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Comprehensive inventory of geoheritage elements of Achanakmar Tiger Reserve area of Central Indian Landscape

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ABSTRACT

Geomorphology its geology and soil are the three important geoheritage elements of any protected area. Natural environment of a protected area comprises of both biodiversity and geodiversity. Presence of biodiversity of any protected area depends on its geodiversity. Achanakmar Tiger Reserve (ATR) is situated at the Mikal hills is an important part of Central Indian landscape and is characterized by its unique biodiversity. It is an integral part of Achanakmar Amarkantak Biosphere Reserve and provides shelter to numerous endangered floral and faunal biodiversity. The area is characterized by diverse landscape where the elevation varies from 305-1080 m above mean sea level. Major geological formations of the reserve area are metamorphic rocks followed by Gneiss-Granitoid Complex and Deccan trap. The dominant soil type is clayey coarse followed by fine loamy. The luxuriant growth of *Shorearobusta* in the area is due to well drained sandy loam soil. The study area represents as excellent natural laboratory to test the geodiversity influence on the landscape aspect and evolution. Maniyari river which flows upto 62 km through ATR is seasonal river and fulfill the major water requirement. Remote Sensing& GIS techniques have been used to analyse the land use land cover pattern and its tree species diversity presence in the ATR area. Rich diversity of tree species have been observed with Sal (*Shorearobusta)* as the dominating tree species.

Key words : *Achanakmar Tiger Reserve (ATR), Geomorphology, geoheritage, Central Indian Landscape*

Introduction

Protected area represents open air laboratories where conservation of both biodiversity and geoheritage go together (Faccini *et al.,* 2018). A clearly defined geographical space that is recognized, reserved and managed by legal or other effective means to achieve long term nature conservation with associated ecosystem services and cultural values is known as protected areas (IUCN, 2008).

Since, there is a very close association between biodiversity and geodiversity so it is important to identify geoheritage elements of a protected area. In many countries conservation is understood as protection of biological diversity, but fact is that natural environment comprises of both biodiversity and geodiversity of an area. Due to intense focus on biodiversity conservation, protection of non-living part of the nature has been less discussed in India.

The geology, geomorphology and pedology of any area form the basis for development and evolution of biodiversity and makes it a unique and the only planet in which life exist and flourish (Crofts, 2019, Gray, 2013 and Raharimahefa, 2012).

Much of the biodiversity depends on the subsoil and surface, thus geodiversity is an essential part of

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nature (IUCN). Geodiversity includes the natural range (diversity) of geological (rocks, minerals, fossils), geomorphological (landform, physical processes) and soil features (Gray, 2013). It consists of wide range of processes, evolution and environments which strongly supports the biodiversity conservation and resilience (Hjort *et al.,* 2015; Hjort and Luoto, 2010; Benito *et al.,* 2009).

Geoheritage elements such as geology, geomorphology and soil are globally significant for conservation due to its effect on species and environment (Douglass *et al.,* 2014). Crofts and Gordon (2014, 2015) provide an introduction to the concepts, terminologies and links between geoconservation and biodiversity conservation. Geoheritage records the Earth's structure preserved in its rocks and landforms (Crofts *et al.,* 2020). Studies related to geoheritage and geoconservation has been subjected to numerous scientific works (Gravis *et al.,* 2020; Pereira *et al.,* 2009). Several authors highlighted the geomorphological aspect in environment conservation (Melelli *et al.,* 2012 and Melelli, 2014).

Geomorphic features are classification based on its surface morphology and have been shown to be significant for delineating the terrestrial habitats (Douglass *et al.,* 2014). The complex and dynamic patterns of soil, topography and geomorphological processes provide mosaic of topographic variation, habitats and corridors for high species richness. For any protected areas, geoheritage elements play an important role in the establishment and flourishing its biological diversity. These geoheritage elements need to be explored and studied to fullfill the broad objective of conservation. On the other hand awareness about the geodiversity, geoheritage elements may aggravate the potential geotourism sites (Straba, 2019; Straba *et al.,* 2018). Several studies have also concluded that geotourism may affect the geoheritage sites (Ticar *et al.,* 2018; Tefogoum *et al.,* 2019, Zangmo *et al.,* 2018; Brilha, 2018). Conserving geoheritage values and their essential geological elements in the protected areas requires continuous monitoring practices and plans (Woo and Worboys, 2019).

Achanakmar Tiger Reserve (ATR) area is a part of Maikal hill landscape and is bestowed with rich pool of germplasm. The place is also known for its rare natural beauty with several noteworthy geological features. Due to its diverse variation in altitude the area is rich in floral and faunal diversity. Most primitive tribal group of Baiga and Gond are found here. The Maikal hill range is one of the broad topographic divisions of the state Chhattisgarh. The Satpura-Maikal landscape (SML) located in the Central Indian Highlands is an important biogeographic province extends for about 500 kilometers (Rodgers *et al.,* 2002). Since, SML has potential to support long term persistence of tigers, this landscape has been categorized as a global priority Tiger Conservation Landscape (TCL) (Dinerstein *et al.,* 2007).

River Maniyari is the life line of ATR which flows from southward to northward in ATR area and merges in Maniyari Tank outside the reserve area. Inside the tiger reserve area more than a forty small and large natural tributaries adjoin this river and provides water seasonally to its catchment.

Due to the uniqueness and richness of biodiversity, Achanakmar has been declared as a Wildlife Sanctuary in the year 1975. It is also an integral part of Achanakmar Amarkantak Biosphere Reserve (AABR) declared by Government of India during the year 2005 under Man and Biosphere (MAB) programme by UNESCO. Due to the presence of magnificent carnivore and endangered species tiger, Achanakmar Wildlife Sanctuary has been declared as a Tiger Reserve in 2009.

Thus for successful conservation of ATR both geodiversity and biodiversity should be analysed in detail. RS and GIS techniques have been used for geo-morphological mapping of Achanakmar Tiger Reserve (ATR) area. This paper aims to point out the potential geoheritage presence and its correlation with biodiversity of ATR.

Study area

Achanakmar Tiger Reserve (ATR) is spread over an area of 914.017 km^2, out of which 626.195 km^2 of area is under core zone (critical tiger habitat) and 287.822 km^2 area is the buffer zone. It is situated at Lormi tehsil of Mungeli district of Chhattisgarh state. Champion and Seth (1968) categorized forest vegetation under Northern Tropical Moist Deciduous and Southern Dry Mixed Deciduous Forest (Roychoudhary, 2013). Sal (*Shorearobusta*) is the dominant tree species of the area followed by sal mixed forest and bamboo forest. Sal mixed forest includes tree species like Saja (*Terminalia tomentosa*), Tendu (*Diospyros melanoxylum*), Haldu(*Adina cordifolia*),Bija (*Pterocarpus marsupium*), Mahua (*Madhuca indica*), Dhaora (*Anogeissus latifolia*), Teak(*Tectona grandis* (plantation)). Bamboo (*Dendrocalamus strictus*) are also found in higher and

lower slopes with miscellaneous tree species (Mandal *et al.*, 2017)

Climate: ATR area has tropical type of climate, characterized by three distinct seasons i.e. summer, monsoon and winter. Summer commences from March and continues up to June followed by monsoon from July to October and winter from November to February. The hottest month is May where the maximum temperature raises upto 46.7°C. December and January were the coldest month and the temperature drops as low as 2°C.The average annual rainfall is approximately 1300mm and maximum rainfall is received during the month of July, August and September.

Materials and Methods

- ARCGIS version 10.3 GIS Software have been used for map composition like DEM, Geomorphology, Geology, Slope, Aspect, Relief and Soil map.
- The essential part of mapping is the digitization of base layers. Survey of India (SOI) topographic maps of 64F10, 64F11, 64 F14 and 64F15 on 1:50,000 scales published by SOI, Dehradun were used for digitalization. Preliminary interpretation of the study area is done on topographical sheets.
- Digital Elevation Model (DEM) data of the study area is downloaded from SRTM satellite (www.usgs.com). DEM raster data layer has been used to derive datasets related to topography. The obtained images have been registered to the Universal Transverse Mercator (UTM) map projection with a datum of WGS-84. The study area is located in zone 43 (N) of UTM.
- Shuttle Radar Topography Mission (SRTM) data was used to prepare aspect map, relief map, slope map. This data has been downloaded from website (http://

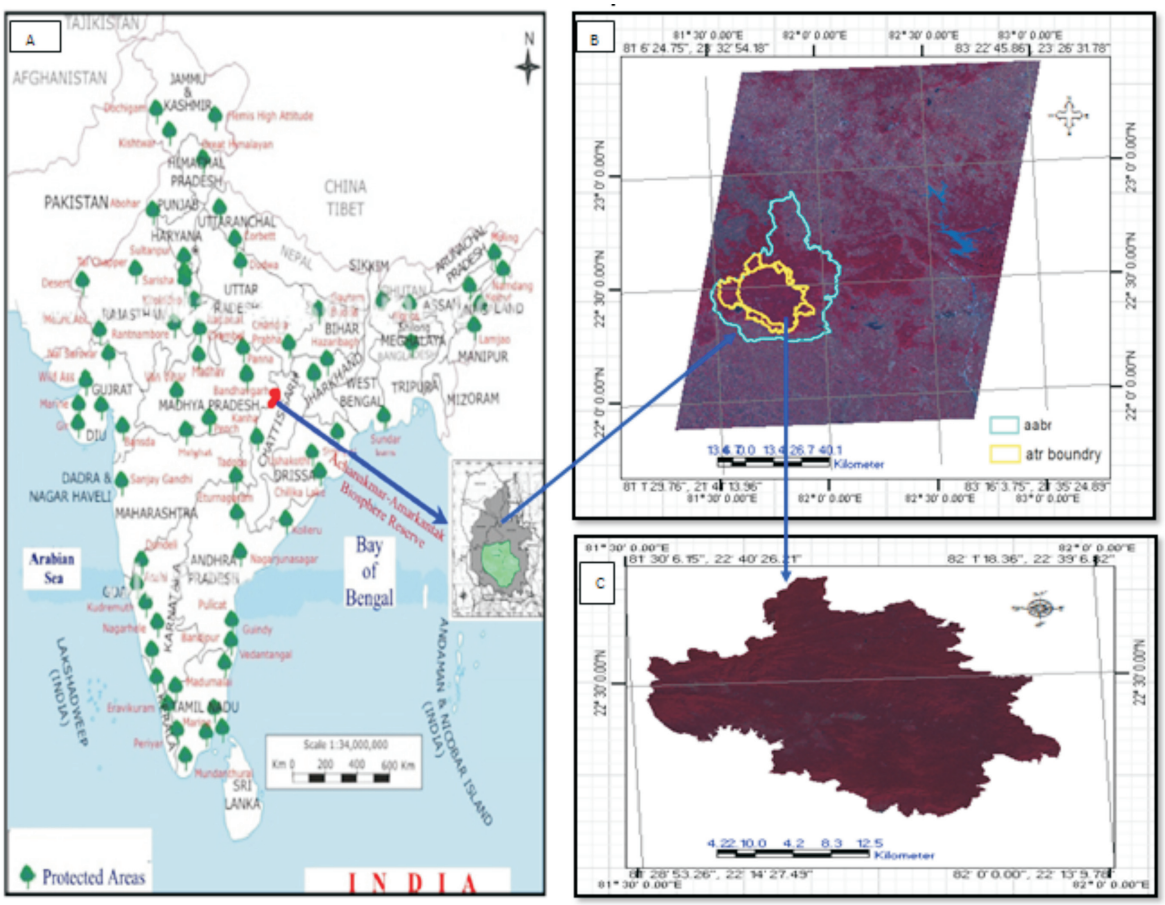


Fig. 1. The location map of ATR A-Protected Areas of India, B- Location of AABR and ATR in IRS LISS III image, C- Location of ATR Area

www.srtm.csi.cgiar.org).

- Soil map of the study area has been digitized from the soil map obtained from National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), Nagpur.
- Geomorphologic map has been digitalized using District Resource Map (DRM) of Mungeli district of Chhattisgarh State by using ARC GIS software.
- Geology map of the study area has been prepared by using District Resource Map (DRM) the of Mungeli district which is further classified into different classes.
- Satellite imagery of Indian Remote Sensing (IRS), P6 satellite having LISS 3 sensor with path 105 and row 56, acquired on 14th December 2013 have been used for land use land cover classification. ERDAS IMAGINE 2013 has been used for supervised classification of ATR area.

Results and Discussion

Digital Elevation Model of ATR

The elevation range of ATR lies between from 305-1080 meters above mean sea level. The highest elevation peaks (910-1080 m) were recorded in Lamni and Khuriya range. The central part of the area falls in low elevation with 305-437 m range, in this region the river Maniyari flows and major settlements are also situated here.The North-West portion of the study area forms a part of eastern boundary of the Satpura series of the Maikal mountain ranges. The area is drained by Maniyari River and its tributaries, which flows in South-West direction.

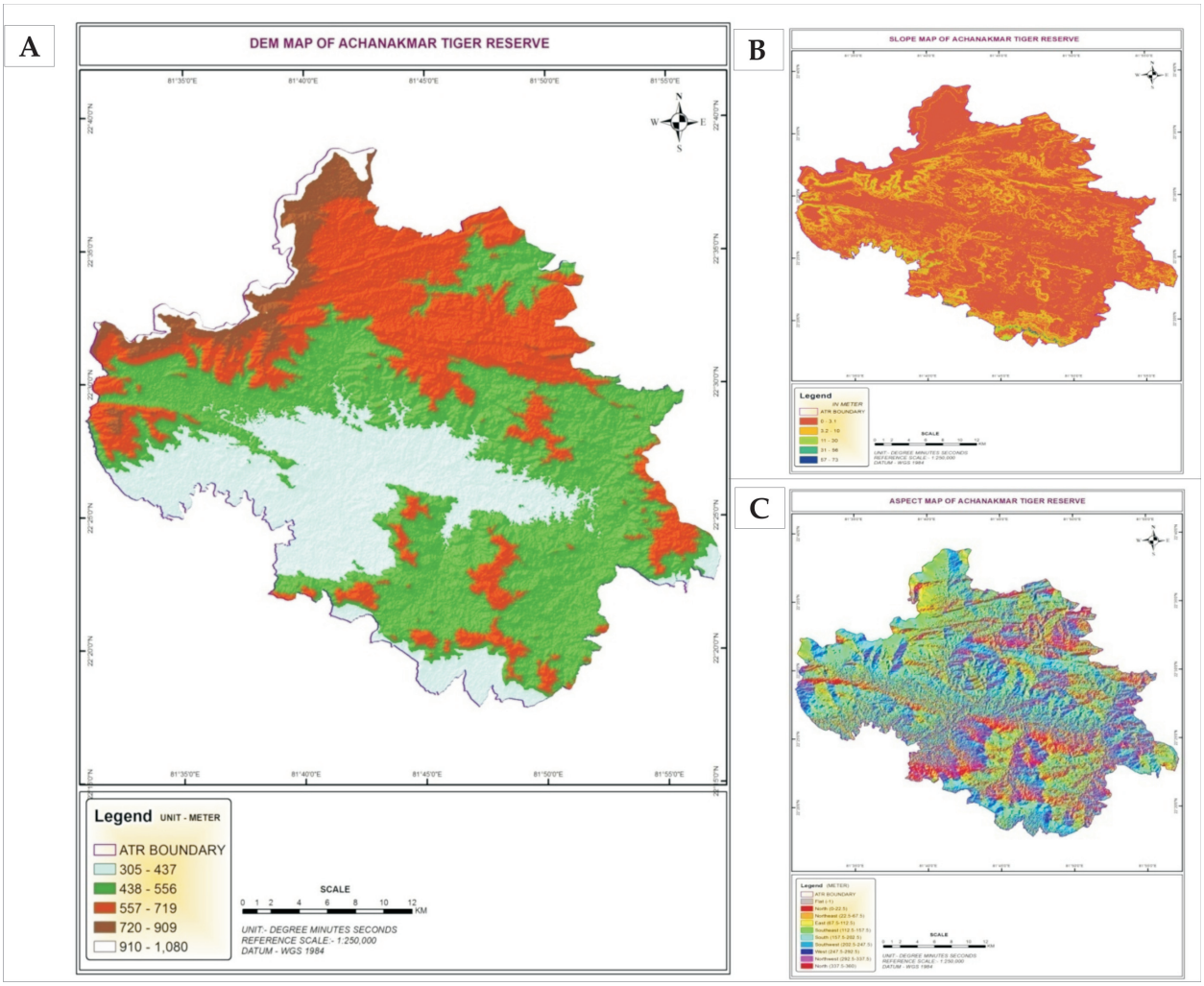


Fig. 2. (A) Digital Elevation Map (DEM), (B) Slope and (C) Aspect map of ATR

Slope categories of ATR

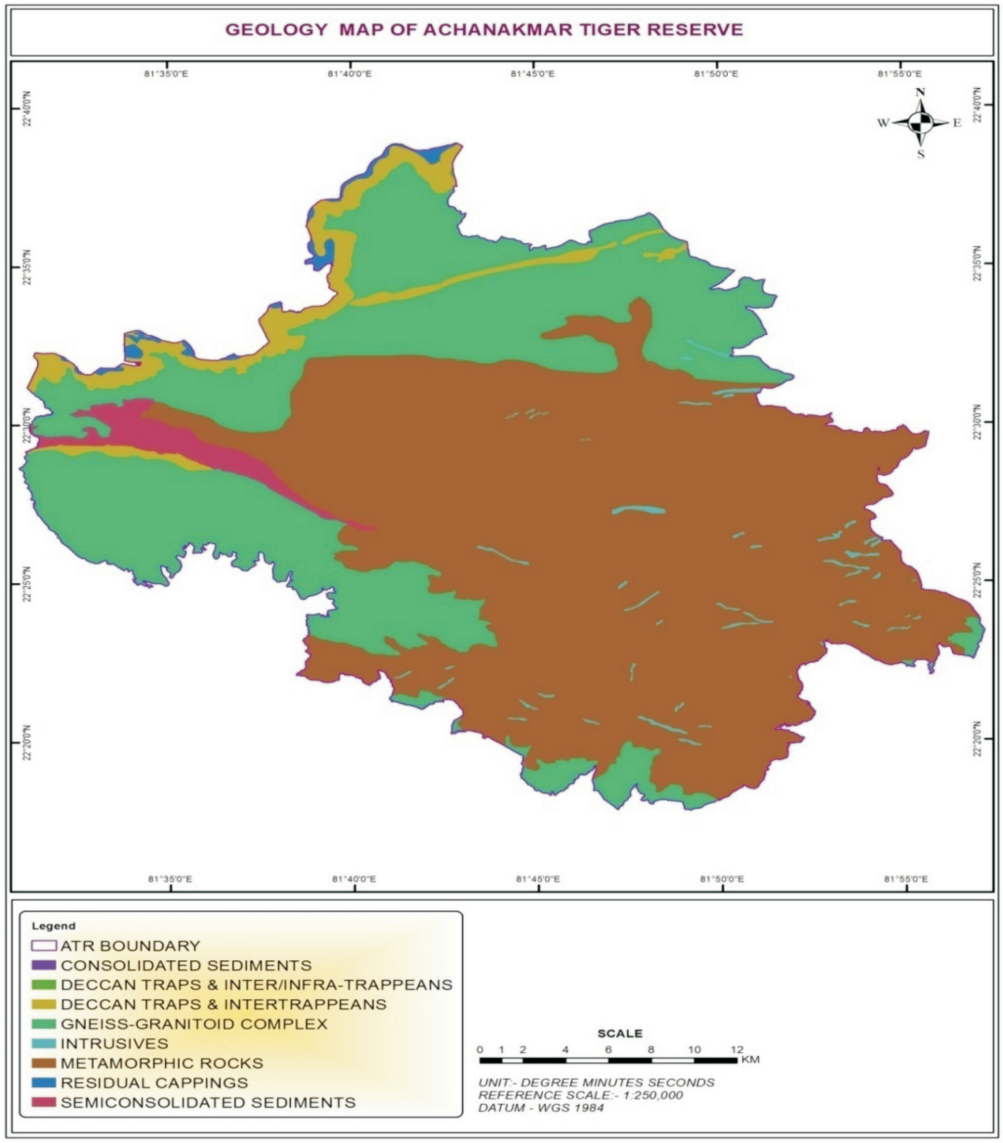
The entire ATR area is grouped into 5 categories (Fig 2 B) on the basis of slope (0-3.1 m, 3.2-10 m, 11-30 m, 31-56 m and 57-73 m). Higher slope value indicates steeper terrain and lower slope value indicates flatter terrain.

Aspect Map

The Aspect map of ATR area is depicted in fig 2 C. The surface direction or aspect of ATR was categorized into ten classes i.e Flat, North, Northeast, East, Southeast, South, Southwest, West, Northwest and North. These classes are represented using an orderly continuation of colour hues thereby creating 3D effect. The Flat areas are represented by -1, having no down slope direction (Pal and Samanta, 2012).

Geology of ATR

Major geological formations of ATR are composed of metamorphic rocks covering more than half of its area. Metamorphic rocks are mainly composed of slate, phyllite, mica, schist with or without granet, staurolite, and anthophyllite. Gneiss-Granitoid Complex recorded the second most dominant rock



(*Source:* District resource map (DRM) of Mungeli district, Chhattisgarh)

Fig. 3. Geology Map of the study area

type of ATR. High grade gneiss supra crustal assemblage belonging to the Archean forms the oldest rock sequence of ATR.

In the north-west of the study area deccan trap rocks of volcanic origin are found. The basaltic lava flows of Cretaceous-Eocene age with sub ordinate inter trapean sediments have also been recorded in the tiger reserve area. The traps comprise horizontal to sub-horizontal lava flows and forms flat trapped terraced plateaus.

Small area of western region is covered by semi consolidated sediments. While, minute portions of the study area is covered by intrusives, residual cappings, consolidated sediments and deccan traps & inter/intra-trappeans. Central Indian shear zone passes the ATR area and some faults have also been recorded in this region.

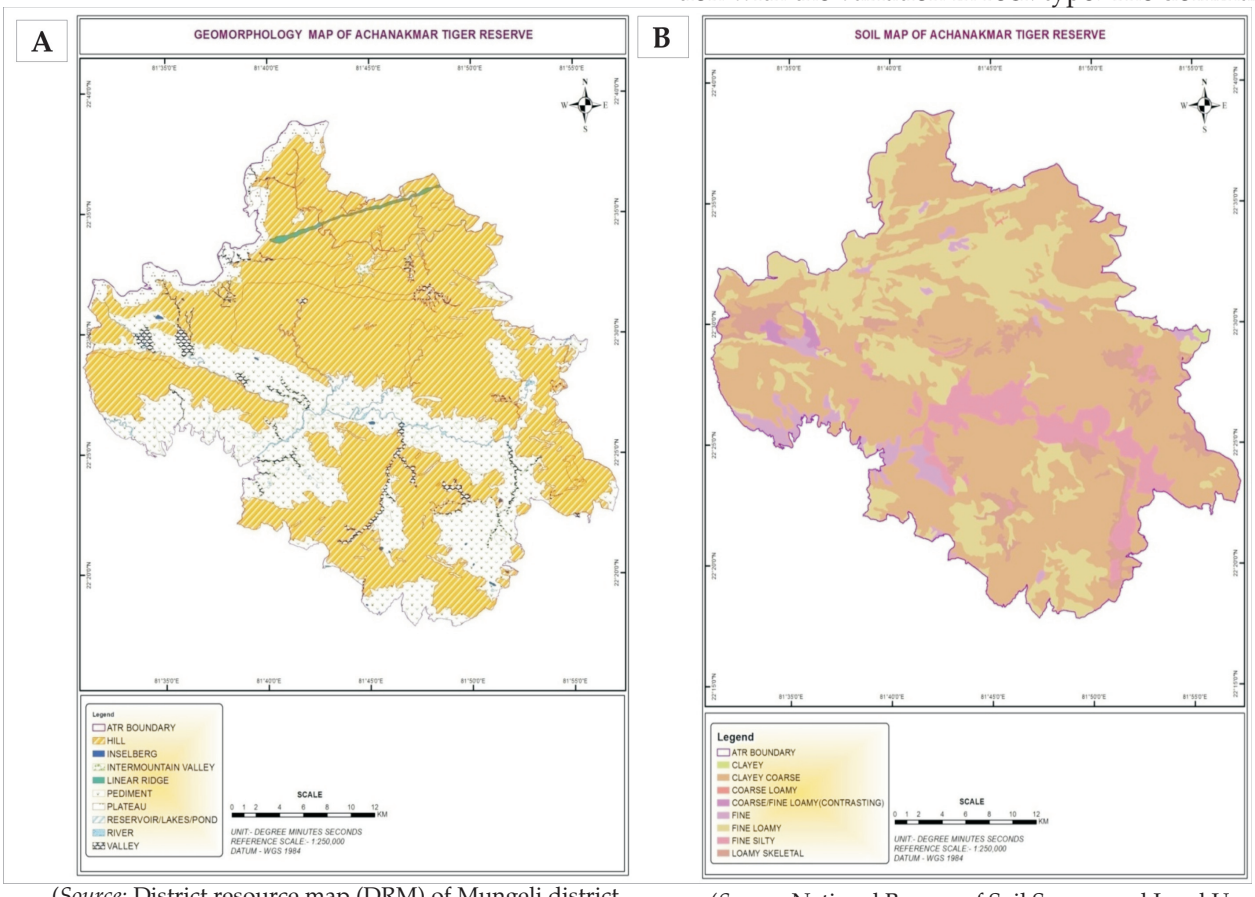
Two major lineaments are found here. The first lineament passes through metamorphic rock above the Lormi Part II buffer zone trending in the E-N-E to W-S-E direction and second one passes through the gneiss-granitoid complex in E-W direction.

Geomorphology

The tiger reserve area is dominated by hills. The other geomorphological features of the region are inselberg, intermountain valley, pediment, plateau and valleys. A stretch of linear ridge is present in north western region. Several faults have been recorded in this region mostly trending N-W and E-W directions. The major portion of the Central Indian shear zone passes through the metamorphic formations in E-W direction. The area is drained by Maniyari River and its tributaries, which flows in South-West direction. Other water bodies of the region include smaller river, nallas and their tributaries and ponds.

Soil type

The soil of ATR area varies in texture and composition with the variation in rock type. The dominant



(*Source:* District resource map (DRM) of Mungeli district, Chhattisgarh)

(*Source:* National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), Nagpur)

Fig 4. (A) Geomorphology map and (B) Soil map of Achanakmar Tiger Reserve area

soil type of the area is clayey coarse followed by fine loamy. Other soil type of the area is clayey, fine silty, loamy skeletal and coarse / fine loamy. Coarse / fine loamy soil also known as alluvial soil of recent origin are found on the banks of river Maniyari and streams and nallas draining into it. The texture of the soil is sandy to loam-clays and colour of the soil ranges from light brown to brownish yellow. Red soil is present in hill tops.

Water resources of ATR

The River Maniyari originates from Sihawal Sagar situated in the core zone is known to be the lifeline of ATR. It flows through the Lormi tehsil of Mungeli districts for about 105 kms and meets river Seonath near Madku island of Bilaspur district. Inside the tiger reserve area, Maniyari river flows about 61.80 km from south towards west and joins Maniyari Tank outside the ATR. The river flowing through ATR area is of alluvial channel character. Inside ATR, the river meandering is natural and influenced by the adaphic and topographic factors during different seasons. The flow area of river Maniyari comes under forested watershed catchment area. At various locations, ATR area has greater width and open area with sand and stony coverage. The river is seasonal with water flowing about seven to eight months of the year and rest of the time it remains dry. Most of its tributaries also originating inside ATR area are seasonal and the situation becomes worse for the wildlife during dry summer months

It has also been observed that the tree species are growing in the close vicinity of the flow line of the river. The most of the tree species along the river are Sal (*Shorearobusta*), Arjuna (*Terminalia arjuna*), Bamboo (*Dendrocalamusstrictus*) etc. The river inside the ATR has shorter riparian zone coverage with herbs and shrub species to its cover.

Land Use Land Cover (LULC) status of ATR

LULC assessment of Achanakmar Tiger Reserve area for the year 2013 shows that dense forest area is the dominant land cover type covering approximately 56.14 % followed by open forest area (34.31 %), scrub land (3.83 %), agricultural land (3.41%) and built up land (0.45 %) respectively. The areas

Fig. 5. View of vast landscape of ATR showing topographic variations (A to D)

covered under water bodies (0.37%) and riverbed (1.49 %) shows fluctuation depending on availability of rainfall.

Tree species diversity of ATR

Sal (*Shorearobusta*) is the dominant tree species of ATR area. The chief associates of Sal in the top storey are Saja (*Terminalia tomentosa*), Bija (*Pterocarpus marsupium*), Dhaora (*Anogeissus latifolia*), Kusum (*Schleicheraoleosa*), Jamun (*Syzygium cumini*) and Mahua (*Madhuca indica*). The middle storey comprises of Tendu (*Dispyros melanoxylon*), Kari (*Saccoprtalum tomentosum*), Tinsa (*Ougeiniaoojeinensis*), Kachnar (*Bauhinia variegata*), Gamari (*Gmelina arborea*), Salai (*Boswellia serrata*), Amla (*Emblica officinalis*) and a few other miscellaneous species.

The under growth consists of Ban-Rahar (*Flemingiasemialata*), Chhind (*Phoenix acaulis*), Dhawai (*Woodfordiafruticosa*), Marophal (*Helicteresisora*), Harsigar (*Nyctanthusarbortristis*), Kurchi (*Holarrhenaanti dysenterica*), Baibarang (*Embeliate jeramcottam*) and Shatori (*Asparagus racemosus*). The undergrowth is very dense in cool and shady localities.

In the areas of Lamni and Lormi ranges, Kalabans (*Colebrookiaoppositifolia*) grows densely particularly along nala and river banks. Bamboo (*Dendrocalamus strictus*) occurs in abundance on the hill slope and along the streams in Achanakmar, Lormi and Lamni ranges. The main climbers occurring in the area are Mahul (*Bauhinia vahlii*), Gurar (*Milletia auriculata*), Palasbel (*Butea superba*), Ramdaton (*smilax macrophylla*) and few others. Of all the climbers, Mahul is the mostly found in cool, shady and moist places and is frequently met with on the slopes of the Maikal hills.

Discussion

Numerous studies have recognized the potential geoheritage sites in India (Singh *et al.,* 2021; Ranawat and George, 2020 and Ghosh *et al.,* 2021) but the geoheritage elements of protected areas are still un-

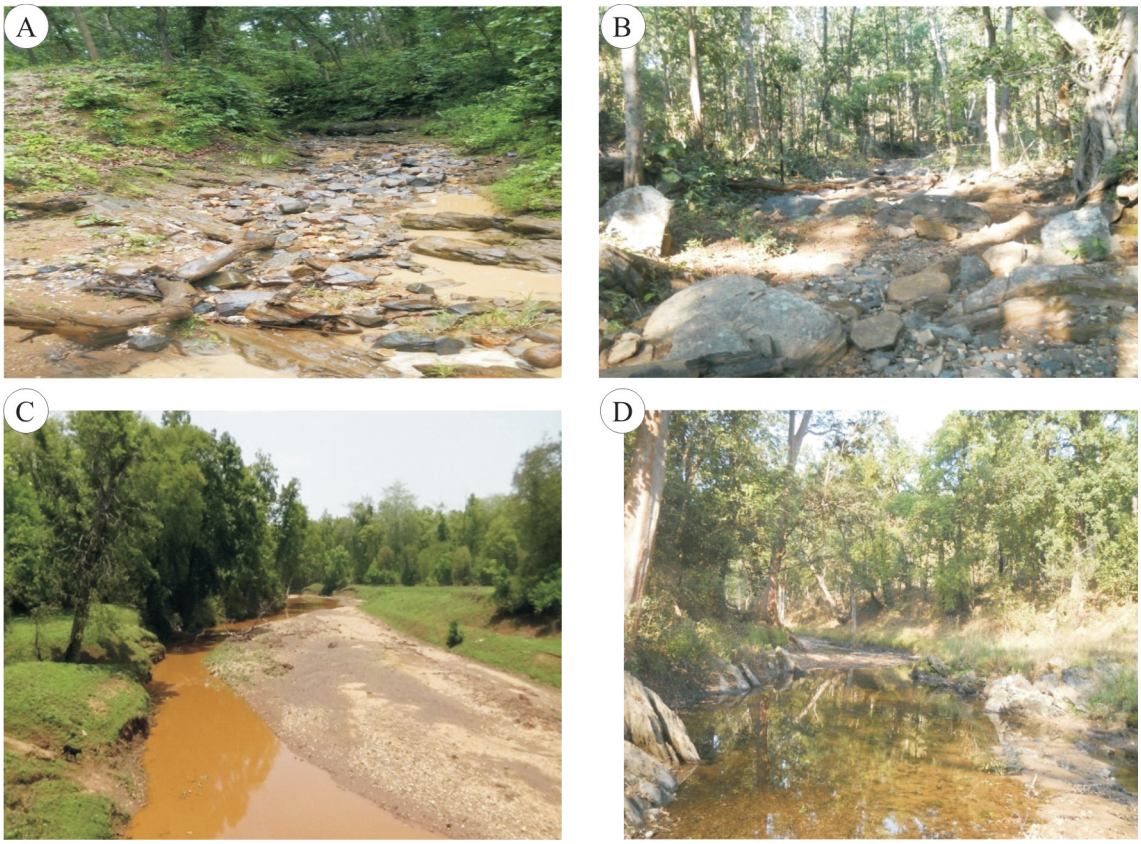


Fig. 6. (A to D) Maniyari river at different locations at ATR showing landscape characteristics and vegetation pattern along the riparian zone

explored. Strba *et al.* (2020) stated that biodiversity of any area depends on its geodiversity. His study promotes the protection of geosites in the protected areas of Slovakia. Further, it also correlates between geoheritage and geotourism of Slovakia.

ATR is a protected area and has a long conservation history. It was declared as a Wildlife Sanctuary in the year 1975 under the provision of The Wildlife (Protection) Act, 1972. ATR is an integral part of Achanakmar Amarkantak Biosphere Reserve (AABR) declared by Man and Biosphere (MAB) programme by UNESCO in the year 2005. Due to the presence of tiger an endangered species, Achanakmar Wildlife Sanctuary has been declared a Tiger Reserve in 2009.

ATR is situated at the eastern part of Maikal hills of Satpura ranges (Mandal *et al.*, 2017) and is characterized by hilly terrain and undulating plains.

In hilly regions, variations in the forests are observed with the changes of aspect and configuration of slopes where underlying rocks do not change (Troup, 1921). The vertical zonation of vegetation has also been observed in ATR due to variation in its altitude. The altitude range of ATR lies between 305 m to 1080 m above mean sea level.

Geomorphology map of ATR (Fig. 4a) depicts that it is dominated by hills with few fault zones. The movement and storage of ground water of the region is influenced by its geomorphology (Gopinathan *et al.*, 2020). More than half of ATR area composed of metamorphic rocks as shown in the geology map (Fig. 3). The distribution of forest community of any space is extremely influenced by its geomorphology, sub surface geology, soil type and climatic conditions (Ott, 2020). Billings (1950) studied that chemically altered rocks of Great Basin of Western North America affect the plant growth and vegetation pattern. His study reported that altered areas support stands of *Pinus jeffreyi*and *Pinus ponderosa*, wholly surrounded by sagebrush (*Artemisia tridentata*). Cottle (2004) reported that vegetation associated with schists and gneiss (high grade metamorphic rock) are rich but they are more influenced by climate.

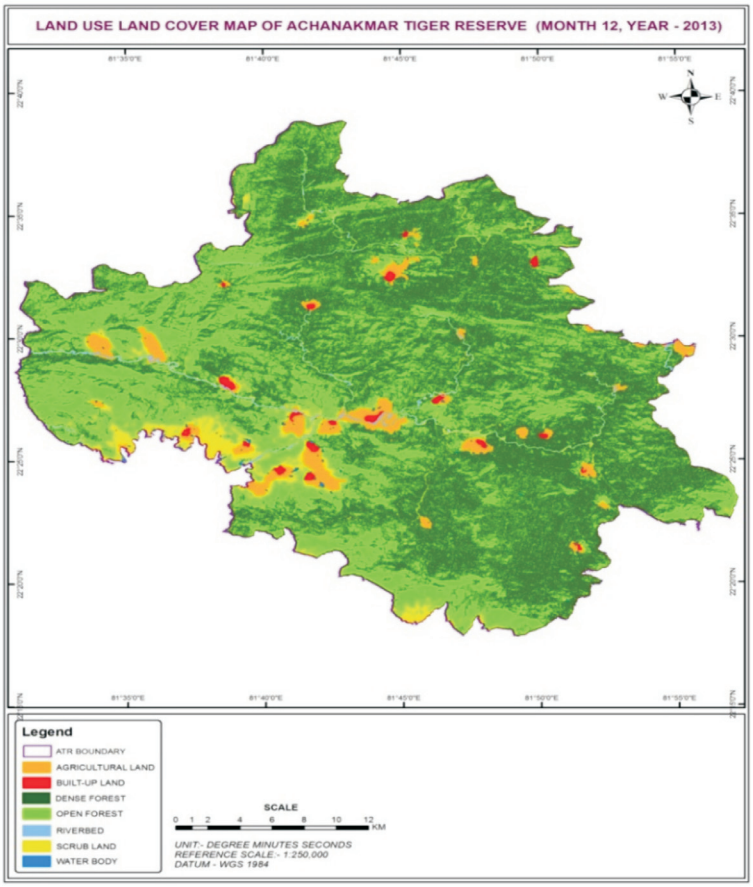


Fig. 7. LULC map of ATR derived from IRS P6, LISS III satellite imagery for the year 2013

Melelli (2014) emphasised the importance of geomorphological aspect of landscape in environmental conservation. Nichols *et al.* (1998) reported that at the landscape scale, geomorphological heterogeneity promotes higher species richness. But, there is a very limited research which mapped the correlation between individual geomorphical, geological and hydrological features with that of plant species richness (Tukiainen *et al.*, 2017).

In ATR dense forest cover indicates that the soil, sub surface rock formation and ground water availability favours the luxuriant growth in this region. Rich sal forest in the area is due to acidic soil.The soil colour of ATR is mainly lateritic yellowish. Its colour changes due to the presence of iron and its quantity. It turns yellow when iron oxide is less in quantity and leaching has started.

Since, most of the elevated topography of ATR area is composed of older metamorphic rocks and are vulnerable to landslides so proper landslide zonation mapping is essential for proper conservation of geology. When conservation is taken into consideration, emphasis should also be given to the lesser known and recent concept of geodiversity, geoheritage elements along with biological diversity. The geoheritage sites should be conserved in a sustainable way by implementing proper monitoring methods because once they are damaged or degraded it cannot be restored (Woo and Worboys, 2019). The very first approach for geomorphological heritage and its conservation is through training of rangers and technical staff (Pereira *et al.*, 2009).

Conclusion

RS & GIS techniques were used for geo-morphological mapping of Achanakmar Tiger Reserve (ATR) area. Achanakmar Tiger Reserve is situated in the lap of Maikal hills, which is characterised by hilly terrain and undulating plains. The amalgation of different type of landscape i.e hills, undulating landscape and lush green forest describes the uniqueness of the area. Thus providing pristine habitat for rich floral and faunal biodiversity.

The altitude varies between 305 m to 1080 m above mean sea level. Lamni and Khuriya range recorded the highest elevation peaks (910-1080 m above msl). Major geological formations are metamorphic, covering more than half of the ATR area. The dominant soil type of the area is clayey coarse followed by fine loamy. Other soil type of the area is clayey, fine silty, loamy skeletal and coarse / fine loamy. Topography of any region is a reflection of subsurface rock formations, their weathering and erosion pattern, and their geological structures etc. The present attempt will be useful for developing an information base, which will facilitate conservation practices in future. The data may be helpful for detail study of different components such as geodiversity, geoheritage elements and geobotanical relevance for landscape management.

Due to specific geoheritage of ATR, there rich diversity of forest tree species exists in the area. Sal (*Shorearobusta*) is the dominant tree species and covers majority area of ATR. The other commonly found tree species are Saja (*Terminalia tomentosa*), Bija (*Pterocarpus marsupium*), Tendu (*Diospyros melanoxylum*), Haldu (*Adina cordifolia*), Mahua (*Madhuca indica*), Dhaora(*Anogeissus latifolia*), and Bamboo (*Dendrocalamus strictus*). There exists a positive correlation between geoheritage pattern and the diversity in flora and fauna of ATR which is a healthy sign for any natural forest.

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Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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