Interaction Between Land-Use / Land-Cover Change and Climate Trends: A Case Study on Herpetofauna in Semi-Arid Solapur District

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Abstract—**This study investigates the combined effects of land-use/land-cover (LULC) dynamics and local climate variability on herpetofaunal diversity and habitat suitability within four tehsils of Solapur District, a semi-arid region of Maharashtra, India. Remote sensing data (e.g. Landsat series) were used to map key LULC classes such as water, developed, barren, forest and planted / cultivated over a two-years period 2021–2022. Land cover transitions including woody plant encroachment into former grasslands and cropland expansion were quantified using supervised classification and change-detection techniques. Climate analysis employed regional climatological datasets to detect trends in variables including maximum /minimum temperature and precipitation seasonality.**

The herpetofaunal survey, carried out across representative habitat types, documented species richness, relative abundance, and occupancy across gradient of land covers. Statistical models were used to correlate distribution patterns and community metrics with LULC transition intensity and climatic trend indices.

Index Terms—**Herpatofauna, ArcGIS, LULC, Species richness, Correlation.**

I. INTRODUCTION

Solapur District in Maharashtra lies within a transitional semi-arid belt of the Deccan Plateau, where thorn scrub vegetation, scattered grasses, and drought-tolerant shrubs form the dominant landscape. Over the last few decades, this fragile dryland system has experienced marked ecological change driven by rapid urban growth, expansion of intensive agriculture, and increasing woody encroachment into open habitats. Recent satellite-based assessments of Sangola, Phandarpur, Malshiras, and Mangalwedha between 2021 and 2022 indicate a notable rise in built-up areas (approximately 15.6%), accompanied by a reduction in open spaces and vegetated land cover. These land-use transitions reflect broader anthropogenic pressures reshaping semi-arid ecosystems across Maharashtra. At the same time, regional climatic conditions are also shifting. Increasing surface temperatures and growing variability in monsoonal rainfall have been widely reported for central and peninsular India, with particularly strong implications for water-limited environments (IPCC, 2023; Guhathakurta et al., 2020). Although changes in land cover and climate trends have been studied independently, their combined influence on local biodiversity—especially at finer spatial scales—remains insufficiently explored in semi-arid districts such as Solapur.

Herpetofauna, comprising amphibians and reptiles, are especially sensitive to alterations in microclimate, soil moisture, and vegetation structure. Amphibian species that rely on seasonal pools, moist soils, or open grassland habitats are highly vulnerable to habitat fragmentation caused by agricultural conversion, urban sprawl, and the spread of woody vegetation. In contrast, certain generalist reptiles are more capable of persisting in modified scrublands and peri-urban environments. Despite this ecological contrast, empirical studies linking herpetofaunal community responses to simultaneous land use/land cover (LULC) change and climatic variability in Solapur District are notably lacking.

The present study addresses this gap by examining: (i) spatial and temporal patterns of LULC change across Solapur District using remote sensing and GIS techniques; (ii) localized trends in temperature and monsoon rainfall; and (iii) corresponding changes in the distribution, richness, and community composition of amphibians and reptiles across varying land-use and climate gradients. By integrating geospatial analyses with systematic field surveys, this research evaluates how interacting environmental drivers influence herpetofaunal abundance, occupancy, and habitat associations.

Furthermore, the study seeks to identify habitat types and landscape zones where climate-resilient conservation interventions may be most effective. Particular emphasis is placed on the conservation of remaining grassland patches, management of woody encroachment, and mitigation of moisture stress for amphibian populations through improved land and water management practices.

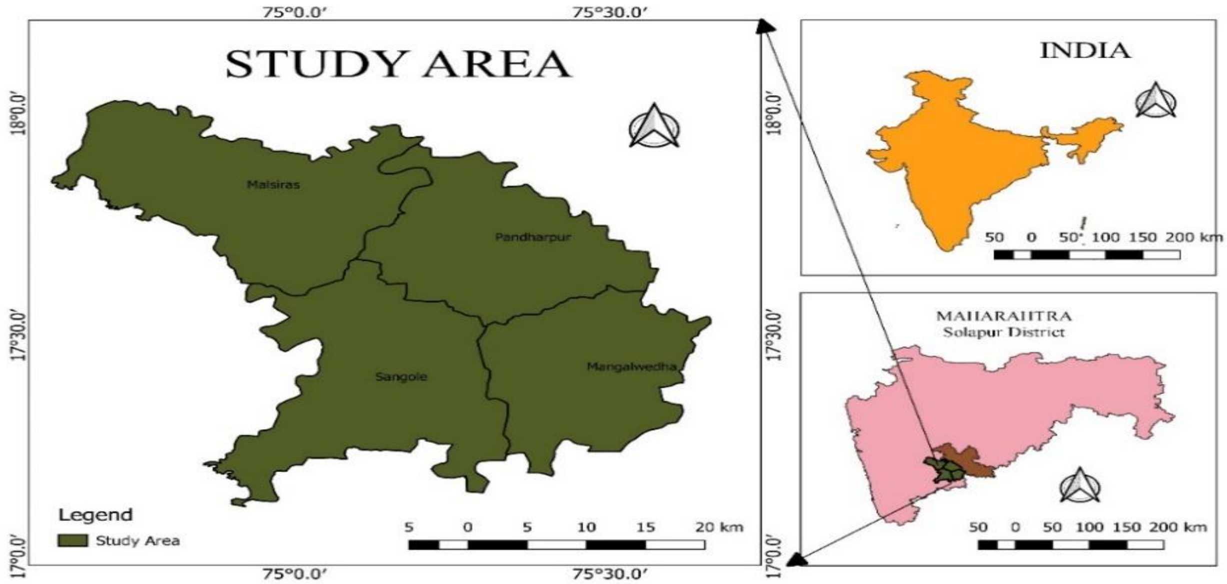
Overall, this research highlights the importance of combining land cover change assessments with climate trend analysis to better understand biodiversity responses in dryland ecosystems. The findings are expected to support spatially explicit conservation planning by identifying priority areas for habitat restoration and adaptive land management, thereby contributing to climate-informed biodiversity conservation strategies in semi-arid regions.

II. MATERIALS & METHODS

2.1: Characteristics of Study area: Solapur district is a part of central Deccan plateau located between 17.10 to 18.32 degrees' north latitude and 74.42 to 76.15 degrees' east longitude, the elevation ranges between 450- 600 meters above sea level, the topography is mostly flat with gentle undulating plains, some areas have rocky regions, the soil type is predominantly black cotton soil, with some red lateritic patches, the drainages lies in the Bhima river basin, with tributaries like the Nira, Man, and Sina rivers affecting wetlands and riparian habitats, has a geographical area of 14844.6 sq.kms. which is 4.82% of the total area of Maharashtra State. Out of the total area of the district 338.8 sq.kms (2.28%) is urban area whereas the remaining 14505.8 sq.kms. (97.72%) is rural area. There is no important hill system in the district. Only in the north of Barshi Taluka several spurs of Balaghat range pass south for a few kilometres. There are also a few scattered hills in Karmala, Madha and Malshiras Talukas. The climate type is of Semi-arid (Rain-shadow zone of the Western Ghats, with a rainfall of Low to moderate, above 400- 600 mm / year, mostly in June to September having temperature ranging in summers from 35- 45 °C, Winters 8- 20^{o}C. The humidity is almost Low for most of the year, except during the monsoon.

2.2: Herpatofaunal Habitat features: The Agricultural fields are more relevant to frogs, toads, skinks, and snakes. The Rocky outcrops important habitats for geckos, agamids, and vipers. Water bodies, such as seasonal ponds, tanks, and rivers, support amphibian breeding grounds. The Scrublands or Grasslands are most favorable for species like the fan-throated lizard, saw-scaled vipers. The human settlements, such as urban or peri-urban habitats, support herpetofauna like house geckos and rat snakes.

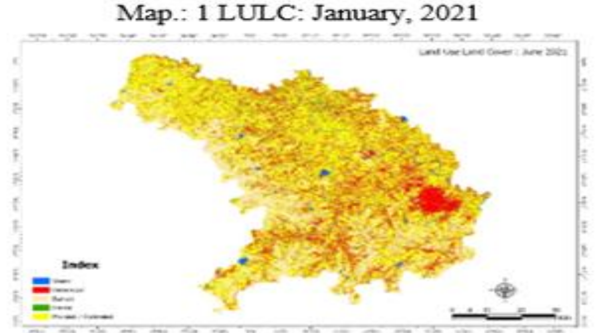
2.3: Anthropogenic Pressures: The agricultural expansions have generated loss of natural habitats, use of pesticides, and the over-grazing pressure of domestic animals has reduced the ground cover for reptiles and amphibians. Deforestation has led to sparse vegetation due to fuel wood collection, contamination of water bodies affecting amphibian breeding. Increasing droughts and extreme heat impact amphibian populations.



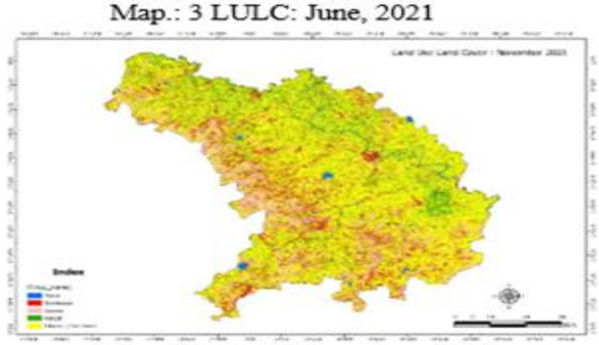
LAND USE LAND COVER (LULC) OF FOUR TEHSILS OF SOLAPUR DISTRICT

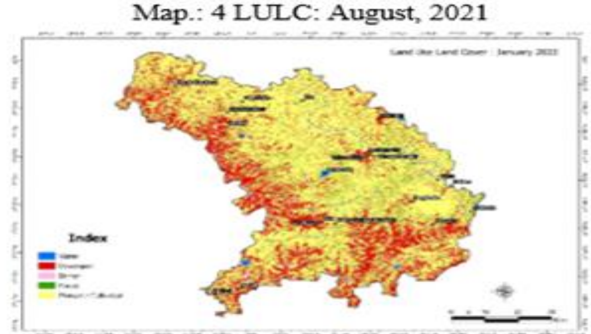

Map.: 1 LULC: January, 2021

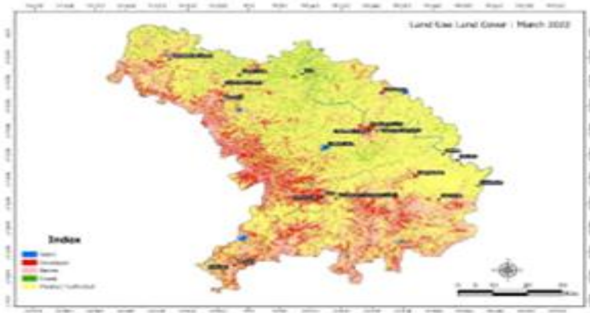

Map.: 2 LULC: March, 2021


Map.: 3 LULC: June, 2021

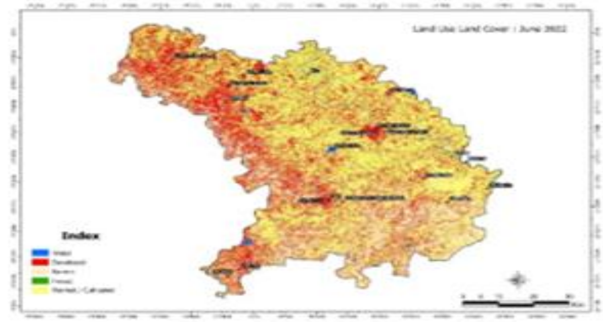

Map.: 4 LULC: August, 2021


Map.: 5 LULC: November, 2021

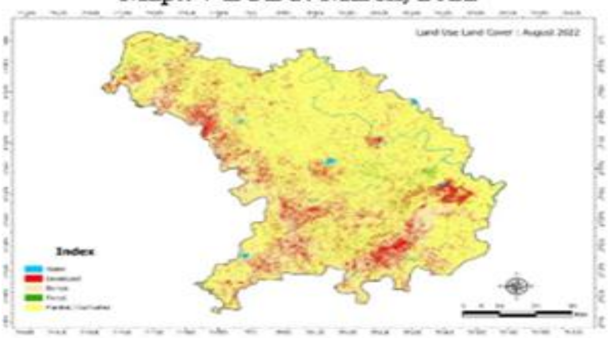

Map.: 6 LULC: January, 2022



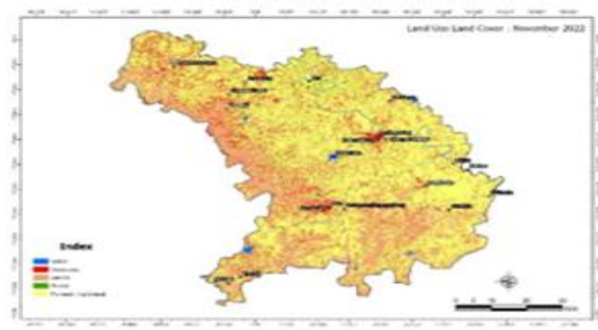
Map.: 7 LULC: March, 2022



Map.: 8 LULC: June, 2022



Map.: 9 LULC: August, 2022



Map.: 10 LULC: November, 2022

III. RESULTS

Analysis of Land Use / Land Cover maps from January 2021 to November 2022 (Map No. 1–10) showed that the landscape across the four tehsils was consistently dominated by agricultural land, followed by scrubland/open vegetation, with built-up areas and water bodies occupying smaller spatial extents. Seasonal variability was evident, with increased vegetation cover and surface water during monsoon months (August 2021 and August 2022) and expanded dry or fallow land during summer months (June 2021 and June 2022). Inter-annual comparison indicated a gradual increase in built-up land and fragmentation of scrub and open habitats.

3.1 Overall Herpetofaunal Richness

Across all maps and survey periods, a total of 46 herpetofaunal species were recorded, comprising 14 amphibian species and 32 reptile species (Table 01). Amphibians represented 30.4% of total species richness, while reptiles accounted for 69.6%**.** Amphibian species belonged to four families, with Dicroglossidae contributing the highest richness (6 species). Reptiles were distributed across 12 families, with Gekkonidae**,** Agamidae, and Mabuyidae showing the highest representation.

Amphibian Richness and Abundance Across Maps

Amphibian species richness varied across Map No. 1–10, ranging from 2 to 9 species per map. Lower richness values were recorded during dry-season maps (June 2021 and June 2022), whereas higher richness values occurred during monsoon-associated maps (August 2021 and August 2022). The Shannon–Wiener diversity index (*H′*) for amphibians ranged from 0.54 to 2.23 across maps. Mean amphibian encounter rates varied from 0.19 to 2.18 individuals per hour**.**

Widely distributed amphibian species recorded across multiple maps included *Duttaphrynus melanostictus*, *Euphlyctis cyanophlyctis*, *Hoplobatrachus tigerinus*, and *Sphaerotheca breviceps*. Seasonal occurrences were documented for *Microhyla ornata*, *Uperodon globulosus*, *Uperodon systoma*, and *Polypedates maculatus*, primarily during maps corresponding to monsoon periods. Burrowing frogs (*Sphaerotheca breviceps*, *S. dobsonii*, *S. pashchima*) were recorded in agricultural fallow lands and scrub-dominated areas across dry-season maps.

Reptile Richness and Abundance Across Maps

Reptile species richness remained comparatively stable across Map No. 1–10, ranging from 9 to 12 species per map. Shannon diversity values (H') ranged from 1.76 to 2.19, while encounter rates varied between 1.29 and 1.92 individuals per hour.

Dominant reptile species recorded consistently across all maps included *Calotes versicolor*, *Hemidactylus flaviviridis*, *Hemidactylus frenatus*, *Eutropis carinata*, and *Varanus bengalensis*. Skinks (*Eutropis macularia*, *Riopa punctata*, *Riopa lineata*) were recorded primarily in scrubland and agricultural mosaics. Fan-throated lizards (*Sitana ponticeriana*, *Sitana laticeps*, *Sarada deccanensis*) were restricted to open grassland and fallow habitats.

Snake assemblages included 14 species, with repeated records of *Ptyas mucosa*, *Naja naja*, *Daboia russelii*, *Echis carinatus*, and *Bungarus caeruleus*. Aquatic and semi-aquatic reptiles such as *Xenochrophis piscator*, *Lissemys punctata*, and *Melanochelys trijuga* were exclusively recorded in maps showing expanded water bodies.

3.2 Conservation Status Summary

Based on IUCN categories, 29 species were classified as Least Concern (LC)**,** 1 species (*Python molurus*) was listed as Vulnerable (VU), and 2 species were recorded under Lower Risk categories**.** The remaining species were categorized as Not Assessed (NA)**.** All recorded amphibian species fell under LC or NA categories.

Table No. 01 Herpatofauna Identified in the Study area of four tehsils of Solapur district.

Sr. No.	Species	Scientific Name	Family	IUCN Status
Amphibians				
1	Common Indian Toad	*Duttaphrynus melanostictus* (Schneider, 1799)	Bufonidae (Gray)	LC
2	Indus Valley Toad	*Duttaphrynus stomaticus* (Lutken, 1864)	Bufonidae (Gray)	LC
3	Indian Skittering Frog	*Euphlyctis cyanophlyctis* (Schneider, 1799)	Dicroglossidae (Anderson)	LC
4	Bombay Wart Frog	*Minervarya syhadrensis* (Annandale, 1919)	Dicroglossidae (Annandale,1919)	LC
5	Cricket Frog	*Minervarya caperata* (Kuramoto, Joshy, Kurabayashi & Sumida, 2007)	Dicroglossidae (Anderson	NA
6	Indian Bull Frog	*Hoplobatrachus tigerinus* (Daudin, 1802)	Dicroglossidae (Anderson)	LC
7	Indian Burrowing Frog	*Sphaerotheca breviceps* (Schneider,1799)	Dicroglossidae (Anderson)	LC
8	Dobson's Burrowing Frog	*Sphaerotheca dobsonii* (Boulenger,1882)	Dicroglossidae (Anderson)	LC
9	Western Burrowing Frog	*Sphaerotheca pashchima* (Padhye, Dahanukar, Sulakhe, Dandekar, Limaye and Jamdade, 2017)	Dicroglossidae (Anderson)	NA
10	Nilphamarai Narrow-mouthed Frog	*Microhyla nilphamariensis* (Howlader, Nair, Gopalan and Merilä, 2015)	Microhylidae (Gunther)	NA
11	Ornate narrow- mouthed Frog	*Microhyla ornata* (Dumeril and Bibron, 1841)	Microhylidae (Gunther)	LC
12	Indian Balloon Frog	*Uperodon globulosus* (Gunther, 1864)	Microhylidae (Gunther)	LC
13	Marbled Balloon Frog	*Uperodon systoma* (Schneider, 1799)	Microhylidae (Gunther)	LC

14	Common Indian Tree Frog	*Polypedates maculatus* (Grey,1830)	Rhacophoridae	LC
Reptiles				
15	Indian Black Turtle	*Melanochelys trijuga* (Schweigger, 1812)	Bataguridae	LR/NT
16	Indian flapshell turtle	*Lissemys punctate* (Bonnaterre, 1789)	Trionychidae	LR/LC
17	Yellow Green House Gecko	*Hemidactylus flaviviridis (*Rüppell, 1835)	Gekkonidae	NA
18	Asian house gecko	*Hemidactylus frenatus* (Dumeril & Bibron, 1836)	Gekkonidae	LC
19	Bark gecko	*Hemidactylus leschenaultii* (Dumeril & Bibron, 1836)	Gekkonidae	NA
20	Murray's house gecko	*Hemidactylus murrayi* (Gleadow, 1887)	Gekkonidae	NA
21	Spotted house gecko	*Hemidactylus parvimaculatus* (Deraniyagala, 1951)	Gekkonidae	NA
22	Termite hill gecko	*Hemidactylus triedrus* (Daudin, 1802)	Gekkonidae	LC
23	Brook s House Gecko	*Hemidactylus brookii* (Gray, 1845)	Gekkonidae	LC
24	Jerdon's snake-eyed lizard	*Ophisops jerdoni* (Blyth,1853)	Lacertidae	NA
25	Common keeled	*Eutropis carinata* (Schneider,1801)	Mabuyidae	LC
26	Three-lined Grass Skink	*Eutropis trivittata* (Hardwicke & Gray, 1827)	Mabuyidae	NA
27	Bronze grass skink	*Eutropis macularia* (Blyth, 1853)	Mabuyidae	LC
28	Common Keeled Skink	*Eutropis carinata* (Schneider, 1801)	Mabuyidae	LC
29	Common Dotted Garden Skink	*Riopa punctata* (Gray, 1845)	Scincidae	LC
30	Lined Supple Skink	*Riopa lineata* (Gray, 1839)	Scincidae	LC
31	Bengal monitor	*Varanud bengalensis* (Daudin,1802)	Varanidae	LC
32	Indian Chamaeleon	*Chamaeleo zeylanicus* (Laurenti, 1768)	Chamaeleonidae	LC
33	Indian Garden Lizard	*Calotes versicolor* (Daudin, 1812)	Agamidae	NA
34	Pondichery Fan throated lizard	*Sitana ponticeriana* (Cuvier, 1829)	Agamidae	LC
35	Flat-headed fan-throated lizard	*Sitana laticeps* (Deepak and Giri, 2016)	Agamidae	NA
36	Deccan fan-throated lizard	*Sarada deccanensis* (Jerdon,1870)	Agamidae	NA

37	Common sand boa	*Eryx conicus* (Schneider,1801)	Erycidae	NA
38	Red sand boa	*Eryx johnii* (Russell,1801)	Erycidae	NA
39	Ocellated shield tail	Uropeltis ocellata (Beddome, 1863)	Uropeltidae	NA
40	Rock python	*Python molurus* (Linnaeus, 1758)	Pythonidae	VU
41	Russell's Viper	*Daboia russelii* (Shaw and Nodder, 1797)	Viperidae	LC
42	Indian saw-scaled viper	*Echis carinatus* (Schneider, 1801)	Viperidae	NA
43	Common Indian Krait	*Bungarus caeruleus* (Schneider,1801)	Elapidae	NA
44	Spectacled Cobra	*Naja naja* (Linnaeus,1758)	Elapidae	LC
45	Indian Rat Snake	*Ptyas mucosa* (Linnaeus, 1758)	Colubridae	NA
46	Asiatic Water Snake	*Xenochrophis piscator* (Schneider, 1799)	Colubridae	NA

Species Composition

Field surveys conducted across Sangola, Malshiras, Phandarpur, and Mangalvedha recorded a total of 46 herpetofaunal species, comprising 14 amphibian species and 32 reptile species (Table 01). Amphibians belonged to five families—Bufonidae, Dicroglossidae, Microhylidae, and Rhacophoridae, while reptiles were represented by 12 families, including Gekkonidae, Mabuyidae, Agamidae, Viperidae, Elapidae, and Colubridae.

Among amphibians, the family Dicroglossidae showed the highest species richness (6 species), followed by Microhylidae (4 species). Reptiles were dominated by Gekkonidae (7 species) and Agamidae (4 species), indicating high representation of lizards adapted to semi-arid and human-modified landscapes.

Amphibian Richness and Abundance Patterns

Across all study sites, amphibian richness remained consistent with the recorded species pool of 14 species. Frequently encountered amphibians included *Duttaphrynus melanostictus*, *Euphlyctis cyanophlyctis*, *Hoplobatrachus tigerinus*, and *Sphaerotheca breviceps*, which were observed across multiple land use categories. These species contributed most to overall amphibian encounter rates. Seasonally restricted species such as *Microhyla ornata*, *Uperodon globulosus*, *Uperodon systoma*, and *Polypedates maculatus* were primarily recorded during periods of increased surface moisture and vegetation cover. Burrowing frogs (*Sphaerotheca breviceps*, *S. dobsonii*, *S. pashchima*) showed repeated occurrences in agricultural fallow land and loose soil substrates.

The Shannon–Wiener diversity index (*H′*) for amphibians ranged from low to moderate values across maps, with higher values recorded during monsoon-associated months corresponding to increased species detectability. Amphibian encounter rates varied spatially, with higher values recorded near water bodies, irrigated croplands, and seasonal pools.

Reptile Richness and Abundance Patterns

Reptile assemblages showed higher overall richness **(**32 species**)** and greater spatial continuity across all maps. Commonly recorded reptile species included *Calotes versicolor*, *Hemidactylus flaviviridis*, *Hemidactylus frenatus*, *Eutropis carinata*, and *Varanus bengalensis*. These species accounted for the majority of reptile encounter records across agricultural, scrubland, and peri-urban habitats.

Skinks (*Eutropis carinata*, *E. macularia*, *Riopa punctata*, *Riopa lineata*) were widely distributed across open fields and scrub patches. Arboreal and semi-arboreal reptiles such as *Calotes versicolor*, *Chamaeleo zeylanicus*, and *Polypedates maculatus* (amphibian) were primarily recorded in areas with woody vegetation and plantation cover.

Snake diversity included 14 species, with consistent records of *Ptyas mucosa*, *Naja naja*, *Daboia russelii*, and *Echis carinatus*. Aquatic and semi-aquatic reptiles such as *Xenochrophis piscator*, *Lissemys punctata*, and *Melanochelys trijuga* were restricted to wetlands, tanks, and irrigation canals.

Reptile Shannon diversity (*H′*) remained moderate to high across all maps, and encounter rates were consistently higher than amphibians across seasons and land use categories.

IV. DISCUSSION

INTERACTION BETWEEN LAND USE/LAND COVER CHANGE AND CLIMATE VARIABILITY

The present study demonstrates that herpetofaunal patterns in the semi-arid landscape of Solapur District are shaped by the combined influence of land use/land cover (LULC) dynamics and seasonal climatic variability. Across Map No. 1 to Map No. 10, agricultural land consistently dominated the landscape, while scrubland, open grasslands, and water bodies fluctuated seasonally. These spatial patterns interacted strongly with monsoon-driven rainfall and temperature regimes, producing distinct temporal responses in amphibian and reptile communities.

Seasonal expansion of vegetation covers and surface water during monsoon months (August 2021 and November 2022) coincided with increased amphibian richness, higher Shannon diversity values, and elevated encounter rates. In contrast, summer maps (June 2021 and June 2022), characterized by reduced vegetation cover, fragmented scrubland, and minimal surface water, showed sharp declines in amphibian richness and abundance. These findings align with broader studies indicating that amphibians in dryland systems are primarily constrained by moisture availability and hydroperiod length rather than land cover alone (Wells, 2010; IPCC, 2023).

AMPHIBIAN RESPONSES TO LULC–CLIMATE GRADIENTS

Amphibian assemblages exhibited pronounced sensitivity to both seasonal climate and land cover configuration. Species such as *Duttaphrynus melanostictus*, *Euphlyctis cyanophlyctis*, and *Hoplobatrachus tigerinus* were recorded across multiple maps and land use types, reflecting their ecological plasticity and tolerance to habitat modification. However, species richness peaked only when suitable climatic conditions (monsoon rainfall) coincided with heterogeneous land cover comprising cropland, scrub patches, and water bodies.

Burrowing species (*Sphaerotheca breviceps*, *S. dobsonii*, *S. pashchima*) persisted during dry-season maps, indicating behavioral buffering against climatic stress through aestivation and use of loose agricultural soils. In contrast, narrow-mouthed frogs (*Microhyla ornata*, *Microhyla nilphamariensis*) and balloon frogs (*Uperodon globulosus*, *U. systoma*) were largely restricted to monsoon-associated maps, suggesting dependence on short-lived moisture pulses and specific breeding microhabitats. The reduced amphibian recovery observed in August 2022 compared to August 2021 suggests cumulative effects of habitat alteration, particularly loss of small wetlands and increasing landscape fragmentation.

REPTILE RESPONSES TO LULC–CLIMATE GRADIENTS

Reptiles displayed comparatively stable richness and diversity across Map No. 1 to Map No. 10, reflecting broader thermal tolerance and reduced dependence on free-standing water. Dominant species such as *Calotes versicolor*, *Hemidactylus spp.*, *Eutropis carinata*, and *Varanus bengalensis* were consistently recorded across seasons and land use categories. This stability indicates that reptiles are more resilient to short-term climatic variability and seasonal LULC shifts. Nevertheless, species composition varied with land cover structure. Open grasslands and fallow agricultural lands supported fan-throated lizards (*Sitana ponticeriana*, *Sarada deccanensis*), while scrub and agricultural mosaics favored skinks and agamids. Aquatic reptiles (*Xenochrophis piscator*, *Lissemys punctata*, *Melanochelys trijuga*) were strictly limited to maps showing expanded water bodies, highlighting indirect climate dependence through hydrological persistence. The continued presence of venomous snakes (*Daboia russelii*, *Echis carinatus*, *Naja naja*) across dry and wet seasons underscores the adaptability of these taxa to human-modified semi-arid landscapes.

IMPLICATIONS OF INCREASING BUILT-UP AREA AND HABITAT FRAGMENTATION

Inter-annual comparison revealed a gradual increase in built-up land and fragmentation of scrub and open habitats between 2021 and 2022. While reptiles continued to occupy peri-urban and agricultural environments, amphibians showed reduced spatial continuity, particularly during dry-season maps. This divergence suggests that ongoing urban expansion, when combined with increasing temperature and erratic rainfall patterns, may disproportionately affect moisture-dependent taxa.

Fragmentation of grassland and scrub habitats also has implications for movement, breeding connectivity, and population stability. Loss of small water bodies and vegetated field margins may reduce functional habitat availability even during favorable climatic periods, limiting post-monsoon recovery of amphibian populations. Similar interactions between LULC intensification and climate stress have been reported from other semi-arid regions of India (Gardner et al., 2007; Jadhav et al., 2021).

CONSERVATION AND MANAGEMENT IMPLICATIONS

The findings highlight the importance of maintaining land cover heterogeneity under changing climatic conditions. Preservation of scrubland remnants, open grasslands, and seasonal wetlands within agricultural matrices appears critical for sustaining amphibian diversity. Water harvesting structures, farm ponds, and vegetated irrigation channels may play a key role in buffering amphibian populations against prolonged dry periods.

For reptiles, conservation strategies should focus on retaining habitat mosaics rather than isolated patches, as species richness remained highest in landscapes combining scrub, agriculture, and limited built-up areas. Given that most recorded species are currently listed as Least Concern or Not Assessed, proactive land management is necessary to prevent future population declines driven by cumulative LULC and climate pressures.

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