Research Article: 08 to 18 (2023)
ISSN: 2583-7419
www.biologyforum.actabotanica.org

The Anthropocene Geology and Biodiversity of North Eastern Ghats Mobile Belt; Odisha; India

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Citation: Siba Prasad Mishra (2023). The Anthropocene Geology and Biodiversity of North Eastern Ghats Mobile Belt; Odisha; India. Acta Biology Forum. V02i01, **08-18. DOI:** http://dx.doi.org/10.5281/zenodo.7645138

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Received 11 October 2022 | Revised 28 December 2022 | Accepted 25 February 2023 | Available Online March 16 2023

ABSTRACT

The Northern Eastern Ghats Belt (NEGB) of length ≈400 km emerges from Bhubaneswar in the east, Lathor of Balangir, and Vishakhapatnam in the south. NEGB is dissimilar from the central and Southern EGB. The hills and the drainage network differ in their stratification lithology, minerals, rivers, forests, hot springs, and numerous waterfalls. The evolvement, topography, drainage system, biodiversity, geographic and geologic structures, and rock characteristics, differ in the NEGB Hills of Odisha, from Bhubaneswar to Malkanagiri, Odisha. The vegetation, shear zones, cratons, faults, and grabens regulate the climate, rainfall, and fluvial, mineral, igneous, and tectonic activities. The under-exploitation of the water resources and over-exploitation of all resources like mines, and forests with poor infrastructural facilities have made the southern fringes of EGB amidst the hilly NEGB Mountains poorly subjugated except for only four hydel schemes. With a lion's share of the scheduled population and plenty of medico-ethnobotanical plants, biological hotspot zones are investigated to convert them from herbal to pharmaceuticals as they are at hand and cost-effective. The waterfalls, geological, geographical, and tourist hotspots in the NEGB Hills can be planned and developed giving exposure to its bio-diversity, for future ecotourism, and hydropower generation in the mountainous districts of southern and southwestern Odisha.

Keywords: EGB, Geography, East coast, Lithology, sandstones, quartz, and laterite coping

INTRODUCTION

Present Anthropocene epoch (assumed from the year 1950), based on human activities, these inaccessible areas are made accessible and converted to building structures, agriculture, mines, and lacustrine environment in these diversities of Nature. It is a unique landscape and assemblage of Scenic views Nature in past seems to be a unique landscape and assemblage of Scenic views. The canyons, coasts, rivers, mountains, lacustrine areas, volcanoes, sands, or caves need to be explored for anthropogenic use [1], [2], [3], [4].

Peninsular India is protected in the east by the Eastern Ghats mobile Belt (EGMB), and Western Ghats (WGB Hills) mountains from the west and north by the sky-touching Himalayan ranges. The thickly populated four large wide deltas along the east coast are regularly washed out by cyclones, heavy rainfalls, high waves, tsunamis, and extreme weather events (EWEs). The geological and lithological studies of the north fringe of EGB hills end along the 850 ridge lines showing tectonic formation that indicates the strike-slip nature of the craton-mobile belt along the north edge of Bhubaneswar near Chandaka range [5], [6].

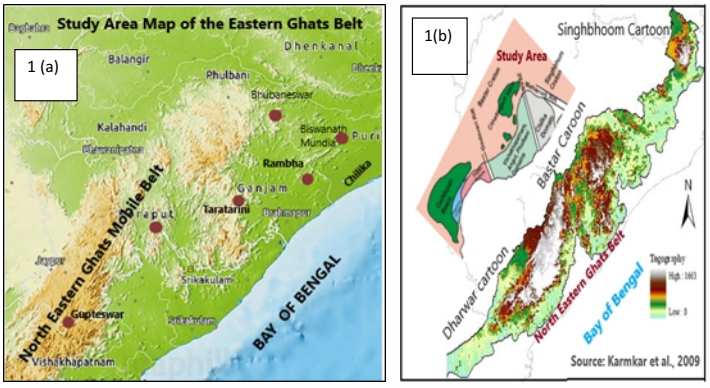

Fig 1(a) & (b): The index map of the study area (NEGB Hills range) and the thematic map

The North Eastern Ghats mobile belt (NEGMB), Odisha has its scenic splendor is a state with rich biodiversity, cultural heritage, aboriginal habitats, and architectural splendor.

Odisha is classified as three distinct lithological crustal blocks, the north Orissa boundary faults (NOBF) along the Mahanadi rift, the Eastern Ghats Mobile belt (EGB), and the West Orissa Craton (WOC). The EGB Hills is the sporadically, discontinuous, poly-metamorphosed mountains, of a multiple-deformed belt housed parallel to the east coast (EC) of India. The Eastern Ghats Hills is of extension 1800km run from Sambalpur to Puri and continue up to Nilagiri knolls of Tamil Nadu, connecting the WGB Hills of Karnataka Fig: 1(a) and 1 (b).

The EGMB hills are divided into three segments NEGMB, starting from Bhubaneswar on the northeast fringe. The Central Eastern Ghats Mobile Belt (EGMB) between the Nagavali and Krishna basins, Southern Eastern Ghats Mobile Belt (EGMB) separated by Krishna and Cauvery Grabens. The huge lagoons Chilika, Kolleru, and Pulikat are lying adjacent to the EGMB hills along the vast coastal plains [7], [8], (Fig 1).

Evolution EGMB:

The chronological tectonic framework of the EGMB has been accepted after Dobemier, and Raith, 2003, [10], [11]. EGB hills range is an ancient orogenic belt shaped by the fender-bender of the continental drift of crustal rocks of the Indian subcontinent during the Gondwana period of Archean Eon. The NEGMB Hills are the series but discontinuous chain of broken/isolated mountainous/ridges of the Peninsular Upland. The EGB hills extend from the southern northeast fringe of the Chota-Nagpur Plateau and continue till the end of the Peninsula including the eastern brink of the Nilgiri hills, Anamalai Mountains, and Palni Hills ([12]). The EGB formation periods are dateable to two distinct convergence episodes. The first rifting occurred during ~ 2.0 Ga before the present (BP) due to rifting of the continent along the eastern shores of the Indian plate. The second type of evolvement is along the Andean-type subduction of continental edge by convergent plate movement at ~1.85 Ga BP. (Fig 1). The lithological assembly and the geographical formations of the NEGB rocks are Meta sediments, Charno-underbite, Migmatitic, Alkaline Genesis, and Massif type of subgroups of origin 4505Myr, 443 ~: 8 Myr, 900-1050 Myr, Mesoproterozoic (1400–1300 Ma) and 950–1000 Ma [13], [14], [15], [16].

Indigenous species of NEGB

Fig 2: Indigenous species of NEGB Hills of Odisha (a) Philautus spp., (Mahendragiri and Taptapani) (b) Crab-eating frog (Rushikuliya basin) (c) Fungicoid frog (Rana malabaricus) in (Kalarapat and Maliparbat) (d) the Sri Lankan Stripe snake (Deomali and Baphimali Hills (e) (green pit viper) Baphlimali and Niyamgiri hills

The major plateau contains the Nabarangpur - Jeypore that originates the Sabari basin. The past Koraput, Balangir, and Kalahandi (KBK) districts have been divided into eight districts: Koraput, Malkanagiri, Kalahandi, Nabarangpur, Balangir, Subarnpur, Rayagada, and Nuapada since 1992-1993. The major mountains, waterfalls (WFs), Hills ranges, wildlife sanctuaries (WLS), and possess distinctive aboriginal indigenous species. The preservation strategies to be chalked some aboriginal buffalo breeds are found in Chilika of Puri and Khurda and Ganjam districts. The special breeds of buffalos (8 breeds) are found in Kalahandi, Rayagada, Koraput (Jirangi), Malkanagiri, Gajapati, and Parlakhemundi are endangered NEGMB species Some indigenous species of NEGMB goats (4 species), cattle (5 breeds), hens (3 types), ducks (4 varieties) and sheep (5) are endangered needs immediate conservative action plans, the New Indian Express; 15th May 2012 09:58 PM., Fig 2 (a-f). During the commencement of the Anthropocene epoch, many species have gone extinct; some are endangered, and vulnerable in the NEGMB realm. Many of them are declared extinct, endangered sorts are given in Table 1

Table 1: The mountains and hills, the endangered and vulnerable species, of the NGEB in Odisha

	[illegible]	[illegible] / Hilllocks or Part	[illegible] / Vulnerable Species EGB Hills	[illegible] waterfalls;
	[illegible]	[illegible]	3potted deer; Chilika cattles, [illegible] monitor ;jackal; Lizard ;Dugong; Hawksbill turtle; limbless skink mongoose ;	[illegible] & long beaches, Mangroves , and their associates;
	[illegible]	[illegible]Khand a giri; Udayagiri ; [illegible]	[illegible] Bengal tiger ; Water Monitor Lizard ; Bengal Tiger	[illegible]Khandagiri /Udaya giri caves ;Kanjia Lake; Chandaka; Nandankanan
	[illegible]	[illegible]; Maninag; Rukhi & Balaram	[illegible] ; hyena, [illegible]	[illegible] Vultures
	[illegible]	[illegible] Solari; Bhaleri; Jatia ; Rambha ; hills ; Budhakhola	[illegible] Ashoka ,Cycas (spherical,orixensis ; Nayagarhensis);Black buck Hawksbil green Turtle ;Peafowl	[illegible]; Narayani fall; NirmalJhar ; Ganjam ; Budhakholo Falls ;
	[illegible]	[illegible],Pokunda, Mathamunda,	[illegible] ;Indianelephant, Bengal tiger, lion, Gharial	[illegible]
	[illegible]	[illegible]mpanga;Debrigarh Lax midungari;Mudesili ;Brooks	[illegible] Bengal tiger, Indian lion,	[illegible] Hirakud Dam; Gandhiminar, Deb Derigarh; Sanctuary
	[illegible]	[illegible] hills ; rivers HillOng,Tel,Suktel,Lant & Indra	[illegible]	[illegible] r part in Gandhamardan Hills
	[illegible]	[illegible] Dongor hillocks;	[illegible] bustard, Forest owl	[illegible] WF; Patalganga spring;
	[illegible]	[illegible] mali ; Kutrumali ; Kutrumali hills	[illegible] , or Cycas N ayagarhensis	[illegible] Falls (Broken) ; many medicinal plants
	[illegible]	[illegible]Ramgiri; Chandragiri ;	[illegible] , or Nayagarhensis ; Peacock,	[illegible] WF, Luha Khamb eswar
	[illegible]	[illegible]oudahandi ; [illegible];Niyamgir i;Krishnmali Khandualmali	[illegible] serpentine (threatened) Cycas Spherical, (Orixensis ; Nayagarhensis); Bodh fish ; Sloth bear, Sambar, Rattel, Wolf ; Pangolin	[illegible] Gudahandi caves
	[illegible]	[illegible]Dumuriput; Deomali ;Baphlimali ;Mali parvat, Panchpat mali,Kodingamali,	[illegible] or Nayagarhensis ; Peafowl ; the smooth - coated otter ; Many butterflies;	[illegible] Duduma Waterfall (175m); [illegible]
	[illegible] Giri	[illegible] o;Akkūru Parvatam, Munas IrālaKonda,Garda Konda,Baria & Pūsukupli ongar	[illegible] ; Flapshell turtles ; the smooth - coated otter ; Golden Orioles, Indian grey hornbills, lesser kestrels, Hill mynas, Green avadavat	[illegible]
	[illegible] pur	[illegible]	[illegible] ; the smooth -coated Otter ; [illegible] bills, lesser kestrels, Hill mynas,Green avadavat	[illegible] ; Ambapani W LS; Hirli Dongri, Chandandhara Waterfalls
	3ubarnpur	[illegible]	[illegible] ortoise ; the smooth -coated otter	[illegible] Pahad;Brahmanikhandi
	[illegible]	[illegible] Hills ; Mukulingia Hills ; [illegible] ;Kalinga; Mandasar;	[illegible] Cycas Nayagarhensis ; Fishing cat ; [illegible] lesser kestrels, Hill mynas, Green avadavat	[illegible] Daringbadi; [illegible] ; Pokadajhar; Ludu waterfalls; [illegible]-saru Kuti ; Kurudia WF.
	[illegible]	[illegible]ambarugarh ;	[illegible]; Peafowl	[illegible]&Laxmipathar and Waterfall ;

Source: Statesman News Service/BBSR/10th Mar.2022/10:30 am; ([17],[18]; www.indiaenvironmentportal.org.in/files/ Reportof BiodiversityofSouthOrissaMany useful but rare plants like Pueraria tuberosa, Gloriosa, superba, Cycax, Tylophora fasciculata Gymnema sylvestre, Cayratia auriculata, Raderrnachera xylocarpa, Rauvolfia serpentina, Melasma thomsonii, Tectaria cicutaria, have been badly depleted due to

over-exploitation for medicinal uses. The conservation of the above plants and many others is warranted to preserve their phytogeographic importance, medicinal values, and the realm of their natural heritage.

Physiography

The Eastern Ghats are older than the Western Ghats. The EGB Hills formation has a complex geologic history. They are related to the assemblage and disintegration of the ancient Supercontinents of Rodinia and Gondwana. At the southern end, the EGB form small hillocks are the low Sirumalai and Karanthamalai hills of Tamilnadu. North of the Cauvery River is higher. They are Rollimalai, Panchaimalai, Shevroy, Kairayan Hills, and Chittering in North Tamilnadu. The Nilgiri hills run east along the river Cauvery ecological forest corridor that connects EFB and WGB hills.

The types of forests in NEGMB are dry/semi-evergreen southern tropical dry mixed deciduous, Dry savannah, southern tropical dry scrub/ thorn; Carnatic umbrella; Southern sub-tropic hill/ thorn &Mangrove forests. Similarly, the rivers emerging from the NEGMB hills are Rushikulya; Bahuda Vansadhara, Palar, Nagavali, Sabari Champavati, Gosthani; Sarada; Sileru, Tammileru; Gundlakamma, Pennai, Yaru, Swarnamukhi, Kundu, Velar; Pennar; (CWC book) covering 6states i.e. Odisha (25%), Andhra Pradesh (40%), Telangana (5), Tamil Nadu (25%) and Karnataka (5%).

Review of literature

The EGMB is a series of ancient orogenic discontinuous ranges of hills formed tectonically due to rifting and shifting of the part of the Rayner Complex of Antarctica, during the Proterozoic period 1.0 to 0.9 Ga Before present (BP) [19]. Various authors substantiated the evolvement of the EGB Hills date back to ~1600 Ma years BP, involving magmatism, sedimentation, metamorphism, and crustal anataxis and comprise of three broadly classified lithological groups (metapelitic granulite, charnockite-ender bite gneisses/ mafic granulite's, and migmatitic gneisses trending regionally NE-SW, [20].

The evolvement of the Eastern Ghats provinces is part of the Rayner complex of Antarctica by rifting and juxta-positioning at various times and events, approximately 983Ma BP, [21], [22], [23],[19]. The systematic study of Gravity-magnetic anomalies, [24], the diversity, composition, and structure of dry tropical forests Fire alter in the Eastern Ghats.

The NW of Chilika Lagoon houses sapphire-spinel-bearing found in tectonically formed caves within the Khondalite and pelitic granulite's in the Kaithapalli (Rambha) area in the northern part of EGMB, [25], [26]. The EGMB is the tectonically dynamic zone, which encompasses three provinces, the Eastern Ghats, the Jeypore, and the Krishna Provinces, along the eastern brim of Peninsular India, with a low-velocity layer containing magma fluid at ~20 km depth of varying depth and susceptible to tremor, [25], [26].

Fold-thrust belt geometry NEGMB

The crash between the Lambert areas of East Antarctica and the Baster–Dharwar craton, under temperatures higher than 700 to 8000 C, (ultra-high temperature) granulite facies metamorphism instituted in the Eastern Ghats occurred during ≈1650 Ma BP, later the collision between 1500 to 1200 Ma BP. It was connected with the partition of the Vestfold Hills and another opening of the proto-Indian ocean. Finally, there was the development of a sequence of basins towards the west of the Eastern Ghats areas i.e. Khariar, Balimela, Upper Kolab, Indravati, Vansadhara, upper Nagavali and Sabari basins in Odisha [27], [28]. The Indravati, Upper Kolab, and Balimela Basins are 9000km2 spread over South, and southwest Odisha, and Chhattisgarh. They are rifts due to outcrop of Proterozoic sediments, in Koraput, Nabarangpur, Malkanagiri, and Chhattisgarh areas.

Floral Biodiversity

These low heightened hill ranges have a collection of tropical vegetation that is supporting thickly populated areas (Pas) in the canopy. Mostly the NEGB hill locks are bald or gradually becoming bald. A series of protected forests representing floral diversities and the number of permanent or fragile exists in the significant ecosystems. The Eastern Ghats have animals like amber, wild pig, deer, Indian elephants, wild boar, jungle cat, Bengal fox, and blackbuck, etc., and avifauna peacocks, eagles, wild owls, vulture, red-whiskered bulbul, and many exotic species found in the forest areas. Biodiversity wise NEGMB is a series of parallel discontinuous forests ranging from evergreen to semi-evergreen tropical moist deciduous forest. They are of savannah type and scrub jungles. Such diversity provides a habitat for 2500 species of flowering plants, 115 species of Herpes to fauna, and 297 species of avifauna. These species are less enumerated and poorly classified in the IUCN list (international union of conservation of nature).

The Fauna and Avifauna

The faunal diversity of the Eastern Ghats is poorly documented in comparison to the Western Ghats. Concrete data against the faunal diversity of EGB Hills is scarcely available. The forests are dry and difficult for the biotic animals to survive with hard-hit summer. However, some endangered species like tigers, leopards, bears, elephants, pangolins, deer, blackbuck, etc. About 311 species of insects and similar families were from the EGB constituting ≈ 0.56% of the total chronicled 400 vertebrate species and 217 invertebrates, (Centre for Envir. & Develop. http://eptrienvis.nic.in/All)

The study domain

The apex of peaks are at heights of Deomali (Odisha), Armakonda (AP), and Kattahi Betta in BR Hills (Karnataka), having heights above MSL are 1672m, 1680m, and 1822m. The study area belongs to the Eastern Ghats belt located between 110 30‟ and 220N latitude and 76050‟ and 86030‟E longitude with strike NE-SW. Based on Geological and tectonic considerations the Eastern Ghats in Odisha start from north of Similipal in the Mayurbhanj district and run through Malkanagiri district. 17 districts of Odisha come under the Eastern Ghats. It covers a total area of around 75,000 km2. Apart from Iron and bauxite ore, the entire EGB region has granulite terrains, mainly Khondalite and Charnockite sheets of rocks, intruded locally by the mafic-ultramafic suits, anorthosites, alkaline rocks, Potassic granites, pegmatites, and quartz veins with Gondwana sediments. The areas under EGMB under study are:

1. Khandagiri: (Lat20.2569°N, Long85.7792°E), The SOI topo sheet No. 73H/16RE:
2. Dhauli : 20.1978° N, 85.8436°E , The SOI topo sheet No. 73H/16RE: 1:125,000
3. Tapang - Golabai : Lat-250 43' N ; Long-850 47' 5” E

4. Balugaon: Lat-190 5' N, Long.-800 23' E,
5. Banapur: Lat-19045' 44" N; Long-85012' 57" E)
6. Taratarini : (19.4889° N, 84.8991° E)
7. Gandahati, in Gajapati district: (18.8777° N, 84.2667° E)
8. Khasada Gajapati District : (18.8777° N, 84.2667° E)

The Northern EGB geography

Bhubaneswar area: This region (Lat-20014'45" N; Long-85047'5" E with Altitude-43m (mean sea level (MSL). Dhauligiri, Khandagiri, and Udayagiri are located at a distance of 15km, 7km, and 7.2km from the temple city, Bhubaneswar, and the capital of Odisha. The caves and the monuments are of historical importance in the 2nd century that comes under the Topo sheet 73H/16 of Survey of India. The geographical studies for structure, stratigraphy, and geometry of rocks in the area are done, in Fig (Fig 3(a), Fig 3(e)), ([29]).

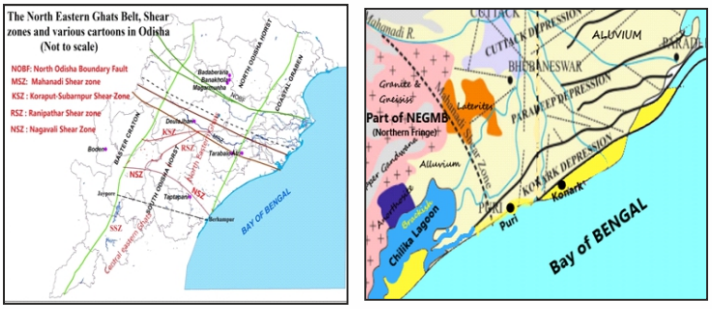

Fig 3(a): The NEGB, shear zones, and cartoons: Fig 3(b): The northern fringe geology; of NEGB 7D_MERO_Bhubaneshwar_Vamsadhara_Rushikuliya_Nagavali_Sarada_WYB_2016-17

Climate

The NEGMB area have a humid tropical climate. The average (av.) annual rainfall of this area is 1451.2mm reducing from north to south. The minimum temperature of the area is around 80C during January months, whereas the maximum temperature is about 450 in May. The Bay of Bengal cyclonic storms slamming NEGB Hills are the highest along the East coast of India. The average temperature is about 27.4°C and major rainfall was received during SW-monsoon days.

Hills around Bhubaneswar

The area comprises of series of small hillocks of steep slopes of height 30m to 90m above MSL. The Dhauligiri Hills is about 90m high on its southern. The north side of the Dhauli mound show closely spaced contours indicating a steep slope whereas the south and eastern side show little wider spaced contour indicating a gentle slope

Geomorphology

The Dhauligiri hillocks are formed as a residual hill, standing as isolated amidst the first flood plain developed by the river Daya. There are two mounds and a valley along the hill slope. Near the foothills, the river Daya is flowing cutting through the hillocks on both sides where the flow direction is changed. The general geomorphic trend is nearly E-W and sporadic flat top with a very steep slope. It is an elongated hillock as indicated by the contour lines. The flood plain encircling Dhauligiri is an old alluvial terrain, supporting rich cultivation and high yield Fig 4 (a-e).

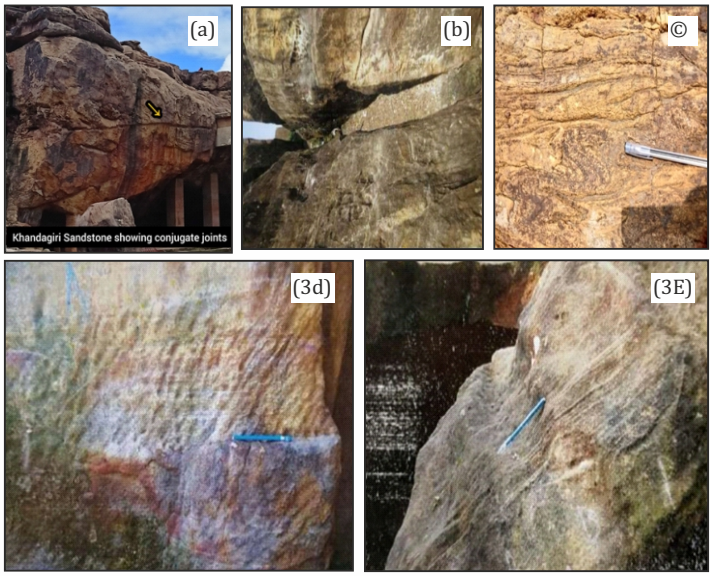

Fig 4: The Khandagiri- Udayagiri Hills showing (a) conjugate joint (b) the master joint(c) complex joint and well preserved (d) ripple marks (e) Bedding planes

Lithology setup

The exposed rocks in the *Khandagiri* and Udayagiri are the Athagarh Sandstones. They are terrigenous Sedimentary Khondalite rocks composed of more than 70% sand and quartz particles displaying ripples and bedding Plains. Feldspar, micas, heavy minerals, and rock fragments, are seen with lateritic rocks over the sandstones. Latosols are the type of soil created from the laterites due to prolonged weathering. The sea level progradation and degradation with transgression due to the shifting of the summer monsoon, and later subsequent upliftment is the reason behind the minimal deformation in the configuration of the hills. The *Dhauligiri* area forms a small part of the Eastern Ghats complex of the Precambrian age.

KHONDALITE AND ANORTHOSITES

Khondalite

It is of reddish brown color with well-marked color bands. Garnet is the quartz-feldspathic material a banded meta-sedimentary rock composed of Quartz, Feldspar, Garnet Sillimanite, and Biotite which are identified as megascopic. Anorthosites of Massif-type are found in the outskirts of the Chilika Lake area, and the Turkel area of Balangir. The Udayagiri housed in the northern fringe of EGB exhibits metamorphic Grenvillian granulite of 950–1000 Ma BP known as Udayagiri anorthosites complex, (UAC), consisting of anorthosites, leuconorite, and norite. They show progradation and retro-gradation of metamorphism before and after the anorthosites invasion, signifying their positioning, ([30], [31], [32], [33]).

Structure and Geometry

The lithologic assemblage especially Khondalite shows different structural features. The rock has suffered high-grade metamorphism and well-marked development of the prominent gneiss. The different structural features are bedding planes, foliation, Schistosity and gneiss, lineation, joints, folds, and faults, ([34]).

Bedding plane and Axial plane foliation

The strike of the bedding plane foliation varies from N-S to S22W, with dip varying from 80 -84 due to W-ly and NW-ly. Whereas the Axial plane foliation is the strike of the axial plane foliation of this rock of this area varies from N65E to S65W having dip towards NW and sometimes Garnets are stretched parallel to the foliation plane. Various lineations found in the northern EGMB lineations are internal, Mineral, Minor metamorphic folds, clear folds, joints, faults, deteriorated sides, etc.

Stratigraphic columns

The stratigraphy column from the frustum to bed planes are known as alluvium/latosols, laterite, quartzite, Khondalite, and finally either charnockite or hard granite black or colored. The topsoil the outskirt of Dhauli hills is either old or newly formed alluvium in the agricultural lands, comprising floodplain deposits. The immediate underlain is a bed of lateritic soil followed by 10m to 15m of porous laterite mines. Later the extension is either quartz or Khondalite or Granites. These are "inselbergs" and they are undergone high-grade metamorphism.

Tapang-Golabai Mundia

(Lat-250 43' N, and Long-850 47' 5" E; altitude-46m) The Golabai and Tapang Mundia are the hillocks coped with lateritic sheets composed of alternate dark and white bands. Charnockite and gneisses dominate the lithology of the area, (Fig 5(a) & 5 (b). They are under heavy quarrying operation.

Fig 5 (a): Nijigarh, granite quarry at Tapang (paleo/latosol overburden) **Fig 5 (b)** Alternate bands of leptynite and charnockite

Charnockite, the meta-igneous rock formed in water-deficient conditions with the abundant occurrence of leptynite (white patches) in the host gneiss found in NEGMB at massive Anorthosites setting at Balangir (~400 km2), Chilika Lake (~250 km2), Jugsai Patna (16 km2), and Turkel (81 km2) massif. The rocks indicated the presence of garnet, quartz, biotite, and feldspars. Rocks are highly metamorphosed and thus show granoblastic texture. Quartz ribbons are also found in these metamorphic rocks in the Tapang quarry. From the mineral assemblage, it is inferred that the rocks are formed in volatile deficient conditions (Granulite facies). Granulite facies are characteristics of the Eastern Ghats rocks.

Banapur and Balugaon

(Lat-190 5' N, Long.-800 23' E, Altitude-38m); The Banapur-Balugaon area is part of the NEGMB has four settings of Chilika west bank (~250Km2).

Fig 6 (a) and (b): Bands of Charnockite preserved within a leptynite rock at Balugaon and Banapur

The phase of magmatism in anorthosites of the north EGMB varies as 1400 Ma BP 792 ± 2 Ma and 983 ± 2.5 Ma for the Chilika Lake complex and ca. 930 Ma for the Balangir complex. The massifs are hosted by a migmatitic garnet-ferrous felsic suite of rocks that vary in composition from granite to monzonite through granodiorite, ([31]). It may also contain sillimanite and graphite. Anorthosites are phaneritic, intrusive rocks consisting of plagioclase feldspar (90-100%) and minimal mafic component. Pyroxene Ilmenite, Magnetite, and olive are most commonly present, Fig 6 (a) & (b).

SW Odisha (Gandahati)

Gandahati (18.8777° N, and 84.2667° E) is a waterfall near Parlakhemundi, in Gajapati, which lies within the southern fringe of the Northern EGMB range of hills in Odisha. The perineal waterfall is 180.5 m above MSL, one of height 20 m, and over the rivulet Mahendra Tanaya.

Fig. 7 (a): Geological settings of Gandahati Waterfall; Fig. 7(b). Porphyritic texture near Rayagada

The rocks of the Gandahati area are of six main types of textures phaneritic, aphanitic, porphyritic, glassy, pyroclastic, and pegmatite (Fig7(a), and Fig 7(b)).

Porphyritic Texture

Porphyritic textures (from igneous rocks) are visible as large crystals, continuous, well-formed; fine-grained over glassy groundmass called phenocrysts are shown by the rock mass at Gandahati.

Cross bedding

Cross-bedding or cross-stratification can form in the dynamic fluvial environment over a bed with mobile material. They are in layers within a stratum and at an angle to the main bedding plane. Gandahati rocks have fairly consistent fixed angles and direction of cross-beds. They are cross-beds that range depth-wise in centimeters, to hundreds of meters based on the depositional environment and the extension of the bed form.

Khasada Waterfall:

(Lat.:19.2556058 N, Long.:84.2330967E) is located near Chandragiri of Gajapati, Odisha **(fig 8 (a) and Fig 8(b)).**

Fig. 8(a). Khasada Waterfall; Fig 8(b): Biological weathering in the Khasada WF in the Chheligarh

Ripple Marks

Ripple marks are found on the surface of the rock bed of the Khasada waterfall zone. The marks are unidirectional or asymmetrical across the gentle up-current slope and a steeper down-current slope. They form in fluvial and aeolian depositional environments. They are Prominent in the lower part of the Lower Flow Regime.

Hornblende Intrusions

The distinct sheet structures on rocks called Veins form when mineral constituents get deposited on the surface due to hydrothermal circulation. They are formed due to open-space filling and crack-seal growth. Hornblende is a rock-forming mineral in acidic and intermediate igneous rocks like granite, diorite, syenite, site, and rhyolite or in metamorphic rocks such as gneiss and schist. These metamorphic rocks are easily identifiable in Khasada waterfall. At Khasada, they are dark in color and have two directions of excellent cleavage that intersect. The presence of cleavage can be used to distinguish it from black tourmaline which often occurs in the same rocks.

Joints

A joint is a brittle-fracture surface in rocks with the least separation. Joints have smooth, clean surfaces extending small, but not extending large depths in the Earth's crust. In weathered rocks, joints are relatively ordinary, but upon weathering, they convert well-marked (mostly in soluble limestone). The water percolating through joints can form large caves and develop underground rivers formed in Gupteswar cave in Koraput. Quarrying operations can facilitate the growth of a well-developed joint system.

Metamorphic bedding

Metamorphic rocks vary in colours from clear to cloudy to milky white, as well as rose, blue, yellow, green, blue, orange, and smoky containing abundant quartz especially those produced from granites, sandstones, or shales. In particular, coarser-grained metamorphic gneiss is marked by distinct bands of quartz and other minerals on the Khasada Hills of Gajapati.

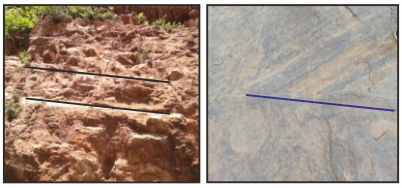

Fig 8 (a). Metamorphic Bedding and Fig 8 (b) quartzite veins in rocks near Khasada Waterfall

Distortions may change the sedimentary bedding by compressing, inclining, folding, or other changes. One of the most common types of bedding is called graded bedding of Khasada.

Quartzite veins

The Quartz veins are mostly fracture related and have clear contact with their host rocks. The simplest type of quartz vein is the filling of an already present crack in Khasada rocks (Fig 8(a) and Fig 8(b)). The crack might form during the folding of the rock in mountain-building processes, by shattering during tectonic events Fig 8(a) and Fig 8(b).

Unconformity

An unconformity is a contact between two rock units in which the upper unit is usually much younger than the lower unit. Unconformities are typically buried erosional surfaces that can represent a break in the geologic record of hundreds of millions of years or more. The Khasada fall has such a type of unconformity (Fig 8(b). There are three kinds of unconformities: disconformities, non-conformities, and angular unconformities.

Tara Tarini, Ganjam: (Lat 19.4889° N, and Long 84.8991° E):in Ganjam district

Layering and bedding

Layering, or bedding, of sedimentary rocks shown by the stratum at Tara-Tarini hills in Ganjam Districts on the bank of the Rushikulya River. These sedimentary rocks are formed particle by particle and bed by bed. The layers are piled one on top of the other, the lower layer is older than the upper one. Strata may range from thin sheets that cover many square kilometers to thick lens-like bodies that extend only a few meters laterally. Original stratification may be destroyed by plants or animals, by recrystallization of limestones, or by other disturbances after deposition as some rocks do not exhibit stratification, Fig 9(a) and Fig 9 (b).

Fig 9(a). Layering and bedding at Taratarini, Fig 9(b). Deterioration of rocks by physical weathering

Weathering Physical/ Biological

Physical weathering is the process of the disintegration of rocks, minerals, and soils without chemical change through abrasion by temperature, frost, pressure, root action, and burrowing animals or human activities shown in many rocks of Taratarini. Biological weathering is the weakening and subsequent disintegration of rock by plants, animals, and microbes. Biological weathering also means organic weathering. It is the disintegration of rocks as a result of the action of living organisms shown in the rocks of Taratarini. Biological weathering can work simultaneously with physical weathering, by physical or chemical weathering, Fig 9 (a) and Fig 9(b).

Ethno - pharmacological uses

The flora, fauna, avifauna, the herbs, are used by the aboriginal peoples of SW-Odisha from NEGMB as traditional medicine (Banousoudhi or naturopathy) but have a little market and poor management. Medicinal plants are intimately attached to people and plants ([35], [36]). Culturally inherited the ethno-threptic plants have fit into, herbal choices, changing lifestyles, social transformations, and perceptions. The NEGB districts famous for ethnobotanical sources are Boudh, Koraput, Kandhamal, Kalahandi, Malkanagiri, Nayagarh, and Ganjam Hills range. The ethnobotanical plants in Odisha are reported by the author in his article search ([37].) The present search involves the reporting of the Floral diversity that is used for botanical practices available in the EGMB hills of Odisha by the aboriginal tribal inhabitants. The present demand is to collect those medicinal plants from the tribal community and have wide research and application to serve humanity with appropriate doses **(Table 3)**

#	Local Name	Botanical name	Part Used for	Districts	#	Local Name	Botanical name	Part Used for	Districts
1	Bachha (root)	Acorus calamus L.	Cataracts, epilepsy, worm infections	Kandhamal, Gajapati,Nayagarh	32	Dhataki (Flower)	Woodfordia fruticosa (L.) Kurz. (Lythraceae)	Dysmenorrhoea	Rayagada
2	Aanla Fruit, leaf)	Emblica officinalis Gaertn	Gout, Dysuria, urticaria, hair loss, dandruff Dysentery	All districts EGB	33	BisalyaKarani(Leaf)	Tridax procumbens L.	Couts & wounds	All districts EGB
3	Bana Haladi(Rhizome)	Curcuma aromatic Salisb.	Blood stool Cardiovascular, Gastric disorder, and snake bite	All districts EGB	34	Ashwagandha (roots)	Withania somnifera (L.) Dunal (Solanaceae)	Spermatorrhoea	Nayagarh
4	Ashoka (bark, seed, flower)	Saraca ashoka (Roxb.) de Wilde.	Irregular menstruation, bleeding, Dysuria, calculus	All districts EGB	35	Gokhura (Roots and fruits)	Tribulus terrestris Linn. (Zygo phylloclade)	Oligomenorrhea, Urinary disorder	Nayagarh, Kalahandi
5	Arakha	Calotropis gigantia L	Cat bite, headache/toothache. Induce abortion and migraine	All districts EGB	36	Guluchi (plant	Tinospora cordifolia Willd. (Menispermaceae)	Spermatorrhoea, leucorrhoea impotency, sterility; UTI	Belghar, Phulbani
6	Gheekuanri (Leave)	Aloe vera L.	Madness, Ashthma, bowel disorder; wound	All districts EGB	37	Harida (Fruit)	Terminalia chebula Retz. (Combretaceae)	Low lactation/ post-natal complaint	Rayagada, Phulbani, Kandhamal
7	Odosomari (Seed, bark, Leaf)	Argemone Mexicana L.	Skin disease, syphilis, wound &ratbites Cancer/ and viral fever	Kandhamal District	38	Arjun (Bark,	Terminalia arjunaWight., Am (Combretaceae)	Urinary Tract Infection	Kandhamal; Ganjam
8	Neem (Leaf, Bark, flower)	Azadirachta indica A. juss	Boils, smallpox, leprosy, skin/mouth diseases/wounds	Kandhamal District	39	Dhuajabhang o	Tadehagi triquetrum (L.) Ohashe (Fabaceae)	Low libido	Phulbani
9	Thalkudi (leaf)	Centella asiatica L.	Jaundice, LQ, memory, immunity; Anaemia	Kandhamal District	40	Jamun (Stem; bark)	Syzygiumcumin (L.) Skeels (Myrtaceae)	Nephrolithiasis	Nayagarh, Phulbani
10	Satavari (plant)	Asparagus racemosus Wild	Protects pregnancy, Rheumatism	Kandhamal District	41	Sahada (root)	Streblus asper ours. (Moraceae)	Leucorrhoea	Pasora, Phulbani,
11	Akanbindhi	Cissampelos pareira L	Leprosy, migraine, hemorrhoids and dysentery Diabetes	Kandhamal District	42	Bhuikadam,	Sphaeranthus indicus L. (Asteraceae)	Polyuria	Koraput
12	Sadabahar (root, leaf)	Catharanthus roseus (L).	Skin disease, insect stings, diabetes, and Tumours	Kandhamal District	43	Ruhen (bark)	Soymida febriguga A. Juss	Menstrual disorder	Western Odisha
13	Bada-Chakunda(root, seed)	Cassia occidentalis L	Eczema, filarial and asthma Cough	Kandhamal District	44	Muturi (root)	Smilax zeylanica L. (Liliaceae)	Leucorrhoea, Metrorrhagia, Spermatorrhea	All EGB districts
14	Aparajeeta (plant)	Clitoria ternatea L.	Acne, boils, filaria, poison affected area	Kandhamal District	45	Muturi laha (root leaf)	Smilax ovalifolia Roxb. (Liliaceae)	Spermatorrhoea	Tikabali; Phulbani
15	Hadabhanga (plant)	Cissus quadrangularis L.	Bone fracture and constipation Appetize	Kandhamal District	46	Bajramuli (all)	Sida cordifolia L. (Malvaceae)	UTI; Haematuria, Gonorrhea, cystitis, Leucorrhoea	Coastal dune Nayagarh
16	Bara (bark, leaf, fruit)	Ficus benghalensis Linn.	Mouth inf., skin diseases diarrhea Sexual impotency	All districts NEGB	47	Biskhapuri (root)	Sida cordata (Burm.f.) Borss. (Malvaceae)	Amenorrhoea	Jamugurha, Belghar, Phulbani,

17	Mandar (leaf, Flower)	Hibiscus RosasinensisL.	Leucorohea ; Indigestion; Hair growth; skin diseases	All districts EGB	48	Sala (Bark)	Shorea robusta Gaertn.f. (Dipterocarpaceae)	Spermatorrhea, Leucorrhoea, metrorrhagia, Amenorrhoea Dysmenorrhoea, Sterility	Kandhamal; Malkanagiri
18	Haladi (Rhizome)	Cureuma longa L.	Boils, eczema, chicken pox, allergies and kill Ecchymosi	Phulbani; Koraput	49	Banaganjei, Sarukuch (all Plant)	Scoparia dulcis L. (Scrophulariaceae)	Spermatorrhoea	Mandakia, Phulbani
19	Kaincha (Seeds)	Abrus Precatorieus L.	Abortifacient	MalkanaGiri	50	Patalgaruda (Whole Plant)	Rauvolfia Serpentina (L.) Benth (Apo cynical)	Oligomenorrhea	Khordha; Nayagarh; Phulbani
20	Sitaparu (root)	Plumbago Zilanica L.	Abortifacient	MalkanaGiri	51	Pordhamara.Rhizome	Pueraria tuber osa (Roxb.ex Willd.) DC (Fabaceae	To increase lactation	Rayagada
21	Palasa (leaves)	Butea monosperma Lam. (Fabaceae)	Unwanted pregnancy	Rayagada; Baudh	52	Kastadaru (stem;bark)	Polyathia longifolia Sonn (Annonaceae)	Gonorrhea	Khordha & Nayagada
22	Olata Kamala	Abroma Augusta (L.) L.F (Malvaceae)	Gonorrhea; Menstrual disorder	Puri, Khordha	53	Chitaparu (root)	Plumbago zeylanica L (Plumbaginaceae)	Unwanted pregnancy, Contraception	Ganjam; Tikabali of Phulbani
23	Pedipediaca (Leave; seed)	Abutilon hirsutum (Vell.)	The urinary problem, Syphilis	Koraput (Sunabeda WL San)	54	Khajuri (root; leap, fruit)	Phoenixacaulis Buch.Ham. ex Roxb. (Arecaceae)	Spermatorrhoea	Kandhamal
24	Manjuati (root;leave)	Lawsonia inermis L.	Jaundice, Leprosy;skin diseases; Hair Loss	Koraput; Mal-Giri	55	Basang (bark)	Adhatoda vasica Nees	Stomach pain	Koraput, Nabarangapu
25	Agara		Rheumatic pain; Eye infection	Koraput; Nawarangpur	56	Pokasungh (leaf)	Ageratum conyzoydes	Scabies	Similiguda N-rangpur
26	Apamaranga Basanga (root);	Achyranthus aspera L. (Amaranthaceae); Adhatodavasicaees.	Expedite delivery	Phulbani;	57	Lembu (Leaf, fruit)	Citrus medica	Boil; Vomiting	N-Rangpur; semilgada
27	Raktakhai (root)	Adiantum lunulatum L	Haematuria	Phulbani;	58	Tulasi	Ocimum santum L. (Lamiaceae	Malaria	All EGB districts
28	Talamuli (root)	Curculigo orchioides Gaertn.(Hypo xidaceae)	Gonorrhea, STD, Impotency; Dysuria, Leucorrhoea	Kandhamal	59	Patala garuda (Root)	Rauvolfia serpentina (L.) Benth. ex-Kurz	orally in snakebite.	Rayagada
29	Nirmal (Whole plant)	Cuscuta reflexa oxb. (Convolvulaceae)	Contraception; Spermato rrhoea	Phulabani	60	(Koltia) Root, bark	Tephrosia purpurea (L.) Pers., Fabaceae	Toothache, constipation	Rayagada
30	Dudura	Daturastram-onium L (Solanaceae)	Infertility in women	Khurdha;Nnayagarh; Puri	61	Basang (bark)	Plumbago Zylanica L.	Cough	All districts EGB
31	Golamaricha (Fruit)	Piper nigrum L.	Indigestion, Cough; cold	Gajapati, GanjamKoraput	62	Bisalyakarani (Leaf)	Tridax procumbens L., Asteraceae	Wound	All districts EGB

Source: In addition to ([37],[18])

Many floral species in the NEGMB are left as they are common and used almost all over India. The present study deals with only those species which are threatened or endangered varieties

DISCUSSION

The NEGB region along the east coast covers 75000 km2 housed between 770 22" – 220 81" E. Long, and 110 31" – 210 0" N lat of crunch shape. The region extends a length of 1750 km. The northern fringe is the Biswanath Mundia, hills the Chilika Lagoon, and the southern periphery is the Nilgiri Hills (TN). The northern coastal stretch is about 400km from Puri to VZG and hills of the southern and southwestern parts of the entire State ([38]; [39], [40]). The frequency of cyclonic disturbances slamming the NEGMB coast is highest along the EC of India. But the NEGMB protects the hinterland from these storms ([41]) The districts Gajapati, Koraput, Kalahandi, Phulbani, and Malkanagiri in the jurisdiction of NEGMB districts are the dense mountainous forests districts, and huge water resources are partly explored. Developments in tourism hubs and hydro-power units, mining, and the forest are exploited and restored. But major parts of the remaining sources are unexplored like some swathes of moist forest, mining belts, scenic waterfalls, and ethno-floral and faunal resources as medicines. The natural large trees and economic plantations (like Peeper, coffee, plantains, etc.) should be added to bio reserves for their faunal and avifaunal biodiversity. Many waterfalls, tourist hotspots, and ethnobotanical biomes warrant exploration. Some Waterfall points, geological hotspots, and WR projects are yet to be ventured into for anthropogenic utilities (Fig 10).

Fig 10: The broken coast parallel hills series NEGMB, and Deomali Hills (source: Terra-metric image NASA;2007;. indiaenvcironmentportal.org.in/files/ReportofBiodiversityofSouthOdisha)

The most neglected community in the area are the aboriginals (Koya, Khonds, Savara, Jatapu, Gadaba, Konda Dora, Manne Dora, mukha Dora, etc.) economically/educationally backward. They have a unique culture, customs, and traditional heritage. Strict adherence to economic plans in backward districts only can make the tribal modernized. A biological and demographic survey of all the ecological niches is necessary.

NEGMB is famous not only for its deep large forest species, and for its plenty of herbal drugs. All these primitive villages nurture these sources of herbal medicines, and forest products for human use, (Fig 10). Extensive researches on these lagging sectors and the compilation of a compendium for the fixation of the doses are essential. The work done in Odiya by Mr. Laxman Mishra (Ex-IPS) is commendable.

Table-3: The prioritized future biodiversity projects (www.odishabiodiversityboard.in/activity/433)

#	Name of the Project	District	The site	Submitted by
1	Mandasaru Gorge, Kandhamal, Odisha	Kandhamal	Biodiversity Heritage Site (BHS)	DFO Phulbani
2	Biodiversity of Badrama-khalasuni Wildlife Sanctuary	Sambalpur	Inventory making of >170 species of animals of different groups, 20 mammals, etc,	DFO Bamara
2	Lakhari valley wildlife sanctuary,	Gajapati	Biodiversity Studies	PCCF; Wildlife
3	Mahendragiri Bio-sphere Reserve (MBR)	Gajapati	Ecological and biological socio-economic aspects	RCCF, Berhampur
4	Balukhand-Konark-wildlife sanctuary.	Puri	floral diversity of Golora RF	PCCF (WL)
5	Kotagarh wildlife sanctuary	Kandhamal	Identified >1500 flora; > 800 faunal species to be documented and their key microhabitats to be found	DFO Baliguda
6	Biodiversity of Lakhari valley wildlife sanctuary (714 plants of 118 families & 326 genera with 632 angiosperms, 23 pteri dophytes, 2gymnosperms, 1Bryo phytates, 31 Fungi, and 15 species of Lichens.	Gajapati	Bar Winged Flycatcher Shrike and Large Billed Green Malkoha are two t bird species for Lakhar	PCCF (Wildlife)
7	Multi-taxa biodiversity inventory of Karlapat wildlife Sanctuary, Funal diversity included 22 mammals, 108 birds, 25 reptiles, 10 species of Amphibians, 57 species of butterflies, etc.	Kalahandi	Documentation for 912 plants of 157 families, 597 genera including 778 angiosperms, 49 pteridophytes, 3 gymnosperms, 21Bryophytes, 46 Fungi, 15 Lichens including 58 climbers, 407 herbs, 101 shrubs, 211trees.	DFO (K-Handi) (S)
8	Dune biodiversity (PCCF WL & CWLW)	Puri/Chilik a coast	For 480km coast Odisha, 70 species of flora, and 314 species of fauna; by 2029-2021	DFO, Chilika WL Div)
9	Biodiversity of Sunabeda Wildlife Sanctuary, Inventory preparation	Nuapada,	101 species of fauna, 200 species of plants, and breeds of different domesticated animals.	DFO Sunabeda
10	Preparation of inventory for a. Sea Turtle (Chilika) b. Floral diversity (Golora)	Puri	Nesting behaviors of turtles; Golora flower diversity in Balukhand of Puri Konark Road	DFO Chilika; DFO Puri

To date, little information and authentic data are available in this direction. The pioneer institutes like the Botanical Survey of India, Zoological Survey of India or IUCN (International union of conservation of nature), and Indian Council of Agriculture of India document are working and are reporting information/data from their genetic resources, etc. on it. Analyzing the data, action plans need formation for the conservation of biodiversity and environmental development. The loss in biodiversity/hotspot areas is caused by anthropogenic stresses, habitat destruction, poaching, poor resource management, and climate change. They can be retrofitted by implementing Biosecurity by the Government, and people in PPP mode (Table 4).

Apart from flora, fauna, and avifaunal diversity, the NEGMB is rich with minerals, panoramic views, tourist hot spots, scarce speleothem formation (Gupteswar caves), medicinal herbs and plants, the aboriginal people of the area, mythological and legendary tales attached with the Malyabantagiri has made the area geologically, geographically, heritage wise, lithological and Limnologically important.

Fig 11: The potential area for tourism in the NEGMB of Odisha (Daringbadi &Mahendragiri)

South and SW Odisha and the southern fringe of NEGMB have about 75000Km2 of hill terrain of average 1000m height above MSL with plenty of water resources for future utilization. Only four reservoirs have been constructed in the districts Koraput and Malkanagiri. Despite many waterfalls, the fifth hydropower unit has been taken up in the district. It is high time to explore those water resources sources in Rayagada, Koraput, Kalahandi, Gajapati, and Malkanagiri to mitigate the energy shortfall of the country, India ([42])

CONCLUSION

Biodiversity is the variability and variety of all life such as flora, fauna, and micro-organisms. Biodiversity conservation along the NEGMB in Odisha amongst the forests, hot springs, and waterfalls is the foremost challenge in the prologue of Anthropocene Odisha. The geography and the geomorphology of nature's panorama need for free-listing with their local names and uses warrants collection, record, and market search by identification of respondents, launching markets, and proper management. Many species of fauna and flora species are in continuation of going to extinction for food, habitat loss, and fire, anthropogenic activities prompted by ecological degradation, climate change, and global warming
The stakeholders, researchers, eco-planners, water-resources managers, and landscape planners are to take proper action through webinars, symposiums, and PPP mode through collaborative dialogs to conserve the flora and fauna and harness the water resources and heritage of the NEGMB.

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