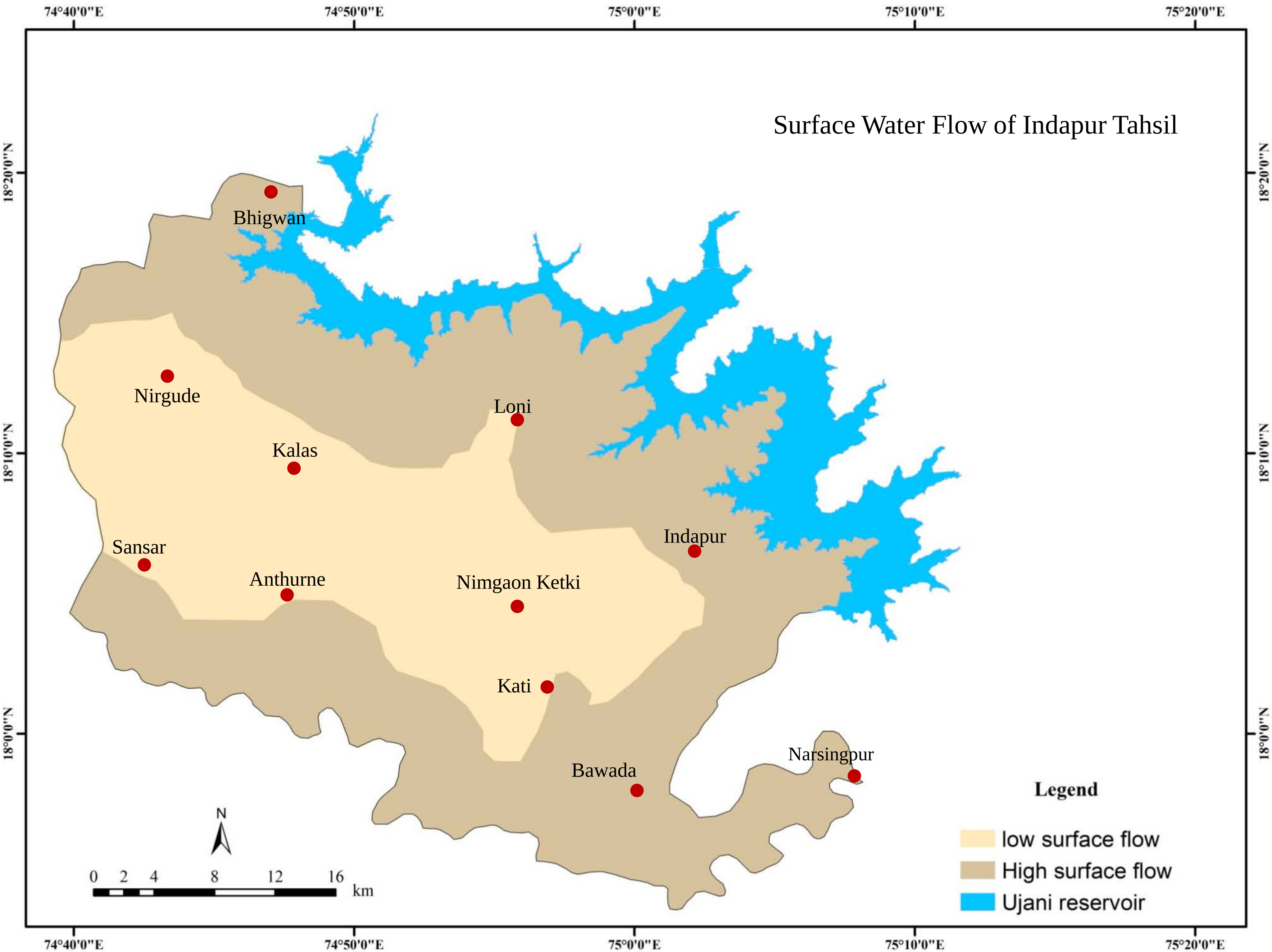
Source: Author **Fig. 2.12**



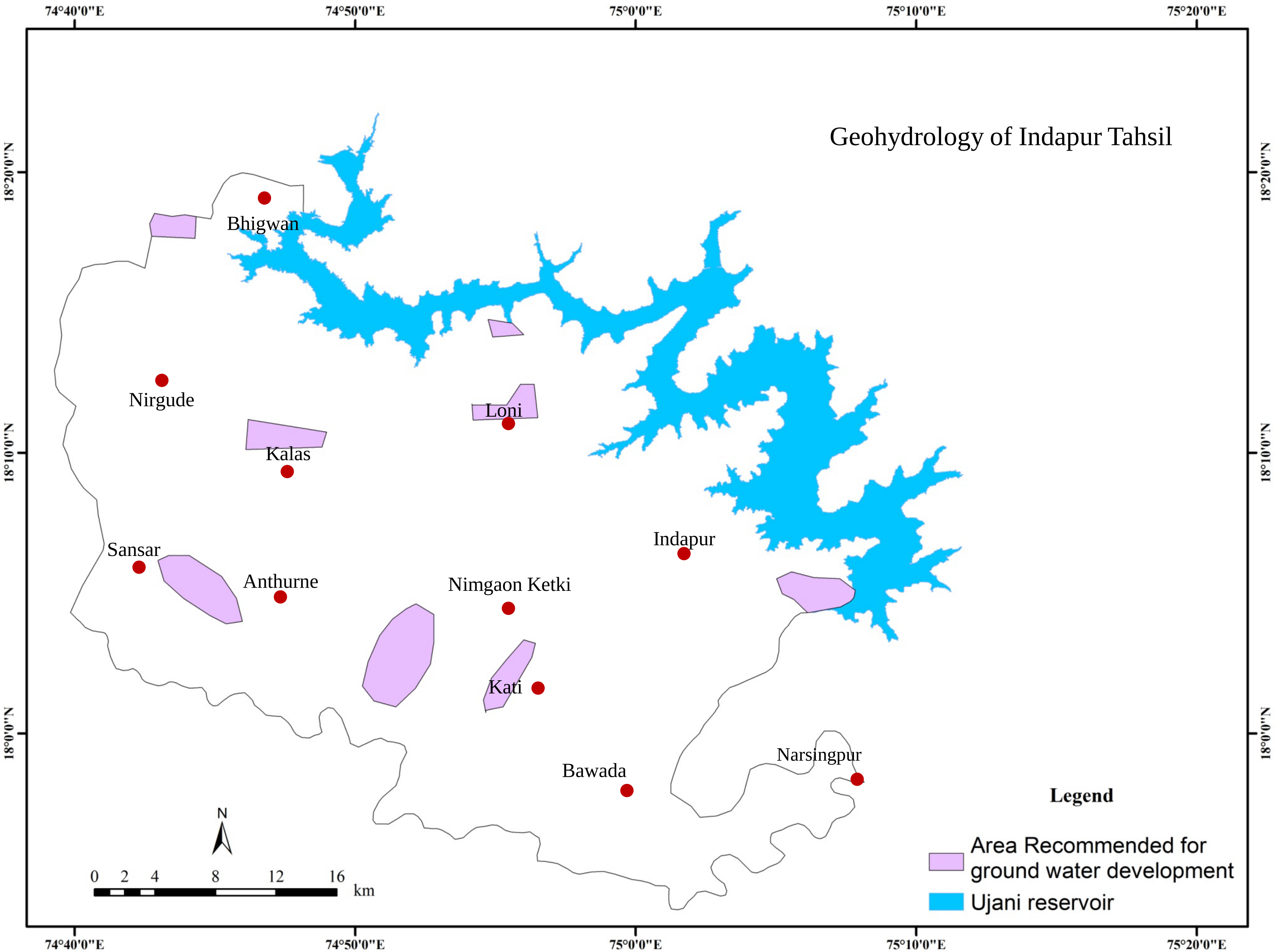
3**Source**: Reproduced from S.O.I. Toposheet and mpcb.gov.in **Fig. 2.13**



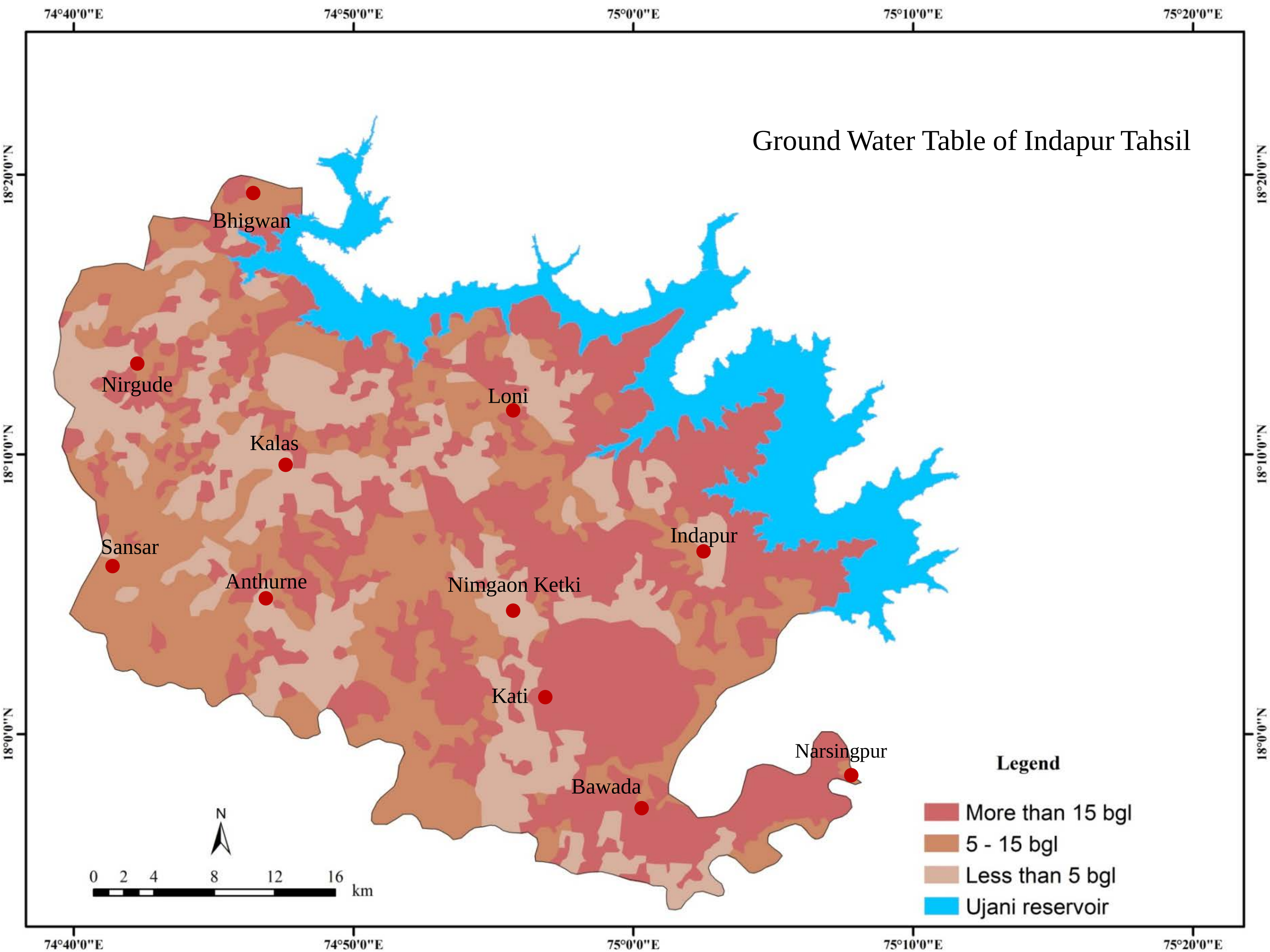
Source: Reproduced from Google image and mpcb.gov.in **Fig. 2.14a**



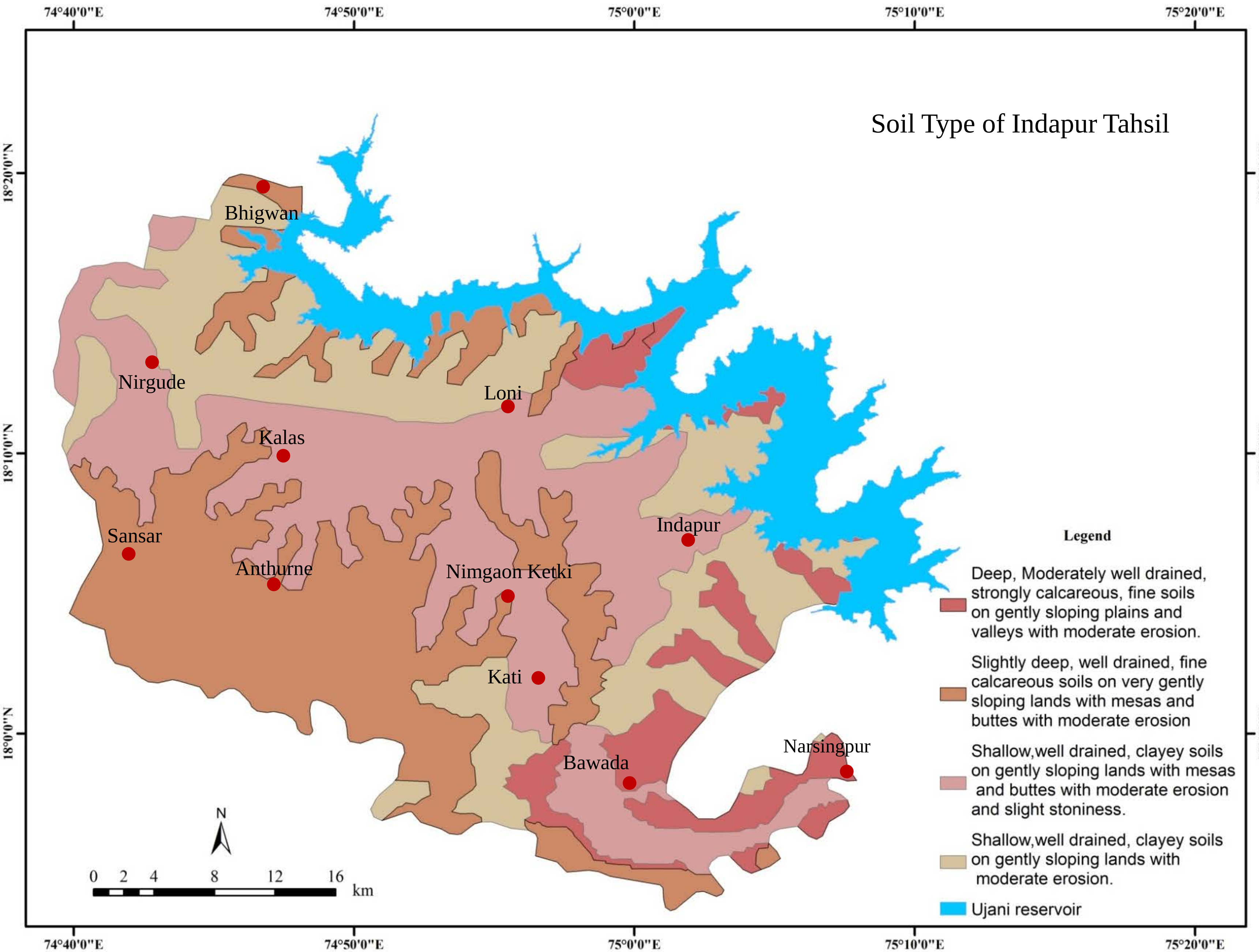
Source: Reproduced from mpcb.gov.in/ DEA Pune maps **Fig. 2.15a**



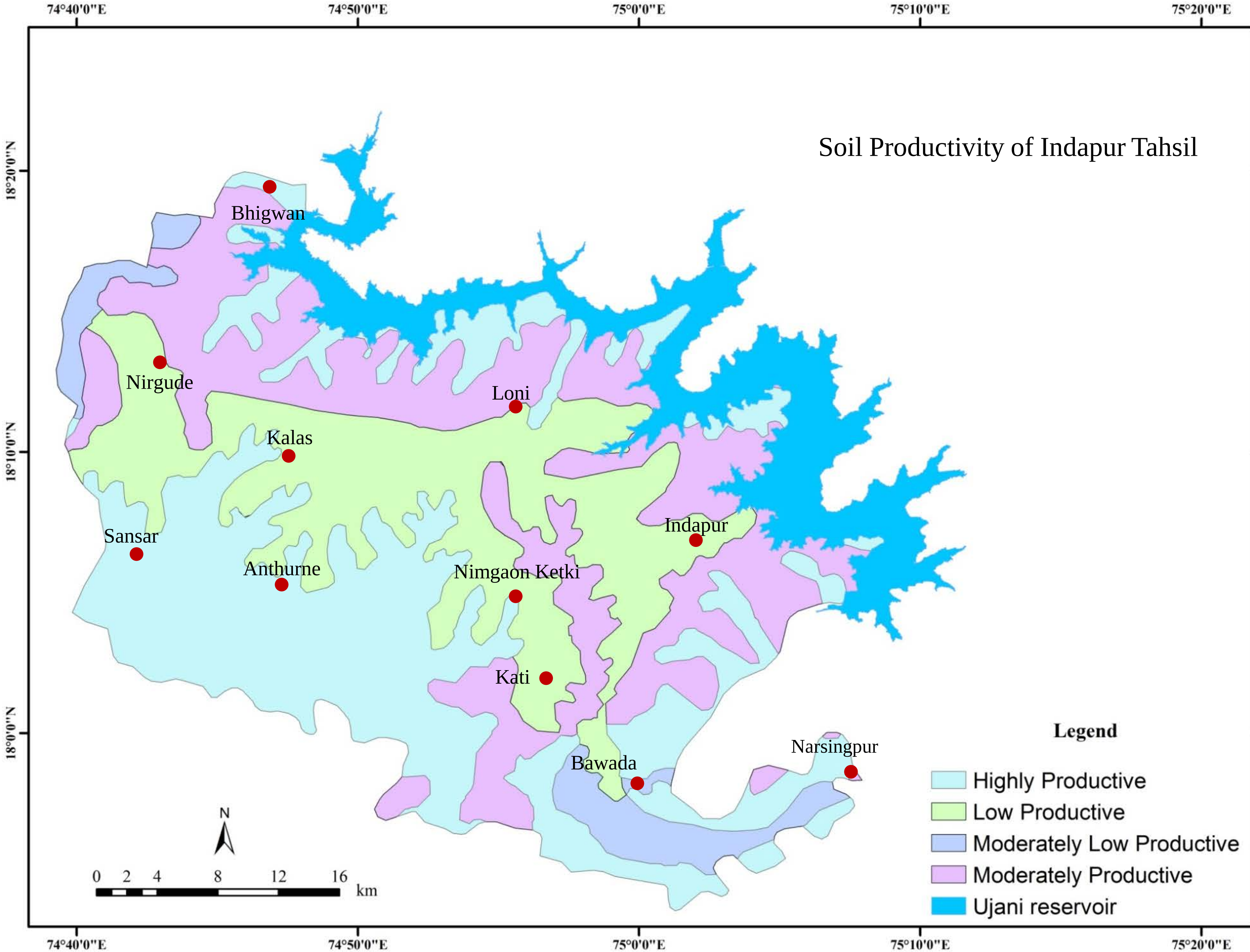
Source: Reproduced from Geological Survey of India, central region, Nagpur. **Fig. 2.16a**



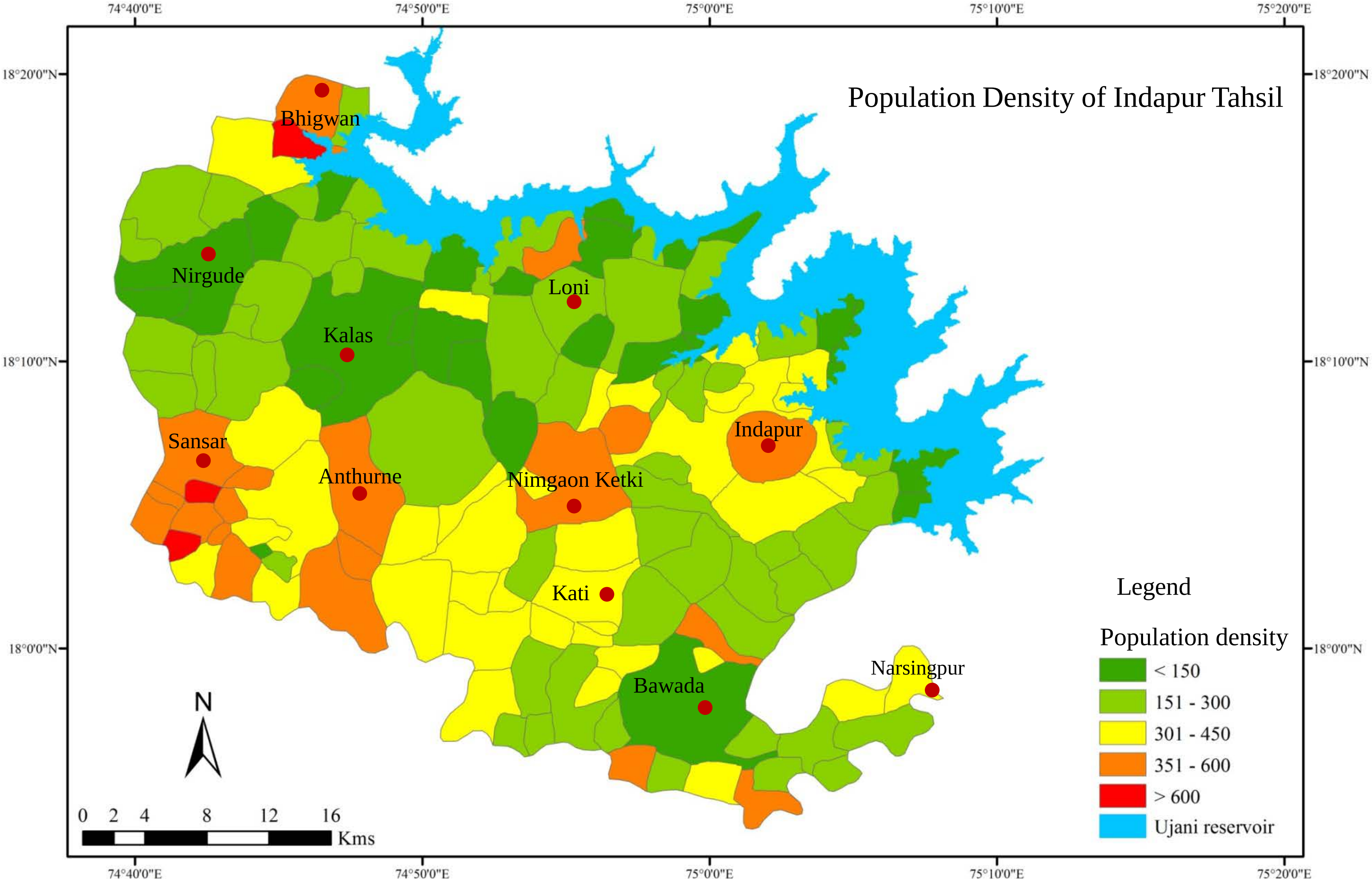
Source: Reproduced from mpcb.gov.in/ DEA Pune maps **Fig. 2.17a**



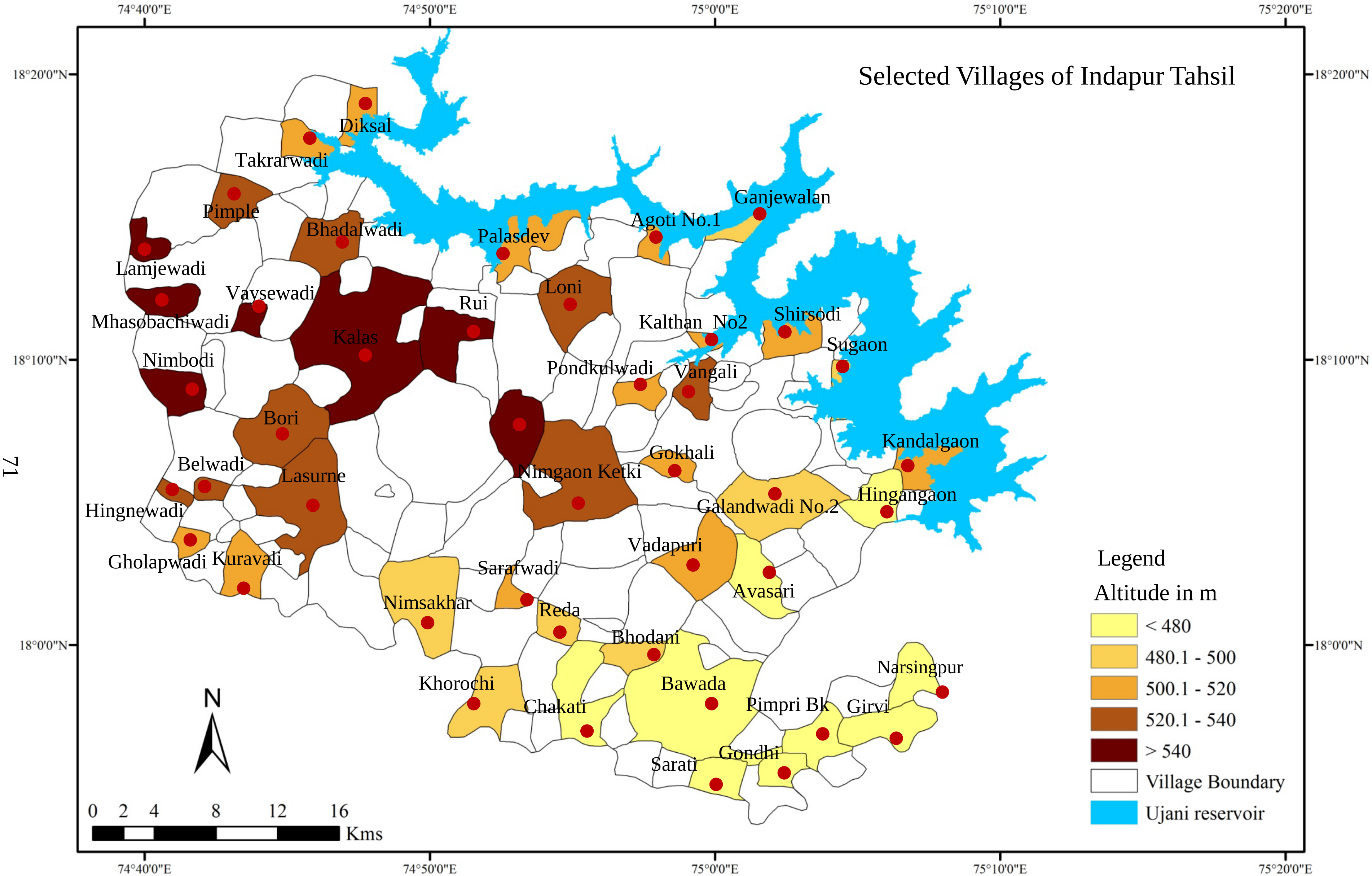
Source: Reproduced from mpcb.gov.in/ DEA Pune maps **Fig. 2.18a**



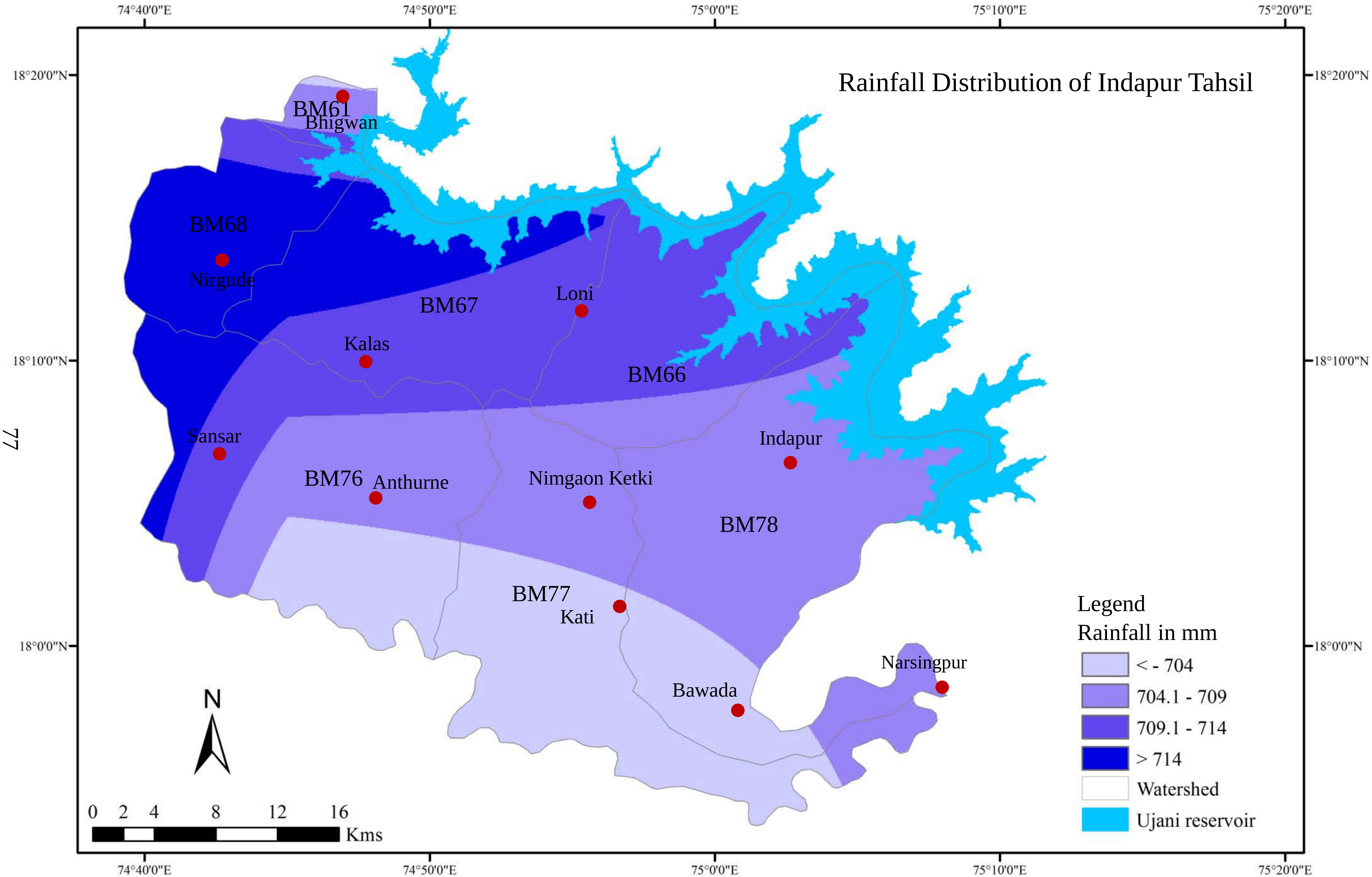
Source: Reproduced from mpcb.gov.in/ DEA Pune maps **Fig. 2.19a**



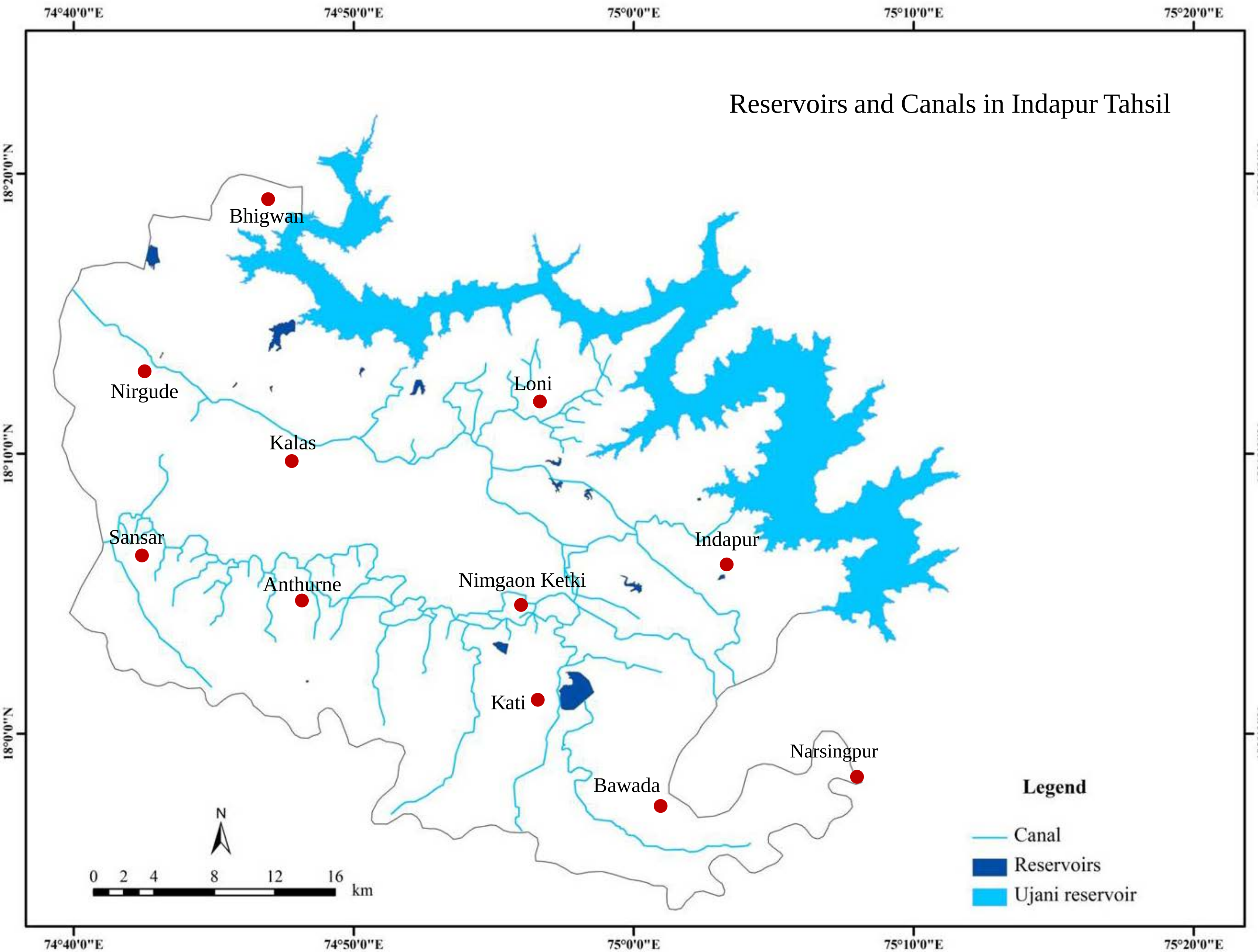
Source: Census of India 2011 **Fig. 2.20**



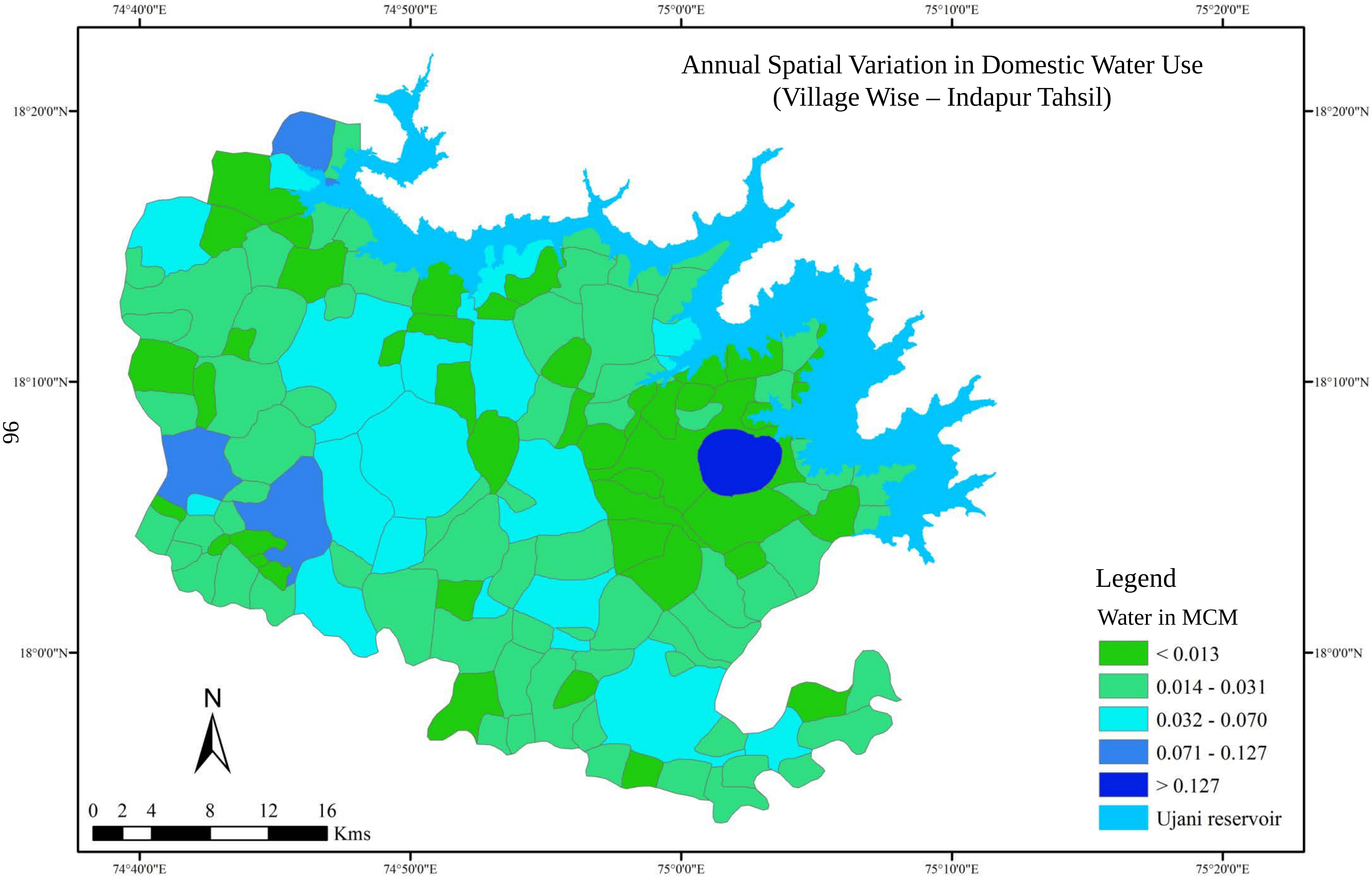
Source: Author **Fig. 3.1**



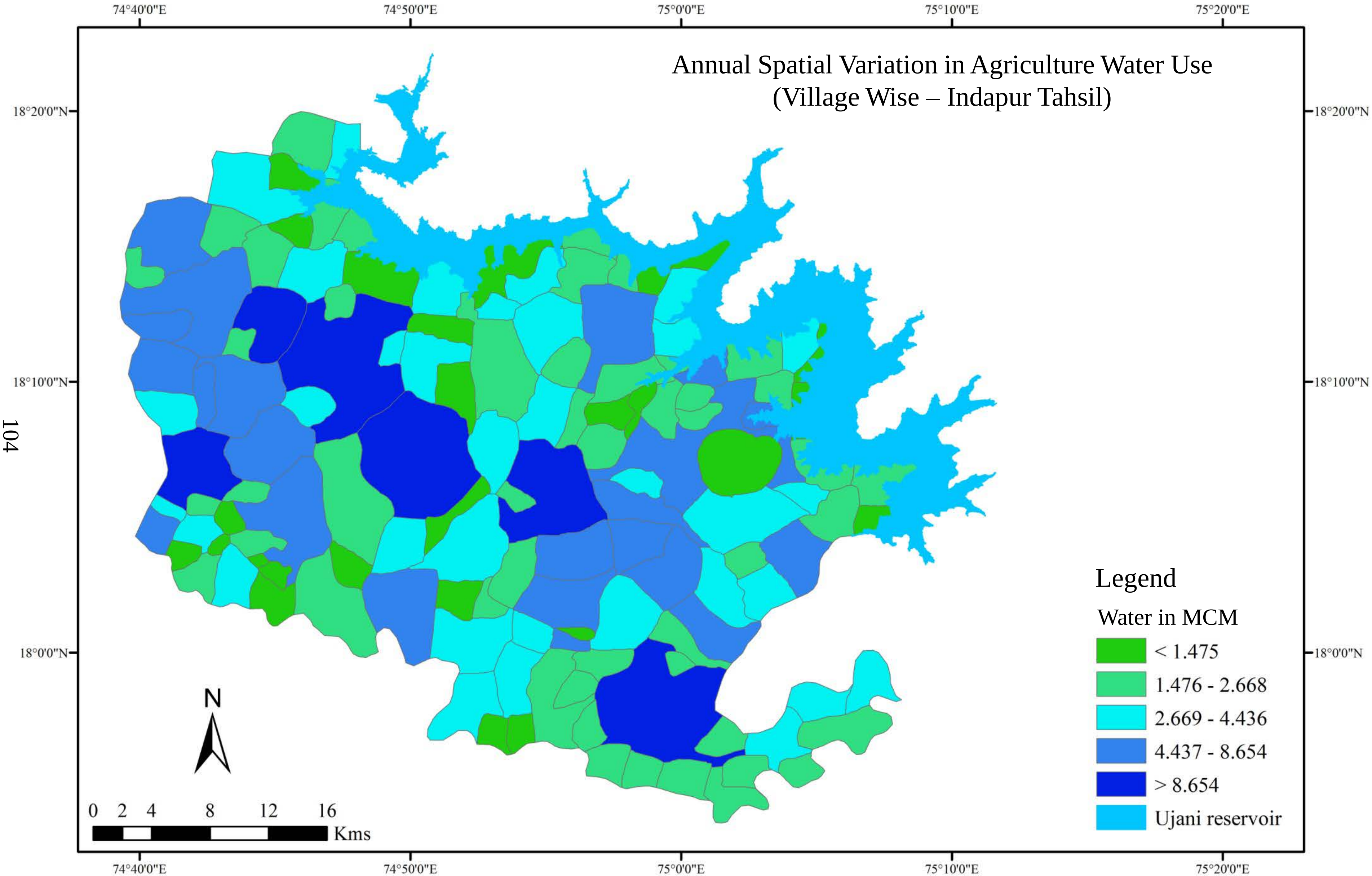
Source: Reproduced from www.india.wris.nrsc.gov.in **Fig. 3.4a**



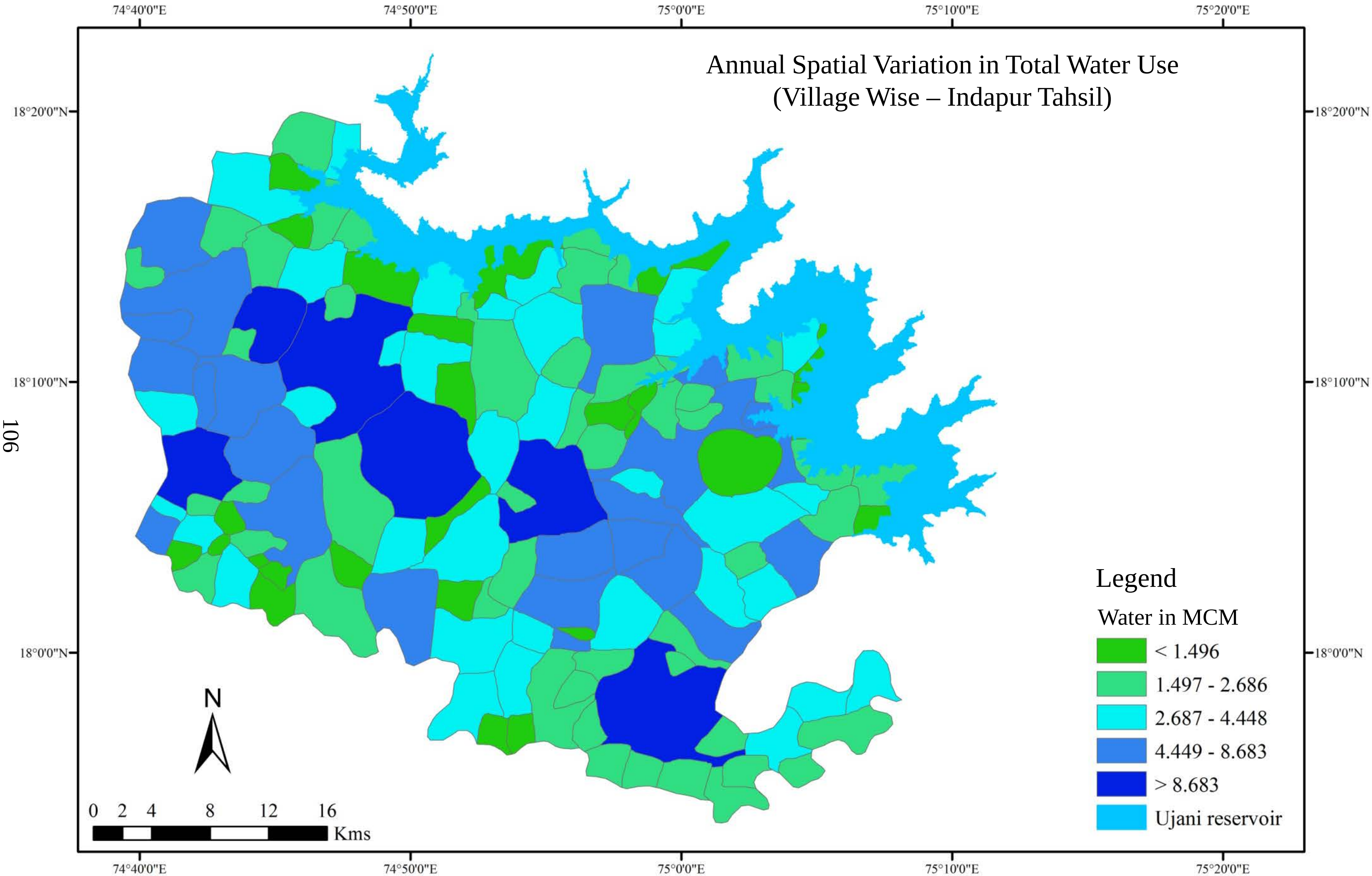
Source: Reproduced from mpcb.gov.in/ DEA Pune maps **Fig. 3.6a**.



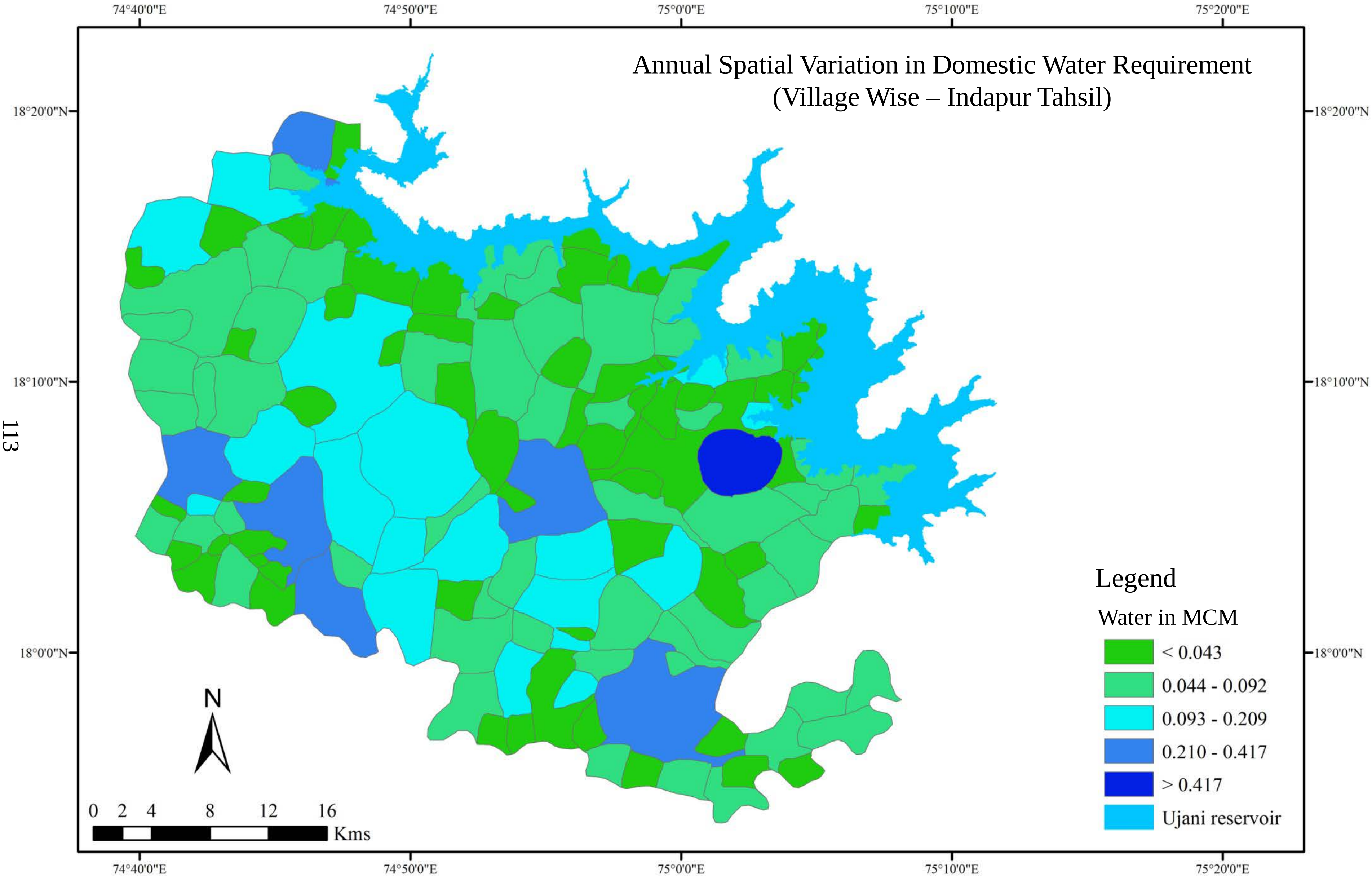
Source: Author **Fig. 4.2**



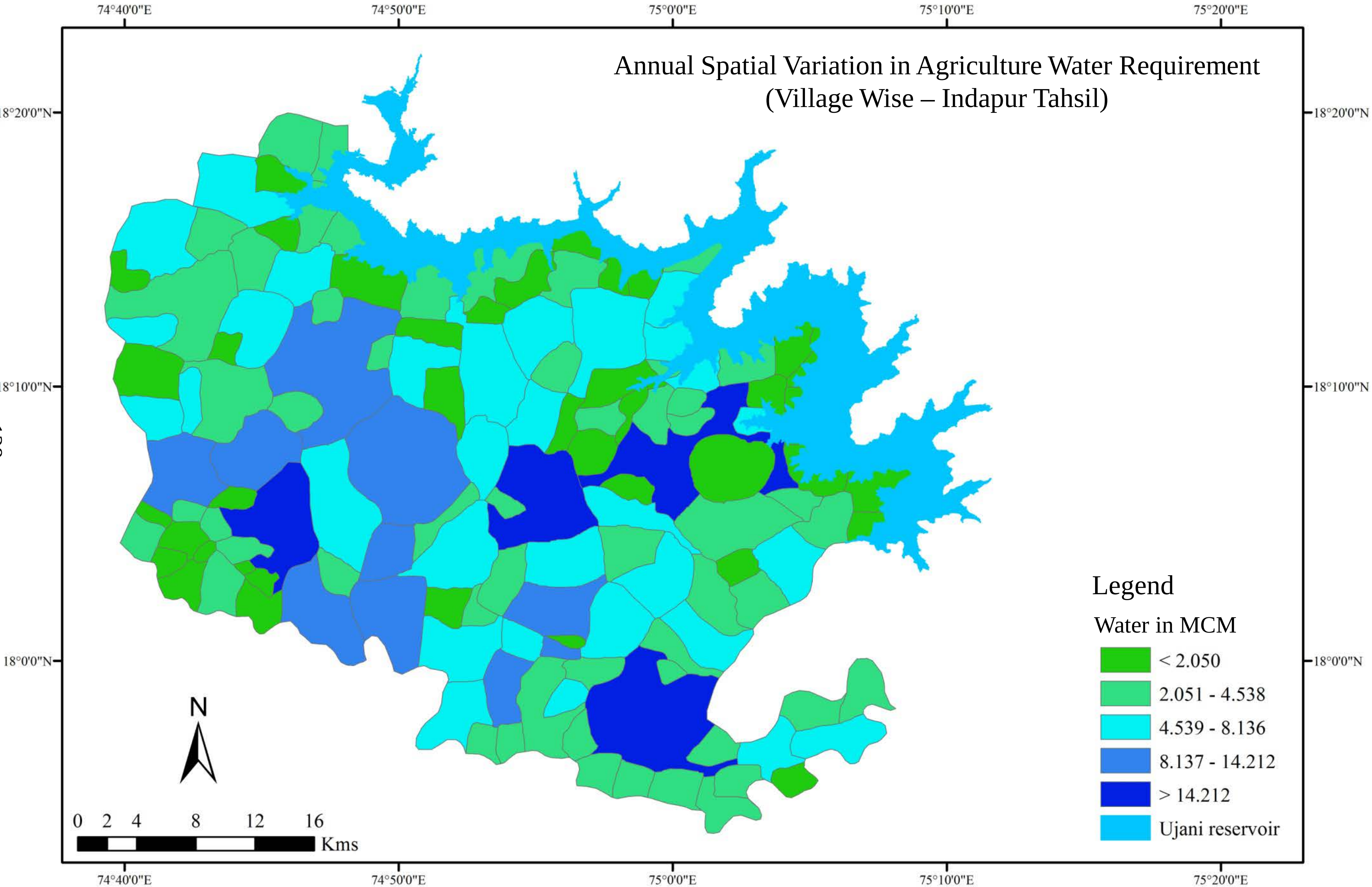
Source: Author **Fig. 4.6**



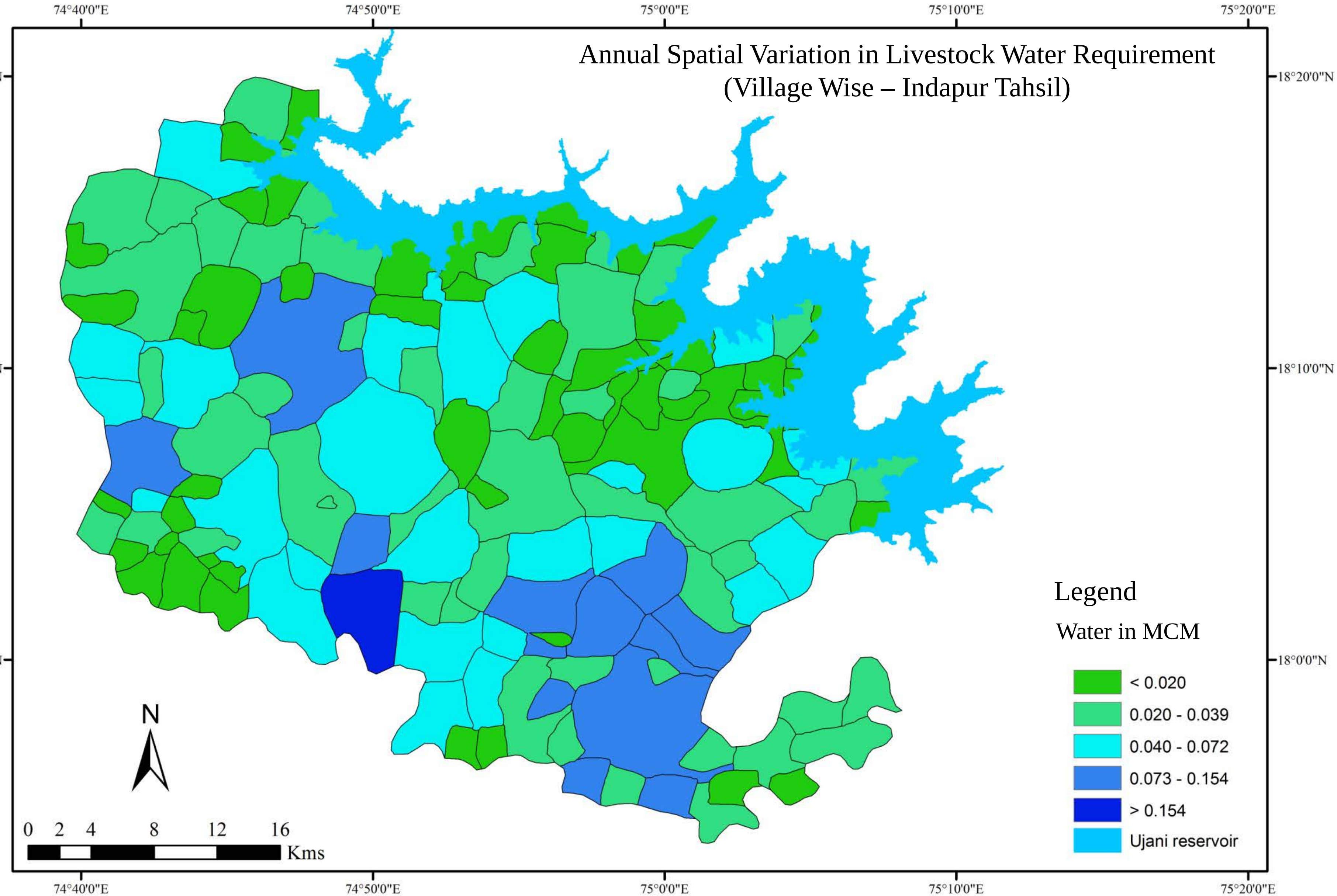
Source: Author **Fig. 4.8**



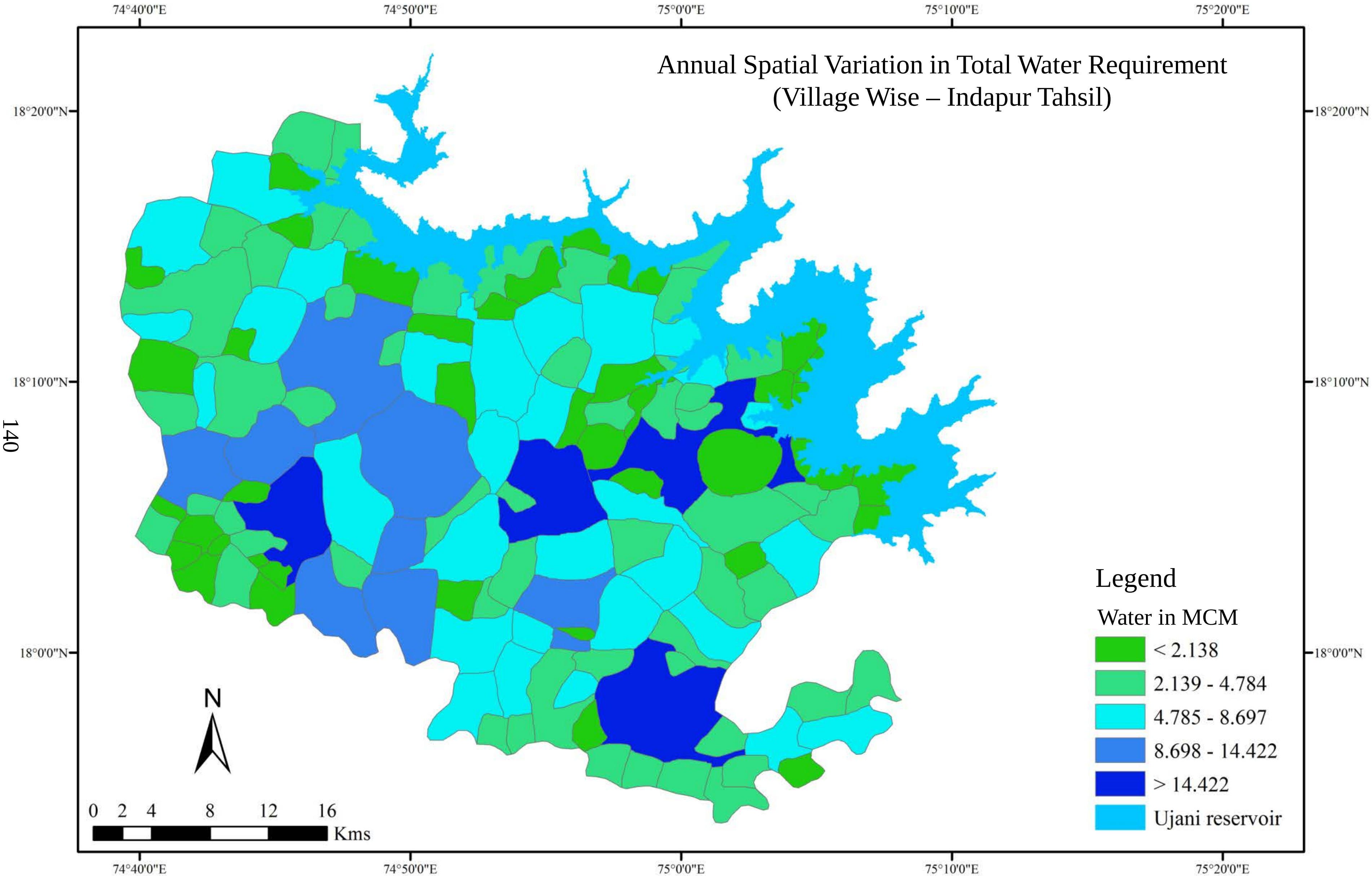
Source: Author **Fig. 4.11**



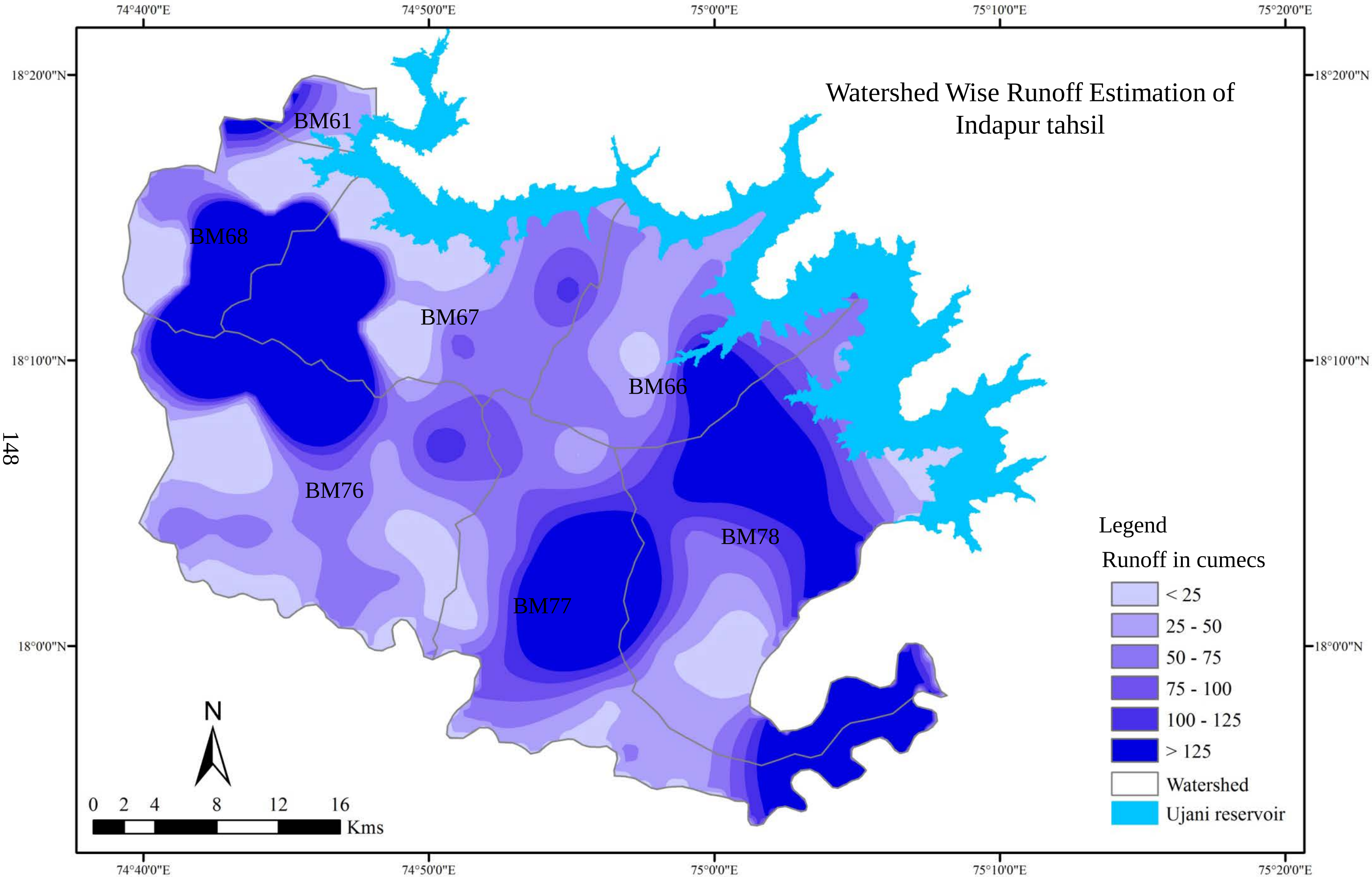
Source: Author **Fig. 4.12**



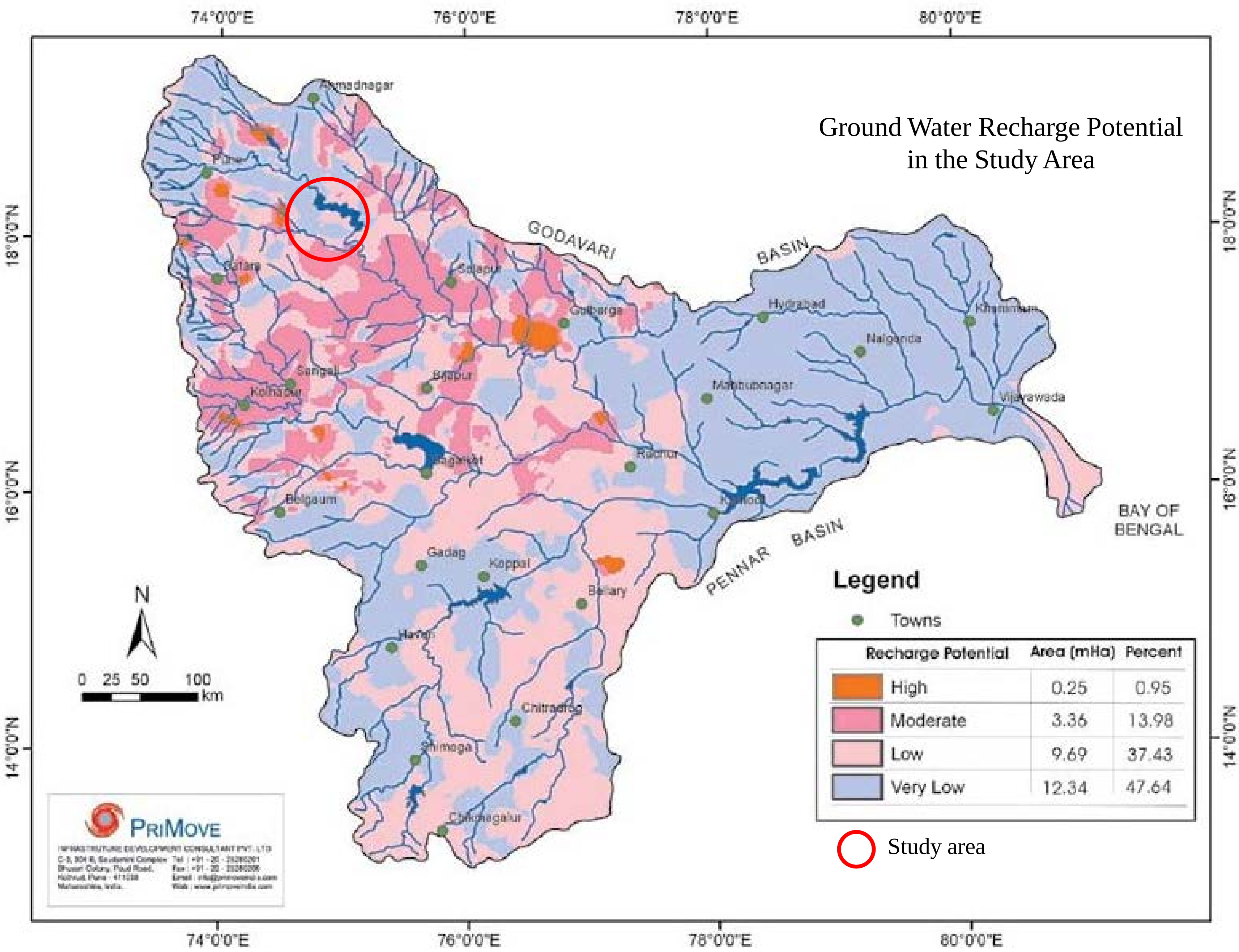
Source: Author **Fig. 4.14**



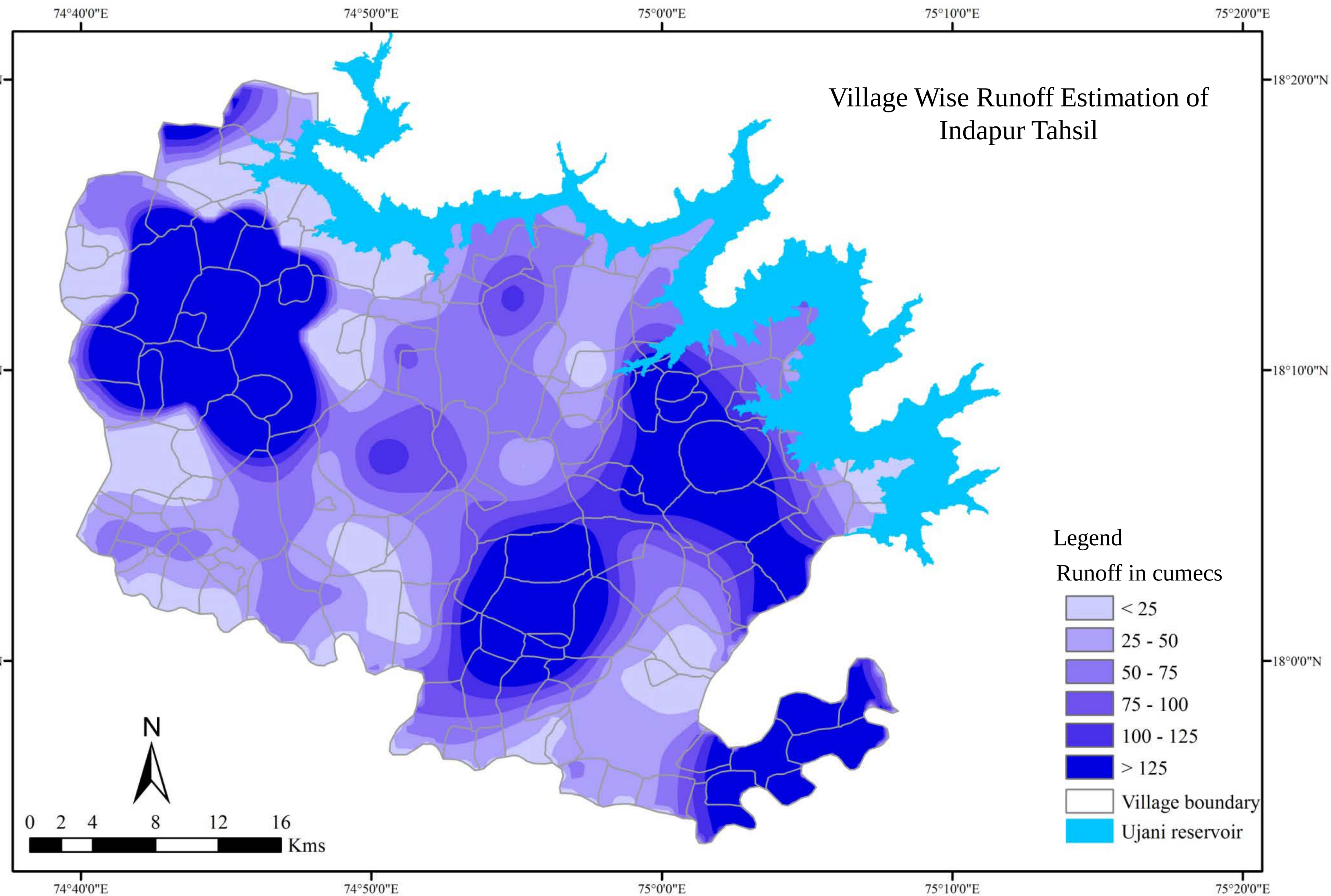
Source: Author **Fig. 4.15**



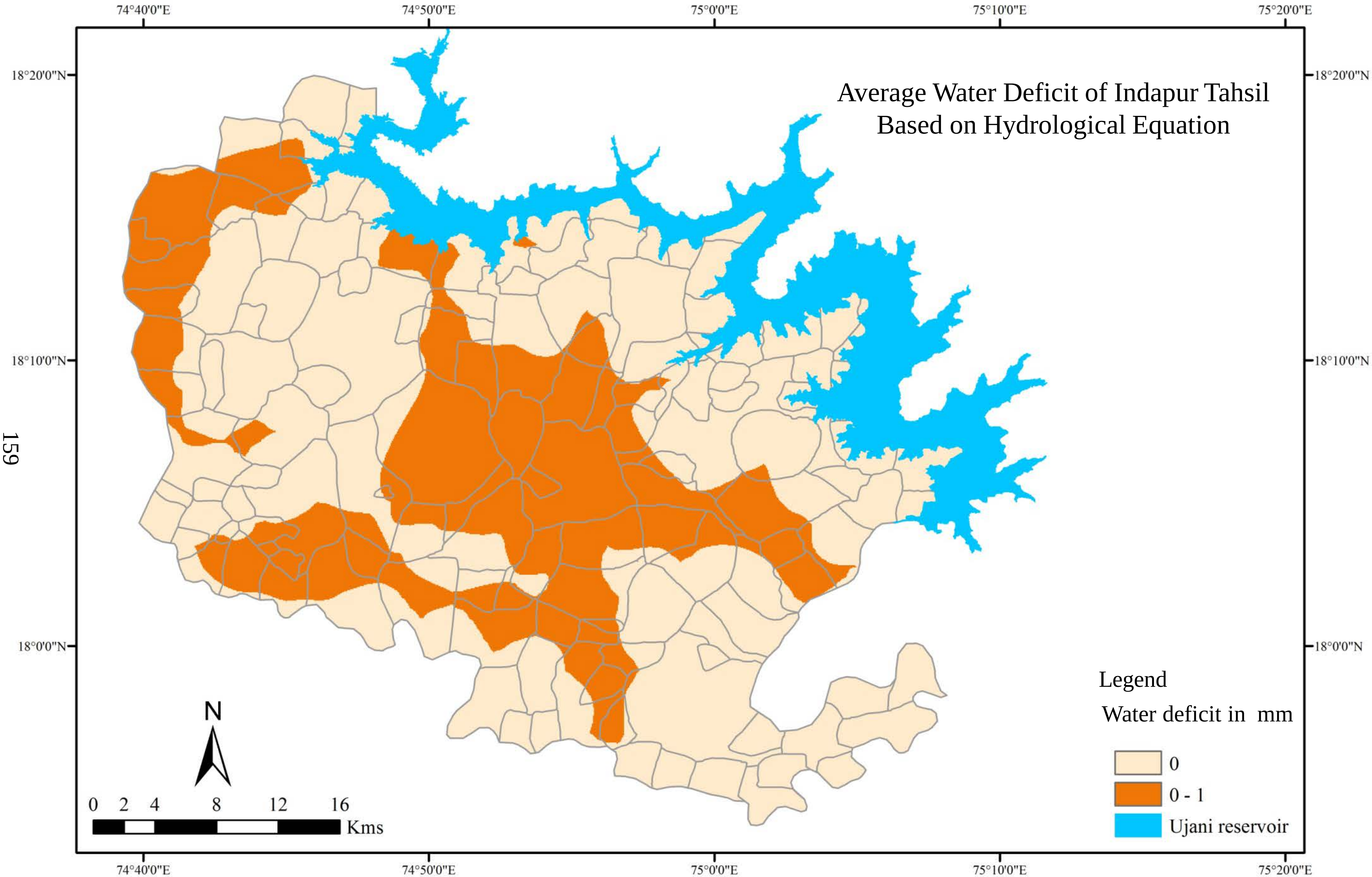
Source: Author **Fig. 5.1a**



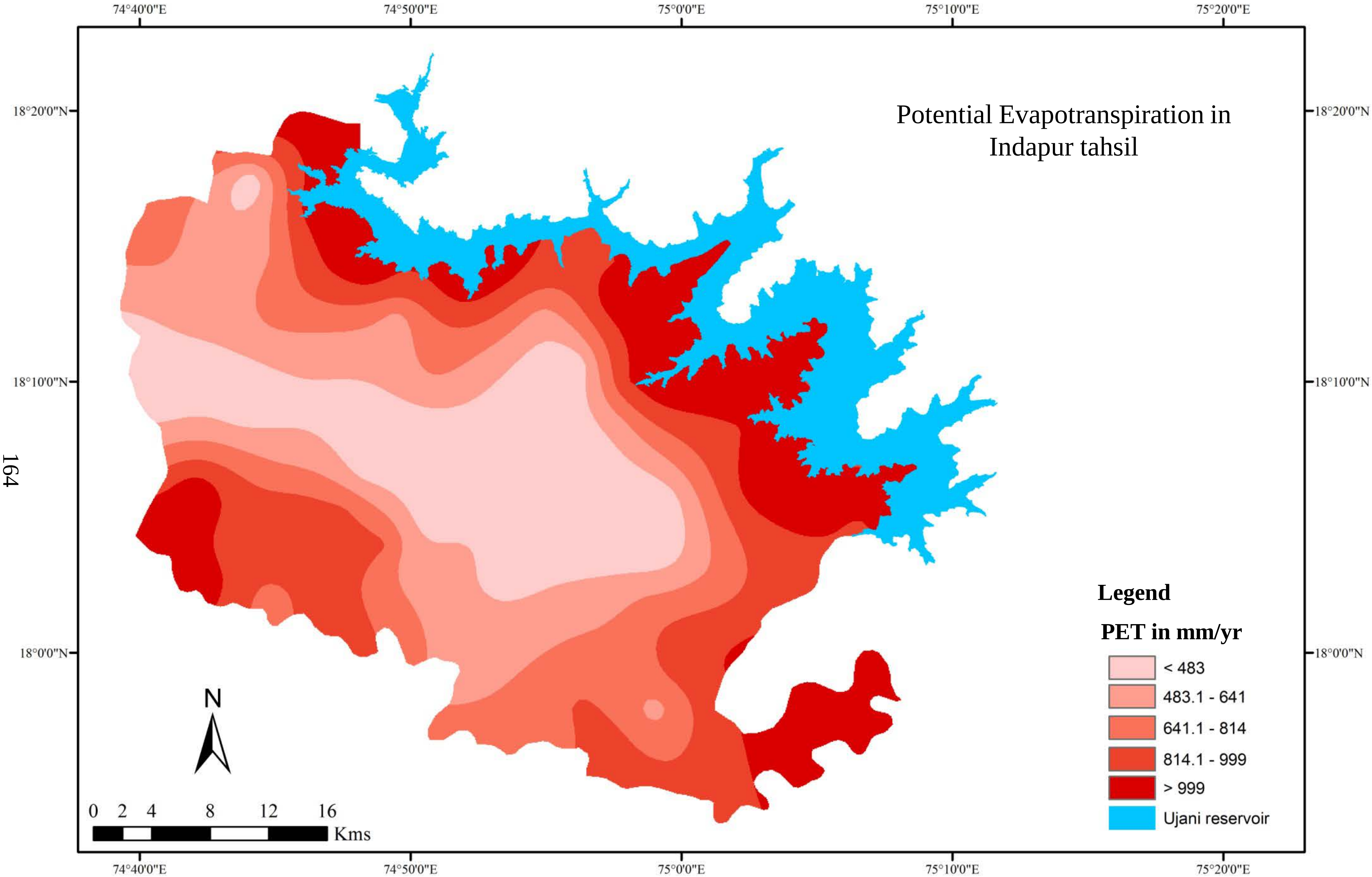
Source: National rain fed area authority planning commission New Delhi 2011 **Fig. 5.3**



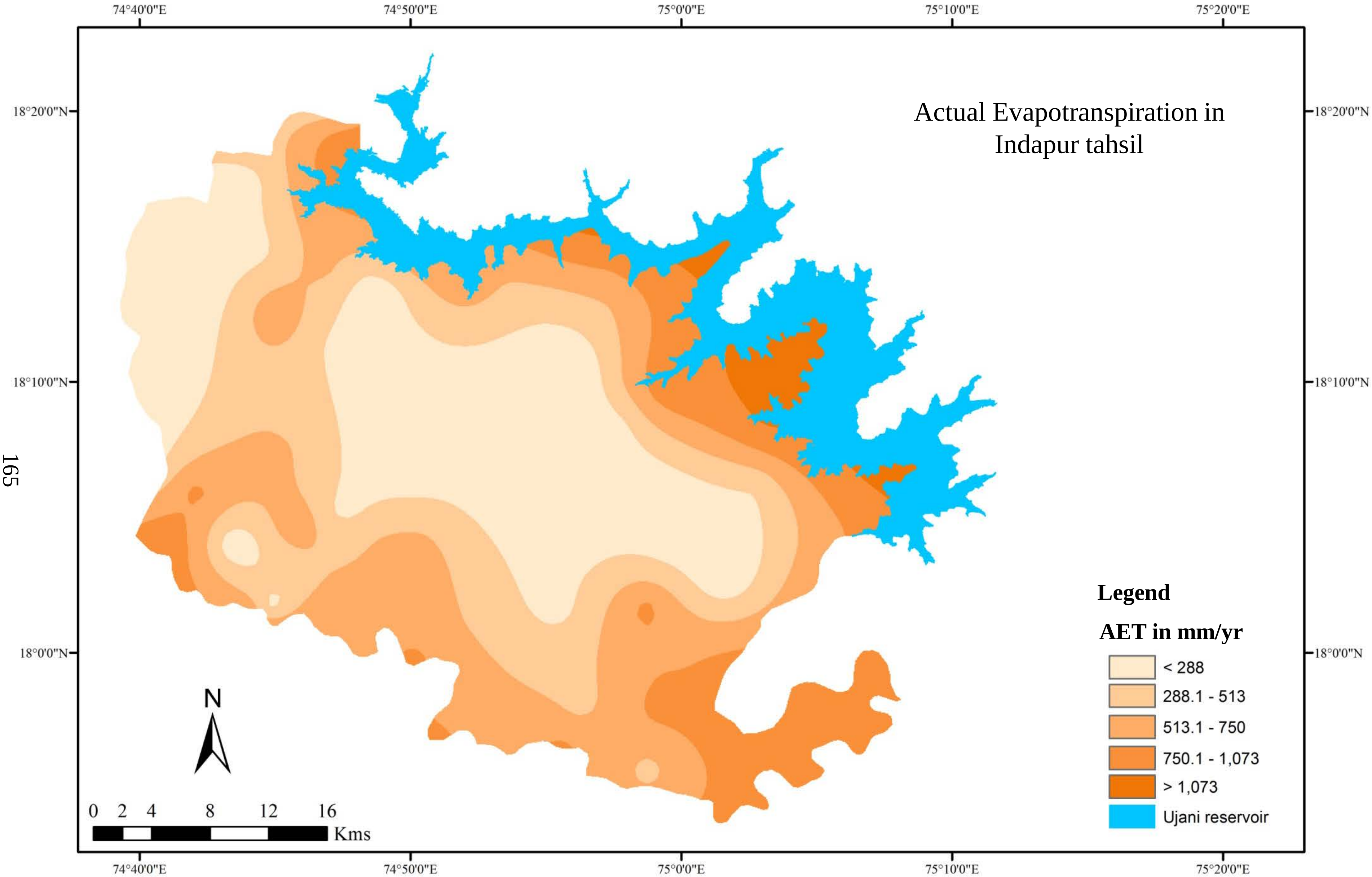
Source: Author **Fig. 5.4**



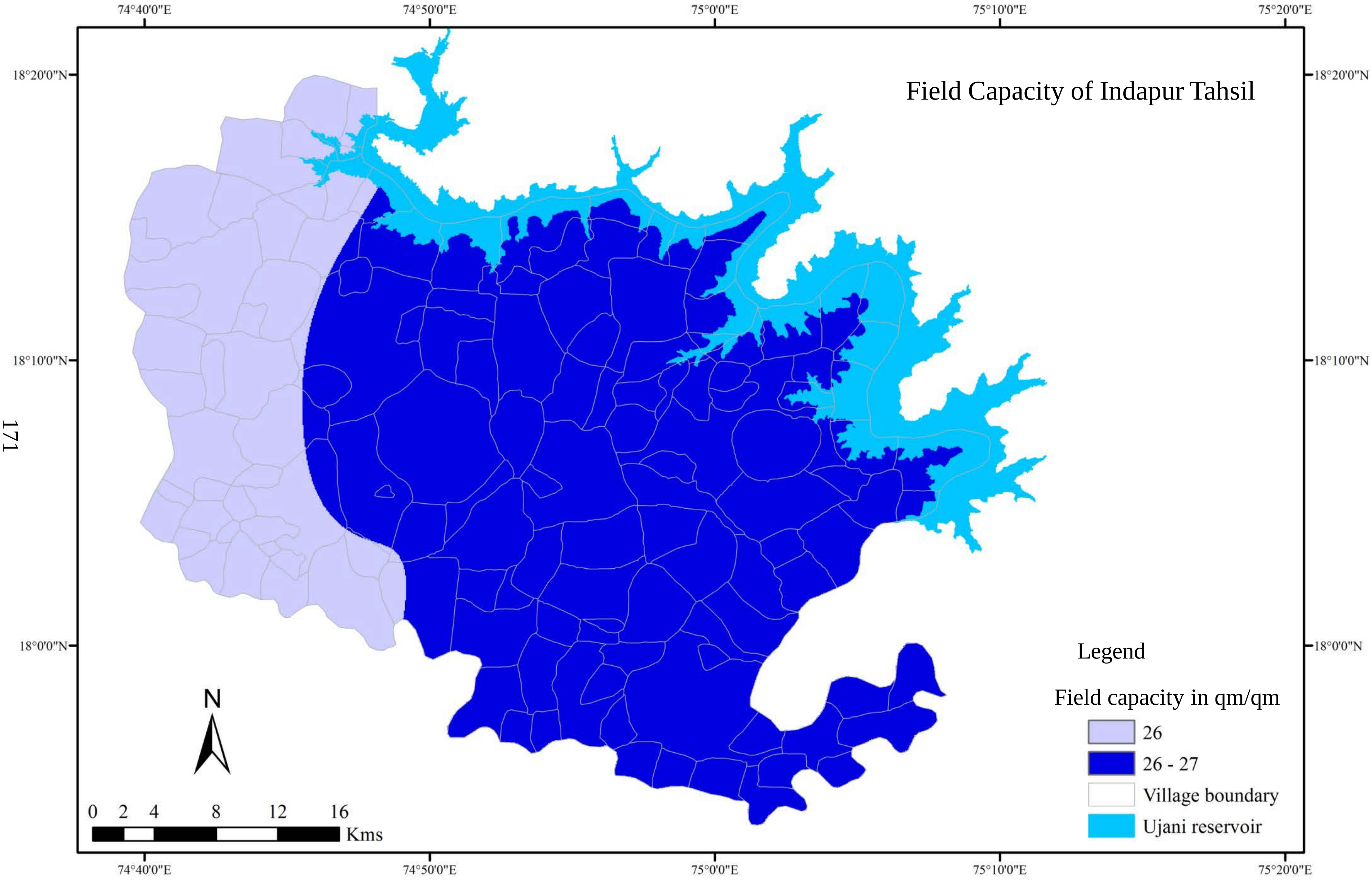
Source: Author **Fig. 5.5**



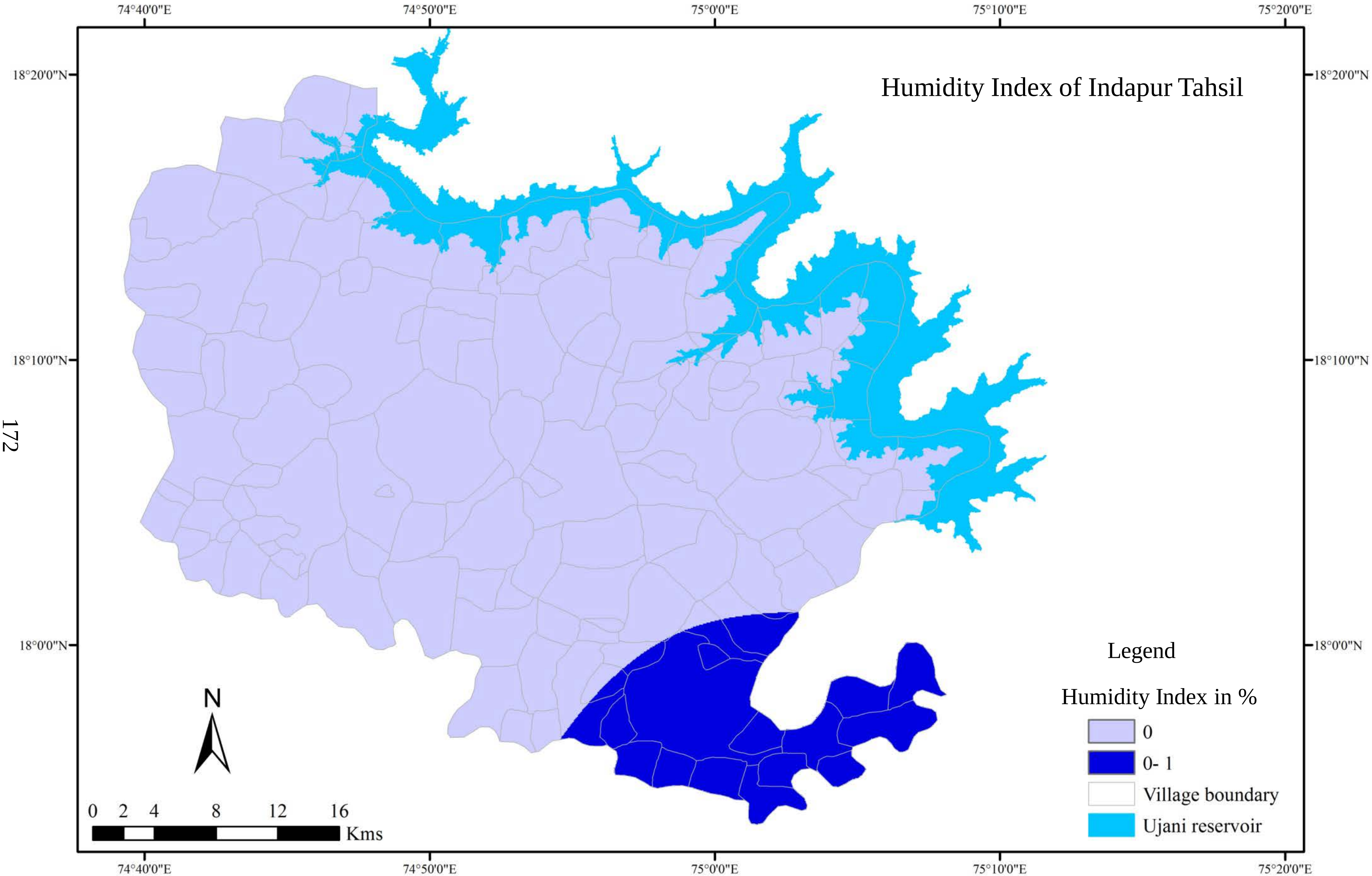
Source: Remote Sensing and Hydrological Modeling of the Upper Bhima Catchment (2006) **Fig. 5.6**



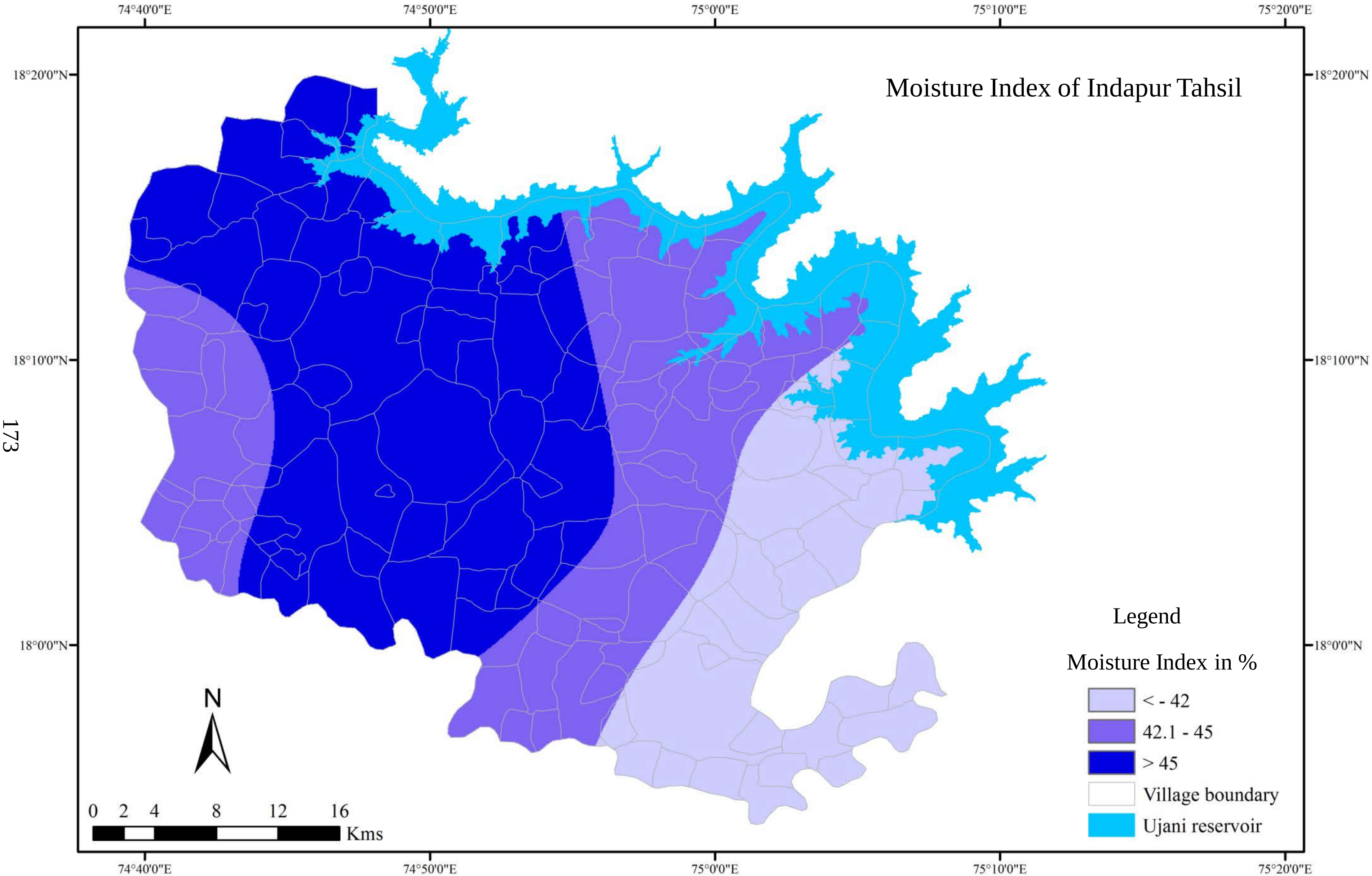
Source: Remote Sensing and Hydrological Modeling of the Upper Bhima Catchment (2006) **Fig. 5.7**



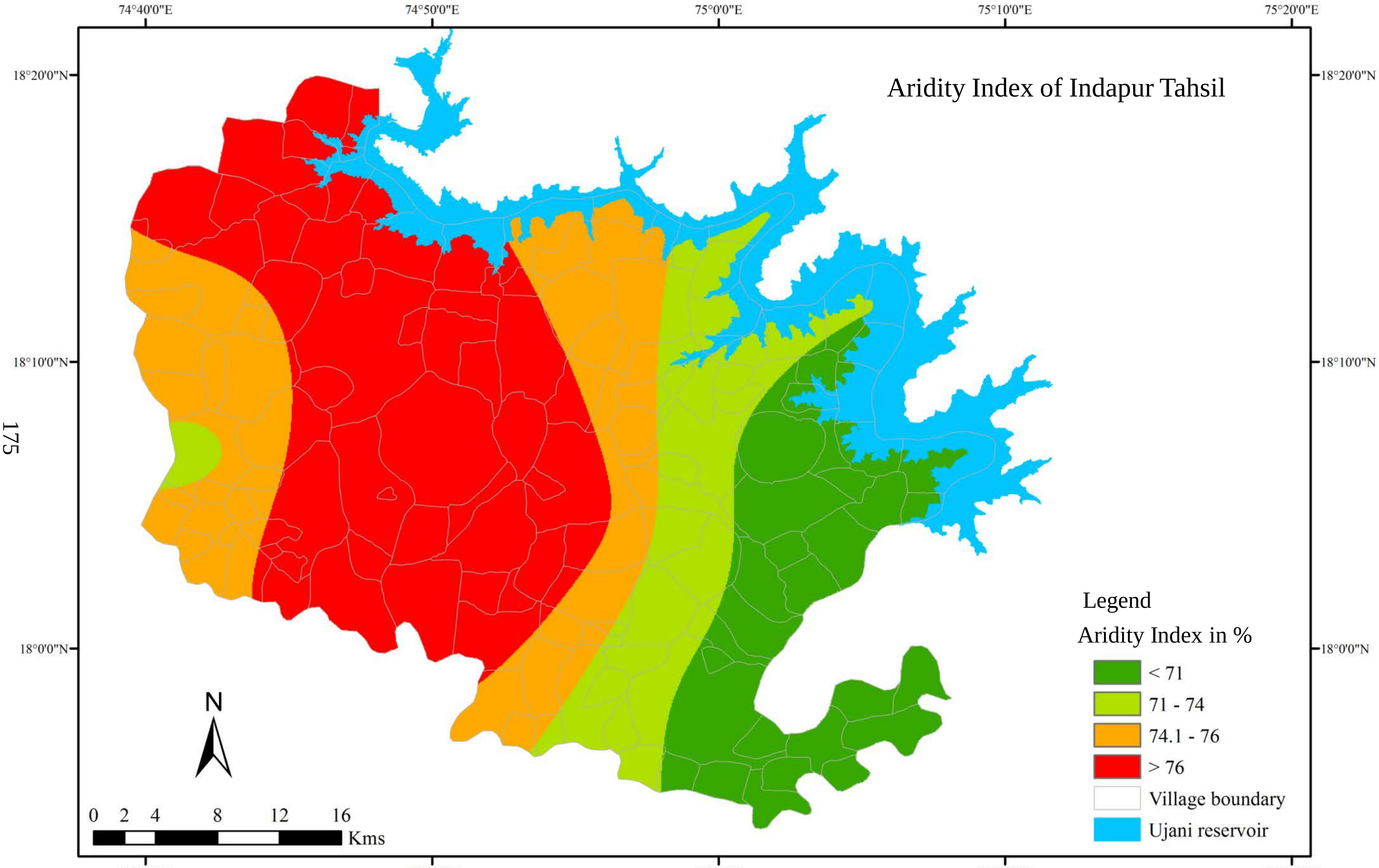
Source: http://www.csi.cgiar.org **Fig. 5.9**



Source: Author **Fig. 5.10**

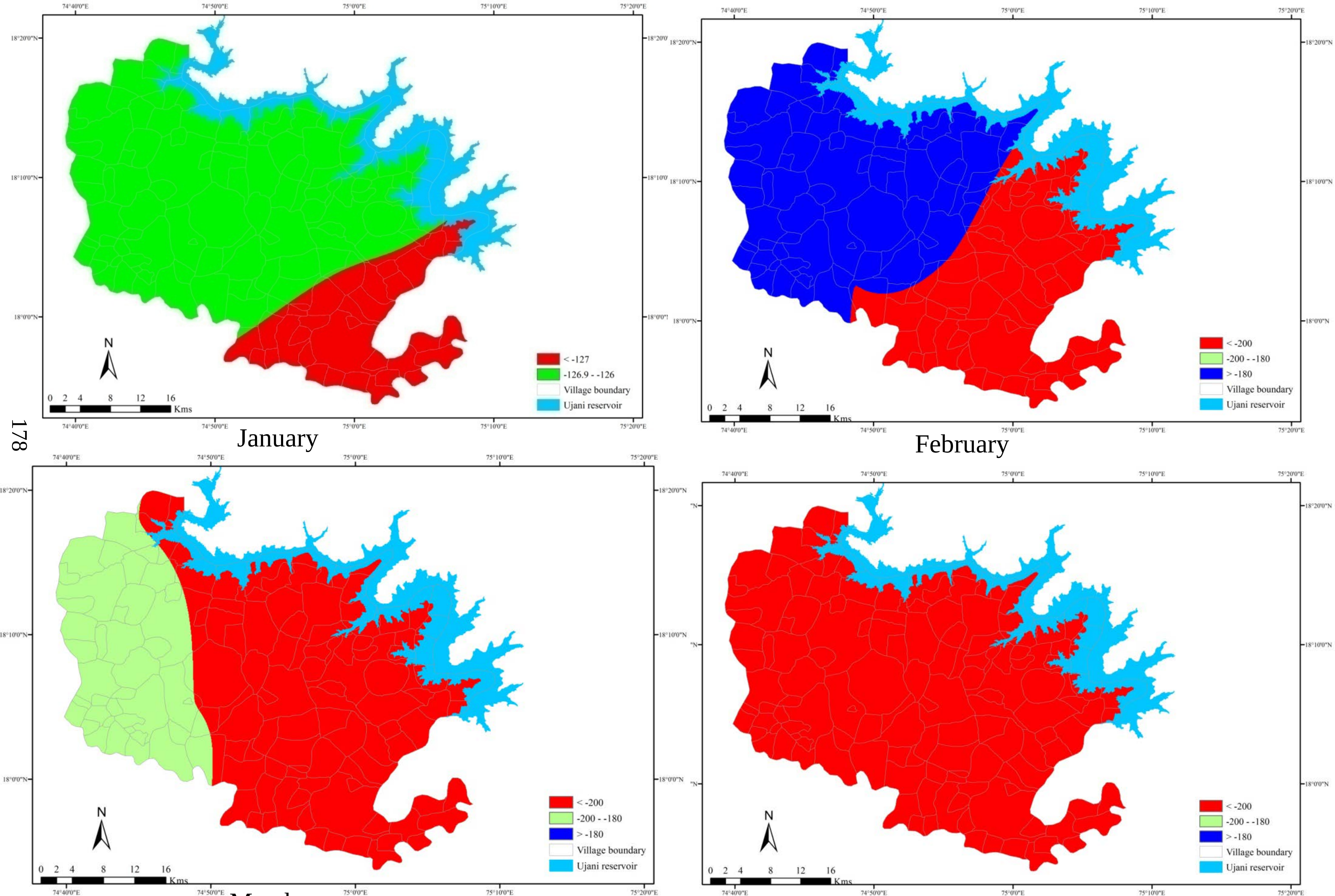


Source: Author **Fig. 5.11**



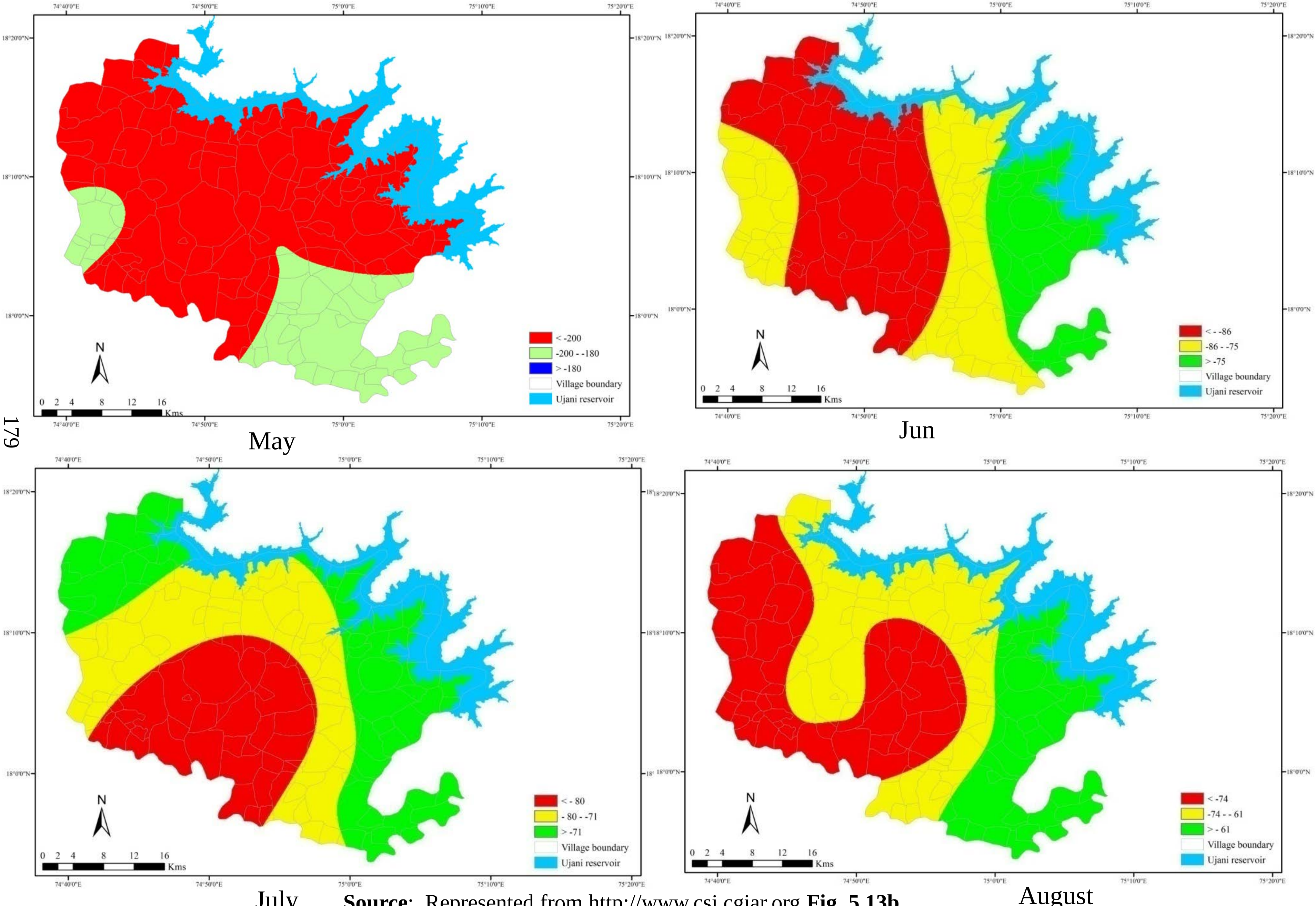
Source: Author **Fig. 5.12**

Month Wise Water Budget of Indapur Tahsil



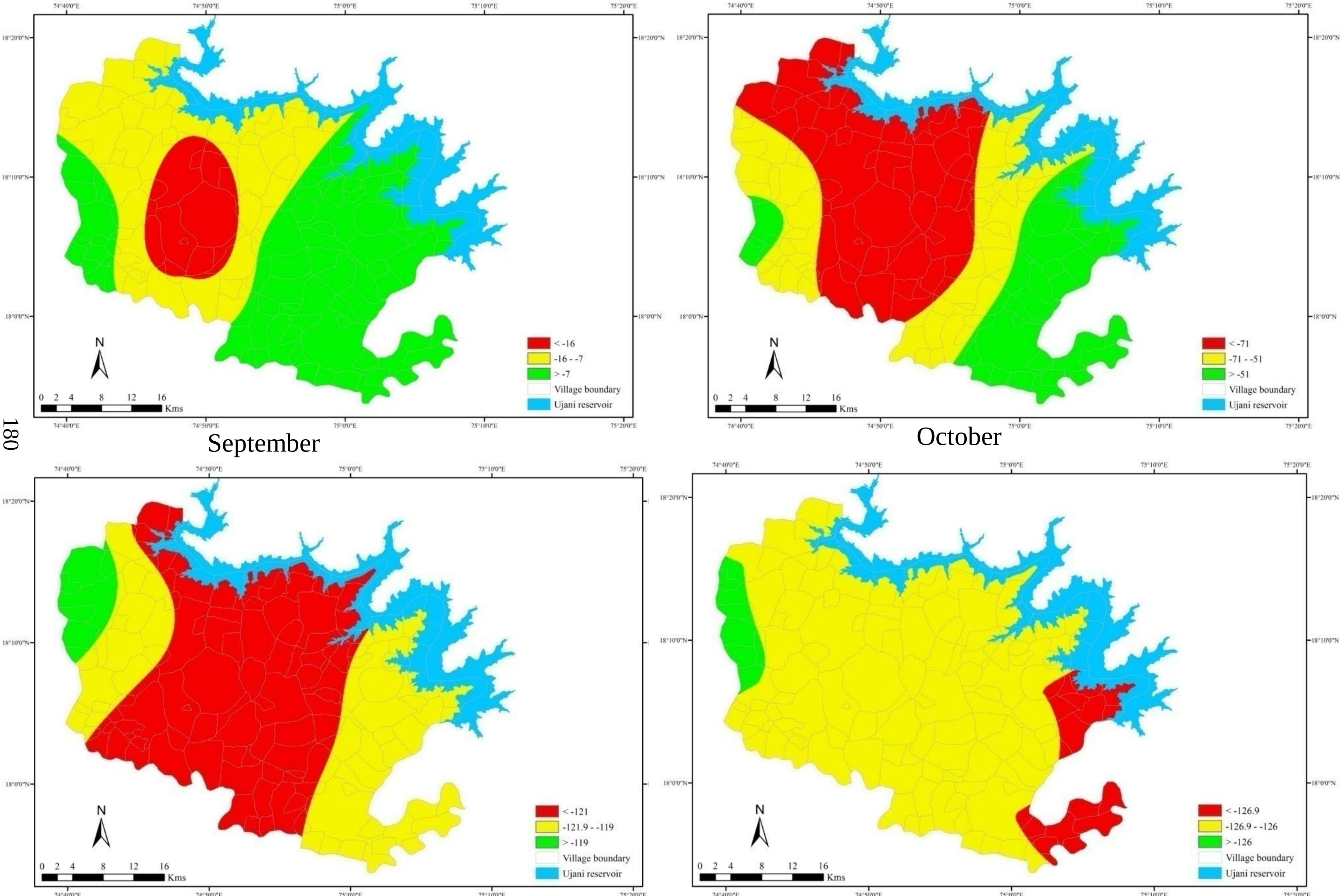
Source: Represented from http://www.csi.cgiar.org **Fig. 5.13a**

Month Wise Water Budget of Indapur Tahsil

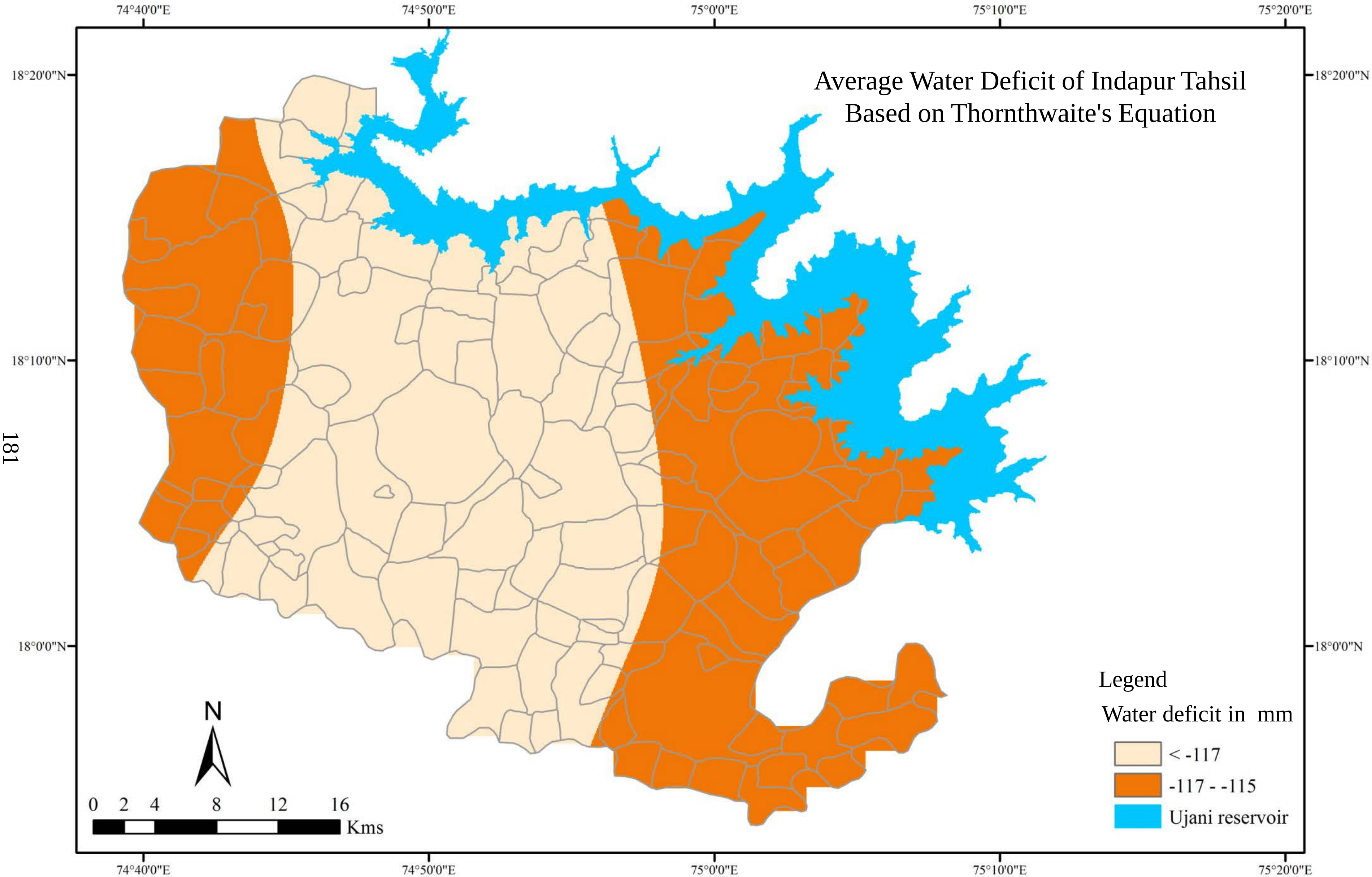


Source: Represented from http://www.csi.cgiar.org **Fig. 5.13b**

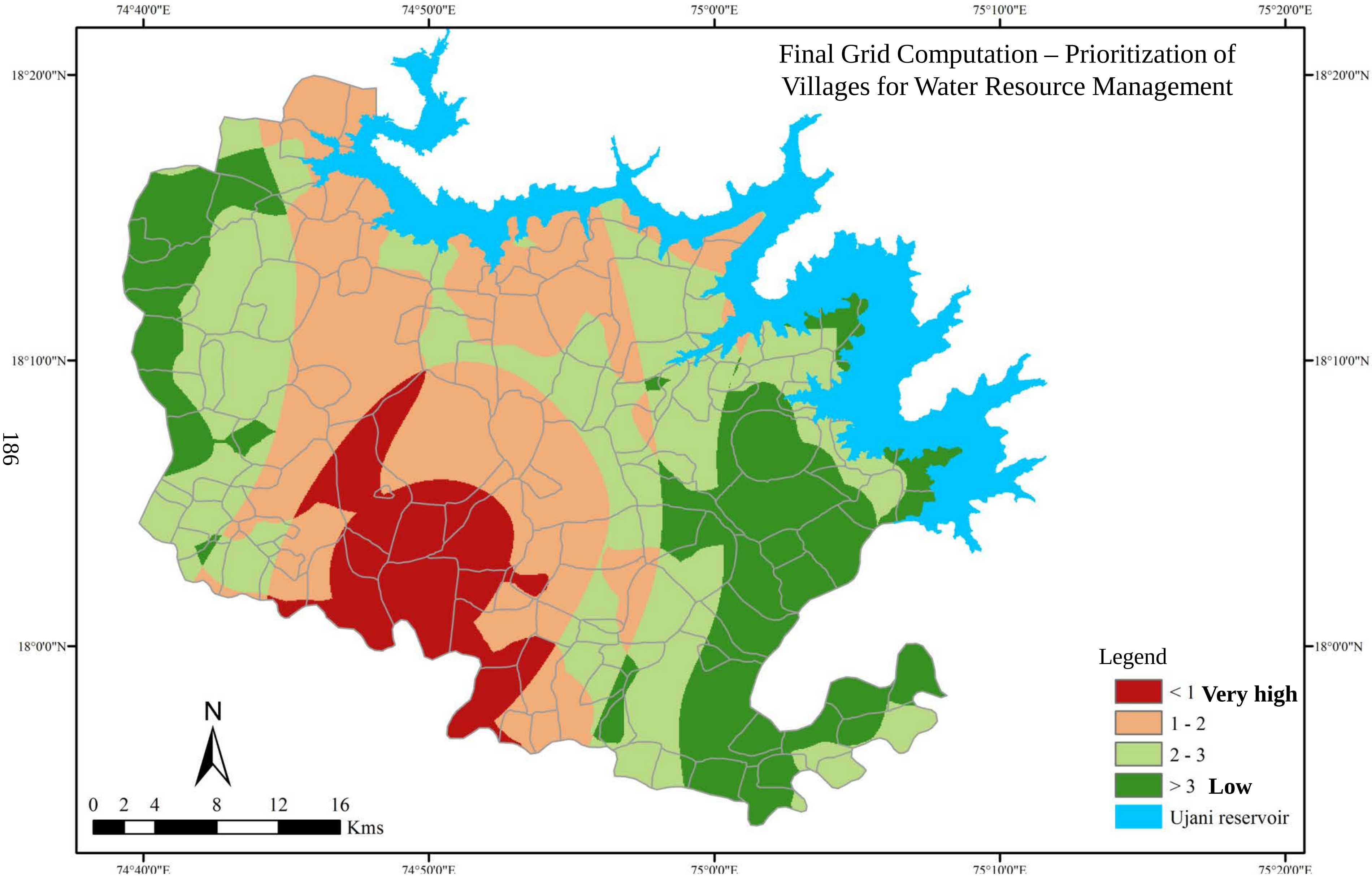
Month Wise Water Budget of Indapur Tahsil



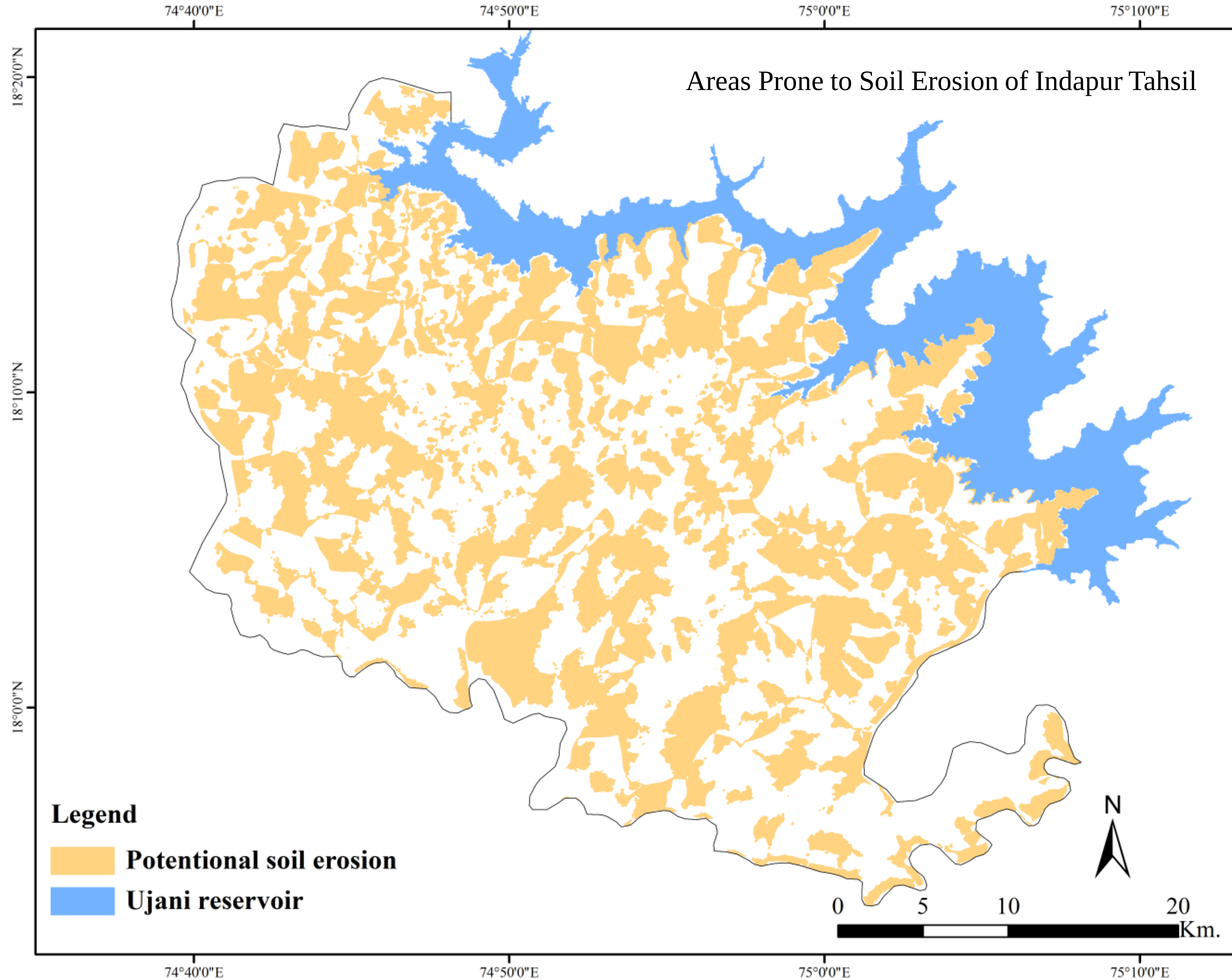
Source: Represented from http://www.csi.cgiar.org **Fig. 5.13c**



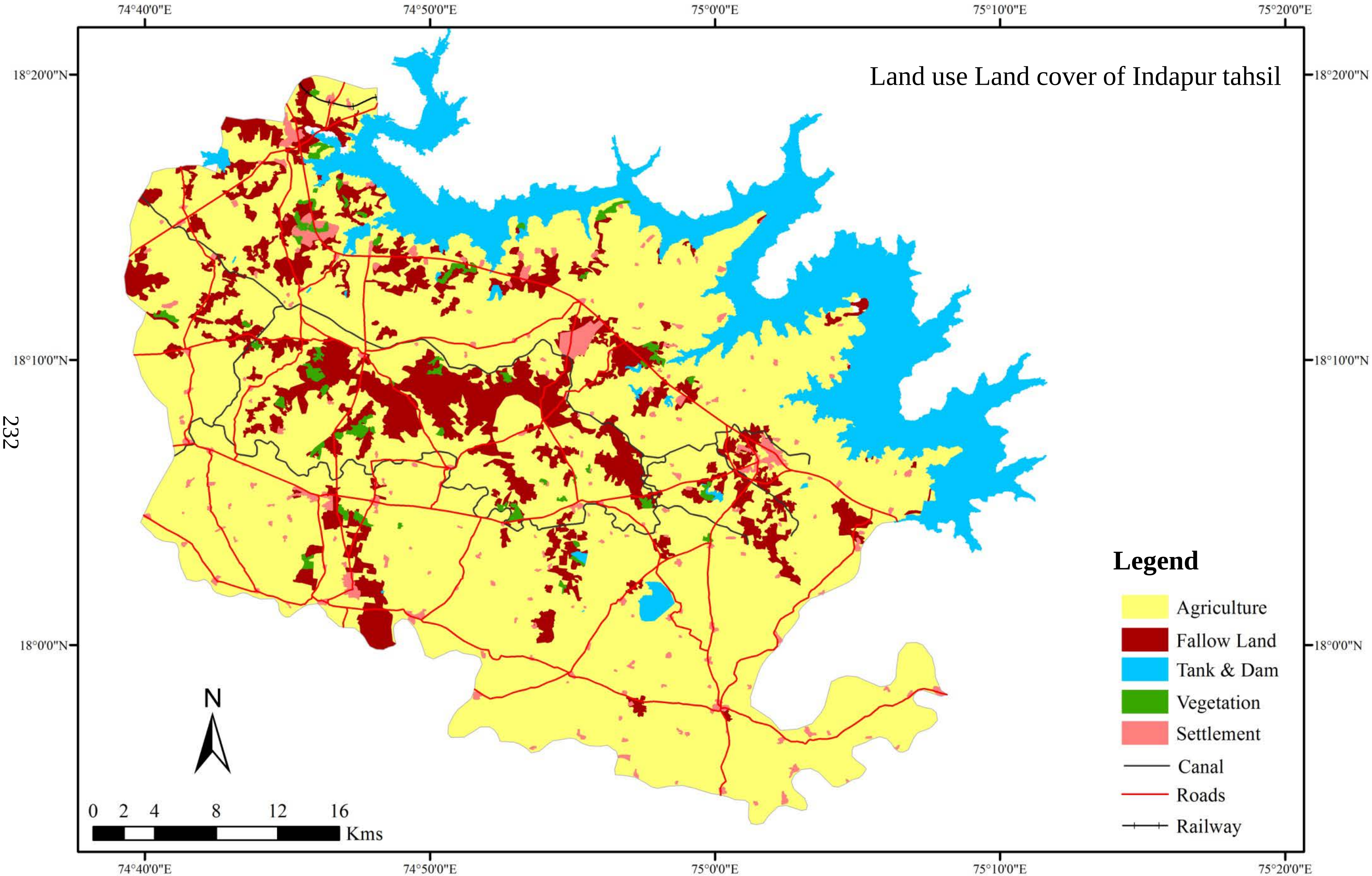
Source: Author **Fig. 5.14**



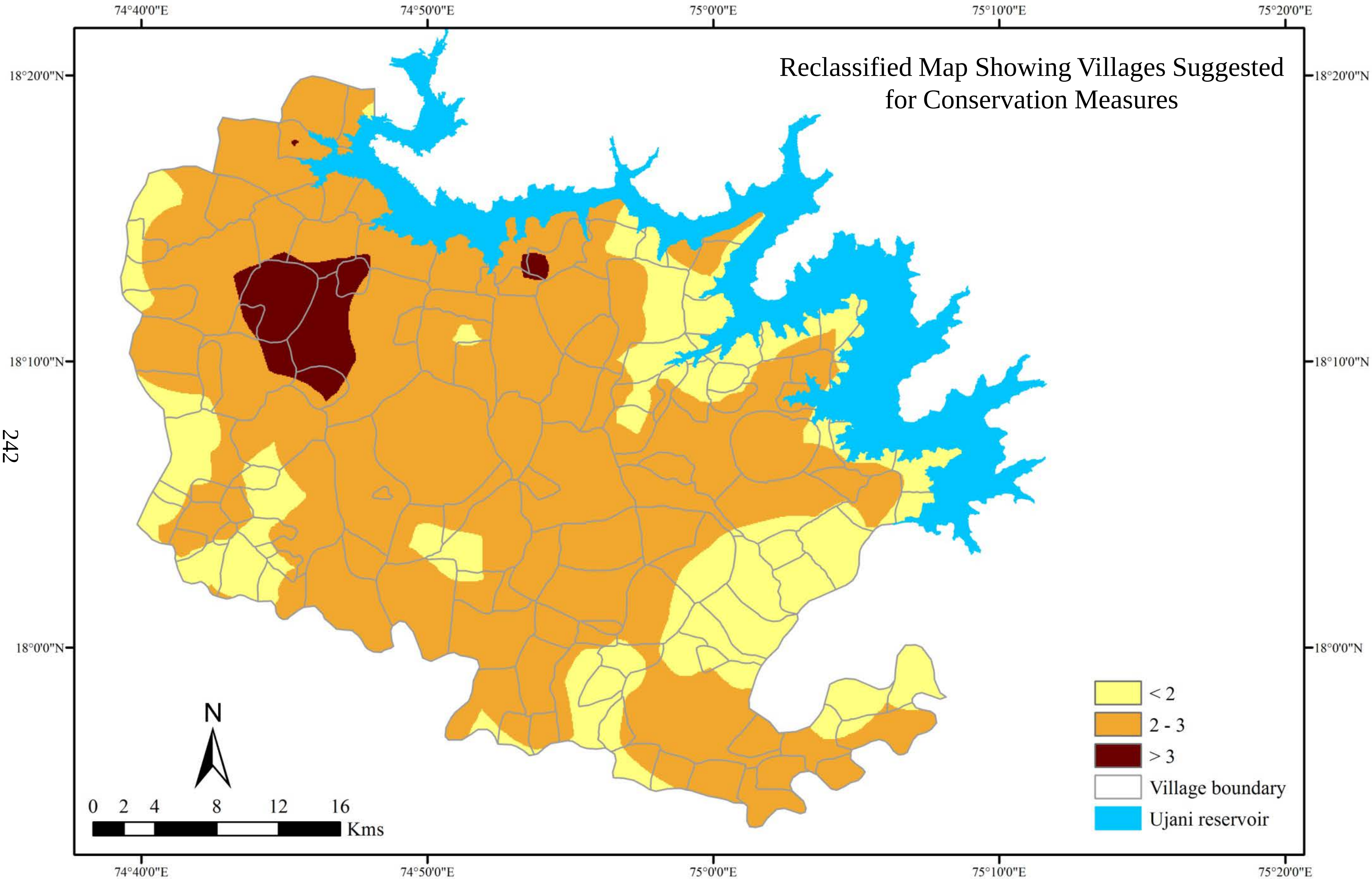
Source: Author **Fig. 5.15**



Source: Author **Fig. 6.3**



Source: Google image **Fig. 7.1**



Source: Author **Fig. 7.2**