CHAPTER 4: TERRAIN CHARACTERISTICS

'Geomorphology, although concerned primarily with the present day landscapes; attains its maximum usefulness by historical extension'

- ***Bryan***

Terrain and its various attributes represent interplay of geological and geomorphological processes. Geological parameters like lithology-tectonism and structures manifest different geomorphic processes that operate in conjunction with area specific climatic vicissitudes.

Further, any modification in terrain is a function of numerous geomorphological processes that operate for a prolonged duration and their manifestations are seen through the diversity in the physiography, slope, landform & drainage characteristics, weathering & soils etc. In fact, variations offered in terrain characteristics play a significant role in assessing the available important resources for the mankind like land and water.

The candidate's endeavour to study the terrain characteristics of the Kim River Basin is with a sole aim of quantifying the land and water resources and assessment of human interventions that has impacted them. The information generated hitherto shall be utilized in computing the Water and Ecological Footprints of the basin.

PHYSIOGRAPHY

The Kim Watershed is geographically bounded between the Co-ordinates N - 21^0 19': 21^0 38' and E – 72^0 40': 73^0 27' and covering a total area of 1320 km^2. The Kim River basin has a general westward slope. The altimetriic variations begin at almost near sea level to as high as 220 metres. From the study of satellite imageries (Plate 4.1) and topographic maps. The study area has been divided into three physiographic divisions (Fig 4.1) viz-

i) The Eastern Rocky Highland (40 - 220m AMSL)

ii) The Central Alluvial Plain (20 - 40m AMSL)

iii) The Western Coastal Plain (< 20m AMSL)

The author from the point of view of offered homogeneity in the processes, material characteristics and land-use practices, adopted these physiographic units as Upper-Middle-Lower basins in the subsequent chapters.

i. The Eastern Rocky Highland:

The eastern undulating highland region of the Kim River watershed constitutes part of the northern extension of the Sahayadri Range and is characterised by a variety of rocky erosional landforms viz. dissected hills, ridges, plateaus and valleys. It is featured by highly rugged and steeply sloping landscape. The high plateaus of the mountain range are dissected by large number of E – W and NW-SE trending lineaments representing fractures and dykes of local extent. This unit is thickly vegetated and account for the majority of the deciduous forests occurring in the study area. Hills and ridges are characterized by the development of narrow pediment zones comprising colluvial material. These local scale depositional landforms are ideal repositories of

groundwater. Owing to high rainfall and intense mechanical weathering, this zone acts as source area for the development of subsequent physiographic units, viz. the alluvial and coastal plains. The highest point in the study area is 225m AMSL and is located in the Rajpipla hill ranges.

Source: Google Earth

Plate 4. 1 Space View of the Physiography of the Study Area

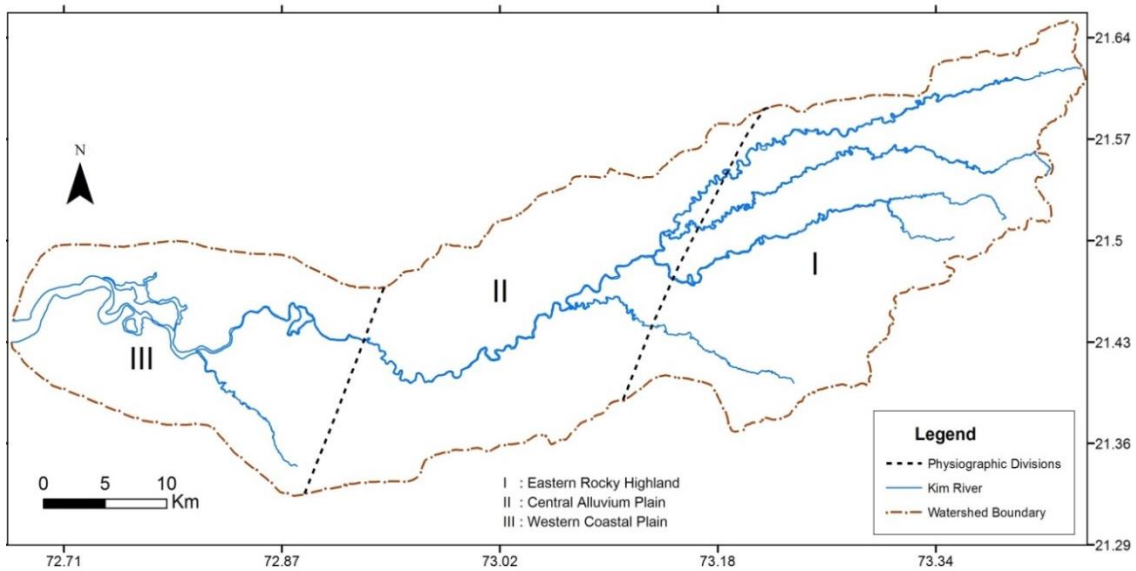


Figure 4. 1 Physiographic Divisions of the Kim Watershed Region

ii. The Central Alluvium Plain:

This physiographic unit is characterised by a gentle westward slopes and constitutes an integral part of fluvial domain. It accounts for a vast accumulation of riverine sediments representing floodplain and river channel bars, thereby, featuring the most productive agricultural land in the study area, with an overall sprawl of 400 km^2. In this unit there exist some elevated and isolated rocky outcrops, particularly in the northern part of the study area, viz around Dinod and Nandav and in the southern part, around Tadkeshwar.

iii. The Western Coastal Plain:

This unit is represented by an extremely gentle planation surface characterised by the predominance of marine (tidal) processes. This region has an altimetry range up to 20m. The coastal plain unit covers about 350km^2 area. This unit inhabits important landforms viz. wide Kim River mouth with distributary channels, tidal mud-flats, salt pans and mangroves in the estuarine part of the region. Large part of this physiographic unit harbours canal irrigated agricultural land, whereas the proximal land to shore line is the saline wasteland.

LANDFORMS

The study area exhibits variety of landforms predominantly formed by the depositional and erosional processes of mechanical, fluvial and marine nature. Occurrence and distribution pattern of the various landforms in the study area show strong controls of physiography, which itself has evolved through geologic time under the factors related to neotectonism and eustatic changes.

Sr. No.	Process	Land form Features
1.	Erosional & Mechanical	Dissected hills & ridges, pediment zones & plains, Inter-mountain valleys
2.	Residual	Planation surfaces with soil, colluvium fans
3.	Fluvial	Floodplain, point bars, shoals, terraces, palaeo-channels and meandering loops, relict alluvium, back swamps
4.	Fluvio-marine	River mouth bars, high & low marsh, deltaic lobes (palaeo & present day)
5.	Tectonic	Falls, knick points, rapids, escarpments, ravines, river pools, dyke ridges

Table 4. 1 Landforms Identified in the Kim River Basin

The Kim River Basin is situated within the Narmada –Tapi doab region, the 02 mega-fluvial systems of western India. A detailed and in depth study carried out by Tiwari & Joshi (2001) and Tiwari et al. (2016) for this doab region has provided an elaborate account on the various landforms. The candidate has adopted their work to substantiate the need for the present study as such (Table 4.1)

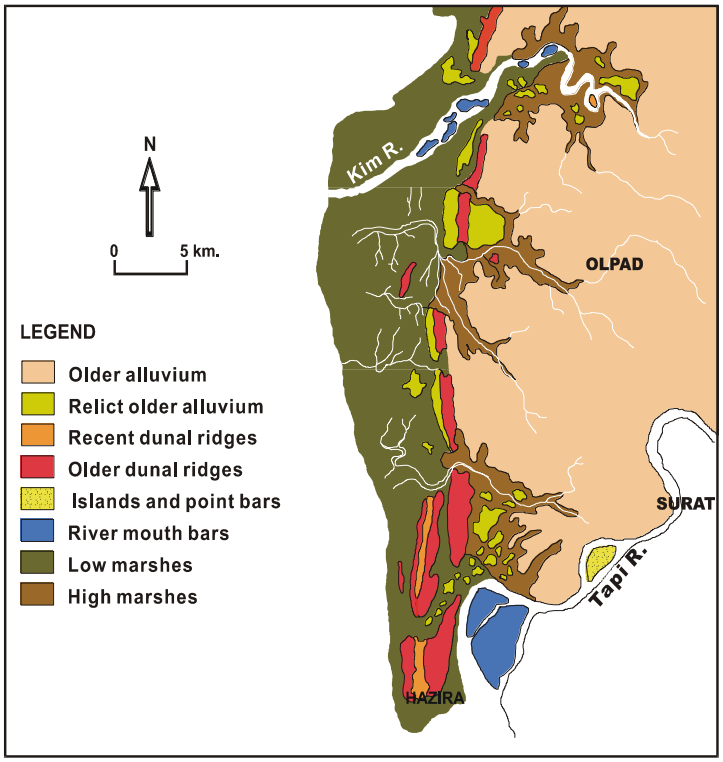


Figure 4. 2 Landforms in the Kim-Tapi Block (After Tiwari & Joshi, 2001)

I. Coastal Landforms:

The coastal block delineated by the Kim River provides interesting picture of diversity in morphology of coastal features and surficial processes. The shoreline features typically represent a "drowned alluvial coast" (Merh, 1987).

a) Mud Flats**: -** These features occupy vast stretch of the inland area behind the onshore barrier ridges. These mudflats owing to their occurrence at two different altitudes, have been classified into two categories viz. high marshes (raised/ palaeo mudflats) and low marshes (present day mudflats). The high marshes (6-8m above MSL) represent higher strandline of the recent past, the Flandrian transgression (Merh, 1987). The patches of older alluvium are ubiquitously seen within the high marshes. Occurrences of these marshes are seen in the estuarine areas of the Kim River and are dissected by the tidal inlets. The low marshes (0-4m above MSL) are along the present day tidal creeks and are subjected to inundation during high tides (Plate 4.2).

Plate 4. 2 Kim Mudflats (low marsh) with Mangrove Forest (Loc. Kim River Mouth, Kantiyajal)

Plate 4. 3 Ripple Marks- A Fluviatile Current Imprints in Sand
(Loc. Kim River mouth near Kantiajal)

b) Mouth Bars**: -** Kim river shows characteristic mouth bar dissected by tidal channels. These bars comprise relatively coarser sediments with the subordinate proportion of silt and clays. Plate 4.4 shows the mouth bar of the Kim River as seen in LANDSAT imagery.

Plate 4. 4 Mouth Bar of Kim River as Seen from Satellite Imagery

II. Fluvial Landforms:

Both the fluvial landforms of erosional and depositional nature are formed by the Kim River. They are listed as under.

a) Flood Plains and Terraces**: -** The middle and lower parts of the Kim River basin is characterized by well-developed Flood Plains. These flood plain deposits have been cut under subsequent base level changes and now represents in the form of benches, i.e. the terrace. In all 03 levels of terraces are present (Tiwari & Joshi, 2001). The flood plain subsequently merges into coastal plain in the lower reaches of the basin. Coastal plains are characterized by the predominance of mud sediments deposited under tidal flat environment. The Kim River channel in its lower part is marked with numerous erosional and depositional landforms of local nature. Important landforms identified by the author are floodplain, river terraces (T_1 & T_2), point bars and mid-channel bars (Plates 4.5 & 4.6).

b) Point Bars and Shoals**: -** These fluviatile features are the products of meandering channels. Point bars are characterised by cut and fill processes under lateral accretion, which gives rise to crescent shaped depositional features (Plate 4.5); displaying cycles of fining upward sedimentation pattern. The shoals are mid-channel bars; normally develop due to sudden check in energy conditions, thereby causing accumulation of sediments tending to bifurcate the channel (Tiwari & Joshi, 2001). In the study area, the lower reaches where the river is wide, commonly shows point bar deposits and shoals (Plate 4.6)

Plate 4. 5 A View of Kim River Meander showing Development of Point Bar-Mid-channel Bar and Terrace. (Loc. D/S Kim-Vadoli Highway Bridge)

Plate 4. 6 Mid-Channel Bar Deposits. (Loc. U/S Kim-Vadoli Highway Bridge)

c) Palaeo-channels and Meandering Loops**: -** They are characteristic features of the Kim River as it shows greater influence of eustatic and tectonic factors. The palaeo-channels are the most important features in working out the drainage evolution of the study area (Tiwari & Joshi, 2001). Kim River is characterized by paleo-channel courses, thereby signifying frequent changes in the channel geometry and its morphology. In the lower reaches, as the river enters the alluvium plains, the meandering loops become more prominent and frequent. Numerous paleo-channels also exist in the lower reaches of the river, which indicates the change of course of river in recent past (Plate 4.7)

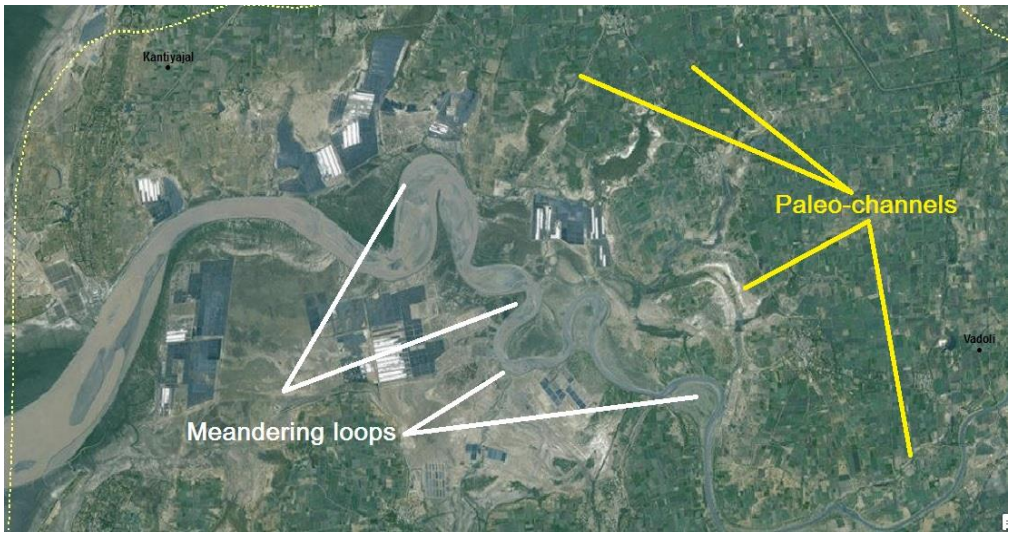
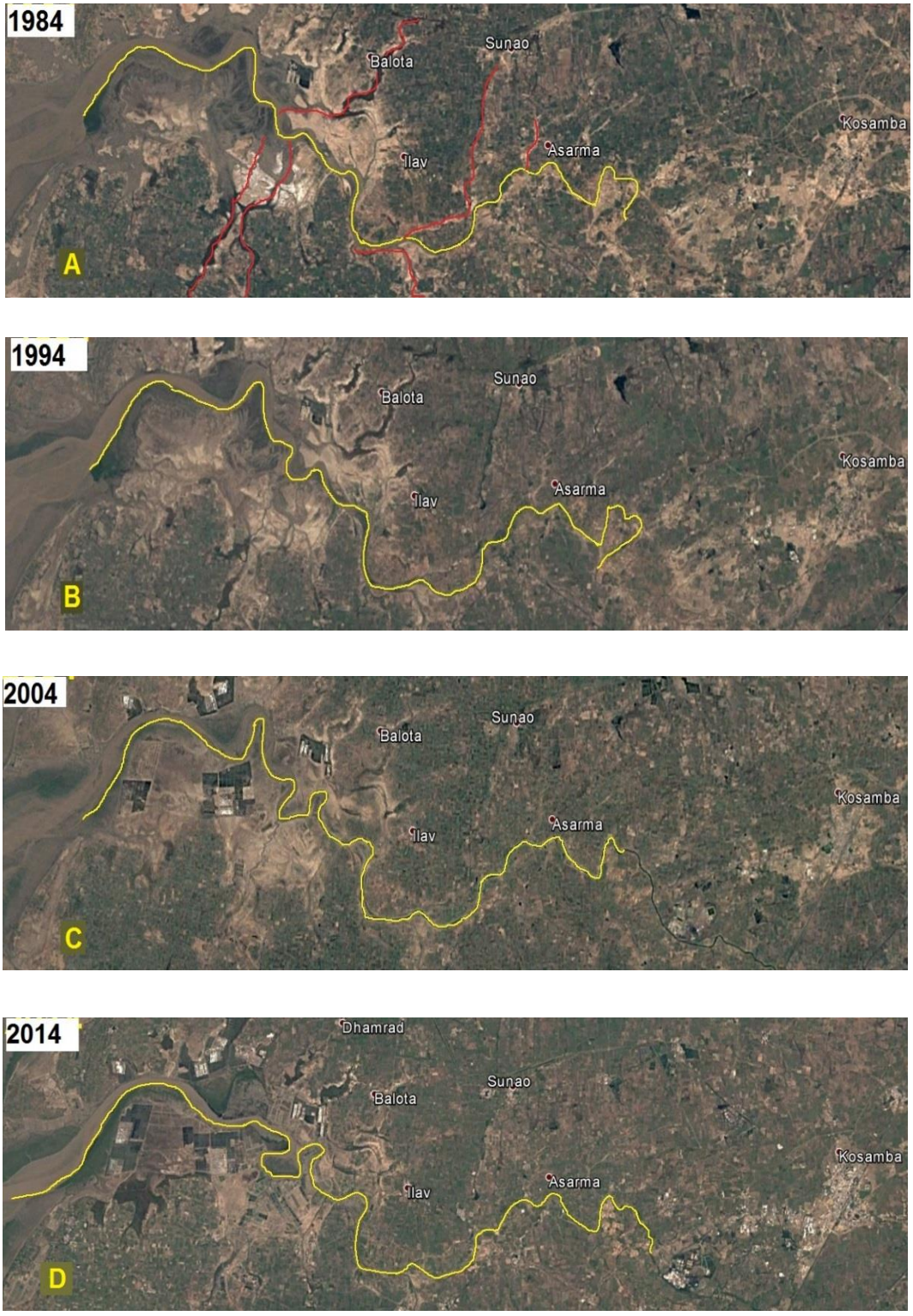


Plate 4. 7 Satellite View of the Present Day Meandering Loops and Paleo-channels of the Kim River in the Alluvium and Coastal Plains

The author through the study of toposheets (1974) and the subsequent satellite imageries of latter period (Google Earth) made an attempt on the evolution of Kim River drainage system, particularly the middle and lower parts of the basin. The study suggests that during the last 40 years of time span, there has been an overall southward shift in the course of the river channel. This is reflected in terms of large number of abandoned meander loops and rivulets. Further, in the coastal plain region and river mouth area, considerable shift in the distributary channels has been observed. There are abandoned feeder channels showing abrupt discontinuation in the proximity of paleo mudflat (old

marsh) region (Plate 4.8 A-D). This suggests a dynamic behaviour of fluvial system that has evolved through time under base level changes and the present day active tectonism.



Source: Google Earth

Main Kim River Channel Abandoned feeder channels

Plate 4. 8 Satellite Imageries Showing Modification of Kim River Drainage (From 1984 to 2014)

The above marked observations by the author may not be on the line of defined objectives in the present thesis. However, the author is of the view that the drainage evolution has considerably impacted the land-use system. Earlier there were no salt pans and aqua-culture existing, but now it's a flourishing industry. Similarly, the agricultural land has also been impacted, whether the impact has been a positive or a negative one, needs further in-depth study.

d) Pediment zones and Inter-montane Valley Flats:- The pediment zones and inter-montane valley flats are characterised by occurrence of colluvial materials and residual soils respectively. Colluvium is a product of mechanical weathering of basaltic rocks, comprising of heterogeneous mixture of boulders, rock fragments and fines. The colluvial deposits are occurring as narrow strip at the foot-zone of the elevated land masses (hills & ridges). Being heterogeneous in sediment characteristics, these colluvials are considered to be an ideal repository of groundwater and hence also characterised by thick vegetation cover. Well-developed triangular facets and thick vegetation growth helps to distinguish them easily. These features commonly occur in the extreme upstream of the study area around villages of Tadphalia, Arethi and Athkol Plate 4.9).

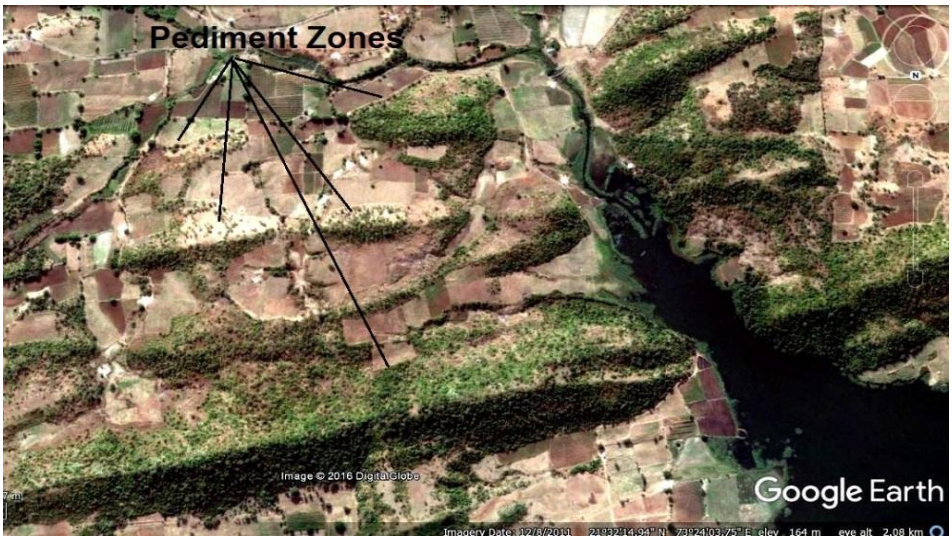


Plate 4. 9 Satellite View of Pediment Zone Around Basalt Ridges with Thick Vegetation (Loc. Baldeva Dam)

III. Tectonic Landforms:

The landforms that have been manifested on account of regional and/or localized subsurface stress release phenomena leading to structural deformation in country rocks. The study area illustrates such tectonic landforms in the upper parts of the basin, which is described as rocky highland. Some of the identified tectonic landform includes dyke ridges, escarpment, waterfall, rapids and knick points. Even local/regional fractures developed within the country rock (in present case basalt) can also be ascribed to a regional tectonic process (Tiwari & Joshi, 2001).

Plate 4.10 A view of local Knick Point Developed due to some local tectonic factor (Loc. Maujha)

Plate 4. 11 Cropping Out of Bed-rock Creating Water Pool and Fall in the River Channel (Loc. Kim River Tributary Stream near Patal Village)

Rapid, fall and Knick points (Plate 4.10) are of very local nature and can be seen running across a river channel. These landforms represent minor displacement in a bed-rock along a well-defined plane, which invariably is considered as groundwater recharge streak to the adjacent bank area aquifers. The presence of water pools in the midst of river channel due to sudden cropping out of the bed rock may be ascribed to local bedrock uplift, obstructing the flow in and otherwise a sandy river segment (Plate 4.10).

These locally developed landforms greatly facilitate in modifying the local hydrogeological regime of the proximal area.

DRAINAGE CHARACTERISTICS

In any area, the drainage system of a region is the combined consequence of the topographical, geological and climatic factors. The terrain of the study area is an interesting combination of three lithological domains viz the Deccan traps, the Tertiary sedimentary formations and the alluviums. These lithlogic domains are characterised by three distinct geomorphic units; (i) the Deccan Traps constitute a part of hilly terrain and pediment zone; (ii) the central Tertiary sedimentary formations forms the central plain region; and (iii) the alluviums that constitute the lower central part of the basin and the coastal plains. The study area is drained by a system of westerly flowing streams and the Kim River constitutes a major drainage having its source in the Eastern Highland Zone.

Drainage Pattern:

Drainage patterns are the designs, formed by the aggregate of drainage pathways in an area regardless of whether they are occupied by permanent streams (Howard, 1967). The author has studied the drainage system through satellite imageries (LANSAT IV) as well as SOI top sheets. The trunk stream of Kim River shows strong influence of regional fracture system characterized by three distinct azimuths viz. E-W, NE-SW and NW-SE

(Power,1986; Tiwari & Joshi,2001). The trunk stream maintains linear consistency along these azimuths (Fig 4.3).

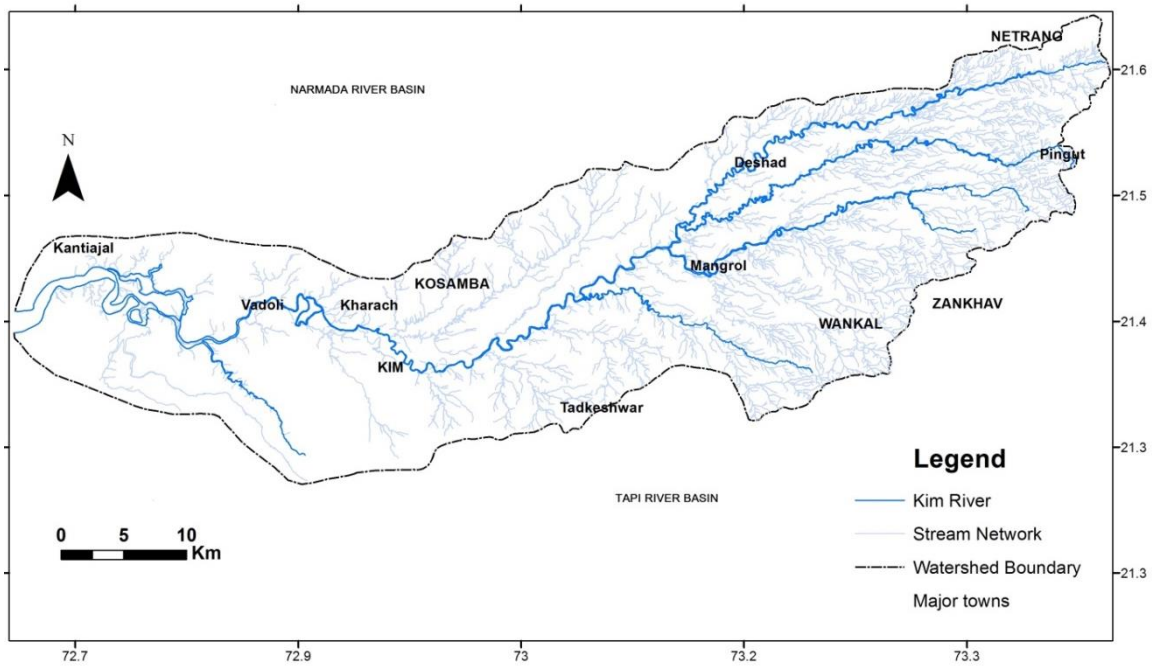


Figure 4. 3 Kim Drainage Network

Streams constituting the Kim River are locally characterised by dendritic and sub-parallel patterns of westward flowing drainage. The eastern highland signifies with a characteristic network of the complex dendritic and trellis drainage patterns (Fig 4.3). The middle part of the basin is characterised by parallel to sub-parallel, rectangular drainage patterns and the lower area of the basin shows innumerable defunct paleo-channel remnants. The development of meandering loops in the Kim River course are on account of its sluggish nature in porous and permeable substratum, constituting a part of alluvium plains.

The physiography, landforms and drainage attributes have been accounted for hydrogeological characterization of the study area dealt in the preceding chapter.

LAND-USE SYSTEM

For any region, basic understanding on land-use system and its critical appraisal constitute the most vital inputs for monitoring, evaluating, protecting and planning available natural resources. For this, remotely sensed multispectral data provides systematic and accurate ability to assess the ground conditions over a large area on a regular basis (Campbell, 1996). Availability of various geo-spatial technologies since past two decades has played a significant role in better monitoring and management of earth resources. Geographic Information System (GIS) along with satellite imageries have proved helpful in the field of natural resource management and decision making process for land-use (Jenson, 2007). In India, noteworthy studies pertaining to utilization of these geo-spatial technologies in land-use mapping and assessment, monitoring & management of water resources is carried out by Balak & Kolarkar,1993; Chaurasiya 1999; Navalgund & Jayaraman, 2007; Chaudhary et all, 2008; Singh P.K., 2009 and Ahilan, 2011.

LAND-USE SYSTEM IN THE KIM RIVER BASIN

Land cover classification is the application of image analysis to obtain classified end-products using appropriate classification techniques which have been developed for the purpose of land cover classification. The land cover classification is categorized into two basic approaches, viz a) Unsupervised and b) Supervised classifications. Unsupervised classification depends on a prior in-depth knowledge regarding the area of study, while supervised classification is based on manual selection of land use categories of the study area by the user, where limited to little knowledge about the area is available (Lu, 2007). The classification process generates a land-cover map with detailed information about the composition and type of land-use existing in the area of interest.

In order to understand and valuate long-term changes in the land use pattern of the Kim River watershed, the author has made a comparative analysis of satellite data *(LANDSAT-IV)* images with interval of 5 years (1998 to 2013). Land use analysis has been carried out using ERDAS Imagine Software

Ver. 9.3 and Q-GIS using Supervised mode of classification. The various categories of land use in the study area (Fig 4.4-4.7) recognized are forest, agricultural land, settlements (including industries), barren lands (that include mining areas), mudflats (including salt-pans) and mangroves. Secular changes in the temporal- spatial land-use system are shown in Figure series 4.4 - 4.7 for the period between 1998 and 2013.

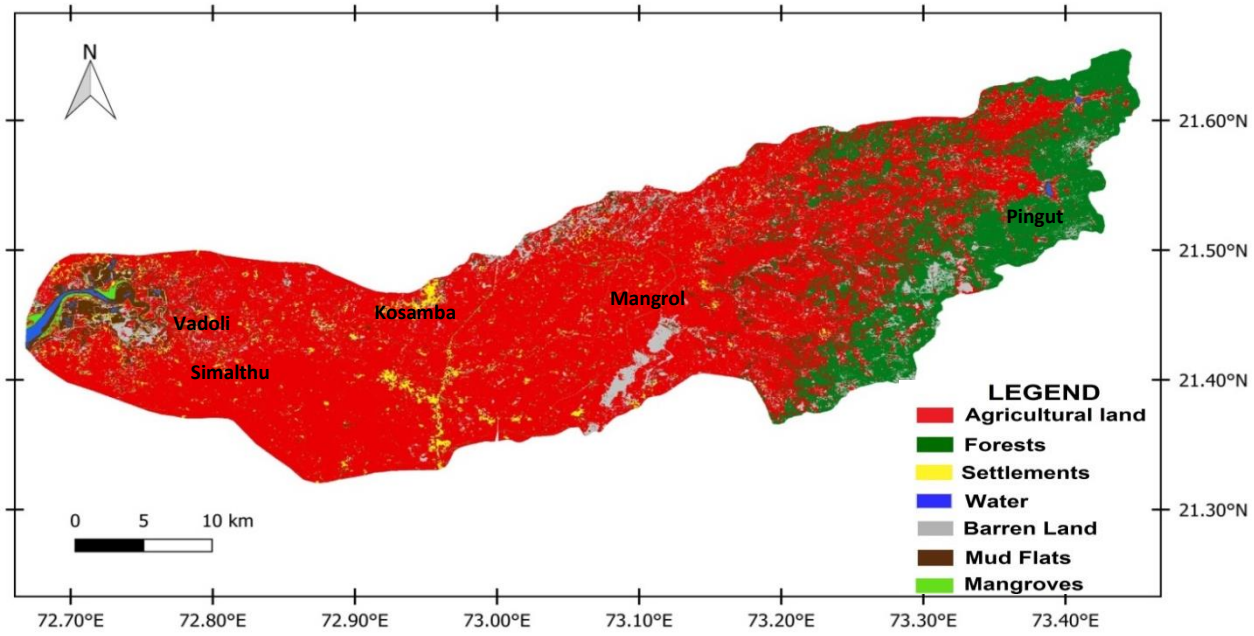


Figure 4. 4 Supervised Classification of Land-use Pattern, Kim River Basin (1998)

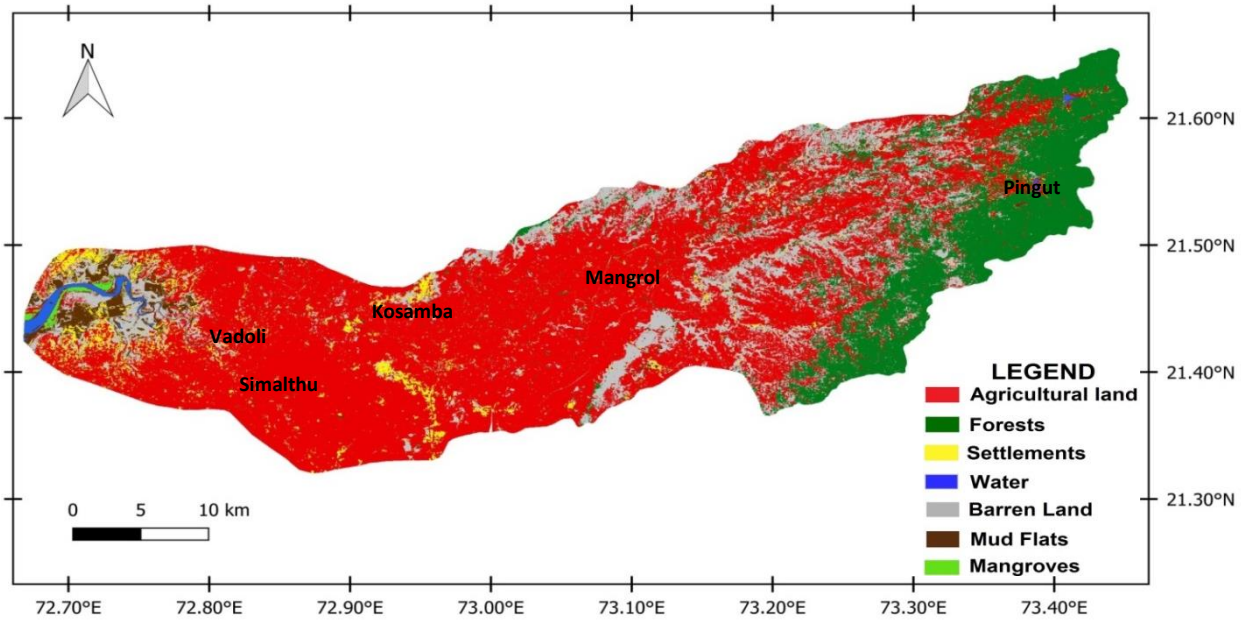


Figure 4. 5 Supervised Classification of Land-use Pattern, Kim River Basin (2003)

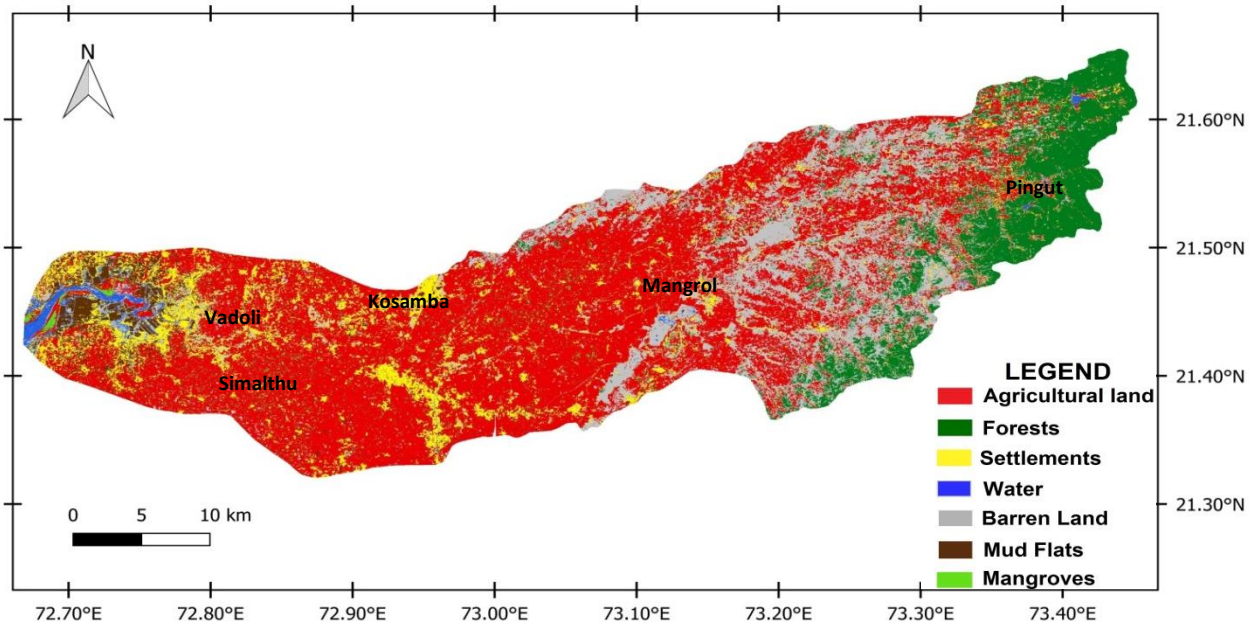


Figure 4. 6 Supervised Classification of Land-use Pattern, Kim River Basin (2008)

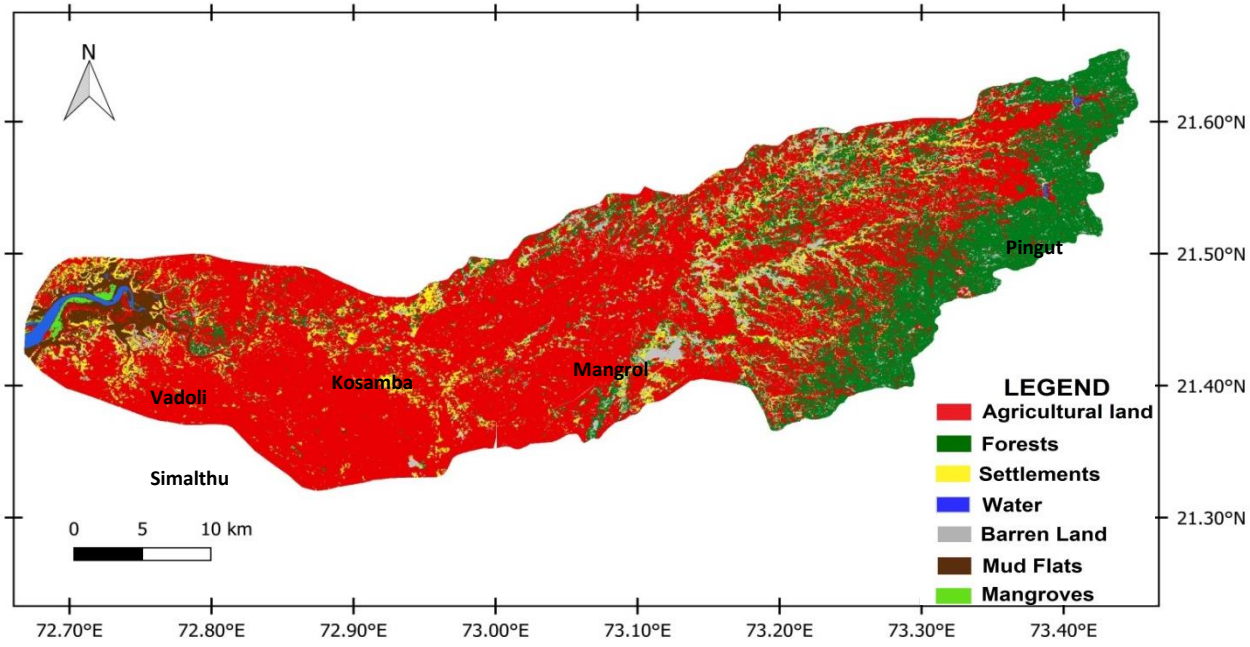


Figure 4. 7 Supervised Classification of Land-use Pattern, Kim River Basin (2013)

Author's derived quantitative analysis of individual land-use categories at 5 years interval and the change there in during 15 years of time interval is given in Table 4.2

Year		LAND-USE CATEGORY					
		Agriculture	**Barren Land**	**Forests**	**Mud-flats**	**Mangroves**	**Settlements**
1998	Area (km^2)	916.00	84.00	262.00	26.00	4.5.00	37.00
	% of Total Area	70.93	6.50	19.2	2.01	0.35	2.86
2003	Area (km^2)	832.00	110.00	213.00	53.00	5.8.00	55.00
	% of Total Area	66.31	8.77	16.97	3.11	0.46	4.38
2008	Area (km^2)	801.00	128.00	213.00	39.00	6.9.00	101.00
	% of Total Area	61.48	9.82	16.35	4.07	0.53	7.75
2013	Area (km^2)	703.00	198.00	196.00	28.00	10.00	185.00
	% of Total Area	53.26	15.00	14.85	2.12	0.76	14.02
Net Change	**Area (km^2)**	**-213.00**	**114.00**	**-28.00**	**2.00**	**5.50**	**148.00**
	% of Total Area	**-17.67**	**8.50**	**-2.50**	**0.11**	**0.41**	**11.15**

Table 4.2 Quantitative Assessment on Change in Land-use Categories in the Kim River Basin (1998-2013)

The temporal-spatial analysis of Land-use pattern of the study area from 1998 to recent times (2013) highlights the following outcomes:

i. The area under agriculture has reduced from 916 km^2 (70.9%) in 1998 to 703 km^2 (53.3%) in 2013 of the total area, which is 17% of the total basin area. This negative change is ascribed to diversion of agriculture land to the land-use category-Settlements. As in the study area, especially in the middle and lower parts, in recent past large number of small and medium scale industries and residential units have come up.

ii. The barren land coverage has increased by almost 8.5% (114 km^2) in the span of 15 years (1998-2013). This is particularly observed in the central and lower parts of the basin. Excessive salt built-up in soils due to water-logging has made the land unsuitable for agriculture; while in the upper highlands, the barren land has increased on account of deforestation, excessive soil erosion as well as coal mining activities.

iii. The forest cover, which was 19% (262 km^2) of the study area in 1998, has reduced to 14% (196 km^2) in 2013. This 2.5% negative change in this land-use category is due to deforestation in the area for construction of housing units, roads and basalt quarrying.

iv. There has been a positive marginal change in the Mangrove cover. The mangrove cover has increased from 0.4% (4.5 km^2) to 0.8% (10 km^2) as afforestation of mangroves is being promoted in the tidal mud-flats region located in the river's estuarine region of the study area.

v. In terms of settlements, the area has shown tremendous expansion from 37 km^2 (3%) in 1998 to 185 km^2 (14%) in 2013. Major settlements have developed in the central and lower parts of the study area. This includes establishment of new small and large scale

industries followed by population settlements, etc. important localities around the towns' viz. Kim, Kosamba, Mota Miya Mangrol, Tadkeshwar and Nani-Naroli; show maximum diversion of land from other land-use categories to the settlements.

Thus, the overall secular land-use analysis of the study area show anthropogenic induced interventions both; (a) an increasing trend in terms of industrialisation and urbanisation; and (b) a reducing pattern in terms of forest cover and agricultural production in the area pointing to deteriorating environmental quality indices. The land-use pattern so obtained by the above classification is utilized in the proceeding chapter to estimate the Ecological Footprints of the study area and its changing scenario.