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‘Water Management Plan’

For central semi-arid region Maharashtra

Design Thesis

Submitted
in the partial fulfillment of the requirements for the award of the degree of

MASTER OF LANDSCAPE ARCHITECTURE

By

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Under the Guidance of
Thesis committee

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Declaration

I **Sonu Bothe**, Scholar No.**2014MLA004**, hereby declare that the thesis entitled 'Water management plan for central semi-arid region of Maharashtra' submitted by me in partial fulfillment for the award of Master Of Landscape Architecture , in School of Planning and Architecture Bhopal, India, is a record of bonafide work carried out by me. The matter embodied in this thesis has not been submitted to any other University or Institute for the award of any degree or diploma.

24/05/2016 **Sonu Bothe**

Certificate

This is to certify that the declaration of **Sonu Bothe** is true to the best of my knowledge and that the student has worked for one semester in preparing this thesis.

RECOMMENDED

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The completion of this thesis had been a task for me but with the presence and kind heartedness of these people around me it has reached its finish line.

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-Sonu Bothe

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ABSTRACT :

“Water, energy and food are freely available for all of kind, if we don´t follow the laws of capital but the logic of nature.”

- Dieter Duhm

India being an agrarian country highly depends upon the water availability from agriculture to any other life sustaining activity. The water which we majorly draw from south west monsoon in the months of June to September varies throughout the country .With the rapid change in global climate the rate of rainfall has also become an issue as some parts of the country are flooded with water and somewhere else it is drought for consecutive years. Central region of the state of Maharashtra is one such case which has a status of water scarcity and drought prone area over the years. Though the region is surrounded by rich western ghats on its western edge which receives an average rainfall of 1200mm ,the central region of state receives a scanty rainfall of 300 to 400mm annually. The one reason being the geography of the region as it lies on the leeward side of western ghats but the other reasons are human interfered activities such as over exploitation through bore wells, pumps, agriculture, over grazing, deforestation, industries and wrong cultivation methods . The recent times have seen the region being declared as drought prone area several times in last two decades. This has led to the governments and private NGOs in taking actions against the problem as it is also affecting the economy adversely. The report by CGWB, Nagpur has termed the over exploitation of water as ‘’water mining’’ which needs to be addressed immediately. The positive rays of hopes were seen when some village communities show the desirable changes in the landscape. Few examples such as Hiware bazar, Ralegan siddhi, Pirewadi ,Purushwadi etc emerged out of the problem with simple and sustainable water solutions for the entire community. Thus as a landscape architect my effort was to work upon this problem and search for more sustainable and planned solutions based upon my field of knowledge and to cater the solutions to the affected community.

The proposal site was one similar example which could be replicated anywhere in the similar geographical and climatic conditions. Located in the district of Ahmednagar ,the site taken for study was a macro watershed with several micro watersheds into it. Efforts were made to understand the taken landscape with its

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issues and suitable solution on planning level were made. Three examples of micro watershed were taken and studied for runoff calculations before and after the proposal condition.

Conclusion drawn out is that the simple and economical solutions can easily tackle the large problem of water crisis on the surface and ground level. Another major aspect of the project was the participatory governance. People of local village need to take voluntary participation in such projects as they are the first one to get the benefits. A mass awareness with demonstrating sites can be helpful for this purpose.

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CHAPTER 1:

INTRODUCTION AND BACKGORUND

1 INTRODUCTION AND BACKGORUND

1.1 Introduction:

The state of Maharashtra is the third largest state by area in India. The geography of state can simply be divided into 3 major physiographic regions-

I) the coastal belt or Konkan

Ii) the sahyadri or Western ghats

Iii) the plateau or Deccan plateau

The coastal strip is vast stretch of 720 km consisting of undulating low lands below 200m.The western ghats are running almost parallel to the sea coast. The average height of Sahyadris is 1200m.The slopes of the Sahyadris are gently descending towards the east and south east. The plateau or the Deccan plateau region, covers the largest area of the region i.e. About 90%.Its elevation ranges from 300 to 600 m. The east –west length of plateau is 750km .Within it there are several plateaux nestled between the hill ranges like the

Ahmednagar plateau, Saswad plateau, Aundh plateau, Buldhana plateau, Malegaon plateau and Toranmal plateau. The region is mostly Semi-arid as it lies on the leeward side of the plateau. It is majorly covered by thorn scrub forest with small regions of deciduous broadleaf forest. Tapi, Godavari, Bhima, Krishna are the main rivers of the region.

1.1.1 Problems faced with the water

Groundwater is one amongst the state's most important natural resources. It provides drinking water to rural as well as urban community, supports irrigation& industry, sustains the flow of streams & rivers and maintains wetland ecosystem. Because of variations in their basic characteristics; physiography and variability in the rainfall, there are limitations on the availability of groundwater in the region. Over extraction of ground water over years without any compensatory replenishment is affecting large tracts of land adversely.

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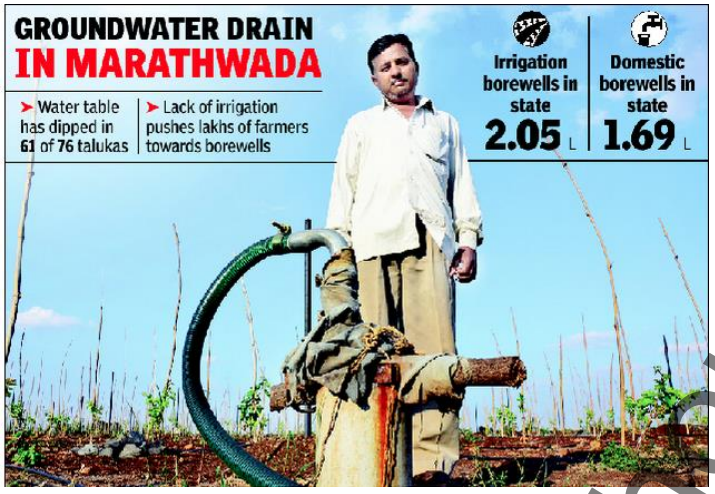

Figure 1-declining ground water table

"The non-replenishment of the shallow aquifers and depletion of the deeper aquifers on account of unregulated sinking of deep bore wells / tube wells , almost amounting to "**water-mining**" unmindful of the adverse ecological effects is one of the contributory causes for recurring droughts"

"The present availability and requirement of water in the state of Maharashtra is extremely uneven, both spatially and temporally and so will be case in the future. Rapid population growth and intensive anthropogenic activities have put both surface and groundwater under heavy stress, and significantly fresh water is becoming scarce and dearer in many areas"

1.1.2 Why a water management plan ?

The constant threat to surface and ground water over the past few decades means an alarming situation when water management needs to be done at every level.

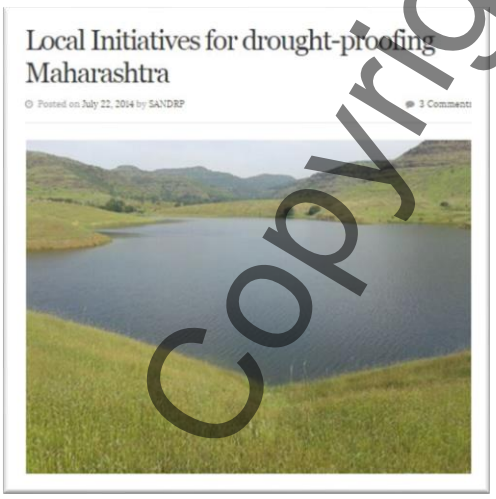

Figure 2- news article highlighting the local efforts (source –SANDRP)

A balance situation can only be achieved through a proper management plan for all required purpose of water utilisation.

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Digging deeper into water scarcity after watershed development

Posted on May 19, 2015 by SANDRP — 8 Comments

Above: Watershed measures in Maharashtra Photo: WOTR ~ Guest Post by Zareen Pervez Bharucha Farmer after farmer had the same story: fields were parched, wells were empty, it was painful to see the land crack up and peel away like the...

Drought and Marathwada: An Oft repeated Tragedy

Posted on August 18, 2015 by SANDRP — Leave a Comment

Marathwada, a region known more for its routine and severe droughts in the recent years, now showing the highest rainfall deficit in the country at 48%[1]. Marathwada (which coincides with Aurangabad Division of Maharashtra) consists of 8 districts in the heart...

Figure 3- Local watershed development (source- SANDRP)

1.1.3 The ray of hope

The state has had a number of remarkable stories like **Ralegan siddhi**, **Hiware bazaar**, soppecom's work on water users associations in **Waghad** and **Palkhed**, work of **paani panchayat**, a farm, etc.

In addition to a number of centrally funded and state funded watershed programs like drought **prone area program** (DPAP), **integrated wasteland development program** (IWDP).

These examples have shown the greater **possibility of restoring** the regions natural water resource through successful techniques of water shed development and community collaboration.

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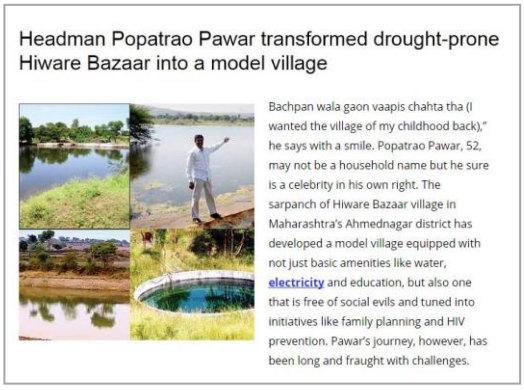

Headman Popatrao Pawar transformed drought-prone Hiware Bazaar into a model village

Bachpan wala gaon vaapis chahta tha (I wanted the village of my childhood back)," he says with a smile. Popatrao Pawar, 52, may not be a household name but he sure is a celebrity in his own right. The sarpanch of Hiware Bazaar village in Maharashtra's Ahmednagar district has developed a model village equipped with not just basic amenities like water, electricity and education, but also one that is free of social evils and tuned into initiatives like family planning and HIV prevention. Pawar's journey, however, has been long and fraught with challenges.

Figure 4- An article on Hiware bazar (source- SANDRP)

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1.2 Thesis formulation

1.2.1 Aim:

To prepare sustainable water management plan for the central semi-arid region of Maharashtra.

1.2.2 Objective:

1. To study and understand the physiography of region.
2. To study the hydrology and geology of the region.
3. To study the traditional water management systems prevailing in the region.
4. To trace the timeline of region's drought in history and present time.
5. To study the causes of water scarcity in the region
6. Delineation of potential site for design intervention.

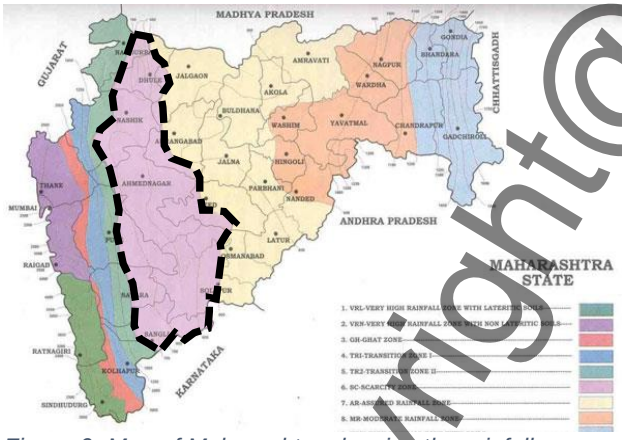

Figure 6- Map of Maharashtra showing the rainfall regions.

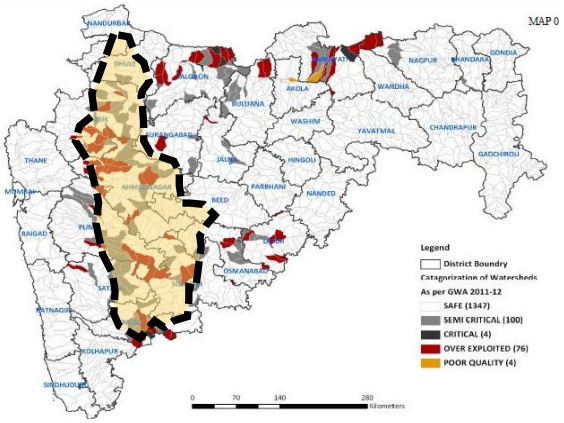

Figure 5- Map of Maharashtra depicting the exploited areas of ground water table.

1.3 Tracing the timeline of drought

1396-1408:

This famine was known as the **Destroyer** or **Durga Devi** famine. The twelve years ending 1408 were said to have passed without rain, and grain was sold at one sher the rupee. The country between the **Godavari** and the **Krishna** yielded very little revenue and was so unsafe that the people who returned were driven from their villages. Dadu Narsu and a Turkish eunuch of the Bidar court were appointed to

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arrange the country and bring back the people. They fixed new limits of villages by amalgamating two or three villages into one. Lands were given to all who would till them. For the first year no rent was asked and for the second the rent was limited to a horse-bag of grain white earth and made into a jelly. It was after the **treaty of Bassein** (31st December 1802) that things came to normal.

1460

In 1460, a failure of grain was said to have been followed by famine over the whole of southern India. It was known as **Damaji-pant's famine**. Damajipant was the keeper of a large Government grain store at Mangalvedha, twelve miles south of Pandharpur in Sholapur district. He distributed the grain to persons who were starving, but was saved from punishment by the god Vithoba whom he worshipped. It was stated that the god Vithoba went to the court at Bidar and paid the value of the grain.

1520

In 1520, the Deccan was so unsettled that no crops were grown and there was a famine.

1629-30

In 1629-30, a failure of rains was followed by famine and pestilence

1802

In 1802, the district passed through a time of greater misery than it had suffered since 1408 mainly because of war between **Yeshvantrao Holkar** and the ***Peshwa*** and **Shinde**. The rainfall of 1802 was plentiful and the prospects were on the whole good in the district. However, two of Holkar's officers Fatesing Mane and Muhammad Khan Pathan **destroyed** all the villages on both sides of the Godavari. Bands of Pendharis were also spread all over the country plundering and wasting. The ripening crops were cut as fodder, the late or cold-weather crops either could not be sown or were destroyed, and the grain stores were also plundered. Even at one *sher* the rupee, no grain was available. Wild vegetables were eaten boiled with a pinch of rotten wheat flour. Young tamarind leaves were mixed with

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white earth and made into a jelly. It was after the **treaty of Bassein** (31st December 1802) that things came to normal.

Figure 8- The dried crop due to failure of rain (source-Google)

Figure 7- A dried orchad of pomegranate (source- Google)

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1803

On the top of this distress came an entire **failure of the late (September-October) rains of 1803.** In the Deccan the crops everywhere failed. In Ahmadnagar alone the deaths were estimated at 5,000 to 6,000. About 5,000 people were fed daily at Ahmadnagar.

1824

In 1824, the **early rains failed** and there was much distress for about four months, probably from May to August. The rupee price of millet rose to 8 shers. In September captain Pottinger sanctioned an expenditure of Rs. 200 on ceremonies for rain, to soothe the people all of whom were in the greatest alarm. A large number of people went to the Nizam's country where the rains were favourable. They did not come back. As such the fields in the district remained waste and large remissions had to be granted.

1832-33

In 1832-33, a partial and in some places an almost **complete failure of rains** caused much distress. The want of grass and fodder drove away the shepherds and stopped the carrying trade.

1845-46

In 1845-46, a **failure of rains** raised the rupee price of millet to 10 shers. The distress lasted for six months.

1862

In 1862, the **failure of the early rains** was followed by great scarcity. Numerous **public works** were sanctioned to employ the destitute. Among them were the construction of roads, from Ahmadnagar to Karmala, Ahmadnagar to the Balaghat and the **improving of the roads** from Ahmadnagar to Sirur, Jeur to Karmala in Sholapur district. To relieve the distress among the lower grades of Government servants grain compensation according to a fixed scale was granted to all Government servants whose pay was less than Rs. 200 a month.`

1876-77

In 1876, **untimely rainfall** of only 10.65 inches caused a **failure of crops** and distress amounting to famine over about **two-third**s of the district. In addition to the failure of the early harvest September and October passed with only a few showers. Except in watered lands no cold-weather crops were sown. A large section of the labouring class fell into distress. However, in February 1877, the large supplies of grain and irrigation relieved much of the pressure. The following hot months again brought a return of distress with a further rise in prices, and afterwards the failure of the early rains caused much anxiety and suffering, which were gradually removed by a timely and plentiful rainfall in September and October, 1877 and at the end of November, the demand for special Government help had ceased.

1972

History has it that in the early 1970s, after several years of good monsoons and a good crop, India considered exporting food and being self-sufficient. Earlier in 1963, the then government of Maharashtra had also declared that the agricultural situation in the state was constantly being watched. It was also said that any relief measures will be taken as soon as any scarcity was detected However, the government was unable to foresee the drought in 1972.In the drought of 1972, the relief measures included employment, tree plantation, conservation of soil, excavation of canals, and building artificial water bodies.

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2012-2013

The 2012-2013 drought in Maharashtra came about after the region received **lower rainfall** during the monsoon season June to September 2012. It is considered as the region's worst drought in 40 years. The worst-hit areas in Maharashtra are Solapur, Ahmednagar, Sangli, Pune, Satara, Beed and Nashik. Resident of Latur, Osmanabad, Nanded, Aurangabad, Jalna, Jalgaon and Dhule districts are also affected by this famine.

Figure 9- Water being transported through train to Latur

Figure 10 - A dried river bed

Figure 11- A well in the region during the peak summers. (source- Google)

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CHAPTER 2

CASE STUDY

2 CASE STUDY

2.1 Hiware Bazar

2.1.1 Background

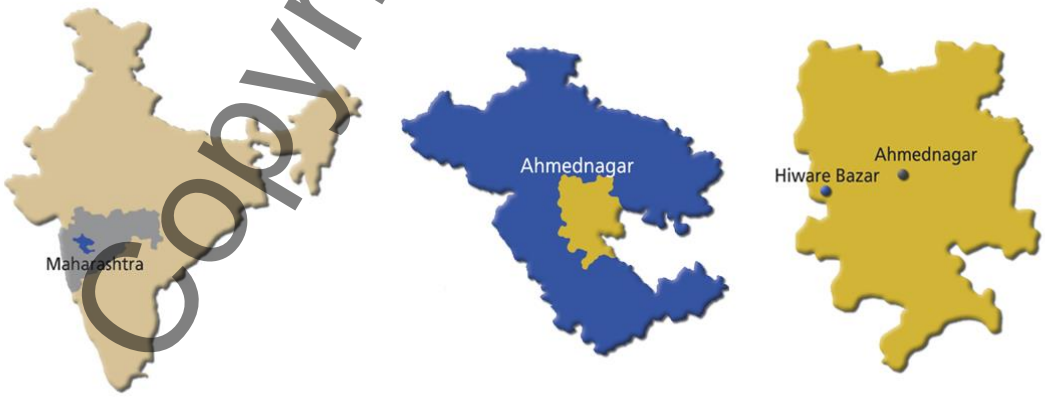
Hiware Bazar lies across **977 hectares** (ha) at the foothills of the *Sahyadris*. The village receives only **300-400 millimeters (mm**) of rainfall a year.

Over time, with steady degradation of their forest land, villagers found themselves with little water available post the monsoon. Without water to irrigate their fields, villagers began to migrate to cities. Those that remained **cut down remaining forest** land for firewood and sustenance. Preparation and **sale of illicit alcohol** became a source of income, and alcoholism and crime were rife.

Over **90 percent of families** lived below the poverty line (BPL). The village lacked medical facilities and due to its bad reputation, teachers were unwilling to teach at the local school. As a result, its **literacy rate at 30%** was well below the national average (45% all-India rural literacy in 1991).

Due to watershed development measures, the **groundwater table rose** and **irrigated area increased** .Farmers, previously able to cultivate only in the *kharif* season and grow **bajra in *rabi***, could now grow in more seasons and switch from the traditional jowar and bajra to cash crops such as **onion, potato, tomato and horticulture**. As area under cultivation and cropping intensity increased and the cropping pattern changed, incomes rose sharply

2.1.2 Demography



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Gram panchayat Hiware Bazar is located in Ahmednagar district of Maharashtra. Village population – 1250(226 families)*As per 1992 Survey, About 168 families were below B.P.L. Present day out of 226 families only 3 families living B.P.L.Per capita income of the village is increased from Rs. 824 to Rs. 24,000. The village Hiware Bazar implemented the Ideal Village Project of Govt. of Maharashtra with the help of peoples of Hiware Bazar and NGO namely “Yashawant Krishi Gram and Watershed Development organization” in such a way that, Hiware Bazar was declared as Adarsh Gaon or Ideal Village

The village which was once severely drought affected has significantly emerged as an ideal example for water management within the same geographic region. With the effective watershed management through construction of a number of bandharas, percolation tank, farm ponds, cct etc. and also by adopting the unconventional measure like bore blast technique the additional water is stored in groundwater has led to comprehensive development of the village.

2.1.3 Regional setting :

The district of Ahmadnagar lying between 18°2' and 19°9' north latitudes and 73°9' and 75°5' east longitudes is situated partly in the upper Godavari basin and partly in the Bhima basin, the interfluve in between forming the extensive Ahmadnagar plateau. The district includes the Sahyadri and its three eastward offshoots,

i) The Kalsubai-Adala range in the north,

ii) The Baleshwar range in the middle and

iii) The Harishchandragad range in the south;

iv) The vast Ahmadnagar plateau. The river basins of the Godavari and Bhima on either side of the plateau.

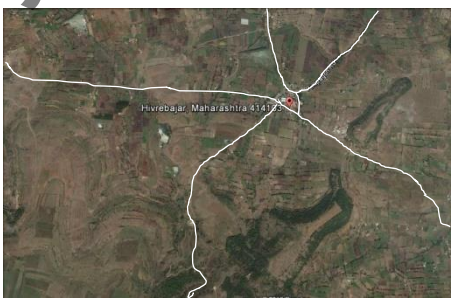

Figure 12- Location of Hiware bazar

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Figure 13- The fields seen in Hiware bazar (source- author)

Figure 14 - Fields can be seen in the backdrop of vegetated hills in Hiware bazar. (source- author)

2.1.4 Soils

Soils on the plateau **vary considerably** depending upon the terrain and slope conditions. Over the plateau in many parts of Parner taluka, the soils though **not very deep** have a **good admixture of lime** and are open as a result of which they are well suited for the production of a number of ***rabi* crops**. However, on the terraces, the soils are too **inferior** and the hill-slopes are **stony and poorer**.

2.1.5 Forest

Over the entire plateau **poor grade forests** dot the hill sections and proportion of area under **barren** and uncultivable wastes is fairly larger-about 10 per cent. The summits and slopes of the hills of the Ahmadnagar plateau are **uniformly bare of trees**, the depth of soils not affording nourishment for anything more than stunted bushes of ***khair* trees** (*Acacia catechu*) and prickly cactus which at a distance can hardly be distinguished from the basalt boulders which are strewn over the hill-sides.

2.1.6 Agriculture

Jowar and ***bajri*** are the two main crops of the plateau traditionally.

Figure 15- A jowar farm in Hiware Bazar (source- author)

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2.1.7 Watershed Development

- Hiware Bazar began its watershed development program in 1992 with **reforestation of their hilly forest land**. Villagers also **built trenches** along contours in the hills to trap and slow rainwater runoff.
- Along natural drainage lines, they built **shal** groundwater stored in the upper reaches of the village to reach farms downstream, villagers undertook an '**aquifer blast**' - a controlled underground explosion **low dams of stone**, **cement or earth.**
- Once ground behind the dam walls is saturated, additional water remains stored as surface water . To allow to create cracks for groundwater to flow through.
- On individual plots, farmers have levelled land and constructed low **earthen barriers** along the perimeter to hold rainwater within the fields. Wealthier farmers have dug **plastic-lined 'ponds'** for additional surface water storage.
- Under the comprehensive watershed development programme, implemented by Zilla panchayat ,the water conservation structures are constructed in the village given in the chart below.

Figure 16 - plastic lined farm ponds in Hiware bazar

Figure 17 - Percolation tank

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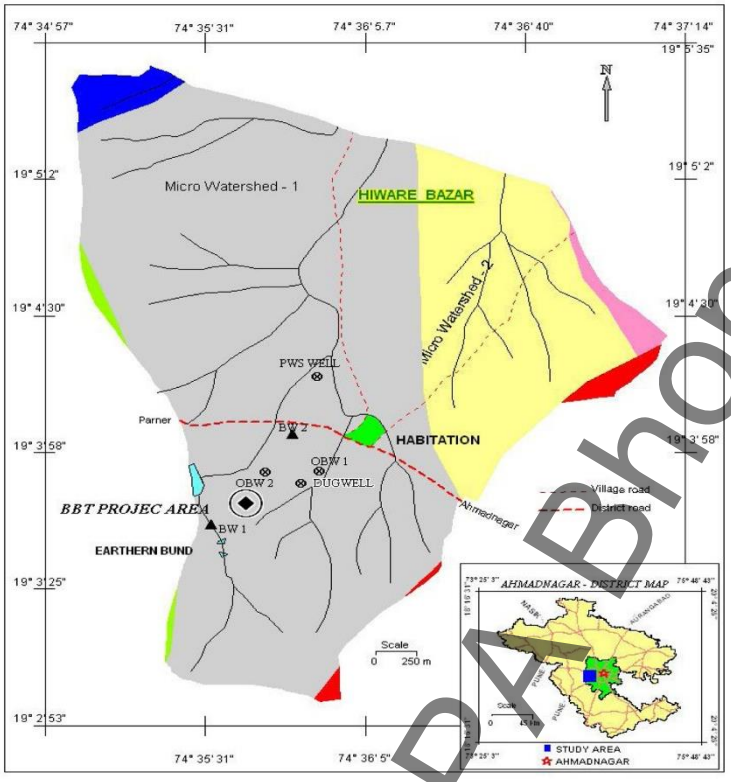

Figure 18 - Micro watershed map of Hiware bazar

Water conservation structures of the village						
Sr. No	**Type**	**No**	**Capacity**	**Percolated water**	**Store water**	
1	**Percolation tank**	**2**	**100**	**10**	**140**	
2	**Cement bandhara**	**4**	**2**	**0.4**	**5.6**	
3	**Gabbian bandhara**	**0**	**0.5**	**0**	**0**	
4	**Farm pond**	**3**	**7**	**1.05**	**14.7**	
5	**Earthen Dam**	**52**	**0.5**	**1.3**	**18.2**	
6	**CCT**	**210**	**Ha**	**37.8**	**0**	
7	**Underground bandhar**	**0**	**0.5**	**0**	**0**	
8	**Looze boulder**	**3035**	**0.01**	**1.52**	**21.25**	
9	**Kolhapur type bandhara**	**6**	**2**	**0.6**	**8.4**	
			Total	**52.67**	**Cr,.ltrs**	

Table 1 - Water coservation structure in Hiware bazar

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Figure 19 - Stone Bunding with vegetation (Source – Author)

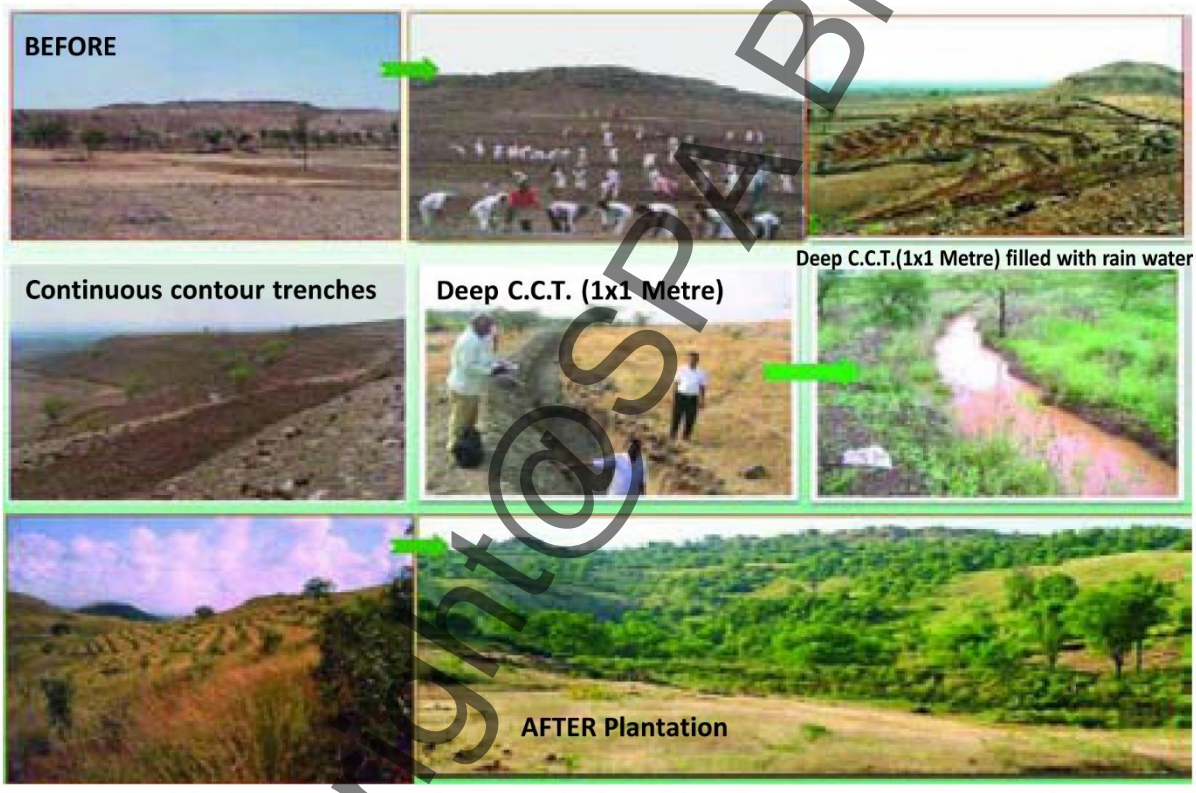

Figure 20 - Before-after scenario

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2.1.8 Bans on activities

Bans on activities that undo watershed efforts

- AGY had introduced **bans on tree-cutting** and grazing which the village continues to adhere to strictly. Through collective GS decisions the village has imposed additional restrictions:

- Ban on open grazing in watershed development areas: grazing is only permitted on private land.

- Ban on tree cutting*:* In the commons, trees and branches cannot be cut but branches can be cut on private land

- Ban on borewells *(except two for drinking water):* To control groundwater over-extraction, drilling borewells is banned and water access is restricted to open wells directly connected to rain/surface water recharge

- Ban on water-intensive crops*:* like sugarcane and banana. For fodder, half an acre of sugarcane per farm may be grown but only with use of drip irrigation

-Ban on 'chullahs' to preserve biomass*:* and reduce indoor pollution

2.1.9 Participatory Governance

Hiware Bazar's success has hinged on the involvement of the entire community who collectively decide their development priorities, contribute labour, and manage their natural resources by regulating and enforcing norms. Most community decisions are taken at Gram Sabha meetings.

2.1.10 Conclusions and inferences:

- The comprehensive development of Watershed by constructing a number of bandharas, percolation tank, farm ponds, cct etc. and also by adopting the **unconventional measure** like **bore blast technique increases** the additional water is stored in groundwater.
- This project can be **replicable** provided suitable site is available and there should not be restriction of strengthening only drinking water source but it should be considered for strengthening of groundwater.
- The **dugwells** are most suitable structures for ground water development in the district as 95% of the area is covered by Deccan Trap Basalt. The sites for borewell and tubewells wherever feasible, need to be selected only after proper scientific investigation.

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- In **Basaltic area**, the artificial recharge structures feasible are **check dams, gully plugs, percolation tanks, nalla bunds**, etc. Existing dugwells can also be used for artificial recharge, however, the source water should be properly filtered before being put in the wells.
- Prominent hill ranges, isolated hillocks and undulations etc., occur which allows for the **higher surface run off**. Hence **small schemes of water conservation** are proved to be quite useful for harvesting the surface run off and there by maintaining the supply during lean period.
- Storage tanks for villages on hill tops, nala bunds, contour bunds, gully plugs, CCT etc., should be constructed after studying the feasibility.
- The existing village ponds need to be rejuvenated to act both as water conservation and artificial recharge structures.

2.2 Case study 2:

2.2.1 Phad Irrigation System

It is diversion based irrigation system. *Phad* irrigation is one of the traditional forms of irrigation practiced in the Khandesh region of Maharashtra. They were prominent in the Dhule and Nashik district across the Panzara and Azim rivers in the Tapi river basin. The system is almost 300-400 years old.(Agarwal and Narayan,1997)

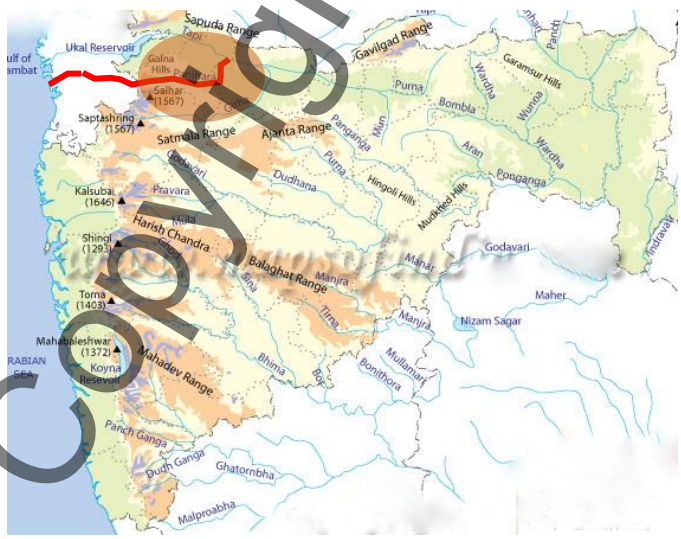

Figure 21 - Location map of Phad system

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2.2.2 Diversion based irrigation system

A diversion based irrigation system is one which diverts a portion of water from a natural stream, water course or a river and uses it with or without intermediate storage for the purpose of irrigating crops and for other human end.

Figure 22 - Dam across the stream

The Panjhara river originates in Sahyadri ranges, runs from west to east and meets Tapi river at Thalner. The above image shows the Panjhra river flowing in pre monsoon and post monsoon season.

2.2.3 Main Features Of Phad System

- The system comprises of diversion based weir **(*bandharas*),**constructed across the stream/river.
- The diversion of water is further done by construction of main canals**(*kalvas* or *pats*)** ,distributaries**(*charis*)** then field channels**(*sarangs)*** and finally to the blocks of agricultural land **(*Phads*).**
- The *phad* system also has provision for drainage of water, back into the river through construction of waste weir**(*Sandwa*)** and escapes **(sandams)**
- The command area of each *phad* locally known as ***kayam bagayat*** were divided into blocks of land known as ***Phad.***
- The size of entire phad varies from 10-200ha with an average size ranging between **100-125ha.**
- A collection of *phads* is known as a ***thal*** *,* and can cover an area upto 400 ha.
- Thus this is a diversion based irrigation that draw its name from the agricultural blocks that it command.

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Figure 23 - Above two schematic diagrams explains the Phad or Pat system.

Figure 24 - Images on the left side are showing the dry canal, water committee on a bandhara, farmer in his field and a concretised distributary in a phad.

2.2.4 Materials used

The materials used are commonly **black stone, coarse concrete mixed with** small pieces of **bricks** and the **very best cement**.

2.2.5 Social functioning

Elaborate rules for irrigation exist wherein water is supplied to the second *phad* only after supplying adequate water to the first *phad.* **Water meetings** are held at the village level where the cropping pattern was decided based on previous years' patterns. Usually a general meeting is held in the **month of April-May** (*Akshaya Tritiya*) where a public announcement is made for community management of the water harvesting and storage structures. Each family has to provide a pair of bullocks and 3 labourers for a day to maintain the system. Families who are not able to fulfill this commitment, have to pay Rs. 30/- for the bullocks and Rs 10/- for 3 labourers. The process of mobilizing the village farmers for the meeting is normally done through a key person of the village, who is often called a *Kotwal*

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Figure 25 - Repairing work finished before monsoon

2.2.6 Topography of region

- The river Panjhra in the Sahyadri range on which the *phad* systems were rampant has a **steep gradient** and flows through **rocky beds**, a topographical feature conducive to construction of diversion weirs.
- Monsoon rains contribute to the runoff apart from the existence of a significant post-monsoon flow that can keep substantial irrigation going, in winter as well as in the summer seasons.
- This provides the context for building a series of *bandharas*, or low water diversion weirs, between one to five meters high of **stone** and **masonry**, across these streams to divert waters for agricultural use.
- *Bandharas* are **constructed in a series** to arrest the supply downstream. The availability of a command area at each *bandhara* site, is also kept in mind. Care is taken to select a site with a good foundation at a reasonable depth.

2.2.7 Selection of site

The process of selecting the site for building the structure is carried out taking into consideration the **base gradient of the river** and the **slope of the command area**.

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2.2.8 Design of a *BANDHARA*

Except a few, built straight **across the stream**, dams are more or less **oblique**, with the water course issuing at the lower end. Where the rock below is not continuous, their forms are mostly irregular. In building a dam, holes are cut in the rock in the proposed line of the wall. In the holes, stone uprights, sometimes small pillars taken from the Hindu temples, are set and a dam is either built in front of these or the stones are built into the dam leaving only the backs of the uprights visible.

The **dams** are **strong**, **clumsy walls** commonly **sloping on both sides** to a narrow top. **Scouring sluices** are provided at different places as per the length of the canal. This works as an **automated cleaning device** for the drainage of sand and silt. The average water discharge from the canal is 7-10 cusecs. The height of the diversion weir is selected in such manner that the excess water from the river is automatically removed with the help of **scouring sluices**. The water required for irrigation purpose is diverted into the main canal, with the provision of scouring sluices in between the head of the canal and the saucer. The head of the canal has no provision of a gate; the saucer and the scouring sluices present between the diversion weir and the head of the canal regulates the water flow. The length and **size of the canals varies** amongst the *bandharas* depending upon the **size of the *phad*** and the **distance of water travelled** from the site selected for the diversion of water through the weir. The reason for the variation of size and length of the canal was **to maintain the velocity of water** so that the water could flow at its own gravity till it reached the main command area or the *thal.*

2.2.9 Governance pattern

To ensure proper water management and distribution, each phad has **Water User Associations** (WUAs) locally known as ***Bagayat committees*** , canal supervisers (*Hawaldars*), Inspectors (*Patkaris*) and water guards (*Jaglias*). This system ensures equal water distribution by making proper arrangements within the system. Each of these members have **different task** and they are made **accountable** for command area farmers. Method of **payment varies** from wholly in kind to wholly in cash with different forms of mixed payments in between. For ex. In **Rayawat bandhara** on Panjhra river system payment is in cash for sugarcane and in kind for other crops. Here each irrigator has to be paid according to the crop grown in the *phad*.

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2.2.10 Decided cropping patterns:

A **uniform cropping** pattern is usually followed within the *phad* in a season, but it could **vary across *phads*** and over the years. **Paddy** is the most common crop under the *phad* system in the Panjhra river; other crops like maize and wheat have also been introduced now. Because all farmers have some share of land in the main *phad*, an **equitable** system of **water distribution** is maintained. *Phads* are used on a **rotation basis**. For example in years of plentiful water, the farmer community decides to grow **sugarcane** in the three *phads* and **millet** in one. But in a year of average rain, the farmers would grow two *phads* of sugarcane and two of millet. In a bad year, they would allow sugarcane in only one *phad*, grow millet in two and kept one fallow***.***

2.2.11 Other similar systems – *KHADIN*

A *khadin*, also called a *dhora*, is an ingenious construction designed to harvest surface runoff water for agriculture. Its main feature is a very long (100-300 m) earthen embankment built across the lower hill slopes lying below gravelly uplands. Sluices and spillways allow excess water to drain off. The *khadin* system is based on the principle of harvesting rainwater on farmland and subsequent use of this water-saturated land for crop production. Catchment areas –shallow ,gravelly and rocky uplands with runoff potential. Flood plain or gently sloping plain area (Khadin area) where soils are suitable for crop production. Periodic cleaning of khadin area required which includes levelling of land plus desilting of khadin area.

2.2.12 Principle:

- The khadin system is based on the principle of harvesting rainwater on farmland and subsequent use of this water-saturated land for crop production.
- The embankment not only helps to increase moisture in the submerged land, but also prevents the washing away of the top soil and the manure added to it.
- Depending upon the amount of rainfall and consequent runoff received during the monsoon, one or two crops are grown.

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2.2.13 Structure :

An earthen embankment built across the general slope which conserves the maximum possible rainwater runoff within the agricultural field.

- The size of the Khadin is designed on the basis of local rainfall patterns, catchment characteristics and soil type.
- On an average, the cultivated area under each Khadin is 10-14 ha with an average dam size between 1.2-1.7 m high x 1.0-1.5 m wide and 100-300 meters in length, depending upon catchment area and number of land holdings.
- The spillways and sluice gates are usually provided at a proper location for excess water during flood conditions.
- The embankment not only helps to increase moisture in the submerged land, but also prevents the washing away of the top soil and the manure added to it.
- This system assures the farmers of at least one crop even in very dry tracts.
- Other than improving socio-economic conditions of desert dwellers, Khadins also have created positive impact on the ecology of the region, effectively checking soil erosion and increasing vegetation cover.

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CHAPTER 3

REGIONAL SETTINGS

3 REGIONAL SETTINGS:

3.1 Introduction of region:

The district of Ahmednagar lies between 18˚2´ and 19˚9´ north latitudes and 73˚9´and 75˚5´east longitudes. It was found in 1494 by Malik Ahmed, the founder of Nizamshahi dynasty of Ahmednagar. Physiographically the district can be broadly divided in four major characteristic landforms viz., hill and ghat section (7.6% area); foothill zone (19.4% area); plateau (3.71% area) and plains (occupy 69.30% area). Enclosed between two high rims is the vast Ahmednagar plateau. the northern rim is a part of Baleshwar range and the southern rim is that of Harishchandragad range. The plateau is running with a north west to south easterly trend with an elevation of more than 500m except in the river valleys. The plateau in large proportions is covered with rock boulders and with practically no vegetal cover.

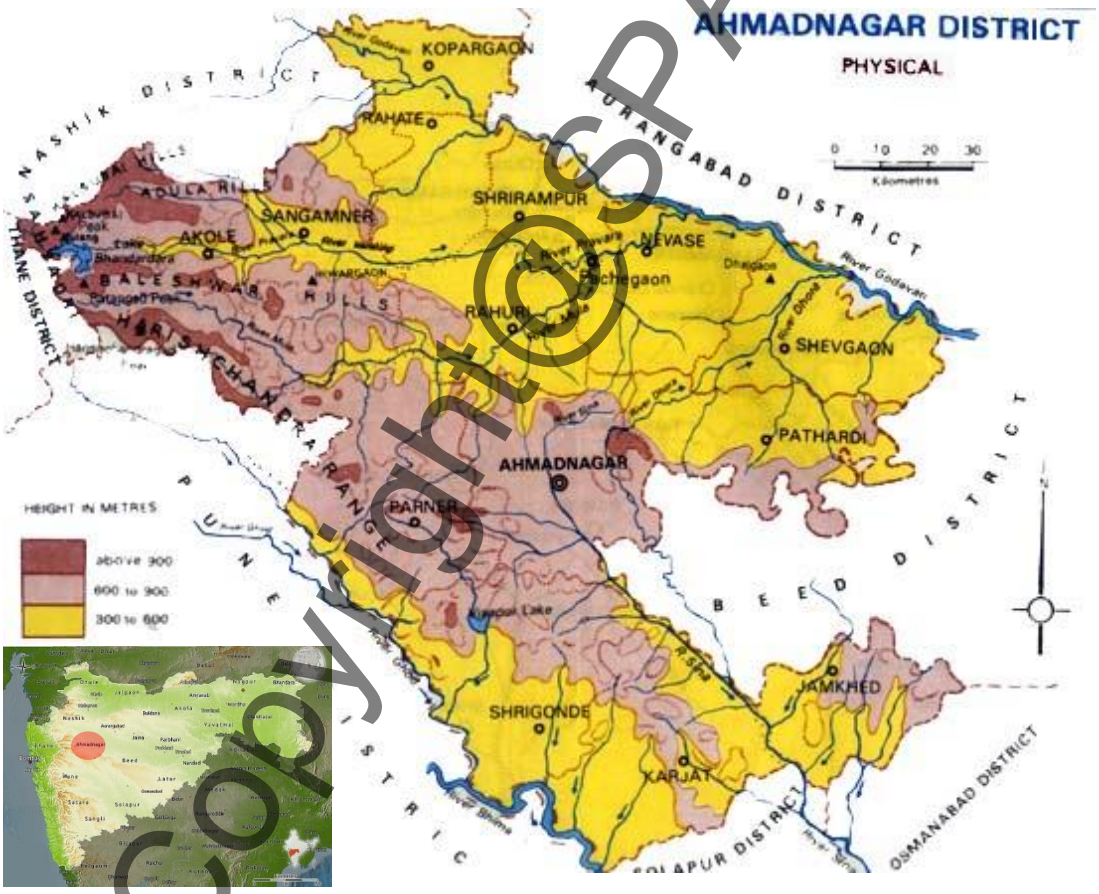

Figure 26 - Physiographical map of Ahmadnagar district

3.2 Geology

The region lies partly in upper hills of the Sahyadri and its three off shoots.

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The major formations under Deccan Trap or Sahydri group are

i) Upper Ratangarh formations

ii) Indrayani formations

iii) Karla formations

iv) Diveghat formations

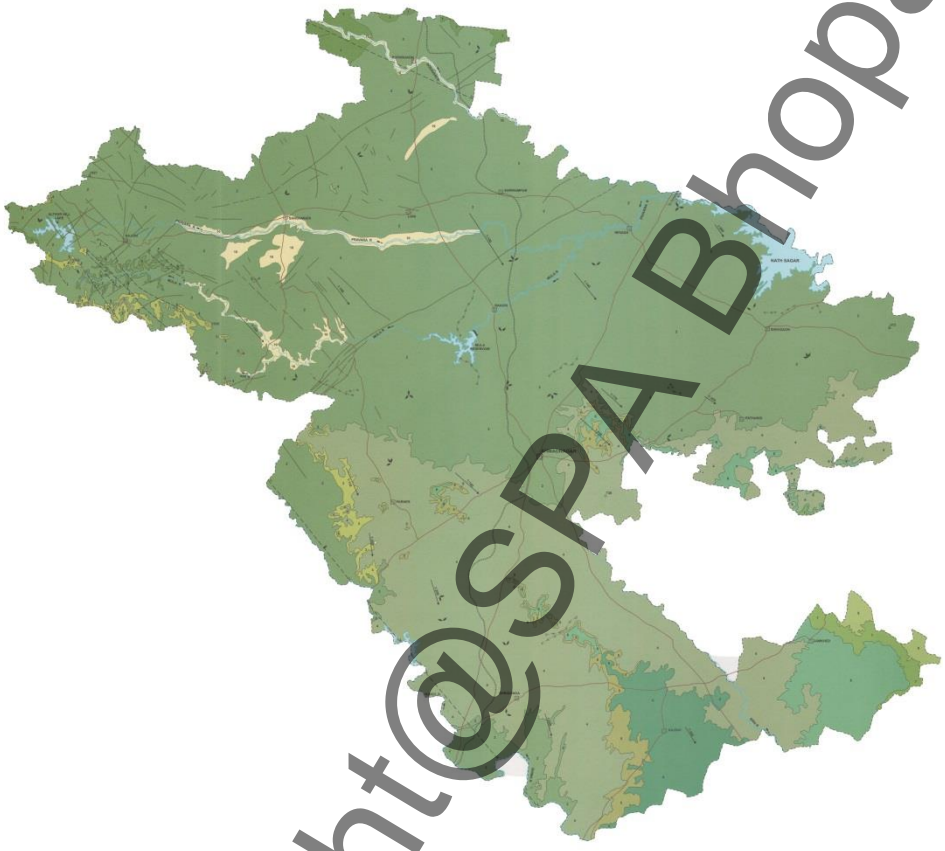

Figure 27- Geological formations of Ahmadnagar district (source- Geological Survey of India)

10	Alluvium		QUATERNARY	Consists of conglomerate, gravel, pebbles, coarse to fine sand and clay
	Basic Intrusive (Dykes)			Dark grey, fine to medium grained, massive, hard and compact rock
9	Basic Sill/Lava channels			Dark grey, fine to medium grained, massive, hard and compact rock
8	2Aa basaltic lava flows (40-50m)	Mahabaleswar Fmn.	DECCAN TRAP (SAHYADRI GROUP)	Dark grey, fine to medium grained, hard and compact and non to sparsely prophyritic in nature
7	2 Aa and 1 simple basaltic lava flows (Max.80m)	Purandargarh Fmn.	UPPER CRETACEOUS TO PALAEOGENE	Dark grey, medium grained, massive, hard and compact and prophyritic
6	3-10 Aa and simple basaltic lava flows (40-100m)	Diveghat Fmn.		Dark grey, fine to medium grained, hard and compact, sparsely to highly porphyritic
5	4-5 compound pahoehoe basaltic lava flows (Max. 60m)	Karla Fmn.		Dark grey, fine to medium grained, hard and compact, non-porphyritic to porphyritic
4	5 Aa and 1 compound pahoehoe basaltic lava flows (Max. 150m)	Indryani Fmn.		Dark grey fine to medium grained, massive, hard compact and non to moderately porphyritic
3	Megacryst compound pahoehoe basaltic Flow M3 (50-60m)	Upper Ratangarh Fmn.		Dark grey, medium grained, massive,hard and compact, highly porphyritic with giant size feldspar phenocrysts, upto 5 cms in length
2	12-14 mainly of compound pahoehoe flows and some Aa flows (Max. 260m)			Dark grey, fine to medium grained, massive, hard and compact non-porphyritic to porphyritic with olivine phenocrysts
1	2 compound pahoehoe flows (40-50m)	Lower Ratangarh Fmn.		Dark grey, fine to medium grained, massive, hard, compact and moderately porphyritic

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3.3 Geomorphology

i) **EA1** - The north western part of the region forms elevation **over 900m** (part of harischandragad range).underlying rock is of extrusive origin mainly basalt.

ii) **EA2** – Much larger part of the district is covered by this unit of extrusive origin and which also consists of Ahmednagar plateau. Elevations ranging from **550-900m**.

iii) **Denudational slope** on Deccan trap is seen in north, north-east and south-east parts of the district.

iv) **Sina river basin** and the **Mula river basin** in north are the older flood plains in the region with inclinations 10˚to 20˚.

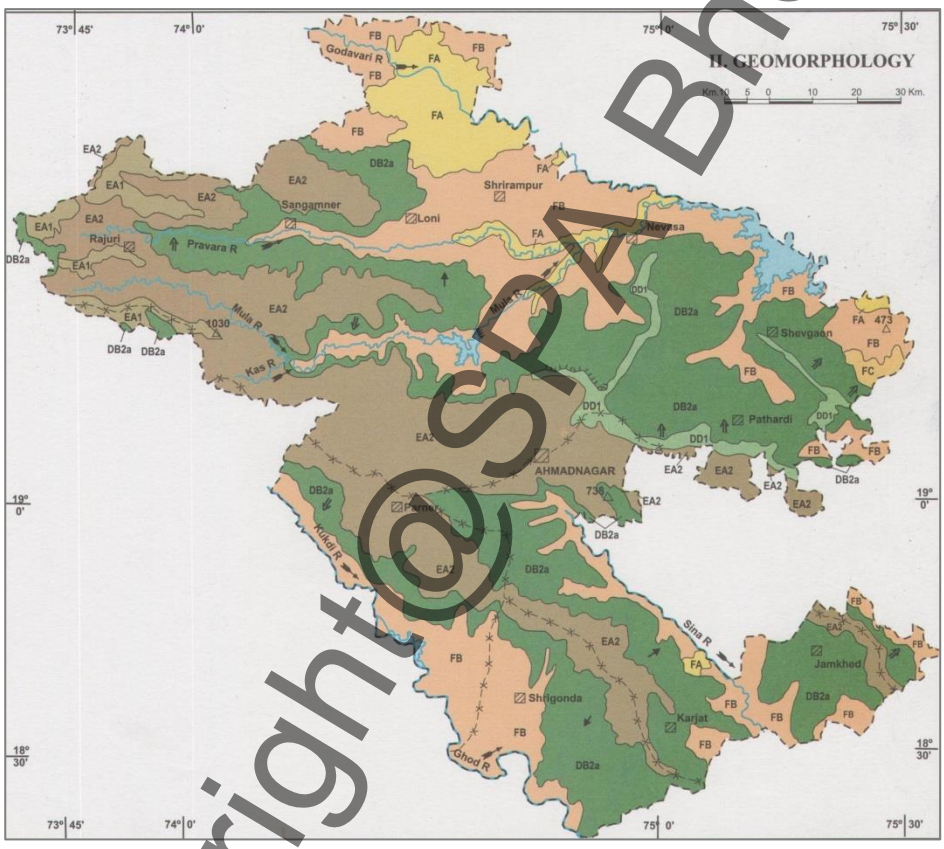
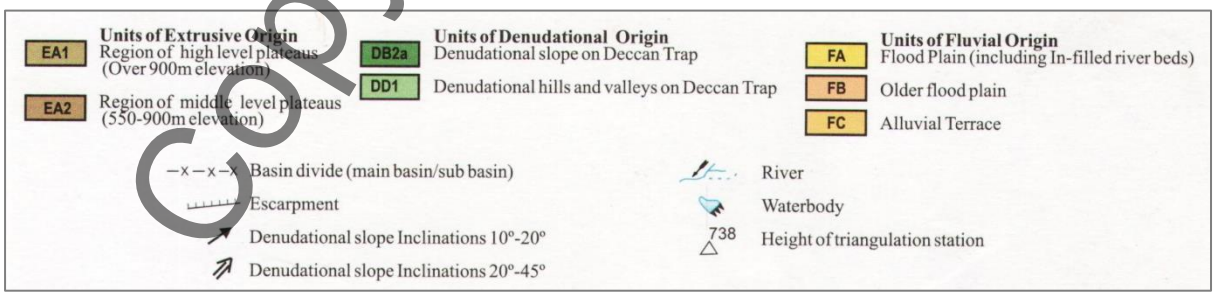


Figure 28- Geomorphological map of Ahmadnagar district (source- Geological Survey of India)



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3.4 Landuse

The district has total geographical area of 17,41,00 hectares of which forest land is 168000 hector (9.85 %). Total irrigated land consist 702000 hectors and 166000 hector lands is barren. About 103000 hector land is used for other purposes.

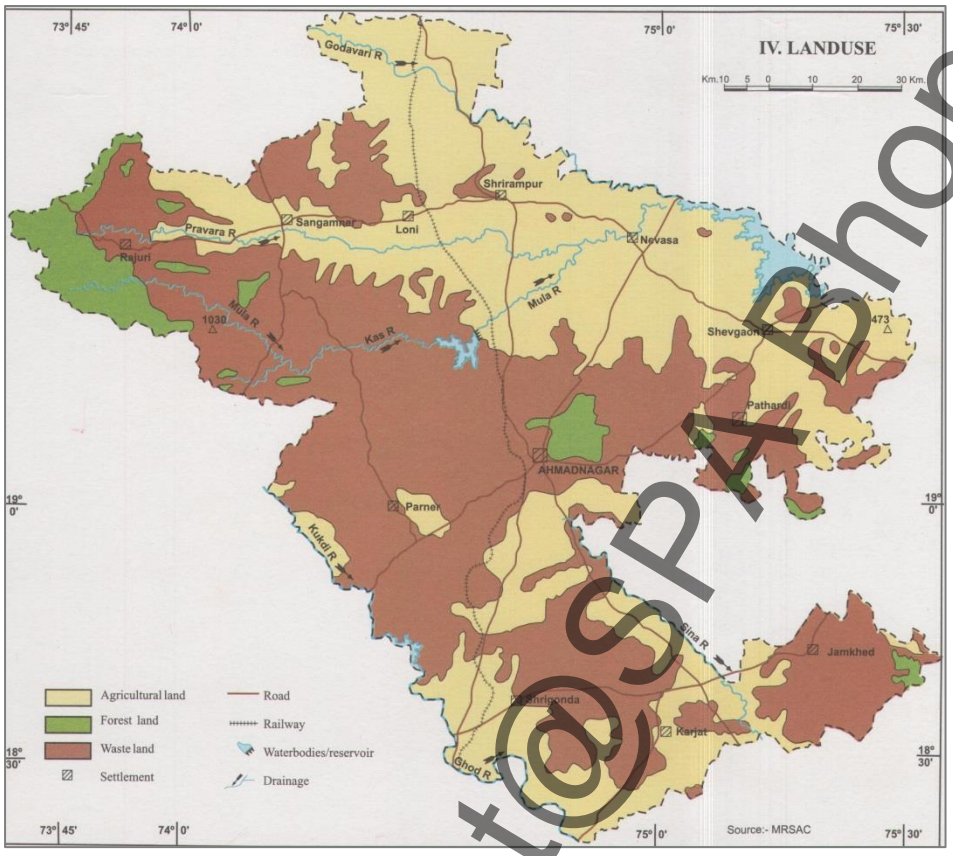
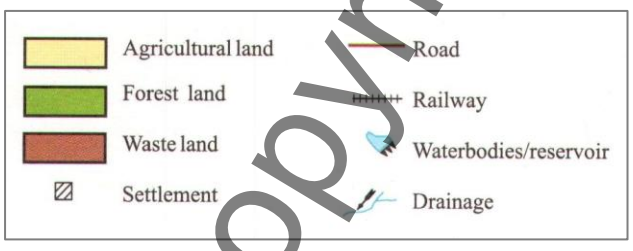
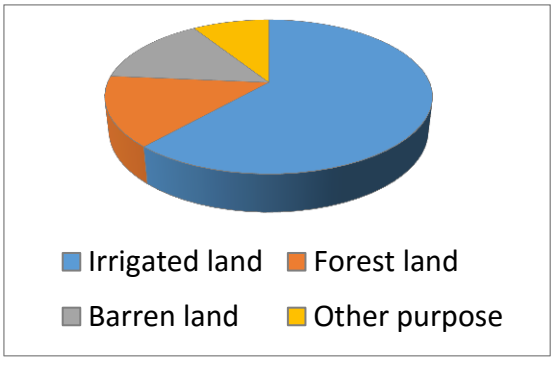


Figure 29-Landuse map of Ahmadnagar district (source- Geological Survey of India)





3.5 Geohydrology

The major part of the district is underlain by the basaltic lava flows, which were formed by the intermittent fissure type eruptions. The Deccan Trap has succession of 19 major flows in the elevation range of 420 to 730 m above mean sea level.

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These flows are characterised by the prominent units of vesicular and massive Basalt. The ground water occurs under phreatic, semi-confined and confined conditions. Generally the shallower zones down to the depth of 20 m bgl form phreatic aquifer.

The water bearing zones occurring between the depths of 20 and 40 m are weathered interflow or shear zones and yield water under semi confined conditions. Deeper semi-confined to confined aquifers occur below the depth of 40 m as the borewells drilled have shown presence of fractured zones at deeper depths at places. The vesicular portion of different lava flows varies in thickness from 8 to 10 m and forms the potential aquifer zones.

3.6 River basins

The drainage of Ahmednagar district deals with two major rivers, the **Godavar**i in the north and the **Bhima** in the south. Apart from these main rivers, no. of tributaries has drained the district. Adula,Pravara, Mula, to the north while Sina, Kukadi, Hanga, Khanduri, are important ones. Pravara, Adula, Mahalungi, Dhor are the main tributaries of Godavari with in the district boundary. The river Mula is the tributary of Pravara. Bhima covers southern part of the district. The main tributaries of the Bhima in the district are Ghod and Sina river. Sina, originates at the hilly region to the east of Ahmadnagar city. The Ahmadnagar city is located on the right bank of Sina. Sina has formed the boundary between the Ahmadnagar and the district Beed. In general these basins have an elevation of between 500 and 600 meters. All the rivers have sub parallel to semi-dendritic drainage pattern.

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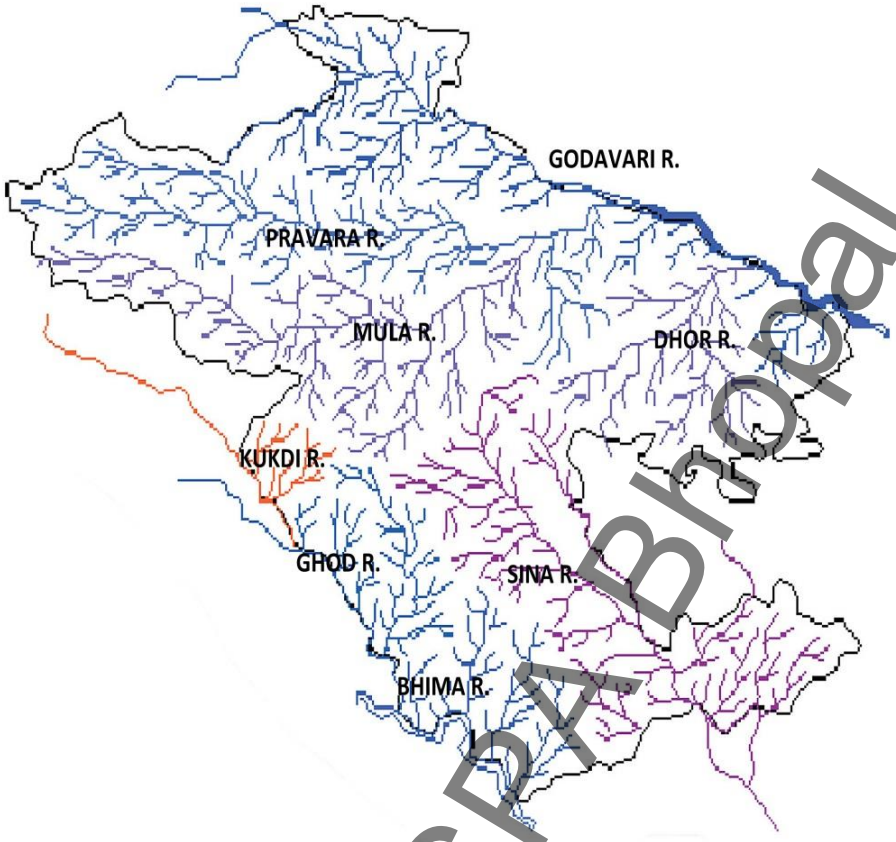

Figure 30- Major drainage basis of Ahmadnagar district

3.7 Soils

The soils of the district are mainly bounded by black cotton soil (*Regur*) and Clay in the river tracts. It is classified into three groups as Black soil, Red or *Tambat* and *Barad* or gray including '*Pandhari*' or white. These soils are subdivided into many more kinds with different names in different parts of the district such as proper black soil is known as black cotton soil.

According to Krishi Vidhyan Kendra (KVK), Pravaranagar, the soil types of the district fall under four categories namely-

1) Coarse Shallow black soil.

2) Medium black soil.

3) Deep black soil.

4) Reddish soil occupying about 38%, 41%, 13% and 8% of the cultivated area respectively.

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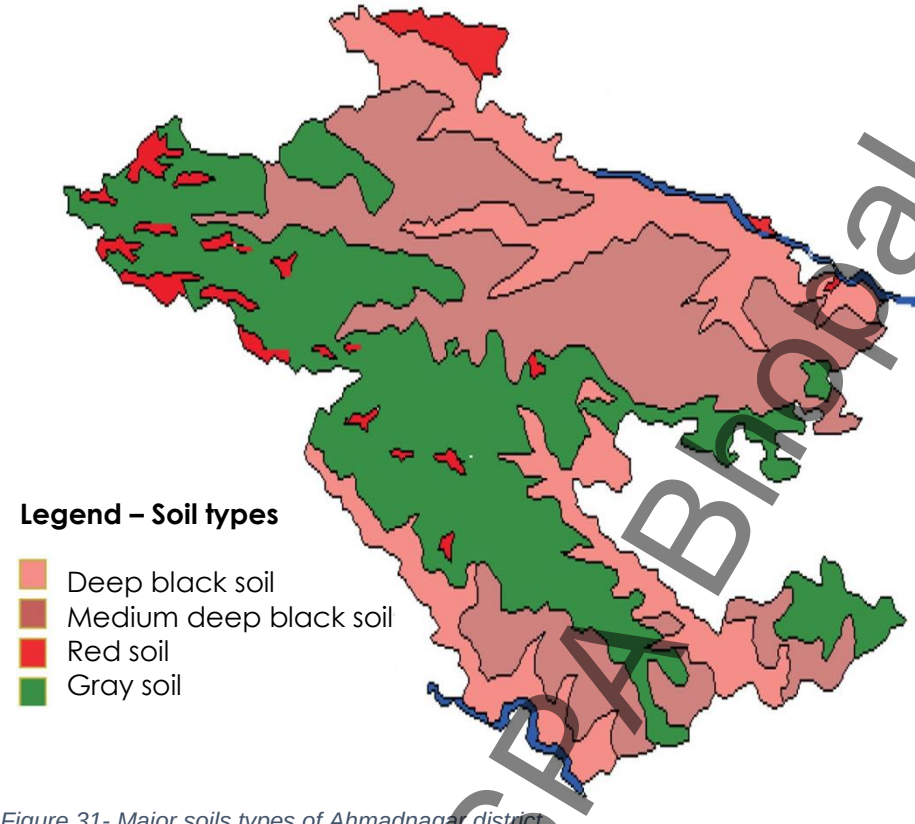
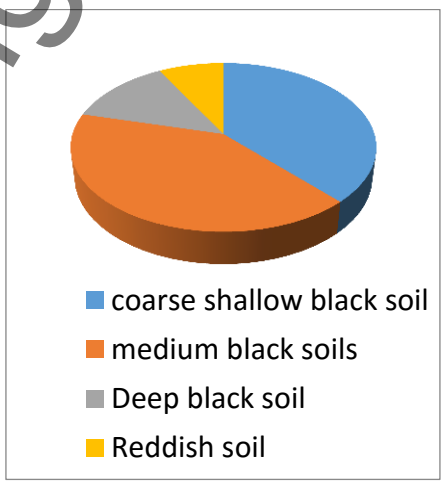


Figure 31- Major soils types of Ahmadnagar district.

Sr.No.	Type of Soil	Depth in Cms.	Available Soil moisture in mm. At saturation
i)	Very shallow soils	Upto 10	16
ii)	Shallow soil	Above 10 & Upto 22.5	37
iii)	Medium deep soils	Above 22.5 & Upto 60	65 to 67
iv)	Deep Soils	Above 60	140



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3.8 Forest

Forest constituted one of the most important basic natural resources in the country. Forest occupies about 12 percent of Ahemdnagar district total land surface which is much below the desired proportion of 33 percent as laid down in the National forest policy.

The highest proportion of forest area is in Akole tahsil which is 81.1 hectares or 27.7 percent and the lowest proportion of forest area in Rahata tehsil it is 10.3 Hectors. Akole, Sangamnar, Pathardi, Parner, Shrigonda, Karjat tahsils the proportion is higher than the average for the district. The proportion is lower than the average for the districts of Kopargaon, Rahata, Shrirampur tahsils.

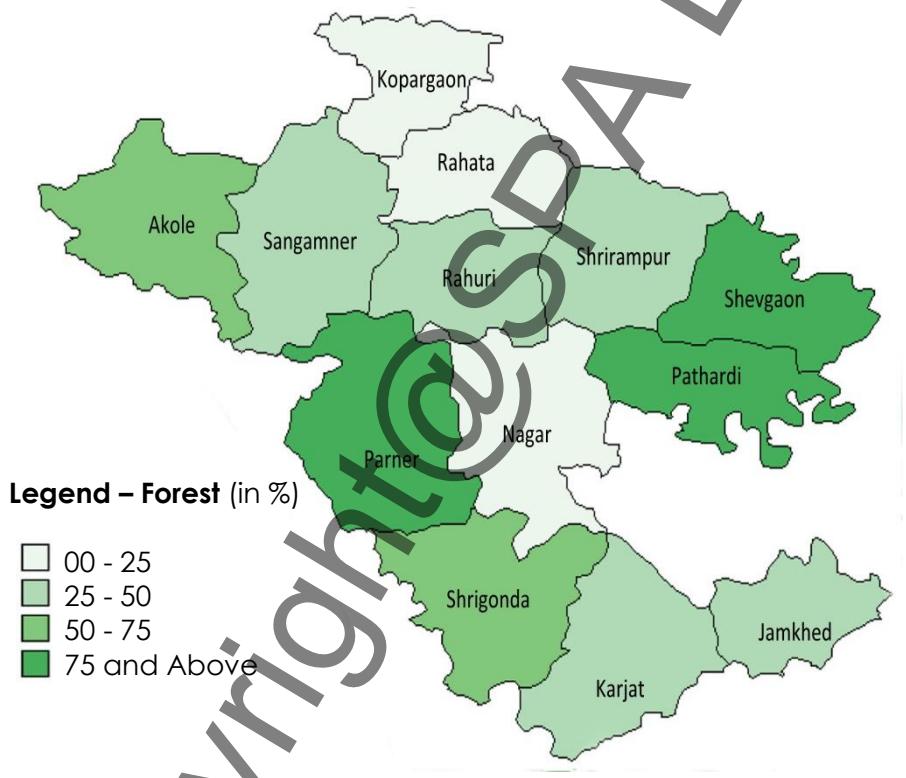

Figure 32- taluka wise forest percentage in Ahmadnagar district.

3.9 Climate

The climate of the district is characterised by a hot summer and general dryness throughout the year except during the southwest monsoon season, i.e, June to September.

The mean minimum temperature is 12.3°C and mean maximum temperature is 39.1°C.Main seasons are-Summer season- March to May, Winter-December to

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February, Rainy / Monsoon - June to September and Rainy with retreating Monsoon –October to November.

The district receives rain from south-west Monsoon and retreating of monsoons. As the location of the district is to the lower side of Sahyadri, it receives scanty rainfall. The average annual rainfall in the district is 583 mm.

Seasonal change in temperature is quite more in the district. May is the hottest month. While Dec is the coldest month of the year.

Sr.No.	Year	Rainfall in mm.	Sr.No.	Year	Rainfall in mm.
1.	1990-91	412	13.	2002-03	411
2.	1991-92	400	14.	2003-04	549
3.	1992-93	385	15.	2004-05	589
4.	1993-94	414	16.	2005-06	566
5.	1994-95	402	17.	2006-07	537
6.	1995-96	426	18.	2007-08	556
7.	1996-97	445	19.	2008-09	577
8.	1997-98	398	20.	2009-10	567
9.	1998-99	386	21.	2010-11	613
10.	1999-2000	427	22.	2011-12	560
11.	2000-01	566			
12.	2001-02	590			

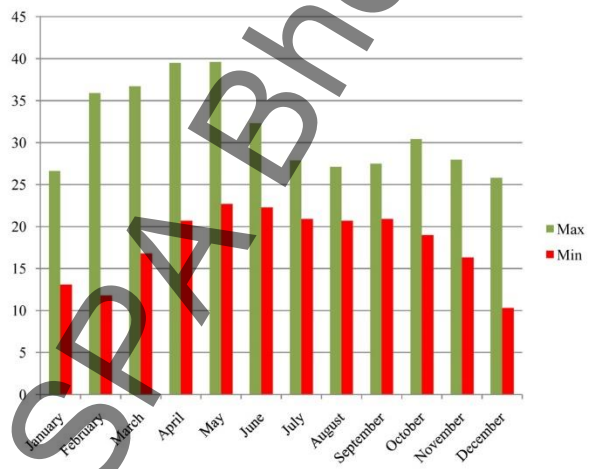

Table 2- Average temperature of the district in 2001(°c) source : www.ahmadngar.gov.in

Table 3- Average Rainfall of Ahmednagar District for the period 1990-91 to 2011-12 (Source: Socio Economic Review of Ahmednagar District from 1990-91 to 2011-12)

3.10 Flora of the region

- The region is very poor in terms of forest and the only patches of forest could be seen in north western part of the district, Akole taluka, there are some patches of natural ever-green type of forests confined to the hills.
- In the rest of the areas of the district there are practically no such patches of natural forest except the afforestation areas cultivated during the last few years. The total area in charge of the territorial forest department is 1375.94 Sq. km, which forms about 8 % of the total geographical area of the district.
- The forests in Ahmednagar district are almost entirely limited in area to those lands, which are found to be unsuitable for cultivation owing to their physical nature. The land is scattered in strips and patches throughout the district.

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- The pressure on the forest too has played a role in limiting the area and has affected the composition and condition of the vegetation to such an extent that no where it has remained in its natural form, except those in extreme west which incidentally have received protection by constitution of protected area ,almost barren and without any tree cover.
- This interference occurred in the west mainly through repeated clear felling and burning for cultivation and in the remaining area through excessive grazing by cattle and removal of tree growth either for fuel or timber such actions have continued with varying intensity for a long period

The following three main types of forests are represented by the Forest Division -

a) The Southern Tropical Semi–Evergreen West Coast Forest

b) The Southern Tropical Dry Mixed Deciduous Forests.

c) The Southern Tropical Thorn Forests

d) The deciduous species being more useful to the man have been constantly removed and this removal coupled with excessive grazing has resulted in reduction of humus, heavy erosion and general impoverishment of the soil.

e) This has led to increased xerophytic conditions with preponderance of thorny species in areas of the central zone, where originally Mixed Deciduous Forests should have existed.

f) The areas are mostly supporting shrub species with varied presence of species like Salai (*Boswellia serrata*), Dhavada (*Anogeissus latifolia*), Moin (*Lannea coromandelica*), Aola (*Emblica officinalis*), Ain (*Terminalia* tomentosa), Beheda (*Terminalia bellerica*), Neem (*Azadirachta indica*), Maharukh (*Ailanthus excelsa*), Bondara (*Lagerstroemia parviflora*) and teak (*Tectona grandis*). Good growth in teak is noticed in well protected privately owned areas with Karvand (*Carissa karanda*), Dhayaty (*Woodfordia fruticousa*), Tambat (*Flacourtia latifolia*), Sabar (*Euphorbia spp*), Nirgudi (*Vitex negundo*) and Lantana (*Lantana camara*) etc., are noticed as an undergrowth. Due to excessive grazing, growth of palatable grasses is scanty, growth of Kusali, phuli and rosha grasses are noticed.

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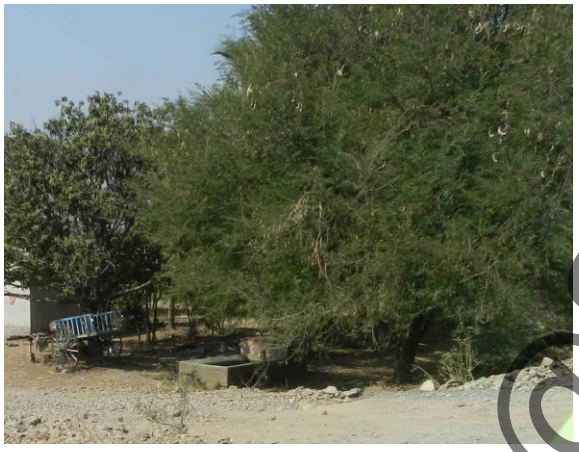
Azadirachta indica(Neem)

Acacia nilotica (Babool)



Tamarindus indica (Imli)

Ficus bengalensis (Bargad)

Capparis decidua(Karir)

Lucaena luecocephala(subabool)

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Figure 33 - Vegetation mapping (source-Author)

3.11 Fauna of the region

Ahmednagar district blessed with variable climatic conditions supports varied fauna which have settled in the area. Accordingly it has been observed that the Panthers are confined more in the Western part of the district, the Black Buck to the Eastern part and a few localized in pockets of the district. Rehekuri Black Buck wildlife sanctuary over 217.31 ha of forest in Rehekuri village of Karjat tehsil of Ahmednagar is an area rich in Black Buck. The other sancturies are Jaikwadi Bird Sanctuary, The Kalsubai - Harishchandragad Wildlife Sanctuary , The Great Indian Bustard Wildlife Sanctuary.

More than 200 different types of birds have been recorded in the area over the years with the principal bird species being the Tufted Pochard, Coot and Demoiselle Crane. Others include Flamingo, Common crane, White necked stork, black necked stork, open bill stork, grey heron, purple heron, Indian reef heron, Indian pond heron, night heron, little cormorant, curlew, avocet, gulls, godwit, dabchick, bramhiny duck, tufted duck, spot bill duck, pintail duck, nakta, red crested pochard, common pochard, mallard, gadwall, wigeon, shoveller, spoonbills, egrets, snipes, sand piper, black whie and glossy ibis, jacanas, moorhens, plover, stilt, kingfisher, barheaded goose, brown fish owl, water hens, common kite.

Wild animals such as Fox, Wolf, Hyena, and Black Buck, Mongoose are noticed in the agriculture fields outside the boundary of the sanctuary Reptiles like Cobra, Rat snake or dhaman, viper and Monitor Lizard are common.

Figure 34 - Fauna of the region

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CHAPTER 4

SITE STUDY

4 SITE STUDY

4.1 Site Introduction

The site taken for design intervention lies in the Nagar tehsil of Ahmednagar district.

It is part of Harischandragad range which has slope trend of north – west to south – east. Harishchandragad range is the longest range of the district and forms the main water shed between the Godavari and Bhima tributaries. The site lies in a region of very irregular and hilly areas, consisting of a series of plateaus at various heights. The highest points are at 969 meters above mean sea level and the lowest land is at 688 meters. A few peaks standing out prominently and forming a large elevated tract are known as *Dongar Pathar* locally. This level tract of a rolling upland inter- spersed with hill- country or *Mal* land is what locally known as the *Munjal*. Large tracts of rugged ground of these *Mal* lands are covered with boulders.

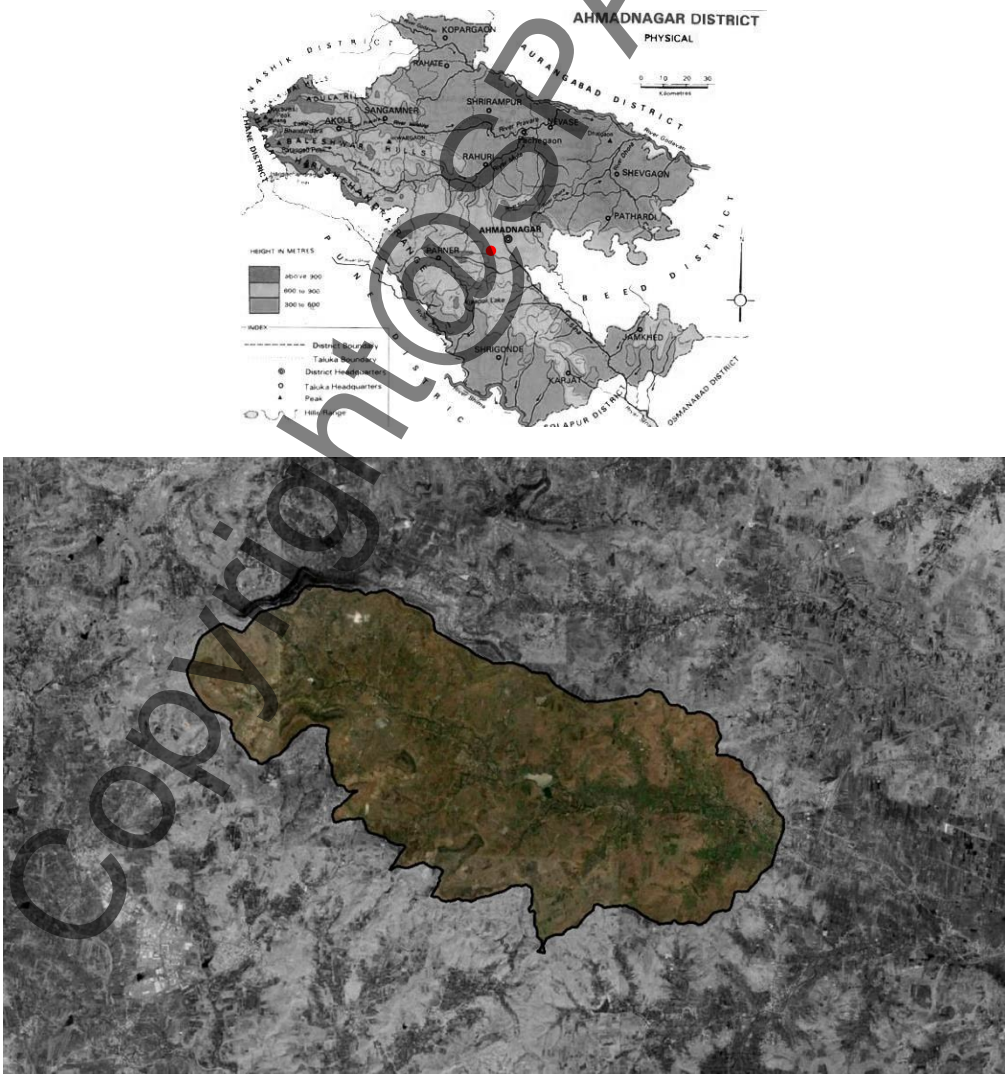

Figure 35 - Intervention site location map

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The site taken is a watershed of Vasumba Nala ,which further is a feeder to Sina river . Sina river is the tributary of Bhima which ultimately is a part of larger Krishna basin.

The site is marked with four major settlement which are compact villages lying in the valley part of the region. These are Pimpalgaon Kauda , Kamargaon, Bhorwadi and Akolner .

The site is traversed by a major road i.e. Pune –Ahmednagar state Highway passing along the north –east to south – west direction.

The total area of site selected is 44sq. Km

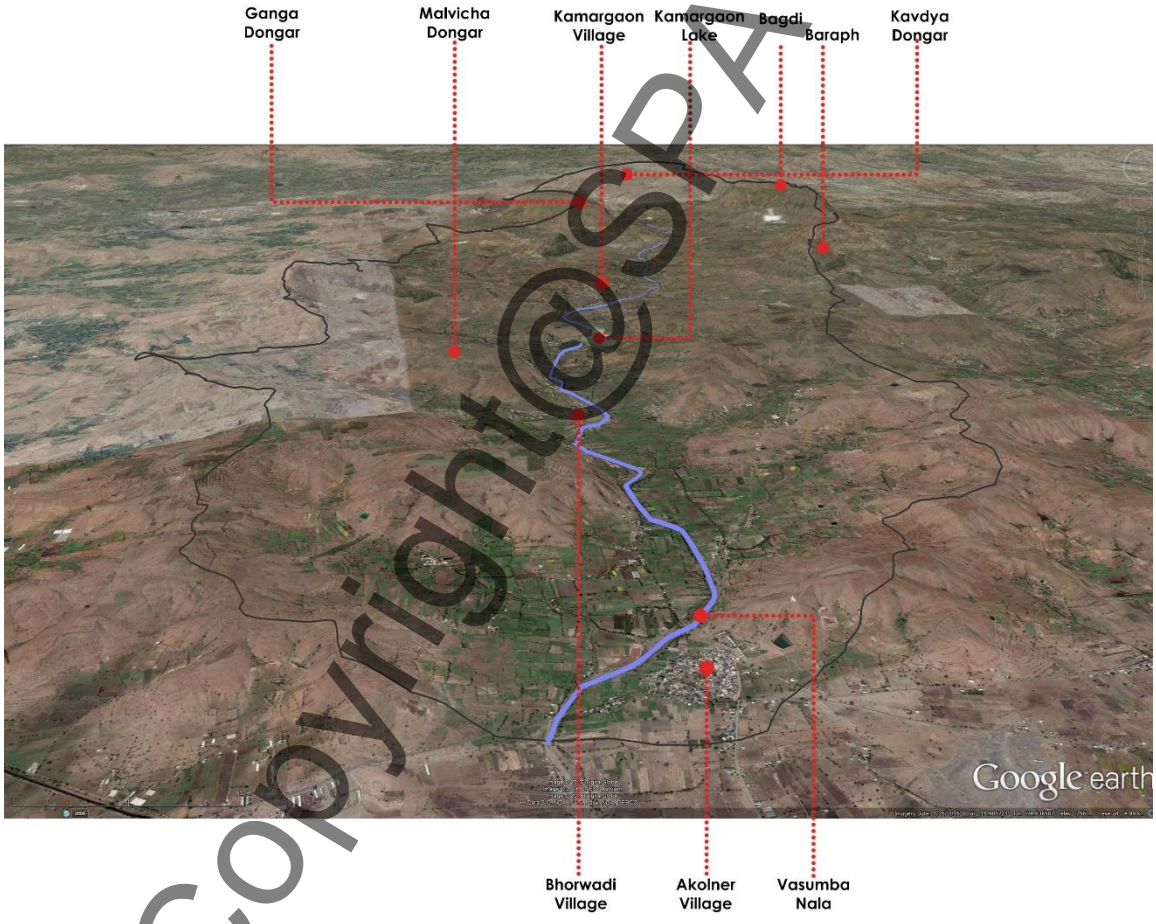

Figure 36 - Important landmarks

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4.2 Criteria for site - selection :

The site is part of larger rain shadow region of western ghats. The Vasumba Nala is one of the Primary feeder channel to one of the major river of the area , river Sina ,which further becomes a part of Bhima- Krishna basin.

The average annual rainfall in the region is 400 mm thus making it a semi- arid landscape. In spite of a major lake called Kamargaon lake and other number of borewells ,the area remains tanker-fed during the summer months of March to mid-June. But the geographic setting of the site makes it predominantly suitable for water conservation and favourable for groundwater development zones. The area is surrounded by gently sloping hills .

Accessibility – the area taken for intervention is well – connected through network of roads.

Agrarian landscape – particular interest in these type of landscape. Also the site was familiar and well – known before commencement of the study.

Figure 37 - Depth to water table pre & post monsoon

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4.3 Profile of Villages:

A brief profile of settlements falling on the site. The four settlements are villages with individual gram panchayats. The total population lying in the area is 9154. All of them are villages with agriculture based economy. Thus groundwater is predominantly used for irrigation purpose.

4.3.1 Pimpalgaon kauda

Pimpalgaon Kauda is a Village in Nagar Taluka in Ahmednagar District of Maharashtra. Pimpalgaon Kauda is a village panchayat which lies between the latitude 18˚96''and longitude 72˚82' . It belongs to Khandesh and Northern Maharashtra region for administrative purposes. It is located 24 KM towards west from District headquarters Ahmednagar. Ahmednagar , Shirur , Rahuri , Shrigonda are the nearby cities to Pimpalgaon Kauda. Total population of Pimpalgaon Kauda is 1302 living in 259 Houses. Total area of Pimpalgaon Kauda is 1454 hectares.

4.3.2 Kamargaon

Kamargaon is a village on the Pune to Ahmednagar State Highway in India. There is a windmill farm 20 km outside town. The village deity is Kamaksha Devi. Coordinates: 20°37′N 77°30′E. Total population of Kamargaon is 3617 , living in 723 Houses. Total area of Kamargaon is 2175 hectares.

4.3.3 Bhorwadi

Bhorwadi is a Village in Nagar Taluka in Ahmednagar District. It belongs to Khandesh and Northern Maharashtra region . It belongs to Nashik Division . It is located 21 KM towards South from District headquarters Ahmednagar.

Total population of Bhorwadi is 1717 .Males are 865 and Females are 852 living in 366 Houses. Total area of Bhorwadi is 1527 hectares. Ahmednagar is the Nearest Town to Bhorwadi which is 21 km from Bhorwadi. A good road connectivity is there from Ahmednagar to Bhorwadi.

4.3.4 Akolner

Akolner is a village near Ahmednager in Maharashtra, India. Akolner is 16 km far from its District Main City Ahmednagar . It is 105 km far from Pune . The nearest towns are Ahmednagar (16.2 km), Rahuri (45 km), Pathardi (58.7 km) and Nevasa (68.6 km). It is a place of pilgrimage known for Vithoba Rukhmai temple & famous for

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the chariot festival (Rath Yatra) which falls on Ashadi Pornima of the Indian calendar. It is also famous for milk production, peacocks found in farms & floriculture. The total population of the village is 2518.

4.4 Vegetation

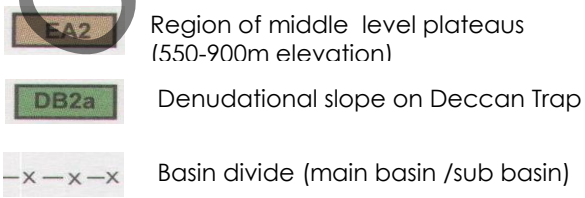
The vegetation found here belonged to the dry mixed deciduous forest with thorny bushes marking the site regularly. Commonly seen species were Azadirachta indica(Neem), Ficus bengalensis(Bargad), Tamarindus indica(Imli), Acacia niltotica and subspecies(Babool), Ailanthes excelsa (Mahaneem), Luceana luecocephala(Subabool), Capparis decidua(Kair),Zizyphus mauritiana(ber) and Mangifera indica(Mango).

4.4.1 Characteristics of vegetation found

- Hardy plants were seen in majority.
- Required less water ,adapted to low water and dry weather conditions.
- Small pinnate leaved to thorny bushes –another adaptation for xerophytic conditions. ex- Tamarindus indica, Acacia nilotica
- Growing on poor soils to black, brown cotton soils. For ex- Neem.
- The deep root system which reaches deep down in search of moisture. Ex- Kair

4.5 Geomorphology

- **Denuadational hills and valleys on Deccan Trap** –Are result of long term of wearing away of the earth surface leading to reduction in elevation and relief of landforms and landscapes.
- Denudational hills are low relief hills.



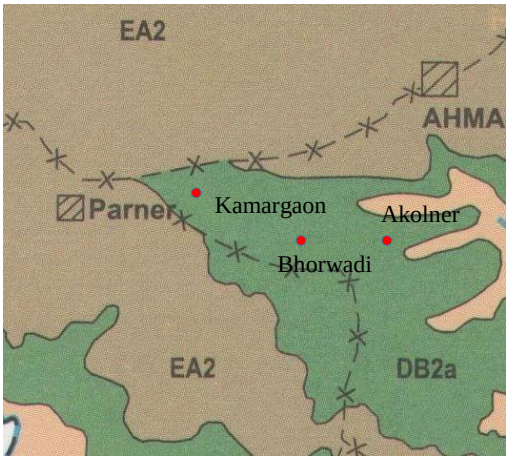


Figure 38 - Geomorphology of site

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Figure 39 - Denudational hills on site

Figure 40 - Kamargaon Lake (Source – author)

4.6 Geology

Part of **Deccan Trap** Or Sahyadri Group.

Characteristics of soils -

Dark to grey colored, fine to medium grained soil, massive, hard, compact.

The chief soils of the entire basin are *kali* or black with a variety of gradations depending upon the local terrain conditions and slope. The soils, by and large derived from weathering of basalts under tropical semi-arid climatic conditions, are ***regurs*** (black cotton soil), a type of clay loam that is moisture-retentive. In this the soil is more suited to wheat than to cotton, excessively sticky and hard to work during rains and full of cracks in the hot weather.

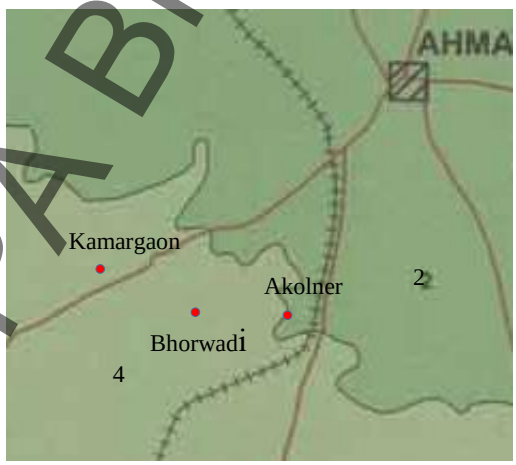

Figure 41- location of site on geological map

pahoehoe flows and some Aa flows (Max. 260m) –

region

5 Aa and 1 compound pahoehoe basaltic lawa flows (Max. 150m) –

Figure 43 - Rock strata on road edge

Figure 42 - Variation of soil on site (source-Author)

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4.7 Landuse

Waste land

The summits and slopes of the hills of the Ahmednagar plateau are uniformly bare of trees, the depth of soils not affording nourishment for anything more than stunted bushes of *khair* trees (*Acacia catechu*) and prickly cactus which at a distance can hardly be distinguished from the basalt boulders which are strewn over the hill-sides.

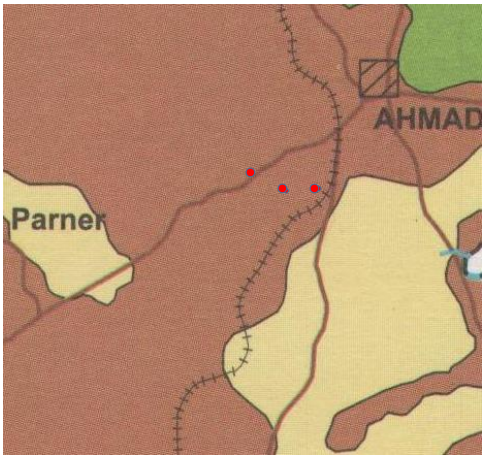

Figure 44- location of site on landuse map

Figure 46- uncultivated land seen in foreground (source- author)

Figure 45- bare hills on site (source- author)

4.8 Geohydrology

- The major part of the district is underlain by the basaltic lava flows, which were formed by the intermittent fissure type eruptions.
- The ground water occurs under **phreatic, semi-confined** and **confined** conditions. Generally the shallower zones down to the depth of 20 m bgl form phreatic aquifer.

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- The water bearing zones occurring between the depths of 20 and 40 m are weathered interflow or shear zones and yield water under semi confined conditions. Deeper semi-confined to confined aquifers occur below the depth of 40 m as the borewells drilled have shown presence of fractured zones at deeper depths at places.

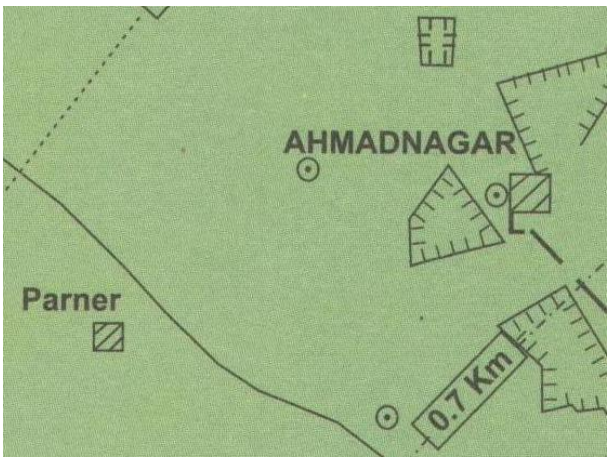

Figure 47- Geohydological map of site

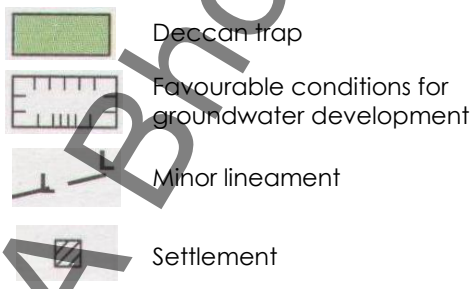

Figure 49 - black soils available in valleys (source- author)

Figure 48- hills are covered with thin and poor soil (source- author)

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CHAPTER 5

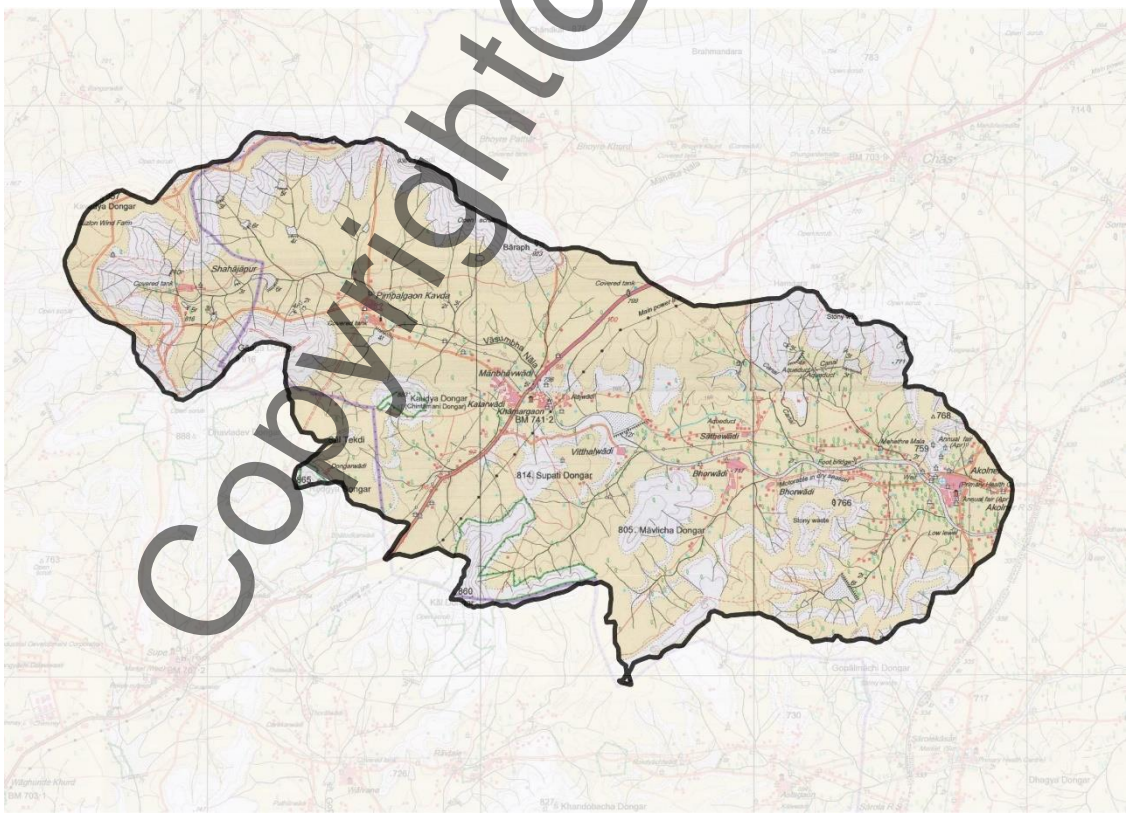
SITE MAPPING AND ANALYSIS

5 SITE MAPPING AND ANALYSIS:

5.1 Mapping :

5.1.1 Google earth map :

5.1.2 Toposheet :



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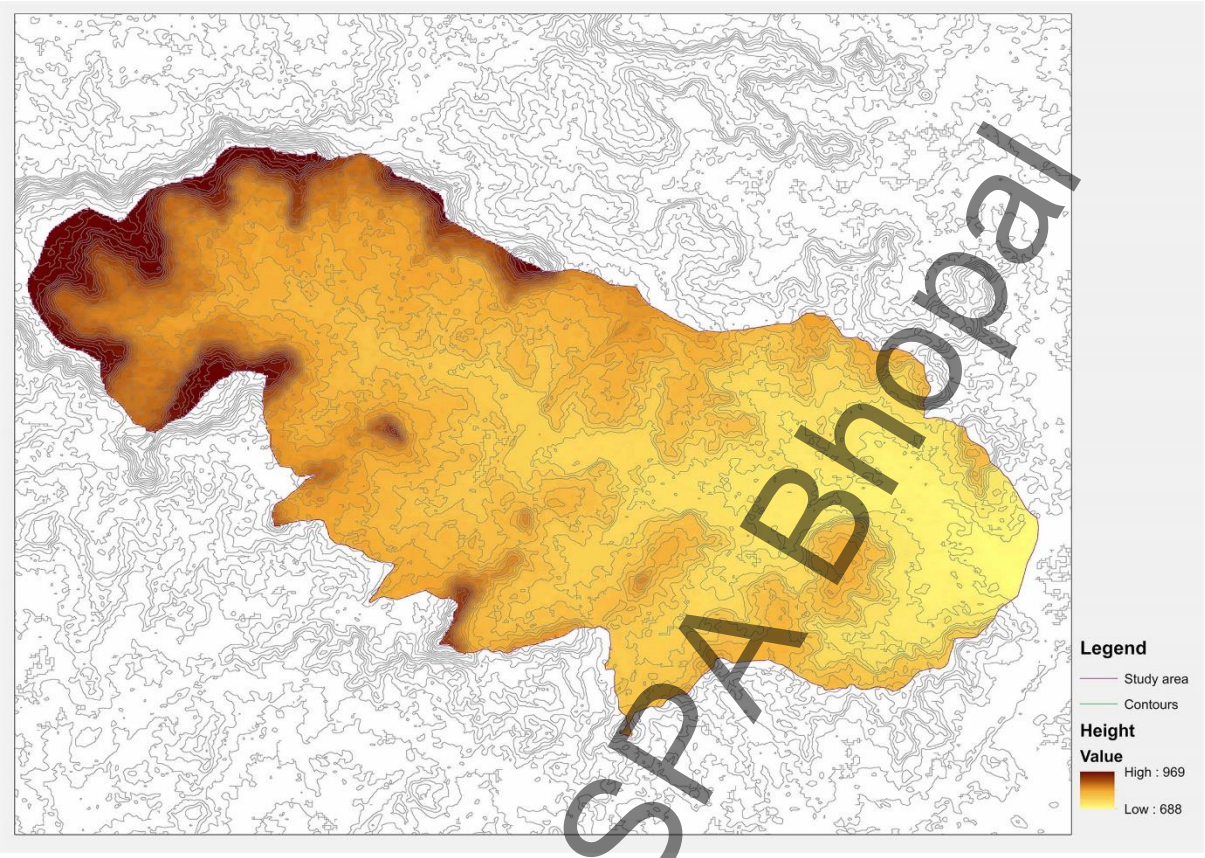
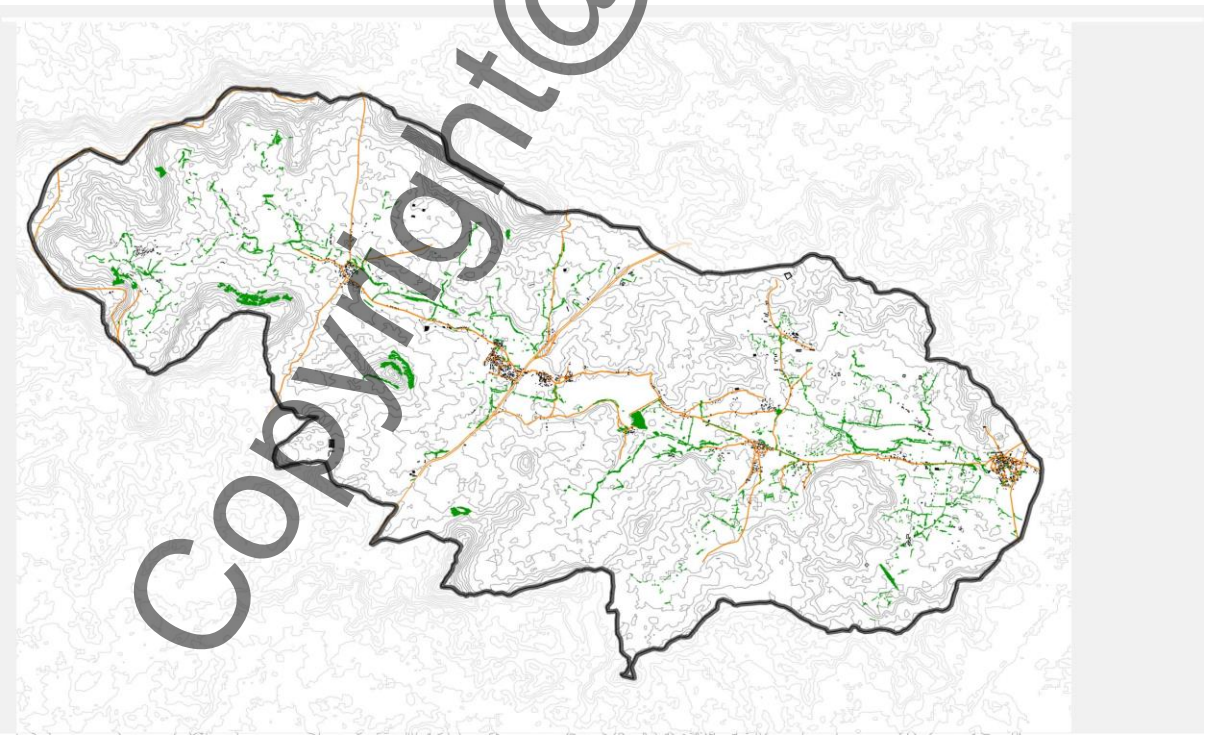
5.1.3 Elevation map



5.1.4 Base map



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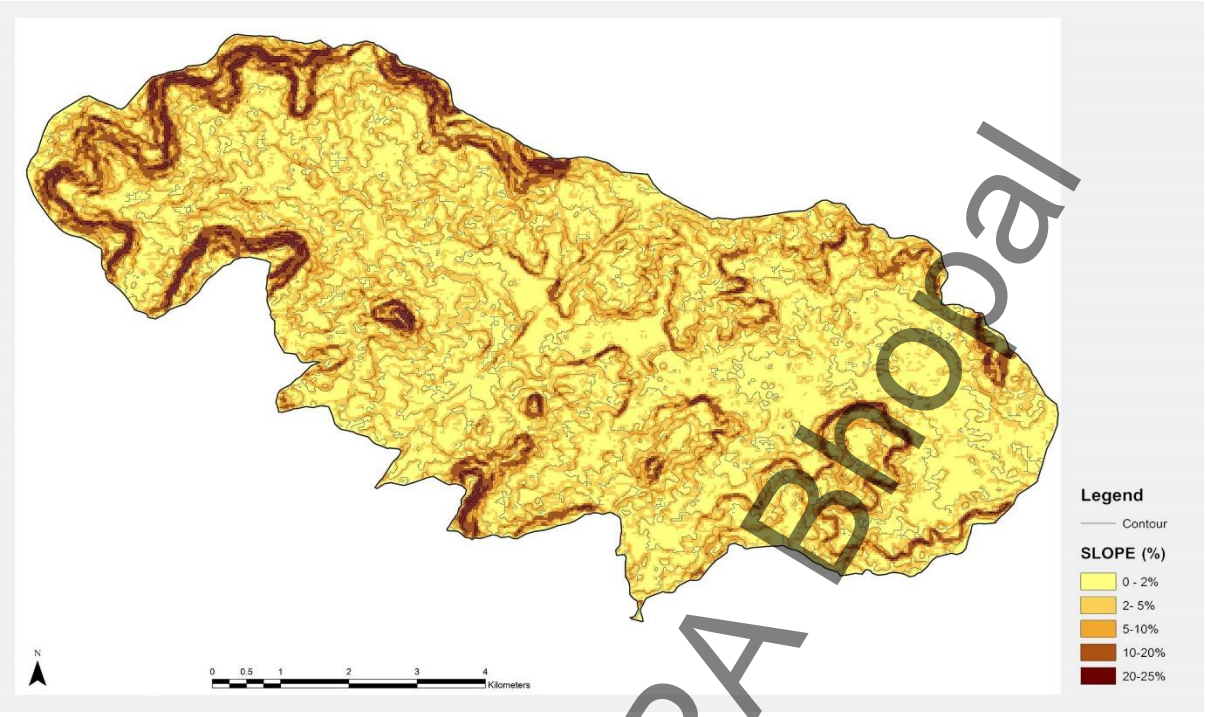
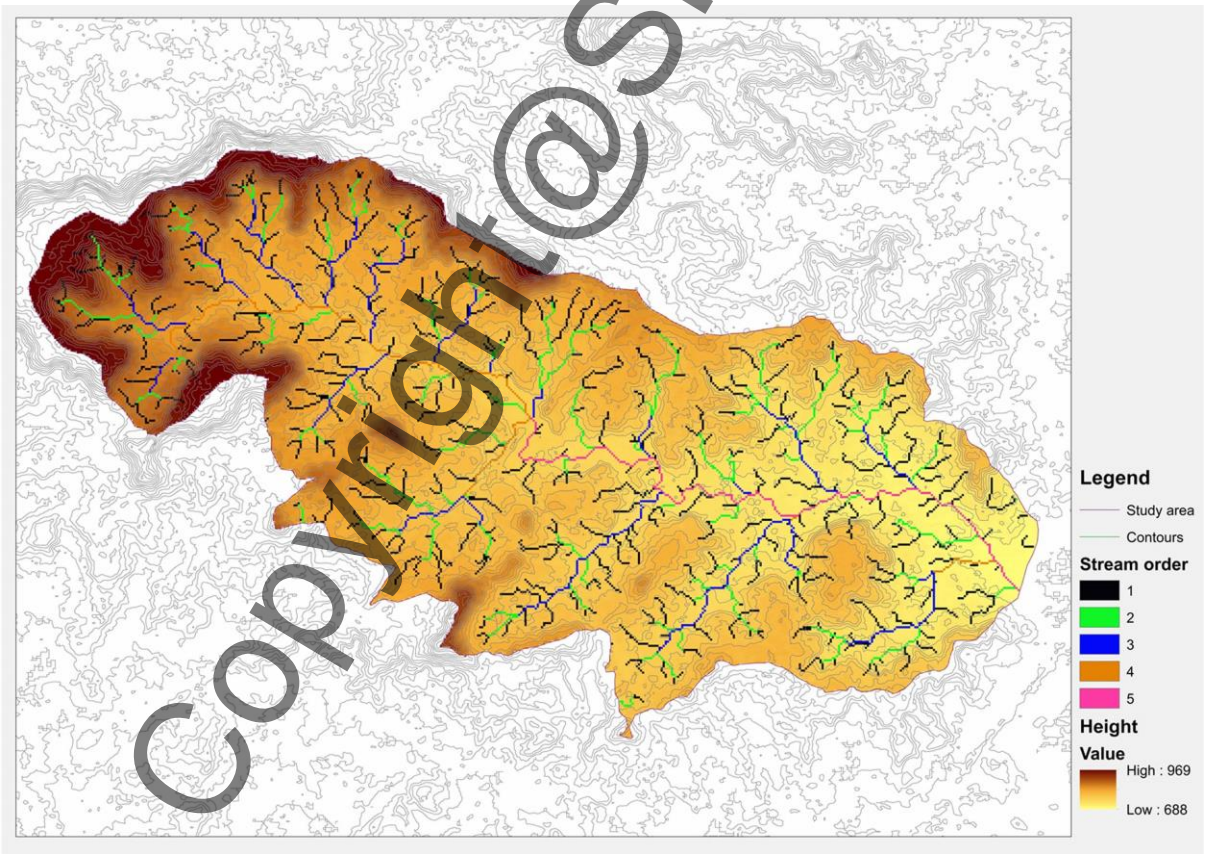
5.1.5 Slope Analysis:



5.1.6 Stream order map



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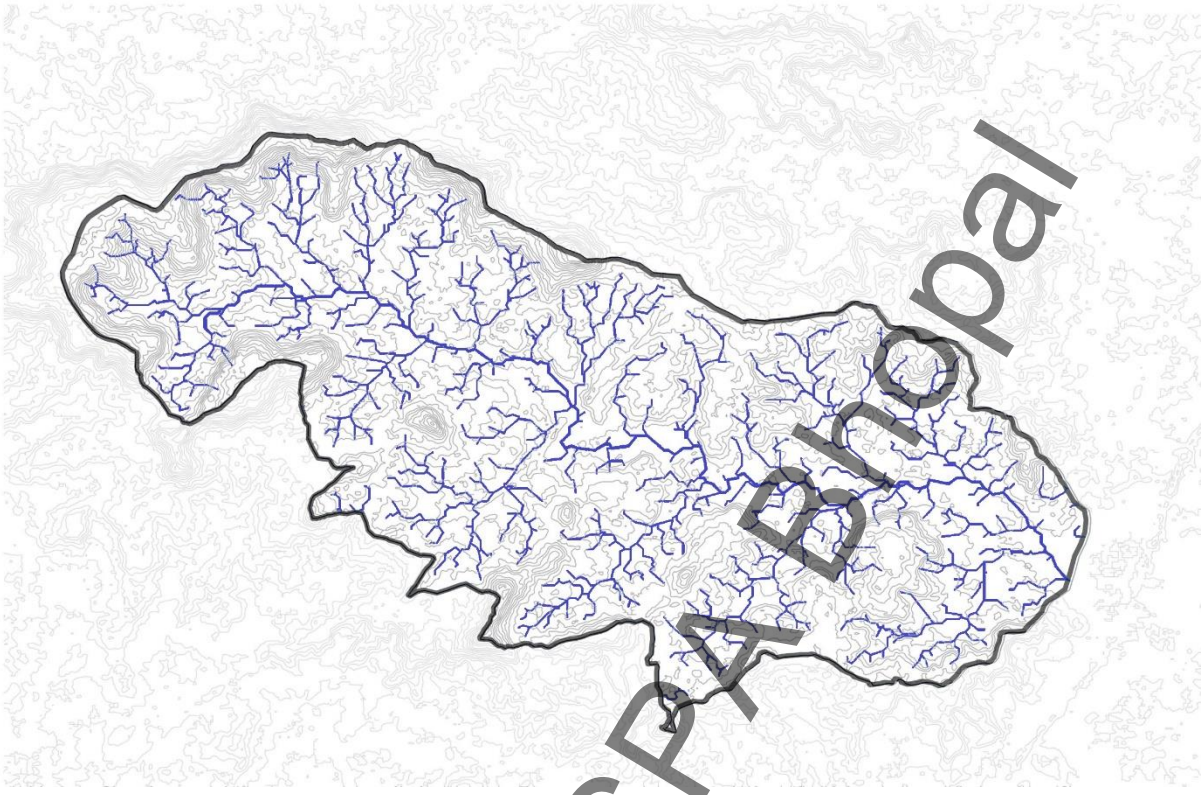
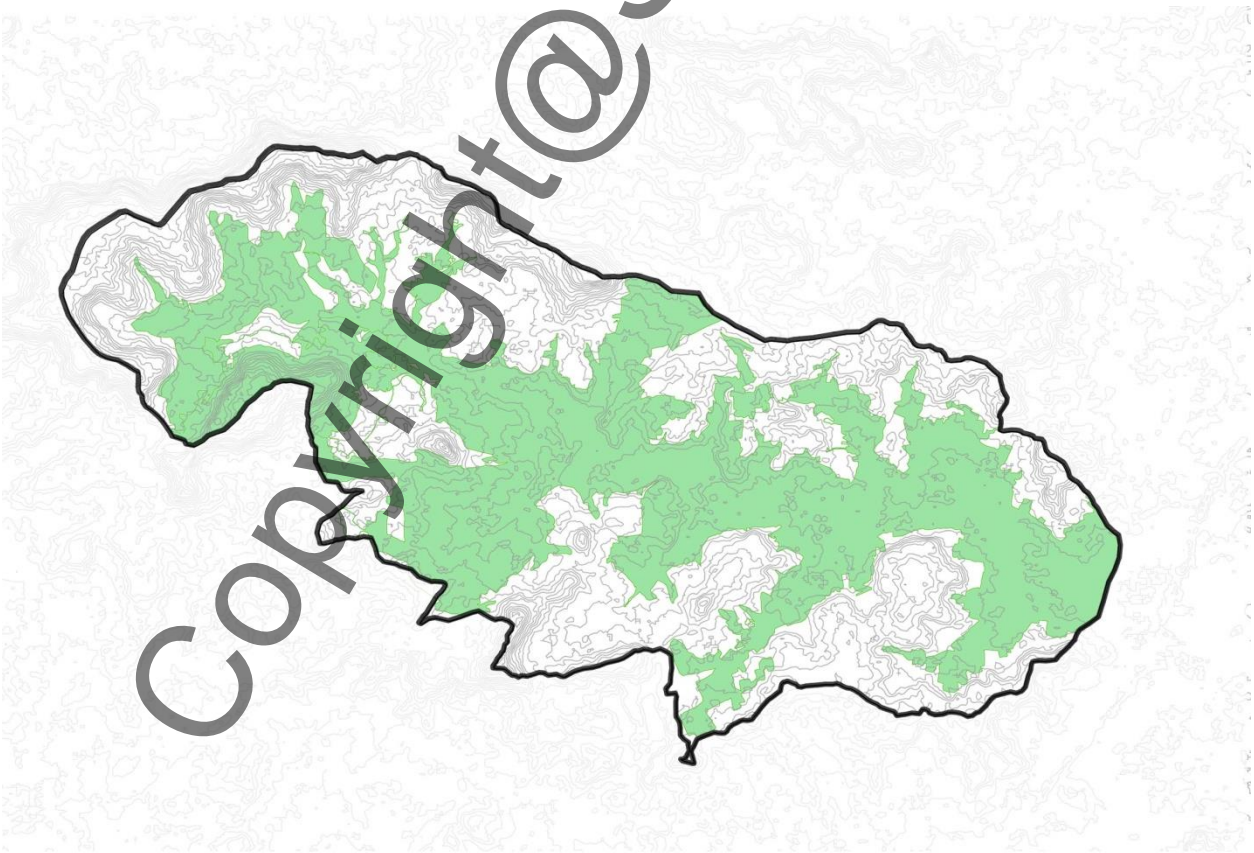
5.1.7 Drainage map



5.1.8 Cultivated Land



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5.2 Site level Issues

5.2.1 Wells:

The site consists of traditional step wells at many places but the old wells are poorly maintained.

The newly constructed - dugwells are made up of Cement concrete to a certain depth ,but these concretized side walls are not provided with any weep holes to allow water seepage through them unlike in the case of traditional stone masonry wells where the water could seep through the side walls as well.

5.2.2 Deforestation:

Trees like Babool (acacia nilotica) and neem (Azadirachta indica) are chopped down for timber and fuel purposes by local villagers.

5.2.3 Water intensive cropping:

Cash crops are taken in the downstream of Vasumba nala as water availability remains high for a longer period of year due to the presence of Kamargaon lake.

5.2.4 Hill degradation:

Hills and hill slopes are completely degraded of any type of vegetation.

5.2.5 Loss of natural vegetation:

Natural vegetation is left only on the site on few farm bunds or boundaries and some clusters around the water bodies.

5.2.6 Soil erosion :

Soil cover on the hills is very shallow and poor (absence of humus layer) hence supporting only a few species of trees and shrubs. Soil erosion is seen on the hill slopes as there is very less or no vegetation cover.

5.2.7 Other Issues :

Borewell remains a favorite choice for ground water extraction in individual plot in spite of having a number of dugwells.

Few of the water harvesting structures such as check dams were constructed but they remain dry even much earlier to the onset of summer months.

The major dependency for the water in peak months of march to June remains on the Water Tankers.

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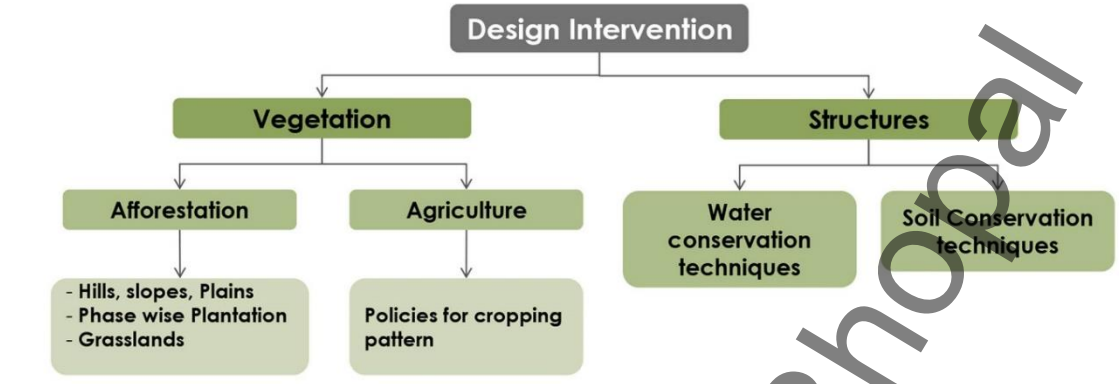
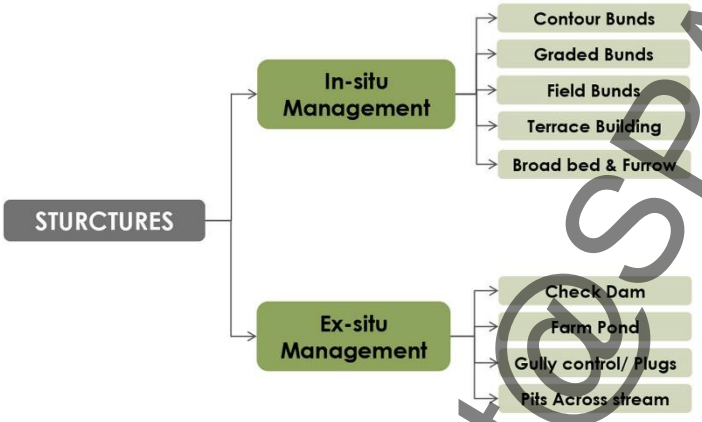
CHAPTER 6

PROPOSALS

6 PROPOSALS:

6.1 Design Approach





Ex-situ Management :
- Reduce peak discharge
- Reclaim gully formation
- Harvest substantial amount of runoff
- Increase in Ground water & Irrigation potential

In-situ Management :
- Protect Land degradation
- Improve soil health
- Increase soil moisture
- Ground water recharge.

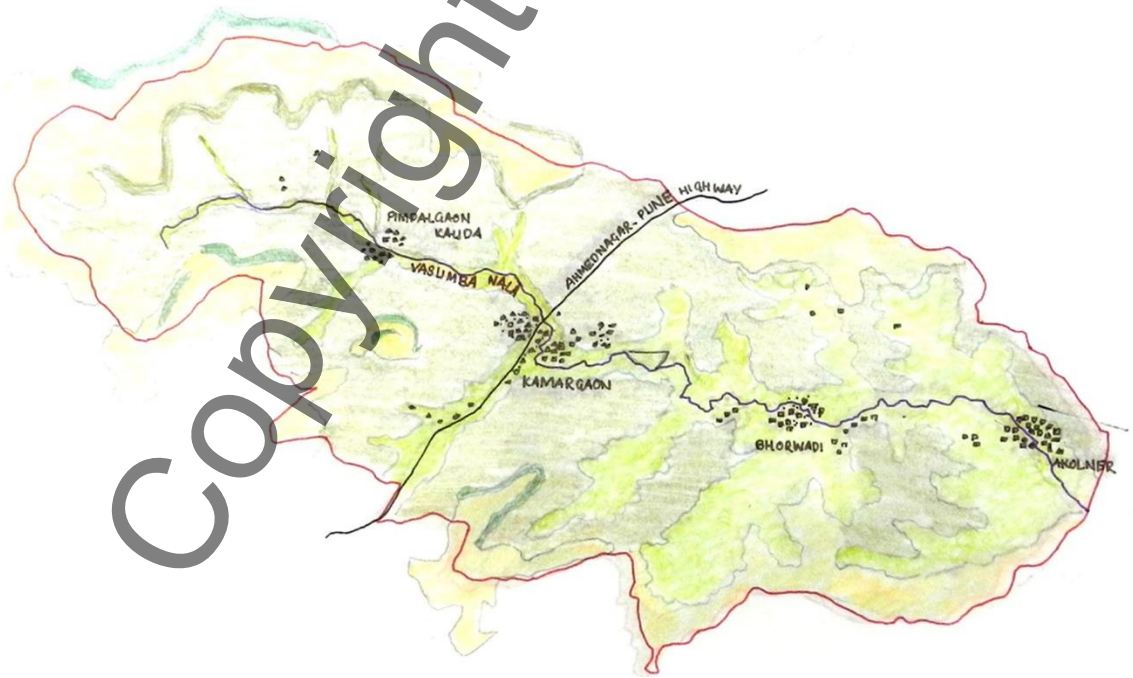


Figure 50 - Initial mapping of existing landuse (source- author)

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Figure 51- Initial marking of proposed landuse (source -author)

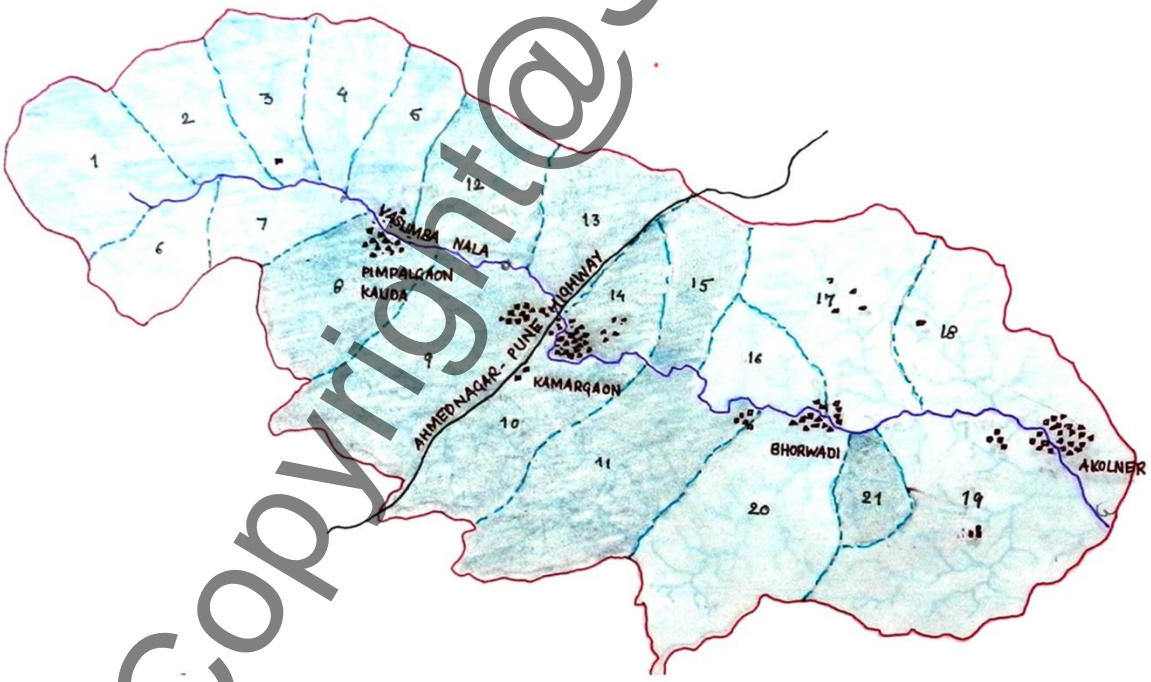

Figure 52 - Identifying the micro watersheds on site

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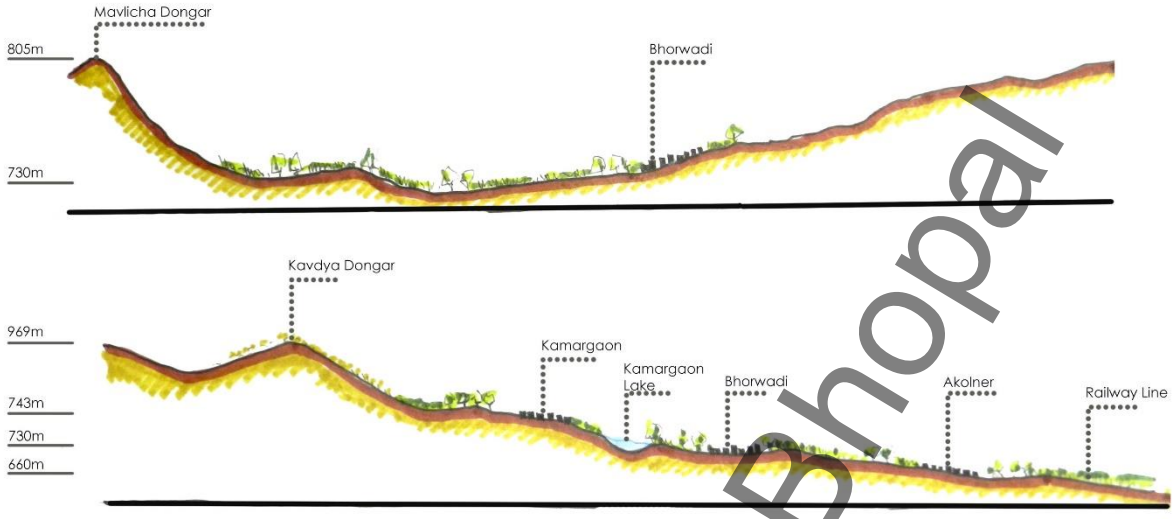

Figure 53 - Site sections to understand the topography

6.2 Proposed Landuse :

6.2.1 Watershed :

The watershed is a natural hydrological entity that covers a specific aerial expanse of land surface from which the rainfall runoff flows to a defined drain, channel, stream or river at any particular point. It is a general phenomenon governed by topography of the terrain.

Types of watersheds

a. Macro watershed: 1000 -10,000 ha

b. Micro watershed: 100 -1000 ha

c. Mini watershed: 10 -100 ha

d. Mille watershed: 1 -10 ha

Site Watersheds:

The entire macro watershed of Vasumba nala is further divided into three typologies of 22 micro watersheds depending upon slope and runoff. These are upper hills, middle hills and plains and lower plains. The entire area of macro watershed of Vasumba nala is 44 sq km or 4400 Ha.

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6.2.2 Existing Landuse Map:

All the major settlements are lying in the main drainage line of vasumba nala along the major valley of the site. The cultivable land is formed around the drainage line along the major and minor valleys. The scrub lands surround the cultivatable land.

These scrub land spreads over the slopes of hills with shrubs like cassia auriculata(tarwad), calotropis gigantea(aak) only be seen. The hill tops are comparatively flat surfaces but devoid of any type of major vegetation. Only seasonal grasses are seen on these hills which are later grazed down by the local communities.

6.2.3 Proposed Landuse Map :

After analysing the existing land use issues the proposal is derived in two major categories-

Afforestation of hills Converting scrub lands into permanent grasslands. Hills are proposed to be afforested in two major phases.

1) First phase –

This will ensure to restore the soil layer by planting grasses, groundcovers and shrubs of native origin.

These grasses will be left for a period of 1 year ,allowing to form mulching over the ground and subsequently increasing the organic matter of top soil.

2) Second phase –

This will consist of major tree plantation in which species would be selected on the basis of various criteria like water requirement, soil improving capacity, fuel, fodder, gum etc.

6.3 Planting strategy:

6.3.1 Grasses :

1)A range of under storey and ground cover species should be planted and not just trees.

2)Grasslands are proposed to be given on the slopes of the hills so they could act as a buffer zone to the forested land above and also specially allocated grazing reserves.

3) All the plant species are carefully chosen from native plant pallet of trees ,shrubs and grasses to sustain dry ,low water conditions prevailing on site.

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6.3.2 Shelterbelts

Revegetation on farm bunds would be more beneficial for stock, pasture and even crops. these linear patches would hold the native vegetation of site in form of grasses, groundcovers, shrubs and trees. To avoid shade to the adjacent crops ,tree branches on the lower side could be pruned . These shelterbelt can also act as wind and soil erosion barrier.

6.3.3 Trees:

Sr no.	Botanical name	Common name	Charachteristics	Uses
1	Azadirachta indica	Neem	Drought tolerant	Fuel, Foliage, shelter,oil seed
2	Acacia nilotica	babool	Soil improver and drought tolerant	Fuel, fodder, timber and gum
3	Albizia lebbeck	Kala shirish	Soil improver and drought tolerant	Fuel, shelter, timber
4	Acacia tortilis	Babool	Soil improver and drought tolerant	Fuel, fodder, gum
5	Prosopis cineraria	Khejri	Soil improver and drought tolerant	Fuel and fodder
6	Leucaena leucocephala	Subabool	Grow in weak soils also	Fuel ,fodder, timber and gum
7	Prosopis juliflora	Vilayti babool	Soil improver and drought tolerant	Fuel ,fodder, shelter and gum
8	Eucalyptus camaldulensis	Nilgiri	Drought tolerant	Fuel, shelter and timber
9	Dalbergia sisoo	Shisham	Drought tolerant and grows in shallow soil depth	Timber,fuel
10	Cassia siamea	kasod	Drought tolerant and grows in shallow and weak soils	Shelter ,timber

Table 4- List of trees used for afforestation

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6.4 Afforestation plan:

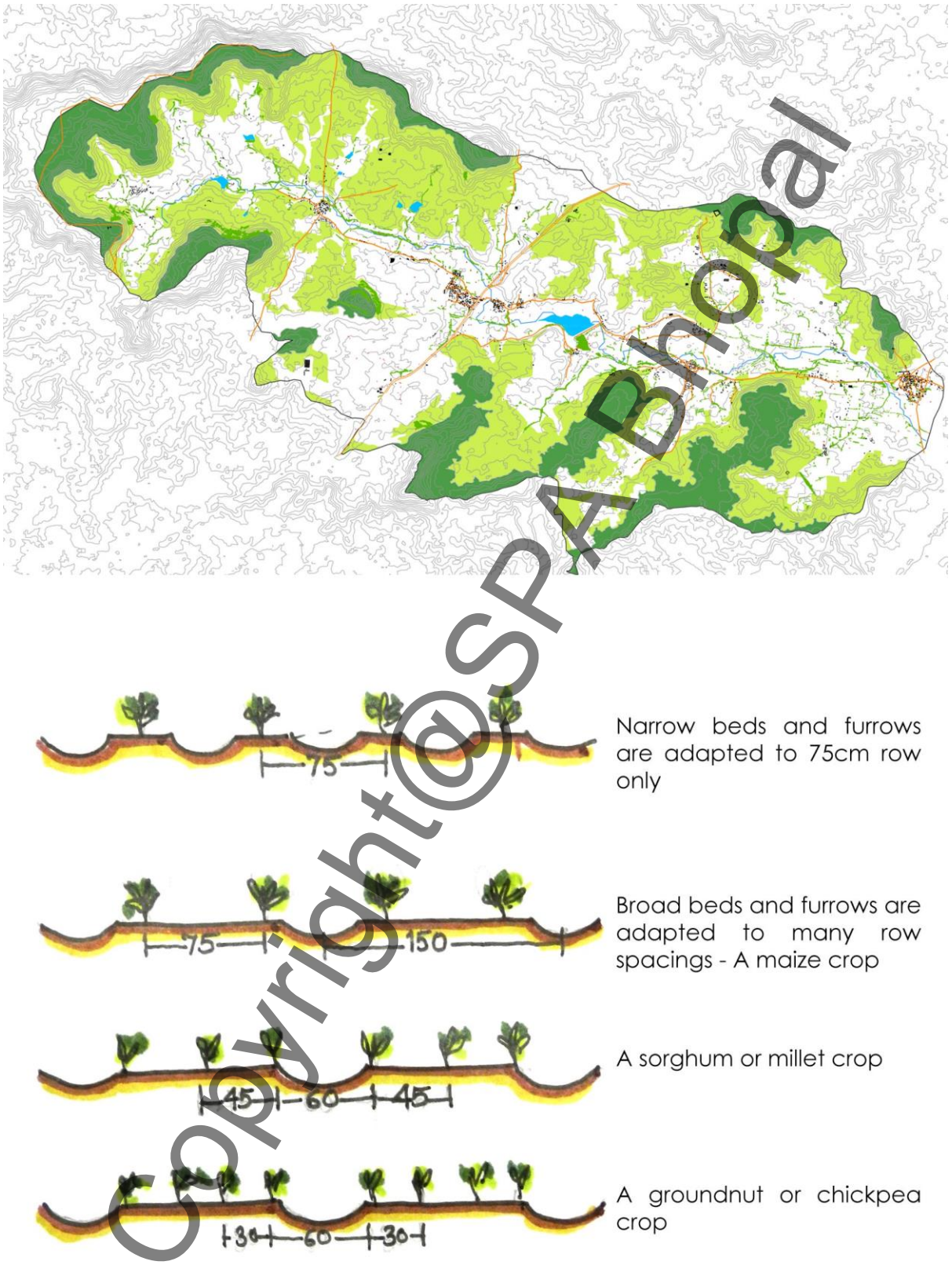

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Figure 54 - Techniques for sustainable cultivation

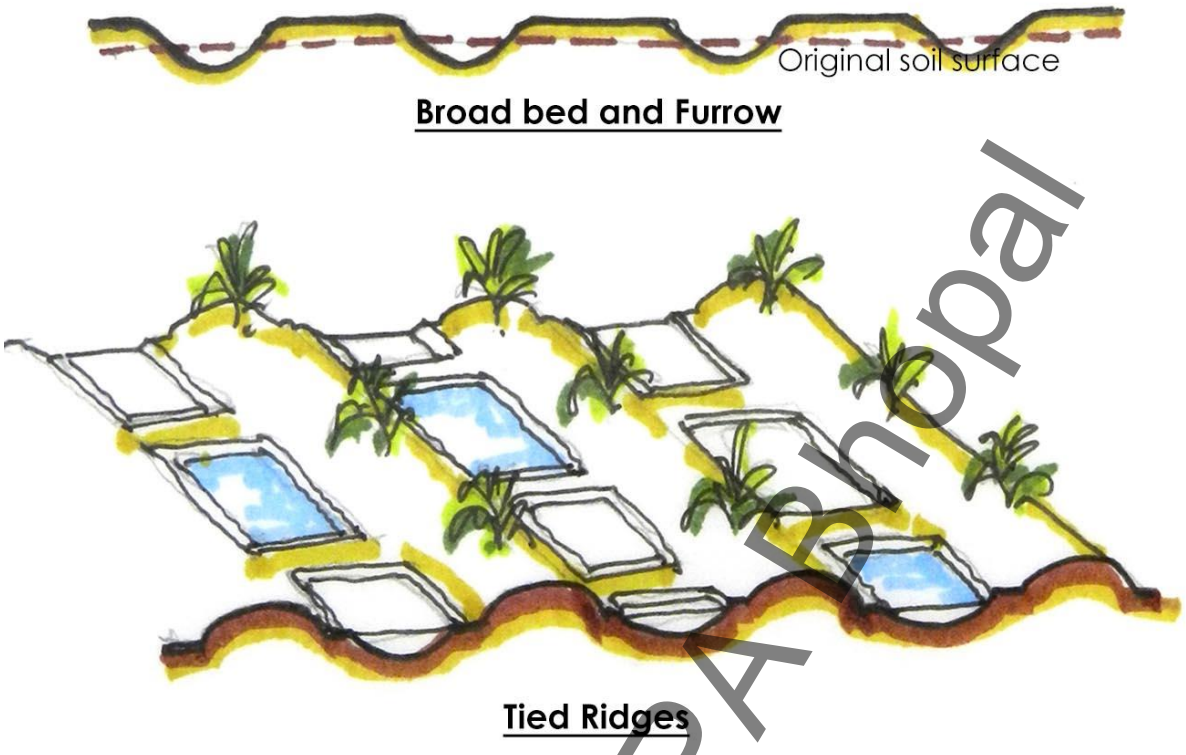

Figure 55 - Water harvesting techniques on farm lands

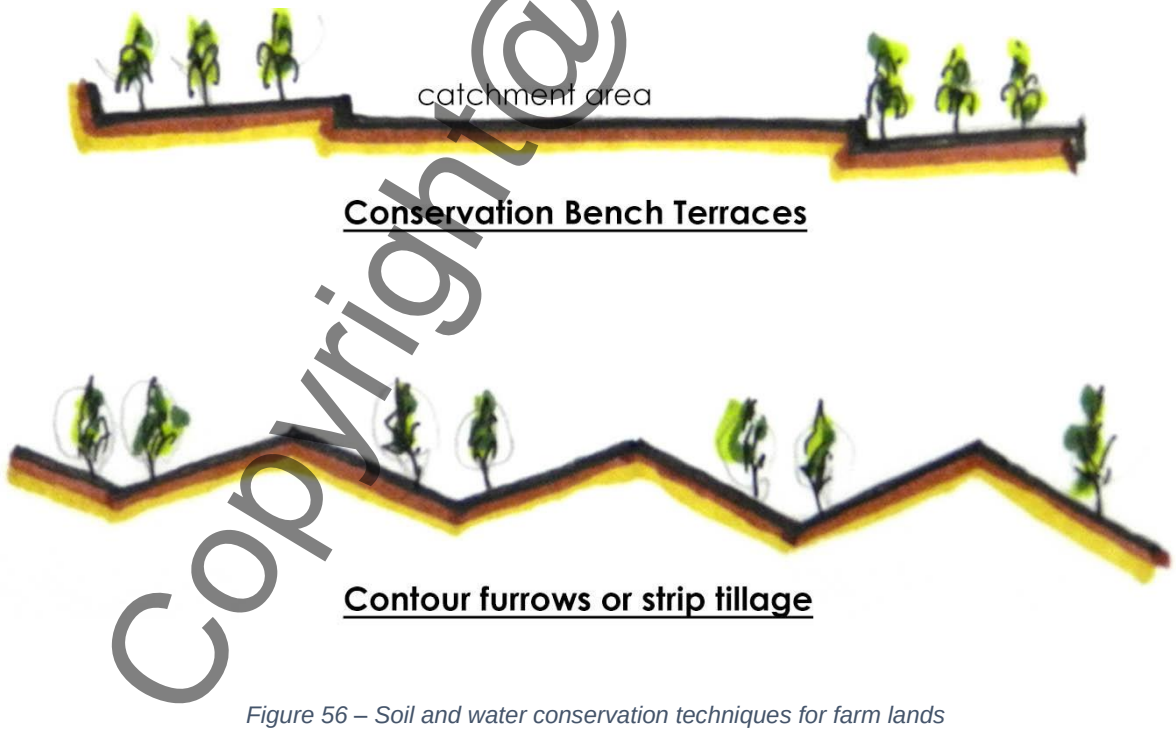

Figure 56 – Soil and water conservation techniques for farm lands

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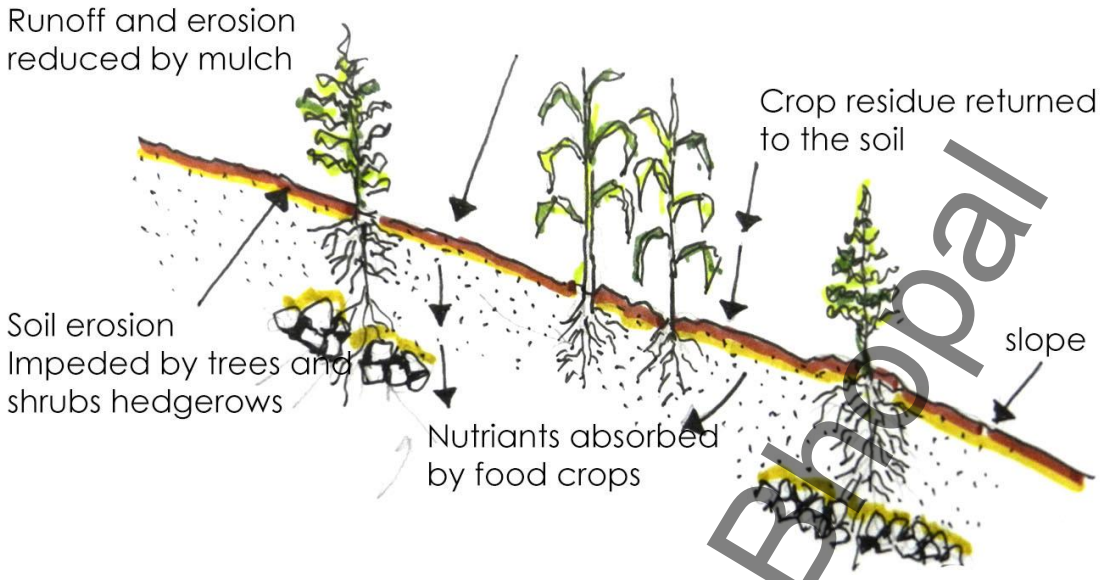

Figure 57 - vegetative methods of soil conservation on slope

Figure 58 - Shelterbelts along the farm bunds

A mulch is a layer of material applied to the surface of an area of soil. It's used for the following purpose:

- To conserve moisture
- To improve the fertility and health of the soil
- To reduce weed growth
- To enhance the visual appeal of the area

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Figure 59 - Layers of vegetation

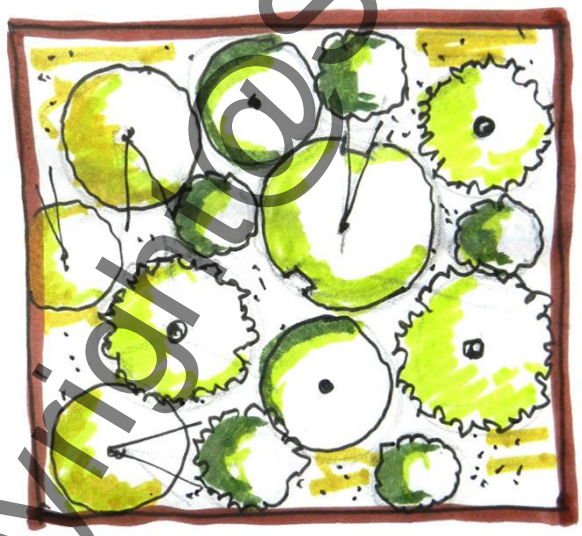

Figure 60 – Mixed vegetation instead of monoculture for afforestation

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6.5 Structural method for soil and water conservation:

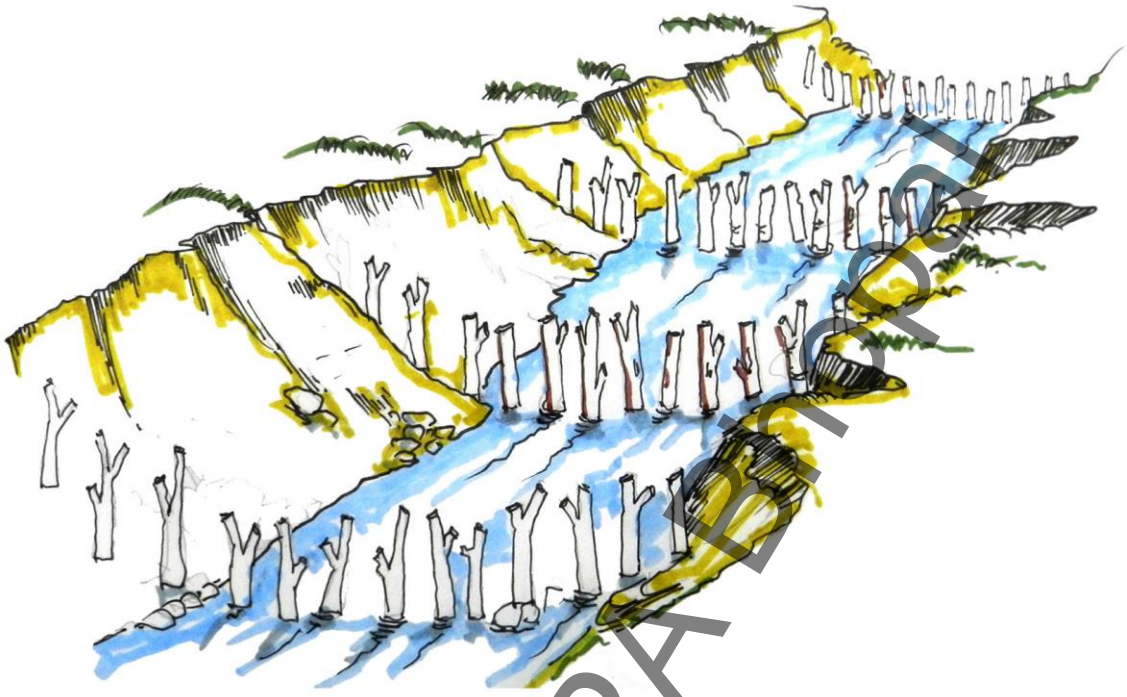

Figure 61 – Gully plugs to control soil erosion

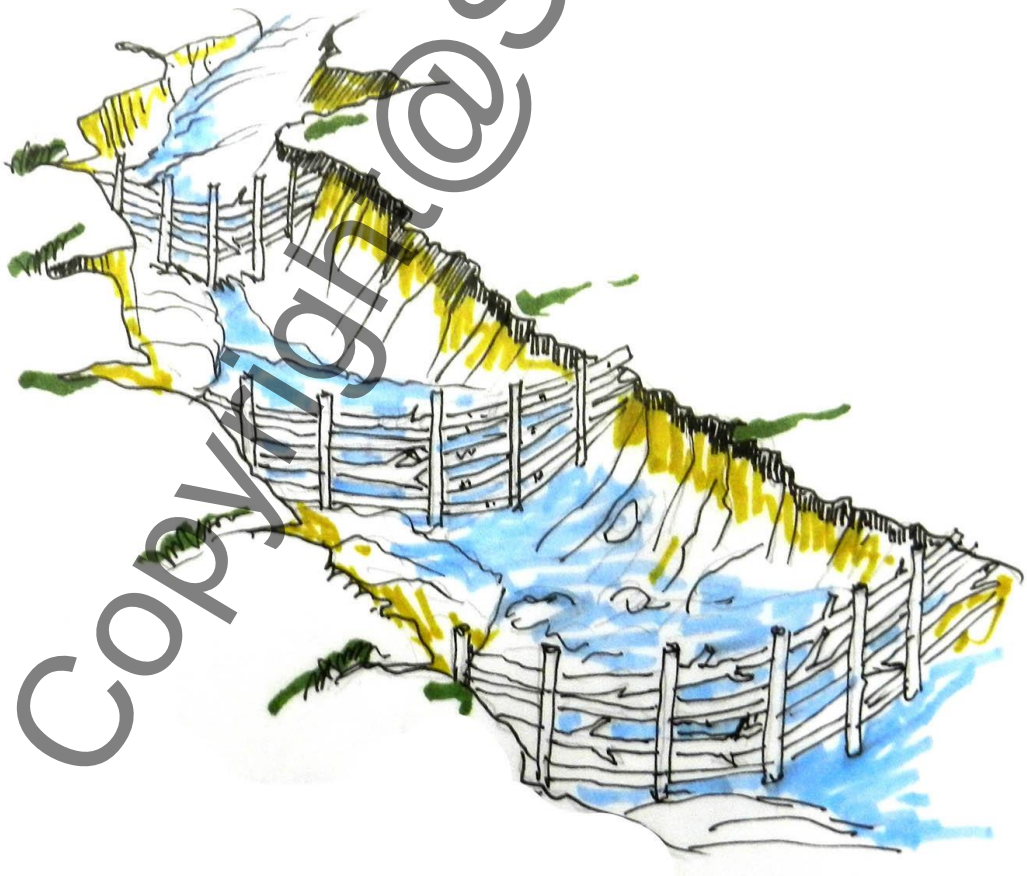

Figure 62 - Gully plug

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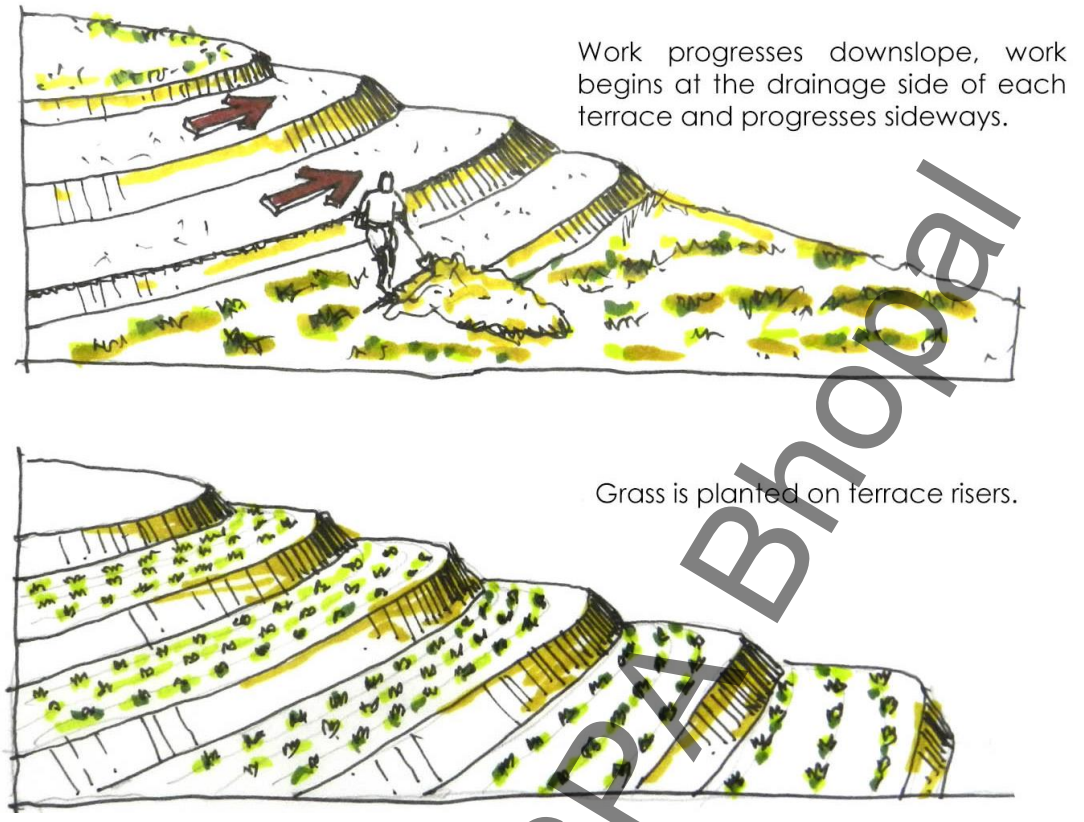

Figure 64 – Terracing technique for soil conservation

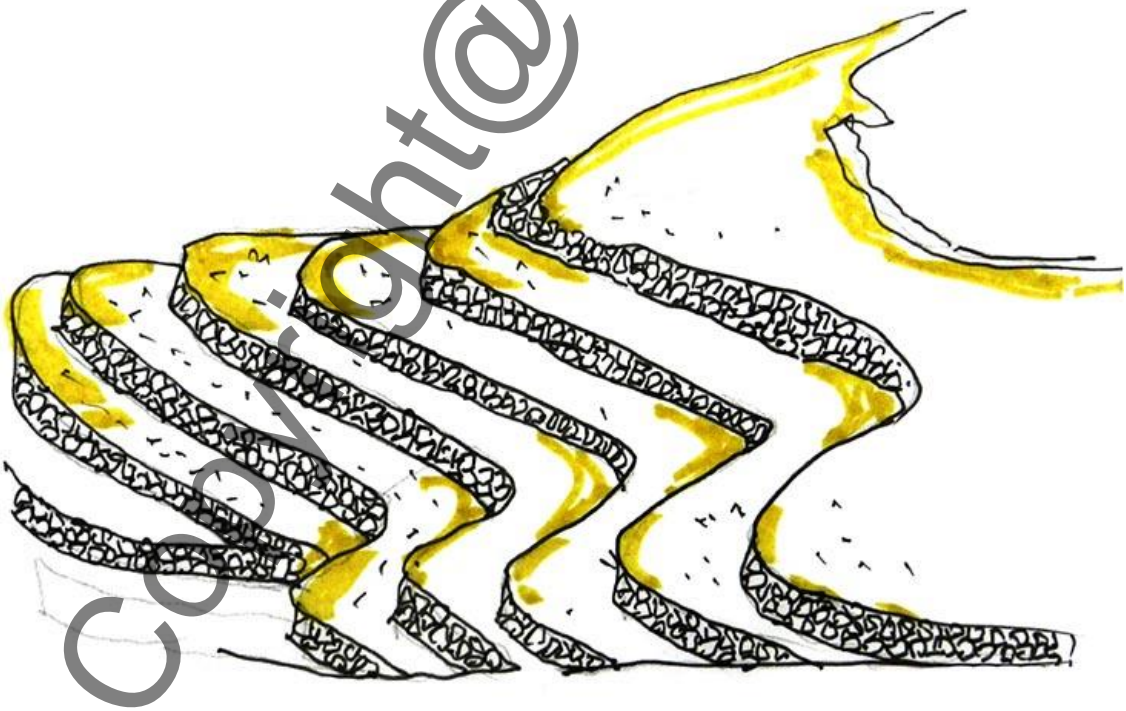

Figure 63 - Stone bunding along the terraces on gentle slopes

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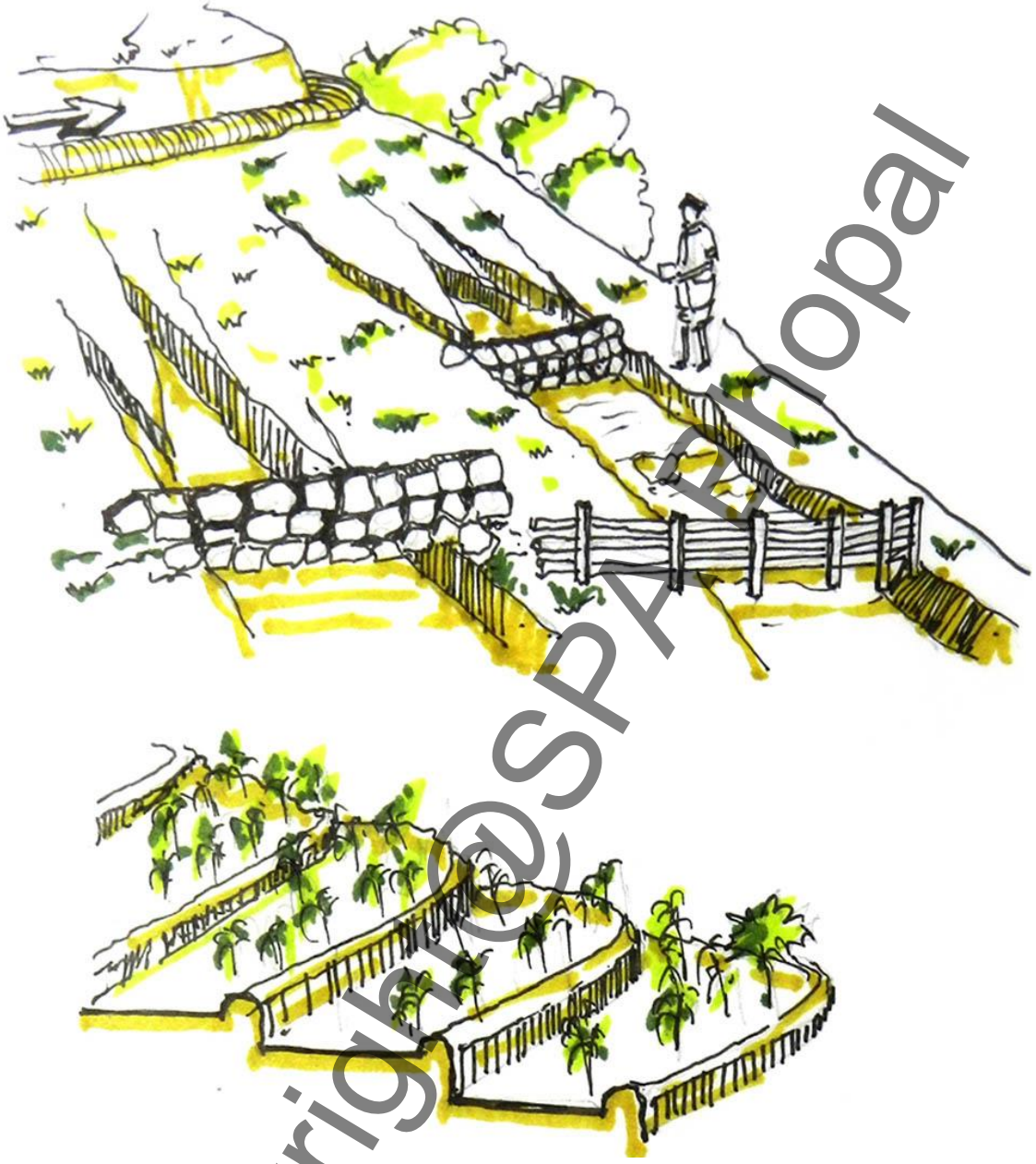
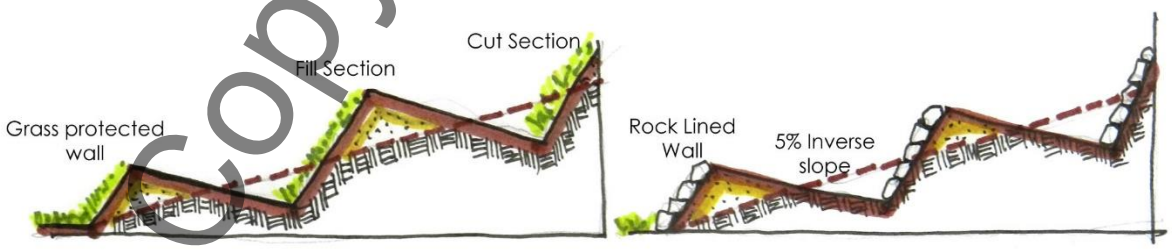


Figure 65 - Methods to control soil erosion



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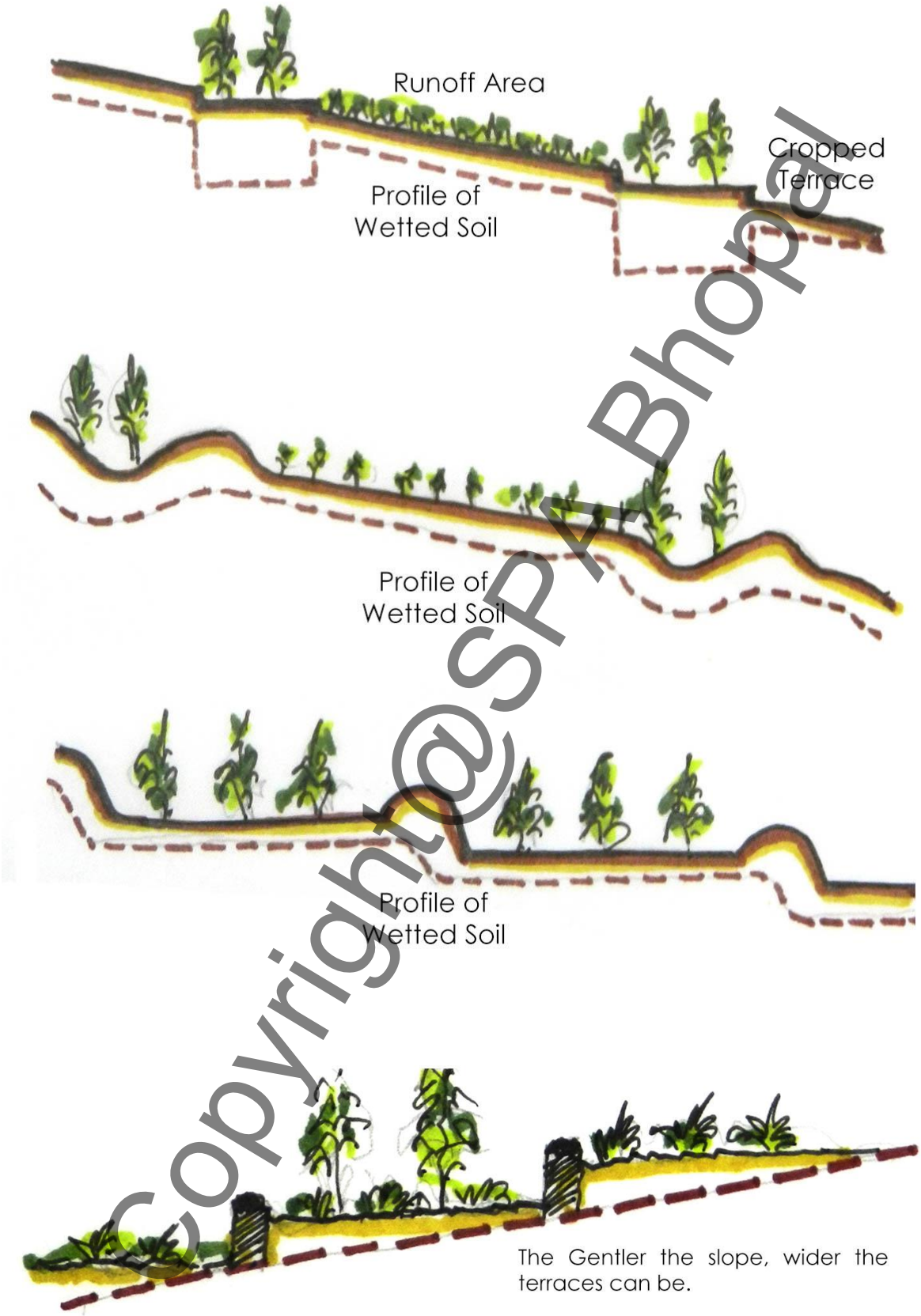

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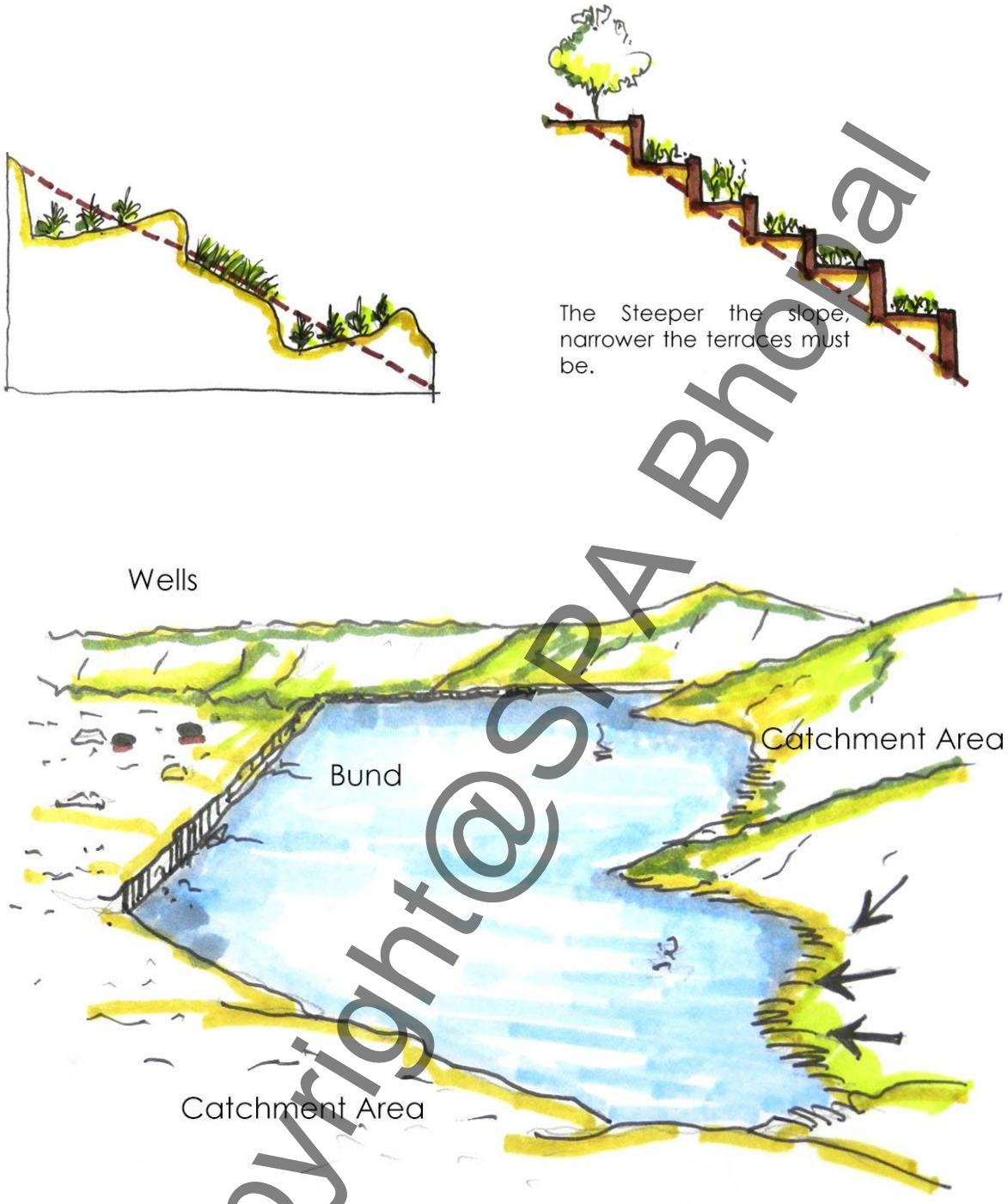

Figure 66 - Khadin system of water harvesting

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CHAPTER 7

CALCULATION AND POLICIES

7 CALCULATION AND POLICIES

7.1 Runoff Calculations:

7.1.1 Factors affecting runoff:

1)Watershed area

2)Slope

3)Rainfall intensity

4)Vegetation

Slope and catchment – steep slope plots produce more runoff quantity which decreases with increasing slope length.
Vegetation – it slows runoff and acts as a filter to catch sediment.
The sample micro - watersheds are taken from the site and existing as well as runoff after proposed land use is calculated approximately.

7.1.2 Runoff :

The following calculations are done by using Rationale method of computing Runoff.
Following are the assumptions used for calculation-

Annual average rainfall – 578 mm
Number of rainy days in year – 35 days.
Rainfall intensity – 19.26 mm/s

Runoff = runoff coefficient x rainfall intensity x watershed area

(Source- CGWB Report ,Ahmednagar and Gazeteer Dept .,Ahmednagar)

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7.1.3 Slope consideration for Runoff:

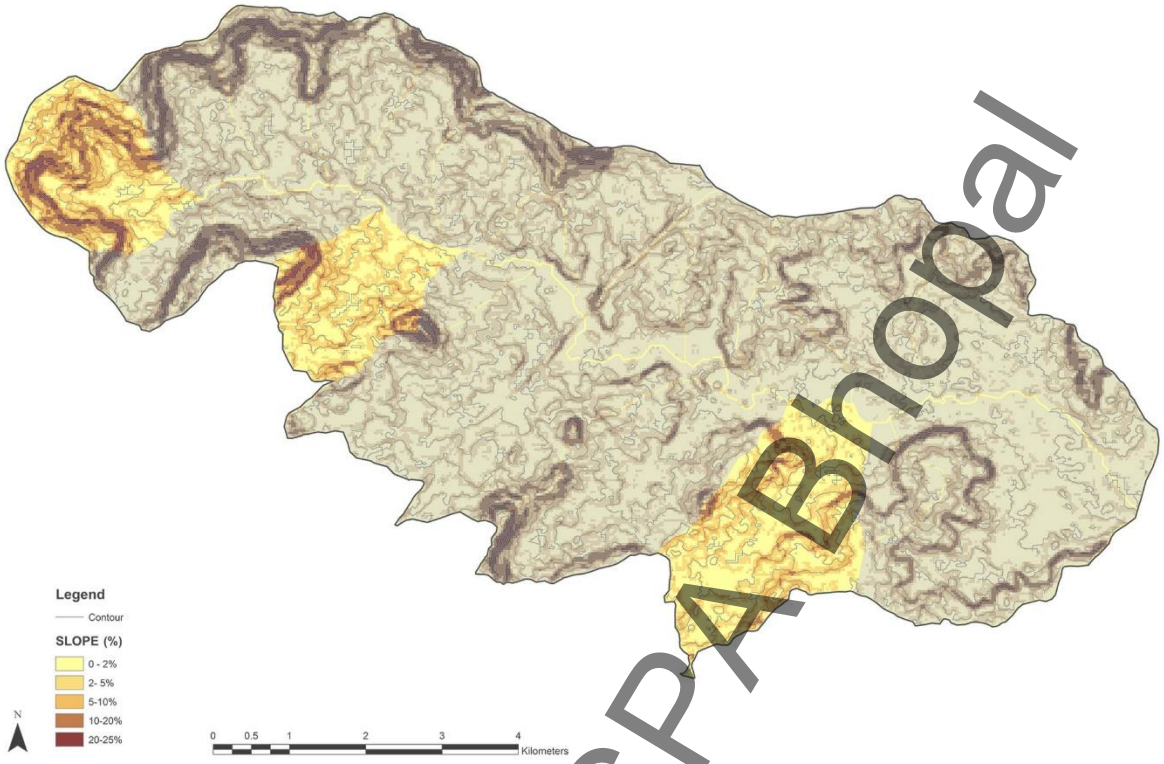

Figure 67 - Selected micro-watersheds on slope map

7.1.4 Micro Watershed – Runoff Calculation

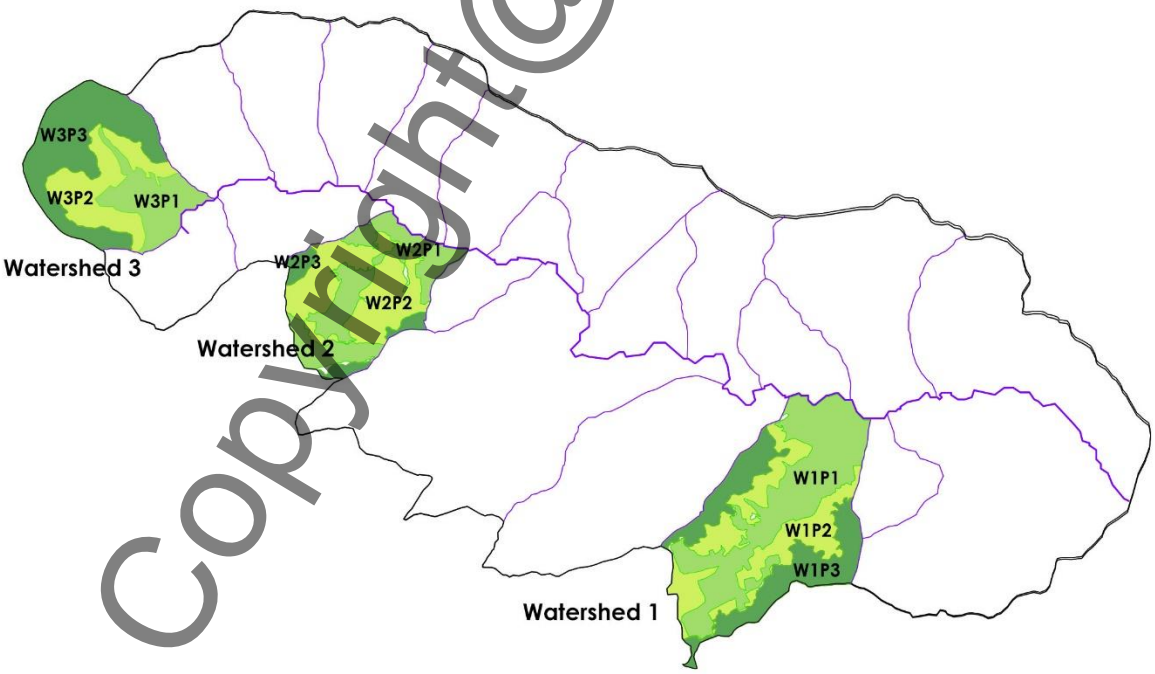

Figure 68 - Proposed landuse of selected micro watersheds

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7.1.5 Existing Runoff Calculation:

		Area(sq m)	Slope (%)	Rainfall intensity (mm)	Runoff coefficient	Runoff (litres)
WATERSHED - 1 (W1)						
W1P1		1264098	5	19.26	0.5	12173263.74
W1P2		864177	20	19.26	0.65	10818631.86
W1P3		840865	10	19.26	0.5	8097529.95
					TOTAL RUNOFF IN W1	**31089425.55**
WATERSHED -2 (W2)						
W2P1		732800	5	19.26	0.5	7056864
W2P2		804715	20	19.26	0.65	10074227.09
W2P3		162033	20	19.26	0.7	2184528.906
					TOTAL RUNOFF IN W2	**19315619.99**
WATERSHED -3 (W3)						
W3P1		457016	5	19.26	0.5	4401064.08
W3P2		546480	20	19.26	0.65	6841383.12
W3P3		915219	25	19.26	0.7	12338982.56
					TOTAL RUNOFF IN W3	**23581429.76**

Table 5 Runoff calculation for existing landuse for selected micro watersheds

7.1.6 Runoff Calculations for Proposed Landuse:

		Area(sq m)	Slope (%)	Rainfall intensity (mm)	Runoff coefficient	Runoff (litres)
WATERSHED - 1 (W1)						
W1P1		1264098	5	19.26	0.5	12173263.74
W1P2		864177	20	19.26	0.42	6990500.588
W1P3		840865	10	19.26	0.35	5668270.965
					TOTAL RUNOFF IN W1	**24832035.29**
WATERSHED -2 (W2)						
W2P1		732800	5	19.26	0.5	7056864
W2P2		804715	20	19.26	0.42	6509500.578
W2P3		162033	20	19.26	0.5	1560377.79
					TOTAL RUNOFF IN W2	**15126742.37**
WATERSHED -3 (W3)						
W3P1		457016	5	19.26	0.5	4401064.08
W3P2		546480	20	19.26	0.42	4420586.016
W3P3		915219	25	19.26	0.5	8813558.97
					TOTAL RUNOFF IN W3	**17635209.07**

Table 6 - Runoff calculation for Proposed landuse for selected micro watersheds

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7.1.7 Runoff comparison for existing and proposed landuse:

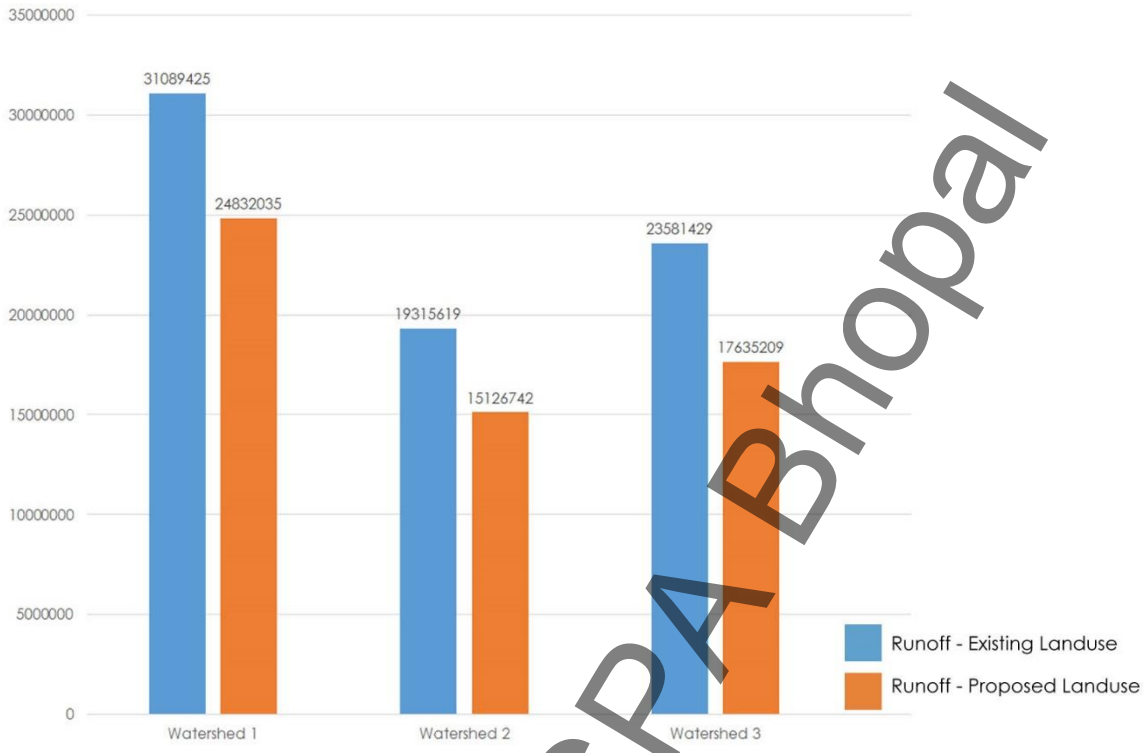

Table 7 - Runoff comparison for existing and proposed landuse

7.1.8 Outcome

The final outcome shows clearly the decrease in the runoff in the each of the watershed after increasing the tree cover and grasslands.

The increase in the forest cover will not only prevent soil erosion but the reduce velocity of water discharge will allow more amount to percolate down and result in rise of ground water gradually.

7.2 Policies:

Policies :

- Hills should be protected as village forest lands and special allocation for grazing lands to be given under Village grazing reserves(VGRs).
- Grazing should be banned completely in the initial phase of recovery of land and later only manual cutting should be allowed to villagers for domestic purpose only.
- Farm bunds should be promoted with more native vegetation of grasses, shrubs

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and trees as they will act as wind barrier as well as shelter belts.

- Wells should be provided with weep holes on the peripheral surface so as to allow percolation of water.
- Ban on borewells for individual agricultural uses. They can only be allowed for community drinking purposes.
- Cropping pattern should not be water – intensive and the local community needs to convince on cultivating selecting drought-resistant varieties such as jowar, millet ,vegetables etc.
- Where possible existing tanks should be restored and maintained . Restoration can involve silt removal to increase the storage capacity of the tank and reduce evaporative loss.

7.3 Findings:

1. The district being situated in "**Rain Shadow**" zone of Western Ghats, often suffers the drought conditions.
2. Almost entire district covering Ahmadnagar, Rahuri , Nevasa, Shevgaon, Jamkhed, Karjat, Srigonda, Pathardi and Parner talukas comes under "**Drought Area**" The major parts of the district are also showing falling ground water level trends mainly in central, northern and eastern parts of the district comprising almost entire Parner, Ahmadnagar, Rahuri, Sangamner, Shrirampur and Pathardi talukas and Jamkhed taluka in south eastern part of the district and parts of Shrigonda, Sangamner, Shevgaon and Akole talukas. Thus, the future water conservation and artificial recharge structures needs to be prioritised in these areas.
3. If the problem is not catered with due solutions the chances are very high that the landscape of this particular region will change from semi-arid to arid zone. This change can cause havoc in the ecology of the region.
4. The ideal examples of Hiware Bazar and Ralegan siddhi are exemplary but care needs to be taken for the villages in the lower plains .Hence the approach needs to be thoroughly studied before being designed and implemented. An **integrated watershed management** can be a better solution rather than a single village development which is the current approach of Govt and NGOs working in the region.
5. Many of the traditional water harvesting systems can be looked upon as sustainable solutions with a more improved approach. For ex- The **dugwells** are

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most suitable structures for ground water development in the district as 95% of the area is covered by Deccan Trap Basalt.

6. The ground water development is recommended in areas with high and medium potential observed in **almost entire** parts of Ahmadnagar.

7. The scope exists for construction of suitable **artificial recharge structures** in the district. The sites for artificial recharge structures need to be located where the hydrogeological conditions are favourable, i.e., where sufficient thickness of de-saturated/unsaturated aquifer exists and water levels are more than 5 m deep during postmonsoon and areas showing falling ground water level trends. Such areas are observed in almost entire Parner and parts of Ahmadnagar.

8. In Basaltic area, the artificial recharge structures feasible are check dams, gully plugs, percolation tanks, nalla bunds, etc. Existing dugwells can also be used for artificial recharge.

9. In parts, where prominent hill ranges, isolated hillocks and undulations etc., occur which allows for the **higher surface run off**. Hence **small schemes of water conservation** are proved to be quite useful for harvesting the surface run off and there by maintaining the supply during lean period.

10. Storage tanks for villages on hill tops, nala bunds, contour bunds, gully plugs, CCT etc., should be constructed after studying the feasibility.

11. The **existing village ponds** need to be **rejuvenated** to act both as water conservation and artificial recharge structures.

7.4 Conclusions:

1. The ideal examples of Hiware Bazar and Ralegan siddhi are exemplary but care needs to be taken for the villages in the lower plains .Hence the approach needs to be thoroughly studied before being designed and implemented. An **integrated watershed management** can be a better solution rather than a single village development which is the current approach of Government and NGOs working in the region.

2. Apart from the integrated watershed management, the present and traditional water conservation practices can give effective results at micro level if properly studied through layers of land and water and merged effectively with modern technologies.

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3. Awareness of local people towards the root cause of the problem is very important. Their involvement will be a key factor in deciding the success of the project. Thus suitable policies and programs to be drawn.

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