Chapter 29
Assessment of Diversity in Landscape Ecology in Parts of the Purba Medinipur Coastal District, West Bengal, with Geospatial Technology

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29.1 Introduction

Landscape ecology is the study of how landscape structure influences the profusion and allocation of organisms at the multiplicity of scales of the landscape. So, landscape ecology focuses on three characteristics of the landscape such as structure, function, and modification. Structure stands for the spatial associations between the typical ecosystems or rudiments, whereas function deals with the relations among the spatial features, and modification comprised the change in the arrangement and purpose of the ecological mosaic over time (Troll, 1968; Godron & Forman, 1983). Two systems collaborate to create landscapes, using edge-specific topographical methods and precise perturbation of factor conditions. Landscapes vary greatly in aerial range, with scales restricted to small areas of a few metres or hundreds of metres being finer than landscapes. Because of the area's geomorphology, the multifaceted landforms and parental materials present are comparatively invariable over a landscape (Neef, 1984; Zonneveld, 1989). Tropical marine ecosystems are frequently dynamic and spatially heterogeneous seascapes in which different habitat types (e.g., coral reef, seagrass, open water, mangrove, and sand) are linked by a variety of biological, physical, and chemical processes. Water movements, including tides and currents, facilitate the exchange of nutrients, chemical pollutants, pathogens, sediments, and organisms among components of the seascape (Paul, 2002; Woodroffe, 2002). Landscape ecology has traditionally been inadequate to the lessons of terrestrial systems; however, the scientific questions and techniques

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are uniformly applicable to maritime and coastal sub-systems. The mutual association between spatial outline and ecological procedure and the overarching consequence of scale on this connection were being investigated in some maritime settings as the common discipline of landscape ecology was growing through the latter two decades of the last century. As with all mechanisms of the biosphere, these associations are decisive for the successful supervision of marine and coastal sub-systems (Naveh, 1995; Wiens, 1997). However, comparatively recent progress in geographic information systems, remote sensing, and computer technologies has commenced dealing with these issues and is now authorising the appraisal of patterns and processes in oceans. This present work intends to emphasise research that is adapting the conception of landscape ecology to respond to ecological questions within coastal sub-systems, to deal with the exclusive challenges expressed in these landscapes, and to motivate an exchange of thoughts and clarification of universal problems.

29.2 Geographical Setup of the Study Area

The studied coast is a large coastal region in the state's far south-west corner. A part of the District of Purba Medinipur, West Bengal, along the Bay of Bengal includes the coastal plain. This rising coastal plain is made up of sand and mud sedimented by the fluvial and aeolian processes and is also a mid-eastern division of the Kanthi Coastal Plain, it covers an area of about 29,439 ha, or 294.39 km^2 (Fig. 29.1). Geologically, the area is characterised by typical Holocene alluvial deposits originating from the Subarnarekha and Ganges River networks. The nature of this geomorphic part is mainly characterised by sand dunes and marshes parallel to the coast.

29.3 Materials and Methods

The present study deals with Survey of India (SOI) toposheets, satellite images of Landsat 5 and Sentinel-2 Multi-Spectral Instrument (MSI), and Google Earth images with different temporal phases. The study has also used climactic data from the India Meteorological Department (IMD), Kolkata; a geological map from the Geological Survey of India (GSI) official portal; and a soil map from the National Bureau of Soil Survey and Land Use Planning (NBSS & LUP) for the assessment of different parameters, and simultaneously repeated field surveys have been conducted with pre-designed questioners for validation of the research results. The radiometric and geometric errors of satellite imagery are methodically corrected, and spectral radiance to surface spectral reflectance is converted through the gain bias method.

A high-resolution Digital Elevation Model (DEM) has been prepared through the bootstrap iterations for determining the precision statistics stochastically (Sharma et al., 2010) using the Advanced Spaceborne Thermal Emission and Reflection

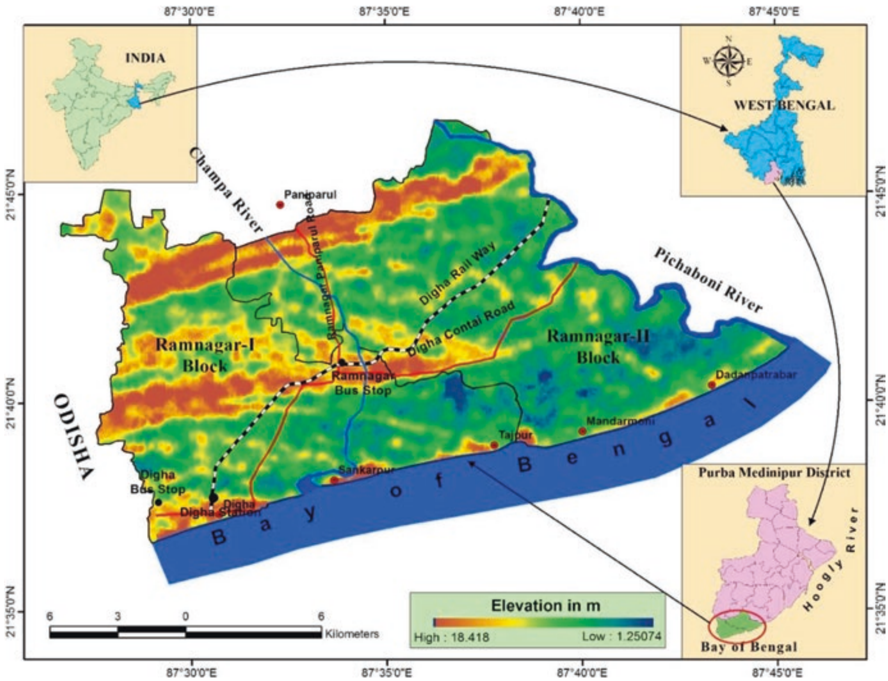

Fig. 29.1 The study areas with landscape ecological components depict the beach ridge chenier swale topography of Kanthi Coastal Plain along the northern fringe of the Bay of Bengal coast

Radiometer (ASTER) Global Digital Elevation Model (GDEM) (Version-215 m, 2014), Shuttle Radar Topography Mission (SRTM: 1 arc-second, 30 m, 2014) DEM, Google Earth elevation, in situ 2000 Ground Control Points (GCP), and Total Station survey data. This model is very significant for identifying the landscape characteristics and evolutionary stages of coastal tracts. High-resolution DEM, existing radiocarbon dating records, Optically Stimulated Luminescence (OSL) dating records, and geomorphological and stratigraphic signatures have been considered for the validation of entire processes of landscape evolution. Image classification techniques, the Shannon-Weiner Diversity Index, Sorenson's Coefficient, and Hierarchical Cluster Analysis (HCA) techniques have been used to estimate, to explore, and to analyse the species richness, evenness, and spatial diversity of coastal habitats in the study area.

Human observational studies are also conducted through repeated field studies to better understand the relationship between human activities (resource uses and land use and land cover changes), coastal hazards, and coastal morphodynamics. At the same time, biological processes have been estimated through phyto-geomorphological mapping. Several quantitative methods incorporate the link between spatial patterns and ecological processes at broad spatial and temporal scales. This linkage of time, space, and environmental change can assist managers in applying plans to solve environmental problems in the coastal landscapes.

29.4 Results and Discussions

29.4.1 Topographic Character and Landform Order

The physiography of the alluvial coast is very important in coastal morphodynamics in response to outer environmental impacts with a significant change in local boundary conditions (Bhandari & Das, 1998; Paul, 2002; Maiti & Bhattacharya, 2009). To predict and establish the evolution of the Chenier coastal plain, the chronology of the coastal evolution is explained using available dating records of different landform units in the existing literature, estimation of present-day wave hydrodynamics and energy level, and estimation of the sediment budget of the near shores (Kamila et al., 2021a). In the wide valley flat surface between the Ramnagar-Deuli beach ridge section and the Digha-Junput beach ridge section, there are three bifurcated ridges in the form of narrow and low-height ridges (Fig. 29.2a, Table 29.1). The three barriers are separated by linear depressions running parallel to the present ridge lines and represent the linear tidal basins of that time. To the east, the wider flats of tidal basins are characterised by the location of younger natural levees and older natural levees and some depressed wetlands (Paul, 2002; Kamila et al., 2020).

The energy of longshore current is calculated and estimated as being highest for the Contai-Paniparul beach ridge chenier, Ramnagar-Deuli beach ridge chenier, and Digha-Junput beach ridge chenier after consideration with the volume of sediment estimation under modern sea-face energy levels. The Chenier Plain is the result of a combination of fluvio-marine deposition of sediment into coastal areas, the occurrence of strong longshore currents at the sea face, the activities of repeated coastal storms, tectonic impacts, and past sea level fluctuations.

However, the shorter beach ridge cheniers are shaped under weaker longshore current energy in the east-east north direction, parallel to the present-day shoreline (Table 29.2). On the other hand, it is also observed that the wide, shallow flats in between landward and seaward beach ridge cheniers were formed by the finer sediments (swale topography) deposited under the lagoonal setting behind the barrier

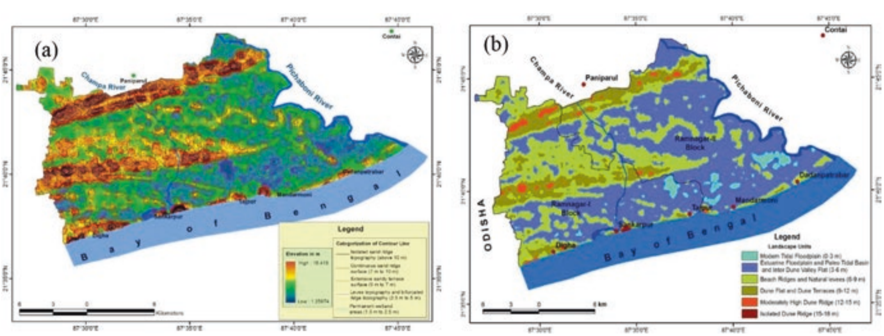

Fig. 29.2 (**a**) The spatial elevation changes depicted by the contour patterns; and (**b**) Landscape habitat fragments in the coastal plain

Table 29.1 Chronology of coastal formations in the study areas of Ramnagar-I and II Administrative Blocks (Kamila et al., 2021a)

Landscapes	Elevation	Pattern	Soil material	Tonal contrast	Existing dating age	Probable age	Ancient processes involved	Sea level indicators
First category of landscapes	Above 10 m	Shore parallel isolated sand ridge	Oxidised sands	Brownish	7000 years BP	Early Holocene	Windblown deposits and erosion by tidal waves	Sea-level steel stand
Second category of landscapes	7–10 m	Shore parallel sand ridge topography	Oxidised sands	Brownish to yellowish	5760 ± 160 years BP	Middle Holocene	Windblown and wind-tidal	Sea-level steel stand
Third category of landscapes	5–7 m	Extensive sandy tract on the side of ridges	Sandy	Greyish	2900 ± 160 years BP	Late Holocene	Over wash reactivated deposits	Transgressive seas
Fourth category of landscapes	2.5–5.0 m	Bifurcated ridges and crenulated levees	Sandy and loamy	Dark grey	2000 ± 100 years BP	Recent to sub-recent	Wave-induced currents and fluvial currents	Regressive seas

Table 29.2 The assessment of hydro-morphodynamics of the past landforms based on modern available data (Maiti, 2013; Kamila et al., 2021a)

Stages	Area of beach ridges in m^2	Average height of beach ridges in m	Volume of depositional sediment in m^3	Duration of deposition in year	Volume of deposition per year in m^3	Energy concentration (e) per year	Area of beach ridges in km^2
1st stage	6,63,96,200	10.38	689,192,556	1240	5,55,800.45	14.98	66.39
2nd stage	1,22,61,700	9.01	110,477,917	1430	77,257.28	2.08	12.26
3rd stage	3,35,20,800	10.25	343,588,200	1430	2,40,271.45	6.48	33.52
4th stage	7,00,6760	9.21	645,322,59	300	2,15,107.53	5.80	7.07
5th stage	90,82,150	8.40	762,900,60	300	23,54,300.20	6.85	9.08
6th stage	64,82,380	9.24	59,897,191	300	1,99,657.30	5.38	6.48
7th stage	1,79,75,600	9.61	172,745,516	1200	1,43,954.60	3.88	17.97

bar systems and the supply of finer sediments by Hugli River mouth discharges into the Late Holocene tidal basin. Most recently, the beach ridge cheniers and shoreline are disconnected by older distributary channels and act as tidal inlet mouths along the beach surface and have been modified by modern coastal processes (Paul, 2002; Kamila et al., 2021a).

29.4.2 Landscape Ecological Diversity

The native vegetation in coastal areas plays a significant role in stabilising the surface against wind erosion and providing a habitat for wildlife. So, the protection of coastal vegetation is important for the long-term protection of beachfront properties. It is not sufficient to describe the patterns of species turnover at an ecotone; one must think about the underlying causes of that turnover, how species are responding to the environment, and the relative distributions of these species along the gradient.

29.4.3 Species Categorisation

The regional species zonation map is prepared with the concern signature of the plant over the entire study area by classifying floral species on a small grid using the Normalized Difference Vegetation Index (NDVI). On the other hand, the

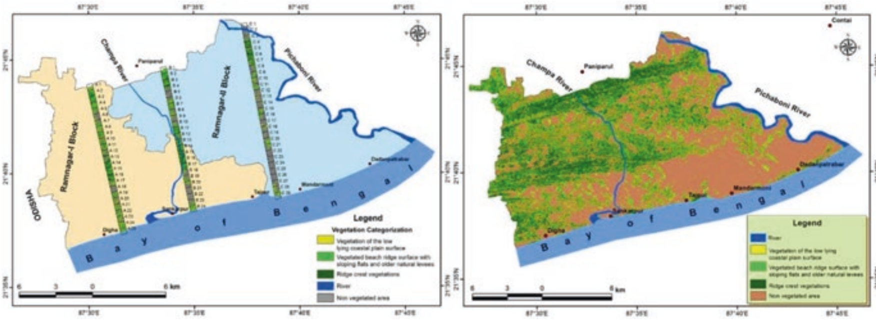

Fig. 29.3 Grid-wise vegetation classification (Left) and overall scenario of vegetation types

classification map of the sampling site can reflect the actual scenario of the plant community in and around the study area. However, the sentinel data offers a higher resolution than other open-source images, so the vegetation is well distributed in this region (Fig. 29.3).

The vegetation is widely distributed and extended over the beach ridge surface, the beach ridge fringed coastal plain, the swale topography, and the inner coastal plain with abandoned creeks and older natural levee bank surfaces. The maximum diversity of vegetation is found in transect B (4.29) in comparison to the other two transects, whereas transect A shows a very high Shannon Diversity Index (4.00), while transect A denotes a very high evenness character compared to the other two transects. The Sorenson's Coefficient is 0.7692, 0.6885, and 0.7731 for AB, BC, and AC transects, respectively, which indicates that the presence of species communities is common in the AC transect when the estimated value is close to 1 (Table 29.3).

The Hierarchical Cluster Analysis result shows that the vegetation belongs to relatively homogeneous groups of species communities. Therefore, the B transect has revealed more heterogeneous characteristics than the other two transects in the present study. Accordingly, the A and C transects denote the consistency of the clustering habit of the species (Kamila et al., 2021b).

29.4.4 Identification of Micro Landscape Units

The study deals with a high-resolution DEM to understand the micro-landscape units of the entire study area. The DEM is categorised into six units based on the altitudinal variations and morphometric characteristics such as isolated dune ridge (15–18 m); moderately high dune ridge (12–15 m); dune flat and dune terraces (9–12 m); beach ridge and natural levees (6–9 m); estuarine flood plain and paleo-tidal basin; interdune valley flat (3–6 m), and modern tidal flood plain (0–3 m) to understand the morphological setup (Fig. 29.2b). After considering the elevation of each intersection, a longitudinal profile is constructed from sea to land to estimate

Table 29.3 Estimation of species diversity through Shannon Weiner Diversity Index and Sorenson's Coefficient

Transect	The maximum diversity (H_{max})	Evenness (EH)	Shannon Diversity Index (H)	Sorenson's Coefficient
Transect – A	4.2484	0.9430	4.0067	AB = 0.7692
Transect – B	4.2904	0.9169	3.9341	BC = 0.6885
Transect – C	3.8918	0.9173	3.5700	AC = 0.7731

grid-based micro-terrain units. Each grid represents a different type of terrain unit (Kamila et al., 2021c).

29.4.5 Linkage Between Morphological Units and Coastal Habitats

The current study area also contains several types of habitat units, such as large trees, small trees, shrubs, heaths, and grasslands, which are closely connected and interact with each other, so that this integrated ecosystem creates a large coastal ecosystem. The transact method identifies five plant community types (e.g., grasses, heaths, shrubs, small trees, and large trees) with 106 species and 25 types of micro-landscape ecological units in the current study area (Kamila et al., 2021c). In Table 29.4, it is very clear that small tree habitation is much more frequent than other habitation of floral species, whereas heathland habitation occupies a very small part of the land. Other habitation zones are lying in between the land cover of these two classes. The beach ridge and natural levees, on the other hand, occupy a larger percentage of land in each habitation zone than other micro morphological units. As a result, micro-morphological units, primarily beach ridges and natural levees, are extremely important in terms of floral species diversity and abundance (Fig. 29.4, Table 29.4).

The maximum variability of floral species exists in the beach ridge surface, beach ridge fringed coastal plain surface, inner coastal plain surface with a narrow beach ridge segment, beach ridge separated by a swale valley, inner coastal plain surface with an older levee bank, inner coastal plain with abandoned creeks, and the inner coastal plain with beach ridge remnant surface. Because the dune furrows, dune valleys, sloping flats of the coastal sand dunes, and ancient beach ridge topography retain sufficient soil moisture content in this sensitive area.

Due to the tidal inundations, the wetlands of the coastal belt support potential zones for the growth and extension of floral habitats. Sediment recycling and nutrient recycling are progressively improved in the micro zones due to the wide-ranging growth of plant communities in hot and humid tropical environments. Finally, the

Table 29.4 Percentage of the area occupied by the plant ecology in different morphological units

Sl. No.	Morphological units	Occupied area of plant ecology (Total area 146.24 km^2)				
		Grass land area in percentage (%)	Heath land area in percentage (%)	Scrub land area in percentage (%)	Small tree area in percentage (%)	Large tree area in percentage (%)
1	Isolated dune ridge (15–18 m)			0.03	0.04	0.14
2	Moderately high dune ridge (12–15 m)	0.13	0.07	0.19	1.01	1.75
3	Dune flat and dune terraces (9–12 m)	2.13	0.57	5.32	7.87	7.96
4	Beach ridge and natural levees (6–9 m)	2.02	1.07	16.99	20.46	10.73
5	Estuarine flood plain and Paleo tidal basin and inter dune valley flat (3–6 m)	3.04	1.04	5.86	4.43	5.29
6	Modern tidal flood plain (0–3 m)	1.66	0.14	0.01	0.02	0
	Total area in percentage (%)	8.97	2.89	28.58	33.79	25.84

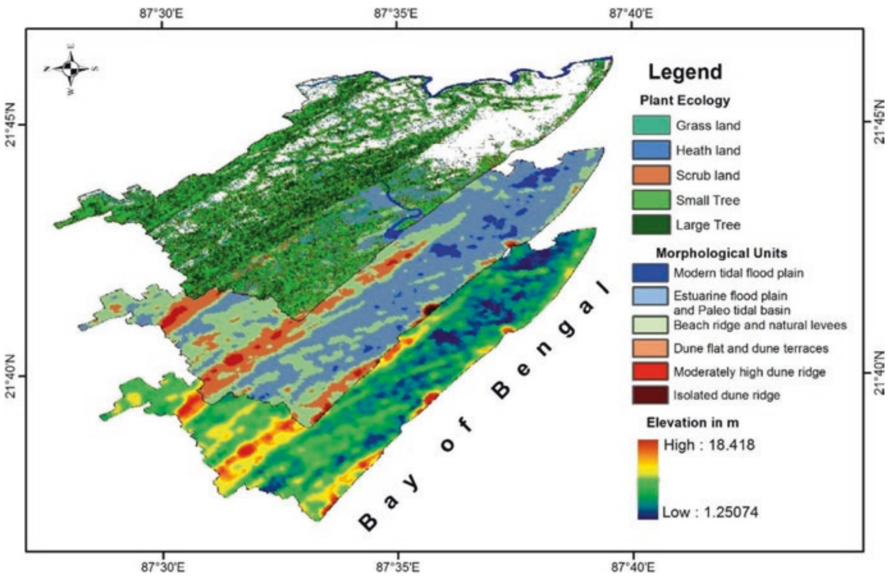

Fig. 29.4 Overlaid illustration of geomorphic units and habitat's existences

spatial allocations of the diverse plant variability zones are incorporated into the microtopographic units of the coastal landscape.

29.5 Conclusions

The coastal plain of alluvium surface with beach ridge chenier and swales was formed during the Early Holocene, Middle Holocene, and Late Holocene periods ranging from 7000 YBP to 500 YBP and the sub-recent stage. There are seven stages of coastal chenier formations on the studied coast (Largely Contai-Paniparul beach ridge chenier, Ramnagar-Deuli beach ridge chenier, and Digha-Junput beach ridge chenier). On the other hand, it is also observed that the wide, shallow flats in between landward and seaward beach ridge cheniers were formed by the finer sediments (swale topography) deposited under the lagoonal setting behind the barrier bar systems and the supply of finer sediments by Hugli River mouth discharges into the Late Holocene tidal basin. According to the hierarchical cluster analysis, the Shannon diversity index, and Sorenson's coefficient, the species diversity is very high in the beach ridge fringed coastal plain, swale topography, beach ridge surface, and inner coastal plain with abandoned creeks and older natural levee bank surfaces. These diverse vegetation zones have high soil moisture contents and subsurface groundwater sources, and they are weakly susceptible to infrastructure development. However, dense orchards have grown up as a result of plantations established by people who have lived there since the beginning of time.

The study reveals that there is a significant connection between the flora and nature of coastal alluvium and influences from the sea and the tides. Backwaters, tidal channels, and tidal flood plains are known to deposit finer alluvial sediments during seasonal and periodic tidal floods in the coastal belt. Gradually, they become very important sediment sinks, temporary floodplain reservoirs, physical buffers, and important bio-shields against advancing seas in coastal lowlands. They also have the very substantial chemical and biological functions of retaining pollutants and filtering water and moisture, making them ideal breeding grounds for fish and resting places for other animals (particularly avifauna).

References

Bhandari, G. N., & Das, S. C. (1998). A study of beach erosion for appropriate protection of Digha Coast. In *Coastal Zone problems, proceedings of national workshop* (pp. 51–60). Jadavpur University.

Godron, M., & Forman, R. T. T. (1983). Landscape modification and changing ecological characteristics. In *Disturbance and ecosystems* (pp. 12–28). Springer.

Kamila, A., Bandyopadhyay, J., & Paul, A. K. (2020). An assessment of geomorphic evolution and some erosion affected areas of Digha-Sankarpur coastal tract, West Bengal, India. *Journal of Coastal Conservation, 24*(5), 1–14.

Kamila, A., Paul, A. K., & Bandyopadhyay, J. (2021a). Exploration of chronological development of coastal landscape: A review on geological and geomorphological history of Subarnarekha chenier delta region, West Bengal, India. *Regional Studies in Marine Science, 44*, 101726.

Kamila, A., Paul, A. K., & Bandyopadhyay, J. (2021b). Assessment of species diversity and topographic variability on beach dune complex of Digha Sankarpur coastal tract, Purba Medinipur district, West Bengal, India. *International Journal of Ecology and Environmental Sciences, 3*(1), 87–97.

Kamila, A., Bandyopadhyay, J., & Paul, A. K. (2021c). Assessment of landscape ecological connectivity for sustainable management of Digha–Shankarpur Coastal Tract, West Bengal, India. *Journal of the Indian Society of Remote Sensing, 49*(11), 2701–2719.

Maiti, S. (2013). Interpretation of coastal morphodynamics of Subarnarekha estuary using integrated cartographic and field techniques. *Current Science, 104*(12), 1709–1714.

Maiti, S., & Bhattacharya, A. K. (2009). Shoreline change analysis and its application to prediction: A remote sensing and statistics-based approach. *Marine Geology, 257*(1–4), 11–23.

Naveh, Z. (1995). Interactions of landscapes and cultures. *Landscape and Urban Planning, 32*(1), 43–54.

Neef, E. (1984). Applied landscape research. *Applied Geography and Development, 24*, 38–58.

Paul, A. K. (2002). *Coastal geomorphology and environment: Sundarban Coastal Plain, Kanthi Coastal Plain, Subarnarekha Delta Plain*. ACB publications.

Sharma, A., Tiwari, K. N., & Bhadoria, P. B. S. (2010). Vertical accuracy of digital elevation model from Shuttle Radar Topographic Mission–a case study. *Geocarto International, 25*(4), 257–267.

Troll, C. (1968). Landschaftsökologie. In *Pflanzensoziologie und Landschaftsökologie* (pp. 1–21). Springer.

Wiens, J. A. (1997). Metapopulation dynamics and landscape ecology. In *Metapopulation biology* (pp. 43–62). Academic.

Woodroffe, C. D. (2002). *Coasts: Form, process and evolution*. Cambridge University Press.

Zonneveld, I. S. (1989). The land unit—a fundamental concept in landscape ecology, and its applications. *Landscape Ecology, 3*(2), 67–86.