

## **CHAPTER - 5**

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# **SOILS AND LAND USE OF THE KHAPRI WATERSHED**

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The texture of soil, the slope and the nature of land use/ land cover influence the amount of precipitation infiltrated in the ground (Valdiya, 2013). Therefore, it is necessary to study the soil characteristics as well as types of land use/land cover to understand the groundwater potential.

### **5.1 Soil**

Soil is defined as a natural part of the earth's surface, being characterized by layers parallel to the surface resulting from modification of the parent materials by physical, chemical and biological processes operating under varying conditions during varying period of time (Bushnell, 1945). The soils are studied by considering their physical as well as chemical characteristics. The physical characteristics of the soil include the observations related to grain size and porosity vis-à-vis soil texture. While, the chemical characteristics include observations about the mineral content, organic content and microbe-mediated (biological) phenomenon such as carbon and nitrogen cycles. From groundwater point of view both, physical and chemical characteristics are important because of their dominant influence on the infiltration capacity as well as groundwater quality.

Soil texture plays a significant role in occurrence and movement of groundwater (Ruidas et al., 2021). It affects the ability of water to infiltrate the soil and recharge the underlying groundwater systems. Soil texture affects the infiltration capacity, permeability, water holding capacity, groundwater recharge and quality (Thakur et al., 2013). Clayey soils, characterized by smaller particles and smaller pore spaces, typically have a low infiltration rate compared to sandy soils, which have large particles and larger pore spaces. In other words, the water can more easily enter the sandy soils, giving rise to faster groundwater recharge. In contrast, the clayey soils have a lower infiltration rate that can limit the groundwater recharge potential (Sophocleous, 1991). Clayey soils have lower permeability on account of their small constituent particles which tend to pack closely together, resulting in reduced interconnected pore spaces and thereby less water movement. On the other hand, the sandy soils possess higher permeability because of larger particle size and greater pore connectivity, allowing water to flow more freely through the soil. Water holding capacity of the soil is the amount of water that is retained within the soil after rainfall or irrigation (Tan et al., 2017). Clayey soils have a higher

water holding capacity compared to sandy soils due to the smaller particles that can hold more water in the smaller pore spaces. This water stored in the soil may contribute to the replenishment of groundwater over time through slow percolation (Tan et al., 2017). So far, groundwater quality is concerned, the fine-textured soils such as clayey soils, have a higher capacity to retain and filter out contaminants, preventing them from reaching to the aquifers. This natural filtering process in clayey soils aids in protecting the quality of groundwater by eliminating or decreasing the presence of geogenic/anthropogenic pollutants. Thus, it is necessary to develop appropriate understanding about the soil texture for the assessment of groundwater occurrence, recharge potential, and quality. It is useful in identifying areas with higher permeability and infiltration rates that are more likely to have groundwater occurrences. This knowledge is valuable for managing water resources, assessing groundwater availability, and planning sustainable use of groundwater for various purposes, such as drinking water supply and agriculture.

The chemical properties such as pH, organic matter content and cation exchange capacity, can affect the movement of pollutants in the groundwater and thereby influence the ultimate quality of groundwater (Badmus et al., 2014; Caliman et al., 2011). For example, soils having higher cation exchange capacity and organic matter proportion can adsorb and retain certain pollutants, reducing their relocation to groundwater and potentially improving groundwater quality (Adriano et al., 2002; Gaines & Gaines, 1994; Hashim et al., 2011). Soil chemical properties can also affect the groundwater quality by leaching the nutrients, such as nitrogen and phosphorus. The extensive use of chemical fertilizers can cause the nutrient-rich runoff to percolate down through the soil and reach groundwater (Withers & Lord, 2002). Salinity of soil refers to the presence of soluble salts in the soil which can also influence the groundwater quality. When soils having higher salt contents are used for irrigation, the salts present can leach into the groundwater over a period of time and thereby increase the total dissolved solids (TDS) in groundwater. High levels of TDS in groundwater can make it unfit for domestic and agricultural uses. Soil pH indicating acidity or alkalinity of the soil has an indirect effect on groundwater quality. Acidic soils can release metals and other pollutants into groundwater, if they come in contact with acidic rainwater (Pagotto et al., 2001; Verma & Dwivedi, 2013). Similarly, the alkaline soils can give rise to high concentrations of ions in groundwater that potentially influence its quality and suitability for the various purposes (Bhardwaj & Singh, 2011). Thus, the effects of soil chemical properties on

groundwater quality and quantity can vary depending on site conditions, land use practices, and hydrogeological factors.

## **5.2 Soil characteristics of the Dangs district**

The district Dangs forms the part of Northern Sahayadris Hills (NSH) in the Soil Resource Mapping of Gujarat, programme of National Bureau of Soil Survey and Land Use Planning. The zone is characterized by high elevations and ruggedness, while its western side gradually merges with the alluvial plains and in general forms a transitional zone between alluvial plains of Gujarat plains and rugged hilly terrain of Northern Shayadris Hills. The soils of Northern Shayadri Hills are residual and formed by disintegration of basaltic rock fragments. The high relief and steep slope of the area are responsible for transportation of the soils to foot hills and local valleys. These soils are identified and demarcated as soil series IX and X (Deota, 1992), which belongs to the family of Typic Ustochrepts, order Inceptisols. As per the Soil Resource Mapping of Gujarat programme of NBSS&LUP (Sharma et al. 2006) the Northern Shayadri Hills are composed of five soil series viz. 140-Ahwa series, 141-Baldha series, 142-Bedmal series, 143-Billimoda series and 144-Vadhvania series. Overall, the soil is shallow to very shallow and gravelly clay in nature. It has low water holding capacity and is well drained.

## **5.3 Soil characteristics of the Khapri watershed**

Three soil series viz. 140-Ahwa series, 142-Bedmal series and 144-Vadhvania series are present in the Khapri watershed. Among three soil series the major part of the Khapri watershed is covered by the 140-Ahwa soil series and small patches of 142-Bedmal series and 144-Vadhvania series occur (figure 5.1). The detailed description such as soil classification, type location, physiographic position, slope, erosion and relief characteristics, drainage and permeability, land-use and vegetation, geology and parent material, distribution and extent of each series is given in the subsections to follow.

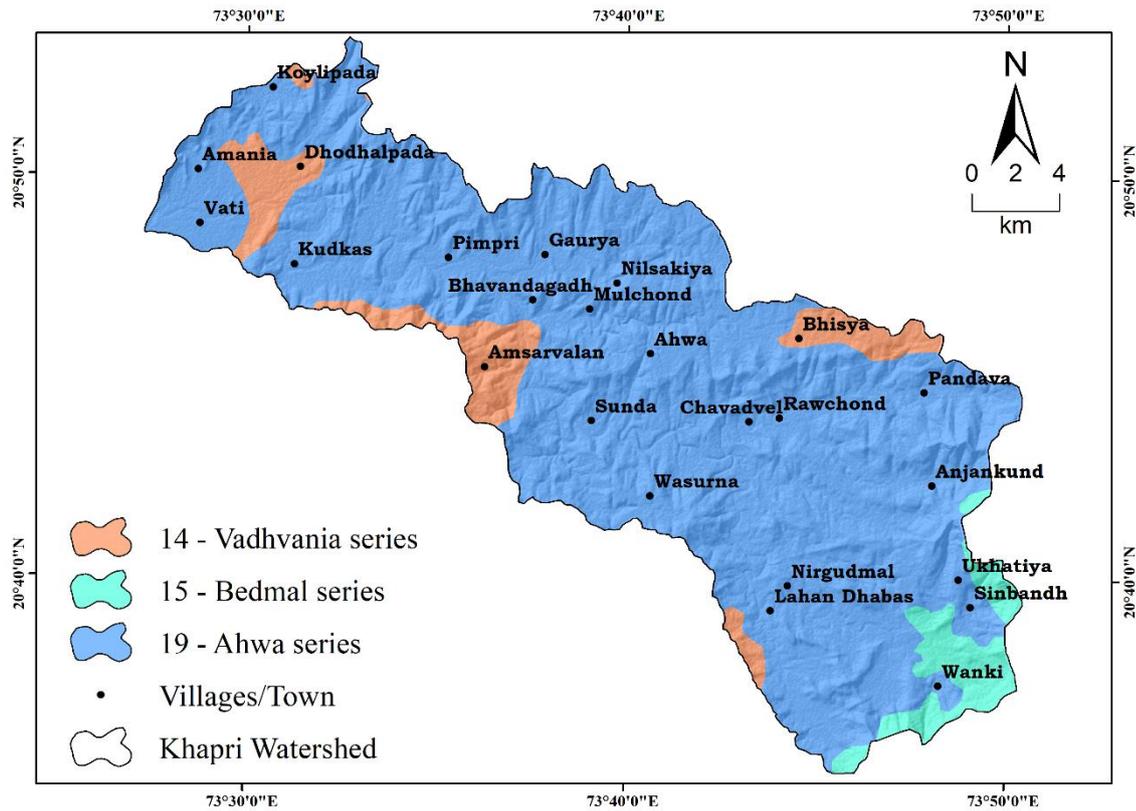


Figure 5.1 Soil map of the Khapri watershed representing 140-Ahwa, 142-Bedmal and 144-Vadhvania soil series.

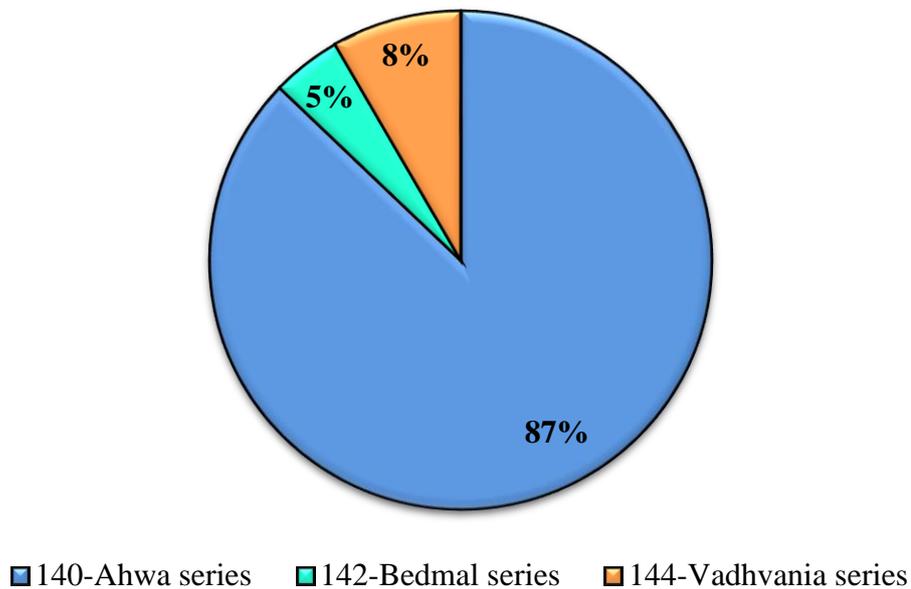


Figure 5.2 Pie diagram representing the percent aerial coverage of 140-Ahwa, 142-Bedmal and 144-Vadhvania soil series.

### **5.3.1. 140-Ahwa series**

The soil of 140-Ahwa series is classified as fine, hyperthermic and lithic haplustepts. The type section of the soil is located in village Nisanpada falia of Ahwa taluka, district Dangs (Sharma et al., 2006). Physiographically, it is positioned on very gently to gently sloping foothill slopes and exhibits moderate to severe erosional characteristics due to rainfall. The soil of this series is excessively drained with rapid permeability. The parent material of the soil is basalt and weathered basaltic material. The dominant land-use on the soil series is dense forest but a considerable proportion is under agriculture and is irrigated and cultivated mostly for Nagli, black gram and other hill millets. These soils are found to be distributed in villages/town such as Ahwa, Borkhet, Pandava, Ajankund, Bilbari, Kalamvihir, Nandenpada, Chaukiya, Nilsakia, Barari, Dhavalidahad, Garmal, Lahancharya, Motacharya, kahandolghodi, Wakarya, Ukhatiya, foot hills of Amsarvalan, Songir, Wasurna, Aherdi, Nilsana, Malin and others of Ahwa taluka of Dangs district covering about 87% area of the Khapri watershed (figure 5.2). Overall, the potential of the soil series is excellent for groundwater recharge and slightly unfavorable for groundwater accumulation.

### **5.3.2. 142-Bedmal series**

The soil of 142-Bedmal series is classified as loamy, mixed, hyperthermic and lithic haplustepts. The type section of the soil is located in village Dhumkhal, on Dhumkal to Dabhan cart track of Ahwa taluka, district Dangs (Sharma et al., 2006). Physiographically, it is positioned on very gently to gently sloping foothill slopes and exhibits slight to moderate erosion due to rainfall. The soil of the series is somewhat excessively drained with rapid permeability. The parent material of the soil is basalt and weathered basaltic material. The dominant land-use on the soil series is dense forest but a considerable proportion is under the agriculture and is irrigated and cultivated mostly for Nagli, Vari, Paddy, Kharsani, black gram, groundnut and other hill millets. These soils are found to be distributed on hill slope and foot hill slopes in the hilly part of the district such as near Saputara, Vanar and Wanki villages covering about 5% area of the Khapri watershed (figure 5.2). Overall, the potential of the soil series is excellent for groundwater recharge and slightly unfavorable from groundwater accumulation point of view as it shows less water holding capacity.

### 5.3.3. 144-Vadhvania series

The soil of 144-Vadhvania series is classified as clayey, smectitic, hyperthermic and lithic haplustepts. The type section of the soil is located in Khadak Vahodi falia of village Linga, Ahwa taluka, Dangs covering about 8% area of the Khapri watershed (Sharma et al., 2006) (figure 5.2). Physiographically, it is positioned on gently to moderate sloping lower foothill slopes and exhibits moderate to severe erosion due to rainfall. The soil is moderately well drained with moderately rapid permeability. The parent material of the soil is basalt and weathered basaltic material. The dominant land-use on the soil series is dense forest but several patches are under the agriculture and is irrigated and cultivated mostly for Nagli and Paddy. These soils are found to be distributed near villages such as Garmal, Linga, Jakhana, Vati, Amsarvalan. Overall, the potential of the soil series is less favorable for groundwater recharge and favorable from groundwater accumulation point of view.

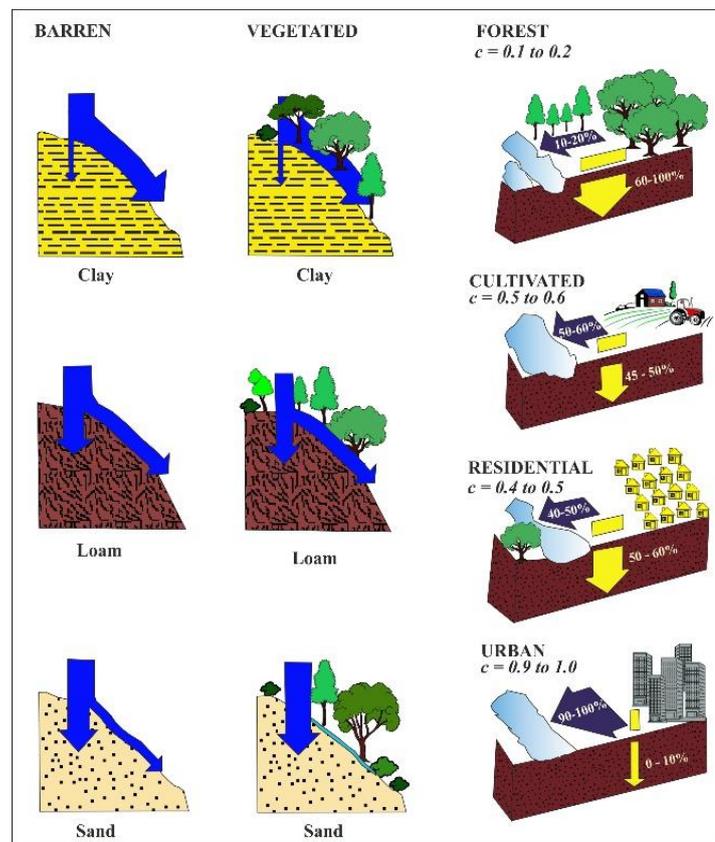
## 5.4 Land-use

The land is a significant finite resource as required by the humans and accounts for 29 % area of the globe (Nagamani and Ramchandran, 2003). It serves as a platform for humans to operate their daily activities such as agriculture, residence, water storage, industries etc. This interaction of human activities with the land resource has led to the rise of terminology “Land use”. Sauer (1919), initially defined the term land use as “the use to which the entire land surface is put”. Subsequently, Clawson and Stewart (1965), defined land use as a term referring to human activities directly related to the land. Burley, (1961) described land cover as the vegetation spread and artificial construction occupying the land surface. In simple words, land use describes the way of land utilization, while land cover specifies what covers the land. Concepts concerning land use/land cover activities are closely associated and, in many cases, have been used interchangeably (Deota, 1992, Fisher & Unwin, 2005, Piyoosh & Ghosh, 2022).

In the present times, the increasing population and their growing demands has led to considerable modifications in land use and have endangered its valuable resources such as soil and water (Ojima et al., 1994, Houet et al., 2010). Due to these reasons appropriate, latest, accurate and meaningful data on land use/land cover is essential to understand the land utilization and formulation of sustainable development plans related

to water resources (NRSC, 2010). Thus, information on existing land use pattern is essential to understand its influence on water infiltration.

Every land use parcel has a definite water resource foot-print. This fact is long recognized, but is hardly transmitted into the groundwater exploration, management and development practices through integrated policies (IFAD, 2010). It is important to link land-use and groundwater because definite land uses such as natural vegetation, forest, barren lands etc. will have different impacts on water infiltration (figure 5.3) (Valdiya, 2013).



**Figure 5.3** The amounts of runoff and infiltration depend, among other factors, on the land uses and the texture of soils and the nature and extent of vegetal cover on the soils. ( $c$ =coefficient of runoff). (From W. M. Marsh and J. Dozier, 1981, *Landscape, Addison-Wesley, Reading*, 637 p., Figs. 11.4 and 13.20.; Valdiya 2013).

According to Valdiya (2013) the precipitation on land with dense forest cover exhibits 60 to 100% of infiltration, while agricultural land is characterized by 45-50% infiltration. Similarly, for the mixed built-up land around 50 to 60 % precipitation infiltrates, while for development similar to urban areas exhibits hardly 10% infiltration.

The vegetation cover or canopy not only protects the soil from the pounding of raindrops but also provides organic matter (humus) for the binding of soil particles in open aggregates, and thus promotes the infiltration. The elimination of the vegetal cover, including that for agriculture, considerably reduces infiltration and proportionately increases runoff. Thus, the land use pattern significantly influences the groundwater recharge rates. Keeping this fact in mind, the land use and land cover aspect of Khapri watershed has been considered as an important geo-environmental parameter to demarcate the groundwater potential zones.

### **5.5 Datasets and methodology**

For the preparation of land use/land cover map of Khapri watershed, sentinel-2b satellite data (10 m) of November 2021 is procured from USGS earth explorer. False Colour Composite (FCC) of the individual satellite data tiles is prepared by combining Bands 8 (NIR), 4 (Red), 3 (Green). The mosaic of individual FCC satellite data tiles is generated using mosaic tool and is subsequently used to mask the extent of Khapri River watershed in Arc GIS 10.4. To identify and classify the image for different land uses at 1:50000 scale, manual (visual image interpretation) as well as automatic (Supervised classification with maximum likelihood classifier and random forest classification with random tree classifier) image classification techniques are employed. Before the classification of satellite data for different land use classes, reconnaissance fieldwork was carried out using GPS. The fieldwork was performed with an intention to obtain location point data for different land use/land cover classes as well as for the creation of the training samples and signature generation. In post satellite data classification stage, ground-truth verification is carried out to ensure the dependability as well as the improvement of the land use map.

In supervised classification the user can define training sample (pixels) from an image that is representative of specific class and then command the image processing software to utilize the training sample as reference for the identification and classification of all other pixels in the image. Training samples (also known as signatures) are selected on the basis of knowledge of the user. Moreover, the user also defines the threshold for grouping similar other pixels in the image. These thresholds are usually set based on the spectral and spatial characteristics of the region where training sample is taken, with minor increase or decrease of a certain brightness or strength of

reflection within the specific spectral bands. Moreover, the flexibility of categorizing the land uses lies with the user (Lillesand & Kiefer, 1979).

The random forest classification is a powerful technique for image classification that is resilient to overfitting and can even operate with segmented images as well as other ancillary raster datasets. For standard imagery, the tool accepts multi-band imagery having any bit depth, and it will perform the Random Trees classification on a pixel basis or segment, based on the input training samples. Random Trees is a collection of individual decision trees where each tree is created from various training samples and subsets of the training datasets. These are called decision trees because for every pixel that is classified, a number of decisions are made in rank order of importance similar to tree branches. This method is called random trees because the dataset is classified number of times on the basis of random sub-selection of training samples, resulting in number of decision trees. Each tree has a vote for making a final decision and aids to mitigate the overfitting. Random Trees is actually a form of supervised classification but driven by machine-learning classifier. It is based on building a multitude of decision trees, selecting random subsets of variables for each tree, and using the most frequent tree output as the overall classification.

In the present study, visual image interpretation of FCC sentinel 2b satellite data of November 2021 is carried out to identify and demarcate the various land-uses in the Khapri watershed. The various land use features are categorized as per the USGS Level - I land use and land cover classification (Anderson et al., 1976). On the basis of visual elements, the image interpretation key is prepared, followed by on screen digitisation of land use feature boundaries through mouse driven cursor in Arc GIS 10.4. The misalignment among shared boundaries of different polygons are rectified using 'align to shape' tool present under advance editing feature of editor tool bar. In addition to visual image interpretation the automatic image classification techniques such as supervised and random forest classification techniques are also employed to generate the land use land cover map of the study area. This exercise was initially carried out in November 2021 prior the fieldwork. The pre-fieldwork map was the outcome of combination of above three methods. The various land use and land cover categories of Khapri watershed were then verified in the field and the finalized map version is created after the necessary modifications. The image classification results obtained from the three

methods and the overall land use categories of Khapri watershed are presented and discussed in the following section.

### 5.6 Land-use/Land cover of the Khapri watershed

Seven categories of land use have been demarcated in the Khapri watershed viz., dense forest, scattered forest, agriculture, mixed built-up, built-up and barren land (figure 5.4). The aerial extent of these land use categories is represented in figure 5.5.

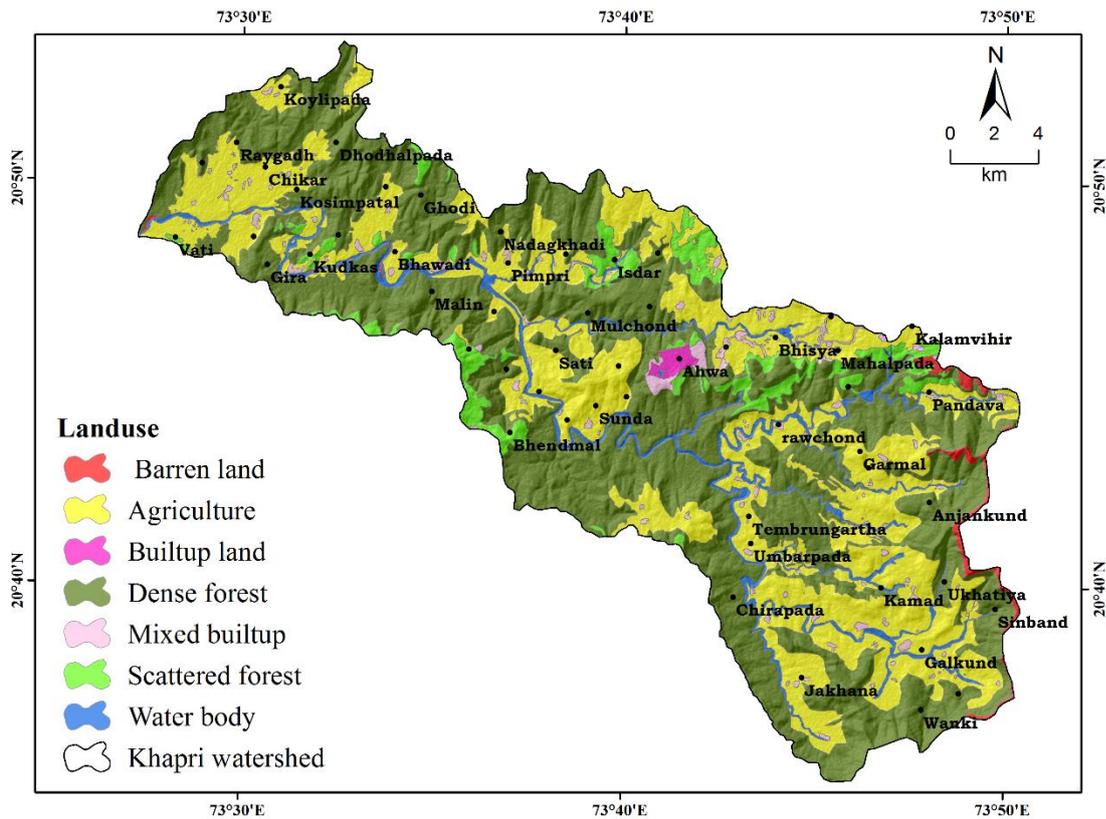


Figure 5.4 Map representing seven categories of land use in the Khapri watershed.

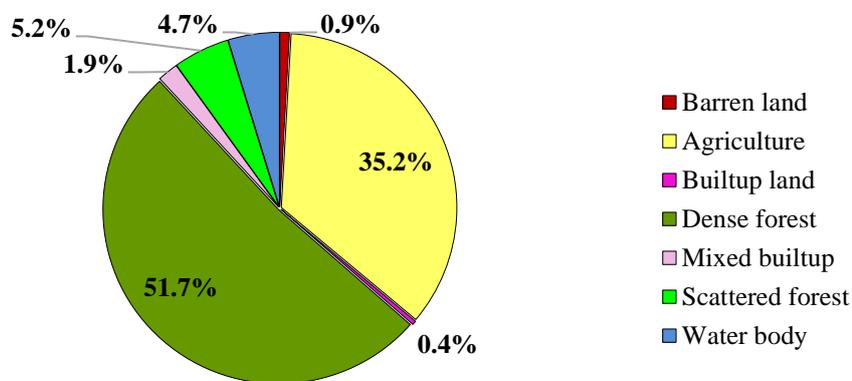


Figure 5.5 Pie chart representing aerial coverage (km<sup>2</sup>) of seven land use categories in the Khapri watershed.

### **5.6.1. Dense and scattered forest**

As per NRSC 2019, the term forest is used for the land having tree canopy cover and aerial extent greater than 10 percent and 0.5 hectare respectively. Moreover, they are stocked with trees capable of producing timber or other wood products and exert an influence on the climate or water regime. Depending upon the canopy density the forest land use of the Khapri watershed is mapped as dense forest (figure 5.6) and scattered forest (figure 5.7). The dense forests are identified on the satellite data by dark red tone, rough texture and irregular shape distributed throughout the watershed. Scattered forest exhibiting dark red to light grey colour, moderate to rough texture are found to be present at the fringes of the dense forest and mixed built-up areas. These areas show a good interference of biotic and abiotic elements. Amongst all the land use categories, the dense forest occupies 51.62 %, while scattered forest occupies only about 5.16 % of the total area of Khapri watershed (figure 5.5).

### **5.6.2. Agricultural land**

These are the lands primarily used for farming and for production of food, fibre, and other commercial and horticultural crops (NRSC, 2019). The agricultural land in the Khapri watershed consists of croplands, plantations, fallow lands and shifting cultivation areas. The croplands on the satellite data are seen as patches of bright red, red, green and grey colour, mottled texture, varying shape and size and are present in continuous to non-continuous pattern. They are widely distributed throughout the Khapri watershed and prominently appear in the irrigated areas. These include kharif, rabi and zaid crop lands along with areas under double or triple crops. Plantations are the areas under agricultural tree crops planted adopting agricultural management techniques. It mainly includes horticultural plantation like coconut, citrus fruits, orchards, fruits, vegetable gardens and agro-horticultural plantation. Fallow is an agricultural system with an alternation between the cropping period of several years and a fallow period. (Coppock & Ruthenberg, 1973). Shifting cultivation areas are the regions, which are taken up for cultivation but are temporarily allowed to rest, remain un-cropped for one or more seasons, but not less than a year. All these variants of agriculture land use are observed in the Khapri watershed, however for convenience the land use is identified as agriculture (figure 5.8). The total area occupied by the agriculture land use in Khapri watershed is 35.18 % (figure 5.5).



*Figure 5.6 Dense forest in the Khapri watershed.*



*Figure 5.7 Scattered forest in the Khapri watershed.*



**Figure 5.8 Agricultural land in the Khapri watershed.**

### **5.6.3. Mixed built-up land**

Built-up land is an area of human habitation developed on account of non-agricultural usage and that possesses a cover of buildings, communication and transport, utilities in association with water, vegetation and vacant lands. The built-up land includes two classes viz., rural and urban. On satellite data mixed built-up land use appears as patches of grey with minor red colour and mottled texture. In Khapri watershed the built-up land use is classified as mixed built-up (refers to land use similar to rural) and built-up (refers to land use similar to urban).

Mixed built-up land is the land used for human settlement with comparatively smaller than the urban settlements with primary activity of agriculture (NRSC, 2019). In Khapri watershed, these are the built-up areas, smaller in size, mainly associated with agriculture and allied sectors and non-commercial activities (figure 5.9). They can be seen in clusters or scattered. The mixed built-up occupies around 1.91 % area of the Khapri watershed (figure 5.5).

### **5.6.4. Built-up land**

The built-up land is non-linear built-up area covered by impervious structures adjacent to or connected by streets (figure 5.4). This cover exhibits the center of population such as in case of headquarters or major towns. On satellite data it appears as light blue to dark grey color with mottled texture. It consist of residential areas, recreational places, public/semi-public utilities, communications, commercial buildings, reclaimed areas, transportation, industrial areas and their dumps, and ash/cooling ponds.

For Khapri watershed such land use is only observed in case of Ahwa town, the headquarters of district Dangs. It occupies only 0.38 % of total area (figure 5.5).

#### 5.6.5. Water bodies

All submerged or water-saturated lands, natural or man-made, inland or coastal, permanent or temporary, static or dynamic, vegetated or non-vegetated, which necessarily have a land-water interface, are defined as waterbodies (NRSC, 2019). On satellite data it appears as blue to black color, fine texture, irregular to curvilinear shape and varying sizes. The water bodies in Khapri watershed include rivers, streams, reservoir and lakes (figure 5.4, 5.10). The land use occupies around 4.7 % of total area of the Khapri watershed (figure 5.5).



*Figure 5.9 Mixed built-up land use in the Khapri watershed.*



*Figure 5.10 Waterbodies a) tributary of the Khapri watershed and b) check dam in the Khapri watershed.*

### **5.6.6. Barren land**

Barren lands are defined as underutilized degraded lands which can be brought under vegetative cover with considerable efforts and which is deteriorating for lack of appropriate water and soil management or on account of natural causes. This land-use class usually comprises of salt affected areas, scrub lands which has shallow skeletal soils, sandy areas such as in deserts, coastal, riverine or inland areas, rann area and rocky/stony lands (NRSC, 2019). On satellite data the barren land exhibits light brown color and medium texture. In Khapri watershed, these are mostly characterized by the rocky exposures observed near escarpments and river beds (figure 5.4, 5.11). It occupies 0.95 % of total area of the Khapri watershed (figure 5.5).



**Figure 5.11 Barren land in the Khapri watershed.**

### **5.7 Epilogue**

Soil texture plays a significant role in occurrence and movement of groundwater. It affects the infiltration capacity, permeability, water holding capacity, groundwater recharge and quality. As per NBSS&LUP (Sharma et al., 2006), the Khapri watershed is composed of three soil series viz. 140-Ahwa series, 142-Bedmal series and 144-Vadhvania series. The soil of 140-Ahwa series is classified as fine, hyperthermic and lithic haplustepts, positioned on very gently to gently sloping foothill slopes. The soil of this series is excessively drained with rapid permeability. The soil of 142-Bedmal series is loamy, mixed, hyperthermic and lithic haplustepts, resting over very gently to gently sloping foothill slopes. The soil of this series is somewhat excessively drained with rapid permeability. The soil of 144-Vadhvania series is clayey, smectitic, hyperthermic and lithic haplustepts and located on gently to moderate sloping lower foothill slopes and

exhibits moderate to severe erosion due to rainfall. The soil is moderately well drained with moderately rapid permeability. Overall, the three soil series are shallow to very shallow, gravelly clay in nature with low water holding capacity and are well drained.

Different land uses such as natural vegetation, forest, barren lands have specific impacts on water infiltration. Khapri watershed is characterized by seven land uses viz., dense forest, scattered forest, agriculture, mixed built-up, built-up and barren land. The dense forest exhibits 60 to 100% infiltration of precipitation, while agricultural land is characterized by 45-50% infiltration. Similarly, the mixed built-up allow 50 to 60 % infiltration, while the urban areas exhibit hardly 10% infiltration. The maximum area (>50%) of Khapri watershed is covered by the dense forest followed by agriculture (35.18%), scattered forest (5.16%), water body (4.7%), mixed built-up (1.91%), barren land (0.95%) and built-up land (0.38%). The highest aerial coverage by dense forest and agriculture land use (>85%) together indicate the land use is favouring the good water infiltration in major part of the Khapri watershed.