Summary Report

Rapid Assessment of the Proposed Biodiversity Heritage Sites in Jamui Forest Division, Bihar

Submitted by

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A report submitted to the Bihar State Biodiversity Board and Jamui Forest Division, Environment, Forest and Climate Change Department, Government of Bihar, India

March 2025

Preferred Citation: Jithin, V., V. Smrithy, N.V. Page (2025). Rapid Assessment of the Proposed Biodiversity Heritage Sites in Jamui Forest Division, Bihar. A report submitted to the Bihar State Biodiversity Board & Jamui Forest Division, Environment, Forest and Climate Change Department, Government of Bihar, India. March 2025.

Submitted to,

The Secretary,

Bihar State Biodiversity Board,

and

The Divisional Forest Officer,

Jamui Forest Division.

***Note**: This is the draft version of the report, and a full report with more species identifications will be submitted later.*

Photograph Credits:

Front Cover: View from the bouldery nubbin inside the Nagi bird sanctuary, in Jamui, Bihar. Photograph: Vijayan Jithin

ACKNOWLEDGEMENTS

We thank the Bihar Biodiversity Board, particularly the Chairman, Bharat Jyoti IFS for encouraging this preliminary study on Bihar rock outcrops. We thank Sri. S. Sudhakar IFS (CCF), Divisional Forest Officers of Gaya (Sri Shashikant Kumar IFS), Nawada (Sri Shresth Kumar Krishna IFS), Jamui (Sri Tejas Jaiswal IFS), and Banka (Sri Shikhar Pradhan IFS) Forest Divisions for their support during the study. Our sincere thanks to all the Forest Department staff who kindly accompanied us in the field visits and our transport facilitator Sri. Vinay Kumar. Our special thanks to Sri Sandeep Kumar, Bird Guide of the Nagi sanctuary for accompanying us during the visit in the sanctuary, and providing valuable inputs throughout. We thank Bhawesh Kumar (GIS & Remote Sensing Officer, Bihar Biodiversity Board) for making the maps used in this report. VJ thanks Dr. Aparna Watve (Coordinator, RLA, IUCN SSC Western Ghats Plant Specialist Group), and Dr. Rohit Naniwadekar (Nature Conservation Foundation (NCF), Mysore) for their encouragement and support during the field visit, and for introducing him to rock outcrop ecology. JV thanks Dr. Shyam Phartyal (Nalanda University, Rajgir) for introducing him to the Bihar rock outcrops. We cannot thank the following experts enough for their critical inputs in identification of various taxa reported in this report in short notice; Dr. Ishan Agarwal (Thackeray Wildlife Foundation, Mumbai), Dr. Jahnavi Joshi (CSIR-Centre For Cellular and Molecular Biology - LaCONES, Hyderabad), Dr. Abhijit Das (Wildlife Institute of India, Dehradun), Mohammad Abdus Shakur (Centre for Ecological Sciences, Indian Institute of Science, Bangalore), Rishikesh Tripathi (Christ College, Irinjalakuda, Kerala), Dr. Deepak Veerappan (Newcastle University, UK), Akshay Dalvi (Br. Nath Pai Junior College, Kudal, Maharashtra), Meghavi Purohit (Wildlife Institute of India, Dehradun), Poornima Viswanathan (Malabar Natural HIstory Society, Kerala), Aashiq Poon VS (Alumni, ICAR-Indian Agricultural Research Institute, Delhi), and Yathumon MA (Alumni, WII).

EXECUTIVE SUMMARY

Formed millions of years ago, rock outcrops are unique habitats in terms of their geomorphology, and biodiversity, but have received poor research and conservation attention compared to forested ecosystems globally. They have been identified as small natural features that have ecological roles extending beyond their area, a concept similar to ‘keystone species’, at an ecosystem scale. Rock outcrops of India remain largely understudied, especially the inselbergs of Bihar. Recent research from the southern Indian rock outcrops shows that rock outcrops are cradles of biodiversity with multiple endemic and threatened species, but are facing multiple anthropogenic threats. The Bihar rock outcrops, especially the inselbergs are noteworthy geological structures, that received poor attention compared to other rock outcrops in India, especially in terms of its biodiversity and ecological value. Previous rapid assessments of rock outcrops in Nalanda, Aurangabad, and Gaya Forest Divisions of Bihar has shown a range of diverse microhabitats and the biodiversity wealth of these habitats. To assess the feasibility and scope of declaring some of the preliminarily identified inselbergs of Bihar as potential ‘Biodiversity Heritage Sites’ (BHS), a rapid assessment was undertaken in the Jamui hill range, Bajrahi, and Nagi bird sanctuary areas of the Jamui Division. Among the examined sites, inselbergs in Nagi bird sanctuary and Bajrahi show great potential as BHSs, considering its relatively undisturbed status, biological, geological, and heritage values. We have recorded a wide range of reptiles, amphibians, insects, gastropods, chilopods, arachnids, mammals, vascular plants including angiosperms and pteridophytes from these sites. This preliminary report summarises the microhabitats, and biodiversity recorded from the hill areas and inselbergs, along with notes on their cultural values, and recommends further actions for the conservation of these important habitats.

1. BACKGROUND

1. Rocky outcrops

1.1. Rock Outcrops: Overview

Rock outcrops are unique habitats in terms of their geomorphology, biodiversity, and were formed millions of years ago. They are found on all continents, in most climate zones and vegetation types, but have received poor research and conservation attention compared to forested ecosystems (Inselberg Research Initiative, 2024). Rock outcrops can be a wide variety of physical environments, such as escarpments, overhangs, cliffs, boulder heaps and inselbergs (Fitzsimons & Michael, 2017). They can be broadly classified into three types; (i) inselbergs, which are large dome shaped outcrops, of granite or gneiss, (ii) rocky plateaus, which are naturally formed flat expanses of any rock type, and (iii) cliffs, which are steep and almost vertical exposed rock faces (Fig. 1). Rock outcrops can be technically distinguished from neighbouring areas by having an average of 55% area as exposed rock (Wiser & White, 1999). Rocky outcrops provide critical breeding sites for multiple organisms ranging from top order mammalian and avian predators to smaller invertebrates. They have been identified as examples of small natural features (SNF) that have ecological roles extending beyond their area, a concept similar to 'keystone species', but at an ecosystem scale (Hunter, 2017). They are also old climatically buffered infertile landscapes (OCBILs), that have contributed to high biodiversity (Hopper, 2023)

Figure 1. Type of rock outcrops. (a) an inselberg in Dhanhara, Bihar, (b) rocky plateau in Ratnagiri, Maharashtra, and (c) a cliff in Bihar Sharif, Bihar.

Geologically, they form due to erosion and weathering of softer parts of the landscape over millions of years, leaving behind the hard core of parent rock (Twidale, 2012). Outcrops of West Africa, Madagascar, Australia, Brazil, and USA have received much

research attention, while rock outcrop ecology of other regions such as India has largely remained understudied (Kulkarni et al., 2023). Rock outcrops are non--forested open natural ecosystems (ONEs) which support high biodiversity as well as livelihoods of millions of people, but are highly threatened due to land conversion (Madhusudan & Vanak, 2022). Rock outcrops provide a wide range of ecosystem services to humans, and they have played an important role in shaping human civilizations in the past (Rock Outcrop India Network, 2018). Though rock outcrops are known to harbour a broad range of endemic and highly specialised taxa globally (Porembski & Barthlott, 2012), there is a knowledge gap in the literature addressing the conservation value of small, rocky outcrops (Michael et al., 2010). This hampers the scientific management of these fragile habitats which is necessary to reverse habitat degradation happening at many of these unique habitats.

1.2. Rock Outcrops in India

India is home to all the three types of rock outcrops across its breadth, which mostly look dry as arid deserts for almost eight months, but transform to green islands from the onset of monsoon rains. They are home to a large number of unique, endemic organisms. For example, the northern Western Ghats rock outcrops, (the most studied rock outcrop system in the country) holds a significant proportion of its flora as endemic (Watve, 2013). The flora and fauna in these landscapes are adapted to the harsh conditions of rock outcrops and many of plant species have evolved unique features such as desiccation tolerance and carnivory (Smrithy et al., 2023). Most of the Indian rocky outcrops are outside of the protected area network, and are used by people for traditional utilities such as grazing, but are also officially classified as ‘wastelands’ by the Government of India due to their ‘barren’ appearance (scarcity of woody species or forest cover) (Wastelands Atlas of India, 2019). Recent studies on the rock outcrops of the northern Western Ghats has shown that land-use change associated disturbances are impacting a wide-range of fauna including endemic and threatened animals (Jithin et al., 2023; Jithin et al., 2024). Despite the huge number of rock outcrops across the country, and their cultural, aesthetic and religious importance, not much is known about its biodiversity and ecology in India (Inselberg Research Initiative, 2024). This makes these habitats prone to developmental,

mining, and industrial activities. These important non-forest habitats thus are vulnerable to anthropogenic threats, despite their ecological, geological, recreational and cultural importance.

1.3. Rock Outcrops in Bihar - Background of Rapid Survey

The Ground Water Information Booklet for the Nalanda district recognizes that the inselberg series of Nalanda surrounded by the Indo-Gangetic alluvium of the Pleistocene age is a notable geological feature, and they mark the northernmost boundary of the Precambrian peninsular shield (Central Ground Water Board, 2013). Similarly, the booklet for the Aurangabad features the granitic gneiss exposures in the region, and states that they occur at places as inlier at the transition parts from hard rock to alluvial plain (Central Ground Water Board, 2013). It also notes the crystalline rocks exposed in Rajgir Hills and bedrock that sloping towards the northern side consist of phyllites and quartzites alongwith pegmatitic intrusions. These Precambrian crystallines have undergone intense structural disturbance in the form of multiple foldings (Central Ground Water Board, 2013). The technical report of the National Biodiversity Strategy and Action Plan (TPCG & Kalpavriksh, 2005) submitted to the then MoEF (presently The Ministry of Environment, Forest and Climate Change) recognizes the importance of rock outcrops of India, especially the inselbergs found in south India and Bihar (see section 4.1 in Chapter 4). It says:

> *"The most prominent rock outcrops in India are as follows: Lateritic plateaus, common in western India in high-rainfall areas. Cliffs form a distinct feature in all the hilly areas, e.g. in the Western Ghats. Inselbergs are isolated rock outcrops rising abruptly above their surroundings and are seen throughout south India and Bihar."*

The draft report of the Biodiversity Strategy and Action Plan for Bihar (Mishra, 2004) also identifies inselbergs in the state's geographic features, though not exactly using the term:

"The alluvial filling south of the Ganga is shallow, a mere veneer and the Peninsular edge is very rugged. Many groups of small craggy hills rise up to 488 metres from islands of bare rock or scrub."

But unfortunately, these reports were not implemented officially, and thus currently these rock outcrops are not under conservation focus.

From 2002 onwards, there have been efforts in different states to declare Biodiversity Heritage Sites (BHS) under section-37 of the Biological Diversity Act-2002. This includes some rocky hillocks in Karnataka (Karnataka Biodiversity Board, 2023), Kerala (Kuttoor, 2020), and Odisha (Odisha Biodiversity Board, 2019). In some areas, such as Ratnagiri in the state of Maharashtra, efforts are ongoing to propose rock outcrops as BHSs and also to conceptualise frameworks for Local Biodiversity Heritage Sites (Watve & Chavan, 2020; Jithin et al., 2023). At present, there are no BHS in the state of Bihar, and the Biodiversity Board has interest in proposing some of the rock outcrops as BHS in the future. Previous rapid assessments of rock outcrops in the Nalanda and Aurangabad Divisions have shown they are home to diverse microhabitats and biodiversity focusing on saxicolous (living on or among rocks) organisms (Jithin, 2024). This report summarises the findings from the short-term assessment and literature review to suggest future prospects. Since the rock outcrop sites explored as part of this study are inselbergs, a section on inselberg ecology and research is given, before examining the site-specific insights.

1.4. Inselbergs: An Introduction

As mentioned before, Inselbergs are isolated rock outcrops that rise abruptly, above the surrounding plains. These granitic and gneissic inselbergs occur throughout different climatic zones across the world, and are geologically and geomorphologically old. The term 'inselberg' has been proposed by Bornhardt in 1900 to describe hills or groups of hills rising abruptly from a peneplain as an island rises from the sea (Willis, 1934). Geologically, granitic inselbergs can be classified into three basic types; i.e. (i) Bornhardts, which are steep-sided, bald and domical hills, (ii) castle koppies (tors or

kopjes) which are steep-sided but angular and blocky with ordered arrangement, and (iii) nubbins, which are conical hills with chaotic mass of blocks and boulders (Twidale, 1981). But these classifications are not rigid, and intermediate forms are many (Fig. 2).

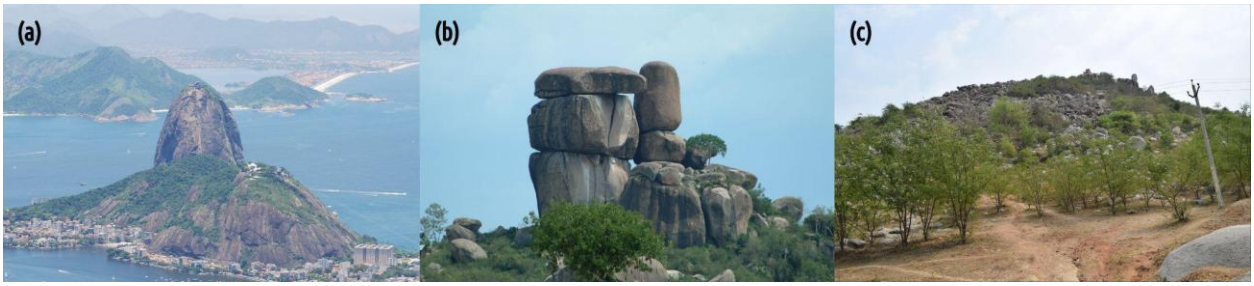


Figure 2. Examples for types of inselbergs; (a) Sugarloaf Mountain, a bornhardt, Rio de Janeiro, Brazil; (b) Kit-Mikayi, a castle kopje near Kisumu, Kenya; and (c) Jhunjhunwa Pahar, a bouldery nubbin in Bihar, India. Photograph (a) by Paul Mannix, CC BY-SA 2.0, and (b) by Valerius Tygart CC BY-SA 3.0 via Wikimedia Commons.

Inselbergs form micro climatically and edaphically dry growth sites, which are home to highly specialised vegetation. Inselbergs are known as ‘microclimatic deserts’ as the air temperature on its slopes and insolation are considerably high, and low relative air humidity compared to the surrounding region (Porembski, 2007). In addition to this, comparatively very less amount of soil is present on these habitats with severe limitation of nitrogen and phosphorus, and high surface water run-off during rains which makes the habitat a harsh environment.

Despite these stressful conditions, inselbergs mainly contain advanced flowering plants, but are also home to ferns, gymnosperms and basal flowering plants. Within the flowering plants group, most species are from the families Poaceae, Cyperaceae (grasses) and Fabaceae (peas). *Vellozia*, *Rhynchospora, Cyperus* (sedges), and *Utricularia* (bladderworts) are among the most species rich genera (Porembski & Barthlott, 2012), as reported from African studies and include biologically interesting groups exhibiting desiccation tolerance, carnivory and succulence. Southeastern Brazil, Madagascar and southwestern Australia are currently known as ‘hot spots of inselberg plant diversity’ (Porembski 2007). But our knowledge of vegetation on inselbergs of several tropical regions such as India and Angola is still sparse, and this requires research attention.

Inselbergs are known to contribute to the local and regional plant species richness (Burke, 2003b). Rocky outcrops such as inselbergs support unique biological communities, with high levels of species endemism, and are considered important in the conservation of biodiversity worldwide (Fig. 3). For example, they occur in fragmented landscapes and play a key role in conserving reptile biodiversity in the modified environments (Michael et al., 2008). Rock outcrops are important to reptiles as they can provide resources such as basking and retreat sites, and micro-gradients in climatic conditions which are often limited in the surrounding landscape (Michael et al., 2010). It is also known that though inselbergs cover a small portion of area, they can provide resources that are uncommon in the landscape, which makes them local hotspots of avian diversity (Trager & Mistry, 2003). Apart from the microscopic organisms that grow on the rocks (Büdel et al., 2000), the rocks also provide spaces suitable for colonisation by macroscopic organisms including cliff flora and carnivorous plants (Larson et al., 2000; Seine et al., 1996). One of the main threats to the inselberg vegetation include invasion of exotic weeds due to high climatic disturbances and human impacts such as intentional burning, grazing, quarrying, construction of buildings such as temples in India, leisure (rock climbing) and touristic activities (construction of buildings, cable cars) (Porembski, 2007; Burke, 2003a; Porembski, 2000). Large scale quarrying for granite and gneiss extraction is one of the leading causes of inselberg destruction (e.g., Bangalore, Karnataka).

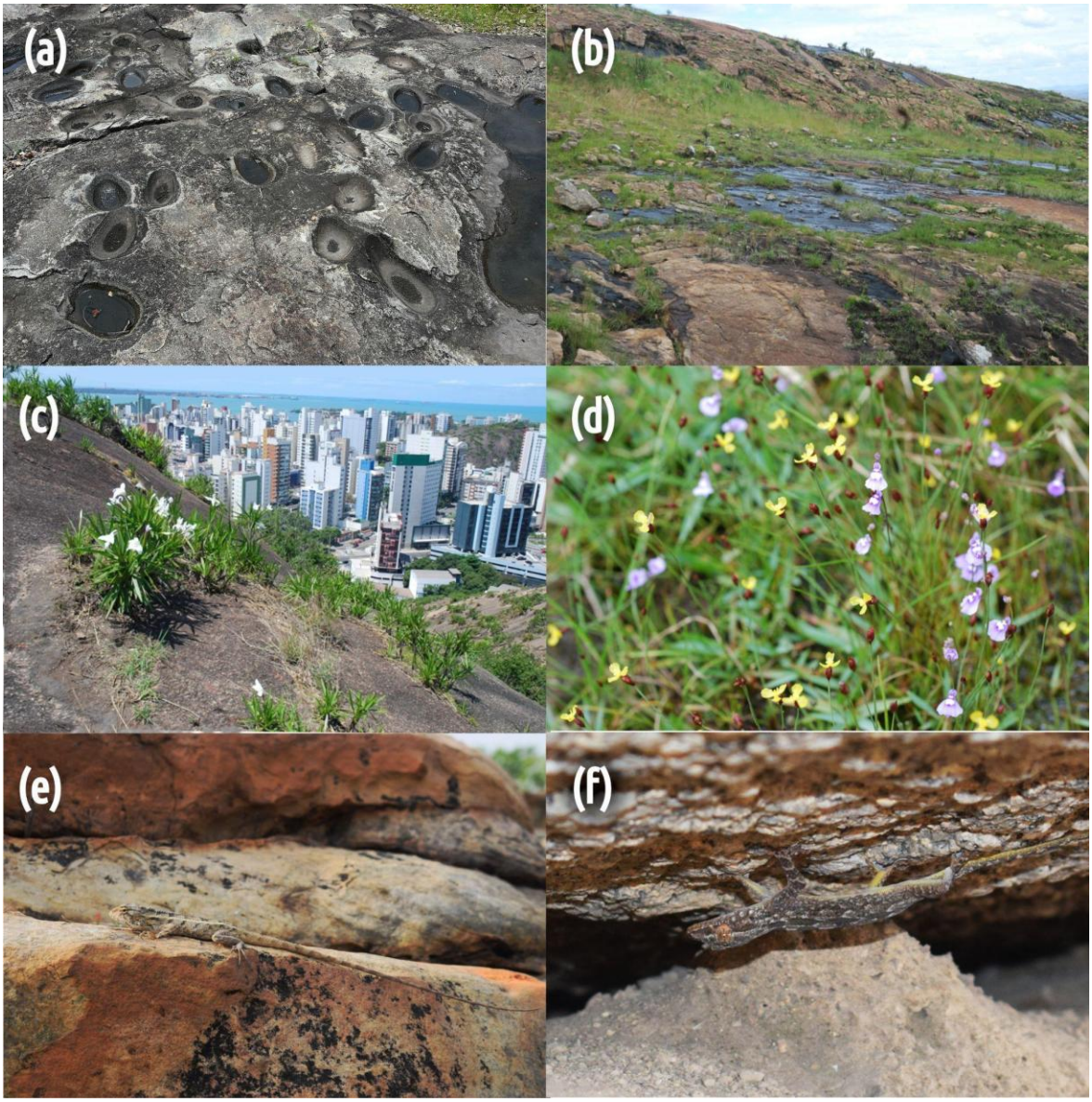


Figure 3. Microhabitats and biodiversity on inselbergs; (a) rockpools on an inselberg in Côte d'Ivoire, Africa; (b) ephemeral flush vegetation on an inselberg in Madagascar; (c) *Vellozia plicata* mats formed in Espirito Santo, Brazil; (d) *Utricularia* sp. and *Xyris* sp. as ephemeral flush vegetation in Madagascar; (e) Common garden lizard and; (f) a Yellow-belly gecko on inselbergs of Bihar, India. Photographs (a-d) courtesy: Inselberg Research Initiative.

1.5. Inselbergs of India

The Indian peninsular landscape, shaped by the divergent weathering and differential erosion after Gondwanaland breakup, are characterised by the granite-gneissic landscape with undulating plains and boulder inselbergs and Deccan Trappean landscape with flat-topped, stepped hills separated by valleys (Kale & Vaidyanadhan, 2014). In peninsular India, especially in the semi-arid continental interior, granite landforms can be seen as rugged clusters of oddly shaped bedrock monoliths and boulders (Gunnell, 2014). Granitic outcrops and boulder-strewn hills (nubbins) create a dramatic landscape in the cratonic parts of the Indian Peninsula. Shravanabelagola, Savandurga, Nandi, and Ramanagara hills near (Bengaluru), Moula Ali and Bhongir Hills (Hyderabad), and Narlai (Aravalli Hills) are examples of domed inselbergs or bornhardts (Fig. 4). Boulder-strewn hills and castle koppies are common such as the one near Hampi, Barabar and Nagarjuni Hills in Bihar. Jalore and Siwana inselbergs in Rajasthan are also well-known (Kale & Vaidyanadhan, 2014).

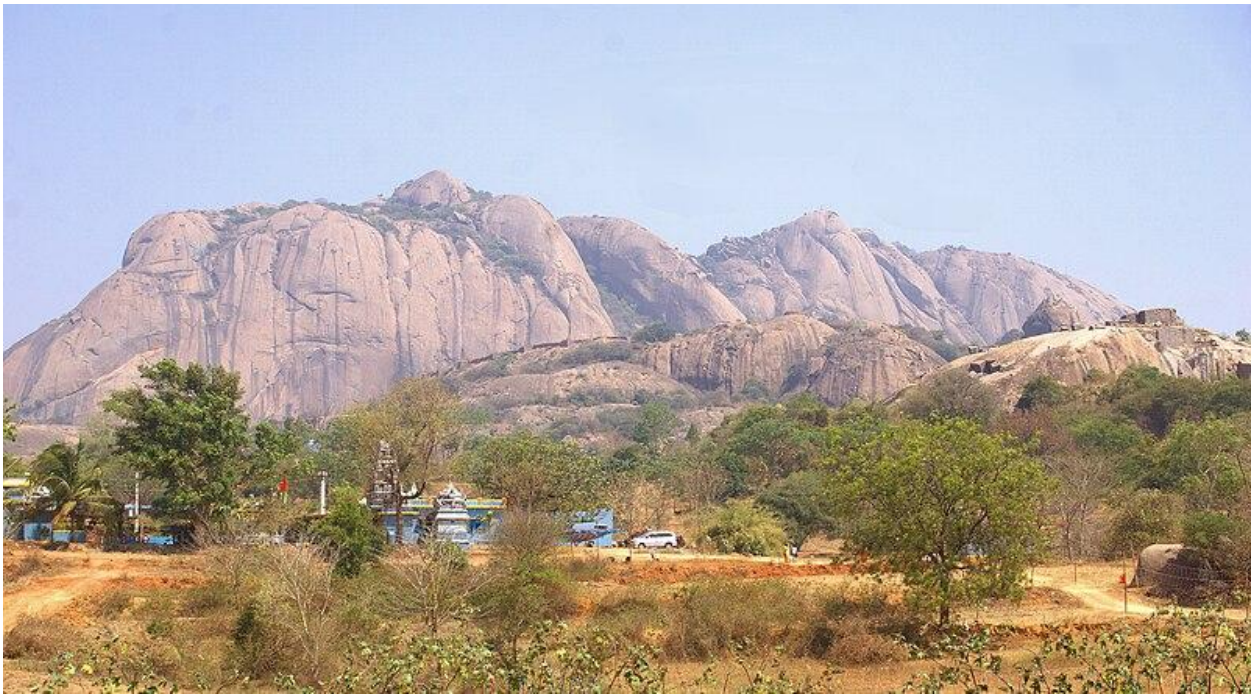


Figure 4. Monolithic Savandurga Hill near Bengaluru in India viewed from the southern side. Photograph by Pravega, CC BY-SA 4.0, via Wikimedia Commons.

Despite the rock outcrop occurrence in huge numbers across the country and their immense multi-dimensional importance, not much is known about their biodiversity and ecology in contrast to the highly studied geomorphology and geology aspects (Inselberg Research Initiative, 2024). Monolithic outcrops are typically found in humid regions such as Kerala, while kopjes dominate the drier parts of India (e.g. Andhra Pradesh, Bihar). It is interesting to note that some of the famous monolithic inselbergs in India are Savandurga near Bengaluru and Mandar hills in Bihar (Rock Outcrop India Network, 2018) (Fig. 5). Indian inselbergs vegetation appearance closely resembles that of other tropical regions with lesser roles of monocotyledonous mats of desiccation-tolerant vascular plants. More information needs to confirm this, in relation to the recent observations of *Tripogon* mats on inselbergs near Bengaluru (Inselberg Research Initiative, 2024).

Figure 5. Mandar hills in Bihar. Photograph by Devesh Bhatta, CC BY-SA 4.0, via Wikimedia Commons.

Many of these tall inselbergs are of potassium-rich late Archean or younger granitic rocks, and compared to other cultures, Indian granitic landscapes have been harnessed in large scale by humans for worship, warfare, runoff agriculture, and stone quarrying. It is also important to note that India has one of the world's largest quarrying industries associated with the rock outcrops (Inselberg Research Initiative, 2024). Many Indian outcrops have small or large shrines and places of worship, and some of the strange rock shapes are explained by myths, anecdotes and stories through traditional knowledge (Rock Outcrop India Network, 2018). Many inselbergs have a pond, or large pool near its base, or agricultural fields, which are using rain water runoff from the inselbergs. They are also places of landscape tourism, wildflower tourism, recreational or adventure tourism. Mass blooming in some of these habitats help pollination of crops nearby (Rock Outcrop India Network, 2018). Though groundwater potentiality is generally poor in inselbergs (Sivakumar et al., 2013), the run-off from these geological formations are critical for adjacent agricultural fields. Studies have shown typical geomorphic attributes such as inselbergs can control the productivity of the land and also the socioeconomic conditions of the local people (Mahato & Jana, 2019).

1.6. Status of Research on Inselbergs

Though the oceanic islands attracted much scientific attention in the past to develop some of the important ecological theories (eg. Charles Darwin - evolutionary processes; Robert H. MacArthur - island biogeography theory), terrestrial habitat-islands such as inselbergs have been somewhat neglected (Porembski, 2007). There is a large knowledge gap on inselbergs of many regions such as India. Discoveries of new rock-dwelling animals and plants continues from rock outcrops in southern India due to the relatively recent research attention it has received (Grandison & Soman, 1963; Biju et al., 2009; Agarwal et al., 2020; Prasanth & Sardesai 2022). There needs to be more research and conservation focus on rock outcrops in other regions of India, such as Bihar.

1.7. Microhabitats on Inselbergs

Recognizing that inselbergs are composed of varying microhabitats relative to their surroundings are important, as they are hypothesised to be bioclimatic ‘islands’ of xeric conditions in a humid matrix in tropical and temperate regions, and ‘islands’ of mesic conditions in arid regions (Burke, 2003a). Microhabitats differ mainly with respect to soil type, depth and moisture and each has its specific vegetation (Rock Outcrop India Network, 2018). A few microhabitats that are found on inselbergs are briefly described below:

1.7.1. Loose Rocks

Loose rocks on the surface of inselbergs are important microhabitats for a broad range of animals and plants (Watve, 2013; Jithin et al., 2023). They are subject to high levels of anthropogenic disturbance, and it is known that land-use change on rock outcrops impacts the animal community living under the loose rocks (Jithin et al., 2023; Goldsbrough et al., 2003). The percentage of animal occupancy varies across study regions. For example, while fauna were present under almost 90% of surveyed rocks in Sydney, ~45% of rocks harboured fauna in the northern Western Ghats (Jithin et al., 2023a; Goldsbrough et al., 2003). The animal community assemblage is mostly dominated by predators and opportunistic scavengers, indicating the low productivity in the habitat. These loose rocks are also home to cyanobacteria, lichens, moss cushions, ferns, and liverworts while supporting lithophytes (plants that grow on bare rock) such as orchids, bladderworts, and grasses (Watve, 2013).

1.7.2. Rock Pools

Rock pools are seasonally water-filled depressions on the rocks with a thin layer of soil. They are mainly inhabited by short-lived plants (ephemerals), which grow only during favourable moist conditions and passing the unfavourable periods as seeds. They are also home to aquatic plants, cryptogams, and a wide range of aquatic invertebrates (Krieger et al., 2003; Jocque et al., 2010). In the otherwise dry environment (soil and microclimate) of rock outcrops, rock pools provide locally

wet conditions. They can act as critical breeding habitats for animals like amphibians (Jocque et al., 2010; Jithin & Naniwadekar, 2024; Jithin et al., 2024).

1.7.3. Shallow Depressions

Shallow depressions are widespread on inselbergs which are small depressions filled with shallow substrate. They are only briefly inundated compared to the rock pools following heavy rains. Though vegetation cover is sparse, plants from the families Poaceae, Asteraceae, Balsaminaceae, Commelinaceae are common in these habitats. They are also habitats for cyanobacteria, liverworts, mosses, annuals, geophytes, and rarely for trees and shrubs (Porembski, 2007).

1.7.4. Cryptogamic Crust

A continuous layer of cryptogamic vegetation (cyanobacteria, lichens, mosses etc.) which supports other vegetation seen on rocky surfaces is known as cryptogamic crust. The greyish or brownish colours at inselbergs rocks are mostly due to cryptogams, which forms almost continuous biofilm on the exposed rocks. They are extremely tolerant to heat, high rates of solar irradiation and survive complete desiccation (Porembski, 2007). Their composition can vary across the surface on which they are growing; eg. exposed rocky slopes, boulders and drainage channels.

1.7.5. Rock Crevices and Clefts

Rock crevices on the inselbergs can be very deep and are rich in humus and soil. They are favourable microhabitats for plants that develop underground storage organs containing a perennating bud (geophytes) and perennial herbs (Porembski, 2007). Under shade conditions, ferns and mosses also occur in the crevices and clefts. Perennial species can be found in clefts, which are broader and deeper.

1.7.6. Monocotyledonous mats

Monocot plants in large clumps and their network of roots forms a mat-like appearance on flat and inclined open rocky slopes. They are attached to the rocks by dense wiry roots. This characteristic feature has been recorded in plants from

the families Bromeliaceae, Poaceae, Cyperaceae and Velloziaceae. They can be xerophytic (plant adapted to survive with little water availability), and desiccation-tolerant. *Tripogons* (Poaceae) can be seen on inselbergs and cliffs, which can be easily lifted up (Porembski, 2007; Smrithy et al. 2023).

1.7.7. Caves

Caves are naturally formed cavities associated with rock outcrops, shelter fauna such as bats, spiders, lizards, geckos and vultures, and are suitable microhabitats for shade-loving rock-dwelling plants. In general, caves are undisturbed due to inaccessibility and thus, the species occupying the caves is undisturbed (Smrithy & Datar, 2023).

1.7.8. Ephemeral Flush Vegetation

Short-lived vegetation that can be seen on the rock surfaces mainly during the rainy period are known as ephemeral vegetation. Typical plants are bladderworts (*Utricularia*) and pipeworts (*Eriocaulons*). They are dependent on the water seepage, and grow in the matrix formed by Poaceae and Cyperaceae (Porembski, 2007; Rock Outcrop India Network, 2018).

1.8. Adaptations on Inselbergs

High diversity of plants, invertebrates, amphibians and reptiles are common on outcrops, especially during the monsoon. Some of these organisms adapt to these extreme habitats to avoid desiccation in dry periods. Both plants and animals show unique adaptive strategies to survive on outcrops. Much is known about the adaptations of plants compared to animals. Inselbergs are known as 'centres of diversity' for plants that are particularly adapted for survival under its extreme environmental conditions (Porembski, 2007). Water scarcity and low nutrient availability in these habitats are leading causes, among many others such as microclimatic and edaphic dryness. This impacts the floristic composition of inselbergs, resulting in a different plant community on inselbergs compared to its surroundings. Some plant adaptations are briefly described below:

1.8.1. Desiccation tolerance

Some plants in the rock outcrop habitats have the unique ability to recover from almost complete loss of water, and thus they can survive periods of drought and recover when water is available (Tuba et al., 1998). They are called desiccation-tolerant (DT) plants or resurrection plants. Ferns such as *Selaginella*, some grasses (Cyperaceae, Poaceae etc.), Figworts, and Velloziaceae plants are known to have this unique adaptation in extreme habitats such as rock outcrops and deserts (Kulkarni et al., 2023). Rock outcrops (such as cliffs, plateaus, and inselbergs) are found to be the most important sites for Indian DT plants, and 90% of the global DT plants are known to grow on inselbergs (Smrithy et al., 2023; Porembski & Barthlott, 2012). DTs can be found as mat-formers, or in shallow depressions and seasonal rock pools (Porembski, 2007). Some of the DT *Selaginella* species are used in Indian traditional medicine, and considered a magical resurrection herb called 'Sanjeevani' (Sah et al., 2005).

1.8.2. Succulent Plants

Some plants on inselbergs have thick and fleshy parts which can retain water in plant tissues of leaves, stems, and roots, and they are known as succulent plants (Biedinger et al. 2000). *Cactus*, *Opuntia* are some examples.

1.8.3. Carnivory

Inselbergs are nutrient-poor habitats. In such conditions, certain plants are evolved to obtain nutrients like nitrogen and phosphorus through phyto- and zoo-planktons, small insects, and nematodes. They attract, ingest, and digest the prey (Givnish 1989). Plant species of Lentibulariaceae and Droseraceae are known for this adaptation.

1.8.4. Dwarfism

On inselbergs, some plants tend to be extremely short, and are termed ‘dwarfism’. Globally, species of Eriocaulaceae, Scrophulariaceae, Juncaceae, and Cyperaceae are known to show dwarfism (Kulkarni et al., 2023).

1.8.5. Other Adaptations

Presence of dual photosynthetic pathways to deal with the scarcity of water, dominance of pollination using wind (anemophily), mass flowering to simultaneously attract a large number of pollinators are some of the other adaptations plants show in these habitats (Kulkarni et al., 2023).

2. APPROACH

2.1. Scope & Objectives

Rapid visual encounter surveys were carried out at hilly area near Jamui Janamsthan, and inselbergs in Bajrahi and Nagi (Table 1):

a. To rapidly assess the ecological value of some of the proposed rocky outcrops BHS in terms of rock-dwelling flora and fauna.
b. To suggest future research and management directions for some of the proposed rocky outcrops BHSs.

2.2. Methodology

The rapid survey site details are explained in the Table below:

Site	Date	Sampling Hours	Duration	Latitude	Longitude
Jamui Janamsthan	6 December 2024	3.5	10:00 am - 1:30 pm	24°51'1.40"N	86° 1'23.65"E
Bajrahi*	6 December 2024	0.5	4:40 pm - 5:15 pm	24°47'17.88"N	86° 7'14.99"E
Nagi Bird Sanctuary (Inside)**	7 December 2024	1.5	9:15 am - 10:45 am	24°49'25.46"N	86° 24'3.97"E
Nagi Bird Sanctuary (Outside)**	7 December 2024	1	11:00 am - 12:00 pm	24°49'39.94"N	86°24'6.77"E

Table 1. Rock outcrops visited during the surveys in Jamui forest division of Bihar. *This additional site was visited on the way from Jamui hills to Gideswar. **These two sub-sites are considered single for the purpose of biodiversity documentation.

The survey route started at the Kshatriyakund Mahatheerth Pravesh Dwar and ended at the same place, after covering the Bala Parsanda Reservoir side, through the Shree Mahavir Diksha Kalyanak Temple. The team surveyed through the motorable road,

occasionally stopping at the road, and going inside the forested areas, and surveying for microhabitats and biodiversity. During the afternoon, the team also surveyed an inselberg on the way to the Gidheswar Pahar. This is on the roadside, situated inside a paddy field, called ‘Bajrahi’, within the Khair block of Jamui district. Geomorphologically, the Janamsthan region covered the ‘moderately dissected structural hills and valleys’ and the Bajrahi covered the ‘pediment-pediplain complex’ areas of the Jamui district (Central Ground Water Board, 2022). While the hill range covers a wide slope range of 0->15%, the Bajrahi fields only cover a range of 0-3%.

Bajrahi was explored from the lowest to highest elevation, while Jamui Janamsthan, due to its large area, was mainly surveyed on the hill top, and at certain intervals of the slopes, and the sides of main road.

The next day, bouldery nubbins inside and outside Nagi bird sanctuary were surveyed. This included the bouldery nubbin inside the park, towards the north of the dam wall, and another nubbin outside the park, situated across the road, directly opposite the sanctuary.

Researchers were accompanied by the Forest Department staff during the surveys. Throughout the survey, microhabitats, flora (herbs, shrubs and woody vegetation) and fauna (focusing on rock-dwelling animals, especially herpetofauna and invertebrates) encountered in the sites were recorded and photographed. These were later identified at broad taxonomic levels using expert inputs. Unidentified plant individuals were collected for identification using available online literature and Flora of Bihar Analysis (Singh et al. 2001), while no animal materials were collected as part of the survey.

4. INSIGHTS

4.1. Jamui hills - Janamsthan Road

Situated in the Lachhuar village of the Khair block of the Jamui district, Jamui hill range (408 m) is an important part of the Chota Nagpur Plateau, bounded by the Indo-Gangetic plain on its north (Ghosh & Bera, 2023). Jamui Hill Range falls in the Hazaribagh portion of the Chota Nagpur Plateau, which is known as India's oldest Precam-brian hard rock terrain (Bera et al., 2022). Around 540 million years old Precambrian rocks are dominant in the region. Chota Nagpur Plateau originated during
the Archean era, and geomorphologically, it is reducing its height due to some exogenic forces and active agents of denudation, weathering and erosion (Singh & Upadhyay, 1980). The surveyed sites in the current study falls inside the hill range with local, midslope and high ridges, and hills in valleys. The area is of structural origin during the Paleoproterozoic-Mesoproterozoic time period, and made of quaternary sediments (Ghosh & Bera, 2023). The Garhi dam and Kiul river is situated nearby to this rocky outcrop, and the area is rich in crystalline rocks such as Sandstone, Mica, Schist, Granite gneiss, Quartzite & Quartz schist, Hornblende schist and Mica (Rao et al., 2025; Central Ground Water Board, 2022).

The hill range is important archaeologically, due to the rock art depictions obtained from the rock shelters near Garhi dam and Tetariya Tanr village between the Deosthan Pahar and Giddheshwar Pahar, and other artefacts including stone tools, microliths and Budha images (Saurabh et al., 2022; Chakrabarti et al., 1995). The Kshatriya Kund temple (in KshatriyaKund Gram), is believed to be the birthplace of Lord Mahavira according to Śvētāmbara tradition, and is one of the important places in the Jain pilgrimage circuit (Bihar Tourism, 2025). It also temporarily housed the ancient 2,600 years old idol of Mahavira.

Forest Habitat of Jamui hill range rocky terrain

The vegetation of the Jamui hill range (especially Janamsthan) and its surrounding can be described as tropical closed canopy forest. This forest varies in composition, with evergreen species predominantly thriving along perennial streams, while deciduous

species dominate the drier, steeper, and higher reaches of the hill slopes. Structurally the forest is a closed canopy, however the canopy was observed to open up on steep and rocky terrain. Vertically, the forest exhibits just one or two strata - canopy and understorey, depending on the location. Canopy height was found to vary between 10 - 20 m, but can reach up to 25 meters at the mouth of the two valleys where the terrain is mostly flat and gentle.

	
Forest area near the Gideswar side of the Jamui hill range	Road connecting the two Jain temples in the area. Forest areas can be seen all along this road.
	
Vertical rocky walls along the road, forming Orthogonal joint sets (?)	Portion of the reservoir with forested area

	
Road leading to the reservoir with forested areas on both the sides	View from the top of the hillock showing the plains

Figure 6. Forest habitat and other surrounding landscapes of Jamui hill range, Jamui, Bihar

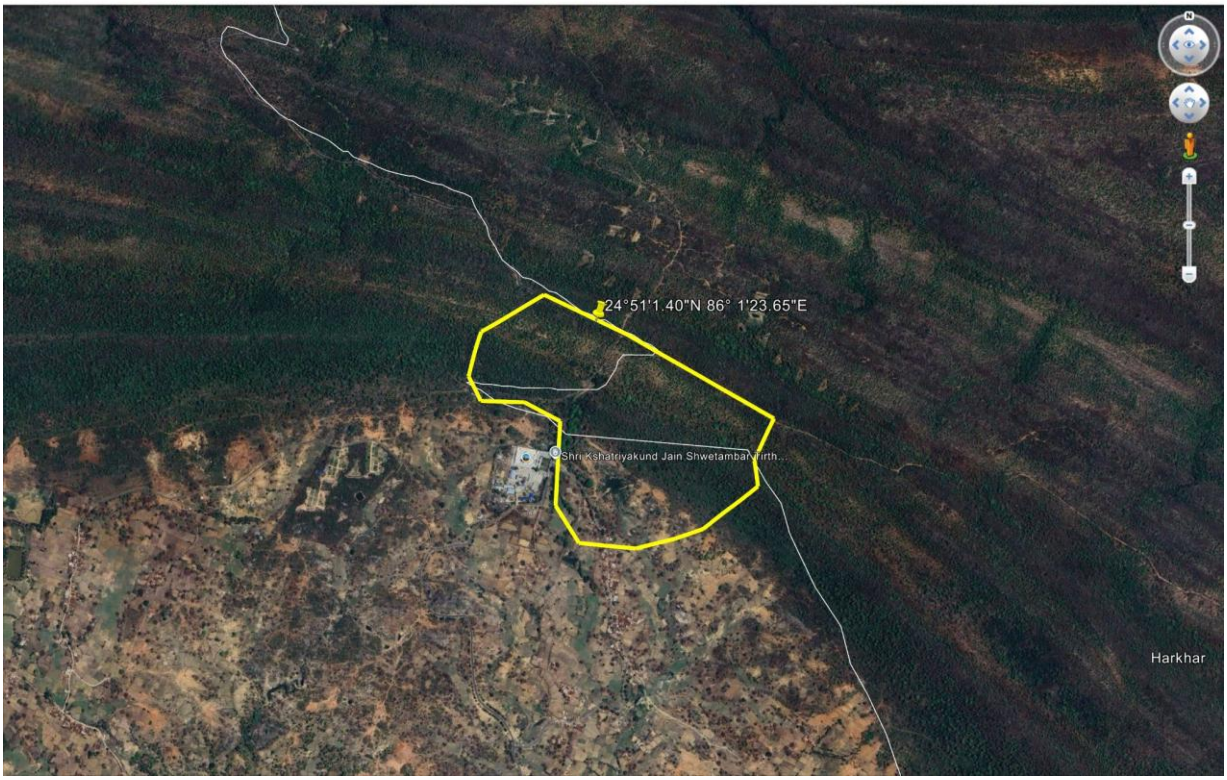
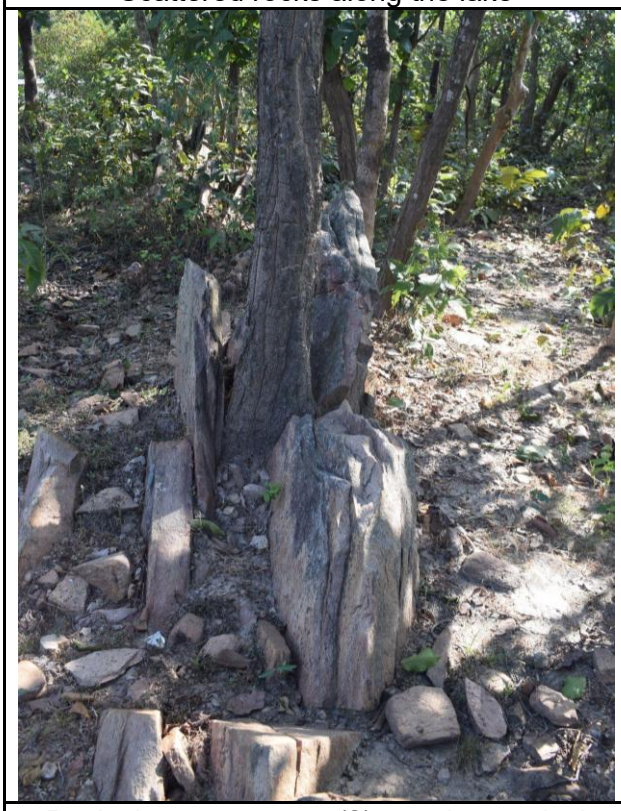


Figure 7. Map showing the Jamui hill range and motorable road

Microhabitat Survey

The details of microhabitats recorded during the rapid survey are given below. Please refer to section 2.4 on microhabitats for detailed descriptions.

	
Scattered rocks along the lake	Vertical Mica sheet structures
	
Rock sheet structures (?) creating vertical microhabitats on ground	Lined rocks creating soil filled microhabitats on ground
	
Loose rocks and soil-filled areas on the vertical	Vertical cliffs showing the orthogonal joints

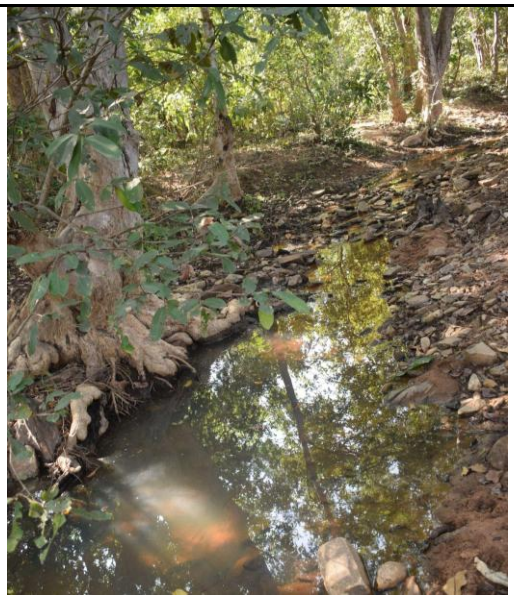
walls	
	
A flat rock slab, under which a scorpion, two toads and spiders cohabit.	A stream, and associated microhabitats
	
An underpass through which the stream continues	Rocky microhabitats along the stream

Figure 7: Photographs of observed microhabitats from Jamui Janamsthan area.

4.1.1. Biodiversity Survey

The details of biodiversity elements recorded during the rapid survey are given below. Please refer to section 2.5 for additional details. Please note that the '[?]' mark indicates the identification needs further verification, and the list is not exhaustive.

4.1.1.1. Fauna

From the Jamui Janamsthan area, we recorded a total of 44 animal species belonging to more than 33 families with 1 reptile, 3 amphibians, 32 insects, 1 gastropod, 1 chilopod, and 6 arachnids. More than 13 orders were identified. Since the surveyed areas are highly

disturbed, further exploration in other, more vegetated areas might improve this documentation. Details are given below:

	
Firouzophrynus stomaticus	*Microhyla nilphamariensis*
	
Minervarya sp.	*Eutropis cf. macularia*
	
Hippasa sp.	Salticidae

	
Lycosidae	Unidentified [Arachnida]
	
Eriovixia excelsa	Buthidae
	
Cormocephalus sp. [Scolopendridae]	Blattodea

	
Ground beetle. [*Chlaenius* sp. ?]	*Gonocephalum* sp. [?]
	
Unidentified [Coleoptera]	Tenebrionidae [?]
	
Teleogryllus sp. [?]	Gryllidae [?]

	
Dytiscidae [Coleoptera]	Gastropoda
	
Seed bug [?] (Hemiptera)	Lampyridae (?)
	
Crocothemis servilia	*Junonia* sp.

	
Zizina otis	*Acraea terpsicore*
	
Euploea core	Pierinae [Pieridae]
	
Crematogaster spp.	*Bothroponera* spp.

	
Lacewing eggs	Pyrrhocoridae ?
	
Coccinella transversalis	Cycloneda [?]
	
Eysarcoris cf. *montivagus*	Orthoptera

	
Orthoptera	Orthoptera
	
Orthoptera	Orthoptera
	
Mythimna albipuncta [?]	*Autocharis* sp.

	
Scopula sp. [?]	*Oncocera* sp. [?]

Figure 8: Documentation of fauna from the Jamui Janamsthan area.

Flora

The Jamui hill range is mostly covered by mixed vegetation ranging from herbaceous flora to dense woodland. Trees are the most dominant lifeforms of this habitat, however, the canopy also supports lianas (woody climbers) and epiphytes. The distribution of shrubs and herbs varies based on the canopy cover and soil moisture, with their highest abundance observed in open-canopy and fully-open areas. The lower slopes of the hill are dominated by climbing shrubs and small trees. Larger trees are more prominent toward the top of the hill. The ephemeral streams and ravines support a different set of species as compared to the more exposed slopes. From the surveyed area, we recorded 101 plant species belonging to 40 families comprising 36 trees, 13 shrubs, 11 climbers and 43 herbaceous species (Table 2). Out of the total, five species belong to pteridophytes. Most of the plants are weeds and exotic.

Table 2: List of recorded plants from the Jamui Janamsthan area

Family	Species	Habit
Acanthaceae	*Andrographis longipedunculata* (Sreem.) L.H.Cramer ex Karthik. & Moorthy	Herb
Acanthaceae	*Andrographis paniculata* (Burm.f.) Wall. ex Nees	Herb
Acanthaceae	*Rostellularia procumbens* (L.) Nees	Herb
Acanthaceae	*Rungia* sp.	Herb
Acanthaceae	*Strobilanthes pavala* (Roxb.) J.R.I.Wood	Herb
Amaranthaceae	*Achyranthes aspera* L.	Herb
Amaranthaceae	*Celosia argentea* L.	Herb
Amaranthaceae	*Anisochilus* sp.	Herb
Anacardiaceae	*Buchanania cochinchinensis* (Lour.) M.R.Almeida	Tree
Anacardiaceae	*Lannea coromandelica* (Houtt.) Merr.	Tree
Annonaceae	*Miliusa tomentosa* (Roxb.) Finet & Gagnep.	Tree
Apocynaceae	*Calotropis gigantea* (L.) Dryand.	Shrub
Apocynaceae	*Carissa* sp.	Shrub
Apocynaceae	*Hemidesmus indicus* (L.) R.Br.	Climber
Apocynaceae	*Holarrhena pubescens* Wall. & G.Don	Tree
Apocynaceae	*Ichnocarpus frutescens* (L.) W.T.Aiton	Climber
Asteraceae	*Acmella uliginosa* (Sw.) Cass.	Herb
Asteraceae	*Chromolaena odorata* (L.) R.M.King & H.Rob.	Shrub

Asteraceae	*Pentanema* sp.	Herb
Asteraceae	*Tridax procumbens* L.	Herb
Bignoniaceae	*Oroxylum indicum* (L.) Kurz	Tree
Boraginaceae	*Cordia* sp.	Shrub
Burseraceae	*Boswellia serrata* Roxb.	Tree
Burseraceae	*Garuga pinnata* Roxb.	Tree
Celastraceae	*Elaeodendron glaucum* (Rottb.) Pers.	Tree
Combretaceae	*Combretum roxburghii* Spreng.	Climber
Combretaceae	*Terminalia anogeissiana* Gere & Boatwr.	Tree
Combretaceae	*Terminalia arjuna* (Roxb. ex DC.) Wight & Arn.	Tree
Combretaceae	*Terminalia bellirica* (Gaertn.) Roxb.	Tree
Combretaceae	*Terminalia tomentosa* Mart. ex Eichler	Tree
Convolvulaceae	*Evolvulus alsinoides* (L.) L.	Herb
Convolvulaceae	*Evolvulus nummularius* (L.) L.	Herb
Convolvulaceae	*Poranopsis paniculata* (Roxb.) Roberty	Climber
Cyperaceae	*Bulbostylis barbata (Rottb.) C.B.Clarke*	Herb
Dioscoreaceae	*Disocorea* sp. 1	Climber
Dioscoreaceae	*Disocorea* sp. 2	Climber
Dioscoreaceae	*Disocorea* sp. 3	Climber
Dipterocarpaceae	*Shorea robusta* C.F.Gaertn.	Tree
Ebenaceae	*Diospyros melanoxylon* Roxb.	Tree
Euphorbiaceae	*Mallotus philippensis* (Lam.) Müll.Arg.	Tree
Fabaceae	*Alysicarpus* sp.	Herb
Fabaceae	*Alysicarpus vaginalis*	Herb
Fabaceae	*Bauhinia racemosa* Lam.	Tree
Fabaceae	*Butea monosperma* (Lam.) Kuntze	Tree
Fabaceae	*Cassia fistula* L.	Tree
Fabaceae	*Dalbergia lanceolaria* subsp. *paniculata* (Roxb.) Thoth.	Tree
Fabaceae	*Erythrina stricta* Roxb.	Tree
Fabaceae	*Indigofera linifolia (L.f.) Retz.*	Herb
Fabaceae	*Senna tora* (L.) Roxb.	Subshrub
Fabaceae	*Zornia gibbosa* Span.	Herb
Gentianaceae	*Canscora alata* (Roth) Wall.	Herb
Lamiaceae	*Coleus strobilifer* (Roxb.) A.J.Paton	Herb
Lamiaceae	*Leucas aspera* (Willd.) Link	Herb
Lamiaceae	*Ocimum americanum* L.	Subshrub

Lamiaceae	*Premna latifolia* Roxb.	Tree
Lamiaceae	*Vitex altissima* L.f.	Tree
Lecythidaceae	*Careya arborea* Roxb.	Tree
Linderniaceae	*Bonnaya ciliata* (Colsm.) Spreng.	Herb
Loranthaceae	*Dendrophthoe falcata* (L.f.) Ettingsh.	Epiphyte
Lythraceae	*Lagerstroemia parviflora* Roxb.	Tree
Lythraceae	*Woodfordia fruticosa* Kurz	Tree
Malvaceae	*Grewia hirsuta* Vahl	Shrub
Malvaceae	*Kydia calycina* Roxb.	Tree
Malvaceae	*Sida acuta* Burm.f.	Herb
Malvaceae	*Sida cordata* (Burm.f.) Borss.Waalk.	Herb
Malvaceae	*Urena lobata*	Herb
Malvaceae	*Waltheria indica* L.	Herb
Moraceae	*Streblus asper* Lour.	Tree
Myrtaceae	*Syzygium cumini* (L.) Skeels	Tree
Oleaceae	*Jasminum arborescens* Roxb.	Shrub
Orchidaceae	*Vanda* sp.	Epiphyte
Phyllanthaceae	*Flueggea virosa* (Roxb. ex Willd.) Royle	Shrub
Phyllanthaceae	*Phyllanthus* sp.	Herb
Poaceae	*Cenchrus pedicellatus* (Trin.) Morrone	Herb
Poaceae	Dactyloctenium aegyptium (L.) Willd.	Herb
Poaceae	*Eragrostis* sp.	Herb
Poaceae	*Eragrostis coarctata* Stapf	Herb
Poaceae	Eragrostis multiflora Trin.	Herb
Poaceae	*Heteropogon contortus* (L.) P.Beauv. ex Roem. & Schult.	Herb
Poaceae	*Oplismenus burmanni* (Retz.) P.Beauv.	Herb
Poaceae	*Saccharum spontaneum* L.	Herb
Polygonaceae	*Persicaria* sp.	Aquatic herb
Rhamnaceae	*Ventilago denticulata* Willd.	Tree
Rhamnaceae	*Ziziphus oenopolia* (L.) Mill.	Climbing shrub
Rubiaceae	*Adina cordifolia* (Roxb.) Benth. & Hook.f. ex B.D.Jacks.	Tree
Rubiaceae	*Hymenodictyon orixense* (Roxb.) Mabb.	Tree
Rubiaceae	*Mitragyna parvifolia* (Roxb.) Korth.	Tree
Rubiaceae	*Morinda pubescens* Sm.	Shrub

Rubiaceae	*Neanotis* sp.	Herb
Rubiaceae	*Spermacoce articularis*	Herb
Salicaceae	*Casearia graveolens* Dalzell	Tree
Salicaceae	*Flacourtia ramontchi* L'Hér.	Tree
Sapindaceae	*Schleichera oleosa* (Lour.) Oken	Tree
Sapotaceae	*Madhuca longifolia* var. *latifolia* (Roxb.) A.Chev.	Tree
Solanaceae	*Solanum virginianum* L.	Herb
Verbenaceae	*Lantana camara* L.	Shrub
Pteridaceae	*Adiantum philippense* L.	Herb
Pteridaceae	*Hemionitis bicolor* (Roxb.) Christenh.	Herb
Pteridaceae	*Hemionitis tenuifolia* (Burm.f.) Christenh.	Herb
Schizaeaceae	*Lygodium flexuosum* (L.) Sw.	Climbing herb
Selaginellaceae	*Selaginella* sp.	Herb

4.2. Site : Bajrahi

Agriculture is one of the principal sources of livelihoods in Jamui district, and rain fed irrigation is the principal component, due to water scarcity. This is where rock outcrops such as the Bajrahi inselberg inside paddy fields play a significant role. The run-off from these geological formations are critical for adjacent agricultural fields as they can control the productivity of the land and also the socioeconomic conditions of the local people (Mahato & Jana, 2019). The Bajrahi inselberg falls in the Banded Gneissic Complex lithographically (Central Ground Water Board, 2022). It is an inselberg with scattered large boulders, rock pools, shrub patches and other various microhabitats. The associated paddy field is also home to many marshy plants that are growing inside the paddy field, along the scattered rocky patches and around the inselberg. It is situated in the Khair block of the Jamui district, south to the Jamui hill range.

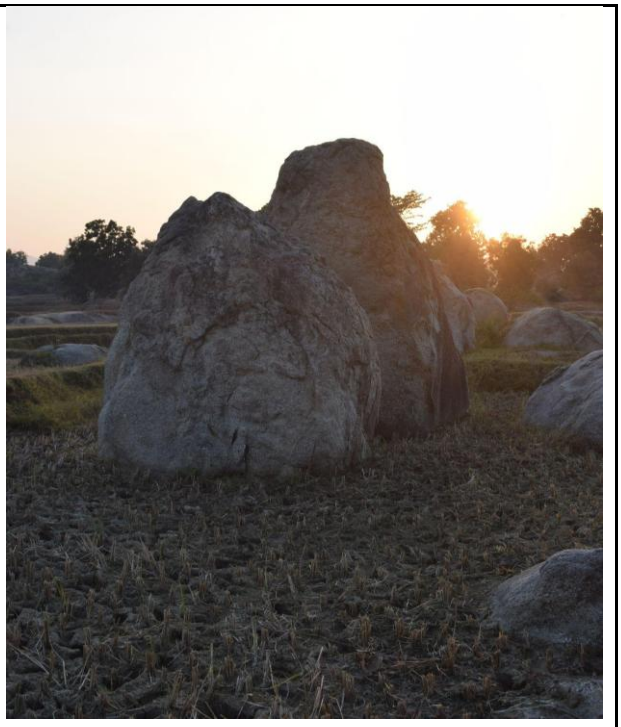
<Map need to be added>
Figure 9. Map showing the Bajrahi inselberg, demarcating the main road and the Garhi reservoir.

	
View from the Bajrahi inselberg, showing the paddy field, constructions near to the road, and survey team on top of the inselberg	View of the nearby rocky patches and paddy field.
	
View from the inselberg top	Scattered rocky patches in the paddy

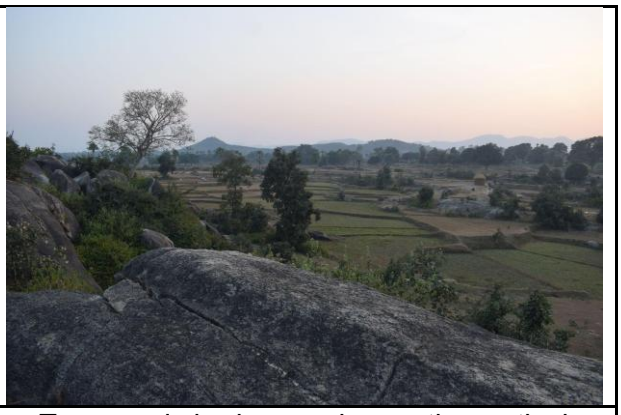
Figure 10: Photographs of the landscapes in Bajrahi, Jamui district, Bihar

4.2.1. Microhabitat Survey

The details of microhabitats recorded during the rapid survey are given below. Please refer to section 2.4 on microhabitats for detailed descriptions.

<table>
<tr><td>  </td><td>  </td></tr>
<tr><td>Occurrence of rock pool in the paddy field</td><td>Occurrence of vertical rocks inside the paddy field</td></tr>
<tr><td>  </td><td>  </td></tr>
<tr><td>A rock pool on the inselberg occupied by the plants in the post-monsoon</td><td>Shallow rock pool on top of the inselberg occupied by mat forming Selaginella bryopteris</td></tr>
</table>

Crevices and small cave-like structures and cryptogamic crusts on the rocks



Trees and shrubs growing on the vertical sides of the inselberg

Fissures on the rock embedded in the paddy field

Crevice beneath the rock serves as a refuge for reptiles

Inselberg with weathered rock fragments and cryptogamic layer

Formation of cave in an isolated rock

Figure 11: Documentation of microhabitats observed in Bajrahi inselberg

4.1.2. Biodiversity Survey

The details of biodiversity elements recorded during the rapid survey are given below. Please refer to section 2.5 for additional details. Please note that the '(?)' mark indicates the identification needs further verification, and the list is not exhaustive.

4.2.1.1. Fauna

From the Bajrahi inselberg, we only recorded a total of 6 animal species belonging to 5 families with 1 mammal, 1 amphibian, and 4 insects only. This was due to the time-constraints, and the survey was carried out towards the end of the daytime. A total of 5 orders are documented during the short visit. Details are given below:

	
Minervarya sp.	*Acraea terpsicore*
	
Agriocnemis pygmaea	Orthoptera

	*<No photograph obtained>*
Orthoptera	*Lepus nigricollis*

Figure 12: Documentation of fauna from Bajrahi inselberg

4.2.1.2. Flora

The floral diversity includes species from the Bajrahi inselberg, surrounding large boulders and adjacent paddy fields. Many of the species found on the marshy areas are opportunistic on rock surfaces when limited soil is available. The present list comprises more herbaceous species to rarely woody trees. A total of 18 plant species belonging to 11 families comprising 2 trees, 1 climber and 15 herbaceous species were recorded (Table 3). Common lithophytic angiosperms were *Polycarpaea corymbosa, Cyperus amabilis, Bulbostylis barbata* and *Chrysopogon fulvus.* Two of the pteridophytes *Hemionitis tenuifolia* and *Selaginella bryopteris* were the most abundant on the studied inselberg; both are desiccation-tolerant plants. Furthermore, *Caesulia axillaris, Eriocaulon* sp., *Rotala densiflora, Ludwigia octovalvis* are typical species growing in damp or marshy areas.

Table 3: List of Flora (Pteridophytes and Angiosperms) from Bajrahi

Family	Species	Habit
Apocynaceae	*Hemidesmus indicus* (L.) R.Br.	Climber

Asteraceae	*Caesulia axillaris* Roxb.	Herb
Asteraceae	*Pentanema* sp.	Herb
Aracaceae	*Phoenix loureiroi* var. *pedunculata*	Tree
Caryophyllaceae	*Polycarpaea corymbosa* (L.) Lam.	Herb
Cyperaceae	*Bulbostylis barbata* (Rottb.) C.B.Clarke	Herb
Cyperaceae	*Cyperus amabilis* Vahl	Herb
Eriocaulaceae	*Eriocaulon* sp.	Herb
Fabaceae	*Butea monosperma* (Lam.) Kuntze	Tree
Lytheraceae	*Rotala densiflora* (Roth) Koehne	Herb
Lytheraceae	*Rotala* sp.	Herb
Onagraceae	*Ludwigia octovalvis* (Jacq.) P.H.Raven	Herb
Poaceae	*Cenchrus pedicellatus* (Trin.) Morrone	Herb
Poaceae	*Chrysopogon fulvus* (Spreng.) Chiov.	Herb
Poaceae	*Eragrostis coarctata* Stapf	Herb
Poaceae	*Oplismenus burmanni* (Retz.) P.Beauv.	Herb
Pteridaceae	*Hemionitis tenuifolia* (Burm.f.) Christenh.	Herb
Selaginellaceae	*Selaginella bryopteris* (L.) Baker	Herb

Note: Flora needs to be surveyed during monsoon as the typical inselberg ephemeral plants and annual plants are not present during the survey period.

4.3. Site : Inselbergs in and around Nagi Bird Sanctuary

Nagi bird sanctuary is a Ramsar site and Important Birding Area (IBA) in Bihar. It is situated in the Jhajha forest range of Jamui forest division. This, along with the Nakti bird sanctuary came into existence after the formation of Nagi and Nakti dams. The area is home to numerous resident as well as migratory birds. The landscape is undulating, and it is dotted with rocky hillocks, in an agricultural land. The management plan of the sanctuary acknowledged the beauty added by the rocky outcrops to the area (Management Plan, 2018). The details about the area, and biodiversity are noted in detail elsewhere (Unknown, 2018; Maurya, 2019). This includes the bird diversity, indicative flora in the Eco-Sensitive Zones, geology, water-quality, plankton diversity, aquatic vegetation, socio-ecological dynamics, recreational value, groundwater recharge, fish diversity (Unknown, 2018; Maurya, 2019; Maurya & Bharati, 2019; Choudhary et al., 2015). The bouldery nubbins are important, since they are amidst the rain fed agricultural fields. The run-off from these geological formations are critical for adjacent agricultural fields as they can control the productivity of the land and also the socioeconomic conditions of the local people (Mahato & Jana, 2019). The Nagi inselbergs fall in the pediment-pediplain complex, and to the Banded Gneissic Complex lithographically (Central Ground Water Board, 2022). It is an inselberg with scattered boulders, rock pools, shrub patches and various other microhabitats.

<Map need to be added>
Figure 13. Map showing the bouldery nubbins surveyed in and around Nagi bird sanctuary, demarcating the reservoir, park, and the main road.

	
View from the Nagi inselberg inside the park, showing the agricultural fields, and other features in the landscape	View of the nearby bouldery nubbins (opposite to park) from the plains.
	
Bouldery nubbin and shrubby vegetation opposite to the park	Rock patches in the surrounding landscape
	
View of the bouldery nubbin from the reservoir	The plain landscape surrounding the nubbins

Figure 14: Photographs of the landscapes in and around Nagi Bird Sanctuary

4.3.1. Microhabitat Survey

The details of microhabitats recorded during the rapid survey are given below. Please refer to section 2.4 on microhabitats for detailed descriptions.

	
Vertical holes on the soil cuttings	An ephemeral pool on the rock
	
Ground holes	Scattered loose rocks and boulders and shrub vegetation

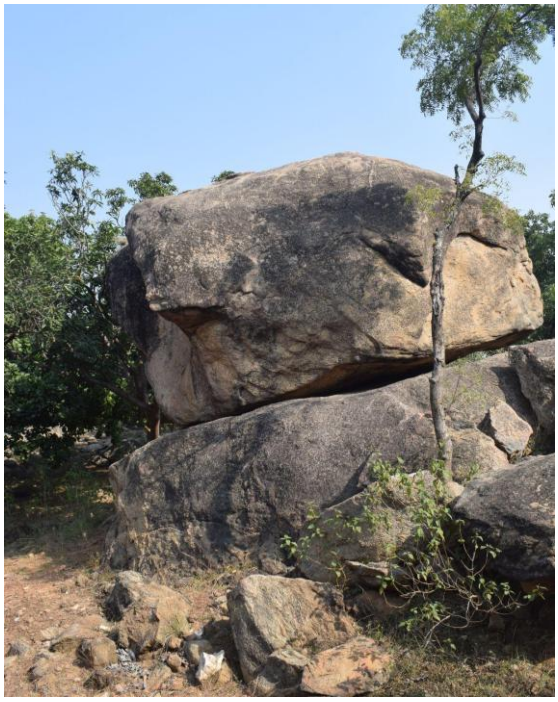
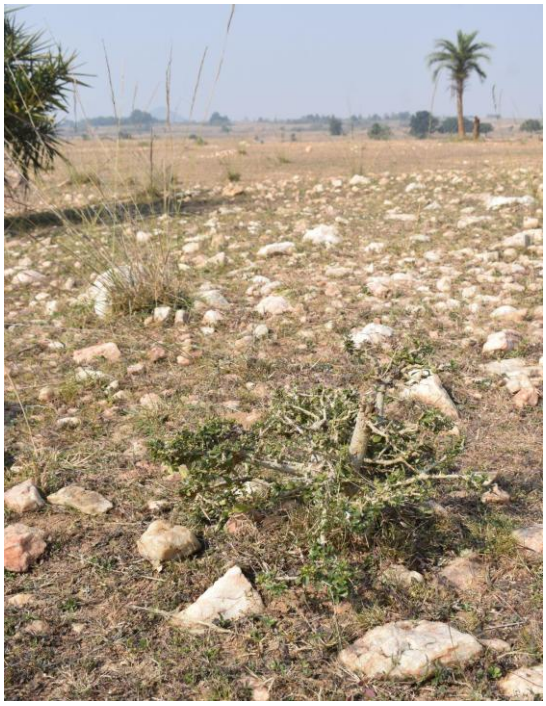
	
Ficus sp. growing out of the fissures on rocks	Rock crevices
	
A flat-faced rock on an inclined plane	Scattered small rocks on the plain area

Figure 15: Documentation of microhabitats observed in Nagi inselbergs

4.1.3. Biodiversity Survey

The details of biodiversity elements recorded during the rapid survey are given below. Please refer to section 2.5 for additional details. Please note that the '(?)' mark indicates the identification needs further verification, and the list is not exhaustive.

4.3.1.1. Fauna

From the Nagi inselbergs, we recorded a total of 18 animal species belonging to 11 families with 1 reptile, 1 mammal, 2 amphibians, 1 arachnid, and 13 insects. A total of 8 orders were documented during the short visit. Details are given below:

	
Sitana cf. *sivalensis*	*Euphlyctis cyanophlyctis*
	
Minervarya sp.	*Lepus nigricollis*

	
Tramea sp.	Gomphidae
	
Orthetrum sabina	*Rhyothemis variegata*
	
Diplacodes trivialis	*Trithemis aurora*

	
Chrotogonus trachypterus	Orthoptera
	
Orthoptera	*Menemerus* sp.
	
Hymenoptera [Unidentified]	*Junonia orithya* [?]

	
Scopula pulchellata	Hesperiidae

Figure 16: Documentation of fauna from Nagi inselbergs and surrounding area

Note: In addition to this, there have been sightings of Russell's viper (*Daboia russelii*), Indian Cobra (*Naja naja*), Bengal Fox (*Vulpes bengalensis*), Golden Jackal (*Canis aureus*), Jungle cat (*Felis chaus*), Indian Crested Porcupine (*Hystrix indica*), Asian Palm Civet (*Paradoxurus hermaphroditus*), Mongoose (*Herpestes* sp.), according to Mr. Sandeep Kumar, Bird Guide of the Nagi sanctuary. He also noted the breeding activity of Indian eagle-owl (*Bubo bengalensis*), and Scaly-breasted munia (*Lonchura punctulata*) in and around the inselberg outside the park.

4.3.1.2. Flora

Nagi inselbergs or the nubbins covers a mixed vegetation ranging from herbaceous to woody plants. A total of 25 species belonging to 13 families comprising 2 trees, 3 shrubs, 1 climber and 19 herbaceous species were recorded (Table 4). The species recorded from this area represents the typical dry-land or semi-arid vegetation and are mostly dominated by grasses (Poaceae) and sedges (Cyperaceae). Most of the deep-soil filled areas are covered by the invasive species *Mesosphaerum suaveolens, Chromolaena odorata* and *Lantana camara,* which may alter the typical flora of inselbergs

Table 4: List of Flora (Pteridophytes and Angiosperms) from Nagi

Family	Species	Habit
Acanthaceae	*Rostellularia procumbens* (L.) Nees	Herb
Amaranthaceae	*Celosia argentea* L.	Herb
Apocynaceae	*Hemidesmus indicus* (L.) R.Br.	Climber
Asteraceae	*Chromolaena odorata* (L.) R.M.King & H.Rob.	Shrub
Asteraceae	*Tridax procumbens* L.	Herb
Aracaceae	*Borassus flabellifer L.*	Tree
Aracaceae	*Phoenix loureiroi* var. *pedunculata* (Griff.) Govaerts	Tree
Caryophyllaceae	*Polycarpaea corymbosa* (L.) Lam.	Herb
Convolvulaceae	*Xenostegia tridentata* (L.) D.F.Austin & Staples	Herb
Cyperaceae	*Bulbostylis barbata* (Rottb.) C.B.Clarke	Herb
Cyperaceae	*Cyperus amabilis* Vahl	Herb
Cyperaceae	*Fuirena ciliaris* (L.) Roxb.	Herb
Eriocaulaceae	*Eriocaulon* sp.	Herb
Lamiaceae	*Mesosphaerum suaveolens (L.) Kuntze*	Subshrub
Molluginaceae	*Paramollugo nudicaulis* (Lam.) Thulin	Herb
Poaceae	*Aristida adscensionis* L.	Herb
Poaceae	*Cenchrus pedicellatus* (Trin.) Morrone	Herb
Poaceae	*Chrysopogon fulvus* (Spreng.) Chiov.	Herb
Poaceae	*Dactyloctenium aegyptium* (L.) Willd.	Herb
Poaceae	*Eragrostis multiflora Trin.*	Herb
Poaceae	*Eragrostiella* sp.	Herb

Poaceae	*Heteropogon contortus* (L.) P.Beauv. ex Roem. & Schult.	Herb
Poaceae	*Oplismenus burmanni* (Retz.) P.Beauv.	Herb
Pteridaceae	*Hemionitis tenuifolia* (Burm.f.) Christenh.	Herb
Pteridaceae	*Hemionitis* sp.	Herb
Verbenaceae	*Lantana camara* L.	Shrub

Note: The floristic survey needs to be conducted during monsoon to record the ephemeral plants.

Figure 17:Photographs representing the flora across the surveyed sites:

	
View of the foothills and plains from top of Janamsthan hill	Deciduous forest along the road passing through the Janamsthan hill

	
Boswellia serrata	*Hymenodictyon orixense*

	
Canscora alata	*Chromolaena odorata*
	

Alysicarpus sp.	*Acmella oleraceae*
	
Spermacoce articularis	*Sida cordata*
	
Phyllanthes sp.	*Persicaria* sp.
	
Dendrophthoe falcata	*Ziziphus oenoplia*

	
Leucas aspera	*Strobilanthes pavala*
	
Hemionitis bicolor	*Selaginella* sp.
	
Andrographis paniculata	*Urena lobata*

	
Lantana camara	*Vanda* sp.
	
Poranopsis paniculata	*Indigofera linifolia*
	
Evolvulus nummularius	*Evolvulus alsinoides*

	
Selaginella bryopteris	*Eriocaulon* sp.
	
Eragrostis coarctata	*Hemionitis tenuifolia*
	
Butea monosperma	*Pentanema* sp.

	
Polycarpea corymbosa	*Caesulia axillaris*
	
Rotala densiflora	*Anisochilus* sp.

	
Phoenix loureiroi var. *pedunculata*	*Borassus flabellifer*
	
Morinda pubescens	*Ventilago denticulata*
	
Woodfordia fruticosa	*Flacourtia ramontchi*

It is important to note that species identification from photographs are preliminary in nature. ***Further detailed field studies during monsoon are essential to confirm some of these observations, and it is possible that there are more interesting animals and plants, especially geckos, and other ephemeral plants, which needs further exploration across seasons and time*** *(eg. Night time surveys are required for more detection of herpetofaunal species including amphibians, agamids and skinks; wet-season surveys are required for ephemeral vegetation).*

4. DISCUSSION

The rapid surveys show that the explored hill range and inselbergs are of great biological, geological and hydrological significance, especially in light of the increasing anthropogenic disturbance and habitat modification. Though much of the seasonal biodiversity has not been documented due to the limited scope of this short-duration assessment in the dry season, a further exploration in the wet-season is highly recommended to reveal the ecological value of these least studied rock outcrops. The preliminary observations that are made in this report will be useful for ecologists and conservation practitioners alike, as these record some of the first documented biodiversity observations of Bihar rock outcrops, which were so far neglected. Bihar is home to some of the very interesting rock outcrops that are of conservation values including the Mandar Hills, inselberg near the Durgavati Reservoir (Fig. 18), and small inselbergs embedded in the agricultural-human settlement matrix, such as the Bajrahi and Nagi inselbergs in this report. They act as refuges that support unique biodiversity in highly modified landscapes, providing necessary ecosystem services to neighbouring regions, with cultural, touristic and aesthetic values.

Figure 18. Inselberg near the Durgavati Reservoir (Karamchat Dam), Kaimur, Bihar. Photograph by Binay Babu, CC BY-SA 4.0, via Wikimedia Commons.

Considering the tourism, and education potential, cultural and archeological values of these poorly known habitats, thorough explorations and ecological studies need to be undertaken in the future, with support from other departments. Given the limited information generated by this report, the following conservation recommendations and future research directions are proposed:

4.1. Conservation Recommendations

4.1.1. The conceptual framework developed for establishing Local Biodiversity Heritage Sites (LBHS) for rock outcrop conservation in the northern Western Ghats can be used as a model, keeping the socio-ecological landscape in mind (Watve & Chavan, 2020).

4.1.2. Possibilities of giving 'Conservation Reserve Status' to the inselbergs can be explored, following similar effort by the joint initiative of the Western Ghats Task Force, Karnataka Biodiversity Board, (Government of Karnataka), and the Ministry of Science and Technology, and Ministry of Environment and Forests (Government of India) (Chandran et al., 2012).

4.1.3. Since some of these inselbergs are also acting as grasslands, their management needs to be in accordance with the guidelines developed to provide clear strategies and steps that different government agencies can undertake to secure and conserve grasslands in India (Watve et al., 2019).

4.1.4. It may be important to note that the proposed conservation measures consider the fact that restricting all forms of human land use and herding activities in these areas (Michael et al. 2008), may negatively impact the biodiversity by reducing habitat diversity. Thus, historical relationships between prehistoric human land-use practices and contemporary conditions of biodiversity requires continued investigation, species inventories and statistical analyses (Bauer, 2018).

4.1.5. How the Biodiversity Act (2000) can be utilised for rock outcrop conservation is a topic that of recent interest, especially with regards to the Konkan lateritic outcrops in Maharashtra. More details on this can be obtained at the Rock outcrop of India Network Website (https://rockoutcropofindia.in/conservation-action/f/use-of-biodiversity-act-2002-for-conservation-of-sada). The extensive discussion arising from this project can be considered as a template for inselberg conservation in Bihar.

4.1.6. Tree plantation in the inselberg habitat would alter the open habitat structure and negatively impact the biodiversity and microclimatic conditions of the original ecosystems.

4.1.7. Since the inselbergs are of importance in terms of geodiversity and geoheritage, which are integral parts of biological diversity and natural heritage, assessments of geoheritage and prospects of geotourism need to be undertaken in these habitats similar to Karnataka and West Bengal (Prabhakar & Radhika, 2022; Ghosh et al., 2021). The scope for this needs to be discussed with the help of Geological Survey of India and other relevant departments in the light of recently announced 'Draft Geoheritage Sites and Geo-relics (Preservation and Maintenance) Bill, 2022'.

4.1.8. Involvement of the Maharashtra Forest Department in rock outcrop conservation and an extensive discussion following that is publicly available. These resources can be utilised (Biome Conservation Foundation, 2013).

4.1.9. To support the conservation of key inselberg species and rock outcrop specialists, restoration efforts can be implemented within protected areas such as Nagi Bird Sanctuary. Collaboration with organizations like the Ecological Restoration Alliance (ERA) can help develop targeted restoration strategies. Further details on such initiatives can be explored on the ERA website. https://era-india.org/project/rao-jodha-desert-rock-park/

4.1.10. Since rock outcrops are classified as ‘wastelands’ in the Govt. of India records, but are important open natural ecosystems (ONEs), examination of identified inselbergs in the background of ONE map need to be done. This can be carried out using the interactive web application (Madhusudan & Vanak, 2022) through which state and district-level- summaries of their area and distribution, and other overlay statistics can be obtained (Available here: https://mdm.users.earthengine.app/view/open-natural-ecosystems).

4.1.11. Conservation of rock outcrops, related land-use and their utilisation as touristic centres needs a nuanced, multi-stakeholder approach (eg. determining the carrying capacity of tourist influx). A recent global literature review on these aspects (Fitzsimons & Michael, 2017) can be another starting point. Micro-planning for this purpose needs to be undertaken by the Forest department, Revenue department, scientists, local NGOs, local community and other relevant stakeholders.

4.1.12. Identification of rock outcrops within working plans of the Forest departments need attention. Capacity building of Forest department staff to deal with conservation of ecologically sensitive areas and special habitats such as the inselbergs is of importance.

4.1.13. Extensive constructions on the rock surface need to be avoided as this will result in microhabitat destruction and its consequences.

4.1.14. Preparation of ‘ecotourism/ conservation tourism’ plans and ‘ethical guidelines for tourism’ are of importance. Since scientific management of rock outcrops in India is at its early stages, rigorous scientific monitoring of managemental impacts and mid-course corrections as and when required need to be done. Panchgani Tableland conservation and related Supreme Court orders can be a background for such activities (The honourable Supreme Court upheld conservation of a small 100 acre rocky plateau, and reducing impacts of tourism infrastructure, using zonation in a revenue land).

4.1.15. Specific management recommendation based on the rapid survey are:

4.1.15.1. Protect inselbergs from human disturbances that cause damage to the microhabitats on rocks (trampling of flora, removing plants and animals from microhabitats, removal and displacement of loose rocks etc.). This could be achieved by restricting the visitors along designated paths.

4.1.15.2. Regular monitoring of vegetation changes on the rock outcrops (using repeated photography across seasons, maybe at bi-weekly intervals) would be useful to gauge the degree of human disturbance (such as tree cutting, firewood extraction and human induced fires) as well as spread of invasive species.

4.1.15.3. Among the sites visited, inselbergs inside and outside Nagi bird sanctuary park may be developed as benchmark inselbergs of this division. The Janamsthan area can be a very good site for biodiversity heritage conservation. Ensuring the proper identification and removal of invasive species such as *Mesosphaerum suaveolens, Chromolaena odorata* and *Lantana camara* by uprooting them at the seedling stage is proposed as a long-term management strategy to preserve and naturally restore the inselberg-specific species. This site could also be declared as a ‘Conservation Reserve’ and also as a potential site for establishing a long term biodiversity monitoring site.

4.1.15.4. Restoration of disturbed (rock removal, grazing, vandalism, loss of native vegetation, chance of weed invasion and fires etc.) rocky habitat areas needs a more nuanced approach based on studies from Australia, and requires further field studies at the site itself (O'Sullivan et al., 2023; Jithin et al., 2023).

4.2. Research Directions

4.2.1. As the first stage, species inventories of inselbergs need to be developed, with the help of experts in various taxa to identify unique species occurring here, in terms of endemism and special adaptations. Help of experts in rock habitat biodiversity from India and abroad can be availed as inselberg ecology is still at a developmental stage in India. Seasonal studies of ephemeral vegetation, cliff-dwelling flora, and rock-dwelling animals need to be undertaken to have a clear picture of the biodiversity in these habitats, which will be crucial in determining its ecological value. This can be done with student volunteers and interns who are interested in conservation and ecological research. Appropriate training for these needs to be conducted.

4.2.2. Identification and mapping of all rocky outcrops in the Bihar state, following proper scientific floral and faunal study need to be undertaken. Their cultural value, importance as habitats of endangered, endemic and rare species, species with unique adaptations, species which are not occuring in the surrounding area, and as ecosystem service providers needs to be understood, which can help managers to decide appropriate conservation measures.

4.2.3. Taxonomists and ecologists need to work together on lesser known taxa such as spiders, fungi, orthopterans, and lichen on inselbergs, and research should be conservation oriented which give feedback to area managers.

4.2.4. Fuel wood collection, medicinal plants extraction (eg. *Selaginella* sp.), and grazing, their sustainability and impacts on biodiversity need to be studied with the involvement of the local community.

4.2.5. Research needs to be undertaken on the livelihood impact in terms of water and nutrient incomes, and to know how the importance of

these habitats can be communicated to the local people and tourists in this area.

4.2.6. Research needs to be undertaken to know how the inselbergs are acting as islands, and thus influencing the evolutionary radiation of rock-dwelling animals such as reptiles in the region, along with threat status assessment of the flora and fauna.

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