Q1. Biodiversity documentation using GIS (for Earth Science students)

(a) Definitions (3 marks)

Biodiversity documentation
Systematic recording of the variety of life—**genes**, **species**, and **ecosystems**—along with where and when each record was observed. It includes field and museum records, remote-sensing observations, eDNA results, photos, and the **metadata** (who/when/how) needed to verify and reuse those records.

Geographic Information System (GIS)
A framework (software + data + methods) to **store, manage, analyze, and map spatial data**. In GIS, information is organized as **layers** (points, lines, polygons, rasters) with a **coordinate reference system** and an **attribute table**. GIS lets us link each biodiversity record to a location, visualize patterns, and run spatial analyses.

Schematic (what each term covers and how they relate)

```
[ Biodiversity Documentation ]
   • Genes   • Species   • Ecosystems
   • Occurrence records + metadata (who/when/how)
   • Sources: field GPS, museums, eDNA, remote sensing
                |
                v (attach coordinates, CRS)
[                GIS                ]
   • Spatial layers: points/lines/polygons/rasters
   • Attribute tables + symbology
   • Tools: overlay, buffer, density, hotspot, change
                |
                v
[ Mapped, analyzable biodiversity patterns ]
```

(b) Process: mapping biodiversity using GIS tools (4 marks)

1) Frame the study
Define **objective** (e.g., map amphibian hotspots), **extent/scale** (watershed, ecoregion), and **time window** (e.g., 2015–2025).

2) Gather data

- **Occurrence data:** GPS points from surveys, citizen science, museum records (species, date, accuracy).

- **Environmental layers:** land cover, elevation/derived terrain (slope, aspect), soils/geology, hydrography, climate/bioclim variables.
- **Remote sensing:** optical indices (e.g., NDVI), thermal, radar; multi-date imagery for change detection.
- **Administrative layers:** protected areas, roads, settlements.

3) Quality control & harmonization
De-duplicate, remove obvious errors (e.g., points in the ocean for terrestrial species), standardize taxonomic names, set a **common projection/CRS**, and document **positional accuracy**.

4) Build the geodatabase
Organize clean layers (vector + raster) with clear naming, metadata, and scales/resolutions matched to the question.

5) Spatial analysis

- **Presence mapping:** plot points with accuracy buffers.
- **Sampling effort correction:** thin clustered records; or use effort layers.
- **Density/Hotspots:** Kernel density, Getis-Ord Gi*, or grid-based **species richness** (count species per cell).
- **Habitat suitability (optional):** environmental overlays or species distribution modeling (SDM) to estimate suitable areas.
- **Connectivity (optional):** least-cost paths or circuit theory for corridors between habitat patches.
- **Change analysis:** compare land cover or habitat metrics across dates.

6) Cartography & communication
Design clear maps (legend, scale bar, north arrow, source/metadata, classification), export layouts, and —if needed—publish web maps/dashboards.

7) Validation & iteration
Ground-truth a subset of sites, update with new surveys, refine layers and models.

Schematic (end-to-end workflow)

```
[Define Objective & Area]
          |
          v
[Collect Data]
 Occurrences | Environment | Remote Sensing | Admin
          |
          v
[Clean & Harmonize]
   • QC coords/taxa  • Common CRS  • Metadata
          |
          v
```

```
[Geodatabase]
  Structured layers & scales
         |
         v
[Spatial Analysis]
  • Points -> buffers
  • Density/Hotspots/Richness
  • Suitability (SDM)
  • Connectivity / Change
         |
         v
[Map Layouts & Web Maps]
  Legend • Scale • Credits
         |
         v
[Validation & Update]
  Field checks • Iterate
```

(c) Two advantages of using GIS in biodiversity conservation (3 marks)

1. **Reveals spatial patterns & priorities**
   GIS exposes **hotspots, gaps, and corridors**—supporting decisions like **where to protect, restore, or survey next**. This improves cost-effectiveness and transparency compared with ad-hoc choices.
2. **Integrates multi-source data for monitoring & scenarios**
   GIS fuses field observations with **land cover, hydrology, geology, and climate** layers, enabling **change detection** (e.g., habitat loss since 2016) and **what-if planning** (e.g., proposed road vs. corridor integrity).

Schematic (how GIS strengthens decisions)

```
[Multi-source Inputs]
 Occurrence ▸ Land Cover ▸ DEM ▸ Soils/Geology ▸ Hydro
         \       |         |        |            /
          \      |         |        |           /
           v     v         v        v          v
           [ GIS Integration & Analysis ]
            • Hotspots   • Connectivity   • Trends
                          |
```

v

[Conservation Actions]

Protected areas ▸ Restoration ▸ Monitoring design