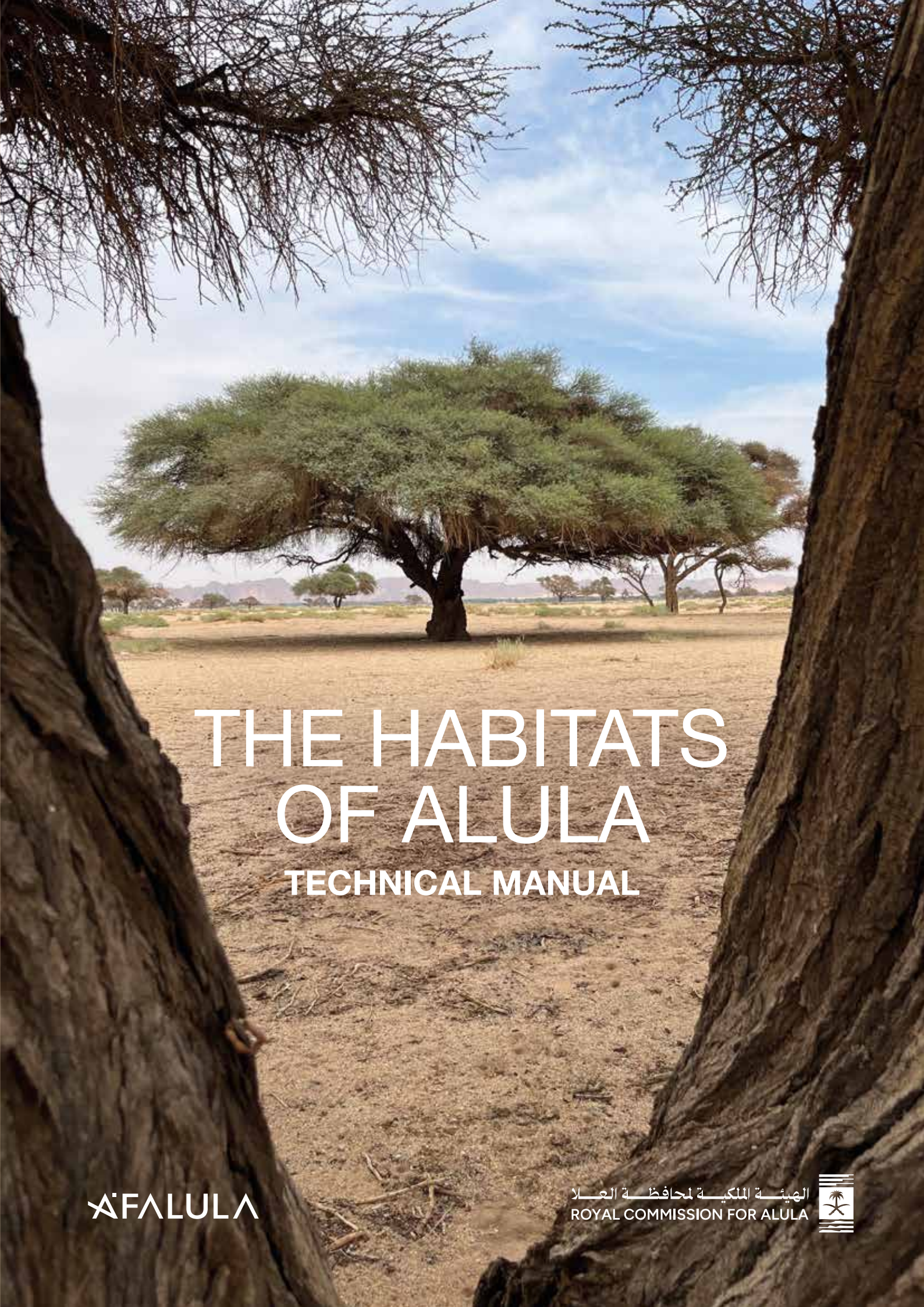


THE HABITATS OF ALULA

TECHNICAL MANUAL

AFALULA

الهيئة الملكية لمحافظة العلا
ROYAL COMMISSION FOR ALULA

THE HABITATS OF ALULA

TECHNICAL MANUAL

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الهيئة الملكية لمحافظة العلا
ROYAL COMMISSION FOR ALULA

AFALULA

CENTRE FOR MIDDLE EASTERN PLANTS

BIOPOLIS

cibio

BIODESERTS

U.PORTO

Valorhiz



KEY CONTRIBUTORS BY ORGANISATION

AFALULA Rana El Zein

BIOPOLIS-CIBIO-BIODESERTS-UPORTO (AlUla Fauna project): José C. Brito, João Campos, Marco Dinis, André V. Liz

CMEP (AlUla Flora project): David Cooper, Andy Griffiths, Sophie Neale, Gail Stott

RCU Ayman Abdulkarem, Jan Freedman, Ahmed Mohammed

VALORHIZ (Baseline assessment: conducted under the project Strategy and Execution Plan for Ecosystem Restoration in AlUla): Inès Ben Ammar, Hassan Boukcim, Youssef Lebrini, Mohamed-Djamel Miara, Robin Sallio

PROJECT TEAM

Lead authors and editors
Sophie Neale and Andy Griffiths

HABITAT FRAMEWORK AND MANUAL DEVELOPMENT

Development of the habitat framework, habitat descriptions, integration methodology and technical review:

Ayman Abdulkarem, Inès Ben Ammar, Hassan Boukcim, José C. Brito, João Campos, Marco Dinis, Rana El Zein, Jan Freedman, Andy Griffiths, Youssef Lebrini, André V. Liz, Mohamed-Djamel Miara, Ahmed Mohammed, Sophie Neale, Robin Sallio, Gail Stott

SPATIAL ANALYSIS AND HABITAT MAPPING

João Campos and Marco Dinis led the development of the harmonised habitat maps and spatial integration workflow

Additional input was provided by Youssef Lebrini and David Cooper

COLLECTION AND ANALYSIS OF NOVEL FIELD DATA

Targeted fieldwork in response to priority gaps, soil sampling and analysis:

Inès Ben Ammar, Mohamed-Djamel Miara

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ABBREVIATIONS / ACRONYMS

AFALULA	French Agency for AlUla Development
AGEDI	Abu Dhabi Global Environmental Data Initiative
CMEP	Centre for Middle Eastern Plants
EUNIS	European Nature Information System
FAO	Food and Agriculture Organization of the United Nations
GET	Global Ecosystem Typology
GIS	Geographic Information System
GNR	Gharameel Nature Reserve
HUBR	Harrat Uwayrid Biosphere Reserve
HZNR	Harrat AlZabin Nature Reserve
IUCN	International Union for Conservation of Nature
KSA	Kingdom of Saudi Arabia
KWV	Khaybar White Volcano
LCCS	Land Cover Classification System
NCW	National Center for Wildlife
NDVI	Normalised Difference Vegetation Index
PMBSRR	Prince Mohammed bin Salman Royal Reserve
RCU	Royal Commission for AlUla
RSG	Red Sea Global
SNP	Sharaan National Park
UNESCO	United Nations Educational, Scientific and Cultural Organization
WDPA	World Database on Protected Areas
WNNR	Wadi Nakhlah Nature Reserve



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FOREWORD

The transformation of AlUla is founded on a simple yet ambitious vision: that economic development, cultural heritage and environmental stewardship must progress together. In this vision, shared by the Royal Commission for AlUla and the French Agency for AlUla Development (AFALULA), the preservation and restoration of nature are not only environmental imperatives, but essential foundations for the long-term resilience, attractiveness and prosperity of the region.

AlUla's extraordinary landscapes—its sandstone canyons, volcanic harrats, mountains, wadis, dunes and oases—support a remarkable diversity of habitats that have shaped both biodiversity and human civilisation for millennia. Understanding these habitats is therefore fundamental to protecting the ecological processes that sustain biodiversity, guiding restoration efforts, informing land-use planning and ensuring that future development remains compatible with the natural character of this exceptional territory.

The Habitats of AlUla marks an important milestone in this journey. Developed through the close collaboration between the Royal Commission for AlUla (RCU), AFALULA and a multidisciplinary team of international and Saudi experts, this manual provides, for the first time, a comprehensive and standardized habitat classification for AlUla County. By bringing together the knowledge generated through numerous scientific programmes into a single coherent framework, it establishes a common language that can be shared by ecologists, planners, engineers, landscape architects, decision-makers and all those contributing to AlUla's future.

Beyond its scientific value, this publication reflects the strength of the long-standing partnership between France and the Kingdom of Saudi Arabia. Since the creation of AFALULA, our mission allowed us to mobilize French expertise in support of the Royal Commission for AlUla's vision while fostering knowledge exchange, innovation and capacity building. This manual exemplifies that ambition: combining international scientific standards with local knowledge and field experience to produce a practical tool that will support biodiversity conservation, ecological restoration and sustainable territorial planning for years to come.



As new research, monitoring programs and field observations continue to enrich our knowledge, this habitat framework is itself intended to evolve alongside them. We hope that this manual will become a living reference—supporting informed decision-making, encouraging collaboration across disciplines, and inspiring future generations of scientists, practitioners and institutions committed to safeguarding AlUla's unique natural heritage.

On behalf of our Agency, I would like to warmly thank the Royal Commission for AlUla, our scientific partners and all the experts, notably from the Royal Botanic Garden of Edinburgh, Valorhiz and Biopolis, whose dedication, expertise and collaborative spirit have made this achievement possible. Their collective work provides a crucial contribution to the conservation and sustainable development of one of the world's most spectacular landscapes, at the heart of a human adventure spanning several centuries.

We are proud to present this manual and trust that it will serve as a lasting reference for all those working to protect, restore and celebrate the remarkable natural heritage of AlUla & Saudi Arabia.

Jean-Yves Le Drian
President
French Agency for AlUla Development (AFALULA)



1 | INTRODUCTION

1 | INTRODUCTION

1.1 PURPOSE AND SCOPE

AlUla County encompasses a diverse mosaic of arid landscapes shaped by long-term interactions between geology, climate, and human land use. Mountains, sandstone landforms, volcanoes, volcanic plateaux (harrat), plains, wadis and dune systems combine to form a highly heterogeneous environment that supports a wide range of specialised ecological communities.

AlUla and its nature reserves are a focal area for large-scale conservation, restoration, and sustainable development under Saudi Arabia's Vision 2030. The Royal Commission for AlUla (RCU) is mandated to guide this transformation, balancing economic development—including tourism, agriculture, and infrastructure—with the protection and restoration of natural and cultural heritage. Within this context, a consistent and robust habitat classification system is a critical foundation for biodiversity assessment, protected area management, ecological restoration, and land-use planning.

Recent survey and research programmes have substantially advanced understanding of AlUla's biodiversity and environment, including its flora, fauna, soils, and patterns of land degradation. These initiatives have generated one of the most comprehensive ecological datasets assembled for north-western Saudi Arabia, including more than 1,000 vegetation plots, 542 fauna survey sites generating more than 38,000 biological records, as well as detailed soil analysis and extensive observations of habitat condition and degradation pressures. 460 vascular plant taxa have been formally documented (Stott et al., 2026) and 622 fauna taxa (Brito et al., 2024), including several plant and animal species new to science.

However, they have also highlighted a key limitation: the absence of a shared, consistent habitat framework through which information can be described, compared, and applied coherently across projects.

The Habitats of AlUla addresses this gap by bringing together and building on existing datasets to provide a standardised, ecologically meaningful framework for identifying, describing, and classifying habitats across AlUla County. It establishes a shared reference system through which ecological information can be interpreted, compared, and applied consistently across projects, sectors, and spatial scales.

In this manual, habitats are defined as mappable ecological units characterised by recurring combinations of environmental conditions and associated biological communities. Where possible these units are aligned with Saudi Arabian national ecosystem types and are distinguished by relatively consistent patterns of landform, substrate, hydrology, and ecological structure. The AlUla Habitat Classification is organised as a two-level hierarchy. At the broadest level, habitats are grouped into six habitat groups representing major landscape types. Each habitat group is then divided into more detailed habitats that capture finer ecological variation in landform, substrate, hydrology and biological communities.

The manual provides a practical foundation for translating ecological understanding into spatial planning and management.

1.2 A LIVING HABITAT FRAMEWORK: ADDRESSING CLASSIFICATION CHALLENGES

Habitat classification and mapping in arid landscapes presents challenges. Vegetation cover is often sparse, highly patchy and temporally variable, with plant communities responding rapidly to episodic rainfall events. Habitat boundaries are frequently diffuse, with gradual transitions occurring across landform, substrate, soil and hydrological gradients. In many areas, degradation resulting from grazing pressure, historical agricultural activity, off-road vehicle use, erosion and habitat fragmentation can also be difficult to distinguish from natural environmental variation.

These challenges have been reflected in previous ecological studies undertaken in AlUla. While such studies have made substantial contributions to understanding the region's habitats, flora and fauna, they were developed for different purposes and therefore employed different survey methods, classification systems, mapping approaches and spatial extents. As a result, no single project has provided a complete or consistent representation of AlUla's habitats across the county.

The habitat classification presented in this manual was developed to address this challenge. It brings together information from multiple ecological programmes, integrating habitat, vegetation, flora, fauna, soil, and environmental datasets within a single framework. Through a combination of spatial analysis, ecological interpretation and expert review, these complementary sources of evidence have been synthesised to produce a consistent and practical classification for describing and mapping habitats across AlUla.

Habitat classification is not a purely objective process. Natural systems are continuous and complex, whereas classifications require the definition of discrete units and boundaries. As a result, expert judgement is inevitably required when interpreting ecological patterns, reconciling differences among datasets and determining how habitats are defined and represented. The classifications and maps presented in this manual should therefore be understood as evidence-based interpretations of ecological patterns rather than definitive representations of on-the-ground conditions.

This manual represents a synthesis of current knowledge rather than a definitive or static classification. Ongoing research, monitoring, and further field observation are expected to refine and expand understanding of AlUla's environments over time. The habitat framework is therefore intended as a living system that can be updated and improved as new data becomes available.

1.3 AUDIENCE AND INTENDED USE

The manual is intended for use by a broad range of practitioners and stakeholders working in AlUla. It is designed to support applications such as habitat mapping and surveys, biodiversity monitoring, land-use planning, conservation prioritisation, ecological restoration design, and environmental assessment. It offers a shared reference framework that can be used consistently across projects and sectors, enabling different users to interpret habitat information and ecological context within a standardised conceptual structure.

The habitat framework is intended to be used alongside AlUla's Strategic Framework Plan and related guidance, helping to ensure that future change in AlUla is grounded in ecological understanding, landscape resilience, and long-term stewardship of both natural and cultural heritage.

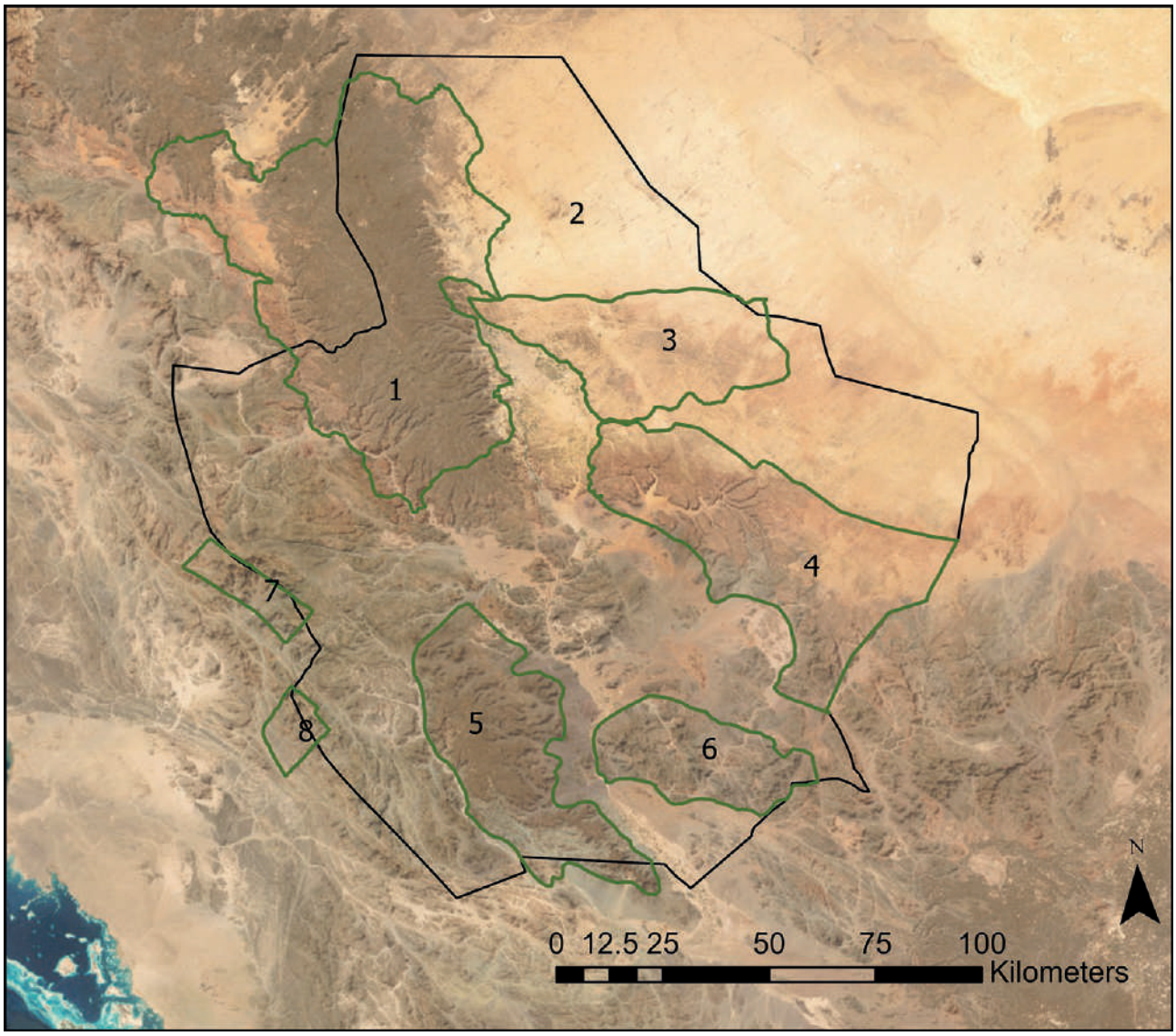
By providing a shared ecological evidence base, the framework can support strategic spatial planning, environmental assessment, the identification of environmentally sensitive areas, conservation prioritisation and ecological restoration across AlUla County, enabling biodiversity considerations to be integrated consistently into decision-making. While not a regulatory tool in itself, the framework is intended to support a common understanding of AlUla's ecological assets and landscape diversity.

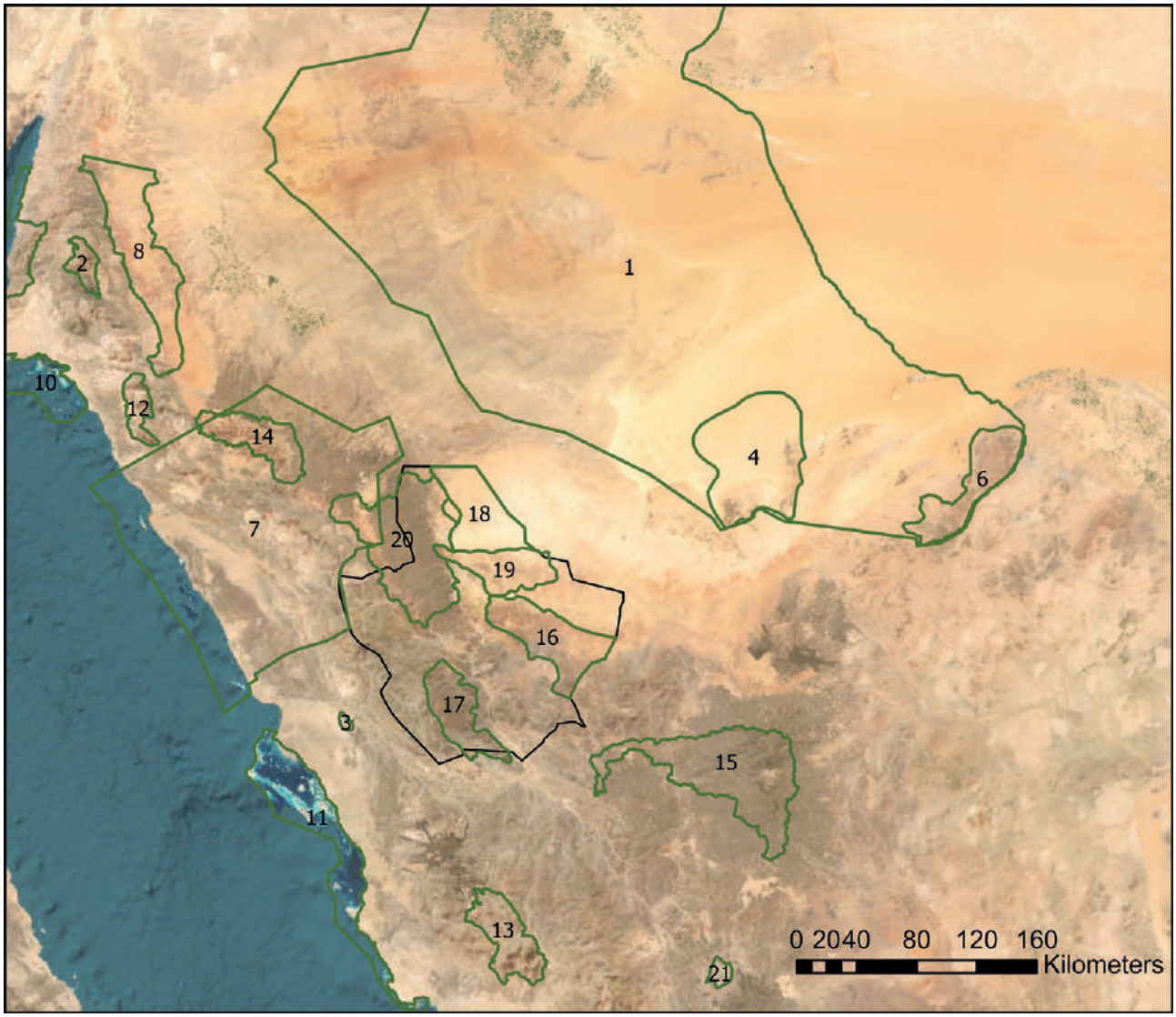
1.4 GEOGRAPHIC CONTEXT

AlUla County lies in the north-western part of Al Madinah Province and covers approximately 22,561 km². The county contains a network of protected areas and sites of conservation significance that together form the focus of biodiversity conservation and ecological restoration initiatives led by the Royal Commission for AlUla (RCU). There are five protected areas within AlUla County, as well as three additional areas designated as areas of conservation significance (Figure 1).

Figure 1 | Location of AlUla County (below) showing the extent of designated nature reserves and areas of conservation significance (right). Nature reserves include 1. Harrat Uwayrid Biosphere Reserve (HUBR) 2. Gharameel Nature Reserve (GNR), 3. Sharaan National Park (SNP) 4. Wadi Nakhlah Nature Reserve (WNNR) 5. Harrat AlZabin Nature Reserve (HZNR). Areas of conservation significance include 6. Jabal Nahar 7. Jabal AlWard, and 8. Jabal Shayoub.




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Kilometers



1. King Salman Bin Abdalaziz Royal Natural Reserve
2. Jabal al-Lawz
3. Jabal Ral
4. Jibal ‘Irnan / Jibal al-Misma
5. Wadi Jawwah / Wadi Jazan
6. Jabal Aja
7. Prince Mohammed bin Salman Royal Reserve
8. Hisma
9. Jazirat al-Huwaysat / Dawhat Duwayhin
10. Ra’s Suwayhil / Ra’s al-Qasbah
11. Al-Wajh Bank
12. Jabal ad-Dubbagh
13. Jabal Radwa
14. Jibal Qaraqir
15. Harrat Khaybar / Wadi Hadiyah
16. Wadi Nakhlah Nature Reserve
17. Harrat AlZabin Nature Reserve
18. Gharameel Nature Reserve
19. Sharaan National Park
20. Harrat Uwayrid Biosphere Reserve
21. The Haram of Al-Madinah
22. Yanbu‘ Coastal Conservation Area

Figure 2 | AlUla County (black outline) in its regional context, showing neighbouring protected areas and sites of conservation importance. Numbered features correspond to the regional protected areas and conservation sites listed in the accompanying key. Protected area boundaries are derived from the World Database on Protected Areas (WDPA, 2025).

1.5 REGIONAL APPLICABILITY

AlUla sits within a wider network of protected and managed landscapes in north-western Saudi Arabia. Most directly this includes the Harrat Uwayrid Biosphere Reserve, a UNESCO Man and the Biosphere site that extends beyond the northern boundary of AlUla into the Prince Mohammed bin Salman Royal Reserve (PMBSRR) (Figure 2). To the southwest AlUla also adjoins the Red Sea Global (RSG) area.

Together, these areas form part of a broader, interconnected landscape shaped by shared geological history, arid climate, and long-standing patterns of human land use. This highlights the potential for ecological connectivity and coordinated conservation across administrative boundaries.

Against this broader geographic and ecological context, the habitat framework developed for AlUla is intended to have applicability beyond the local area. Many of the habitats described here occur across the region and are shared with adjacent conservation areas and reserves.

As such, the manual has been designed with transferability in mind, providing a framework and approaches that can contribute to habitat mapping, monitoring, and management in other parts of north-western Saudi Arabia. The framework is intended to complement and support habitat and ecosystem work being undertaken in neighbouring reserves and regional initiatives, while recognising that local refinement and adaptation will always be required to reflect site-specific conditions and management objectives.

1.6 USING THE MANUAL

This manual, and the process through which it has been developed, is intended to be accessible to a wide range of users. It is designed to support both practical application and technical understanding. Users are not expected to read the manual sequentially. Instead, it is designed to be consulted selectively, depending on purpose and level of detail required.

The manual is arranged into several parts:

- **Sections 1–3** | Background to the project and an overview of the environment of AlUla.
- **Section 4** | Explains how the habitat framework was developed, including its conceptual basis and the integration of multiple datasets and projects.
- **Section 5–6** | Maps and descriptions of AlUla's habitats.
- **Section 7** | Future work.
- **Appendices** | contain more extensive technical details.



2 | THE ENVIRONMENT OF ALULA COUNTY

2 | THE ENVIRONMENT OF ALULA COUNTY

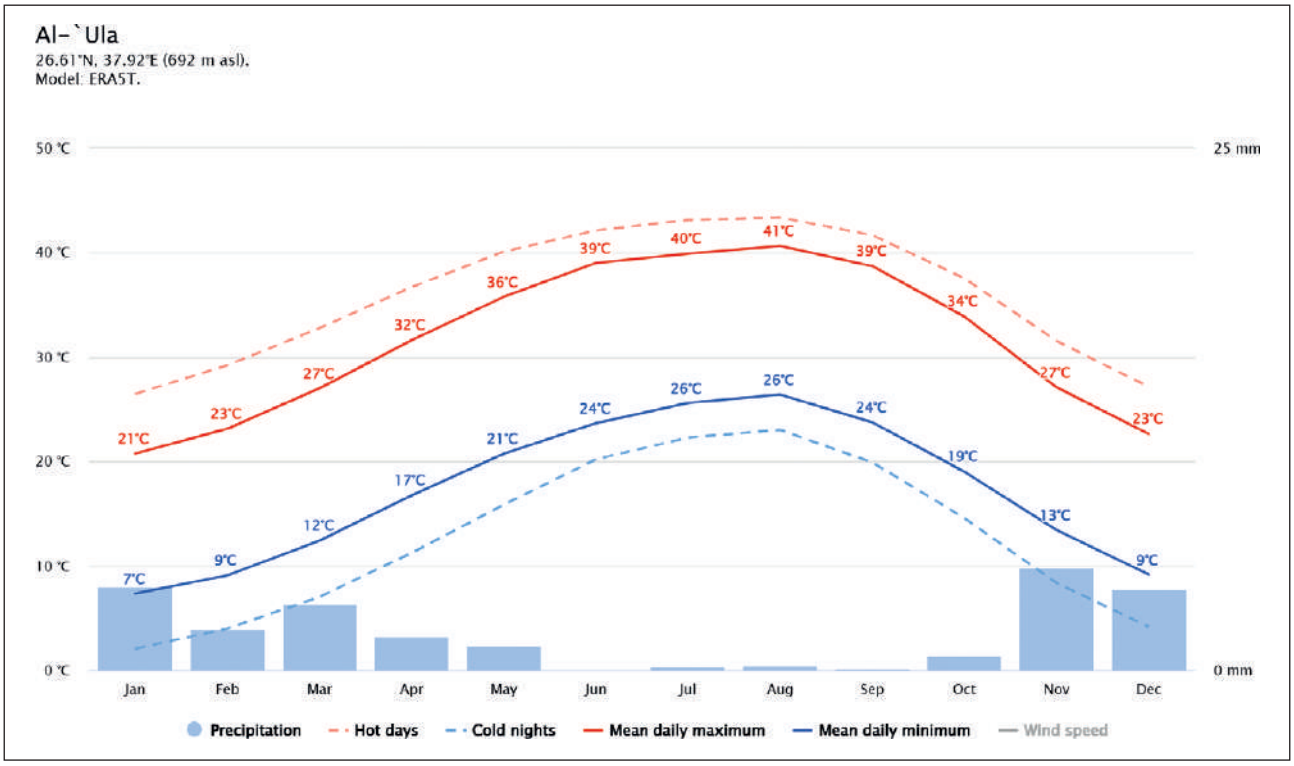
2.1 CLIMATE

AlUla has a hot desert climate (BWh) typical of much of Saudi Arabia (Beck et al., 2018). The climate is characterised by very hot summers, mild winters, extremely low humidity, and minimal rainfall throughout the year (Figure 3).

Temperatures in AlUla in summer (June – September) are very hot with an average daytime maximum commonly reaching 41°C and average low of 24 °C. Winter temperatures are comparatively mild with daytime highs up to 23 °C, while nighttime temperatures can fall below 4 °C.

Rainfall in AlUla is extremely limited, averaging 20–30 mm per year with most precipitation occurring in short episodes in winter and early spring. Rare, intense rainfall events can trigger wadi flows and localised flooding, which have historically shaped the area's geomorphology and cultural settlement patterns. Meteorological observations within AlUla are limited, and much of the available climate information is derived from modelled datasets. There is variation through the county with higher altitude areas experiencing cooler temperatures.

Figure 3 | Climate profile for AlUla County. Source: Meteoblue climate data for AlUla, Saudi Arabia (www.meteoblue.com), accessed July 2026.



2.2 GEOLOGY

AlUla's landscape represents a complex geological history spanning nearly one billion years, covering a large variety of igneous, metamorphic and sedimentary rock types, exposed across a relatively small area (Figure 4).

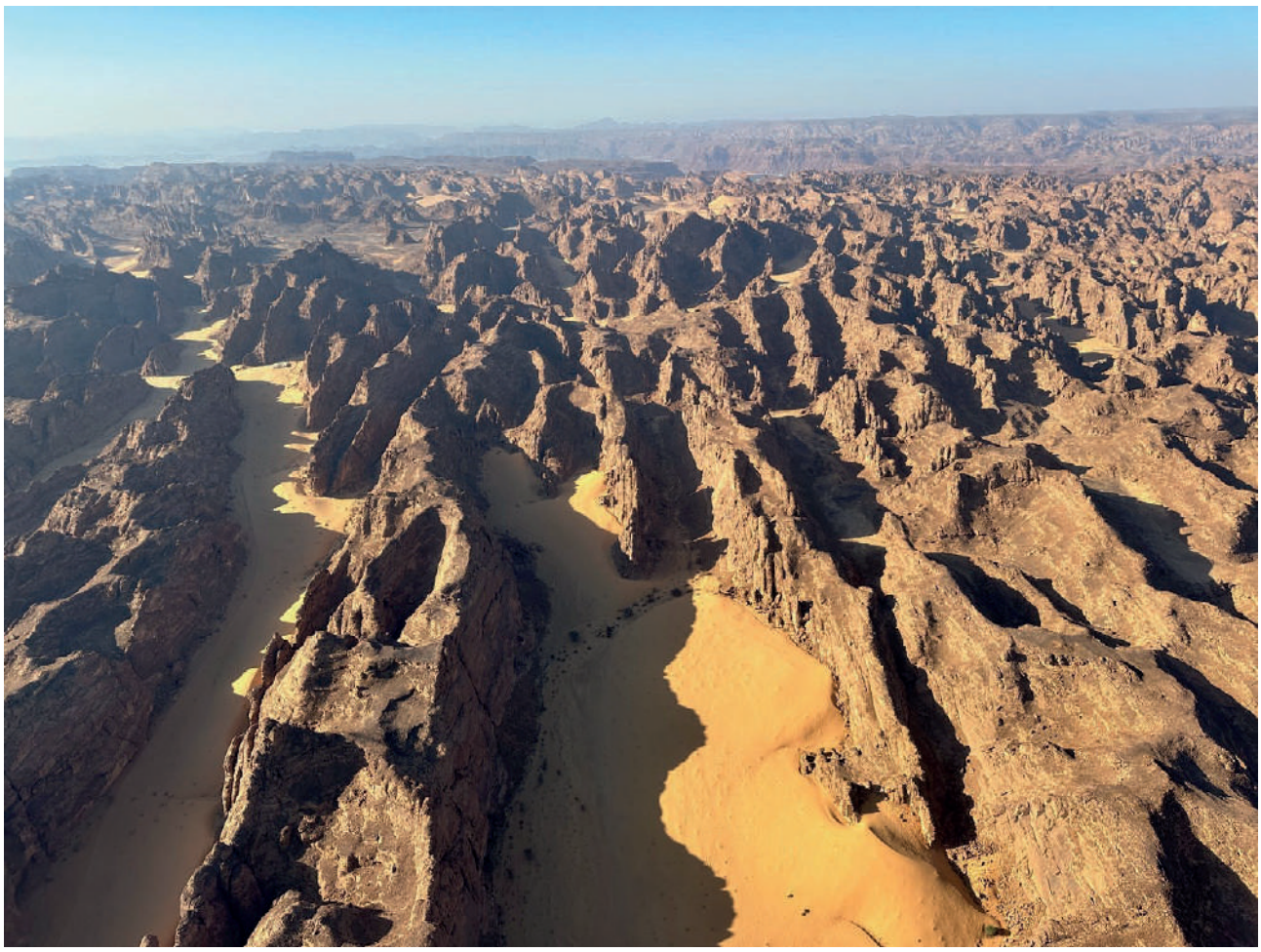
The oldest formations in AlUla are found in the south of the region. These Late Precambrian igneous and metamorphic complexes, a part of the Arabian Shield, create jagged mountains (Hadley, 1987). The Precambrian basement rocks are overlain by Cambrian and Ordovician sandstones (Hadley, 1987). Evidence of large series of faulting through tectonic activity can be seen across the entire AlUla region. The Late Precambrian Najd fault system, one of the largest Proterozoic shear zones on Earth, spreading through Saudi Arabia and Egypt (Stern, 1985; Stüwe et al., 2014), caused folding and fractures in the rocks in the south of AlUla. Later, faulting during the Oligocene/Miocene, resulting from the Red Sea rifting, produced further faulting in the sandstones (Rasul, Stewart, and Nawab 2015).

Overlaying the Precambrian rocks are the oldest sandstones, the Siq Sandstone, which is very well cemented, red in colour due to high iron content, and heavily fractured. These sandstones from the Early Cambrian, around 540–510 million years old, demonstrate medium to coarse-grained beds, with large cross-bedding throughout, evidence of a large, high-energy fluvial channel (Hadley, 1987). The lighter, Quweria Sandstone lies unconformably above the Siq Sandstone, and is dominated by fluvial deposits (Vaslet et al., 1994). The youngest sedimentary formation, the Saq Sandstone, demonstrates fluctuating environments, from shallow seas to river deltas, with medium-grained, well-rounded sands, graded bedding, and ripple marks at some sites (Hadley, 1987). Less compacted and cemented, the Saq sandstone demonstrates different erosion to the older Siq Sandstones, resulting in a large number of geomorphological landforms.

In the hyper-arid environment, the geology is exposed in the landscape, creating the diverse habitats of the region. The southern area displays a more mountainous look due to the weathering of the crystalline igneous and metamorphic formations, and towards the north, the Cambrian and Ordovician sandstones demonstrate numerous types of aeolian formations.

The oldest rocks in AlUla, in the south, creating a mountainous landscape, with sandy and gravel plains.

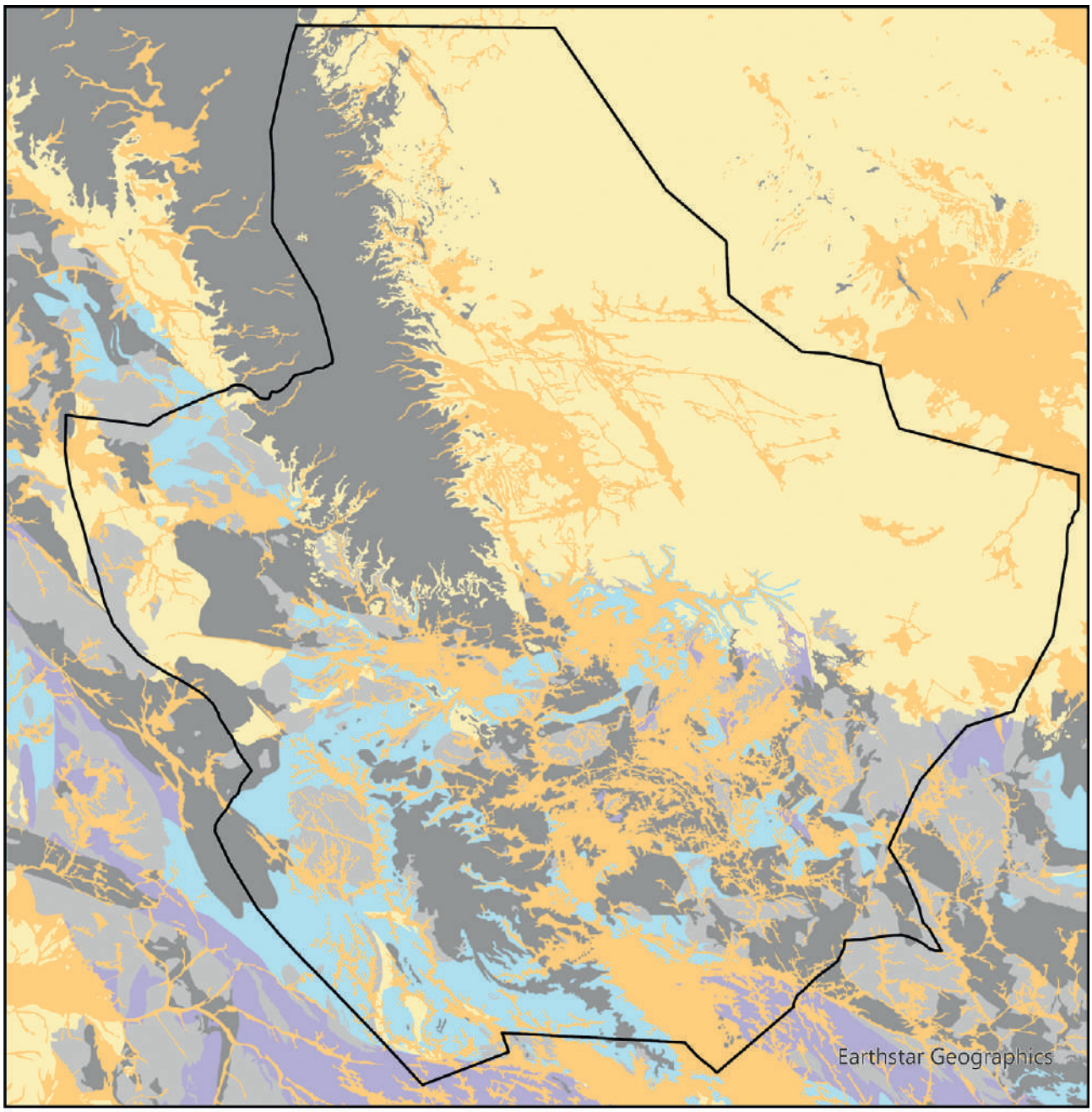




Cambrian sandstone formations exposed where aeolian erosion has carved out canyons, sandy wadis, and plains.



Harder metamorphic rocks survive as hills surrounded by gravel and sandy plains in the south of AlUla. It shows the diversity of the landscapes and habitats of AlUla.



Igneous extrusive rocks
Igneous intrusive rocks
Metamorphic rocks
Polylithologic rocks
Sedimentary rocks
Sedimentary surficial deposits

Figure 4 | Overview of the geological diversity of AlUla showing the distribution of lithological families across the county (black outline). Source: Geology 250k map provided by the Saudi Geological Survey, National Geological Database. Copyright Saudi Geological Survey. https://ngp.sgs.gov.sa/

Tertiary basalt lava flows (known as harrats), which cover the Saq sandstones in several places, create extensive plateaus: the largest of these is the Harrat Uwayrid Biosphere Reserve (Sen et al., 2025). These basalts date from around 10 million years ago until 500,000 years ago and are the result of crustal melting from the rifting of the Red Sea. (Altherr et al., 2019), and volcanoes can still be seen on Harrat Uwayrid. Throughout the region, several fine to coarse-grained alluvium deposits can be seen, which formed during the Quaternary. This material is typical in valley (or wadi) environments and can range from large water-travelled boulders to fine wind-blown sand (Bramkamp et al., 1963; Al-Bassam, Khalil, and Kassem, 2014).

2.3 FLORA AND FAUNA

AlUla lies within the Palaearctic realm and is dominated by the deserts and xeric shrublands biome. Its exceptional biogeographical position places it at the transition of several of this biome's ecoregions: Arabian Desert, North Arabian Desert, Red Sea-Arabian Desert Shrublands (Dinerstein et al., 2017). Portions of Jabal AlWard fall within the Mediterranean forests, woodlands and scrub biome and belong to a fifth ecoregion, the Eastern Mediterranean conifer broadleaf forests.

AlUla also lies roughly midway between two global biodiversity hotspots, namely the Mediterranean basin and the Horn of Africa (which extends into the south western Arabian Peninsula). From a biogeographic perspective, the flora and fauna of AlUla comprise a mixture of widely distributed desert taxa and regionally restricted species, alongside elements with affinities to Mediterranean, Irano-Turanian and Sudanian floristic regions (Miara et al., 2025). This reflects both the historical connectivity of the Arabian Peninsula and the role of AlUla as a transition zone influenced by multiple biogeographic regions.

The flora of AlUla is diverse but characteristically adapted to arid environments, comprising 460 recorded vascular plant taxa across 65 families and 277 genera (Stott et al., 2026). This represents approximately 20% of the flora of Saudi Arabia, seven species endemic to the Kingdom, and three endemic to the Arabian Peninsula. Recent botanical surveys have significantly improved knowledge of these taxa, documenting important new populations and range extensions for several national endemics, including *Euryops jaberiana* and *Nepeta sheilae*.

In addition, more than 70 species recorded in AlUla are considered range-restricted, occurring only within north-western Saudi Arabia and neighbouring countries such as Jordan and Egypt. For some species, including *Phlomis brachyodon*, AlUla represents the southernmost known extent of their distribution, while for others, such as *Ferula sinaica*, populations in AlUla are of national conservation importance because of the species' limited distribution within Saudi Arabia.


1



Although the majority of AlUla's plant species are widespread, most have not yet been assessed using the IUCN Red List Categories and Criteria. Two of the Saudi endemic taxa are currently recognised as globally threatened or Near Threatened, while many others remain classified as Data Deficient, reflecting broader gaps in botanical knowledge, taxonomic research and distribution data across the region.

The presence of threatened and range-restricted taxa, including species such as *Thymbra nabateorum*, highlights both the importance of AlUla for plant conservation and the continuing potential for new botanical discoveries (Abdulkarem et al., 2025).

Recent cryptogam surveys have also revealed an unexpectedly high diversity in AlUla, with 48 bryophyte species recorded in AlUla County and more than 100 lichens documented across the AlUla-Khaybar region (Hugonnot et al., 2025a, 2025b; Hugonnot et al., 2026a, 2026b; Marques et al., 2025, 2026). These findings highlight the importance of AlUla's varied geology, topography and microclimatic refugia in supporting a diverse cryptogam assemblage within an otherwise arid landscape. Several bryophytes, including *Riella affinis*, *Gymnostomiella vernicosa*, *Hymenostylium hildebrandtii* and *Ptychostomum cellulare*, have been identified as being of exceptional conservation importance within AlUla, owing to their rarity, restricted distributions, and dependence on specialised refugial habitats.

1 *Nepeta sheilae* a national endemic
2 Sooty Falcon (*Falco concolor*).

1 *Euryops jaberiana* a national endemic.
2 Camel grazing in gravel wadi

Although generally less conspicuous than vascular plants, bryophytes and lichens make an important contribution to AlUla's biodiversity. They occur primarily within environmentally favourable microhabitats, including shaded sandstone canyons, seepages, spring systems, runoff channels, sheltered rock faces, and higher-altitude mountain environments. Lichens form an important component of AlUla's cryptogam diversity and are particularly associated with biological soil crusts, rock surfaces and moisture-enhanced microhabitats. Lichens including *Peltula euploca*, *Peltula africana*, *Lichinella cribellifera*, *Lichinella stipatula* and *Thallinocarpon nigritellum* are characteristic of seepage tracks and runoff channels, while *Psora decipiens* and *Catapyrenium squamulosum* are key constituents of biological soil crust communities. Together, these assemblages contribute to soil stabilisation, nutrient cycling, and the ecological functioning of AlUla's desert ecosystems (Marques et al., 2026).



Due to its geographic position, AlUla also supports high faunal diversity. The current faunal list of AlUla comprises 622 taxa identified to the levels of species or genus (Brito et al., 2024). IUCN range maps indicate up to 32 mammal species potentially present in AlUla. The Arabian leopard (*Panthera pardus nimr*) is a prominent flagship species with historic observations in the AlUla region (Al-Johany 2007), suggesting the area acts as a suitable habitat or a dispersal corridor, despite its absence in AlUla for decades. Historical records of the cheetah (*Acinonyx jubatus*) and the Asian wild ass (*Equus hemionus*) indicate potential for future reintroductions, as well as for the reintroduction of the leopard (Dunford et al., 2022). IUCN range maps also list 122 bird species occurring in AlUla. Notable bird species include the Asian houbara (*Chlamydotis macqueenii*), a flagship desert species with cultural and tourism value (Goriup et al., 1997), and the Sooty falcon, with an estimated 2% of the world's population occurring in AlUla (Martins et al., 2026). The native Arabian ostrich (*Struthio camelus syriacus*) is extinct, but habitat restoration could allow reintroduction of other arid adapted subspecies (Zafar-ul Islam et al., 2008). Western KSA and AlUla lie on major migratory flyways (e.g. Launay et al., 1999; Javed et al., 2012), and oases, wadis, and plantations provide critical stopover and resting sites during seasonal migrations. In addition, reptile diversity in the Arabian Peninsula is high, with more than 50% of its recognised species found nowhere else in the world (Cox et al., 2012). Endemism is particularly pronounced among lizards, while 23% of snakes are endemic (Mallon 2011). Emblematic endemics include the Arabian cobra (*Naja arabica*), Yemen monitor (*Varanus yemenensis*), and Veiled chameleon (*Chamaeleo calyptratus*). Amphibian diversity is low due to regional aridity, and only the Arabian toad (*Sclerophrys arabica*) and the Arabian five-fingered frog (*Euphlyctis ehrenbergii*) are known from the AlUla region (Aloufi and Amr 2015; Aloufi et al., 2021; IUCN 2024). Although considerable progress has been made in documenting AlUla's fauna, research has focused predominantly on larger vertebrates, and further survey and taxonomic work is needed to better understand the diversity and distribution of lesser-known invertebrates.



2

2.4 ENVIRONMENTAL DEGRADATION

Degradation and habitat descriptions

Environmental degradation is a defining contextual feature of AlUla's landscapes. This section provides an overview of the principal forms and drivers of environmental degradation in AlUla County and explains how degradation influences the *condition* of habitats, their ecological integrity, and their restoration potential. It does not alter the definition of habitat classes themselves.

Long-term human-environment interactions

Human presence in the AlUla region extends back millennia, and the landscape has evolved in association with human land use. For centuries, and likely longer, nomadic and semi-nomadic pastoral systems operated across the region using adaptive strategies closely tuned to rainfall variability and forage availability (AboHassan, 1981; Ministry of Agriculture and Fisheries, 1982). Practices such as seasonal herd movement, rotational grazing, and the likely use of socially regulated access systems - including variants of the *hima* system (Gari, 2006; Lancaster, 1999), helped to maintain ecological resilience and balance livestock use with the availability of natural resources.

As a result, many ecosystems in AlUla represent long-established cultural landscapes, shaped through sustained yet regulated interaction between people, livestock, and arid ecosystems. These systems maintained ecological resilience over extended periods, meaning that much of the vegetation cannot be considered natural in the strictest sense, but instead reflect cultural landscapes (Abo-Hassan, 1981; Lancaster, 1999).

Contemporary drivers of degradation

In contrast to these long-standing land-use systems, recent decades have seen a marked intensification of pressures that exceed the buffering capacity of many habitats across Saudi Arabia. Contemporary national assessments estimate that around 70% of Saudi Arabia's rangelands are affected by desertification and are considered moderately to extremely degraded (Dawelbait, 2025). Longstanding pressures include overgrazing, woodcutting, agricultural expansion and drought. Extensive field observations and previous studies consistently indicate that in common with other areas of Saudi Arabia, overgrazing by domestic livestock is the dominant contemporary driver of vegetation degradation in AlUla (Neale et al., 2023; Valorhiz, 2024).



Sustained grazing pressure drives a range of interrelated impacts, including reduced plant species diversity, a shift from palatable to unpalatable species, declines in vegetation cover, density, and biomass, and an increasing dominance of grazing-resistant life forms (see Box 1 for information on plant indicators of grazing pressure). These changes are frequently associated with disrupted vegetation dynamics, reduced seedling establishment, and soil degradation processes such as compaction and erosion (e.g. Assaeed, 2001; Al-Taisan, 2022). Collectively, these changes can have cascading ecological effects, reducing habitat availability, shelter and food resources for wildlife, and contributing to declines in species dependent on structurally diverse native vegetation.

Woodcutting for fuel has traditionally been a significant driver of degradation with both direct effects on vegetation such as loss of woody vegetation, changes in species composition and reduced cover, as well as indirect effects including soil degradation. Woodcutting is now more driven by recreational camping use (Abuzinada, 2004).

Beyond overgrazing and woodcutting, other pressures such as off-road driving, agricultural practices and development also drive environmental degradation. Off-road driving causes damage to both the vegetation and to the soil surface. This is particularly significant in arid environments due to the slow rate of recovery of many native perennial plants meaning that even a single event can leave lasting damage (Assaeed et al., 2019). To address these pressures, the Royal Commission for AlUla has introduced measures prohibiting driving activities that damage vegetation cover. This policy is intended to reduce habitat degradation, support ecosystem recovery, and contribute to the long-term conservation of AlUla's natural landscapes (RCU, 2021). Historical and abandoned agricultural practices have further contributed to habitat degradation in some areas through soil disturbance, compaction, pollutants and increased salinity (Youssef et al., 2024; Maurice et al., 2024).

Off-road driving tracks on sand dunes

Climate change represents an additional long-term pressure on AlUla's ecosystems. Climate projections for the Arabian Peninsula indicate continued increases in temperature, alongside changes in rainfall patterns and the frequency and intensity of extreme weather events, including droughts and heavy rainfall episodes. These changes may interact with existing pressures by increasing water stress on vegetation, influencing species distributions, reducing ecosystem resilience, and altering erosion and flood dynamics. In arid environments, the effects of climate change are often difficult to separate from other drivers of degradation, but they are likely to influence the future condition, distribution and restoration potential of habitats across AlUla.

Recognising degradation in the field

The effects of degradation are often evident in the field through a range of visible indicators. Signs of overgrazing include reduced vegetation cover, a lack of recruitment, browsing damage to shrubs and trees, and the increasing dominance of unpalatable or grazing-resistant species. In woody habitats, mature trees may persist while younger age classes are absent, indicating long-term suppression of regeneration. Vehicle disturbance is typically expressed through the formation of informal tracks, damaged vegetation, disruption of soil surfaces, and localised erosion. Woodcutting may be recognised through reduced woody cover, the presence of cut stumps, and a simplified vegetation structure. Further information on plant species that may serve as indicators of grazing pressure and habitat degradation is provided in Box 1.

BOX 1 Plant indicators of grazing pressure

Certain plant species respond predictably to grazing pressure and can therefore be used as indicators of rangeland condition and condition trend. Species that decline under increasing grazing pressure are termed *decreasers*, whereas those that become more abundant are termed *increasers*. Monitoring changes in the relative abundance of these groups is widely recognised as an effective approach for assessing rangeland condition and ecological change.

Decreasers are species that decline in abundance under increasing grazing pressure because they are generally palatable and selectively grazed by livestock. Their presence often indicates relatively good rangeland condition.

Examples of decreasers found in AlUla together with examples of references where their status as a decreaser is noted or discussed include:

- *Calligonum comosum* (Barth, 1999; Mandaville, 1990).
- *Panicum turgidum* (Al-Taisan, 2022; Al-Rowaily et al., 2012; Mandaville, 1990; Batanouny, 1979)
- *Rhanterium epapposum* (Alzarah, 2020; Mandaville, 1990)
- *Stipagrostis* spp.: Many species in the genus are important for grazing (Mandaville, 1990).

Examples of decreaser species:
1 *Stipagrostis plumosa*
2 *Rhanterium epapposum*
3 *Calligonum comosum*
4 *Stipagrostis ciliata*





2



3



4


1


2



Increasers are species that tend to increase in abundance under heavy grazing pressure because they are less palatable, grazing tolerant, or better adapted to disturbed conditions. Their dominance may indicate declining rangeland condition.

Examples of increaser species:
1 *Calotropis procera*
2 *Rhazya stricta*
3 *Asphodelus tenuifolius*

Examples of increasers found in AlUla together with examples of references where their status as an increaser is noted or discussed include:

- *Asphodelus tenuifolius* (Mandaville, 1990).
- *Calotropis procera:* Mixed narrative on the palatability of this species. However, it is a sign of increasing pressure of man on environment (Miller and Morris, 1988). Livestock are said to avoid it, and it is often the only standing plant around villages where otherwise livestock would have eaten everything (Mandaville, 1990).
- *Citrullus colocynthis:* Leaves unpalatable. Goats can eat immature fruit if there is very little else to feed on (Miller and Morris, 1988).
- *Rhazya* stricta (Assaeed and Al-Doss, 2001).
- *Senna italica* (Al-Sodany et al., 2020; Rowaily, 2015).
- *Tephrosia purpurea* subsp. *apollinea*: Often abundant in overgrazed areas. Eaten only during dry season when animals are very hungry (Miller and Morris, 2004), widely considered an indicator of overgrazing (Miller and Morris, 2004; Jongbloed et al., 2003).



3 | ALULA IN REGIONAL AND GLOBAL HABITAT FRAMEWORKS

3 | ALULA IN REGIONAL AND GLOBAL HABITAT FRAMEWORKS

3.1 TYPES OF CLASSIFICATION FRAMEWORKS

A range of global and regional frameworks have been developed to classify and describe habitats and ecosystems at broad spatial scales. These provide an important context for national and local classifications, enabling comparison, reporting, and alignment with international conservation initiatives. However, these frameworks differ both in their underlying purpose and the spatial scale at which they operate. Understanding these differences is essential for positioning the AlUla habitat classification appropriately.

At the most general level, land cover classification systems—such as the FAO **Land Cover Classification System (LCCS)** (Gregorio and Leonardi, 2016) are designed to describe the observable physical characteristics of the Earth's surface, such as vegetation cover, bare ground, or water. These systems are widely used in remote sensing and global mapping, but they do not aim to capture ecological processes or define habitats in an ecological sense.

In contrast, the **IUCN Habitat Classification Scheme** provides a standardised framework for describing the habitats used by species, primarily within the context of the IUCN Red List of Threatened Species (IUCN, 2012). It offers a globally consistent vocabulary for recording species–habitat associations but operates at a relatively coarse level and is not intended to define or map ecosystems spatially.

At broader spatial scales, biogeographic frameworks, such as the **Ecoregions 2017 classification** (Dinerstein et al., 2017), delineate large ecological regions based on patterns of biodiversity and species assemblages. These ecoregions are nested within global biomes and biogeographic realms and provide a spatial framework for conservation planning and biodiversity assessment (Figure 5). However, they operate at a coarse resolution and are not designed to support detailed habitat mapping or site-level analysis.

Together, these approaches provide important context, but they do not replace the need for process-based ecosystem frameworks or higher-resolution, application-focused classifications for mapping and management.

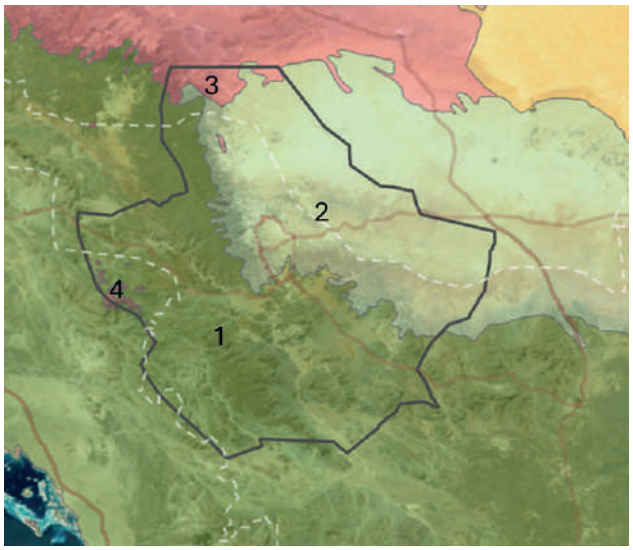


Figure 5 | Four ecoregions in AlUla together with their associated biomes and realms from Ecoregions 2017 classification (Dinerstein et al., 2017). Spatial data obtained from the Ecoregions 2017 database (RESOLVE, https://ecoregions.appspot.com/; accessed July 2026).

	Ecoregion	Biome	Realm
1	Red Sea -Arabian Desert shrublands	Deserts and Xeric shrublands	Palearctic
2	Arabian desert	Deserts and Xeric shrublands	Palearctic
3	North Arabian desert	Deserts and Xeric shrublands	Palearctic
4	Eastern Mediterranean conifer-broadleaf forests	Mediterranean Forests, Woodlands & Scrub	Palearctic

Global ecosystem framework: IUCN Global Ecosystem Typology

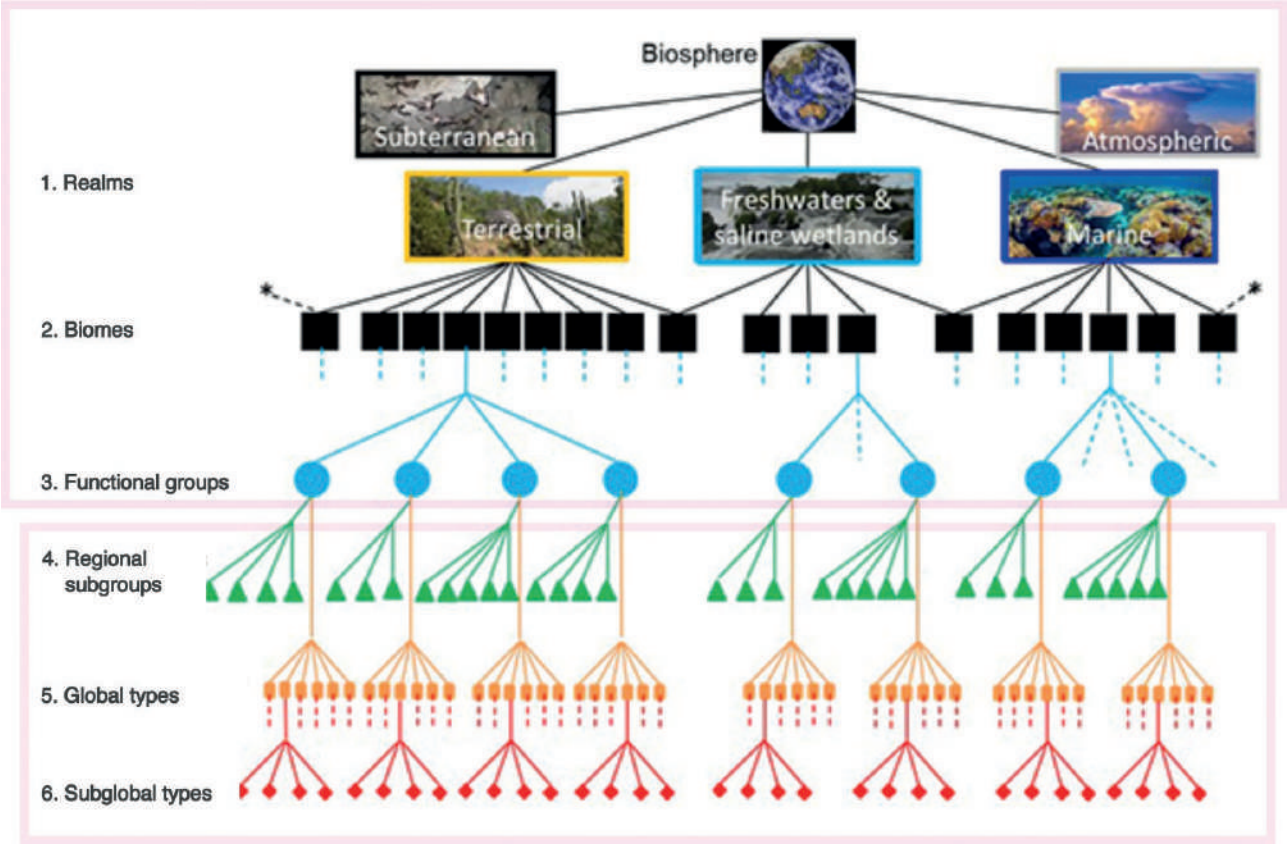
The **IUCN Global Ecosystem Typology (GET)** provides a standardised, process-based framework for describing ecosystems globally (Keith et al., 2022). It groups ecosystems according to shared ecological drivers, functional characteristics, and biophysical processes, enabling consistent comparison and integration across regions and scales.

The typology is structured as a six-level hierarchical system, spanning global to local scales. The upper levels 1–3 (realms, biomes, and ecosystem functional groups) group ecosystems based on broad environmental conditions and dominant ecological processes (Figure 6). In contrast, the lower levels (4–6) distinguish regionally and locally specific ecosystem types and are informed by bottom-up classification, drawing on national and subnational typologies and ground-based observations to capture finer variation in species composition and environmental settings.

A central principle of the GET is the explicit separation of ecosystem identity from ecosystem condition. Ecosystem types are defined by relatively enduring ecological characteristics, while degradation, land use, and other pressures are treated as attributes of condition rather than as defining features of the ecosystem itself. This distinction is particularly important in landscapes such as AlUla, where long-term human influences are widespread.

The GET therefore provides a global reference framework, supporting conceptual consistency and cross-scale linkages, rather than prescribing detailed local habitat classifications.

Figure 6 | The six levels of the IUCN Global Ecosystem Typology hierarchy. Reproduced from the IUCN Global Ecosystem Typology website (https://global-ecosystems.org/page/typology; accessed July 2026).



3.2 REGIONAL AND NATIONAL FRAMEWORKS

At regional and national scales, ecosystem classification frameworks typically provide greater spatial resolution and practical applicability, incorporating finer distinctions in landform, substrate, hydrology, and vegetation. These systems are designed to support mapping, planning, and management, and therefore operate at a level of detail not captured in global typologies.

At regional scales habitat classification systems have been developed to support practical mapping and management. In Europe the **European Nature Information System (EUNIS)** Habitat Classification and the EU Habitats Directive Annex I habitat types, for example, combine abiotic factors (such as substrate and hydrology) with biotic characteristics, particularly vegetation structure and composition, within a multi-level hierarchical system, and play a key role in biodiversity management regionally (Davies et al., 2004; European Commission, 2013; Chytrý et al., 2020; European Environment Agency (EEA), 2023). In the Arabian region the **Abu Dhabi Global Environmental Data Initiative (AGEDI)** ecological habitat map was developed from existing geospatial datasets and expert derived bioregional classifications as part of a conservation prioritisation process (AGEDI, 2013).

The Saudi Arabian component of the AGEDI map was based on the national bioregion classification developed by the National Center for Wildlife (NCW) to support protected area planning (Llewellyn, 2013). In line with the IUCN Global Ecosystem Typology, these units are now referred to as ecosystem types and together form the **Saudi Arabian ecosystem classification** (Box 2) (Qurban et al., 2024).

There are 56 terrestrial ecosystem types in Saudi Arabia, derived from combinations of key environmental drivers, including climate, geology, landform, soils, and vegetation structure, reflecting the primary factors that shape ecological variation in arid landscapes. The framework was originally developed to support the design and management of the national protected area network and provides a consistent basis for ecological characterisation, spatial planning, and biodiversity assessment. The 56 ecosystem types represent Level 6 (Sub-global Ecosystem Types) of the IUCN Global Ecosystem Typology and are nested within the Ecoregions 2017 classification (Dinerstein et al., 2017), which corresponds to Level 5 of the typology.

Importantly, the terminology of the national system has been updated to align with the IUCN Global Ecosystem Typology, supporting conceptual consistency with international approaches. In this way, the national framework functions as a translation layer, linking global ecosystem concepts with regionally appropriate ecological units. As such, it provides a primary point of reference for aligning local classifications, including that developed for AlUla, with broader ecosystem frameworks.

Position of the AlUla habitat classification

The AlUla habitat classification is a subregional, application-focused system developed to support habitat mapping, ecological assessment, and environmental management within AlUla County.

The classification has been designed to align, as far as practicable, with the Saudi Arabian national ecosystem types (Llewellyn, 2013), and through this, indirectly with the wider structure of the IUCN Global Ecosystem Typology. It refines broader ecosystem units into spatially explicit habitat classes, defined by recurring combinations of environmental conditions and associated ecological communities.

In doing so, the classification operates at a finer level of thematic and spatial resolution than either global frameworks or national ecosystem types. Its relationship to these frameworks is one of general correspondence rather than direct equivalence. Habitat units should be understood as locally differentiated expressions of broader ecosystem types, interpreted through the structure provided by the national framework.

The system integrates key environmental drivers—including topography, geology, soils, and hydrology—with vegetation structure and species assemblages. This reflects the specific requirements of arid landscapes, where landform, substrate, and hydrological processes play a dominant role in structuring habitats.

By maintaining this balance, the classification ensures local ecological relevance while remaining conceptually consistent with wider ecosystem frameworks.

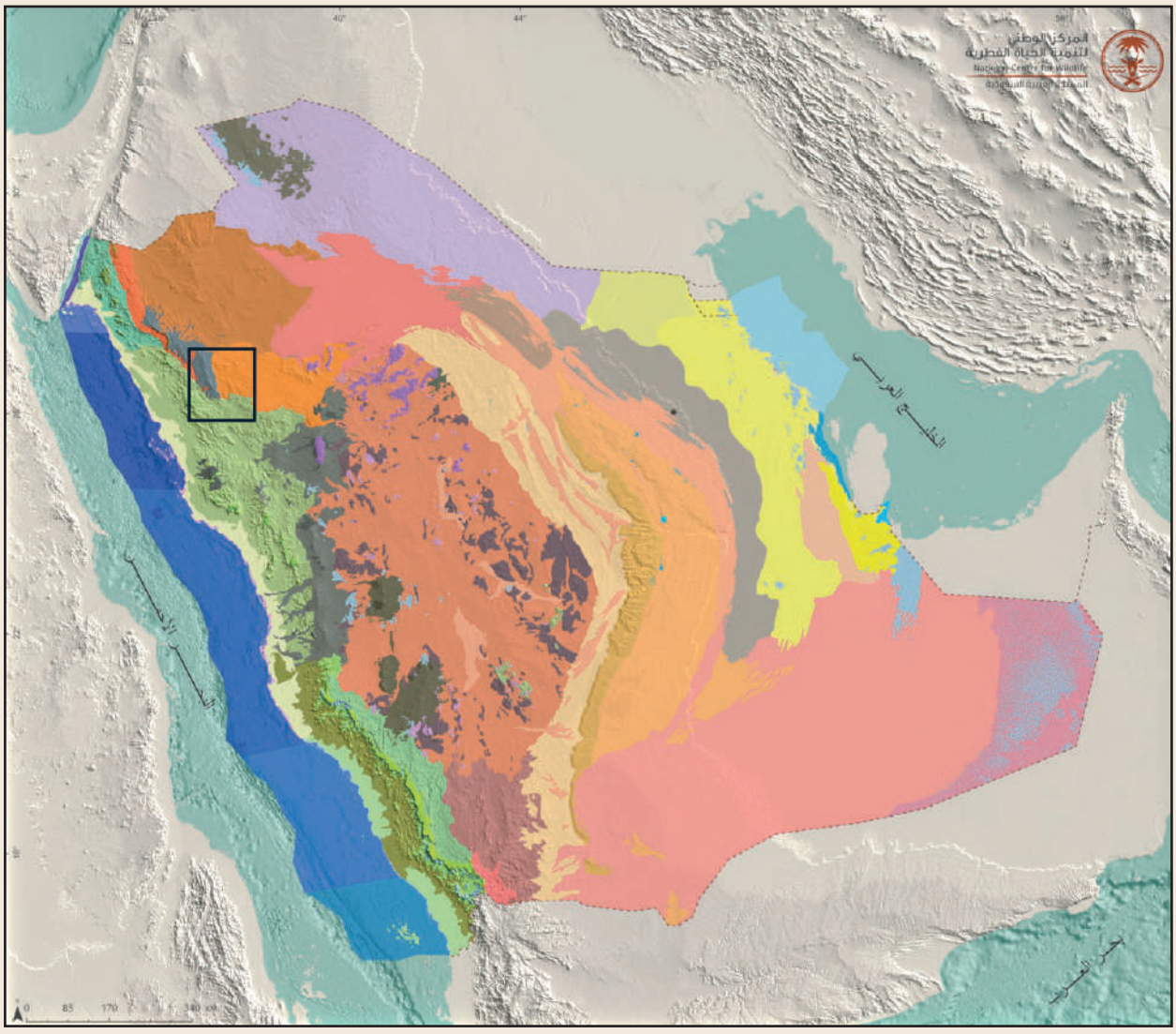
BOX 2 - Ecosystem Types in the Kingdom of Saudi Arabia

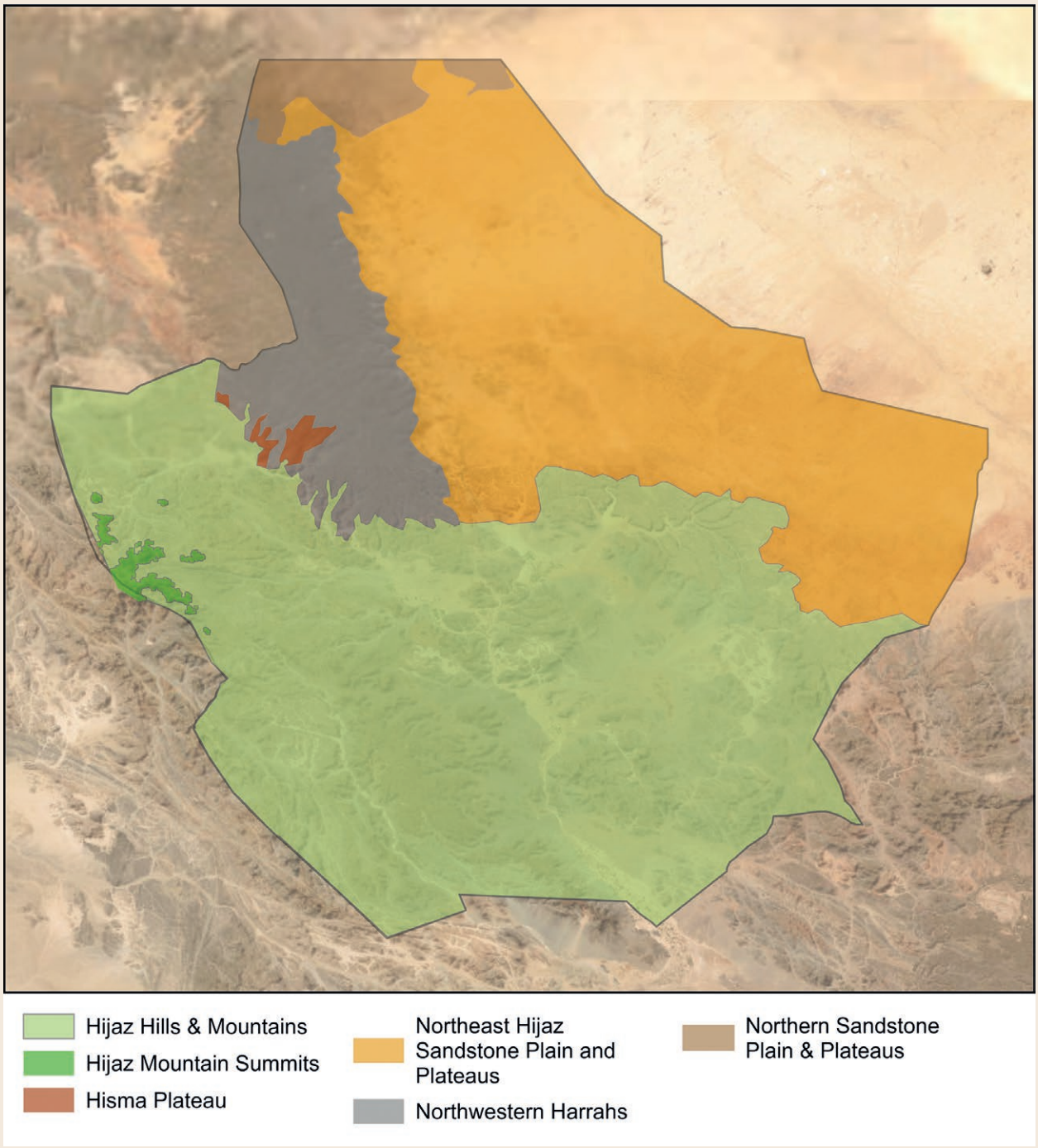
The national ecosystem types presented below are adapted from mapping provided by the National Center for Wildlife (NCW) (Qurban et al., 2024). The framework provides a national-scale ecological classification that supports protected area planning, biodiversity assessment, and ecosystem characterisation across Saudi Arabia. Within AlUla, several of these ecosystem types are represented, reflecting the region's diverse geology, landforms, and climatic gradients

AlUla lies primarily within two ecoregions: the Red Sea-Arabian Desert Shrublands and the Arabian Desert (Figure 5). Within the Red Sea-Arabian Desert Shrublands ecoregion, the principal national ecosystem types found in AlUla are the **Hijaz Hills and Mountains (300–1500 m)** and the **Northwestern Harrats**. The **Hijaz Mountain Summits (1500–2500 m)** ecosystem type, associated with Jabal AlWard and the highest elevations of the Hijaz Mountains, falls within a small area of the Eastern Mediterranean Conifer-Broadleaf Forests ecoregion, reflecting the distinctive environmental conditions found at the highest elevations in AlUla.

The Arabian Desert ecoregion is represented primarily by the **Sandstone Plain and Uplands of Northeastern Hijaz** ecosystem type. This extends eastwards from Harrat Uwayrid and encompasses much of the extensive sandstone and sandy desert environments of eastern AlUla. In the north of AlUla County this ecosystem type may transition into the Northern Sandstone Plains and Uplands ecosystem, based on national ecosystem mapping, but the presence and boundary of this ecosystem type (and the ecoregion of which it is part) is not clear and requires further investigation.

A small area of the **Hisma Plateau** ecosystem type is also shown within the AlUla region. However, the occurrence, extent and ecological distinction





of this ecosystem type relative to the Sandstone Plains and Uplands of Northeastern Hijaz within AlUla require further investigation. Small areas classified as Hijaz and Madyan Montane Wadis in the Palearctic wetland ecoregion, are present within the national level map. This ecosystem type is defined as perennial or near-perennial watercourses of the Western Highlands. The extent to which these conditions occur within AlUla requires further investigation, and the applicability of this ecosystem type should be verified.

Due to the broad scale at which these ecosystem types have been mapped, their boundaries within AlUla should be considered indicative rather than definitive. In several areas, these are likely to require further refinement through additional analysis and field verification. For example, Harrat AlZabin is not represented in the current mapping, and the extent or boundaries of some ecosystem types within AlUla County remains uncertain.

Figure 7 | Ecosystem types of Saudi Arabia (left) showing the location of AlUla and (above) the national ecosystem types found in AlUla. National map and spatial data provided by the National Center for Wildlife.



4 | ALULA HABITAT CLASSIFICATION

4 | ALULA HABITAT CLASSIFICATION

4.1 OVERVIEW

The AlUla Habitat Classification has been developed by integrating data, outputs, and expert knowledge from three independent but complementary projects commissioned by RCU. Each of these projects was delivered for different purposes and used distinct methodologies; this manual brings them together through a single, harmonised classification approach that draws on their respective strengths.

This chapter outlines the conceptual and methodological principles underpinning this classification. It then goes on to provide background on the contributing projects and explains how the consolidated classification for AlUla was developed via a 3-stage process. This is illustrated in Figure 8 and outlined in the following sections of text. Readers seeking more detailed technical information on dataset integration and map production can refer to Appendix 2.

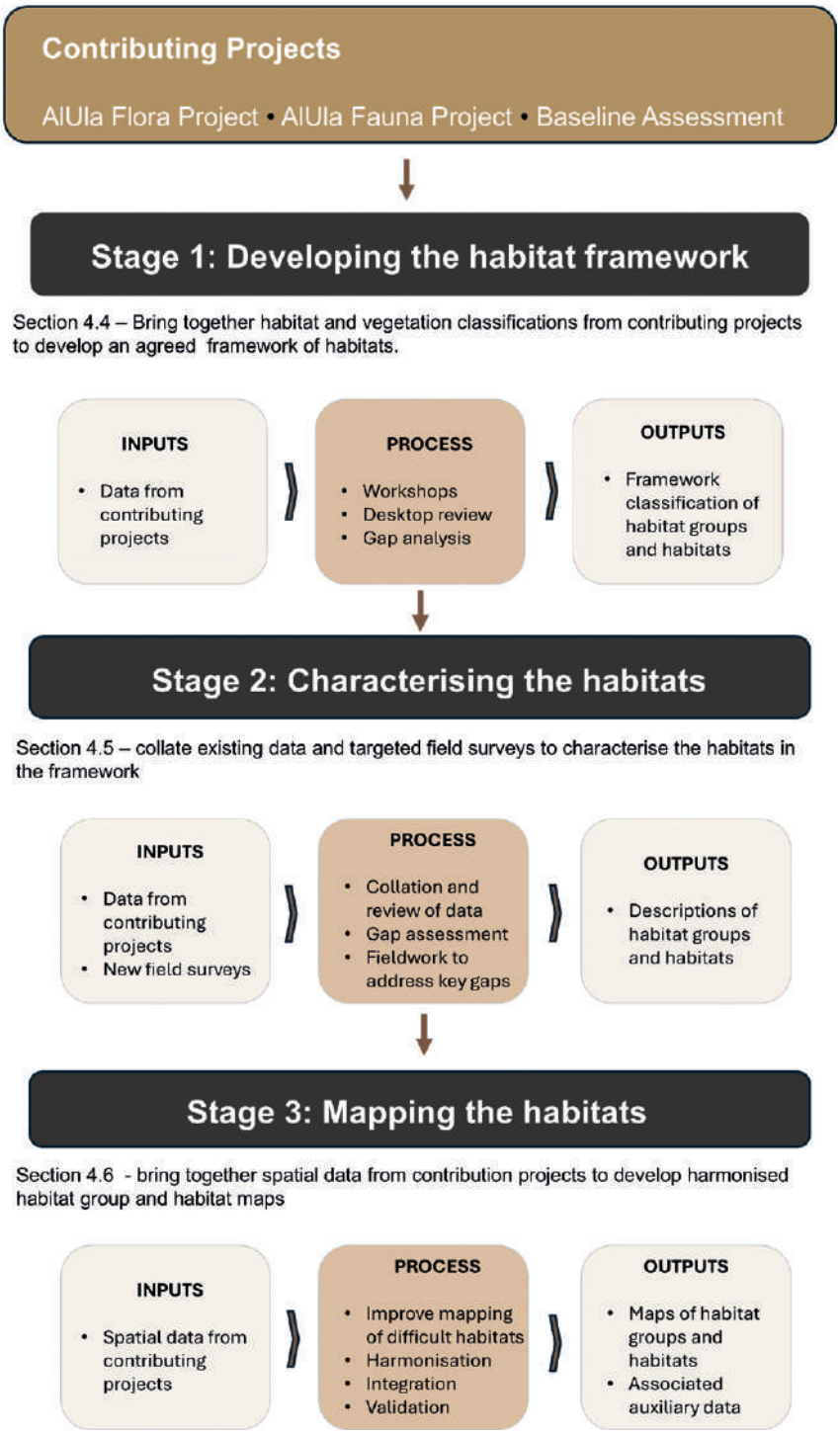


Figure 8 | Schematic overview illustrating the contributing projects, integration stages, and process used to develop the habitat classification for AlUla.

4.2 CONCEPTUAL APPROACH

What is meant by “habitat” in AlUla

In this manual, the term habitat is used to describe spatially recognisable ecological units characterised by recurring combinations of environmental conditions and associated biological communities. Habitats are defined by the integration of abiotic and biotic components, including:

- Landform and geomorphology
- Soils
- Hydrological setting
- Vegetation structure and composition
- Associated flora and fauna

These components operate together at a consistent spatial scale to form identifiable ecological units that can be mapped and described across the landscape.

This definition is aligned conceptually with ecological classifications such as the EUNIS Habitat Classification (European Environment Agency, 2023) in which habitats are understood as combinations of environmental conditions and biological communities, rather than as places defined for individual species.

Subjectivity and ecological gradients

Habitat classification and mapping are inherently interpretative processes that rely on informed human judgement about which environmental features are most important for distinguishing and defining different environments. They involve decisions about how complex, continuous natural variation is conceptualised, simplified, and represented as a set of discrete units.

This is particularly evident in arid environments such as AlUla, where landscapes are strongly heterogeneous. Variations in soils, landform, water availability, and vegetation structure frequently occur over very small spatial scales, creating transitional zones and a mosaic of closely interlinked habitat types rather than uniform units. Accordingly, decisions on habitat definition and mapping were guided by ecological theory, practical management needs, and the need to capture this inherent landscape complexity.

Rather than attempting to eliminate or oversimplify such variation, the habitat classification seeks to represent it transparently. Mapped habitat units are treated as ecological generalisations that capture dominant patterns at the scale of interest, rather than every local variation. Where relevant and possible, areas of variability and ambiguity are described within the manual to support informed interpretation of habitats in the field.

This approach acknowledges that habitat classification is not a purely objective or mechanistic exercise. Decisions regarding the selection of defining features, the placement of boundaries, and the level of thematic detail inevitably involve expert judgement.

Principles underpinning the classification

The conceptual development of the AlUla Habitat Classification was guided by the following core principles derived from established ecological classification frameworks (e.g. Keith et al., 2022) and adapted to the context of AlUla.

- **Ecological relevance**
  Habitats are differentiated using environmental and biological attributes that are meaningful for ecological processes, biodiversity patterns, and species–habitat relationships.
- **Integration of multiple evidence sources**
  The classification synthesises data on geomorphology, soils, vegetation, flora, fauna and remote sensing. This integrated approach avoids reliance on any single data source and strengthens ecological interpretation.
- **Consistency with wider frameworks**
  Where possible, the classification aligns conceptually and terminologically with the Saudi Arabian national ecosystem typology, enabling comparison, reporting, and potential future cross-referencing with this and global frameworks.
- **Transparency and reproducibility**
  Conceptual assumptions, classification logic, and known limitations are documented to ensure the system can be understood, applied consistently, and refined as new data becomes available.
- **Fitness for purpose**
  The classification is designed to support multiple uses, including conservation planning, restoration design, environmental assessment, monitoring, and research, while remaining practical for spatial implementation. It should be no more complex than needed and should use accessible and clearly defined terminology.

From concept to mapped space

In this manual, habitat groups represent areas where a particular combination of landform and substrate is dominant at the mapping scale. Habitats are used to capture meaningful internal variation within broader habitat groups, allowing finer ecological differentiation where sufficient data exists.

This approach reflects a balance between ecological realism and cartographic clarity. It acknowledges that habitat maps are models of complex landscapes rather than exact replicas, and that they should be interpreted as decision-support tools rather than definitive statements of on-ground conditions.

Structure of the classification: habitat groups and habitats

The AlUla classification is structured hierarchically and has been developed from the bottom up. Habitats represent the most detailed units. These are defined by specific combinations of abiotic and biotic characteristics e.g. differences in substrate, slope, hydrology, or vegetation assemblages.

These habitats are grouped into broader habitat groups based on higher-level environmental structure including landform, geomorphological context, geology and/or biogeography e.g. mountain systems, volcanic landscapes, sandstone landforms.

This structure reflects the way ecological variation is organised in AlUla, where fine-scale differences are often driven by local environmental conditions, and broader patterns are structured by major landscape features such as mountains, harrats and wadis. This hierarchy allows the classification to be used at different levels of detail, depending on purpose, scale, and user needs—for example, broad landscape planning at the habitat class level, or more detailed ecological assessment at the habitat level.

4.3 CONTRIBUTING PROJECTS

The manual draws on expertise and data from three distinct projects. These are summarised in Figure 9 and more detail of each of these is provided in Appendix 1.

4.4 STAGE 1 DEVELOPING THE HABITAT FRAMEWORK

The first stage of this project brought together habitat and vegetation classifications from the contributing projects to establish a single, coherent habitat framework for AlUla. This process focused on identifying areas of agreement and reconciling differences between classifications.

Review of habitats from contributing projects

Habitat and vegetation classes identified in the contributing projects were reviewed and compared through a series of workshops. Despite differences in methodology and project objectives, a core set of habitat classes were consistently recognised across the studies, providing a strong foundation for the unified framework.

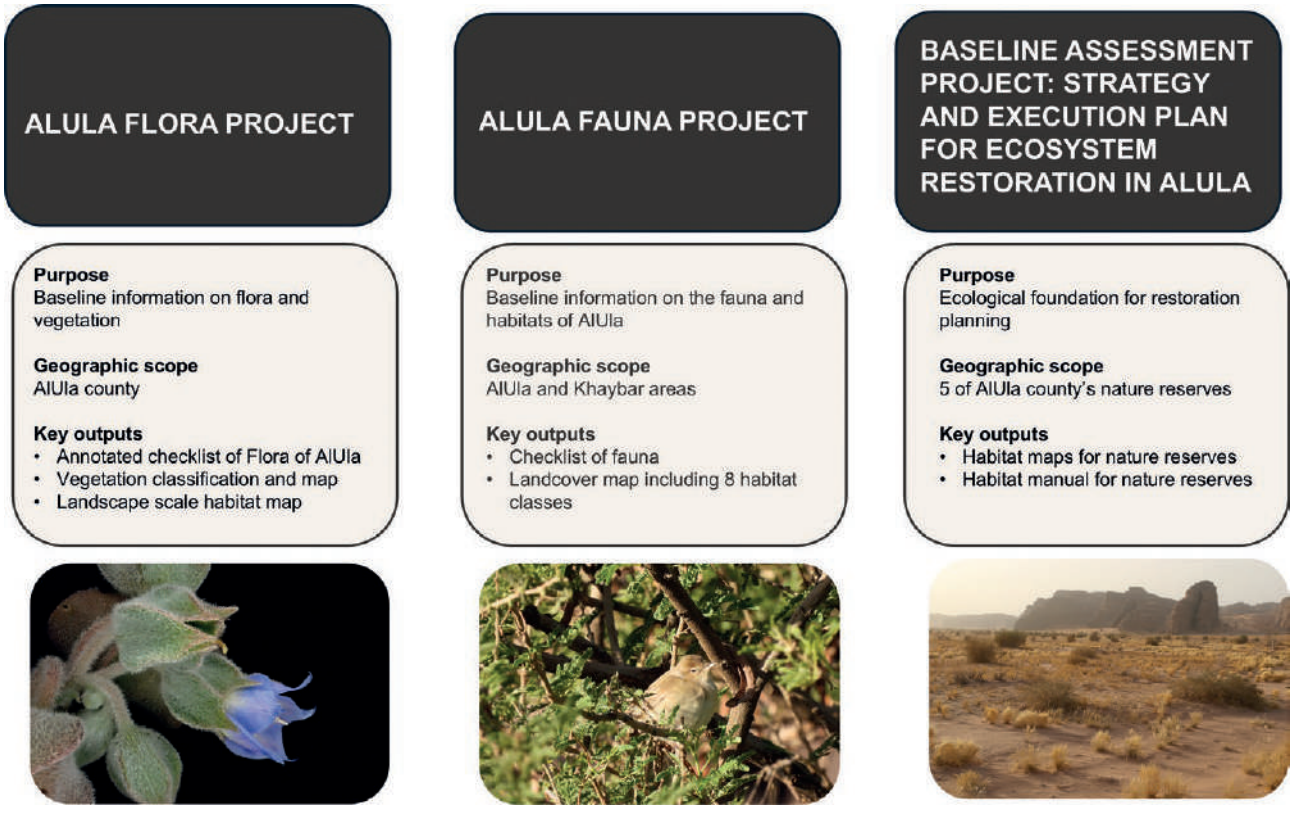
Figure 9 | Three key studies that have contributed to the classification and mapping of AlUla's habitats.

Where differences occurred, they generally reflected one of two factors:

- Differences in the geographic coverage of the contributing projects, meaning that some habitats were not present within all study areas. For example, high-altitude mountain habitats were not represented within all reserve-based surveys.
- Conceptual or methodological differences in how habitats were defined, grouped, or mapped, leading to variation in the level of ecological detail captured.

Agreement, alignment and gaps

Habitats that were recognised consistently across projects were adopted directly into the unified classification. Where classifications differed, these differences were reviewed to determine whether they represented genuine ecological variation requiring separate habitat units, or whether they reflected methodological differences that could be harmonised. This process resulted in an agreed habitat framework that retained ecologically meaningful distinctions while ensuring consistency across datasets and future applications.



Identifying gaps in habitat coverage

The review process also identified habitat types that were recognised as ecologically important but had only been mapped within limited parts of the study area. These habitats required additional analysis and mapping before they could be fully incorporated into the framework.

Examples included:

- Volcanic cones, which had previously been mapped by one of the projects outside of the AlUla County area.
- Ephemeral flooded depressions in volcanic craters.
- Ephemeral flooded depressions occurring outside volcanic systems.

These habitats were subsequently prioritised for further spatial analysis and mapping during Stage 3.

Outcome of Stage 1

The outcome of Stage 1 was a harmonised habitat framework that provided the foundation for all subsequent work. This framework established the habitat groups and habitats used throughout the manual and formed the basis for habitat characterisation (Stage 2) and spatial mapping (Stage 3).

4.5 STAGE 2 CHARACTERISATION OF THE HABITATS

Following agreement on a unified habitat classification framework, the next stage focused on characterising each habitat to provide a consistent and evidence-based description of their ecological and physical attributes. This work drew together available sources of information, including existing spatial datasets, previous survey data and expert knowledge, to describe the environmental conditions, landform characteristics and broad ecological properties associated with each class.

Where existing information was incomplete, targeted field surveys and focused observations were undertaken to address key knowledge gaps. The following sections outline the sources of data that were used to characterise habitats.

Data sources

- **Geology** | Geological information used to support habitat classification in this manual is derived from a combination of published geological maps (Hadley 1987), expert input and landscape interpretation from remote sensing and field surveys. Field data were used to validate substrate type, surface expression, and geomorphological context.
- **Soils** | Most of the soil data was obtained from the baseline assessment project dataset with additional supplementary data generated by this project to fill gaps using the same methodology. For each habitat the dominant soil type unit is described in the profile and more detailed analysis included in Appendix 3.

- **Flora and Vegetation** | Information on the flora and vegetation characterising the habitats is derived from two of the contributing projects, AlUla Flora project and the Baseline Assessment. Flora occurrence data for habitats was based on information from field data.

  Data and descriptions of plant communities, vegetation structure and characteristic taxa was extracted from these projects with additional expert review to provide a broad general description of the vegetation within each of the habitats.
- **High conservation value flora** | There are various ways to define the 'conservation value' of a species. To compile a list of priority plant species for conservation action in AlUla, we have focused on taxa that are globally, regionally, or nationally threatened, and taxa that have a restricted global range and are 'rare' in Saudi Arabia. Threatened taxa are those that have been assessed using IUCN Red List categories and criteria. Global and Regional IUCN Red List Assessments for some species have been obtained from Forrest and Neale, 2023. No national IUCN Red List assessments exist for plants in Saudi Arabia. Rarity is based on field knowledge from extensive field surveys across northern Saudi Arabia (A.G. Miller pers comm., 2023). A list of all the flora species mentioned in the manual is available in Appendix 4.
- **Fauna** | Fauna data included in the habitat descriptions were derived from the AlUla Fauna project with species lists based on field data recorded from habitat locations.
- **High conservation value fauna** | Following the criteria previously established during the Fauna project, the priority fauna were selected based on species endemic to the Arabian Peninsula, fauna species classified as threatened following the IUCN Red List criteria (CR – Critically Endangered; EN – Endangered; or VU – Vulnerable) when applied to a regional scale, and geographically restricted species, i.e. species with very constrained area occupancy or extent of occurrence.

  A list of all the fauna species mentioned in the manual is available in Appendix 5.
- **Degradation** | Information on key drivers of degradation were collected during field surveys for two projects. This included observations on off-road driving, wood cutting and grazing.

4.6 STAGE 3 MAPPING OF HABITAT GROUPS AND HABITATS

This stage focused on producing harmonised habitat maps for AlUla through the integration of spatial datasets generated by the contributing projects. The objective was to combine the strengths of each dataset to develop a consistent, county-wide representation of habitat distribution suitable for conservation, planning, management, and ecological assessment. A more detailed technical description of the mapping workflow is provided in Appendix 2.

Overview of the mapping approach

The final maps were produced at a spatial resolution of 10 × 10 m through the integration of spatial datasets generated by the three contributing projects. Rather than relying on any single dataset, a structured workflow was developed to combine information from multiple sources while minimising inconsistencies and addressing known limitations.

The mapping process comprised five principal steps:

- Mapping gaps and under-represented habitats
- Standardisation of input datasets
- Integration of spatial datasets
- Accuracy assessment
- Post-classification refinement

Mapping gaps and under-represented habitats

Prior to integration, additional analyses were undertaken to address known gaps and limitations within the contributing spatial datasets. Several habitats were either not mapped consistently across contributing datasets or could not be reliably distinguished using standard remote-sensing approaches.

Key examples included:

- **Volcanic cones**, which had previously been mapped only within parts of the Harrat Khaybar landscape outside of AlUla County. Additional hyperspectral imagery was used to identify and map volcanic cones within AlUla.
- **Ephemeral flooded depressions**, which had previously been mapped only within reserve boundaries. These were identified using a five-year time series of multispectral satellite imagery to capture seasonal wetness and vegetation dynamics.
- **Wadi systems**, for which temporal and spectral analyses were used to improve the identification of drainage features and seasonal hydrological patterns.
- **Mountain and harrat habitats**, were refined using elevation and slope auxiliary data, respectively.

The outputs from these analyses were incorporated into the mapping workflow prior to dataset integration.

Standardisation of input datasets

Prior to integration, all input datasets were standardised to ensure that they could be directly compared and combined. This was achieved through the following:

- Aligning classifications with the habitat framework developed in Stage 1.
- Reviewing and reclassifying input datasets, including merging or splitting original classes where necessary to match the agreed habitats.
- Applying a common coding system across all datasets.
- Standardising spatial properties, including coordinate reference system, extent and spatial resolution (10 × 10 m) so that all datasets aligned at the pixel level.

Integration of spatial datasets

Once standardised, the datasets were combined into a single map using an agreement-based approach to ensure that the final map reflects areas of strong agreement, while providing a structured method for resolving uncertainty and retaining ecologically important habitat distinctions.

Where multiple datasets identified the same habitat, that classification was retained directly. Where classifications differed, additional ecological and accuracy-based rules were applied to determine the most appropriate habitat assignment. This ensured that disagreements were resolved systematically and transparently rather than relying on any single source of information.

Particular attention was given to rare or distinctive habitats that were recognised as ecologically important. These habitats were protected from being lost during the integration process and were retained where supporting evidence indicated their presence.

Habitat map products

The integration process resulted in two primary spatial products:

- A **habitat map**, showing the full set of mapped habitats across AlUla County.
- A **habitat group map**, showing habitats aggregated into the six broad habitat groups used within this manual.

In addition, an **agreement map** was produced (Appendix 2 Figure A2-3) showing where contributing datasets agreed strongly and where habitats were more uncertain. This helps users understand relative confidence across the landscape. The agreement map showed high levels of congruence between partners, with 82% of the area showing total or partial consensus among all contributing projects.

Accuracy assessment

The final maps were independently evaluated using field survey data, expert photo-interpretation, and statistical measures of classification performance.

Validation indicated high reliability at the habitat group level, with an overall accuracy of 77%, a balanced accuracy of 87%, and a Cohen's Kappa value of 0.71. Habitat-level mapping also performed well, achieving an overall accuracy of 71%, a balanced accuracy of 82%, and a Kappa value of 0.69 (Appendix 2). These results indicate that the classification provides a robust representation of broad habitat patterns while successfully capturing a high level of ecological detail.

Post-classification refinement

Following integration, the outputs were reviewed by project specialists and subjected to a series of post-classification refinements. These included correcting known misclassifications, resolving mapping artefacts, and incorporating additional ecological expertise where appropriate. These refinements improved the consistency and ecological realism of the final outputs while retaining the transparent structure of the integration process.

Limitations and interpretation

Despite the robustness of the mapping process, some limitations remain. Certain habitats remain difficult to distinguish using currently available remote-sensing data, some rare habitats are not comprehensively mapped across the full study area, and habitat transitions may be generalised where ecological boundaries are gradual rather than discrete.

The maps should therefore be interpreted as the best available representation of habitat distribution at the mapping scale, rather than as exact representations of field conditions at every location. Field verification should always be undertaken where site-level decisions depend on precise habitat boundaries.



5 | OVERVIEW OF ALULA HABITATS

5 | OVERVIEW OF ALULA HABITATS

5.1 HABITAT FRAMEWORK SUMMARY

The table below summarises the hierarchical structure of the AlUla Habitat Classification, showing the relationship between habitat groups and the habitats they contain.

KSA NATIONAL ECOSYSTEM TYPE	HABITAT GROUP	HABITAT
Northwestern Harrats	**1000** Volcanics	**1100** Harrat plateau and slopes **1200** Harrat cliffs and steep slopes **1300** Harrat drainage lines and wadis **1400** Un-weathered lava flow **1500** Volcanic cones **1600** Ephemeral flooded depressions in volcanic craters
Northeast Hijaz Sandstone Plain and Plateaus	**2000** Sandstone landforms	**2100** Sandstone outcrops **2200** Sandstone boulder slopes and screes **2300** Sandstone canyons
Northeast Hijaz Sandstone Plain and Plateaus	**3000** Sandy plains and dunes	**3100** Sandy plains **3200** Sand sheets with exposed bedrock **3300** Sand dunes
Hijaz Mountain Summits and Hijaz Hills and Mountains	**4000** Mountains and associated plains	**4100** High-altitude mountains **4200** Mid-altitude mountains **4300** Low-altitude mountains **4400** Gravel plains
Mixed	**5000** Wadis and ephemeral flooded depressions	**5100** Sandy wadis **5200** Gravel wadis **5300** Ephemeral flooded depressions
	6000 Agricultural lands	**6100** Agricultural lands



5.2 MAP OF ALULA'S HABITAT GROUPS

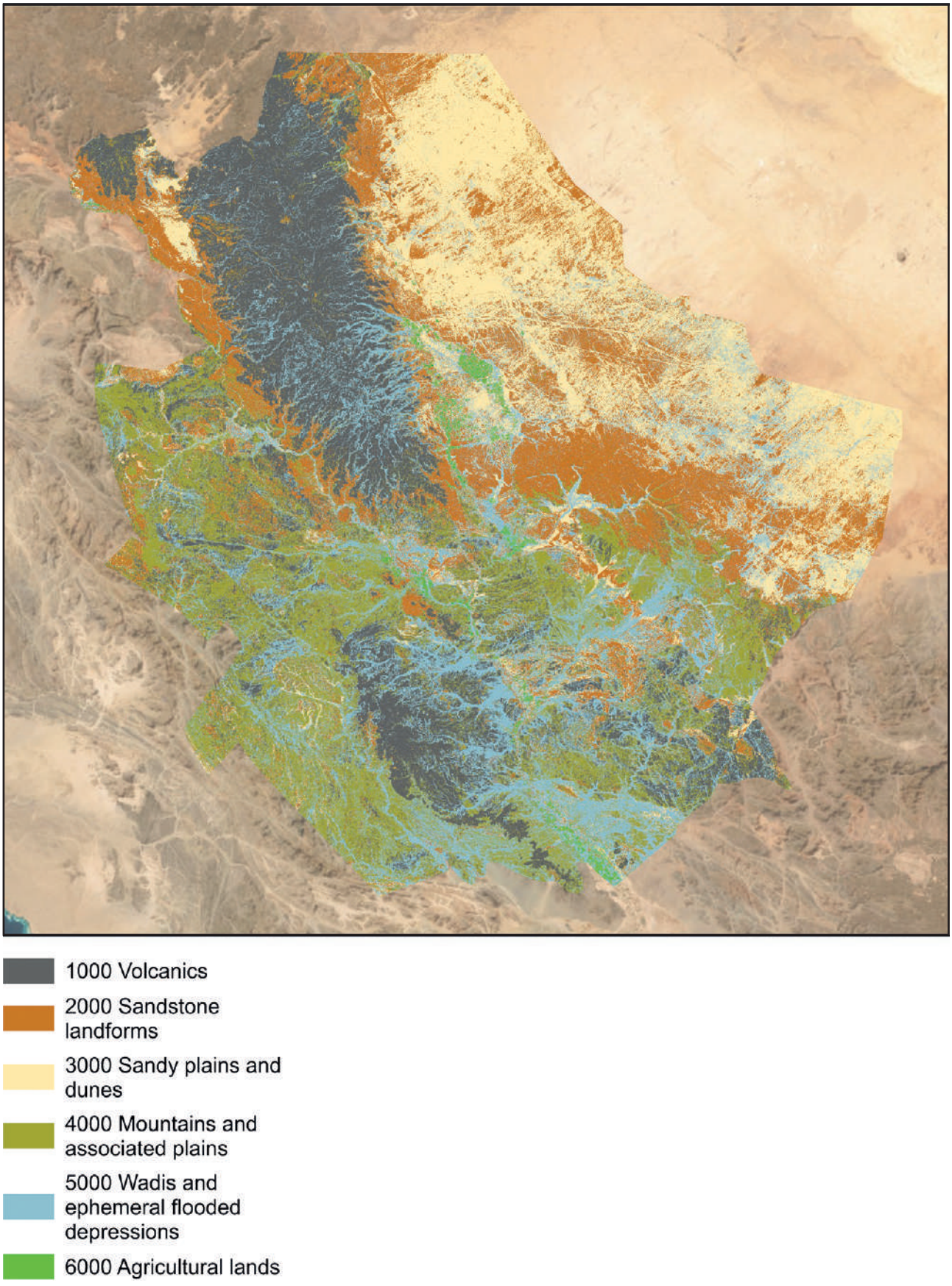


Figure 10 | Harmonised habitat group level classification for AlUla.

5.3 MAP OF ALULA'S HABITATS

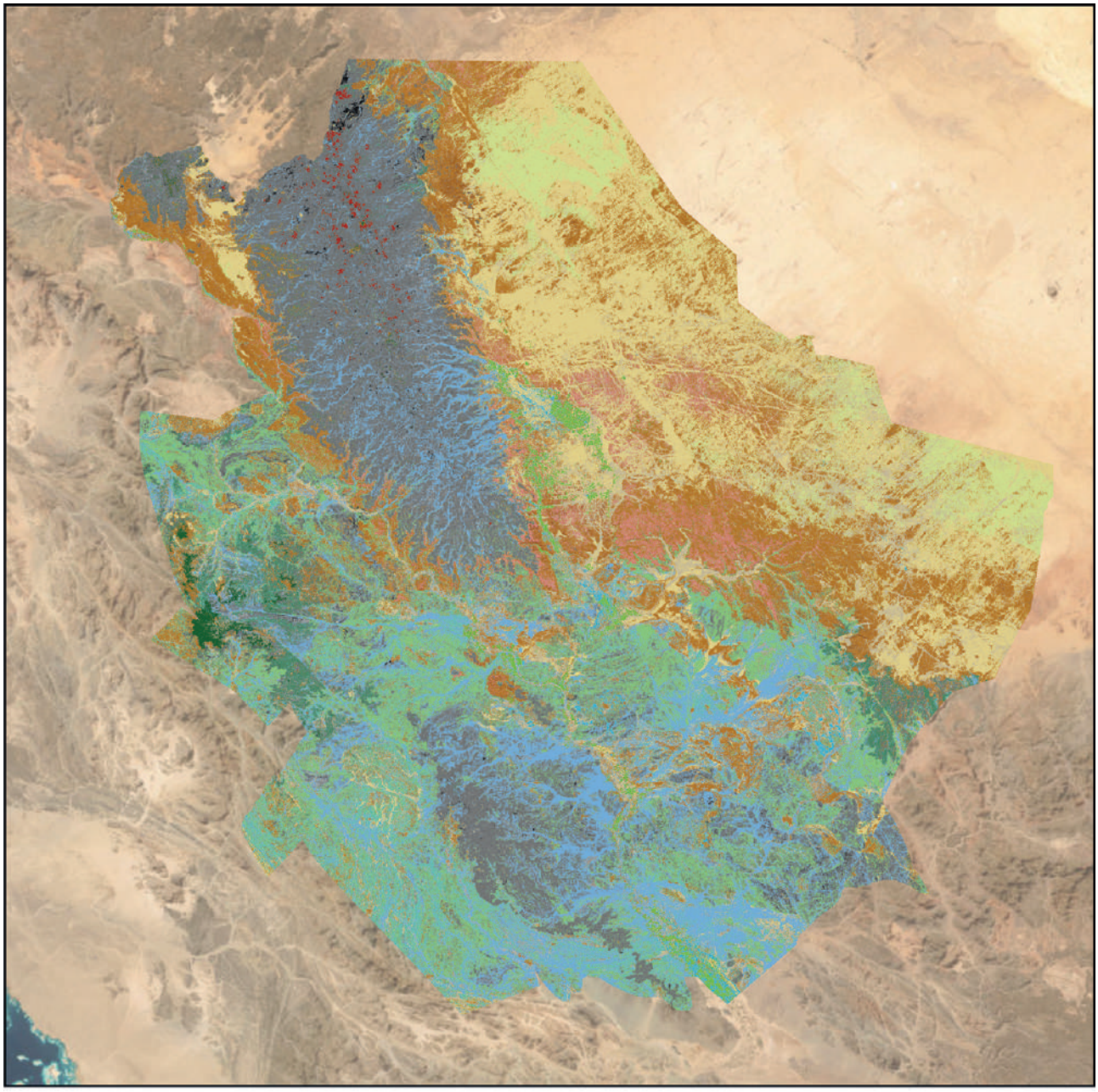


Figure 11 | Harmonised habitat level classification for AlUla County.



6 | HABITAT DESCRIPTIONS

6 | HABITAT DESCRIPTIONS

6.1 EXPLANATORY NOTES ON THE HABITAT DESCRIPTIONS

DESCRIPTION
Descriptive overview of the habitat.

GEOGRAPHIC AREA
Description and map of the distribution of this habitat type in AlUla.

GEOLOGY
Description of the habitat geology and an indication of the dominant bedrock.

SOILS
Description of the dominant soil type in the habitat.

VEGETATION
Description of the structure of the vegetation and the dominant species, together with an indication of the variation in the vegetation found within the habitat. Intended as a practical tool for the field.

FLORA
Characteristic flora
Species that are regularly and predictably found within the habitat. This includes species that are dominant or very frequently seen in the habitat and those that might be uncommon but show a strong association with the habitat based on field data and literature. Very widespread generalists are avoided where they are not dominant or extremely common in a habitat, as they contribute little to defining the habitat's ecological identity.

High conservation value flora
A list of species identified as being of high conservation significance, based on national endemism, restricted range and rarity or their threatened status on the IUCN Red List (CR, EN, VU).

FAUNA
Characteristic fauna
Same as for plant species, animal species will be considered if they are regularly found in the habitat. Some species may occur in multiple habitats, but they should be listed according to how representative they are of the specific habitat. Very widespread generalists should be avoided for the same reasons already mentioned for plant species.

High conservation value fauna
List of fauna species selected based on endemism to the Arabian Peninsula, threatened status (CR, EN, VU) under IUCN Red List criteria at a regional scale, and restricted geographic range.

DEGRADATION
The drivers of degradation recorded in the field or known from other studies in the area are recorded here.

RELATED HABITATS
Habitats that commonly occur in association with, transition into, or may be confused with the focal habitat. This section provides guidance on ecological relationships and key features that help distinguish similar habitat types in the field and during mapping.





1000 | VOLCANICS

1100 | HARRAT PLATEAU AND SLOPES
1200 | HARRAT CLIFFS AND STEEP SLOPES
1300 | HARRAT DRAINAGE LINES AND WADIS
1400 | UN-WEATHERED LAVA FLOW
1500 | VOLCANIC CONES
1600 | EPHEMERAL FLOODED DEPRESSIONS IN VOLCANIC CRATERS



Figure 12 | Distribution of the Volcanic habitat group (1000) in AlUla County.

OUTLINE

The Volcanics habitats encompass the range of landforms associated with the volcanic features of AlUla. These harrat systems form some of the largest continuous volcanic fields in Arabia and define much of the regional landscape character. Their varied topography and generally higher elevations create in places cooler, more sheltered microenvironments that act as important refugia for specialised plant and animal communities.

ASSOCIATED KSA NATIONAL ECOSYSTEM TYPES

Northwestern Harrats.

HABITATS

- **1100** | Harrat plateau and slopes
- **1200** | Harrat cliffs and steep slopes
- **1300** | Harrat drainage lines and wadis
- **1400** | Un-weathered lava flow
- **1500** | Volcanic cones
- **1600** | Ephemeral flooded depressions in volcanic craters









1100 | HARRAT PLATEAU AND SLOPES

DESCRIPTION

The Harrat plateau and slopes habitat comprises broad volcanic uplands and gentle sloping terrain formed from extensively weathered basaltic lava flows. Over time, these flows have broken down into a complex mosaic of rough, rubbly pavements, often interspersed with shallow depressions and pockets of finer sediments. The terrain is characteristically dark, rocky, and uneven, shaped by repeated volcanic episodes and long-term physical weathering.

GEOGRAPHIC AREA

Harrat plateau and slopes habitat is found on Harrat Uwayrid and Harrat AlZabin.

GEOLOGY

The substrate is dominated by several mafic lava types. Basalt dominates with fine grained minerals, but this habitat can also include picrite (high olivine content), ankaramite (pyroxene rich), vesicular basalt, and in some areas close to volcanoes, scoria boulders and gravels can be found. The different types of basalts erode differently and create different types of habitats.

SOILS

The soils are predominantly loamy and derived from the weathering of basaltic parent material. Surface layers are typically stony, with abundant basalt rocks and gravels resulting from past volcanic activity. Wind-blown sand accumulates in depressions and sheltered locations, forming localised pockets of finer sediment across the harrat landscape.









1 *Alectoris chukar* (Chukar)
2 *Morettia parviflora*
3 *Pallenis hierochuntica*
4 *Anastatica hierochuntica*

VEGETATION

Absent or very sparse degraded dwarf shrubland typically dominated by *Fagonia bruguieri* and *Morettia parviflora*.

Vegetation is restricted to sandy pockets between rocks and in distinctive shallow depressions where an annual flush forms.

FLORA

Characteristic flora

Perennials

- *Anvillea garcinii*
- *Diplotaxis harra*
- *Fagonia bruguieri*
- *Helianthemum lippii*
- *Morettia parviflora*

Annuals

- *Anastatica hierochuntica*
- *Asphodelus tenuifolius*
- *Bromus tectorum*
- *Centaurea sinaica*
- *Leysera leyseroides*
- *Pallenis hierochuntica*
- *Plantago afra*
- *Plantago ovata*
- *Senecio flavus*
- *Stipellula capensis*
- *Trigonella stellata*
- *Zoegea purpurea*

High conservation value flora

- *Ferula sinaica*

FAUNA

Characteristic fauna

- *Alectoris chukar* (Chukar)
- *Gerbillus dasyurus* (Wagner's gerbil)
- *Phoenicurus ochruros* (Black Redstart)
- *Steatoda cf. paykulliana* (False widow spider)
- *Thanatus cf. setiger.*(False crab spider)

High conservation value fauna

- *Agrotis ipsilon*
- *Canis lupus* (Grey wolf)
- *Capra nubiana* (Nubian ibex)
- *Hyles livornica*

DEGRADATION

The major driver of degradation in this habitat is overgrazing. Off-road driving also has a significant impact in some areas.

RELATED HABITATS

None







1200 | HARRAT CLIFFS AND STEEP SLOPES

DESCRIPTION

Steep rocky boulder strewn slopes and cliffs of the higher altitude harrat.

These areas are characterised by sharp relief, exposed rock faces, and accumulations of angular basalt blocks derived from collapse and erosion of cliff edges. Slopes range from nearvertical rock faces to steep rocky slopes. In places the basalt boulders are mixed with boulders from the underlying sandstone. The smooth basaltic rock faces on small cliffs create refugia in these habitats for a number of range-restricted plant species only found in the NW of the country such as *Roemeria hybrida, Ballota undulata and Echinops glaberrimus*.

GEOGRAPHIC AREA

These are found in all the harrat areas.

GEOLOGY

Similar to Harrat plateau and slopes (1100), the dominant rock is basalt. These are boulders of varying sizes, ranging from angular to sub-angular in shape with gaps providing space for animals and plants.

SOILS

Located in the steep stony slopes, these shallow soils are found in micro-depressions and flat areas between rocks. The sloping position of these soils makes them susceptible to erosion by run-off.

VEGETATION

Open mixed dwarf shrubland.

Typically dominated by species such as *Helianthemum lippii and Cymbopogon schoenanthus* with *Diplotaxis harra.*



1



2

1 *Artemisia sieberi*
2 *Cuprella homalocarpa*

FLORA

Characteristic flora

Perennials

- *Agathophora alopecuroides*
- *Artemisia sieberi*
- *Ballota undulata*
- *Caroxylon villosum*
- *Cymbopogon schoenanthus*
- *Diplotaxis harra*
- *Echinops glaberrimus*
- *Ephedra ciliata*
- *Fagonia mollis*
- *Helianthemum lippii*
- *Morettia parviflora*

Annuals

- *Bromus scoparius*
- *Bromus tectorum* subsp. *lucidus*
- *Cuprella homalocarpa*
- *Roemeria hybrida*
- *Rumex vesicarius*
- *Senecio flavus*
- *Stipellula capensis*

High conservation value flora

- *Ducrosia flabellifolia*
- *Hyocyamus viscosus*

FAUNA

Characteristic fauna

- *Euchloe belemia* (Green-striped white)
- *Tropiocolotes yomtovi* (Yom-Tov's sand gecko)

High conservation value fauna

None

DEGRADATION

The major driver of degradation on this habitat is overgrazing.

RELATED HABITATS

1500 | VOLCANIC CONES. It can be difficult to distinguish these two habitats in the field, particularly where volcanic cones are highly eroded.









1300 | HARRAT DRAINAGE LINES AND WADIS

DESCRIPTION

Harrat drainage lines and wadis comprise the network of narrow channels and upper wadi systems that dissect volcanic plateaus and slopes within the harrat.

Drainage lines range from small, rocklined runnels with sparse vegetation to broader channels forming well-defined upper wadis, where deeper soils and more continuous plant cover develop. Together, they form linear features that link the volcanic uplands with downslope wadi systems, occupying a transitional position within the broader harrat landscape mosaic.

GEOGRAPHIC AREA

Found in all of the harrat areas.

GEOLOGY

Dominant rock is basalt, in the form of sub-rounded to rounded boulders. Mixed with the basalt is finer gravel and wind-blown sands that have been transported through the wadi systems.

SOILS

Stony alluvial soil in the wadis of the harrat plateau. It originates from strong erosion-deposition processes driven by water, capable of transporting rock fragments and breaking them down to stones. Plants growing in these soils benefit from drained water but may occasionally be subjected to these erosive factors.

VEGETATION

Open mixed dwarf shrubland developing into a sparse woodland in larger channels.

Typically dominated by species such as *Retama raetam*, *Lycium shawii*, *Anvillea garcinii*, *Helianthemum lippii, Ephedra ciliata* and *Cymbopogon schoenanthus.* Forming a very open *Vachellia* woodland in larger wadis, primarily *Vachellia gerrardi* var. *najdensis* on Harrat Uwayrid with *Vachellia oerfota* on Harrat AlZabin.



1



2



3

1 *Anvillea garcinii*
2 *Scorpio fuscus* (Dark large-clawed scorpion)
3 *Platyceps saharicus* (Saharan racer)

FLORA

Characteristic flora

Perennials

- *Anvillea garcinii*
- *Artemisia sieberi*
- *Astragalus spinosus*
- *Centaurea ammocyanus*
- *Cymbopogon schoenanthus*
- *Ephedra ciliata*
- *Fagonia bruguieri*
- *Fagonia mollis*
- *Helianthemum lippii*
- *Lycium shawii*
- *Ochradenus baccatus*
- *Retama raetam*
- *Vachellia gerrardi* var. *najdensis*
- *Vachellia oerfota*
- *Vachellia tortilis* subsp. *raddiana*
- *Zilla spinosa*

Annuals

- *Asphodelus fistulosus*
- *Asphodelus tenuifolius*
- *Plantago amplexicaulis*
- *Stipellula capensis*
- *Trigonella stellata*
- *Zoegea purpurea*

High conservation value flora

- *Astragalus echinus*
- *Ducrosia flabellifolia*
- *Ferula sinaica*
- *Pulicaria guestii*

FAUNA

Characteristic fauna

- *Agrotis segetum*
- *Casama innotata*
- *Chalcides ocellatus* (Ocellated bronze skink)
- *Curruca leucomelaena* (Arabian Warbler)
- *Gerbillus dasyurus* (Wagner's gerbil)
- *Scorpio fuscus* (Dark large-clawed scorpion)
- *Selenops radiatus (*Palm wall crab spider)
- *Streblote acaciae*

High conservation value fauna

- *Agrotis ipsilon*
- *Buteo rufinus*
- *Caprimulgus nubicus*
- *Junonia orithya* (Blue pansy)
- *Pandesma robusta*
- *Platyceps saharicus* (Saharan racer)

DEGRADATION

The major driver of degradation on this habitat is overgrazing.










1

1 *Pulicaria undulata*

1400 | UN-WEATHERED LAVA FLOW

DESCRIPTION

Un-weathered lava flows consisting of relatively fresh basaltic surfaces where original volcanic textures remain clearly expressed. Distinct features such as a'a lava are visible, forming sharp, blocky surfaces or the smooth, ropy pahoehoe lava forms with minimal breakdown. These flows are structurally young, with limited soil development and high surface roughness, creating an environment dominated by exposed basalt and angular lava blocks. Despite being relatively young, the lava contains lots of cracks as the surface crust is separated by air. There are numerous pyroducts varying from 1 meter to several meters in length, creating areas of refugia for small mammals and reptiles.

GEOGRAPHIC AREA

This habitat is well represented in other areas such as the Harrat Khaybar White Volcano Geopark south of AlUla, where the observations used to characterise and define the habitat were recorded. The photographs used to illustrate the habitat were taken in Harrat Khaybar. Remote sensing analyses suggest that similar un-weathered lava flows may also occur in limited areas of the northern part of Harrat Uwayrid. However, these occurrences have not yet been verified through targeted field survey and should therefore be regarded as provisional.

GEOLOGY

The un-weathered lava flows are composed from basalt. These lava flows have varying surface types. Smooth pahoehoe lava, has a ropey type texture, whereby the surface is a relatively thin crust creating several areas of collapses which can be inhabited by small mammals and reptiles. Pyroducts, such as lava tubes can also be found under pahoehoe lava, where collapses have opened them up. A'a lava is the second main type of lava, which consists of sharp, angular, slabs.

SOILS

In the micro-depression of the lava geologic formations, fine particles have been deposited over time with winds and water, forming very shallow soil accumulation, silt-clay which in turn allows the germination of the few seeds.

VEGETATION

Vegetation is extremely sparse and confined to small pockets where sand and soil accumulate in fractures, or between lava blocks.

FLORA

Characteristic flora

- *Achillea fragrantissima*
- *Artemisia judaica*
- *Pulicaria undulata*
- *Schouwia purpurea*
- *Scrophularia deserti*

High conservation value flora

- *Artemisia judaica*

FAUNA

Characteristic fauna

- *Zelotes sp.* (Ground spider)

High conservation value fauna

- *Calandrella eremica* (Rufous-capped Lark)

DEGRADATION

This habitat is relatively protected from degradation due to its inaccessibility.

RELATED HABITATS

The presence of this habitat in AlUla County needs to be further verified by on the ground assessments.





1500 | VOLCANIC CONES

DESCRIPTION

Volcanic cones form steep, well-defined landforms built around central vents, with slopes composed of loose scoria, ash, and fragmented weathered basalt. These cones transition from highly exposed upper slopes to more sheltered lower flanks, creating strong microtopographic and microclimatic gradients. In the AlUla harrat system, they occur as a spectrum of forms, from well-preserved cinder cones with intact crater rims, to highly eroded remnants where only degraded flanks or partial ridges remain.

GEOGRAPHIC AREA

Found in all harrat areas.

GEOLOGY

The geology depends upon the volcano type. In AlUla, the geology is basalt and scoria. The state of the volcano depends upon its age. Older volcanoes are much more weathered, losing the classic 'volcano shape', whereas younger volcanoes will maintain the slopes and crater.

SOILS

These soils come from volcanic and colluvial deposits. They are located on the slopes of volcanic reliefs which by erosion and deposition form these accumulations soils. These soils are potentially rich in mineral elements.

VEGETATION

The vegetation is usually composed of species such as *Artemisia judaica*, *Gypsophila capillaris, Noaea mucronata* and *Ducrosia flabellifolia*.

FLORA

Characteristic flora

- *Artemisia judaica*
- *Ducrosia flabellifolia*
- *Gypsophila capillaris*
- *Noaea mucronata*

High conservation value flora

- *Ducrosia flabellifolia*

FAUNA

Characteristic fauna

- *Freyeria trochylus* (Grass jewel)
- *Scorpio fuscus* (Dark large-clawed scorpion)
- *Tropiocolotes yomtovi* (Yom-Tov's sand gecko)

High conservation value fauna

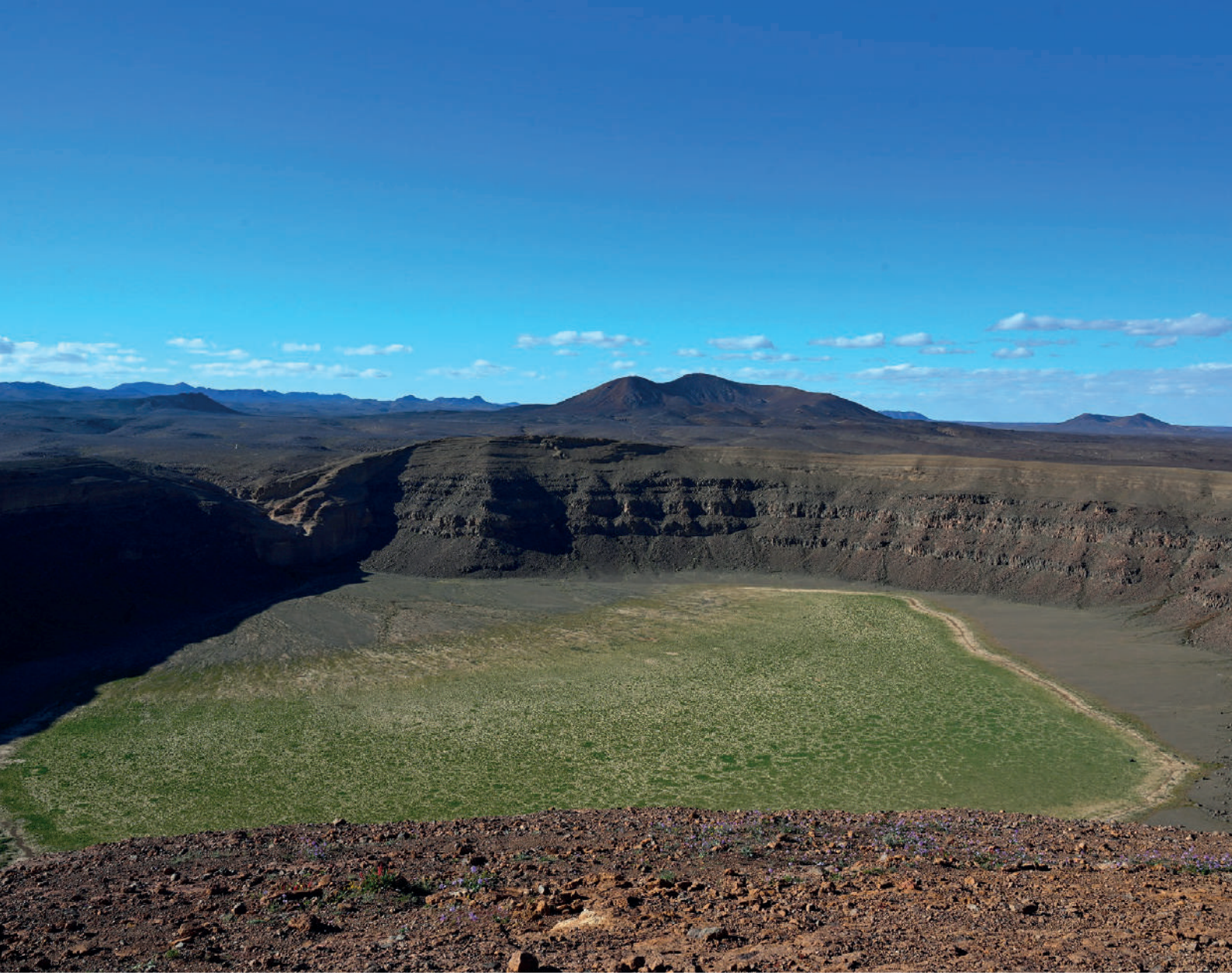
- *Junonia orithya* (Blue pansy)

DEGRADATION

These areas are fairly inaccessible but the principal driver of degradation is overgrazing.

RELATED HABITATS

1200 | HARRAT CLIFFS AND STEEP SLOPES.
It can be difficult to distinguish these two habitats in the field, particularly where volcanic cones are highly eroded.






1

1600 | EPHEMERAL FLOODED DEPRESSIONS IN VOLCANIC CRATERS

DESCRIPTION

Bowl shaped depression within a volcanic cone.

GEOGRAPHIC AREA

These are found within some of the volcanic cones in the harrat areas of AlUla.

GEOLOGY

Basaltic volcanic bedrock (basalt lava flows and scoria deposits). Within the crater, weathered scoria often dominates the surface substrate.

SOILS

Ephemerally flooded microsites occur within flat depression basins. Soils are highly compacted and characterised by high silt and clay content, resulting in low permeability. Some areas also exhibit salt crust formation. Temporary flooding occurs following heavy rainfall events. Together, these factors create an extremely challenging environment characterised by harsh edaphic and microclimatic conditions.

VEGETATION

Vegetation in this unique habitat typically includes *Ducrosia flabellifolia, Noaea mucronata, Gypsophila capillaris, Helianthemum lippii, Farsetia aegyptia, Ballota undulata, Salvia deserti, Diplotaxis acris* and *Artemisia judaica*.

1 *Salvia deserti*

FLORA

Characteristic flora

- *Artemisia judaica*.
- *Ballota undulata*
- *Ducrosia flabellifolia*
- *Farsetia aegyptia*
- *Gypsophila capillaris*
- *Helianthemum lippii*
- *Noaea mucronata*
- *Salvia deserti*

High conservation value flora

- *Ducrosia flabellifolia*

FAUNA

Characteristic fauna

- *Acanthodactylus boskianus* (Bosk's fringe-fingered lizard)
- *Stenodactylus doriae* (Dune sand gecko)

High conservation value fauna

None

DEGRADATION

The craters are relatively well protected from the impact of grazing and off-road driving.

RELATED HABITATS

5300 | EPHEMERAL FLOODED DEPRESSIONS. These two habitats are functionally similar however these are enclosed within volcanic landforms, whereas 5300 occur across a broader landscape context, typically within wadi systems, plains, or low-lying areas.

2000 | SANDSTONE LANDFORMS

2100 | SANDSTONE OUTCROPS
2200 | SANDSTONE BOULDER SLOPES AND SCREES
2300 | SANDSTONE CANYONS

OUTLINE

Sandstone landforms comprise extensive sandstone plateaus, inselbergs, buttes, mesas, cliffs, and associated slopes that dominate large parts of eastern and northeastern AlUla. These landscapes are defined by exposed sandstone bedrock shaped by long-term erosion, resulting in a strongly dissected terrain of high relief and distinctive rock forms.

In central AlUla, the dominant bedrock is the Siq Sandstone, which is very well cemented, red due to high iron content, and heavily fractured. These are hard blocky sandstones creating large ridges, or mesa. In central AlUla and moving towards the north, the lighter, Quweria Sandstone is exposed creating a mixture of sandstone formations and sandy plains and dunes. The Saq Sandstone lies to the north and north east, with hard iron beds exposed, interspersed with pebble gravel plains and accumulations of fine sandy plains.

Sandstone landforms provide the physical framework for a range of associated habitats, including outcrops, boulder slopes, screes, and canyons. Shallow soils and variable exposure lead to patchy vegetation cover, while shaded cliffs, ledges, and sheltered slopes form important refugia for specialised and locally restricted species. Collectively, these landforms constitute a key structural component of the AlUla landscape, contributing strongly to its ecological diversity, visual character, and natural and cultural heritage.

ASSOCIATED KSA NATIONAL ECOSYSTEM TYPES

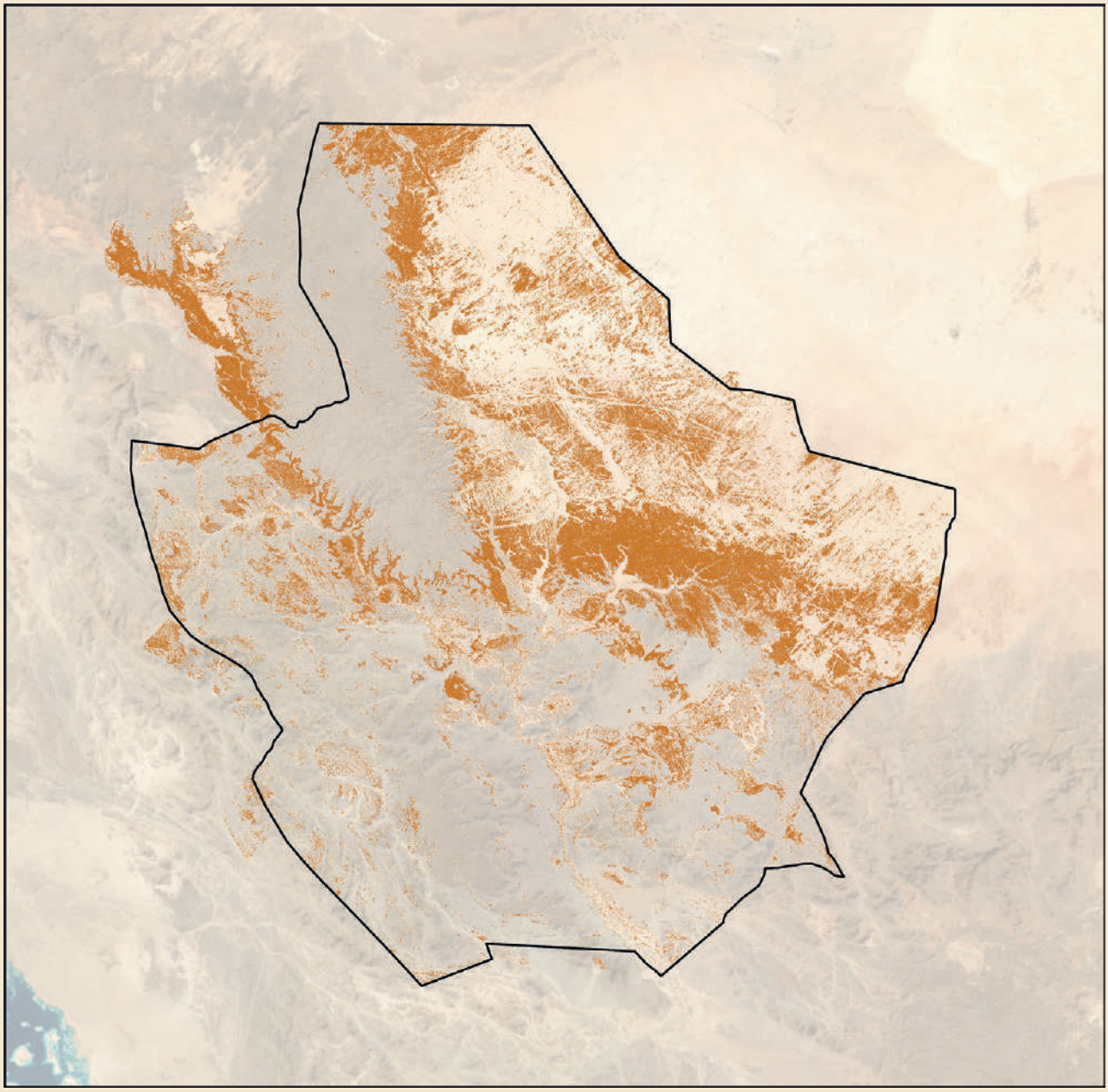
Northeast Hijaz Sandstone Plain and Plateaus

HABITATS

- **2100** | SANDSTONE OUTCROPS
- **2200** | SANDSTONE BOULDER SLOPES AND SCREES
- **2300** | SANDSTONE CANYONS

Figure 13 | Distribution of Sandstone Landform habitat group (2000) in AlUla County.















2100 | SANDSTONE OUTCROPS

DESCRIPTION

Sandstone bedrock and loose shale and gravel pavements of the summits of inselbergs, buttes, mesa, and sandstone hills.

GEOGRAPHIC AREA

Central, North East and East of AlUla.

GEOLOGY

In central AlUla, the Siq Sandstone, which is very well cemented, red due to high iron content, creates large flat-topped ridges (mesas). Moving towards the north, aeolian weathering of the softer Quweria Sandstone and Saq Sandstone create a variety of landforms dominated by tafoni features on the exposed surfaces.

SOILS

Soils develop as very shallow accumulations within small pockets, fissures, and depressions on eroded sandstone surfaces. Their formation results from the combined effects of sandstone weathering and the deposition of wind- and water-transported fine particles, allowing limited pedogenesis in an otherwise exposed and rocky environment.

VEGETATION

Bare rock or sparse mixed perennial herb community.

Plants are concentrated along runnels and in cracks on the summits of buttes and sandstone hills. Typically dominated by a dwarf shrubland of *Fagonia bruguieri*, *Helianthemum lippii, Gymnocarpos decander* and *Anvillea garcinii.*



1



2



3

1 *Gymnocarpus decander*
2 *Helianthemum lippii*
3 *Buthacus yotvatensis* (Yotvata sand scorpion)

FLORA

Characteristic flora

Perennials

- *Anvillea garcinii*
- *Ephedra ciliata*
- *Fagonia bruguieri*
- *Farsetia aegyptia*
- *Gymnocarpos decander*
- *Haloxylon salicornicum*
- *Helianthemum lippii*
- *Soda schweinfurthii*
- *Stipagrostis ciliata*

Annuals

- *Asphodelus tenuifolius*
- *Diplotaxis acris*
- *Leysera leyseroides*
- *Picris* spp.
- *Plantago amplexicaulis*
- *Plantago ciliata*
- *Rumex vesicarius*
- *Savignya parviflora*
- *Schismus barbatus*
- *Senecio flavus*
- *Stipellula capensis*

High conservation value flora

- *Pterocephalus sanctus*
- *Ramaliella intricata*

FAUNA

Characteristic fauna

- *Artema nephilit* (Giant daddy-long-leg spider)
- *Buthacus yotvatensis* (Yotvata sand scorpion)
- *Coturnix coturnix* (Common Quail)
- *Curruca nana* (Asian Desert Warbler)
- *Eremalauda eremodites* (Arabian Lark)
- *Oenanthe oenanthe* (Northern Wheatear)
- *Psammophis schokari* (Schokari sand racer)
- *Pseudotrapelus sinaitus* (Sinai agama)
- *Ptyodactylus ananjevae* (Ananjeva's fan-fingered gecko)
- *Uroctea cf. thaleri* (Bordered disc web spider)

High conservation value fauna

- *Ammomanes cinctura* (Bar-tailed Lark)
- *Circus aeruginosus* (Western Marsh-harrier)

DEGRADATION

Primary degrader is overgrazing.

RELATED HABITATS

2200 | SANDSTONE BOULDER SLOPES AND SCREES. These two habitats are closely related and commonly occur together as part of the same sandstone landform systems.











2200 | SANDSTONE BOULDER SLOPES AND SCREES

DESCRIPTION

Sandstone boulder slopes and screes are erosion-dominated landforms that form on or below sandstone outcrops. These slopes are shaped by the breakdown and collapse of sandstone boulders, producing accumulations of coarse debris. Large boulders and irregular sandstone fragments create a mosaic of shaded pockets, sheltered voids, and small microterraces that retain moisture and fine sediments.

GEOGRAPHIC AREA

Scattered across the sandstone areas of AlUla.

GEOLOGY

In central AlUla, the dominant bedrock is the Siq Sandstone, which is very well cemented, red due to high iron content, and heavily fractured. Northwards, the geology is dominated by the Quweria Sandstone and the Saq Sandstone.

SOILS

This soil originates from intense mechanical weathering of sandstone combined with gravity-driven erosion processes, producing coarse sand, gravel, and angular rock fragments that accumulate on scree slopes and at the base of cliffs. These soils are shallow and weakly developed, reflecting limited pedogenic processes under hyper-arid climatic conditions.

VEGETATION

Very sparse mixed dwarf shrub vegetation.

Commonly with the shrub *Ephedra ciliata* and dwarf shrubs *Anvillea garcinii*, *Iphiona scabra, Helianthemum lippii* and *Farsetia spp*. In places this develops into a very open woodland dominated by scattered trees of *Vachellia tortilis* subsp. *tortilis* and *Vachellia tortilis* subsp. *raddiana* and the tussock grass *Panicum turgidum* becoming transitional with sandy wadis and plains.



1



2

FLORA

Characteristic flora

Perennials

- *Anvillea garcinii*
- *Ephedra ciliata*
- *Farsetia burtonae*
- *Farsetia longisiliqua*
- *Haloxylon salicornicum*
- *Helianthemum lippii*
- *Iphiona scabra*
- *Ochradenus baccatus*

High conservation value flora

None

1 *Ephedra ciliata*
2 *Farsetia burtonae*

FAUNA

Characteristic fauna

- *Artema nephilit* (Giant daddy-long-leg spider)
- *Buthacus yotvatensis* (Yotvata sand scorpion)
- *Curruca nana* (Asian Desert Warbler)
- *Eremalauda eremodites* (Arabian Lark)
- *Gerbillus dasyurus* (Wagner's gerbil)
- *Monticola solitarius* (Blue Rock-thrush)
- *Oenanthe oenanthe* (Northern Wheatear)
- *Plecotus christii* (Christie's big-eared bat)
- *Psammophis schokari* (Schokari sand racer)
- *Pseudotrapelus sinaitus* (Sinai agama)
- *Ptyodactylus ananjevae* (Ananjeva's fan-fingered gecko)
- *Uroctea cf. thaleri* (Bordered disc web spider)

High conservation value fauna

- *Ammomanes cinctura* (Bar-tailed Lark)
- *Bubo ascalaphus* (Pharaoh Eagle-owl)
- *Canis lupus* (Grey wolf)
- *Circus aeruginosus* (Western Marsh-harrier)
- *Curruca melanocephala* (Sardinian Warbler)

DEGRADATION

The principal driver of degradation is overgrazing.

RELATED HABITATS

- **3100** | SANDY PLAINS and **5100** | SANDY WADIS. In places the vegetation may develop into a very open woodland dominated by scattered *Vachellia tortilis* subsp. *tortilis* and *V. tortilis* subsp. *raddiana*, with *Panicum turgidum*, becoming transitional to these habitats.
- **2100** | SANDSTONE OUTCROPS. These two habitats are closely related and commonly occur together as part of the same sandstone landform systems.













2300 | SANDSTONE CANYONS

DESCRIPTION

Sandstone canyons are deeply incised, narrow wadi systems cut into sandstone landforms. They are characterised by steep to near-vertical rock walls, confined valley floors, and strong contrasts between exposed, sunlit slopes and shaded, sheltered canyon interiors.

Also included here are sandstone gullies which represent smaller-scale incisions that dissect sandstone slopes and canyon walls. These share many structural and ecological characteristics but lack extensive canyon floors or developed riparian vegetation.

GEOLOGY

The dominant geology is the Quweria and Saq sandstones.

GEOGRAPHIC AREA

Sandstone landscapes of eastern and northeastern AlUla.

SOILS

These soils formed from fluvial deposits shaped by erosion and sedimentation. Located downstream of rocky and unstable slopes, their stony texture reflects the energy and turbulence of past floods, while visible stratification reveals changes in flow velocity during deposition.

VEGETATION

Typically dominated by species such as *Retama raetam* and *Ochradenus baccatus* and *Vachellia gerrardi* var. *najdensis* with *Ficus* spp. in wetter areas.


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FLORA

Characteristic flora

- *Abutilon bidentatum*
- *Anvillea garcinii*
- *Citrullus colocynthis*
- *Dodonaea viscosa*
- *Farsetia aegyptia*
- *Ficus palmata*
- *Ficus salicifolia*
- *Heliotropium ramosissimum*
- *Hyoscyamus pseudoalbus*
- *Lavandula coronopifolia*
- *Lavandula pubescens*
- *Lycium shawii*
- *Nanorrhinum acerbianum*
- *Ochradenus baccatus*
- *Panicum turgidum*
- *Periploca aphylla*
- *Phagnalon sinaicum*
- *Retama raetam*
- *Vachellia gerrardi*
- *Vachellia tortilis* subsp. *raddiana*
- *Withania somnifera*

High conservation value flora

- *Hyoscyamus pseudoalbus*

1 *Phagnalon sinaicum*
2 *Ficus salicifolia*
3 *Cerastes gasperettii* (Gasperetti's viper)
4 *Dodonaea viscosa*
5 *Bubo ascalaphus* (Pharaoh Eagle-owl)

FAUNA

Characteristic fauna

- *Agrotis segetum*
- *Buthacus yotvatensis* (Yotvata sand scorpion)
- *Cerastes gasperettii* (Gasperetti's viper)
- *Drasteria flexuosa*
- *Felis lybica* (Afro-Asiatic wildcat)
- *Plecotus christii* (Christie's big-eared bat)
- *Ptyodactylus ananjevae* (Ananjeva's fan-fingered gecko)
- *Rhinopoma cystops* (Arabian Mouse-tailed bat)
- *Spalerosophis diadema* (Diadem snake)
- *Streblote acaciae*
- *Thanatus cf. setiger* (False crab spider)
- *Uromastyx aegyptia* (Egyptian mastigure)
- *Zamarada minimaria*

High conservation value fauna

- *Agrotis ipsilon*
- *Apus apus (*Common Swift)
- *Bubo ascalaphus* (Pharaoh Eagle-owl)
- *Canis lupus* (Grey wolf)
- *Capra nubiana* (Nubian ibex)
- *Falco concolor* (Sooty Falcon)
- *Falco peregrinus* (Peregrine Falcon/Barbary Falcon)
- *Hyles livornica*
- *Pandesma robusta*
- *Platyceps saharicus* (Saharan racer)

DEGRADATION

Overgrazing and off-road driving both impact sandstone canyons.

RELATED HABITATS

5100 | SANDY WADIS and **3100** | SANDY PLAINS.

Canyons have steep rock walls and are narrow relative to the wall height. Wadis are less confined fluvial systems; where associated with sandstone relief, valley width exceeds the height of the surrounding walls. This relationship should be interpreted at the landscape scale, as local widening or narrowing within a system may not reflect the dominant landform.

3000 | SANDY PLAINS AND DUNES

3100 | SANDY PLAINS
3200 | SAND SHEETS WITH EXPOSED BEDROCK
3300 | SAND DUNES

OUTLINE

The sandy plains and dunes habitats encompasses the extensive sand-dominated landscapes of eastern AlUla, along with smaller patches distributed across the wider county. These deposits originate from a mix of geomorphological processes and long-distance aeolian transport. Surface stability varies widely: sandy plains typically form gently undulating, semi-stable terrain, while deeper accumulations develop where sand becomes trapped against natural barriers such as sandstone buttes, wadi margins, or topographic features.

Vegetation structure reflects this variability. Sandy plains commonly support open dwarf shrubland dominated by drought-tolerant shrubs and grasses, while deeper or more mobile sands support more specialised dune vegetation, including open shrubland and, in some areas, very open *Haloxylon persicum* woodland. These habitats form a key ecological matrix linking sandstone landforms, wadis, and gravel plains, supporting flora and fauna characteristic of sandy desert systems.

ASSOCIATED KSA NATIONAL ECOSYSTEM TYPES

Northeast Hijaz Sandstone Plain and Plateaus

HABITATS

- **3100** | Sandy plains
- **3200** | Sand sheets with exposed bedrock
- **3300** | Sand dunes

Figure 14 | Distribution of Sandy plains and dunes habitat group (3000) in AlUla County.













3100 | SANDY PLAINS

DESCRIPTION

Sandy plains are open, low-relief landscapes dominated by sand-rich substrates. They range from extensive areas of almost pure sand to mixed sandy-gravel plains where sand remains the dominant surface material. The substrate is typically composed of fine, well-sorted sand, although larger rounded pebbles may occur locally.

GEOGRAPHIC AREA

Most widespread in the east of AlUla associated with the sandstone landforms. Also occur in scattered areas of the west of AlUla in association with sandstone and granite areas.

GEOLOGY

Quartz sandstones predominantly derived from the Quweria Sandstone and Saq Sandstone.

SOILS

This alluvial soil is the result of the transport and deposition of sand particles, creating a lamellar structure. One of the characteristics of this soil is its high-water permeability.

VEGETATION

Open dwarf shrubland characteristically dominated by *Haloxylon salicornicum* with a herb layer (desert grassland) typically dominated by the grasses *Stipagrostis plumosa* and *Stipagrostis obtusa*. In areas, *Ephedra alata* and or *Retama raetam* become codominant with *Haloxylon salicornicum* often forming large nabkha.

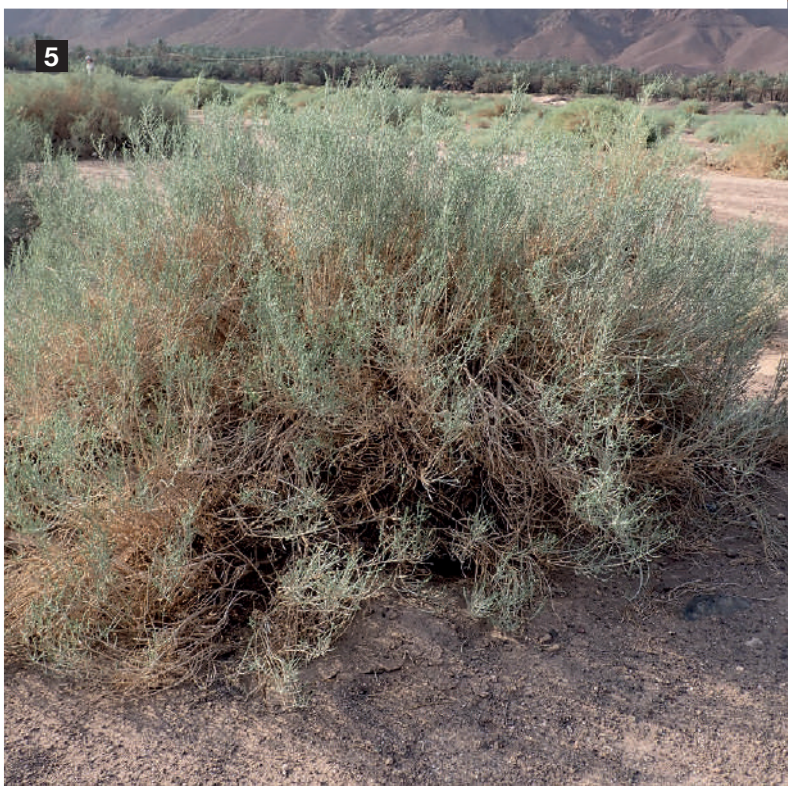
In places, such as nabkha, where there is deeper sand, a desert herb community commonly with *Artemisia monosperma*, *Polycarpaea repens*, *Centropodia forskaolii*, and *Convolvulus cephalopodus* subsp. *bushiricus* develops becoming transitional with the deep sand dune community (3300).


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FLORA

Characteristic flora

Perennials

- *Ephedra alata*
- *Haloxylon salicornicum*
- *Polycarpaea repens*
- *Retama raetam*
- *Stipagrostis ciliata*
- *Stipagrostis plumosa*

Annuals

- *Anthemis deserti*
- *Arnebia hispidissima*
- *Asphodelus tenuifolius*
- *Ifloga spicata*
- *Medicago laciniata*
- *Monsonia nivea*
- *Neurada procumbens*
- *Plantago amplexicaulis*
- *Schismus barbatus*

High conservation value flora

None

FAUNA

Characteristic fauna

- *Acanthodactylus schmidti* (Schmidt's fringe-fingered lizard)
- *Alaemon alaudipes* (Greater Hoopoe-lark)
- *Colotis danae* (Crimson tip)
- *Eremalauda eremodites* (Arabian Lark)
- *Felis lybica* (Afro-Asiatic wildcat)
- *Latrodectus revivensis* (Desert widow spider)
- *Ophiusa tirhaca*
- *Ptyodactylus ananjevae* (Ananjeva's fan-fingered gecko)
- *Sylvia borin* (Garden Warbler)

High conservation value fauna

- *Canis lupus* (Grey wolf)
- *Capra nubiana* (Nubian ibex)
- *Gazella arabica* (Arabian gazelle)
- *Gerbillus cheesmani* (Cheesman's gerbil)
- *Holocnemus pluchei* (Marbled daddy long-legs spider)

DEGRADATION

Overgrazing and off-road driving both have significant impacts.

RELATED HABITATS

- **3300** | SAND DUNES. Sandy plains grade naturally into sand dune systems where sand depth increases.
- **3200** | SAND SHEETS WITH EXPOSED BEDROCK. Found in a mosaic with this habitat in the northern AlUla.
- **5100** | SANDY WADIS. Sandy wadis often grade into sandy plains and may be difficult to distinguish on the ground in heavily degraded areas. Using satellite imagery can support interpretation.
- **4400** | GRAVEL PLAINS. In practice, the boundary between sandy and gravel plains is not always distinct, as many areas exhibit mixed substrates. Within this manual, plains are differentiated based in part on their geomorphological context: generally plains associated with sandstone landscapes are classified as Sandy plains (including sandy plains with some gravel), whereas plains associated with mountain systems of the Arabian Shield are classified as Gravel plains (4400).

1 *Capra nubiana* (Nubian ibex)
2 *Canis lupus* (Grey wolf)
3 *Gazella arabica* (Arabian gazelle)
4 *Sylvia borin* (Garden Warbler)
5 *Haloxylon salicornicum*





3200 | SAND SHEETS WITH EXPOSED BEDROCK

DESCRIPTION

Thin, discontinuous sandsheets overlie a lowrelief sandstone bedrock platform, with frequent areas of exposed rock.

GEOGRAPHIC AREA

Northeastern AlUla.

GEOLOGY

This can be observed in the Saq Sandstone. Due to the transgressive environment when the sediment was deposited, the softer river sediment erodes quicker, leaving the more compact sediments from the shallow seas exposed. Often iron beds, more resistant to erosion, and found in small higher relief exposures.

SOILS

This soil is characterised by a very shallow depth and a sandy texture, formed by the accumulation of mobile sand particles directly over the bedrock. It likely reflects limited weathering of the underlying parent material, combined with superimposed sand deposition. These soils are well-drained due to their coarse texture, facilitating excellent permeability and aeration. However, their nutrient retention capacity may be limited.

VEGETATION

Very sparse dwarf shrubland.

Characteristically dominated by *Rhanterium epapposum* with associated species such as *Fagonia glutinosa*, *Astragalus spinosus and Helianthemum lippii* with *Retama raetam* in sandy runnels. The density of this dwarf shrubland is variable but is generally very sparse due to overgrazing.

Local variation in the vegetation composition occurs depending on sand depth, bedrock topography, and proximity to other dune or rocky habitats, producing a mosaic of sandy patches, bare rock, and vegetated microsites.


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FLORA

Characteristic flora

Perennials

- *Astragalus spinosus*
- *Ephedra alata*
- *Fagonia bruguieri*
- *Fagonia glutinosa*
- *Fagonia paulayana*
- *Gymnocarpos decander*
- *Haloxylon salicornicum*
- *Helianthemum lippii*
- *Kickxia aegyptiaca*
- *Launaea mucronata*
- *Plantago albicans*
- *Plantago amplexicaulis*
- *Retama raetam*
- *Rhanterium epapposum*
- *Stipagrostis ciliata*
- *Stipagrostis plumosa*
- *Stipellula capensis*
- *Zilla spinosa*

Annuals

- *Anisosciadium lanatum*
- *Anthemis* spp.
- *Crucianella membranacea*
- *Eremobium aegyptiacum*
- *Erodium laciniatum*
- *Koelpinia linearis*
- *Leysera leyseroides*
- *Medicago laciniata*
- *Picris* spp.
- *Plantago ciliata*
- *Schismus barbatus*

High conservation value flora

- *Thymbra nabateorum*

1 *Curruca nana* (Asian Desert Warbler)
2 *Fagonia glutinosa*
3 *Kickxia aegyptiaca*
4 *Rhanterium epapposum*

FAUNA

Characteristic fauna

- *Acanthodactylus schmidti* (Schmidt's fringe-fingered lizard)
- *Acanthodactylus tilburyi* (Tilbury's fringe-fingered lizard)
- *Alaemon alaudipes* (Greater Hoopoe-lark)
- *Anumeta spilota*
- *Buthacus yotvatensis* (Yotvata sand scorpion)
- *Cerastes gasperettii* (Gasperetti's viper)
- *Curruca nana* (Asian Desert Warbler)
- *Eliomys melanurus* (Black-tailed Garden dormouse)
- *Felis lybica* (Afro-Asiatic wildcat)
- *Latrodectus revivensis* (Desert widow spider)
- *Lepus capensis* (Cape hare)
- *Monticola solitarius* (Blue Rock-thrush)
- *Oenanthe oenanthe* (Northern Wheatear)
- *Orthonama obstipata*
- *Platyceps elegantissimus* (Elegant racer)
- *Psammophis schokari* (Schokari sand racer)
- *Pseudotrapelus sinaitus* (Sinai agama)
- *Ptyodactylus ananjevae* (Ananjeva's fan-fingered gecko)
- *Scincus conirostris* (Sandfish skink)
- *Spalerosophis diadema* (Diadem snake)
- *Steatoda cf. latifasciata* (False widow spider)
- *Stenodactylus doriae* (Dune sand gecko)
- *Uroctea cf. thaleri* (Bordered disc web spider)
- *Uromastyx aegyptia* (Egyptian mastigure)
- *Varanus griseus* (Desert monitor)

High conservation value fauna

- *Ammomanes cinctura* (Bar-tailed Lark)
- *Bubo ascalaphus* (Pharaoh Eagle-owl)
- *Canis lupus* (Grey wolf)
- *Capra nubiana* (Nubian ibex)
- *Circaetus gallicus* (Short-toed Snake-eagle)
- *Circus aeruginosus* (Western Marsh-harrier)
- *Falco concolor* (Sooty Falcon)
- *Pandesma robusta*
- *Psammomys obesus* (Fat sand rat)
- *Telescopus dhara* (Arabian cat snake)

DEGRADATION

This area is highly degraded with evidence of heavy grazing on shrubs.

RELATED HABITATS

3100 | SANDY PLAINS. Found in a mosaic with this habitat in northern AlUla.











3300 | SAND DUNES

DESCRIPTION

Mounds or ridge-like accumulations formed by aeolian deposition of loose sand. Often where sustained wind deposition has built up thick bodies of sand against rock outcrops or natural topographic barriers. For the purposes of this classification this habitat type also includes areas of deep sand.

GEOGRAPHIC AREA

Scattered across AlUla. Particularly in the Sandstone areas of the east of AlUla e.g.in the west of Sharaan, South of Mughayra village and the western borders of Wadi Nakhlah.

GEOLOGY

Quartz sandstones predominantly derived from the Quweria Sandstone and Saq Sandstone.

SOILS

Typical soil of dunes, formed and shaped by the wind, accumulating back to the wind and eroding in front of the wind. Fine particles are too light to settle and coarse elements too heavy to be carried by the wind. The soil structure is homogeneous, fragile, loose and permeable.

VEGETATION

Variable in density and composition ranging from unvegetated to open woodland depending on local factors including water availability, recent rainfall and dune stability.

Many dunes support only ephemeral annual vegetation following rainfall, with species such as *Anthemis desertii*, *Silene arabica*, *Monsonia nivea*, and *Neurada procumbens* appearing rapidly. Where dunes are more stable a characteristic open dwarf shrubland can develop including species such as *Centropodia forskaolii, Moltkiopsis ciliata, Convolvulus cephalopodus subsp. bushiricus.* In some areas, particularly on larger or more stable dune systems where there is deep ground water, *Haloxylon persicum* can form an open woodland.


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1 *Artemisia monosperma*
2 *Acanthodactylus schmidti* (Schmidt's fringe-fingered lizard)
3 *Moltkiopsis ciliata*
4 *Convolvulus cephalopodus* subsp. *bushiricus*
5 *Haloxylon persicum*

FLORA

Characteristic flora

Perennials

- *Artemisia monosperma*
- *Calligonum comosum*
- *Centropodia forskaolii*
- *Convolvulus cephalopodus* subsp. *bushiricus*
- *Haloxylon persicum*
- *Haloxylon salicornicum*
- *Heliotropium digynum*
- *Moltkiopsis ciliata*
- *Polycarpaea repens*
- *Retama raetam*
- *Scrophularia hypericifolia*
- *Stipagrostis ciliata*
- *Stipagrostis drarii*
- *Stipagrostis plumosa*

Annuals

- *Asphodelus tenuifolius*
- *Cakile arabica*
- *Crucianella membranacea*
- *Monsonia nivea*
- *Neurada procumbens*
- *Schismus barbatus*

High conservation value flora

Haloxylon persicum woodland is highlighted as a potential conservation priority vegetation type (Neale et al., 2023). *Haloxylon persicum* is an economically important rangeland plant throughout the sand deserts of KSA. It has heavily degraded across most of its range and almost certainly used to be much more widely distributed. It is a pivotal species for restoration of the sand dune habitats.

FAUNA

Characteristic fauna

- *Acanthodactylus schmidti* (Schmidt's fringe-fingered lizard)
- *Acanthodactylus tilburyi* (Tilbury's fringe-fingered lizard)
- *Alaemon alaudipes* (Greater Hoopoe-lark)
- *Buthacus yotvatensis* (Yotvata sand scorpion)
- *Cerastes gasperettii* (Gasperetti's viper)
- *Cursorius cursor* (Cream-coloured Courser)
- *Eremalauda eremodites* (Arabian Lark)
- *Gerbillus dasyurus* (Wagner's gerbil)
- *Jaculus loftusi* (Arabian jerboa)
- *Stenodactylus doriae* (Dune sand gecko)
- *Uromastyx aegyptia* (Egyptian mastigure)

High conservation value fauna

- *Ammomanes cinctura* (Bar-tailed Lark)
- *Gerbillus cheesmani* (Cheesman's gerbil)
- *Pandesma robusta*

DEGRADATION

Off-road driving, overgrazing

RELATED HABITATS

- **3100** | SANDY PLAINS. Sand dunes grade naturally into sandy plains.
- **2100** | SANDSTONE OUTCROPS. Where sand blows up at the base of the buttes a mosaic of habitats can develop.

4000 | MOUNTAINS AND ASSOCIATED PLAINS

4100 | HIGH-ALTITUDE MOUNTAINS
4200 | MID-ALTITUDE MOUNTAINS
4300 | LOW-ALTITUDE MOUNTAINS
4400 | GRAVEL PLAINS

OUTLINE

The Mountains and associated plains comprise the Hijaz mountain systems of AlUla and their adjoining foothill and gravel plain environments. It spans a broad altitudinal gradient from rugged upland summits and steep slopes to lower foothills and depositional lowland plains.

The mountain landscapes are formed predominantly from Precambrian crystalline rocks of the Arabian Shield, creating rugged, dissected terrain with extensive areas of exposed bedrock and shallow soils. In contrast, the associated plains are composed of gravel and alluvial deposits derived from long-term erosion and downslope transport of mountain material.

Vegetation structure transitions from montane shrublands at high altitude to open Vachellia woodlands and perennial grasslands on foothills and plains.

High-altitude areas form a distinct ecological zone within AlUla, functioning as climatic and topographic refugia. These areas support a distinct flora and fauna with a higher proportion of range-restricted and conservation-significant species compared to the surrounding lower altitude areas. In addition to supporting a high proportion of range-restricted vascular plants and fauna, they also provide important refugial habitat for bryophytes and other cryptogams.

ASSOCIATED KSA NATIONAL ECOSYSTEM TYPES

- Hijaz Mountain Summits (1500–2500 m) – habitat 4100
- Hijaz Hills and Mountains (300–1500 m) – habitats 4200, 4300, and 4400

HABITATS

- **4100** | High-altitude mountains
- **4200** | Mid-altitude mountains
- **4300** | Low-altitude mountains
- **4400** | Gravel plains

Figure 15 | Distribution of the habitat group Mountains and associated plains (4000) in AlUla County











4100 | HIGH-ALTITUDE MOUNTAINS

DESCRIPTION

Mountainous uplands with summits, ridges and structural plateaus. Terrain ranges from gently sloping, to steep cliffs and convex summit areas. From around 1500m to the highest summit areas of Jabal AlWard (2096m) including associated runnels and gullies. Cooler and comparatively moister conditions support a distinct assemblage of plant and animal species, including endemic species and others of particular conservation significance.

High-altitude areas function as important refugia for cryptogams. Cooler temperatures, enhanced moisture availability and the presence of shaded cliffs, rock crevices and sheltered runnels support a distinctive bryophyte flora, including *Clevea spathysii, Molendoa handelii* and *Syntrichia rigescens* (Hugonnot et al., 2025b). These upland environments also provide favourable conditions for lichen communities, with Jabal AlWard identified as a particularly important area for future survey owing to its higher moisture availability and abundance of sheltered microhabitats (Marques et al., 2025).

GEOGRAPHIC AREA

Found on Jabal AlWard and in other small areas in the vicinity.

GEOLOGY

Precambrian igneous and metamorphic rocks.

SOILS

These shallow, gravelly soils of the high-altitude Hijaz are weakly developed under arid conditions, with profile evolution limited by physical weathering and aeolian deflation of fine particles. Their minimal horizon differentiation indicates an early stage of pedogenesis.

VEGETATION

Open shrubland characteristically dominated by *Retama raetam* and *Artemisia sieberi*. In some surveyed summit areas, the Saudi Arabian endemic *Euryops jaberiana* becomes codominant.

This is associated with a diverse mixed shrubland of dwarf shrubs such as *Ballota undulata*, *Teucrium polium*, *Astragalus spinosus*, *Ferula sinaica, Tanacetum sinaicum* and *Stachys aegyptiaca*. Trees such as *Pistacia khinjuk*, *Sageretia thea* and other species such as *Nepeta sheilae*, and *Umbilicus horizontalis* are found in more sheltered areas.


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1 *Papaver glaucum*
2 *Alcea striata*
3 *Aquila verreauxii* (Verreaux's Eagle)
4 *Searsia tripartita*
5 *Teucrium polium*
6 *Psammophis schokari* (Schokari sand racer)

FLORA

Characteristic flora

Perennials

- *Alcea striata*
- *Alkanna orientalis*
- *Anarrhinum orientale*
- *Artemisia sieberi*
- *Astragalus caprinus*
- *Astragalus spinosus*
- *Ballota undulata*
- *Bromus tectorum*
- *Centropodia forskaolii*
- *Colchicum ritchii*
- *Dianthus sinaicus*
- *Diplotaxis harra*
- *Echinops glaberrimus*
- *Erodium laciniatum* subsp. *pulverulentum*
- *Euryops jaberiana*
- *Farsetia aegyptia*
- *Ferula sinaica*
- *Filago griffithii*
- *Fumaria parviflora*
- *Galium sinaicum*
- *Globularia arabica*
- *Helianthemum lippii*
- *Hordeum murinum*
- *Morettia parviflora*
- *Nepeta sheilae*
- *Onopordum ambiguum*
- *Papaver glaucum*
- *Peganum harmala*
- *Phlomis brachyodon*
- *Pistacia khinjuk*
- *Retama raetam*
- *Sageretia thea*
- *Scandix stellata*
- *Searsia tripartita*
- *Stachys aegyptiaca*
- *Stipellula tigrensis*
- *Tanacetum sinaicum*
- *Teucrium polium*
- *Umbilicus horizontalis*

Annuals

- *Anchusa milleri*
- *Bromus danthoniae*
- *Bromus fasciculatus*
- *Isatis lusitanica*
- *Senecio glaucus*
- *Stipellula capensis*

High conservation value flora

- *Alcea striata*
- *Astragalus echinus*
- *Euryops jaberiana*
- *Ferula sinaica*
- *Nepeta sheilae*
- *Phlomis brachyodon*

FAUNA

Characteristic fauna

- *Gerbillus dasyurus* (Wagner's Gerbil)
- *Hecatera dysodea*
- *Lycosa piochardi* (Tarantula wolf spider)
- *Psammophis schokari* (Schokari sand racer)
- *Vulpes cana* (Blanford's Fox)

High conservation value fauna

- *Agrotis ipsilon*
- *Aquila chrysaetos* (Golden Eagle)
- *Aquila fasciata* (Bonelli's Eagle)
- *Aquila verreauxii* (Verreaux's Eagle)
- *Canis lupus* (Grey wolf)
- *Falco peregrinus* (Peregrine Falcon/Barbary Falcon)
- *Helicoverpa armigera*
- *Heliothis nubigera*
- *Pandesma robusta*
- *Platyceps saharicus* (Saharan racer)

DEGRADATION

Inaccessible areas. Some grazing but it appears relatively limited in areas surveyed.

RELATED HABITATS

4200 | MID-ALTITUDE MOUNTAINS – these two habitats are delimited based on altitude.







4200 | MID-ALTITUDE MOUNTAINS

DESCRIPTION

Rocky mountain uplands of the Hijaz mountain area between about 1200 and 1500m with associated runnels and upper wadi systems. Mid-altitude mountains represent the transition between arid foothill systems and cooler high-altitude massifs.

GEOGRAPHIC AREA

Western and southern mountain areas.

GEOLOGY

Precambrian igneous and metamorphic rocks.

SOILS

These shallow, gravelly soils of the mid-altitude Hijaz have formed under arid conditions through the interplay of physical weathering and aeolian redistribution of fine particles. Their profile expression remains weak, with limited horizon differentiation.

VEGETATION

Low montane shrubland.

Slopes are typically dominated by species such as *Helianthemum lippii* and *Gymnocarpos decander* with *Centaurea pseudosinaica* and *Fagonia mollis*. A characteristic *Retama raetam* and *Zilla spinosa* shrubland is found in areas of the west of AlUla with *Retama raetam* rare and concentrated in wadis and runnels at lower altitudes becoming more frequent at higher altitude.

In the runnels and wadis the vegetation becomes denser and is typically characterised by *Lycium shawii* and *Ephedra ciliata* shrubland with an associated mixed montane shrubs including *Blepharis ciliaris*, *Ochradenus baccatus*, *Gypsophila capillaris*, *Lavandula coronopifolia*, *Gymnocarpos decander*, *Helianthemum lippii*. Species such as *Teucrium polium* and *Otostegia fruticosa* found in wadis at higher altitudes and *Vachellia tortilis* subsp. *tortilis* woodland at lower altitudes.


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1 *Gymnosporia senegalensis*
2 *Centaurea pseudosinaica*
3 *Lycium shawii*
4 *Oenanthe xanthoprymna* (Kurdish Wheatear)
5 *Zilla spinosa*

FLORA

Characteristic flora

Perennials

- *Blepharis ciliaris*
- *Ephedra ciliata*
- *Erodium hirtum*
- *Fagonia bruguieri*
- *Fagonia mollis*
- *Farsetia aegyptia*
- *Ferula ovina*
- *Forsskaolea tenacissima*
- *Gagea reticulata*
- *Gymnocarpos decander*
- *Gymnosporia senegalensis*
- *Helianthemum lippii*
- *Lavandula coronopifolia*
- *Lycium shawii*
- *Morettia parviflora*
- *Ochradenus baccatus*
- *Pistacia khinjuk*
- *Plantago ovata*
- *Ramaliella tortuosissima*
- *Retama raetam*
- *Sageretia thea*
- *Searsia tripartita*
- *Teucrium polium*
- *Verbascum shiqricum*
- *Zilla spinosa*

Annuals

- *Asphodelus tenuifolius*
- *Bromus tectorum subsp. tectorum*
- *Centaurea pseudosinaica*
- *Echium rauwolfii*
- *Matthiola longipetala*
- *Plantago afra*
- *Senecio flavus*
- *Stipellula capensis*
- *Trigonella stellata*

High conservation value flora

- *Aloe* cf. *porphyrostachys*
- *Daphne mucronata* subsp. *linearifolia*
- *Kickxia pseudoscoparia*

FAUNA

Characteristic fauna

- *Alectoris chukar* (Chukar)
- *Buteo buteo*
- *Lycosa piochardi* (Tarantula wolf spider)

High conservation value fauna

- *Agrotis ipsilon*
- *Aquila fasciata* (Bonelli's Eagle)
- *Aquila verreauxii* (Verreaux's Eagle)
- *Canis lupus* (Grey wolf)
- *Colotis chrysonome* (Golden arab)
- *Gnamptonyx innexa*
- *Holocnemus pluchei* (Marbled daddy long-legs spider)
- *Hyles livornica*
- *Oenanthe xanthoprymna* (Kurdish Wheatear)
- *Pandesma robusta*
- *Platyceps saharicus* (Saharan racer)

DEGRADATION

Overgrazing and woodcutting.

RELATED HABITATS

- **4100** | HIGH-ALTITUDE MOUNTAINS.
  These two habitats are delimited based on altitude.
- **4300** | LOW-ALTITUDE MOUNTAINS.
  These two habitats are delimited based on altitude.









4300 | LOW-ALTITUDE MOUNTAINS

DESCRIPTION

Lower slopes and foothills of the Hijaz Mountains, extending from approximately 1200 m down to surrounding plains and major wadi systems. The terrain is rugged and irregular, characterised by rocky slopes with associated runnels and gullies, screes and locally steep rock faces transitioning downslope into gentler terrain.

GEOGRAPHIC AREA

Widespread across the west and the south of AlUla.

GEOLOGY

Precambrian igneous and metamorphic rocks.

SOILS

The lower Hijaz foothills host shallow, gravelly soils weakly developed in arid conditions, where physical weathering prevails and wind erosion removes fine particles. Horizon differentiation remains minimal.

VEGETATION

Very sparse montane herb community with scattered shrubs and trees in drainage channels and wadis.

Many low-altitude slopes are bare of vegetation apart from a flush of grassland that develops after rains and is dominated by *Stipagrostis* spp. In some areas a very sparse montane herb community is typically dominated by species such as *Fagonia bruguieri*, *Forsskaolea tenacissima* and *Tetraena simplex* with scattered *Lycium shawii* and shrublike *Vachellia* spp. in drainage channels.

In more sheltered areas a very sparse drought deciduous mixed woodland is still seen that varies in composition but includes *Vachellia tortilis* subsp. *tortilis*, *Moringa peregrina*, *Senegalia hamulosa*, *Commiphora gileadensis*, *Vachellia tortilis* subsp. *raddiana* with an understory shrubland of *Lycium shawii*, *Lavandula coronopifolia*, *Ochradenus baccatus*, *Hibiscus micranthus*. This woodland, now largely restricted to sheltered wadis and rocky refugia, would have been much more widespread over these slopes in the past, but trees have been cut for fuel and building material.


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4

1 *Trichodesma boissieri*
2 *Vachellia tortilis* subsp. *tortilis*
3 *Moringa peregrina*
4 Otus brucei (Pallid Scops-owl)

FLORA

Characteristic flora

Perennials

- *Abutilon fruticosum*
- *Blepharis ciliaris*
- *Boerhavia sinuata*
- *Commiphora gileadensis*
- *Echinops glaberrimus*
- *Enneapogon persicus*
- *Ephedra ciliata*
- *Fagonia bruguieri*
- *Fagonia mollis*
- *Farsetia longisiliqua*
- *Forsskaolea tenacissima*
- *Gymnocarpos decander*
- *Gypsophila capillaris*
- *Heliotropium aegyptiacum*
- *Hibiscus micranthus*
- *Kohautia caespitosa*
- *Lavandula coronopifolia*
- *Lycium shawii*
- *Maerua crassifolia*
- *Morettia parviflora*
- *Moringa peregrina*
- *Ochradenus baccatus*
- *Otostegia fruticosa*
- *Panicum turgidum*
- *Senegalia hamulosa*
- *Stipagrostis hirtigluma*
- *Tephrosia purpurea* subsp. *apollinea*
- *Tetraena simplex*
- *Vachellia tortilis* subsp. *tortilis*
- *Vachellia tortilis* subsp. *raddiana*

Annuals

- *Asphodelus tenuifolius*
- *Centaurea pseudosinaica*
- *Rumex vesicarius*
- *Senecio flavus*

High conservation value flora

- *Kickxia pseudoscoparia*
- *Ramaliella intricata*
- *Trichodesma boissieri*

FAUNA

Characteristic fauna

- *Colotis danae* (Crimson tip)
- *Curruca leucomelaena* (Arabian Warbler)
- *Drasteria flexuosa*
- *Felis lybica* (Afro-Asiatic wildcat)
- *Freyeria trochylus* (Grass jewel)
- *Hypotacha ochribasalis*
- *Vulpes cana* (Blanford's fox)

High conservation value fauna

- *Canis lupus* (Grey wolf)
- *Capra nubiana* (Nubian ibex)
- *Colotis chrysonome* (Golden arab)
- *Heliothis nubigera*
- *Junonia hierta* (Yellow pansy)
- *Otus brucei* (Pallid Scops-owl)
- *Pandesma robusta*

RELATED HABITATS

4200 | Mid-altitude mountain. These two habitats are delimited based on altitude.

DEGRADATION

Principal drivers of degradation include overgrazing and woodcutting.









4400 | GRAVEL PLAINS

DESCRIPTION

Plains and low slopes of the Hijaz mountains area covered in loose gravel and rocks.

Gravel plains comprise gently undulating to locally sloping surfaces characterised by a covering of loose gravel, stones, and coarse clasts. These plains occur at the base of mountain systems and across intermontane areas and intermediate between rocky mountain slopes and sandy plains.

GEOGRAPHIC AREA

In the south and west of AlUla, the Hijaz area.

GEOLOGY

Precambrian igneous and metamorphic rocks. In some areas broken pieces of sub-rounded igneous rocks. In areas with metamorphic rock, angular fragments are common. Often the gravel plains will contain high concentrations of calcite or quartz minerals on the surface, of varying sizes.

SOILS

These soils, derived from moderate alluvial deposits, are composed of loamy-sand to gravel particles, differential erosion leaves heavier particles like gravels on the surface, inducing slight soil compaction between deposit layers.

VEGETATION

Vegetation is variable depending on factors such as degradation.

It ranges from very open *Vachellia tortilis* subsp. *raddiana* and *Vachellia tortilis* subsp. *tortilis* woodland with an understory of *Haloxylon salicornicum, Ochradenus baccatus, Panicum turgidum* and *Lycium shawii* through to a sparse shrubland of *Vachellia* spp. with very occasional *Haloxylon salicornicum* eventually becoming denuded plains.



1



2



3

1 *Vachellia tortilis* subsp. *raddiana*
2 *Vachellia tortilis* subsp. *tortilis*
3 *Ammomanes cinctura* (Bar-tailed Lark)

FLORA

Characteristic flora

Perennials

- *Fagonia bruguieri*
- *Fagonia paulayana*
- *Haloxylon salicornicum*
- *Lycium shawii*
- *Morettia parviflora*
- *Senna italica*
- *Vachellia tortilis* subsp. *raddiana*
- *Vachellia tortilis* subsp. *tortilis*

Annuals

- *Aizoon canariense*
- *Aristida adscensionis*
- *Asphodelus tenuifolius*
- *Schismus barbatus*

HIGH CONSERVATION VALUE FLORA

None

FAUNA

Characteristic fauna

- *Alaemon alaudipes* (Greater Hoopoe-lark)
- *Buthacus yotvatensis* (Yotvata sand scorpion)
- *Curruca nana* (Asian Desert Warbler)
- *Cursorius cursor* (Cream-coloured Courser)
- *Eremalauda eremodites* (Arabian Lark)
- *Eremophila bilopha*
- *Gerbillus dasyurus* (Wagner's gerbil)
- *Jaculus loftusi* (Arabian jerboa)
- *Psammophis schokari* (Schokari sand racer)
- *Pseudotrapelus sinaitus* (Sinai agama)
- *Sympetrum fonscolombii* (Red-veined darter)
- *Uromastyx aegyptia* (Egyptian mastigure)

High conservation value fauna

- *Agrotis ipsilon*
- *Ammomanes cinctura* (Bar-tailed Lark)
- *Bubo ascalaphus* (Pharaoh Eagle-owl)
- *Capra nubiana* (Nubian ibex)
- *Heliothis nubigera*
- *Hyles livornica*

DEGRADATION

Impacted by overgrazing and woodcutting. However, impact is very variable, some areas are extremely degraded with no or very limited vegetation, other areas retain an open woodland.

RELATED HABITATS

- **5200** | GRAVEL WADIS. It can at times be extremely difficult to distinguish between gravel plains and wadis on the ground. Satellite imagery can support this distinction.
- **3100** | SANDY PLAINS. The boundary between sandy and gravel plains is not always distinct, as many areas exhibit mixed substrates. Within this manual, plains are differentiated based partly on their geomorphological context: generally plains associated with sandstone are classified as sandy plains (3100) including sandy plains with some gravel, whereas plains associated with mountain systems of the Arabian Shield are classified as gravel plains (4400).



5000 | WADIS AND EPHEMERAL FLOODED DEPRESSIONS

5100 | SANDY WADIS
5200 | GRAVEL WADIS
5300 | EPHEMERAL FLOODED DEPRESSIONS

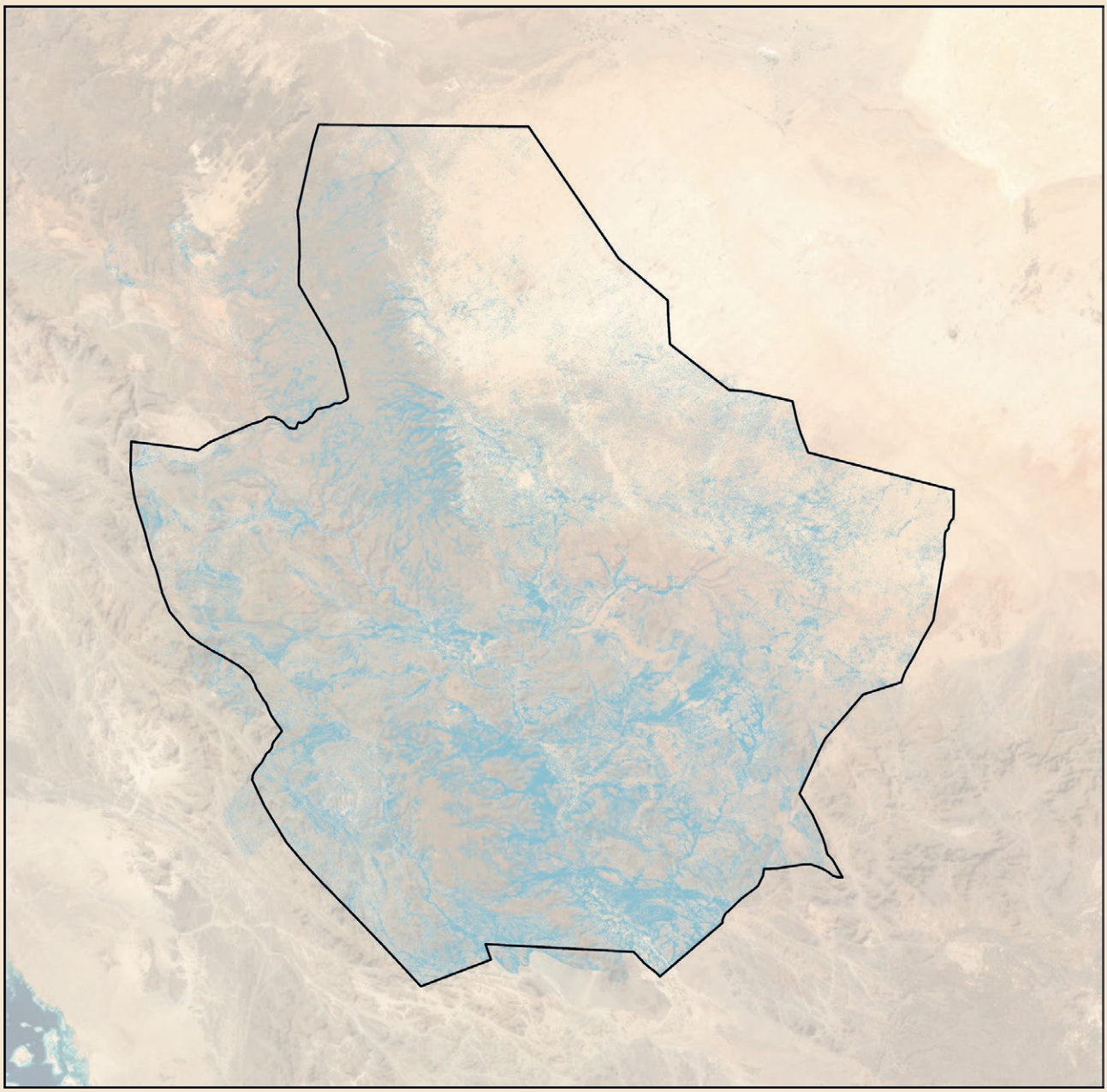


Figure 16 | Distribution of the habitat group Wadis and ephemeral flooded depressions (5000) in AlUla County.

OUTLINE

Wadis comprise the network of ephemeral drainage systems across AlUla, ranging from small incised channels and tributaries to broad valley floors. They are shaped by episodic surface water flow following rainfall and act as major conduits for sediment, water, nutrients, and biological connectivity across the landscape.

ASSOCIATED KSA NATIONAL ECOSYSTEM TYPES

Mixed

LIST OF HABITATS

- **5100** | Sandy wadis
- **5200** | Gravel wadis
- **5300** | Ephemeral flooded depressions

RELATED HABITATS

1300 | Harrat drainage lines and wadis while functionally similar are treated under the Volcanics habitat group.











5100 | SANDY WADIS

DESCRIPTION

Dry ephemeral riverbed characterised by aeolian and alluvial sand deposits, supporting a woody vegetation denser than that of the surrounding sandy plains.

GEOGRAPHIC AREA

Primarily found in the east of AlUla associated with areas of sandstone.

GEOLOGY

Predominantly Siq and Quweria sandstones, but in areas close to the harrats, basalt boulders can be found mixed with the sandstone.

SOILS

These soils are dominated by sand and formed from sediments deposited during episodic fluvial flows. Their sandy texture reflects low-energy water transport, allowing fine particles to settle while coarser debris is washed away, and their formation is strongly influenced by the frequency and intensity of seasonal floods.

VEGETATION

Open Vachellia woodland.

Typically dominated by *Vachellia tortilis* subsp. *raddiana* at lower altitudes and *Vachellia gerrardi* var. *najdensis* at over 1000m. With a shrubland dominated by *Retama raetam* and *Haloxylon salicornicum.*





FLORA

Characteristic flora

Perennials

- *Astragalus spinosus*
- *Citrullus colocynthis*
- *Gymnocarpos decander*
- *Haloxylon salicornicum*
- *Lycium shawii*
- *Ochradenus baccatus*
- *Panicum turgidum*
- *Retama raetam*
- *Stipagrostis plumosa*
- *Vachellia gerrardi* var. *najdensis*
- *Vachellia tortilis* subsp. *raddiana*

Annuals

- *Aizoon canariense*
- *Asphodelus tenuifolius*
- *Cakile arabica*
- *Crucianella membranacea*
- *Ifloga spicata*
- *Medicago laciniata*
- *Plantago amplexicaulis*
- *Rumex vesicarius*
- *Schismus barbatus*
- *Stipellula capensis*

High conservation value flora

None

FAUNA

Characteristic fauna

- *Acanthodactylus schmidti* (Schmidt's fringe-fingered lizard)
- *Artema nephilit* (Giant daddy-long-leg spider)
- *Buthacus yotvatensis* (Yotvata sand scorpion)
- *Casama innotata*
- *Cerastes gasperettii* (Gasperetti's viper)
- *Curruca nana* (Asian Desert Warbler)
- *Felis lybica* (Afro-Asiatic wildcat)
- *Hypotacha ochribasalis*
- *Hypsugo ariel* (Fairy Pipistrelle)
- *Jaculus loftusi* (Arabian jerboa)
- *Lytorhynchus diadema* (Crowned leafnose snake)
- *Palpimanus gibbulus*
- *Phoenicurus ochruros*
- *Plecotus christii* (Christie's big-eared bat)
- *Psammophis schokari* (Schokari sand racer)
- *Pseudotrapelus sinaitus* (Sinai agama)
- *Ptyodactylus ananjevae* (Ananjeva's fan-fingered gecko)
- *Steatoda cf. paykulliana*
- *Stenodactylus doriae* (Dune sand gecko)
- *Streblote acaciae*
- *Tathorhynchus exsiccata*
- *Uromastyx aegyptia* (Egyptian mastigure)
- *Uromastyx ornata* (Ornate mastigure)
- *Varanus griseus* (Desert monitor)





High conservation value fauna

- *Barbastella leucomelas* (Eastern Barbastelle)
- *Bubo ascalaphus* (Pharaoh Eagle-owl)
- *Capra nubiana* (Nubian ibex)
- *Falco concolor* (Sooty Falcon)
- *Gazella arabica* (Arabian gazelle)
- *Gerbillus cheesmani* (Cheesman's Gerbil)
- *Gnamptonyx innexa*
- *Heliothis nubigera*
- *Oryx leucoryx* (Arabian Oryx)
- *Pandesma robusta*
- *Platyceps saharicus* (Saharan racer)
- *Psammomys obesus* (Fat Sand Rat)

DEGRADATION

Grazing, woodcutting, off-road driving.

RELATED HABITATS

- **3100** | SANDY PLAINS, Typically differentiated by the contracted vegetation of the wadi bed but this can be difficult in very degraded areas.
- **2300** | SANDSTONE CANYONS. Many sandy wadis originate within or pass through canyon systems.









5200 | GRAVEL WADIS

DESCRIPTION

Dry, ephemeral riverbeds characterised by coarse alluvial substrates, including boulders, cobbles, pebbles, and gravel. This habitat also includes alluvial fans.

GEOGRAPHIC AREA

Associated with the mountain, foothills and plains of the Hijaz mountain areas.

GEOLOGY

Mostly a mixture of igneous and metamorphic rocks.

SOILS

These soils, shaped by fluvial deposits and erosion processes, are downstream of stony and unstable reliefs. The stony composition of these soils testifies to the strength and turbulence of the floods. The stratification of the soil testifies to variations in the speed of the water current.

VEGETATION

Vegetation is variable depending on factors such as degradation.

It ranges from very open *Vachellia tortilis* subsp. *raddiana* and *Vachellia tortilis* subsp. *tortilis* woodland with an understory of *Haloxylon salicornicum, Ochradenus baccatus, Lycium shawii, Panicum turgidum,* through to a sparse shrubland of *Vachellia* spp. with very occasional *Haloxylon salicornicum,* through to wadis which are completely denuded.


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3

1 *Tetraena simplex*
2 *Tribulus terrestris*
3 *Vachellia tortilis* subsp. *raddiana*

FLORA

Characteristic flora

Perennials

- *Aristida adscensionis*
- *Citrullus colocynthis*
- *Fagonia bruguieri*
- *Forsskaolea tenacissima*
- *Haloxylon salicornicum*
- *Lycium shawii*
- *Morettia parviflora*
- *Ochradenus baccatus*
- *Rhazya stricta*
- *Tetraena simplex*
- *Vachellia tortilis* subsp. *tortilis*
- *Vachellia tortilis* subsp. *raddiana*

Annuals

- *Aizoon canariense*
- *Asphodelus tenuifolius*
- *Tribulus terrestris*

FAUNA

Characteristic fauna

- *Colotis halimede* (Yellow patch white)
- *Colotis liagore* (Desert orange tip)
- *Curruca leucomelaena* (Arabian Warbler)
- *Daphnis nerii*
- *Freyeria trochylus* (Grass jewel)
- *Hypotacha ochribasalis*
- *Streblote acacia*

High conservation value fauna

- *Canis lupus* (Grey wolf)
- *Capra nubiana* (Nubian ibex)
- *Gnamptonyx innexa*
- *Heliothis nubigera*

DEGRADATION

Overgrazing and woodcutting.

RELATED HABITATS

- **5100** | SANDY WADIS. Transitional zones between gravel and sandy wadis are common and should be classified based on dominant substrate and channel form.
- **4400** | GRAVEL PLAINS. In some areas, particularly where drainage channels are broad or poorly defined, gravel wadis can be difficult to distinguish from adjacent gravel plains. Wadis are typically associated with active drainage features and evidence of periodic flooding, whereas gravel plains occur outside the main fluvial system.
- **5300** | EPHEMERAL FLOODED DEPRESSIONS. Ephemeral flooded depressions may occur within or adjacent to gravel wadi systems where water accumulates in localised low-lying areas. These depressions are characterised by prolonged water retention and distinct soil and vegetation conditions compared with the surrounding wadi habitat.















5300 | EPHEMERAL FLOODED DEPRESSIONS

DESCRIPTION

Ephemeral flooded depressions are shallow basins that temporarily hold water following rainfall. As the water recedes, these microsites support short-lived but diverse annual growth, often including halophytic species adapted to saline, fine-textured soils. During the driest months, vegetation cover is minimal and the exposed silty-clay surfaces are highly vulnerable to wind erosion. Despite their limited extent and brief hydroperiod, larger depressions function as important ecological hotspots, providing seasonal foraging habitat for a range of bird species that utilise the vegetation flush and temporary moisture.

GEOGRAPHIC AREA

Widespread across AlUla.

GEOLOGY

Variable, dependant on the location of depression.

SOILS

Ephemeral flooded microsites are flat depression basins. Soils are highly compacted with a high silt and clay, making them low permeable. Some areas also present some salt crust. The area experiences temporary flooding after heavy rainfall events.



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4





1 *Platyceps saharicus* (Saharan racer)
2 *Polycarpaea robbairea*
3 *Anabasis setifera*
4 *Suaeda vermiculata*

VEGETATION

Variable depending on the location of the depressions, seasonality and levels of degradation. Frequently dominated by halophytic species.

FLORA

Characteristic flora

Perennials

- *Anabasis setifera*
- *Andrachne telephioides*
- *Asteriscus graveolens*
- *Atriplex turcomania*
- *Caroxylon imbricatum*
- *Farsetia aegyptia*
- *Seidlitzia rosmarinus*.
- *Suaeda* spp.,
- *Traganum nudatum*

Annuals

- *Aizoon canariense*
- *Lepidium aucheri*
- *Malva parviflora*
- *Polycarpaea robbairea*

High conservation value flora

None

FAUNA

Characteristic fauna

- *Uromastyx aegyptia* (Egyptian mastigure)
- *Varanus griseus* (Desert monitor)

High conservation value fauna

- *Barbastella leucomelas* (Eastern Barbastelle)
- *Bubo ascalaphus* (Pharaoh Eagle-owl)
- *Gazella arabica* (Arabian gazelle)
- *Platyceps saharicus* (Saharan racer)

DEGRADATION

Overgrazing, off-road driving.

RELATED HABITATS

1500 | Ephemeral flooded depressions in volcanic craters. Can be distinguished by location.



6000 | AGRICULTURAL LANDS

6100 | AGRICULTURAL LANDS

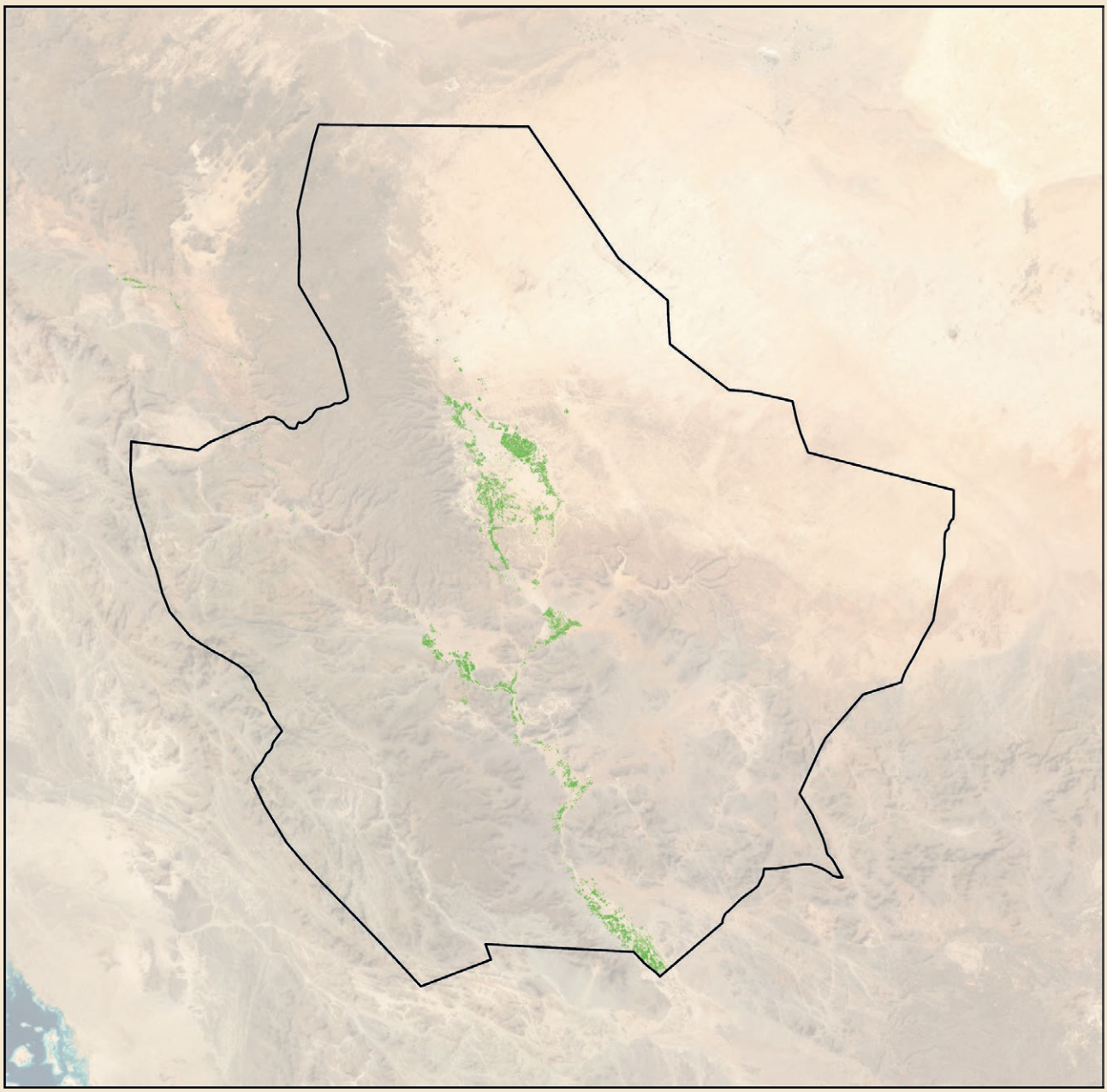


Figure 17 | Distribution of habitat group Agricultural lands (6000) in AlUla County.

DESCRIPTION

Agricultural lands comprise areas that are actively or recently managed for crop production, oases, or irrigated cultivation. These landscapes are strongly shaped by long-term human management, water abstraction, and soil modification, and form an important component of the cultural landscape of AlUla.

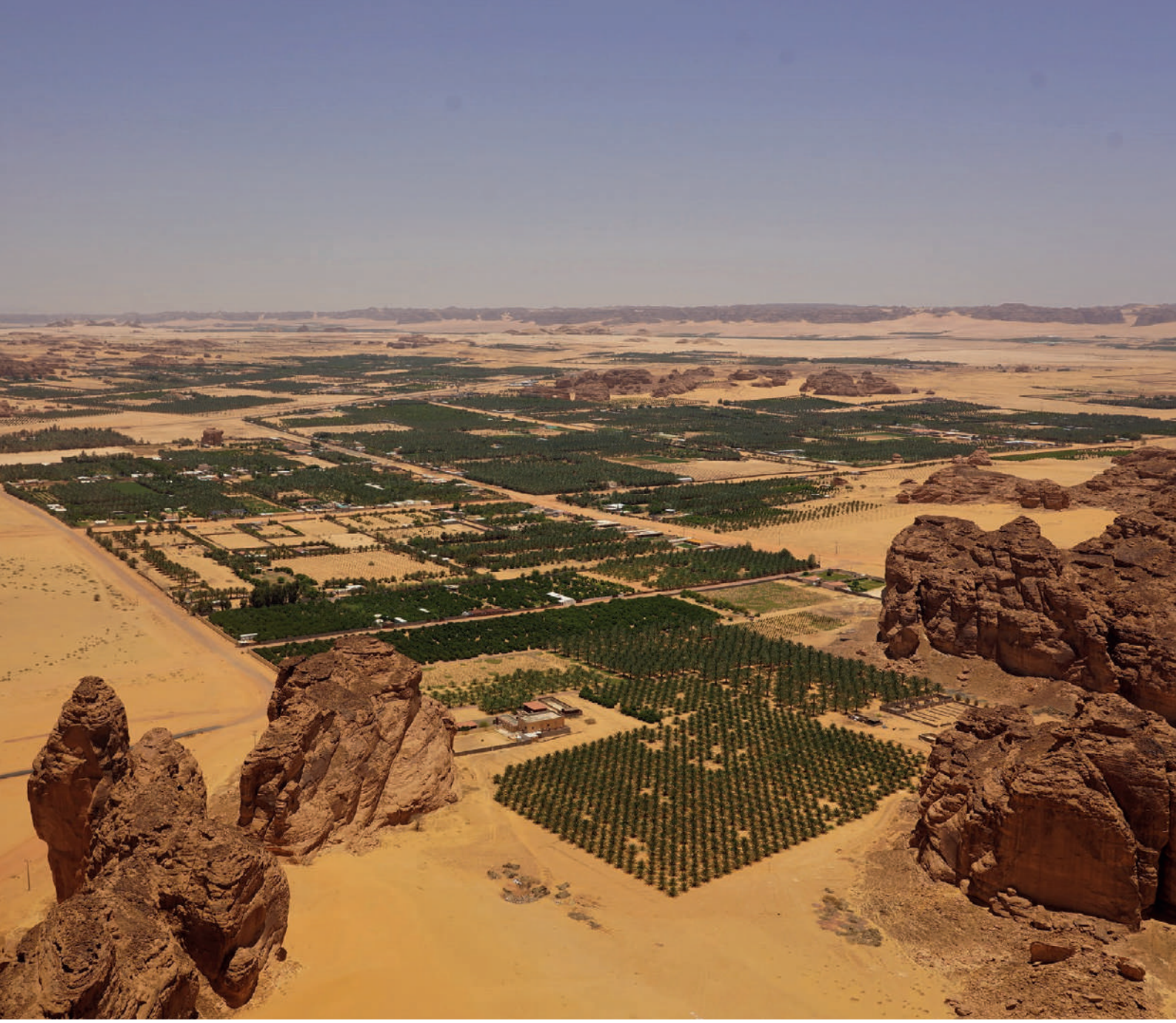
Agricultural lands occur primarily within valley floors, oases, and low-lying plains where access to groundwater, springs, or surface water has enabled sustained cultivation.

ASSOCIATED KSA NATIONAL ECOSYSTEM TYPES

Not applicable

HABITATS

6100 | Agricultural lands







6100 | AGRICULTURAL LANDS

DESCRIPTION

This includes all agricultural land in AlUla, including the oasis areas, fields and pivot agriculture, both in areas where agriculture is active and in recently abandoned areas.

GEOGRAPHIC AREA

Found across AlUla with the largest concentration around the AlUla valley.

GEOLOGY

Typically underlain by Quaternary fluvial deposits associated with wadis and valley floors, with bedrock geology varying depending on location (sandstone, volcanic, or crystalline basement).

SOILS

Agricultural soils show strong variability depending on local topography and hydrological conditions. Agricultural activities are mainly concentrated in plain areas, where soils range from sandy loam to more clay-rich textures. These soils are often compacted and may exhibit chemical imbalances, as well as localised salt accumulation.

VEGETATION

Vegetation is dominated by cultivated (particularly date palm *Phoenix dactylifera*), non-native fruit trees, and seasonal crops. Some agricultural areas can support a relatively high diversity of weedy and ruderal plant species, reflecting frequent disturbance, irrigation, nutrient enrichment, and the mixing of native, naturalised, and introduced taxa.

FLORA

Characteristic flora

- *Alhagi maurorum*
- *Celosia trigyna*
- *Cenchrus echinatus* (non-native)
- *Euploca ovalifolia*
- *Momordica balsamina*
- *Setaria viridis*

FAUNA

Characteristic fauna

- *Brephidium exilis* (Western pygmy blue)
- *Chalcides ocellatus* (Ocellated bronze skink)
- *Euodice cantans*
- *Gegenes nostrodamus* (Mediterranean skipper)
- *Hemidactylus granosus* (Grainy house gecko)
- *Hogna sp.*
- *Larinia chloris*
- *Leptotes pirithous* (Lang's short-tailed blue)
- *Oecobius sp.*
- *Pelopidas mathias* (Black-branded swift)
- *Ploceus galbula*
- *Pycnonotus leucotis*
- *Spalerosophis diadema* (Diadem snake)
- *Thyene imperialis*
- *Zizeeria karsandra* (Dark grass blue)

High conservation value fauna

- *Junonia hierta* (Yellow pansy)
- *Junonia orithya* (Blue pansy)
- *Pipistrellus kuhlii* (Kuhl's Pipistrelle)
- *Rousettus aegyptiacus* (Egyptian Rousette)
- *Streptopelia turtur* (European Turtle-dove)


1


2


3



1 *Periploca aphylla*
2 *Ficus palmata* subsp. virgata
3 *Adiantum capillus-veneris*

MICRO HABITATS

OUTLINE

These are highly localised habitat types that have not been mapped. Although requiring further characterisation, they represent important features of ecological significance in AlUla and are therefore included here in brief.

These microhabitats are also of particular importance for bryophytes, which are largely restricted to sites with locally enhanced moisture availability. Notable species include the aquatic liverwort *Riella affinis*, known from only two ponds in Sharaan, together with the wetland and seepage specialists *Ptychostomum cellulare*, *Ptychostomum pseudotriquetrum, Gymnostomiella vernicosa,* and *Eucladium verticillatum* (Hugonnot et al., 2025b). These habitats act as important moisture refugia within an otherwise hyper-arid landscape and support several species considered to be of high conservation importance in AlUla. The occurrence of these species highlights the ecological value of small-scale refugia and moisture-dependent habitats within AlUla's predominantly arid landscape, reinforcing the importance of protecting seepages, canyon systems and montane habitats that support disproportionately high biodiversity. Similar moisture-buffered microhabitats are also recognised as key centres of lichen diversity, particularly where seepages, rock crevices and stable substrates provide protection from desiccation stress (Marques et al., 2025).

SEEPAGE

Sandstone seepages are highly localised microhabitats formed where groundwater emerges slowly along sandstone fractures, bedding planes, or rock faces. They occur mainly in shaded cliffs, ledges, boulder slopes, and canyon walls, creating persistent moist microsites within otherwise arid areas. Although limited in extent, seepages support distinctive moisture-dependent vegetation and act as important ecological refugia.

VEGETATION

Vegetation is typically small scale and highly localised but structurally distinct from surrounding habitats. Plant cover may include ferns, sedges, and moisture-dependent herbs, often accompanied by shrubs or trees rooted nearby that benefit from enhanced water availability.

CHARACTERISTIC FLORA

Perennials

- *Adiantum capillus-veneris*
- *Cynodon dactylon*
- *Ephedra ciliata*
- *Ficus palmata* subsp. *virgata*
- *Haloxylon salicornicum*
- *Juncus rigidus*
- *Launaea spinosa*
- *Lavandula pubescens*
- *Periploca aphylla*
- *Phoenix dactylifera*
- *Pistacia khinjuk*
- *Retama raetam*
- *Vachellia gerrardi* var. *najdensis*

Annuals

- *Schismus barbatus*
- *Senecio flavus*

CHARACTERISTIC FAUNA

Not yet determined


1


2



1 *Juncus rigidus*
2 *Mentha longifolia*

MOUNTAIN SPRINGS AND POOLS

Where groundwater emerges naturally at the surface producing visible flowing water, persistent wet ground, or localised pooling. Springs support distinctive vegetation that differs markedly from surrounding dry habitats. This may include dense shrub or tree growth, hygrophilous herbs, reeds, or ferns, reflecting consistently elevated moisture availability. As a result, springs function as important ecological focal points, providing water, shade, and foraging resources for a wide range of fauna and acting as long-term refugia within otherwise arid environments.

FLORA

- *Andrachne aspera* var. *glandulosa*
- *Chrozophora oblongifolia*
- *Farsetia aegyptia*
- *Forsskaolea tenacissima*
- *Juncus rigidus*
- *Mentha longifolia*
- *Phragmites australis*
- *Pulicaria arabica*
- *Pulicaria undulata* subsp. *undulata*
- *Typha domingensis*
- *Verbascum sinaiticum*
- *Zilla spinosa*

FAUNA

- *Bufotes sitibundus* (Variable green toad)
- *Duttaphrynus dhufarensis* (Oman toad)
- *Sclerophrys arabica* (Arabian toad)



FUTURE WORK

GLOSSARY

BIBLIOGRAPHY



FUTURE WORK

The habitat classification, descriptions, and mapping presented here provides a robust baseline understanding of the habitats of AlUla and their distribution. However, opportunities exist to further enhance and refine the evidence base through additional habitat characterisation, mapping, and ecological research.

Further habitat characterisation would improve understanding of the diversity and distribution of habitats and ecological features across AlUla. Targeted surveys could help identify fine-scale habitat variation, transitional communities, and localised ecological features that support key species or ecosystem processes. Additional characterisation would also strengthen understanding of habitat condition, vegetation dynamics and the factors influencing habitat change through time.

There is also scope to enhance habitat mapping. Future work could incorporate higher spatial and spectral resolution remote sensing data, including very high-resolution multispectral and hyperspectral imagery, to improve the discrimination of habitats that are difficult to distinguish using existing datasets. The use of multi-temporal imagery would further support the identification of seasonal and phenological patterns, as well as the dynamics of ephemeral habitats and periodically flooded systems.

Future approaches could implement harmonised remote sensing data to provide standardised results across the different spatial-temporal-spectral resolutions. In addition, the integration of additional auxiliary layers into individual classifications such as topographical data could provide complementary information where spectral separability is low for very specific habitats (e.g., Harrat cliffs and steep slopes, Gravel plains).

Mapping accuracy could also be improved through the incorporation of additional environmental datasets, such as topography, geology, hydrology, and soils. These complementary layers can provide valuable contextual information where habitat types exhibit similar spectral signatures, helping to improve the classification of environmentally distinct but spectrally similar habitats, including steep harrat slopes, gravel plains, and other heterogeneous landscape features.

Further improvements could be achieved through increased stratified ground-truth sampling and targeted field campaigns, particularly for underrepresented habitats and areas with greater classification uncertainty. Survey effort should prioritise habitat types and geographic areas associated with higher levels of uncertainty or higher misclassification rates.

Collectively, these activities would strengthen the evidence base for the habitats of AlUla, improve confidence in habitat mapping and classification, and provide a more detailed understanding of habitat condition, vegetation dynamics, and ecological change through time. By addressing current knowledge gaps and reducing uncertainties, future research would contribute to a more complete understanding of the patterns, processes, and features that underpin the habitats of AlUla.

GLOSSARY

Aeolian | Wind-driven. Used to describe landforms, sediments, and geological processes shaped by the action of wind.

Alluvial fan | Alluvial fan deposits are low, outspread, relatively flat to gently sloping masses of loose rock material, shaped like a fan or segment of a cone. They are deposited by streams at the mouths of tributary valleys onto a plain or broad valley.

Bioregion | A geographical area defined by characteristics of the natural environment. Saudi Arabian Bioregions (Llewellyn, 2013) are based on physiography (geology and topography), altitude, climate, soils, and vegetation structure and composition.

Biotype | Similar to a habitat but defined in relation to a suite of species.

Butte | An isolated hill with steep sides and a flat, slightly rounded top.

Canyon | Large chasms between cliffs.

Clasts | Fragments or grains of pre-existing rocks and minerals.

Crater | The top of a volcano, which is lower than the surrounding rim.

Decreaser species | Species that are present in an area with low to no degradation, with balanced ecosystem dynamics and controlled grazing conditions. These species are often palatable and are hence coined "decreasers" given their tendency to decrease as environmental degradation heightens in intensity.

Degradation | The process by which the quality of a natural habitat is reduced, making it less able to support wildlife. This can be caused by human or natural causes. In this context we refer to human causes.

Ecosystem type | Complex of organisms and their associated physical environment that are united by similar ecological processes and that exhibit substantial differences in biotic structure and composition to that of other ecosystem types.

Endemic species | Plants or animals existing naturally in a specific geographic region. For example, national endemics which are found only in Saudi Arabia or Arabian endemics which are found only in the countries of the Arabian Peninsula.

Geographically restricted | Fauna species with a limited distribution, defined as having an Area of Occupancy (AOO) of <10 km² and/or an Extent of Occurrence (EOO) of <100 km², following the IUCN methodology for estimating species range size.

Geomorphology | Branch of geology that is concerned with the structure, origin, and development of the topographical features of the earth's surface.

Habitat | Plant and animal communities as the characterising elements of the biotic environment, together with abiotic factors (soil, climate, water availability and quality, and others), operating together at a particular scale, following the EUNIS definition (European Environment Agency, 2023).

Harmonised | The process of aligning and integrating data from different sources, methodologies, or classification systems to create a consistent and comparable dataset.

Harrat | Lava flows giving rise to high plateau. Harrat surfaces clearly reflect their age. Older harraat are severely weathered and eroded. Younger harraat have little weathering or erosion and can appear as an impassable and chaotic jumble of angular blocks.

Increaser species | Species that might be native to KSA (therefore aren't alien invasives) but are quick-spreading species related to environmental degradation or overgrazing. Some may be unpalatable to grazers. Some may compete with established plant species/communities in the given area when environmental degradation commences or intensifies.

Inselberg | Isolated rock hill, ridge, or small mountain, that rises abruptly from a virtually level surrounding plain.

Lamellar | Rocks, minerals, or soils composed of fine, alternating, parallel layers or flat plates.

Lava flow | A stream or sheet of molten or solidified lava which has erupted from a volcano onto the Earth's surface. Lava flows in a solidified context can be described as fresh or eroded.

Mesa | A flat-topped hill with steep sides. They are smaller than a plateau and the sides are much steeper. Mesa can be separated from a plateau in AlUla as they are typically in the sedimentary rocks. The plateau is seen as the harrats.

Mountain | A naturally raised landform, with steep, sharp edges and a peak.

Nabkha | Accumulation of wind-blown sediment around plants forming a raised fertile mound.

Outcrop | An area of exposed rock sticking out from the surrounding ground.

Overgrazing | Intensive grazing by animals on an area of land, particularly rangelands and grasslands, such that vegetation is damaged and the soil becomes liable to erosion by wind and rain, sometimes resulting in desertification.

Pediment | A gently sloping bedrock surface that forms at the base of a mountain or hill. Often covered by a thin layer of gravel or alluvium.

Pediplain | Extensive gently sloping plain formed by the joining of multiple pediments at the base of a mountain range.

Pedogenesis | The process of soil formation.

Plateau | A large flat expanse that rises above the surrounding landscape, they often rise steeply above.

Pyroducts | A natural tube formed through the flow of lava. When emptied of lava it can resemble a tube or elongated cave. Also called a lava tube.

Quweria Sandstone | A sandstone formation in AlUla. Defined by its honey-coloured, fairly massive layers, dominated by fluvial deposits and quartz sediment. The cement is relatively weakened through hydrolysis and chemical weathering.

Range-restricted | Refers to species that are known to occur in Saudi Arabia and neighbouring countries. They are not considered regional endemics but have a restricted range.

Refugia | Areas that components of biodiversity retreat to, persist in, and can potentially expand from under changing environmental conditions.

Runnel | A small stream or channel.

Sand sheet | Low-relief sand surfaces largely devoid of dunes although they may exhibit low-relief aeolian features.

Saq Sandstone | The youngest sandstone formation in AlUla. It is a medium-grained, well-rounded sands, with graded bedding, interlaid with shallow marine deposits, demonstrating a transgressive environment. The cement is relatively weakened through hydrolysis and chemical weathering, whereas the marine deposits demonstrate hard iron beds.

Shear zone | Result of faulting from tectonic movements of the opening of the Red Sea, where strain in the rock forces opposing sides to slide past each other. At the fault, the rock is broken and more brittle than the surrounding rock, and these act as weak spots where erosion works faster.

Siq Sandstone | Oldest sandstone formation in AlUla. The formation is composed of several thick beds of medium to coarse-grained beds, with large cross-bedding throughout, indicating high-energy fluvial channels.

Substrate | In ecological terms this is the substance, surface, or base upon which biological processes occur or an organism lives.

Tafoni features | Rounded smooth cavities or hollows in rock. Often grouped and described as honeycomb weathering.

Un-weathered lava flow | As fresh lava flow. Where the basalt lava has not been significantly eroded.

Vegetation type | Dominant plant species and their structural characteristics in an area.

Volcanic cone | A hill-shaped landform that forms around a volcano.

Wadi | The river channel but can also include the floodplain and associated valley of a stream that is usually dry except during the rainy seasons.

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APPENDICES

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APPENDIX 1

CONTRIBUTING PROJECTS

ALULA FLORA PROJECT

Conducted between April 2022 and December 2023 this project was designed to establish a botanical baseline to support conservation and land-use planning in AlUla.

KEY OBJECTIVES

- Inventory the vascular flora of AlUla County, including proposed conservation areas and nature reserves.
- Classify and describe vegetation and habitats across AlUla.
- Produce spatial vegetation and habitat maps, including an assessment of vegetation degradation.
- Develop a practical botanical monitoring plan to support long-term conservation management.

GEOGRAPHIC SCOPE

AlUla County

APPROACH

Field surveys were undertaken in different seasons across AlUla County using a landscape unit approach (Sayre et al., 2014) to support systematic sampling of environmental variation, primarily defined by landform and geology. A total of 819 survey sites were recorded, comprising both detailed vegetation plots and observational records. These data were used to generate a verified species checklist, drawing on field observations, herbarium records, and taxonomic standardisation.

Vegetation classification was based on 539 plot samples, with perennial species used to characterise community composition. Floristic relationships among plots were analysed using Bray–Curtis dissimilarity and hierarchical clustering, supported by bootstrap resampling to assess cluster stability. Resulting vegetation assemblages were interpreted in conjunction with field knowledge and environmental data (including geology, landform, and topography) to define 29 classes. These formed the primary biotic basis for habitat definition. Individual assemblages were linked to broader habitat units through their shared environmental context (e.g. substrate, landform, slope, altitude), allowing floristically defined communities to be interpreted as expressions of underlying habitat types.

Spatial mapping of these units combined field data with remote sensing and environmental predictors. Sentinel-2 imagery and derived vegetation indices were integrated with topographic variables (elevation and slope), and a Random Forest model was applied to predict the distribution of vegetation and habitats across the landscape. Additional analytical work was subsequently undertaken to refine the spatial model. This included the incorporation of expanded predictor datasets (e.g. spectral components, vegetation indices, geology, and texture metrics) and feature selection procedures to improve class discrimination, particularly between mountain and harrat systems.

To support broader interpretation and application, vegetation communities were further aggregated into a set of higher-level habitat classes (e.g. mountains, harrat, plains and wadis, sand dunes, sandstone systems, and agricultural areas). These were mapped using a comparable Random Forest approach, resulting in a generalised habitat map.

Vegetation degradation was assessed using field-based indicators, including grazing pressure, woodcutting, and off-road disturbance. This was supported by analysis of the proportion of increaser and decreaser species.

KEY OUTPUTS

- Annotated Checklist of the Flora of AlUla
- Vegetation classification and map
- Landscape scale habitat map

INVENTORY OF ALULA FAUNA PROJECT

This project was conducted between June 2022 and May 2024 and was aimed at increasing baseline information on the fauna and habitats of AlUla

KEY OBJECTIVES

- Collect baseline information on fauna in the AlUla region.
- Develop guidelines for the long-term conservation, rehabilitation and management of faunal diversity in the region.
- Increase the knowledge and capacity building of the RCU staff in field studies, species identification and monitoring, and species and habitat mapping.
- Develop field guides for birds, reptiles and invertebrates of AlUla region to be used for monitoring, research and tourism purposes.

GEOGRAPHIC SCOPE

AlUla and Khaybar areas. The landcover map is for a rectangular extent.

With a particular focus on 12 conservation areas; Gharameel, AlUla Oasis, Harrat AlZabin, Harrat Khaybar, Harrat Uwayrid, Jabal AlWard, Jabal Nahar, Jabal Shayhoub, Old Khaybar, Sharaan, Tayma, Wadi Nakhlah.

APPROACH

The fauna inventory of AlUla was undertaken using a stratified, multi-method survey design to ensure coverage of the range of environmental conditions across the study area. Sampling locations were defined using an environmental regionalisation approach based on remotely sensed variables (e.g. NDVI and land surface temperature), ensuring representation of key environmental gradients and habitat types.

Field surveys were conducted across 542 sites, including reference, general, fast, and ad hoc sites, using a suite of complementary techniques tailored to different taxonomic groups. These included visual encounter surveys, point counts, camera trapping, acoustic monitoring, mist netting, and live trapping, generating over 38,000 species observations across mammals, birds, reptiles, amphibians, fish, and invertebrates.

Species identification combined field-based methods with laboratory analyses. Standardised photography, taxonomic expertise, and regional reference materials were supplemented by DNA barcoding where required, using mitochondrial markers and phylogenetic comparison to confirm species identity. This enabled a high level of taxonomic resolution, with most vertebrate records identified to species level.

Species distribution patterns were mapped using a GIS framework based on georeferenced observation data within a 10 × 10km grid. To address uneven sampling effort, species distribution models were developed using climatic envelope approaches derived from remotely sensed environmental variables, allowing prediction of occurrence probabilities across the landscape at 1 x 1 km of spatial resolution.

Habitat mapping was undertaken through integration of extensive field-based ground-truthing and remote sensing analysis. Over 11,000 control points describing substrate, geomorphology, vegetation cover, and hydrological conditions were collected and used to develop a supervised land-cover classification. This resulted in a set of broad habitat classes (e.g. volcanic systems, mountains, sandstone, plains, oases, and salt flats) representing the dominant environmental units across AlUla.

Faunal observations were explicitly linked to these habitat classes through the recording of habitat characteristics at each sampling location. This enabled analysis of species–habitat associations and identification of habitat-specific assemblages, as well as supporting the identification of critical habitats such as bat roosts, freshwater systems, oases, and cliff environments that are particularly important for biodiversity.

In addition to inventory and mapping, the approach included assessment of threats and conservation status using IUCN Red List criteria at the regional scale. Spatial prioritisation tools (Marxan) were then applied to species distributions and critical habitats to identify priority areas for conservation and connectivity across the landscape.

KEY OUTPUTS

- Landcover map including 8 habitat classes
- Checklist of fauna
- List of threats following the IUCN standard classification schemes
- Short-term and long-term guidelines for the monitoring of species and habitats
- Recommendations on conservation management and priorities of species, habitats and conservation areas
- Training on specific groups of fauna
- Field guides for mammals, birds, reptiles and invertebrates

BASELINE ASSESSMENT PROJECT

October 2023 – February 2024

The baseline assessment was designed to provide the ecological foundation for restoration planning.

KEY OBJECTIVES

- Establish a robust ecological baseline across soil, vegetation and habitats.
- Conduct field-based soil and vegetation surveys, supported by georeferenced databases.
- Develop high-resolution habitat maps for all six reserves.
- Assess land degradation and ecological condition.
- Identify and spatially delineate priority areas for active ecological restoration.
- Provide decision-support tools, including habitat guidance and priority species lists, to inform restoration, conservation and land management actions.

GEOGRAPHIC SCOPE

Boundaries of the 6 study reserves - Sharaan, Harrat Uwayrid, Harrat AlZabin, Gharameel, Wadi Nakhlah, Harrat Khaybar

APPROACH

The Baseline Assessment was undertaken to provide an integrated ecological foundation for restoration planning across 5 protected areas within AlUla County together with the Khaybar White Volcano Geopark. The approach combined systematic field surveys, laboratory analysis, and spatial modelling within a unified GIS framework to characterise soils, vegetation, habitats, and ecological condition at fine spatial resolution.

Field data collection followed a structured sampling design using grid-based frameworks, quadrats, and transects to ensure representative coverage of environmental gradients within each reserve. Vegetation surveys recorded species composition, structure, and cover, while soil surveys involved detailed in situ description of profile characteristics (e.g. texture, structure, colour, compaction, and surface stoniness) and sampling to a standardised depth of approximately 40 cm. Laboratory analyses included physico-chemical characterisation (e.g. pH, electrical conductivity, carbonate content, and organic carbon), as well as elemental analysis using portable X-ray fluorescence (XRF), enabling quantitative assessment of soil properties relevant to ecosystem function and degradation processes.

Spatial mapping integrated these field datasets with remote sensing and predictive modelling. Sentinel-2 imagery and derived indices (including NDVI) were combined with terrain data (elevation, slope) to generate spatial predictors, which were used within machine-learning workflows (using the proprietary Cassia® platform) to extrapolate field observations across each reserve. This supported the production of high-resolution spatial layers, including Soil Typological Units (STUs), Soil Map Units (SMUs), vegetation distributions, and habitat classes.

Habitats were defined through a hierarchical classification approach based primarily on abiotic drivers, including landform, substrate, and hydrological context, with vegetation characteristics used to support interpretation. This resulted in a set of broad habitat types (e.g. dunes, wadis, volcanic systems, rocky outcrops, and ephemeral depressions) representing the dominant environmental units across the reserves. Soil and vegetation data were used to characterise these habitats and to describe their ecological properties and variability.

A central component of the approach was the assessment of ecological condition and degradation. Field observations and spatial analysis were used to identify and map key pressures, including overgrazing, agricultural disturbance, off-road driving, and soil erosion. These pressures were analysed alongside soil properties and vegetation condition indicators to define patterns of degradation, soil vulnerability, and ecosystem resilience across the landscape.

The resulting datasets were integrated within a spatial prioritisation framework to support restoration planning. Habitat condition, ecological value, connectivity, soil characteristics, and accessibility were combined within a multi-criteria scoring system to identify priority restoration areas within each reserve. In addition, plant species were evaluated for restoration suitability based on ecological function, regeneration potential, and contribution to ecosystem recovery.

KEY OUTPUTS

- Habitat maps
- Habitat manual

APPENDIX 2

SPATIAL ANALYSIS AND INTEGRATION OF HABITAT MAPS

This section explains in detail how multiple habitat maps, produced by the contributing projects using different methods, were combined into a single, coherent habitat map for AlUla.

1. HARMONISATION AND IMPROVEMENT OF INDIVIDUAL CLASSIFICATIONS

The development of the contributing projects outlined in Appendix 1 resulted in the production of three distinct maps covering different areas and relying on unique habitat frameworks, based on a heterogeneous set of habitat characteristics (e.g., floral/fauna communities, soil composition and structure, spectral profiles). Following the establishment of a unified habitat framework, it became necessary to standardise the maps produced by contributing projects, in order to allow their integration into a unified map for AlUla County.

Standardisation was performed independently by the teams involved with each project and largely consisted of three common steps: (1) renaming existing classes to bring them in line with the corresponding class nomenclature defined in the habitat framework; (2) merging existing classes; and (3) splitting existing classes. This last step relied on multiple approaches depending on the contributing project, including manual verification, application of spatial masks to isolate relevant geographic features, use of auxiliary data (e.g., topography) and analysis of satellite imagery time series to identify vegetation seasonality patterns associated with wadis and agricultural lands.

In addition to nomenclature harmonisation, several targeted refinements were undertaken to improve consistency between project outputs and align classifications with the unified habitat framework. These analyses included the derivation of additional habitats from broader habitat classes using topographic and temporal remote-sensing data, refinement of habitat classes derived from the AlUla Fauna Project mapping, and targeted mapping of habitat types that were absent or only partially represented within individual project classifications. Together, these refinements improved alignment between datasets, addressed gaps in habitat coverage, and produced the standardised classification products used as inputs to the subsequent harmonisation workflow.

DERIVATION OF ADDITIONAL HABITATS

Within the AlUla Fauna Project mapping workflow several procedures were conducted to derive habitats identified in the AlUla habitats framework. To distinguish the three mountain habitats, the classification obtained in the last section was overlapped with a Digital Elevation Model (DEM). The overlapping areas between the DEM and the class Mountains allowed the reclassification of the three mountain habitats (i.e., Low mountains with less than 1200 m of altitude; Mid-altitude mountains between 1200-1500 m; and High mountains higher than 1500 m of altitude). The same procedure was used to differentiate Harrat plateaus and harrat slopes, through an overlap between the habitat group Harrats and a slope variable obtained through a DEM.

Regarding the different types of wadis, a time-series dynamic harmonic regression model was developed using the SAVI data from 2020–2024. The model was fitted across the entire region using image-array calculations. Coefficient values were integrated into an unsupervised classification (K-means with 20 fixed clusters, using 1×10^6 randomly distributed points). The clusters that corresponded with wadi regions were selected and later overlapped with the habitat's previous classification, allowing the distinction of the main wadi habitats (e.g., sandy wadis, gravel wadis).

2. CLASSES REQUIRING FURTHER RESEARCH AND MAPPING ANALYSIS

Three main classes were selected for additional mapping analysis, specifically because they were only available from one of the contributing projects and / or were mapped only partially across the AlUla region.

In particular, three classes were targeted:

- Volcanic cones
- Ephemeral flooded depressions
- Ephemeral flooded depressions in volcanic craters

2.1 METHODS TO IDENTIFY CLASSES REQUIRING ADDITIONAL RESEARCH

2.1.1 Volcanic cones

Initial remote sensing analyses were conducted using multispectral satellite imagery (e.g., Landsat 8-9 and Sentinel-2 image collections) to categorise volcanic cones, but due to the lack of spectral resolution usually associated with multispectral data, the distinction between volcanic cones from other habitats, and particularly volcanic sub-classes, was ultimately inconclusive. As such, a second trial was conducted across the entire volcanic regions of AlUla, using a collection of hyperspectral images, specifically from the EnMAP (Environmental Mapping and Analysis Program; www.enmap.org) satellite. The central coordinates of the individual images, scanning areas and temporal periods were defined on the request for image data. The most important parameters were selected based on image quality, referring to the percentage of cloud cover (0%). Only Level-2DA products were selected, since these correspond to the best processed products from EnMAP, available after procedures of atmospheric correction and orthorectification.

In total, the entire volcanic region in AlUla was covered by 37 image scenes, each one with a spatial resolution of 30 m, 224 bands (420–2450 nm) with a spectral resolution of 10 nm and a swath width of 30 km. Following image acquisition, a preliminary analysis was conducted to assess the quality regarding geometric corrections and atmospheric effects through QGIS v.3.34.12-Prizren Long Term Release (QGIS Development Team 2024). Specifically, a plugin developed for hyperspectral data was used, the EnMAP Box v3.13.3 plugin. Each band was observed individually regarding potential radiometric noise typically found in hyperspectral data. After this procedure, different combinations of spectral bands (image composites) were built and analysed to assess their potential contributions to distinguishing the geologic characteristics of volcanic cones and eventually other landscape components. In addition, bands presenting radiometric inaccuracies or lack of data were excluded from the analysis. Finally, a Spectral Angle Mapper algorithm was applied, calibrated with 30 main polygons and validated using a series of control points (N=30). Both the calibration and validation datasets were selected through photointerpretation. All the hyperspectral analysis were conducted using ENVI v.6.1 software.

2.1.2 Ephemeral flooded depressions

Having taken into account that the ephemeral flooded depressions have specific seasonal characteristics, especially in comparison with their surrounding environments or habitats, we applied an approach for the determination of seasonal coefficients using dynamic harmonic regression models. To do this, we analysed a series of satellite images from the Sentinel-2 satellite for the temporal period between 2020 and 2024. Each image was subjected to a process of atmospheric and radiometric correction, following common procedures designated by the European Space Agency. Subsequently, a vegetation spectral index frequently used to identify vegetation status and trends across arid and semi-arid regions, concretely the Soil-Adjusted Vegetation Index (SAVI), was calculated for each image. Then, the harmonic regression models were built on a pixel basis using the SAVI values for the entire period analysis. The main result was an image summarizing the main seasonal components of vegetation across the study area. After this analysis, the resulting image was included in an unsupervised classification. This classification was conducted using 20 maximum clusters and 1% of the total study area pixels as calibration of a K-means clustering algorithm. The unsupervised classification was examined through photointerpretation and using a series of field control points referring to ephemeral flooded depressions (13,800 points, consisting of 10,500 presence points representing ephemeral flooded depressions and 3,300 absence points representing other landscape features), in order to evaluate not only the number of clusters that would correspond to the main class of interest, but also to assess the accuracy of the final clustering selection regarding the separation of ephemeral flooded depressions features.

2.1.3 Ephemeral flooded depressions in volcanic craters

Analogous analyses based on dynamic harmonic regression models were performed to classify this sub-habitat. The remote sensing analyses were inconclusive regarding the distinction of this habitat from the ephemeral flooding depressions, a pattern explained by the very similar spectral and seasonal characteristics of both habitats.

Additional analysis should be conducted in the future, specifically focused on the collection of additional ground-truth data, in order to better characterise the spectral traits of these habitats which eventually will lead to its effective detection in future workflows.

3. MAPPING INTEGRATION AND GENERATION OF FINAL HABITAT GROUP AND HABITATS MAPS

3.1 STANDARDISATION OF PARTNER CLASSIFICATIONS AND ACCURACY ASSESSMENT

The habitat classifications produced by the contributing projects were developed independently and therefore differed in spatial extent, file structure and coding schemes, despite efforts to align them with the updated habitat framework. The AlUla Flora Project produced a classification covering the entirety of AlUla County, while the Baseline Assessment Project focused on the six protected areas of Harrat Uwayrid Biosphere Reserve, Harrat AlZabin Nature Reserve, Khaybar White Volcano Geopark, Gharameel Nature Reserve, Sharaan Nature Reserve and Wadi Nakhlah Nature Reserve. The AlUla Fauna Project covered the largest extent, corresponding to the minimum rectangular area encompassing all six protected areas. Additional differences included pixel-level spatial misalignment, inconsistent numerical coding of habitat classes and variation in file structure, with the Baseline Assessment Project delivered as six separate reserve-level classifications. Consequently, the harmonisation process initially operated on eight independent classification files.

To support harmonisation, all classifications were first standardised to a common spatial and thematic framework. Numerical working codes ranging from 1 to 20 were assigned to the habitat classes, ensuring that the same habitat was represented by the same code across all project outputs. Each classification was reclassified according to a crosswalk table linking original class codes to the harmonised coding scheme.

The AlUla Fauna Project classification was used as the spatial reference because it covered the largest extent. All classifications were aligned to its extent, origin and Coordinate Reference System (CRS). Spatial extents were expanded where necessary, pixel alignment was corrected through reprojection, and areas introduced during standardisation that contained no data were assigned a value of zero to facilitate subsequent processing. The six Baseline Assessment Project classifications were merged into a single raster by identifying the maximum class value for each pixel.

Following standardisation, all project classifications shared a common extent, projection, pixel alignment, spatial resolution (10 x 10 m) and coding scheme, allowing the harmonisation workflow to be applied consistently across all datasets.

3.2 PRODUCTION OF THE SIMILARITY MATRIX

A set of traits characterizing each habitat were gathered from diverse sources, to serve as the basis for the creation of a habitat similarity matrix. General habitat characteristics were included, namely association with steep slopes, presence of pronounced water seasonality dynamics, surface albedo and general habitat class. Water dynamics were further represented using the wetness component of a Tasseled Cap Transformation (TCT). The TCT components were obtained after decomposing an atmospherically corrected surface reflectance Landsat-8 image collection (median of 2020–2024), using the 5-band (green, red, near-infrared, short-wave infrared 1 and short-wave infrared 2) coefficients derived for the Landsat-8 satellite surface reflectance bands (see Zhai et al., 2022). Mean wetness per habitat class was calculated using zonal statistics. This was done independently for each contributing project, to avoid biasing the values towards any particular classification, and the results were averaged to produce a single value per class. Finally, we included a set of descriptive characteristics on dominant geology, major landform and soil (texture, compaction, coloration, presence of roots/rock fragments, structure and coarse surface elements) as described in the soil profiles (Appendix 3). Soil traits were decomposed into sub-categories when necessary to maximise the amount of interclass variability captured in the table and aid the differentiation between classes. For example, texture was partitioned into general granulometry (e.g., sandy, silty, clayish) and presence/absence of loam.

Computation of the habitat similarity matrix was performed using Gower distances to account for the presence of categorical variables (e.g., Dinis et al., 2025). All categorical variables were treated as factorial for the purposes of this calculation, and the resulting distance matrix was then inverted to produce the final similarity matrix. A dendrogram was produced to summarise the matrix in an intuitive format.

The similarity table included a set of 17 habitat traits (Table A2-1). While most of the table was successfully filled out, some fields relating to soil traits contained missing data, corresponding to a total of 9% of the table. These refer predominately to the classes Agricultural lands (where we opted to exclude soil-related data as it can be highly variable within the class), Ephemeral flooded depressions in volcanic craters (for which soil characterisation was not available), and Ephemeral flooded depressions (for which soil data was only partially available).

The similarity matrix showed good differentiation between habitat classes, with unique similarity values for each pair of habitats. This was crucial to avoid situations where two pairs of classes would exhibit the same similarity value, which could cause problems in the similarity voting system. The similarity dendrogram divided the 20 classes into 8 major clusters, largely corresponding to natural groupings of classes (for example, all sandy habitats were grouped into a single cluster, indicating that these classes were treated by the matrix as more similar to each other than to any other habitat; Figure A2-1).

Table A2-1 | Similarity traits used to create the habitat similarity matrix. Zero values represent missing data.

CLASS	SOIL TEXTURE	LOAM	SOIL COMPACTION	PRIMARY COLOUR	SECONDARY COLOUR	BRIGHTNESS	ROOT PRESENCE	STRUCTURE
1100 | Harrat plateau and slopes	Sandy to silty	Yes	Very compact	Brown	NA	Moderate	Without roots	Massive
1200 | Harrat cliffs and steep slopes	NA	Yes	Loose	Brown	NA	Moderate	Without roots	Massive
1300 | Harrat drainage lines and wadis	Clayish	Yes	Compact	Brown	Yellow	Light	Without roots	Massive
1400 | Un-weathered lava flow	NA	Yes	Slightly compact	Brown	NA	Dark	With roots	Massive
1600 | Ephemeral flooded depressions in volcanic craters	0	0	0	0	0	0	0	0
1500 | Volcanic cones	Sandy	Yes	Slightly compact	Grey	NA	Moderate	With roots	Massive
2100 | Sandstone outcrops	Sandy	No	Slightly compact	Brown	NA	Very pale	Without roots	Rock
2200 | Sandstone boulder slopes and screes	Sandy	Yes	Loose	Pink	NA	Moderate	Without roots	Rock
3100 | Sandy plains	Sandy	No	Loose	Yellow	NA	Moderate	With fine roots	Layered
3200 | Sand sheets with exposed bedrock	Sandy	No	Loose	Red	Yellow	Moderate	With roots	Layered
3300 | Sand dunes	Sandy	No	Loose	Yellow	NA	Moderate	With very fine roots	Layered
4100 | High-altitude mountains	Sandy	Yes	Loose	Brown	NA	Very pale	With very fine roots	Massive
4200 | Mid-altitude mountains	Sandy	Yes	Loose	Brown	Yellow	Light	Without roots	Massive
4300 | Low-altitude mountains	Sandy	Yes		Brown	NA	Light	Without roots	Layered
4400 | Gravel plains	Sandy	Yes	Compact	Brown	Grey	Very dark	Without roots	Stratified
5100 | Sandy wadis	Sandy	No	Loose	Yellow	Red	Moderate	With fine roots	Single grain to weakly
5200 | Gravel wadis	Sandy	Yes	Compact	Black	Green	Moderate	Without roots	Layered to single grain
2300 | Sandstone canyons	Sandy	No	Loose	Red	Yellow	Moderate	Without roots	Single grain
5300 | Ephemeral flooded depressions	Silty	Yes	Compact to very compact	Brown	NA	Light	Without roots	0
6100 | Agricultural lands	0	0	0	0	0	0	0	0

ROCK FRAGMENTS	COARSE SURFACE ELEMENTS	MAJOR LANDFORM	ALBEDO	GEOLOGY	SLOPE	WATER DYNAMICS	HABITAT CLASS	WETNESS
Yes	Stones	Plateau	Low	Volcanic basalt	No	No	Volcanics	-0.1208
Yes	Rock fragments	High-gradient of escarpment zone, relief, hill	Low	Volcanic basalt	Yes	No	Volcanics	-0.1176
Yes	Rock fragments	Plateau	Low	Volcanic basalt	Both	Yes	Volcanics	-0.1160
Yes	Lava gravels	Lava	Low	Volcanic basalt	No	No	Volcanics	-0.0707
0	0	0	0	0	No	Yes	Volcanics	-0.1802
Yes	Rock fragments	Grey volcanic relief	Low	Volcanic basalt	Yes	No	Volcanics	-0.1636
No	Rock fragments	Sandstone plateau	Moderate	Sandstone	Yes	No	Sandstone	-0.2837
Yes	Rock fragments	Dissected sandstone plateau with erosional remnants	Moderate	Sandstone	Yes	No	Sandstone	-0.2468
Yes	Gravel	Alluvial plain	High	Sandstone	No	No	Sandy plains and dunes	-0.3246
No	None	Sandstone reliefs & plain	High	Sandstone	No	No	Sandy plains and dunes	-0.3667
No	None	Sandstone reliefs	High	Sandstone	Yes	No	Sandy plains and dunes	-0.3505
Yes	Rock fragments	Mountainous uplands	Low	Pre-Cambrian crystalline basement	Yes	No	High altitude Hijaz Mountains	-0.1512
Yes	Rock fragments	Mountainous uplands	Low	Pre-Cambrian crystalline basement	Yes	No	Hijaz foothills and plains	-0.1456
No	Rock fragments	Foothills / Piedmont plains	Low	Hadiyah Group	Yes	No	Hijaz foothills and plains	-0.1519
Yes	Gravel	Alluvial plain	Moderate	Hadiyah Group	No	No	Hijaz foothills and plains	-0.1655
Yes	Gravel	Valley floor (wadi) and plain	High	Sandstone	Both	Yes	Wadis	-0.2289
Yes	Rock fragments	Valley floor (wadi) and plain	Moderate	Hadiyah Group	Both	Yes	Wadis	-0.1696
Yes	None	Valley floor (wadi)	Moderate	Sandstone	Yes	Yes	Wadis	-0.2586
0	0	0	High	Quaternary deposits	No	Yes	Habitats associated with standing water and moist ground	-0.3236
0	0	0	Low	0	Both	Yes	Anthropogenic	-0.2214

3.3 HARMONISED HABITAT CLASSIFICATION

Production of a harmonised classification was based on a majority voting system (see Figure A2-2), relying on having the three or at least two partner classifications in agreement for any given pixel. Situations of complete disagreement between classifications would be resolved first by assessing the most similar pair of sub-classes, and then by choosing among these two candidates by class-level accuracy metrics.

3.3.1 Data preparation and assignment of priority and single-classification areas

Several habitats were represented in only one project classification and would therefore never achieve a majority vote during harmonisation. These included Sand sheets with exposed bedrock, Sandstone canyons and Sandstone boulder slopes *and screes* (mapped only by the AlUla Flora Project), *Ephemeral flooded depressions in volcanic craters* (mapped only by the Baseline Assessment Project), *Volcanic cones* (mapped throughout the study area by the AlUla Fauna Project), and Un-weathered lava (mapped by the AlUla Fauna Project throughout the study area).

To avoid underrepresentation of these classes in the harmonised classification, pixels containing these habitat classes were placed in a priority habitat mask and removed from the voting system entirely. The harmonised classification instead directly assigned pixels to these classes wherever they occurred.

Due to spectral similarities between habitats with similar substrates (e.g., sandy wadis vs. sandy plains), confusion between wadis and plains was found throughout the harmonised map, leading to an underrepresentation of wadis. The AlUla Fauna Project had produced a high-quality mapping of wadi systems due to its reliance on mapping of seasonal vegetation dynamics (see section 1 of this appendix). The wadis mapped by the AlUla Fauna Project were therefore assigned priority status by reclassification of these wadi classes into higher numerical values than those contemplated in the habitat framework, and combined with the habitat map by determining the maximum value per pixel among the two maps. This approach contemplated the wadi classes 5100 – Sandy wadis and 5200 – Gravel wadis, as well as class 1300 - Harrat drainage lines and wadis.

Also, several mountainous areas in Wadi Nakhlah were misclassified as 1100 - Harrat plateau and slopes, likely due to spectral similarity between local geology and harrats. This issue affected all contributing projects except the AlUla Flora Project, due to the reliance of the latter on auxiliary geological data. Consequently, mountain classes of the AlUla Flora Project were given priority status in Wadi Nakhlah. The area was isolated by a spatial mask derived from the Baseline Assessment Project, and prioritisation of mountains was performed following the same approach used for wadis. All remaining pixels were subject to majority voting.

Figure A2-1 | Clustering dendrogram summarizing environmental distance between habitats, calculated from the habitat similarity matrix.

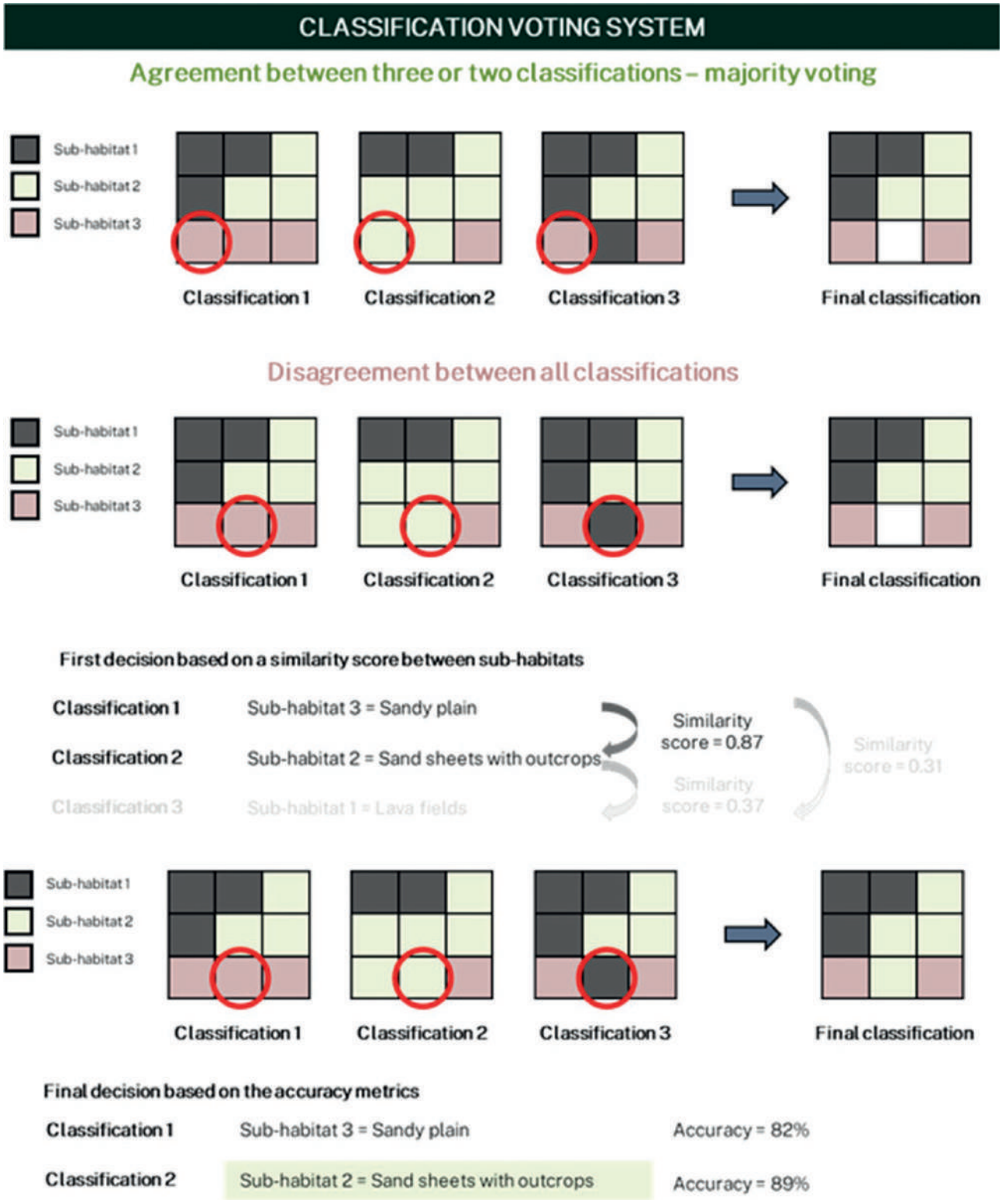


Figure A2-2 Synthesis of the classification voting system applied to integrate individual classifications and obtain the final habitats and habitats maps.

3.3.2 Harmonisation of areas included in all classifications

For areas where classifications from all three projects were available, four agreement masks were generated representing the possible majority-vote outcomes: (1) agreement among all three classifications, (2) agreement between the AlUla Fauna Project and AlUla Flora Project, (3) agreement between the AlUla Fauna Project and Baseline Assessment Project, and (4) agreement between the AlUla Flora Project and Baseline Assessment Project. Pixels contained within each mask were assigned the corresponding majority class. The four majority masks were subsequently combined into a single raster representing all pixels for which a majority decision could be reached. This raster was then inverted to identify pixels where all three classifications disagreed and therefore required additional analysis. The individual agreement masks were retained for subsequent generation of agreement maps.

For pixels where the three classifications disagreed, the habitats identified by each classification were paired and their respective similarities were extracted from the habitat similarity matrix described in section 3.2 of this appendix. The maximum similarity value among them was identified and the partner classification not included in the corresponding pair was excluded from the analysis. The final decision between the two most similar classifications was made by determining which had the highest accuracy. This was achieved by identifying the maximum pixel-level value of the relevant accuracy rasters.

3.3.3 Harmonisation of areas included in only two classifications

Harmonisation of areas where only two classifications were available followed the same general procedure described in Section 3.3.2, but with fewer possible agreement scenarios. Because the AlUla Fauna Project covered the largest spatial extent, all two-classification overlap areas consisted of either AlUla Fauna Project/AlUla Flora Project or AlUla Fauna Project/Baseline Assessment Project combinations. Pixels where the two available classifications agreed were assigned directly to the agreed class.

The resulting majority-vote raster was then inverted to identify pixels where disagreement occurred between the two classifications. For these pixels, class-level accuracy values were compared and the class associated with the highest accuracy was assigned to the harmonised classification

3.3.4 Integration of majority vote outputs

Production of the final harmonised map consisted of the sum of four products previously created (pixels with priority classes, AlUla Fauna Project only, all classifications available, and AlUla Fauna Project / AlUla Flora Project only). The independent analysis of these five scenarios ensured that every pixel was assigned a single habitat class value. Numerical working codes were reclassified to four-digit codes, where the first digit indicates the parent habitat class and the second refers to the distinct habitats within a shared habitat class. The last two digits were kept at zero for further characterisation of habitats (out of the scope of this project).

3.3.5 Final integration results

The harmonisation process produced a classification covering the maximum extent of all contributing classifications, corresponding to the extent of the AlUla Fauna Project, and including all 20 habitat classes. The resulting map was broadly consistent with the known distribution of habitats across AlUla County and surrounding areas, with volcanic habitats dominating the harrats, sandy and sandstone habitats occurring predominantly east and north-east of AlUla, and mountain habitats concentrated in the southwest within the Hijaz mountain range.

Two post-classification corrections were subsequently applied to address residual sources of uncertainty. First, the silty wadi class was merged with Gravel wadis. Although both classes are recognised as distinct mapping units, uncertainty regarding differences in substrate composition limited their reliable separation within the harmonised classification.

Second, mountain areas within Wadi Nakhlah that had been incorrectly classified as Harrat plateau and slopes were corrected. This issue resulted from spectral similarity between local geological features and harrat landscapes, as well as the general underrepresentation of mountain habitats in this area within some project classifications. Because the AlUla Flora Project incorporated auxiliary geological information and produced the most reliable representation of mountain habitats in Wadi Nakhlah, it was used as a reference to replace these misclassified areas with the appropriate mountain classes where available.

3.3.5.1 Habitat-level classification

Creation of a harmonised habitat type classification was done by simple reclassification of the habitat level product. Each habitat class was assigned a unique four-digit code consistent with the numbering scheme. The habitat product was then reclassified to assign each habitat class to the corresponding habitat-level class.

The habitat-level classification followed the same specifications as the habitat classification it was derived from, both in terms of extent and resolution. The classification included all 6 habitat groups. Both habitat type and habitat level classifications were masked to AlUla County

3.3.5.2. Agreement map

An agreement map was produced for all areas where classifications from the three contributing projects overlapped. The four agreement masks generated during harmonisation (full agreement among all three classifications, agreement between the AlUla Fauna Project and AlUla Flora Project, agreement between the AlUla Fauna Project and Baseline Assessment Project, and agreement between the AlUla Flora Project and Baseline Assessment Project) were combined into a single raster. To distinguish complete agreement from partial agreement, the full-agreement mask was assigned a value of 2, while masks representing agreement between two classifications were assigned a value of 1. Pixels where no agreement occurred retained a value of 0. The resulting map therefore represented three levels of agreement: full agreement (2), partial agreement (1) and disagreement (0). The proportional area associated with each level was subsequently calculated to quantify agreement among project classifications.

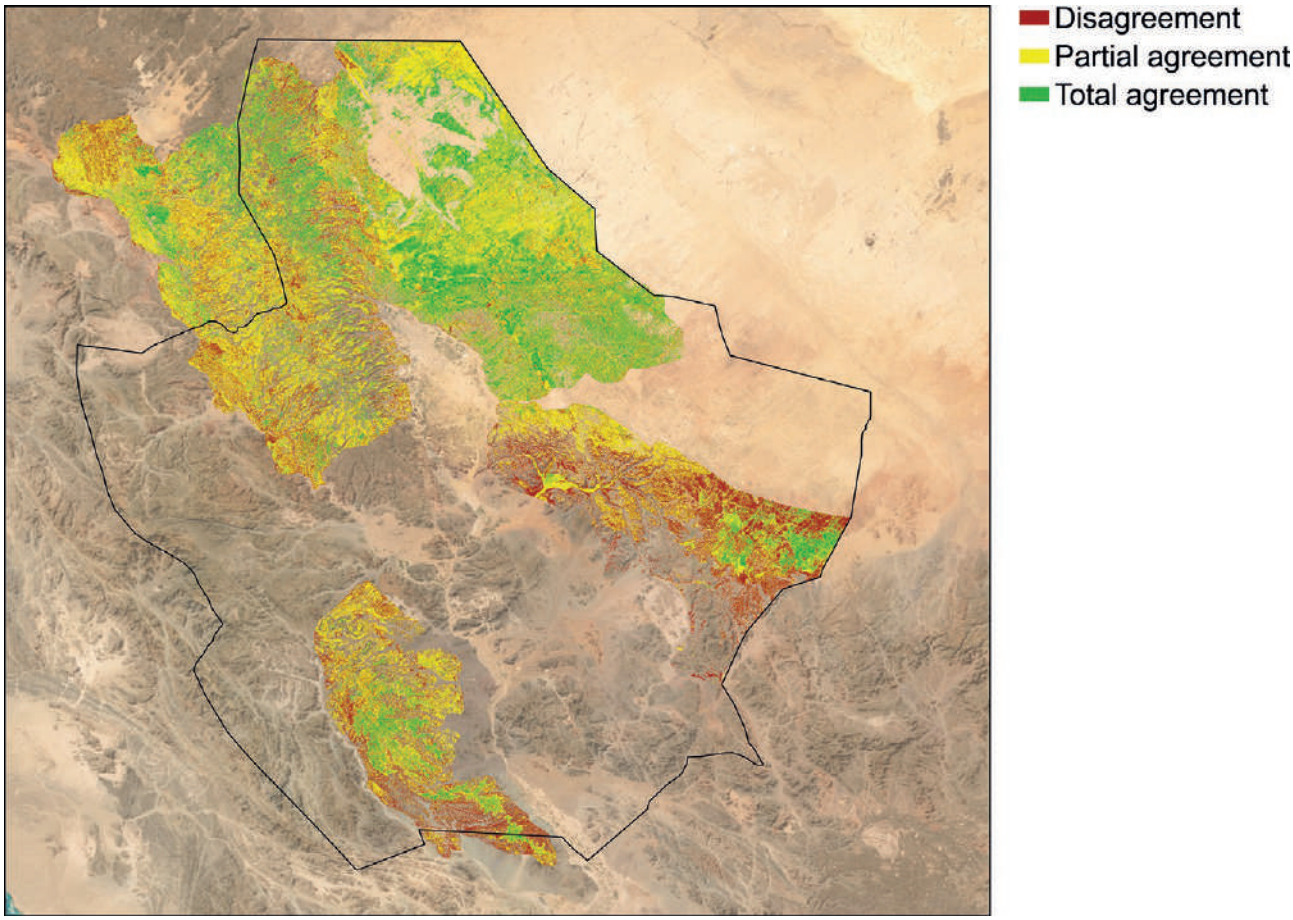


Figure A2-3 | Map of agreement between partner classifications.

The agreement map covered the protected areas where all three classifications were available, namely Harrat Uwayrid, Harrat AlZabin, Gharameel, Sharaan and Wadi Nakhlah. Partial agreement between two classifications was the most common outcome, representing 56% of the analysed area. Full agreement among all three classifications occurred across 26% of the area, while complete disagreement accounted for 18% (Table A2-5). Full agreement was most prevalent in Gharameel and Sharaan, indicating strong consistency among classifications in these areas. In contrast, disagreement was concentrated in Wadi Nakhlah, reflecting the greater environmental heterogeneity and classification complexity of this landscape (Figure A2-3).

VALUE	PIXEL COUNT	% OF PIXELS FOR THE TOTAL AREA
0 - Disagreement	16529932	18%
1 - Partial agreement	51983618	56%
2 - Total agreement	24558936	26%
Total pixel count	93072486	

Table A2-5 | Distribution of agreement levels on the area where all three partner classifications were available. Total number of pixels corresponding to each level of agreement, as well as their respective percentages, are represented. Total number of pixels in the target area is likewise presented.

3.4 VALIDATION OF HARMONISED CLASSIFICATION

Validation of the harmonised classification combined existing ground-truth data collected by the contributing projects (254 points) with an independent photo-interpretation exercise using a stratified sampling approach. Photointerpretation was used to supplement field observations and ensure that all habitat and habitat groups were adequately represented within the validation dataset.

To generate the photo-interpretation dataset, the proportional area occupied by each habitat was calculated and used to determine the required number of validation points per class. An average target of 30 points per class was adopted and adjusted according to class extent, resulting in between 18 and 33 points per class and a total of 564 validation points. The final number of points allocated to each class was constrained to multiples of three to allow equal distribution among project teams. Validation points were then randomly sampled within each habitat class and assigned unique identifiers.

The validation dataset was randomly divided into three equal subsets, each containing the same number of points per class. To ensure a blind assessment, the subsets contained only point identifiers and coordinates, with no information regarding the class assigned by the harmonised classification. The three subsets were then distributed among the participating project teams for independent interpretation.

Photointerpretation was conducted using the most recent ESRI imagery available at the time of analysis, supported by Digital Elevation Model and slope layers. For each validation point, interpreters assigned a habitat class and recorded a confidence score (High, Moderate or Low). Following completion of the exercise, the datasets were integrated and matched to the corresponding classes predicted by the harmonised classification using the unique point identifiers. Only points assigned a high confidence score were retained for accuracy assessment.

Consequently, these high confidence identification points were grouped with the additional ground-truth datasets. As such, the resulting final validation dataset was composed of 488 points. The final accuracy assessment results of the integrated map were then calculated using the R package "caret" v.7.0-1.

The results demonstrate that the habitat groups were classified with high values of accuracy (Table A2-6). The results show that the highest correctly classified rates are associated with volcanic habitats, mountains and associated plains and agricultural lands. These correspond to the classes that are most spectrally distinct, reflected by the high accuracy values in both the individual classifications and consequently in the integrated map. Similarly, these habitats can be identified with a higher degree of confidence through photointerpretation, explaining the high accuracy values at the habitat level. The general accuracy values indicate an overall accuracy of 0.77, with a 95% confidence interval varying between 0.73 and 0.80 (kappa = 0.71), which are considered as high agreement values. Nonetheless, given that the majority of the validation points were derived from photointerpretation, we also evaluated the balanced accuracy metrics. Using the balanced accuracy metrics (Table A2-6), calculated by accounting for correctly identified cases as well as true negative rates, i.e., overall balanced accuracy = (sensitivity + specificity) / 2, we observe high values that correspond to the degree of improvement in the integrated map following the integration of the individual classifications. Considering the general accuracy at the habitat level of the integrated map, the results reveal a general balanced accuracy of 87%.

Table A2-6 | Confusion matrix showing the number of photointerpretation points and ground-truth data correctly classified (diagonal) and incorrectly classified as other habitats. The overall classification accuracy metrics are also indicated, as well as the metrics in accordance with habitat classes (User's, Producer's and Balanced accuracies). The axes numbers refer to each habitat group code number: 1000 - Volcanics; 2000 – Sandstone landforms; 3000 – Sandy plains and dunes; 4000 – Mountains and associated plains; 5000 – Wadis and ephemeral flooded depressions; 6000 – Agricultural lands.

HABITATS	1000	2000	3000	4000	5000	6000	USER'S ACCURACY	BALANCED ACCURACY
1000	92	2	1	3	6	0	0.88	0.91
2000	0	53	7	0	8	2	0.76	0.86
3000	0	7	66	1	17	0	0.73	0.88
4000	14	4	2	78	16	0	0.68	0.89
5000	2	2	1	7	62	0	0.84	0.75
6000	0	1	3	0	8	23	0.66	0.91
Producer's accuracy	0.85	0.77	0.83	0.88	0.53	0.92	0.88	0.95
Overall accuracy	0.77							
Kappa	0.71							
Balanced accuracy	0.87							

At the habitat level, accuracy values are lower compared with those at the habitat group level (Table A2-7). Nevertheless, performance remained high with an overall accuracy of 0.71 (kappa = 0.69), with a 95% confidence interval varying between 0.66 and 0.75, which is considered moderate to high accuracy values. These lower values in comparison to the map at the habitat group level, however, was an expected outcome given the considerably higher categorical resolution of the final integrated habitat map. Classes with low accuracies include the Ephemeral flooded depressions, some volcanic habitats (Harrat drainage lines and wadis and Harrat cliffs and steep slopes) and Gravel plains. These lower scores may be related to specific reflectance separability characteristics, which challenge the distinction by photointerpretation even using auxiliary topographic data. Some examples are the distinction between Harrat drainage lines and wadis and Harrat cliffs and steep slopes, and between Sandstone outcrops and Sandstone boulder slopes and screes. The most evident cases are sandy habitats and the distinction between low- and mid-altitude mountains. Nonetheless, these habitats are not confounded at the habitat group level, as indicated by the high accuracy rates for volcanic

HABITATS	1	2	3	4	5	6	7	8	9	10	11
1	23	0	2	0	3	0	1	0	0	0	6
2	0	29	0	6	0	0	1	1	0	0	0
3	0	0	28	0	0	0	1	0	0	0	1
4	0	4	1	5	0	0	2	1	0	0	0
5	0	0	11	0	39	1	0	0	0	0	0
6	0	0	1	1	1	8	0	0	0	0	0
7	2	0	4	0	2	2	23	0	0	0	1
8	0	5	0	2	0	1	2	17	1	0	0
9	0	1	1	1	0	1	0	0	19	0	0
10	0	2	2	1	0	0	0	0	0	31	0
11	0	0	0	0	1	0	0	0	0	0	4
12	0	3	0	0	0	0	0	0	0	0	0
13	0	2	0	0	0	0	0	0	1	0	0
14	0	1	0	0	0	0	0	1	1	0	0
15	0	0	0	0	0	0	0	0	0	0	0
16	0	0	3	0	6	0	7	0	0	0	2
17	0	0	1	0	0	0	0	0	0	0	0
18	0	0	2	0	2	0	1	0	0	0	0
19	0	0	0	0	0	0	1	0	0	0	0
20	0	0	0	0	1	0	0	0	0	0	0
Producer's accuracy	0.92	0.62	0.50	0.31	0.71	0.62	0.59	0.85	0.86	1	0.29
Overall accuracy	0.71										
Kappa	0.69										
Balanced accuracy	0.82										

and sandstone habitat groups. In contrast, several habitats relevant in the region of AlUla County presented very high balanced accuracy metrics, namely sandy plains, agricultural lands, Gravel wadis, volcanic cones, Ephemeral depressions in Volcanic craters and High-altitude mountains. Considering the general accuracy at the habitat level of the integrated map, the results reveal a general balanced accuracy of 82%. Considering that this habitat map presents a considerable categorical (20 classes) and spatial (10x10 m) resolutions, the balanced accuracy assessment metric is particularly high, corresponding to the quality of the individual classifications of each project partner, but also reflecting the improvements of habitat classifications observed in the integrated map.

Table A2-7 | Confusion matrix showing the number of photo interpretation points and groundtruth data correctly classified (diagonal) and incorrectly classified as other habitats. The overall classification accuracy metrics are also indicated, as well as the metrics in accordance with habitat classes (User's accuracy – UA; Producer's accuracy – PA; and Balanced accuracy – BA). The axes numbers refer to each habitat code number: 1 – Agricultural lands; 2 – Gravel wadis; 3 – Sandy wadis; 4 – Gravel plains; 5 – Sandy plains; 6 – Sand dunes; 7 – Sandstone outcrops; 8 – Low-altitude mountains; 9 – Mid-altitude mountains; 10 – High- altitude mountains; 11 – Ephemeral flooded depressions; 12 – Harrat drainage lines and wadis; 13 – Harrat plateau and slopes; 14 – Harrat cliffs and steep slopes; 15 – Un-weathered lava; 16 – Sand sheets with exposed bedrock; 17 – Sandstone boulder slopes and screes; 18 – Sandstone canyons; 19 – Volcanic cones; 20 – Ephemeral flooded depressions in volcanic craters.

12	13	14	15	16	17	18	19	20	UA	BA
0	0	0	0	0	0	0	0	0	0.66	0.80
1	1	0	0	0	0	0	0	0	0.74	0.75
0	0	0	0	0	0	0	0	0	0.93	0.65
0	0	0	0	0	0	0	0	0	0.38	0.84
0	0	0	0	1	0	0	0	0	0.75	0.80
0	0	0	0	0	0	0	0	0	0.73	0.77
0	0	0	0	1	2	7	0	0	0.52	0.90
3	2	3	0	0	0	0	0	0	0.47	0.92
1	1	1	0	0	0	0	0	0	0.73	0.99
2	1	0	0	0	0	0	0	0	0.79	0.64
0	0	0	0	0	0	0	0	0	0.80	0.50
0	0	0	0	0	0	0	0	0	0.00	0.92
0	37	0	0	0	0	0	2	0	0.88	0.66
0	0	2	0	0	0	1	0	0	0.33	1.00
0	0	0	25	0	0	0	0	0	1.00	0.90
0	0	0	0	10	0	0	0	0	0.36	0.83
0	0	0	0	0	4	0	0	0	0.80	0.83
0	0	0	0	0	0	16	0	0	0.76	0.93
0	1	0	0	0	0	0	13	0	1.00	1.00
0	0	0	0	0	0	0	0	12	0.80	0.80
0.0	0.86	0.33	1.00	0.83	0.67	0.67	0.87	1.00		

APPENDIX 3

SOIL DATA

CODE	HABITAT GROUP	HABITAT
1000	Volcanics	
1100		Harrat plateau and slopes
1200		Harrat cliffs and steep slopes
1300		Harrat drainage lines and wadis
1400		Un-weathered lava flow
1500		Volcanic cones
1600		Ephemeral flooded depressions in volcanic craters
2000	Sandstone landforms	
2100		Sandstone outcrops
2200		Sandstone boulder slopes and screes
2300		Sandstone canyons
3000	Sandy plains and dunes	
3100		Sandy plains
3200		Sand sheets with exposed bedrock
3300		Sand dunes
4000	Mountains and associated plains	
4100		High-altitude mountains
4200		Mid-altitude mountains
4300		Low-altitude mountains
4400		Gravel plains
5000	Wadis and ephemeral flooded depressions	
5100		Sandy wadis
5200		Gravel wadis
5300		Ephemeral flooded depressions
6000	Agricultural lands	
6100		Agricultural lands

Table A3-1 | Showing habitats with complete soil data (shaded). Soil profile information for each of these are included in this appendix.

SOIL DATA METHODOLOGY

Soil mapping was initially developed during the Baseline Assessment through the integration of remote sensing, GIS analysis, and predictive modelling, using multispectral satellite imagery and terrain data to derive soil related indices (including brightness, redness, and carbonate indices). These predictors were used to support digital soil mapping, allowing spatial extrapolation of soil properties across the reserves.

Field validation during the Baseline Assessment was carried out using a systematic grid-based sampling design. Soils were described in situ using standard pedological field indicators, including landform position, surface stoniness, texture, structure, compaction, colour (Munsell notation), evidence of erosion or salinity, and anthropogenic disturbance. A soil sample was collected at a standard depth of approximately 30–40 cm for laboratory analysis. A minimum number of interest (POIs) were investigated for each Soil Typological Unit (STU).

The integration of predictive mapping, field observations and laboratory analyses enabled the identification and characterisation of Soil Typological Units (STUs), representing soil bodies with consistent morphological, physical, and chemical properties. These STUs were subsequently aggregated into Soil Map Units (SMUs), forming the baseline soil classification and mapping framework.

The resulting soil classification and mapping framework was cross-analysed with habitat spatial datasets to establish soil–habitat relationships and assess the representativeness of soil data across ecological units. This cross-analysis enabled the identification of gaps in soil data coverage and sampling representativeness across habitats, which were prioritised for complementary soil surveys. These gaps were addressed through targeted field surveys, using the existing Baseline STU classification framework and applying the same sampling protocol. Up to 15 additional samples were collected per under-represented habitat, depending on accessibility and field conditions.

For at least one point of interest per STU, a reference soil profile was described in detail, recording horizon thickness, texture, structure, rock fragment content, root distribution, and moisture conditions. All locations were georeferenced and supported by photographic documentation of soil surface, profile, and surrounding environment.

Soil samples collected during both phases followed the same preparation and analytical protocol (drying, sieving, grinding) prior to analysis. During the Baseline Assessment, a representative subset of samples from each Soil Typological Unit (STU) was analysed for physico-chemical properties, including pH, electrical conductivity (EC), calcium carbonate ($CaCO_3$), soil organic carbon (SOC), C/N ratio, particle size distribution (granulometry), nutrients (N, P, K), and cation exchange capacity (CEC). These data provided quantitative indicators of soil fertility, salinity, texture and degradation status.

Laboratory analyses focused on soil properties relevant to function and degradation in arid environments. All samples from both the Baseline Assessment and complementary surveys followed a unified analytical workflow combining portable X-ray fluorescence (XRF) and Visible and Near Infrared Reflectance Spectroscopy (VNIRS). XRF quantified the relative abundance of major and trace elements from magnesium (Mg) to uranium (U), while VNIRS, calibrated on regional models, provided estimates of key physical, chemical, and organic soil properties.

Exploratory statistical analyses and multivariate approaches, including principal component analysis (PCA), were used to examine relationships among soil variables and to refine soil typologies. Field observations and laboratory results from the complementary surveys were integrated with the Baseline Assessment dataset to refine the characterisation of existing Soil Typological Units (STUs) and to assign newly surveyed soils to the established soil classification and mapping framework.

For habitat characterisation, soil information was subsequently integrated at the habitat level. Landscape, Soil Surface, and Soil Profile descriptions were derived from the dominant STU identified within each habitat, while Soil Texture and Soil Properties were based on the pooled analytical results from all STUs represented within the habitat. This approach allowed the capture of both the dominant soil characteristics and the full range of physicochemical variability, providing a comprehensive representation of soil heterogeneity at the habitat scale.

1100 | HARRAT PLATEAU AND SLOPES

The predominant soil type in the area is a loam derived from the weathering of parent material, with a surface overlay and sometimes subsurface mix of basaltic rocks and gravels from post volcanic activity.

LANDSCAPE

Major landform: Plateau
Minor landform: Harrat plateau
Topography: Flat
Dominant bedrock: Basaltic and picrite–ankaramite lavas.



SOIL SURFACE

Land use: Natural
Coarse surface elements: Surface covered by stones
Salt: None



SOIL PROFILE

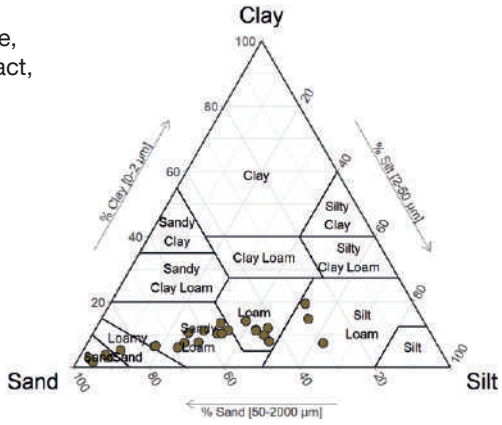


SOIL PROFILE DESCRIPTION

H1: 0 to 100 cm

Loamy texture, massive structure, with rock fragments, very compact, without roots, brown

SOIL TEXTURE

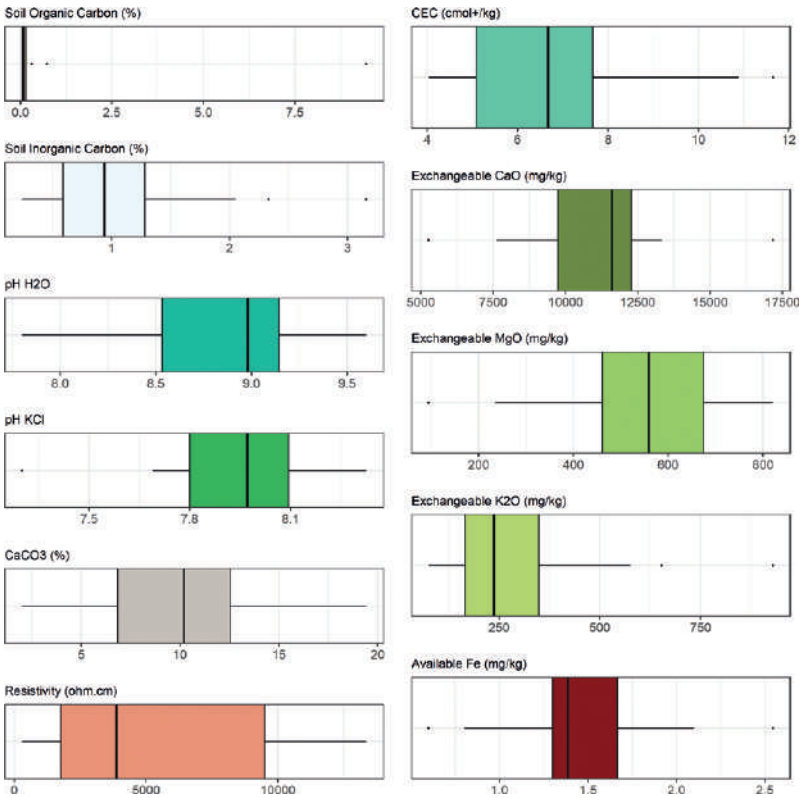


SOIL PROPERTIES

Soil texture varies from sand to silt loam, reflecting heterogeneous volcanic and colluvial inputs, physical weathering, and the incorporation of volcanic gravels. This results in well-drained conditions, although water retention remains limited in the coarser fractions.

Soil organic carbon is extremely low, indicating minimal biological activity and limited organic inputs. The soils are strongly alkaline. Despite moderate calcium carbonate contents, the elevated pH H_2O mainly reflects evaporation-induced concentration of soluble alkaline constituents, particularly bicarbonates, in the soil solution, rather than simple calcite buffering. Cation exchange capacity is low to moderate, while electrical resistivity indicates non-saline to weakly saline conditions. The exchange complex is base-rich, with high exchangeable calcium and magnesium levels, alongside moderate to high potassium levels, reflecting the mafic volcanic parent material.

Despite this high base status, nutrient availability remains constrained: elevated pH severely restricts micronutrient solubility, particularly iron, and reduces phosphorus availability through precipitation as poorly soluble calcium phosphates. Overall, these weakly developed volcanic soils combine limited water retention with chemical constraints related to high alkalinity.



1200 | HARRAT CLIFFS AND SLOPES

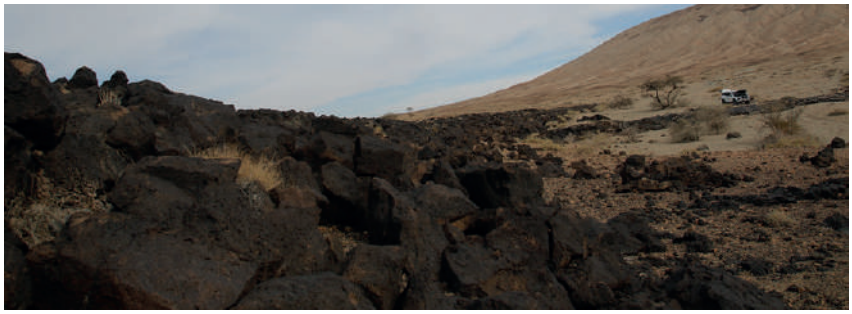
Located in the steep stony slopes, these shallow soils (30–40 cm average depth) are found in micro-depressions and flat areas between rocks. The sloping position of these soils makes them susceptible to erosion by run-off. Only plant species resistant to these difficult conditions can establish themselves at an economical growth rate.

LANDSCAPE

Major landform: High-gradient of escarpment zone, relief, hill
Minor landform: Upper slope
Topography: Slope
Dominant bedrock: Basalt.

SOIL SURFACE

Land use: Natural
Coarse surface elements: Surface covered by various rock fragments
Salt: None





SOIL PROFILE

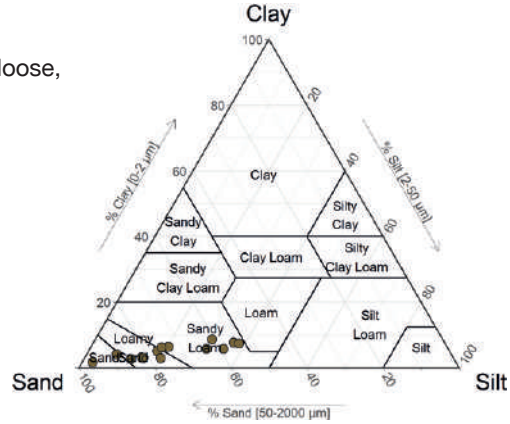


SOIL PROFILE DESCRIPTION

H1: 0 to 10cm
Sandy Loam texture, massive structure, with rock fragments, loose, without roots, brown

H2: 10 to 35cm
Sandy Loam texture, massive structure, with rock fragments, compact, without roots, brown

SOIL TEXTURE



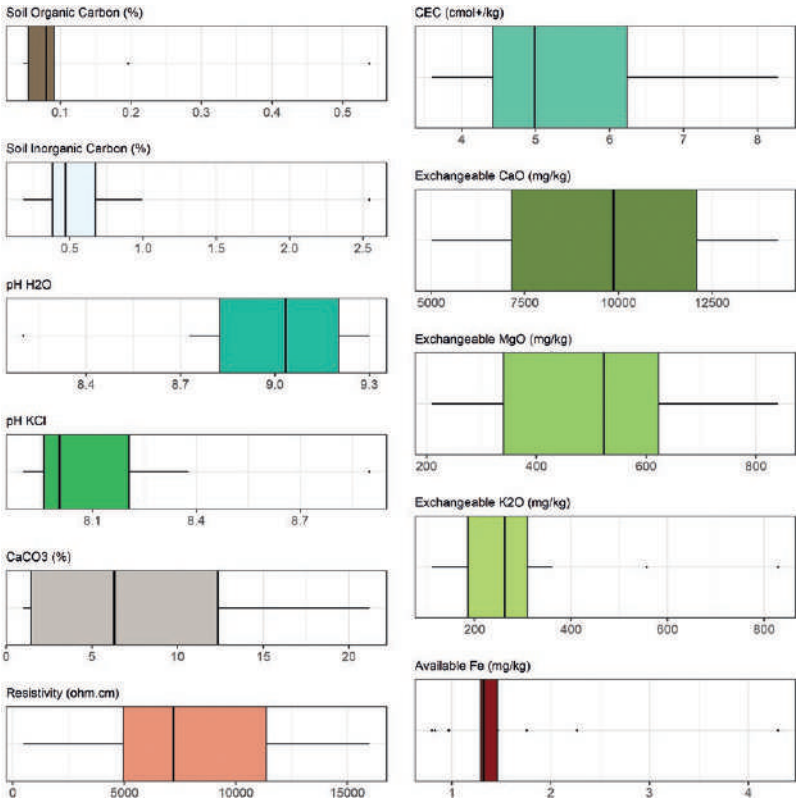
SOIL PROPERTIES

Shallow soils on these stony volcanic slopes occur mainly in rock depressions where fine material accumulates. Dominated by coarse textures (sand to sandy loam), they promote rapid drainage but restrict water and nutrient retention.

Soil organic carbon is very low, reflecting sparse organic inputs and restricted biological activity. Cation exchange capacity is low to moderate. The soils are very strongly alkaline, driven by intense evaporation and the concentration of soluble alkaline constituents in the soil solution. With low to moderate calcium carbonate contents, the base-rich exchange complex is dominated by exchangeable calcium and magnesium, consistent with the basaltic parent material. Electrical resistivity indicates non-saline conditions.

Exchangeable calcium and magnesium levels are high, alongside moderate potassium levels, reflecting the influence of the underlying basaltic volcanic lithology. Despite this relatively high base status, nutrient availability remains constrained: iron solubility is strongly reduced under alkaline conditions, while phosphorus availability may be limited through the formation of poorly soluble calcium phosphates.

Overall, these soils are shallow, weakly developed, and chemically constrained, combining limited water-holding capacity with high susceptibility to erosion.



1300 | HARRAT DRAINAGE LINES AND WADIS

Stony alluvial soil in the wadis of the Harrat plateau. It originates from strong erosion-deposition processes driven by water, capable of transporting rock fragments down to stones. Plants growing in these soils benefit from drained water but may occasionally be subjected to these erosive factors.

LANDSCAPE

Major landform: Plateau
Minor landform: Valley floor (wadi) and plain
Topography: Flat, low gradient slope
Dominant bedrock: Basalt



SOIL SURFACE

Land use: Natural
Coarse surface elements: Surface covered by various rock fragments
Salt: None



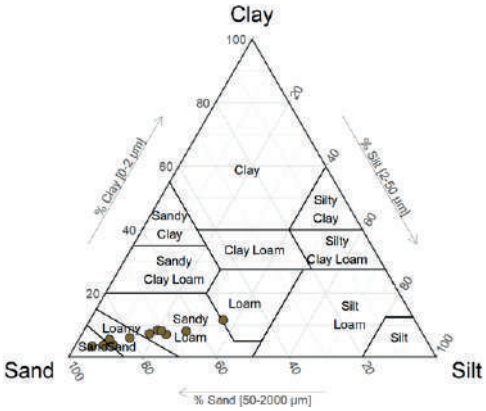
SOIL PROFILE



SOIL PROFILE DESCRIPTION

H1: 0 to 30 cm
Sandy loam texture, massive structure, with rock fragments, compact, without roots, light yellowish brown

SOIL TEXTURE

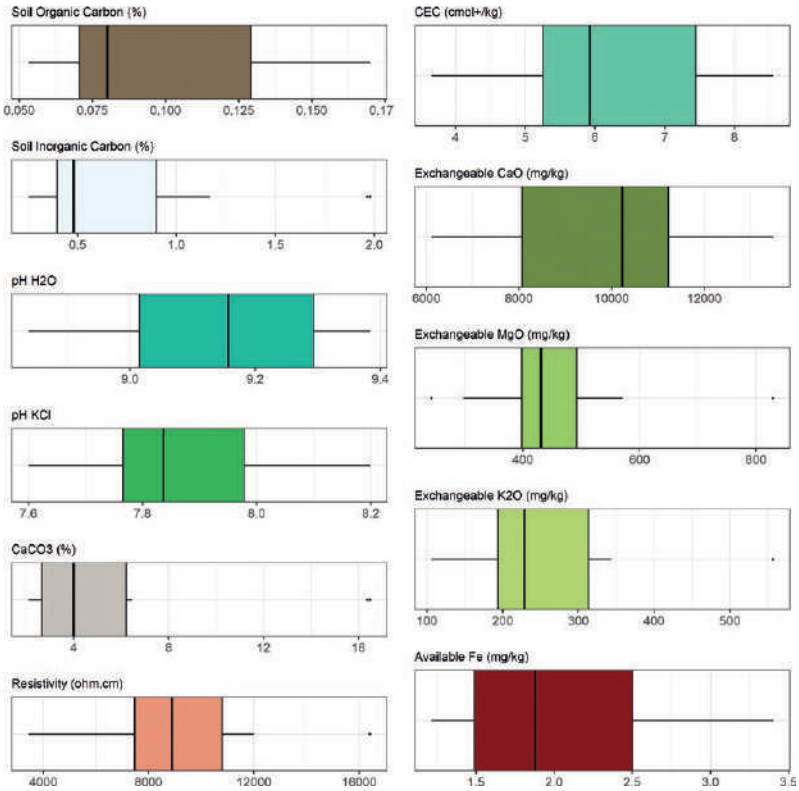


SOIL PROPERTIES

Harrat drainage lines and wadis are shaped by episodic high-energy runoff, accumulating heterogeneous stony alluvial materials across valley floors and adjacent plains. Textures range from sand to sandy loam, with abundant coarse fragments promoting rapid drainage and limiting water retention.

Soil organic carbon and soil inorganic carbon are extremely low, reflecting sparse organic inputs and active sediment turnover. The soils are very strongly alkaline. Despite low calcium carbonate contents, the elevated pH H_2O is driven by evaporation-induced concentration of soluble alkaline constituents, particularly bicarbonates, in the soil solution. Cation exchange capacity is low, while electrical resistivity indicates non-saline conditions. The exchange complex is base-rich and dominated by exchangeable calcium, accompanied by moderate to high levels of exchangeable magnesium and potassium derived from the mafic basaltic alluvium. Elevated pH constrains micronutrient availability, particularly iron, and reduces phosphorus availability through precipitation as poorly soluble calcium phosphates.

Overall, these soils exhibit weak pedogenic development, combining limited water storage with chemical constraints on nutrient availability despite their base-rich exchange complex.



1400 | UN-WEATHERED LAVA FLOW

In the micro-depression of the lava geologic formations, fine particles have been deposited over time with wind and water, forming very shallow soil (30–40 cm average depth) accumulation, silt-clay which in turn allows the germination of the few seeds

LANDSCAPE

Major landform: Lava
Minor landform: Depression
Topography: Depression
Dominant bedrock: Recent basalt flows

SOIL SURFACE

Land use: Natural
Coarse surface elements: Surface covered by lava gravels
Salt: None





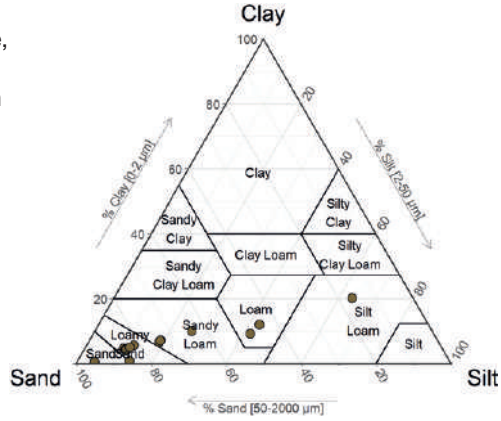
SOIL PROFILE



SOIL PROFILE DESCRIPTION

H1: 0 to 30 cm
loamy texture, massive structure, with rock fragments, slightly compact, with roots, dark brown

SOIL TEXTURE



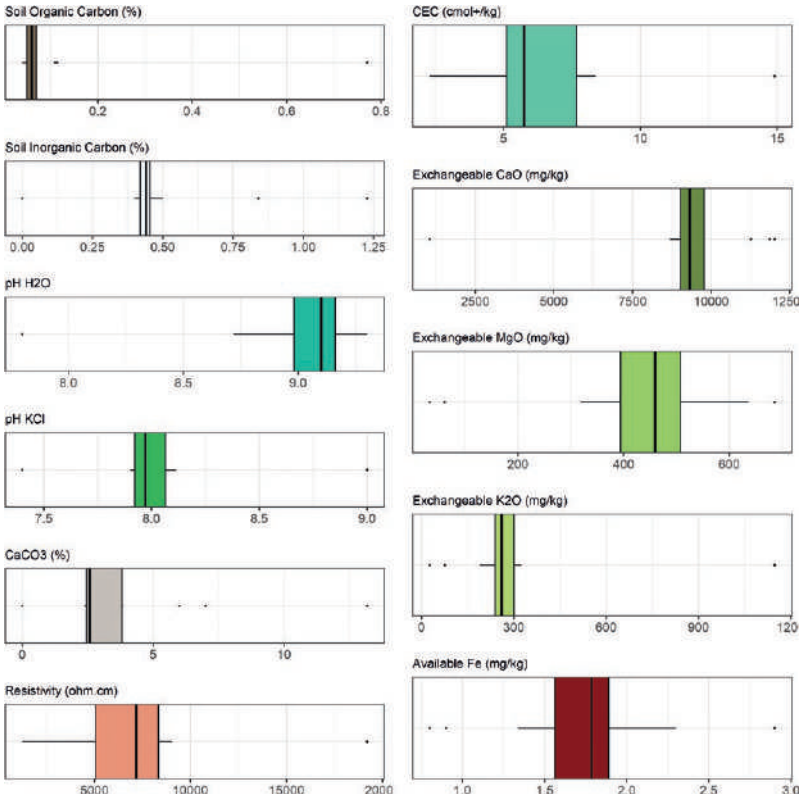
SOIL PROPERTIES

These young volcanic soils are coarse-textured, ranging from sand to silt loam, and develop on young basaltic lava flows under hyper-arid conditions. Pedogenesis is extremely weak because of the fragmented substrate and irregular microtopography, while fine particles accumulate in rock depressions through aeolian deposition and localized runoff, forming shallow pockets that support sparse vegetation.

Soil organic and inorganic carbon contents are extremely low, reflecting minimal organic inputs and weak calcification. The soils are very strongly alkaline, with pH H_2O substantially higher than pH KCl. Despite low calcium carbonate contents, alkalinity reflects evaporation-induced concentration of soluble constituents, particularly bicarbonates. Electrical resistivity indicates non-saline to weakly saline conditions.

Cation exchange capacity is low to moderate because of limited clay and organic matter, whereas exchangeable calcium and magnesium remain high, reflecting weathering of the mafic basaltic parent material. Elevated pH strongly restricts micronutrient solubility, particularly iron, and favors phosphorus precipitation as poorly soluble calcium phosphates.

Overall, these soils are early-stage volcanic systems controlled by mafic lithology, aridity, and limited biological activity.



1500 | VOLCANIC CONES

These soils come from volcanic and colluvial deposits. They are located on the slopes of volcanic reliefs which by erosion and deposition form these accumulations soils. These soils are potentially rich in mineral elements.

LANDSCAPE

Major landform: Grey volcanic relief
Minor landform: Foot of volcanic relief
Topography: Medium-low gradient slope
Dominant bedrock: Trachyte pyroclastics



SOIL SURFACE

Land use: Natural
Coarse surface elements: Surface covered by rock fragments
Salt: None



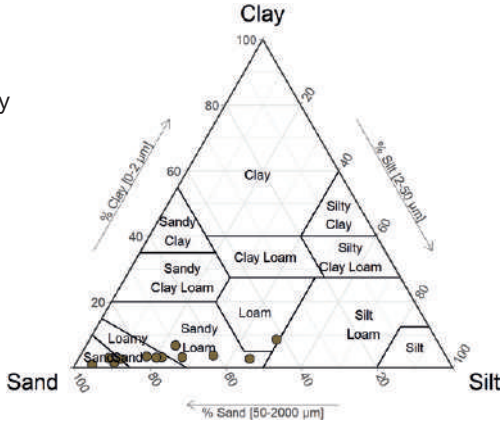
SOIL PROFILE



SOIL PROFILE DESCRIPTION

H1: 0 to 40 cm
Sandy loam texture, massive structure, with rock fragments, slightly compact, with roots, grey

SOIL TEXTURE

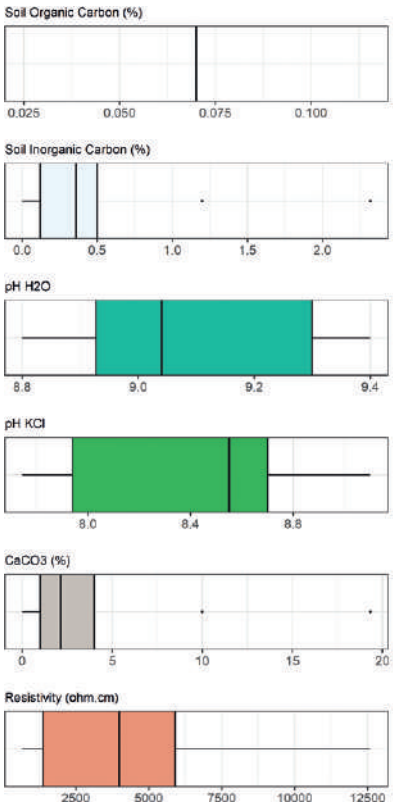


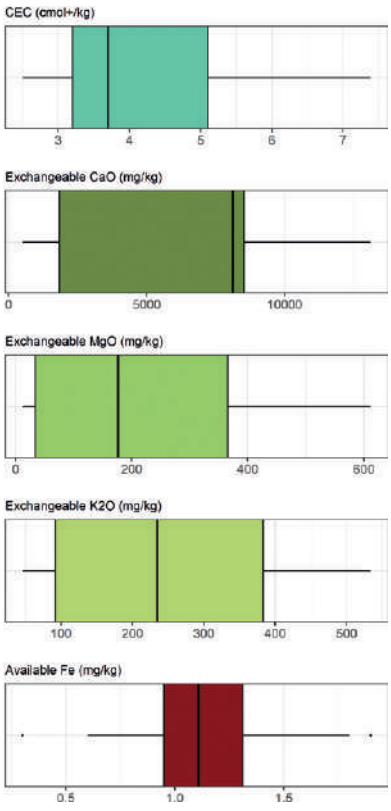
SOIL PROPERTIES

Textures range from sand to sandy loam and local loam, reflecting heterogeneous volcanic ash and colluvial deposits on the slopes of volcanic cones. These coarse-textured materials promote rapid drainage and limited water retention and contain abundant volcanic rock fragments.

Soil organic carbon and soil inorganic carbon are extremely low. The soils are very strongly alkaline. Despite very low calcium carbonate contents, this elevated pH H_2O is driven by intense evaporation concentrating soluble alkaline constituents, particularly bicarbonates, in the soil solution. Cation exchange capacity is low to very low, consistent with the scarcity of fine colloids and organic matter. Electrical resistivity indicates non-saline to weakly saline conditions. Exchangeable calcium dominates the base-rich exchange complex, accompanied by moderate magnesium and potassium levels derived from the mafic basaltic substrate. Micronutrient availability, particularly iron, is strongly restricted under elevated pH, while phosphorus availability is reduced through precipitation as poorly soluble calcium phosphates.

Overall, these young volcanic soils combine rapid drainage with chemical constraints related to high alkalinity, despite the base-rich nature of the exchange complex.





2100 | SANDSTONE OUTCROPS

Soils develop as very shallow accumulations within small pockets, fissures, and depressions on eroded sandstone surfaces. Their formation results from the combined effects of sandstone weathering and the deposition of wind- and water-transported fine particles, allowing limited pedogenesis in an otherwise exposed and rocky environment.

LANDSCAPE

Major landform: Sandstone plateau
Minor landform: Rocky outcrops, mesas and summits
Topography: Elevated, dissected relief with steep edges and exposed bedrock
Dominant bedrock: Quartz sandstones (Quweira, Ram, Umm Sahm)



SOIL SURFACE

Land use: Natural
Coarse surface elements: Surface covered by various rock fragments
Salt: None



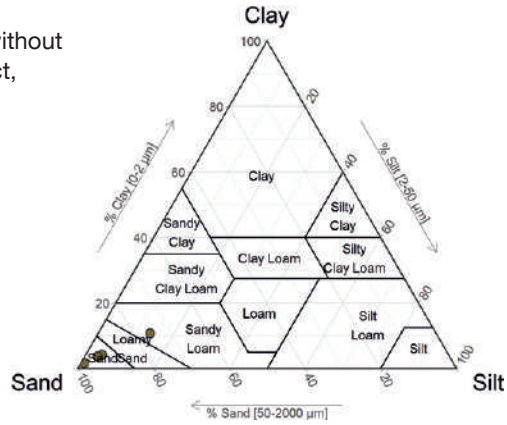
SOIL PROFILE



DESCRIPTION

H1: 0 to 30 cm
Sandy texture, rock structure, without rock fragments, slightly compact, without roots, very pale brown

SOIL TEXTURE



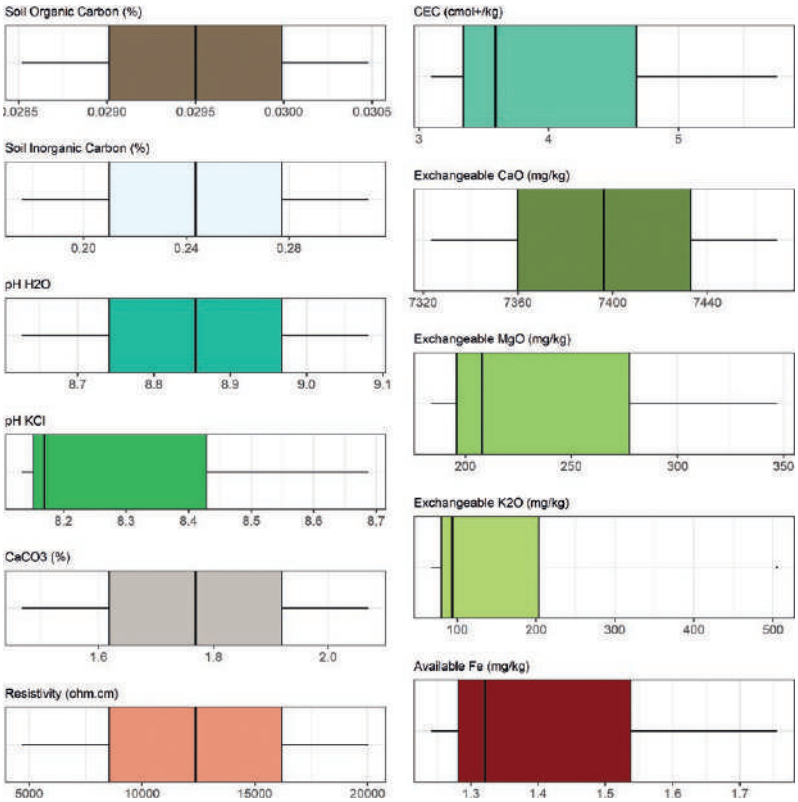
SOIL PROPERTIES

These shallow soils (30–40 cm average depth) develop in sandstone pockets and fissures through weak weathering and localized fine material accumulation. Textures range from sand to sandy loam across microsites.

Organic carbon and cation exchange capacity are very low, reflecting limited organic matter and clay contents. Soils are strongly alkaline, reflecting evaporation and limited leaching under arid conditions. Calcium carbonate contents are low, yet extractable calcium dominates the exchange complex while pH KCl remains alkaline, indicating a persistently alkaline chemical environment. Electrical resistivity confirms non-saline conditions.

High pH limits iron solubility and phosphorus availability, while low magnesium and potassium levels reflect the siliceous sandstone substrate.

Overall, these weakly developed sandstone soils exhibit low fertility and strong limitations for plant establishment.



2200 | SANDSTONE BOULDER SLOPES AND SCREES

This soil originates from intense mechanical weathering of sandstone combined with gravity-driven erosion processes, producing coarse sand, gravel, and angular rock fragments that accumulate on scree slopes and at the base of cliffs. These soils are shallow (30–40 cm average depth) and weakly developed, reflecting limited pedogenic processes under hyper-arid climatic conditions.

LANDSCAPE

Major landform: Dissected sandstone plateau with erosional remnants
Minor landform: Sandstone cliffs, boulder slopes, scree, ledges, residual pillars
Topography: Rugged cliffs and slopes
Dominant bedrock: Quartz sandstones (Quweira, Ram, Umm Sahm)

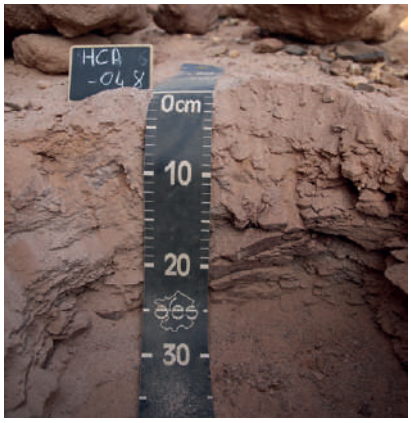


SOIL SURFACE

Land use: Natural
Coarse surface elements: Surface covered by various rock fragments
Salt: None



SOIL PROFILE



DESCRIPTION

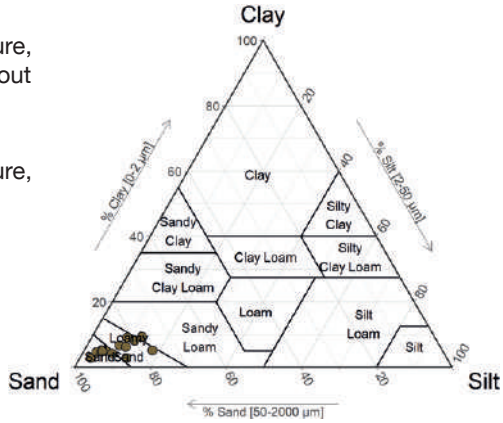
H1: 0 to 5 cm

Sandy loam texture, rock structure, with rock fragments, loose, without roots, pink

H2: 5 to 40 cm

Sandy loam texture, rock structure, with rock fragments, compact, without roots, pink

SOIL TEXTURE



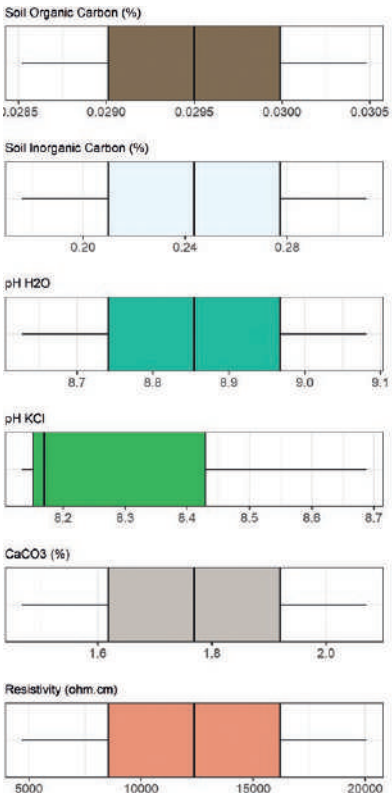
SOIL PROPERTIES

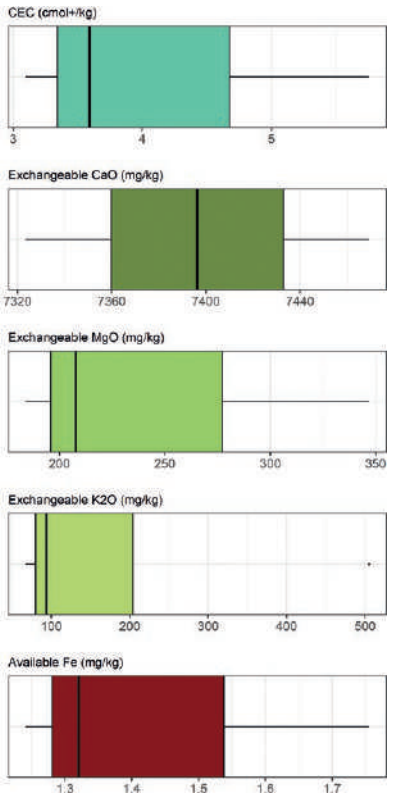
These shallow soils develop on sandstone boulder slopes, scree and ledges, where fine aeolian and colluvial material accumulate over minimally weathered substrate. Coarse textures (sand to loamy sand) promote rapid drainage but severely limit water and nutrient storage. Together with steep slopes and sparse vegetation, this results in high erosion risk.

Pedogenic development is weak, with extremely low organic and inorganic carbon. Soils are very strongly alkaline. Despite low calcium carbonate content, elevated pH reflects evaporation-driven concentration of soluble alkaline constituents, particularly bicarbonates, rather than carbonate accumulation. Cation exchange capacity is low to very low, limited by scarce clay and organic colloids. Electrical resistivity indicates non-saline conditions.

Exchangeable calcium dominates the exchange complex; magnesium and potassium are subordinate, consistent with the siliceous sandstone substrate. High pH strongly limits micronutrient availability, especially iron, while phosphorus is immobilized as poorly soluble calcium phosphates.

Overall, these weakly developed sandstone soils show low natural fertility and high erosion susceptibility.





2300 | SANDSTONE CANYONS

These soils formed from fluvial deposits shaped by erosion and sedimentation. Located downstream of rocky and unstable slopes, their stony texture reflects the energy and turbulence of past floods, while visible stratification reveals changes in flow velocity during deposition.

LANDSCAPE

Major landform: Valley floor (wadi)
Minor landform: Valley floor (wadi)
Topography: Flat, low gradient slope
Dominant bedrock: Quartz sandstones (Quweira, Ram, Umm Sahm)

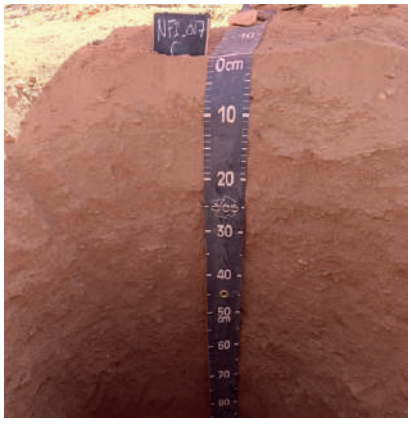


SOIL SURFACE

Land use: Natural
Coarse surface elements: None
Salt: None



SOIL PROFILE



SOIL PROFILE DESCRIPTION

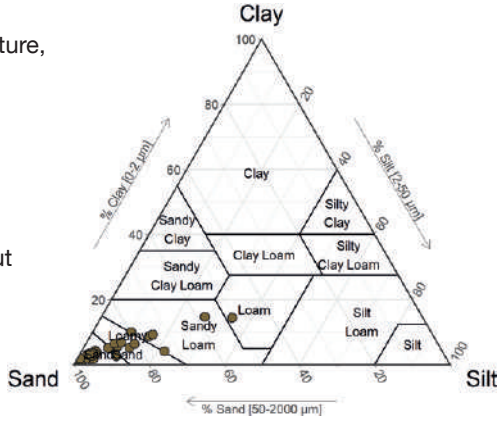
H1: 0 to 15 cm

Sandy texture, single grain structure, with fine gravel rock fragments, loose, without roots, yellowish-reddish

H2: 15 to 100

Sandy loam texture, massive structure, with fine gravel rock fragments, very compact, without roots, reddish

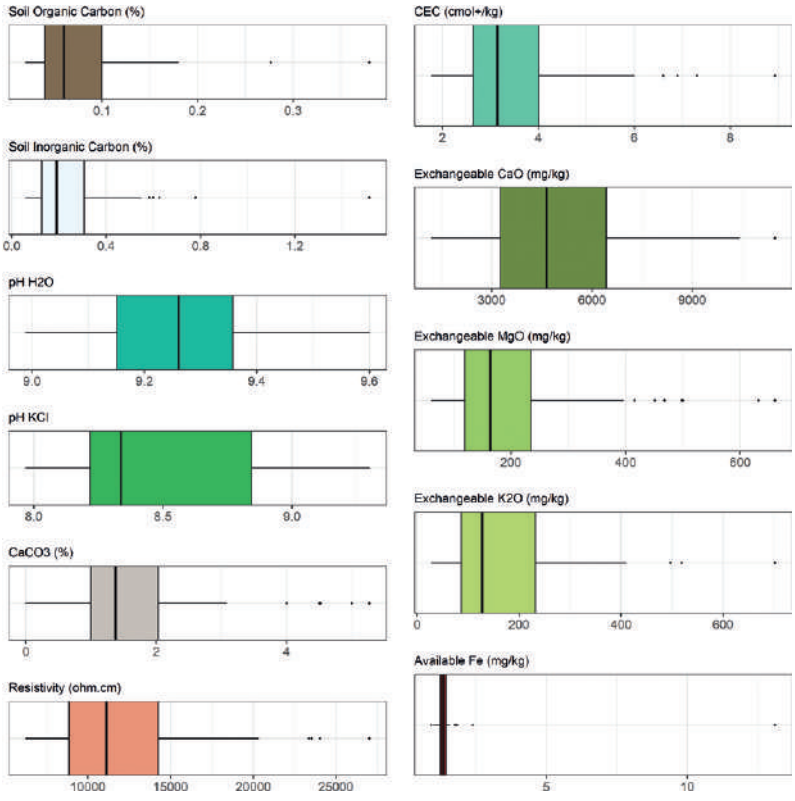
SOIL TEXTURE



SOIL PROPERTIES

These soils occur in wadi systems within narrow sandstone canyons, where textures range from sand to loamy sand, sandy loam, and occasional loam fractions, reflecting mechanical weathering of sandstone parent material and episodic alluvial inputs from flash floods.

Soil organic carbon and inorganic carbon are extremely low, indicating limited biological activity and organic inputs. The soils are very strongly alkaline. Despite low calcium carbonate contents, this elevated pH H_2O is driven by intense evaporation-induced concentration of soluble alkaline constituents, particularly bicarbonates, during dry periods following episodic flood events. Cation exchange capacity is very low, reflecting sandy dominance and limited clay or colloidal fractions. Electrical resistivity indicates non-saline conditions in these dry environments. The exchange complex is base-rich and dominated by exchangeable calcium, accompanied by moderate exchangeable magnesium and low to moderate potassium levels. Under strongly alkaline conditions, micronutrient availability is severely restricted, particularly through reduced iron solubility, while phosphorus availability is limited through calcium phosphate precipitation. Overall, these soils are weakly developed and well-drained alluvial systems, characterized by poor nutrient retention, limited nutrient availability, and restricted water retention capacity.



3100 | SANDY PLAINS

This alluvial soil is the result of the transport and deposition of sand particles, creating a lamellar structure. One of the characteristics of this soil is its high-water permeability.

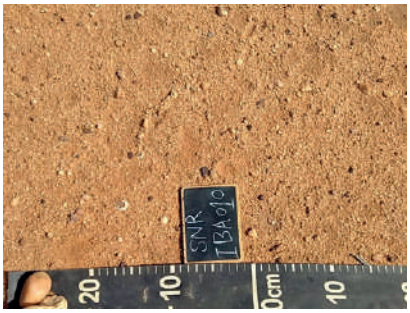
LANDSCAPE

Major landform: Alluvial plain
Minor landform: Valley floor (wadi) and plain
Topography: Flat, low gradient slope
Dominant bedrock: Quartz sandstones (Quweira, Ram, Umm Sahm)



SOIL SURFACE

Land use: Natural
Coarse surface elements: Surface covered by gravels
Salt: None



SOIL PROFILE

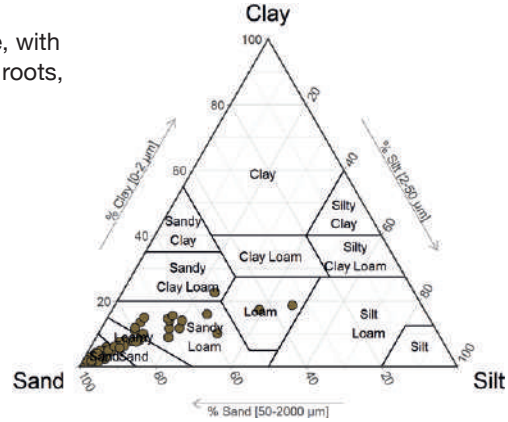


SOIL PROFILE DESCRIPTION

H1: 0 to 50 cm

Sandy texture, layered structure, with rock fragments, loose, with fine roots, yellow

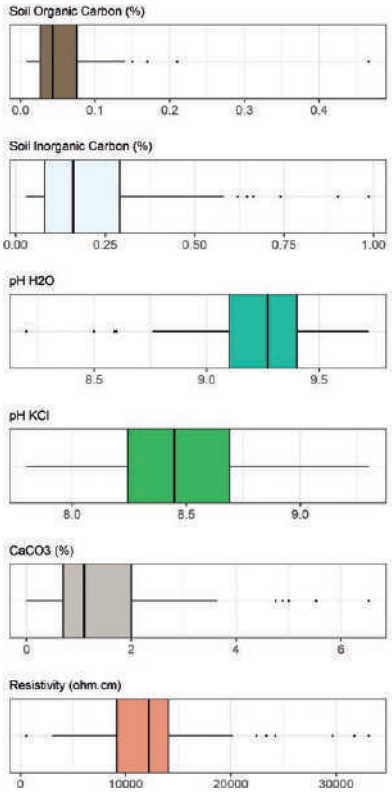
SOIL TEXTURE

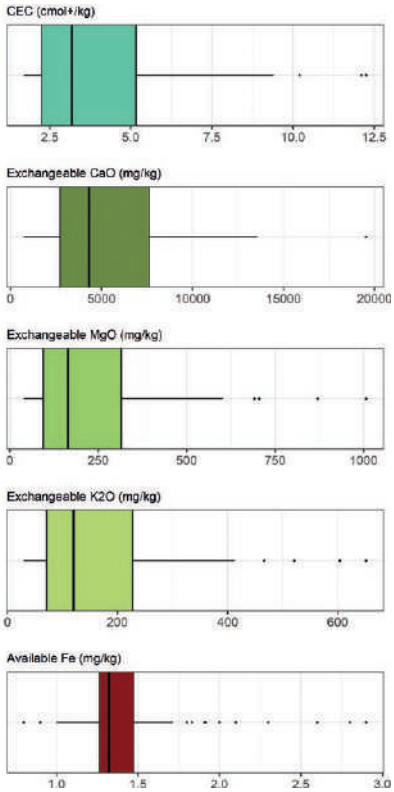


SOIL PROPERTIES

These soils develop on flat sandy plains, with coarse textures ranging from sand and loamy sand to sandy loam, alongside minor local finer fractions. These sandy materials confer high permeability, rapid drainage, and very low water-holding capacity.

Soil organic carbon and inorganic carbon are extremely low, reflecting sparse vegetation cover and limited organic inputs. The soils are very strongly alkaline. Despite very low calcium carbonate contents, this elevated pH H_2O is driven by intense evaporation-induced concentration of soluble alkaline constituents, particularly bicarbonates, in the soil solution. Cation exchange capacity is low to very low, constrained by the scarcity of clay and organic colloids. High electrical resistivity confirms non-saline conditions. The exchange complex is base-rich and dominated by exchangeable calcium, accompanied by moderate magnesium and potassium levels. Elevated pH strongly restricts micronutrient availability, particularly iron, while phosphorus availability is reduced through precipitation as poorly soluble calcium phosphates under alkaline conditions. Overall, these coarse-textured soils represent weakly developed sandy systems characterized by poor nutrient retention, limited nutrient availability, and severe water constraints.





3200 | SAND SHEETS WITH EXPOSED BEDROCK

This soil is characterized by a very shallow depth (30–40 cm average depth) and a sandy texture. The sand particles are mobile and deposited directly on the bedrock. These soils are well-drained due to their coarse texture, facilitating excellent permeability and aeration. However, their nutrient retention capacity may be limited.

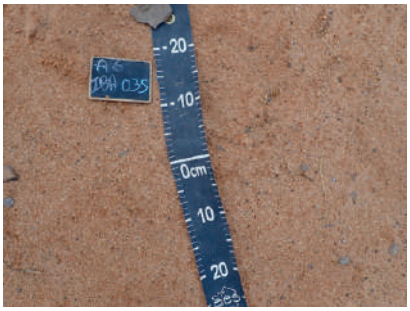
LANDSCAPE

Major landform: Sandstone reliefs & plain
Minor landform: Plain
Topography: Flat
Dominant bedrock: Saq sandstone

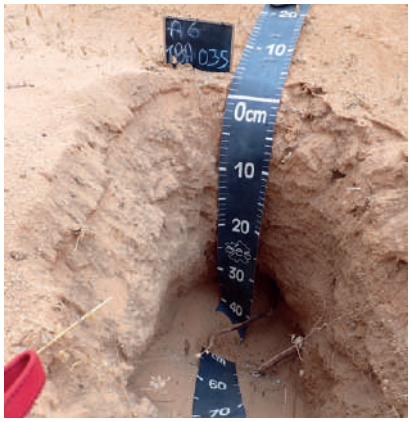
SOIL SURFACE

Land use: Natural
Coarse surface elements: None
Salt: None





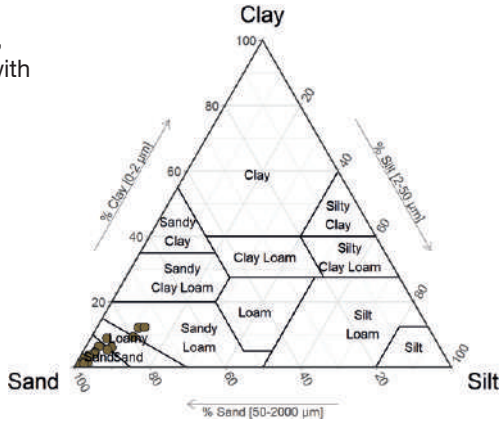
SOIL PROFILE



SOIL PROFILE DESCRIPTION

H1: 0 to 40 cm
Sandy texture, layered structure, without rock fragments, loose, with roots, yellowish red

SOIL TEXTURE

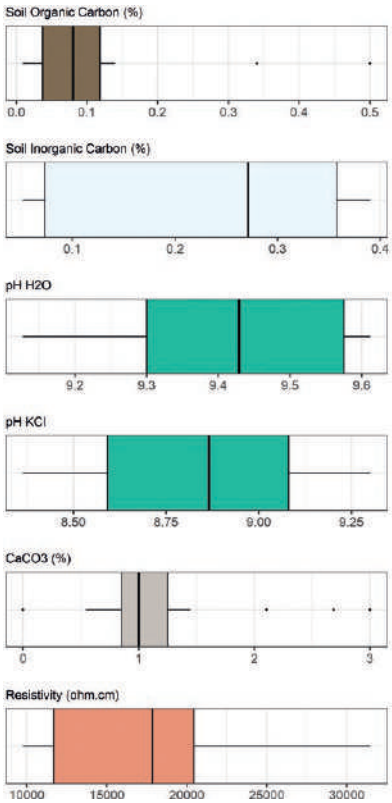


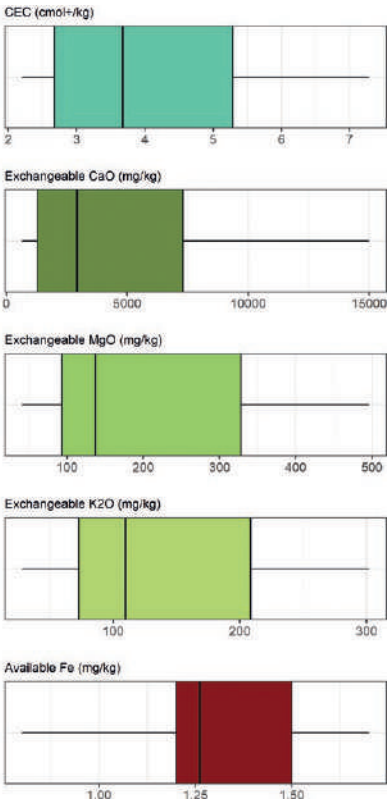
SOIL PROPERTIES

Sand sheets with exposed bedrock are dominated by sand-sized particles derived from Ordovician–Cambrian sources, forming loose substrates with high permeability and minimal structural development.

Soil organic carbon and soil inorganic carbon are extremely low, reflecting sparse vegetation cover, limited biological activity, and minimal organic inputs. The soils very strongly alkaline. Despite very low calcium carbonate contents, this elevated pH H_2O is driven by intense evaporation-induced concentration of soluble alkaline constituents, particularly bicarbonates, in the soil solution. Cation exchange capacity is low to very low, consistent with the scarcity of clay and organic matter. High electrical resistivity confirms non-saline conditions. Exchangeable calcium dominates the base-rich exchange complex, accompanied by lower concentrations of magnesium and potassium. Under strongly alkaline conditions, micronutrient availability is severely restricted, particularly for iron, while phosphorus availability is reduced through precipitation as poorly soluble calcium phosphates.

Overall, these soils represent weakly developed, highly permeable sandy systems characterized by strong chemical constraints, limited nutrient retention, and very low nutrient availability.





3300 | SAND DUNES

Typical soil of dunes, formed and shaped by the wind, accumulating back to the wind and eroding in front of the wind. Fine particles are too light to settle and coarse elements too heavy to be carried by the wind. The soil structure is homogeneous, fragile, loose et permeable

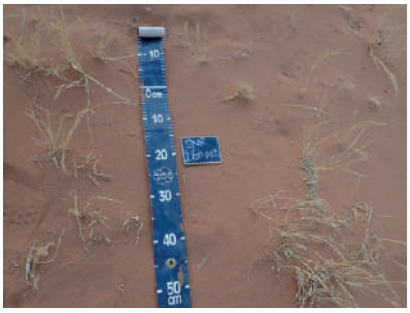
LANDSCAPE

Major landform: Sandstone reliefs
Minor landform: Dune
Topography: Irregular: dunes and microdunes
Dominant bedrock: Quartz sandstones (Quweira, Ram, Umm Sahm)

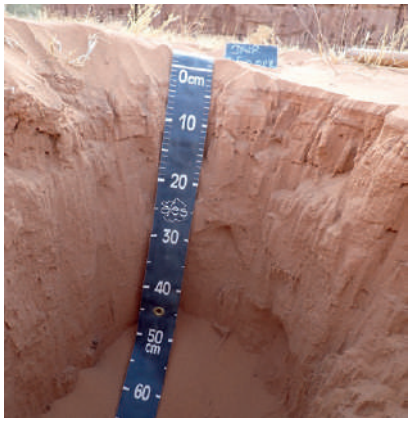
SOIL SURFACE

Land use: Natural
Coarse surface elements: None
Salt: None





SOIL PROFILE



SOIL PROFILE DESCRIPTION

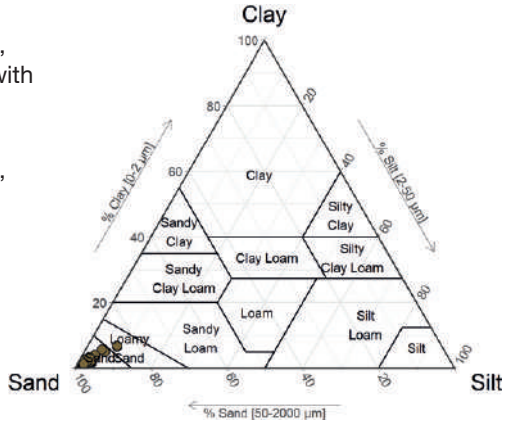
H1: 0 to 10 cm

Sandy texture, layered structure, loose, without rock fragments, with very fine roots, yellow

H2: 10 to 50 cm

Sandy texture, layered structure, slightly compact, without rock fragments, with very fine roots, yellow

SOIL TEXTURE

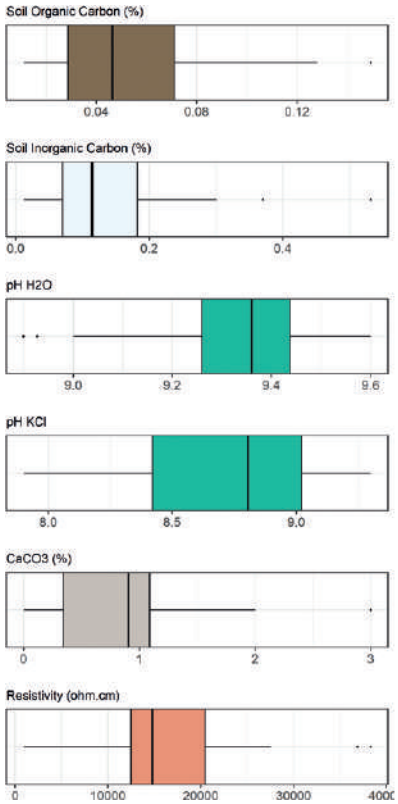


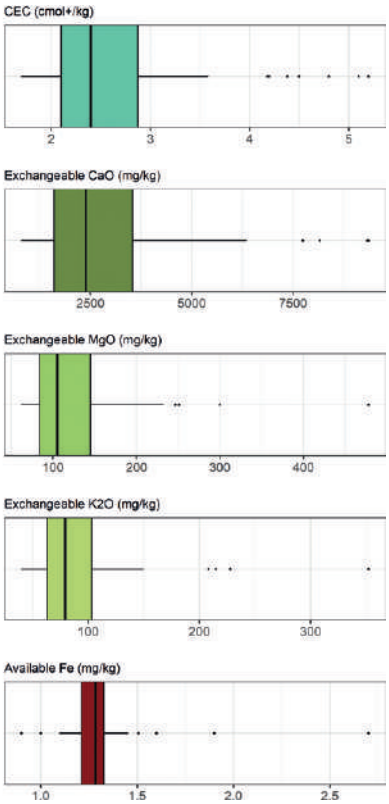
SOIL PROPERTIES

Aeolian processes govern the formation of these soils on sandstone-derived dune systems, where wind-driven transport and sorting produce well-sorted sandy to loamy sand materials with high permeability and minimal structural development.

Soil organic carbon and soil inorganic carbon are extremely low, reflecting sparse vegetation cover, limited biological activity, and very limited organic inputs. The soils are very strongly alkaline. Despite very low calcium carbonate levels, this elevated pH H_2O is driven by intense evaporation-induced concentration of soluble alkaline constituents, particularly bicarbonates, in the soil solution. Cation exchange capacity is extremely low, consistent with very limited clay content and organic colloids. High electrical resistivity indicates dry, non-saline conditions. Exchangeable base contents are generally very low, with calcium remaining the dominant exchangeable cation despite the overall low base status. Under strongly alkaline conditions, micronutrient availability is strongly constrained, particularly for iron, while phosphorus availability is reduced through precipitation as poorly soluble calcium phosphates.

Overall, these soils represent weakly developed, highly permeable aeolian systems characterized by strong chemical constraints, minimal nutrient retention, and extremely low nutrient availability.





4100 | HIGH ALTITUDE MOUNTAINS

These shallow, (30–50 cm average depth) gravelly soils of the high-altitude Hijaz are weakly developed under arid conditions, with dominant physical weathering and aeolian removal of fine particles. They exhibit minimal horizon differentiation and consistent with weakly developed arid-zone soils.

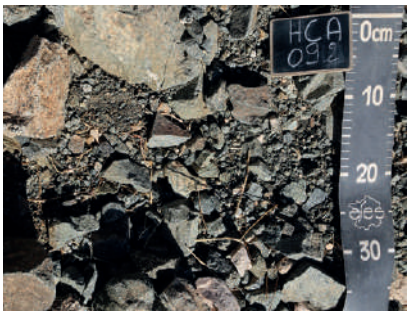
LANDSCAPE

Major landform: Mountainous uplands
Minor landform: Summit ridges and structural plateaus
Topography: Gently sloping to steep, convex summits with shallow, gravelly soils
Dominant bedrock: Felsic volcanic rocks and sedimentary arenites



SOIL SURFACE

Land use: Natural
Coarse surface elements: Surface covered by various rock fragments
Salt: None



SOIL PROFILE



SOIL PROFILE DESCRIPTION

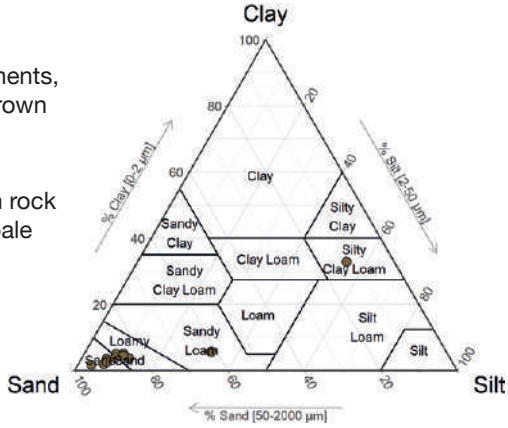
H1: 0 to 15 cm

Loamy sand texture, massive structure, loose, with rock fragments, with very fine roots, very pale brown

H2: 15 to 40 cm

Loamy sand texture, massive structure, slightly compact, with rock fragments, without roots, very pale brown

SOIL TEXTURE



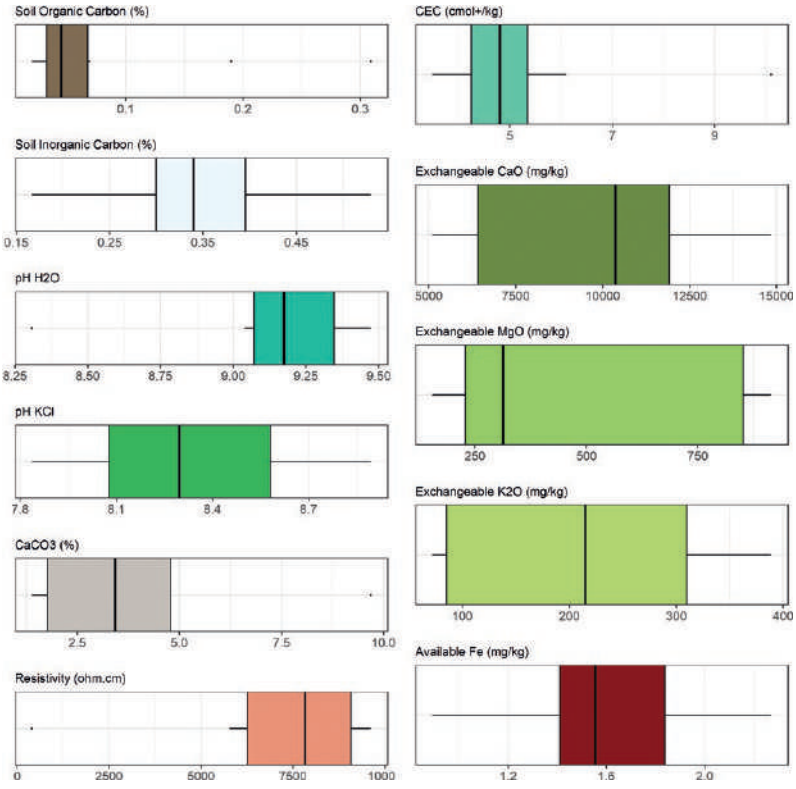
SOIL PROPERTIES

High-altitude soils in the Hijaz region range from sand to loamy sand and sandy loam, dominated by sand with minimal clay content. This coarse texture promotes high permeability but restricts water retention.

Due to the scarcity of organic and mineral colloids, soil organic carbon and cation exchange capacity are very low. The soils are very strongly alkaline, reflecting intense evaporation and concentration of soluble alkaline constituents in the soil solution, particularly bicarbonates. Despite low to moderate calcium carbonate levels, extractable calcium dominates the exchange complex, reflecting the calcium-rich nature of the soil environment. Electrical resistivity confirms non-saline conditions.

High pH markedly reduces micronutrient solubility, particularly iron, while phosphorus availability is reduced through precipitation as poorly soluble calcium phosphates. Weathering of the parent material contributes moderate to high exchangeable magnesium and potassium levels.

Overall, these shallow, gravelly soils combine low water retention with chemical constraints related to high alkalinity, strongly limiting vegetation development.



4200 | MID ALTITUDE MOUNTAINS

These shallow (30–50 cm average depth), gravelly soils of the Mid-altitude Hijaz are weakly developed under arid conditions, with dominant physical weathering and aeolian removal of fine particles. They exhibit minimal horizon differentiation and consistent with weakly developed arid-zone soils.

LANDSCAPE

Major landform: Mountainous uplands
Minor landform: Summit ridges and structural plateaus
Topography: Gently sloping to steep, convex summits with shallow, gravelly soils
Dominant bedrock: Felsic volcanic rocks and sedimentary arenites

SOIL SURFACE

Land use: Natural
Coarse surface elements: Surface covered by various rock fragments
Salt: None





SOIL PROFILE

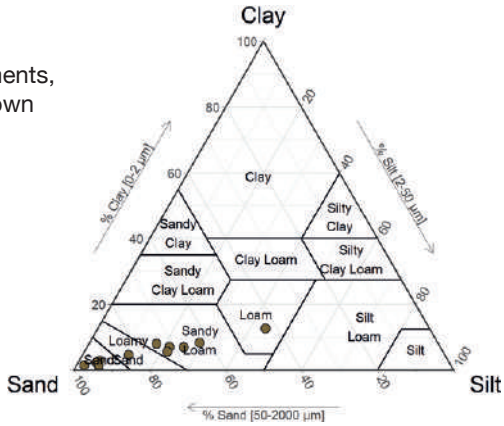


SOIL PROFILE DESCRIPTION

H1: 0 to 10 cm
Sandy loam texture, massive structure, loose, with rock fragments, without roots, light yellowish brown

H2: 10 to 40 cm
Sandy loam texture, massive structure, compact, with rock fragments, without roots, light yellowish brown

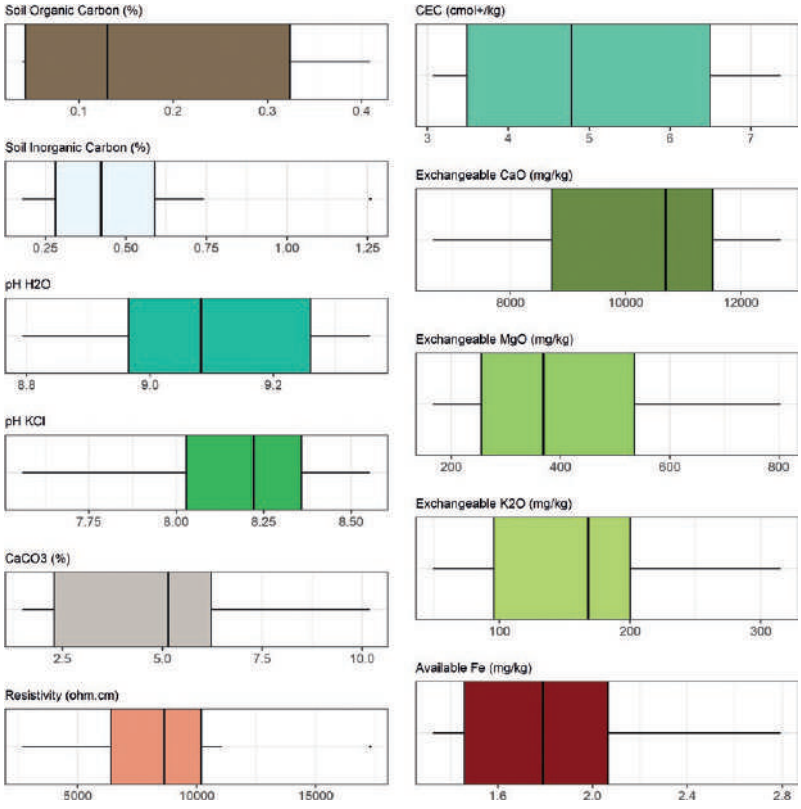
SOIL TEXTURE



SOIL PROPERTIES

Mid-altitude slope soils of the Hijaz region are shallow and coarse-textured, ranging from sand to sandy loam and locally loam. Particle-size distribution is dominated by sand, though silt contribution increases relative to lower positions, reflecting physical weathering, aeolian inputs, and slope colluviation. These weakly developed arid soils exhibit minimal horizon differentiation and rapid drainage, restricting long-term water storage.

Due to low clay and organic matter contents, cation exchange capacity is very low. The soils are very strongly alkaline, reflecting intense evaporation and the concentration of soluble alkaline constituents under arid conditions, especially bicarbonates. Despite moderate calcium carbonate contents, extractable calcium dominates the exchange complex, indicating a calcium-rich alkaline chemical environment (pH KCl ≈ 8.2). Electrical resistivity confirms non-saline conditions. These physicochemical conditions strongly constrain nutrient availability: high pH reduces iron solubility, while phosphorus availability is limited by precipitation as poorly soluble calcium phosphates. The dominance of exchangeable calcium may also contribute to cation imbalances affecting magnesium and potassium uptake. Overall, these chemically constrained soils exhibit low natural fertility and limited capacity to support vegetation establishment.



4300 | LOW ALTITUDE MOUNTAINS

The lower Hijaz foothills host shallow, gravelly soils weakly developed in arid conditions, where physical weathering prevails and wind erosion removes fine particles. Horizon differentiation remains minimal, consistent with Aridisol characteristics.

LANDSCAPE

Major landform: Foothills / Piedmont plains
Minor landform: Alluvial fans and pediments
Topography: Gently to moderately sloping, convex foot slopes with gravel pavements
Dominant bedrock: Granodiorite and quartz monzonite (Hadiyah Group)

SOIL SURFACE

Land use: Natural
Coarse surface elements: Surface covered by various rock fragments
Salt: None





SOIL PROFILE



SOIL PROFILE DESCRIPTION

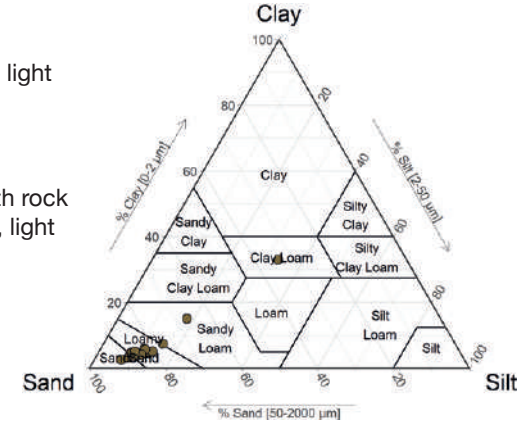
H1: 0 to 15 cm

Loamy sand texture, layered structure, with rock fragments, light brown

H2: 15 to 80 cm

Loamy sand texture, layered structure, slightly compact, with rock fragments, with very fine roots, light brown

SOIL TEXTURE

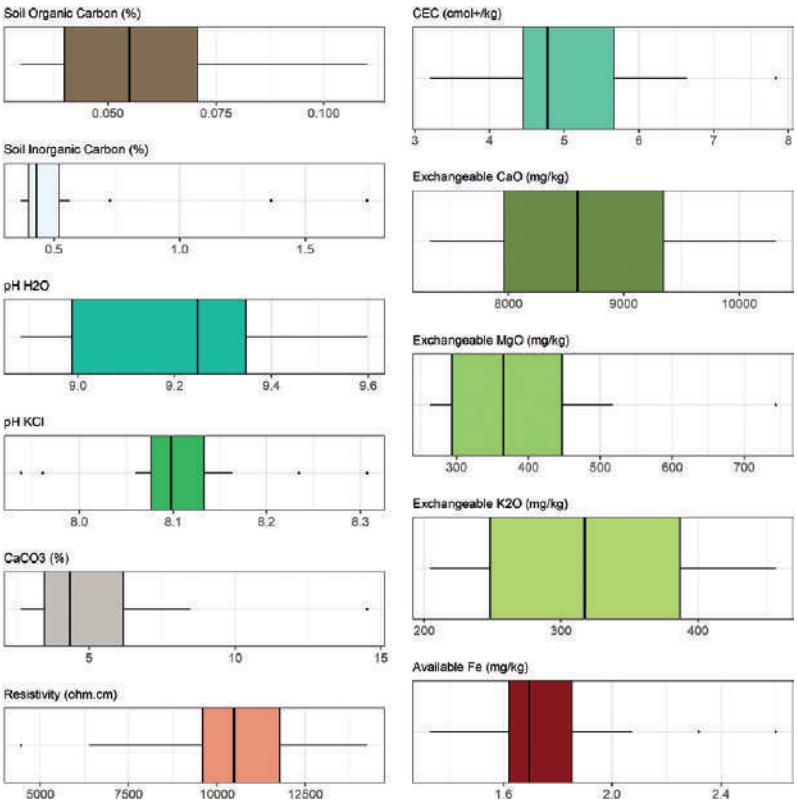


SOIL PROPERTIES

In the lower foothills of the Hijaz region, soils range from sand to loamy sand, sandy loam, and locally clay loam, with sand remaining the dominant fraction and clay generally limited. This coarse texture promotes rapid infiltration and drainage but limits water retention and nutrient availability.

Soil organic carbon is extremely low, reflecting minimal organic inputs and high mineralization rates under arid conditions. Consequently, cation exchange capacity is very low. The soils are very strongly alkaline, reflecting intense evaporation and the accumulation of soluble alkaline constituents in the soil solution, particularly bicarbonates. Despite moderate calcium carbonate contents, extractable calcium dominates the exchange complex, indicating a calcium-rich alkaline chemical environment. High electrical resistivity confirms non-saline conditions.

These physicochemical conditions strongly constrain nutrient status: elevated pH reduces iron solubility, while phosphorus availability is limited by precipitation as poorly soluble calcium phosphates. The dominance of exchangeable calcium may also contribute to cation imbalances affecting magnesium and potassium uptake by plants. Overall, these weakly developed soils are chemically constrained, combining limited moisture retention with low nutrient status.



4400 | GRAVEL PLAINS

These soils, derived from moderate alluvial deposits, are composed of loamy-sand to gravel particles, differential erosion leaves heavier particles like gravels on the surface, inducing slight soil compaction between deposit layers.

LANDSCAPE

Major landform: Alluvial plain
Minor landform: valley floor (wadi) and plain
Topography: flat, low gradient slope
Dominant bedrock: Granodiorite and quartz monzonite (Hadiyah Group).



SOIL SURFACE

Land use: Natural
Coarse surface elements: Surface covered by gravel
Salt: None



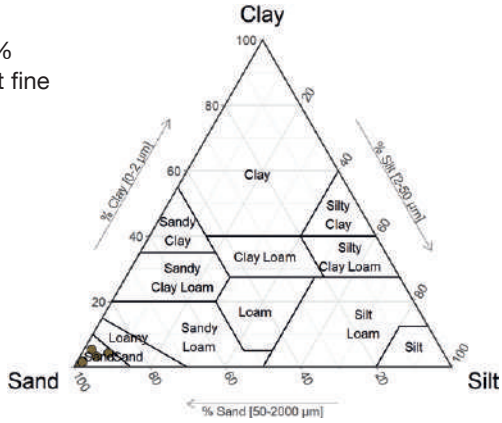
SOIL PROFILE



SOIL PROFILE DESCRIPTION

H1: 0 to 70 cm
Sandy texture, Stratified, 25-50% rock fragment, compact, without fine roots, very dark greyish brown

SOIL TEXTURE



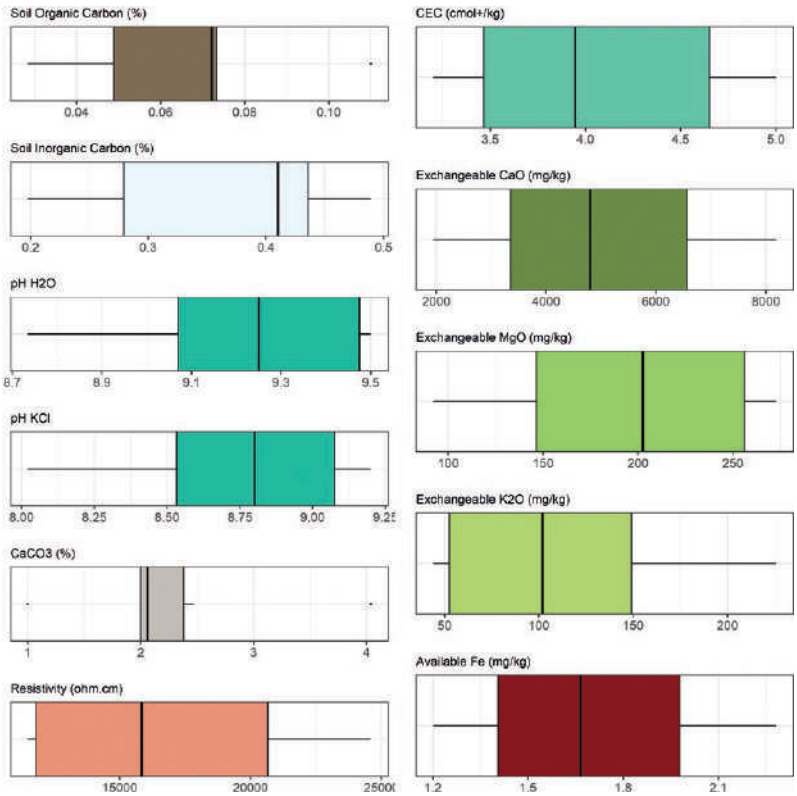
SOIL PROPERTIES

Derived from moderate alluvial deposits, these soils consist of a sandy to loamy-sand matrix rich in gravel particles. Differential erosion leaves heavier gravels on the surface, inducing slight compaction between stratified layers. Combined with a minimal clay fraction, these characteristics produce highly permeable profiles with rapid drainage and extremely low water retention capacity.

Soil organic carbon is extremely low, reflecting reduced biological activity, sparse vegetation cover, and an absence of fine roots. Despite low carbonate contents, the soils display strong to very strong alkalinity driven by high base saturation. Cation exchange capacity is strictly limited due to the scarcity of clay particles and organic colloids. Electrical resistivity values confirm dry, non-saline conditions.

Exchangeable calcium overwhelmingly dominates the sorption complex, followed by moderate magnesium and low potassium levels. Under these strongly alkaline conditions, nutrient availability is severely constrained by iron immobilization and calcium-driven phosphorus fixation.

Overall, these represent weakly developed, compact, and coarse-textured alluvial soils characterized by low inherent fertility and very poor water and nutrient retention.



5100 | SANDY WADIS

These soils are dominated by sand and formed from sediments deposited during episodic fluvial flows. Their sandy texture reflects selective sediment deposition during seasonal flood events, with coarse sandy materials preferentially deposited while finer particles remain in suspension and are transported further downstream. Their formation is therefore strongly influenced by the frequency and intensity of seasonal floods.

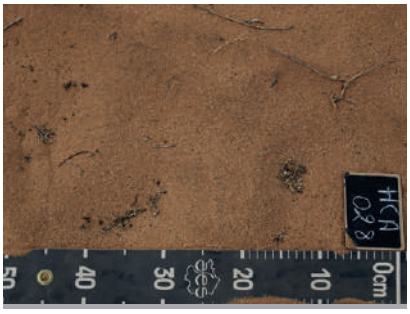
LANDSCAPE

Major landform: Valley floor (wadi) and plain
Minor landform: Valley floor (wadi) and plain
Topography: Flat, low gradient slope
Dominant bedrock: Quartz sandstones with shale and conglomerate.

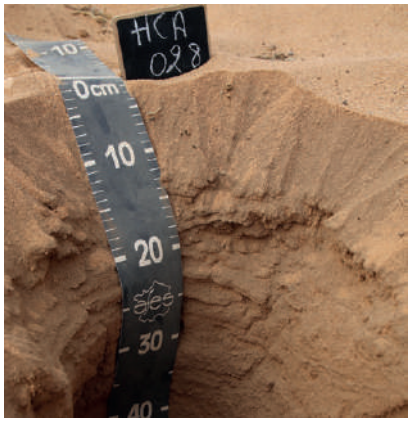
SOIL SURFACE

Land use: Natural
Coarse surface elements: None
Salt: None





SOIL PROFILE

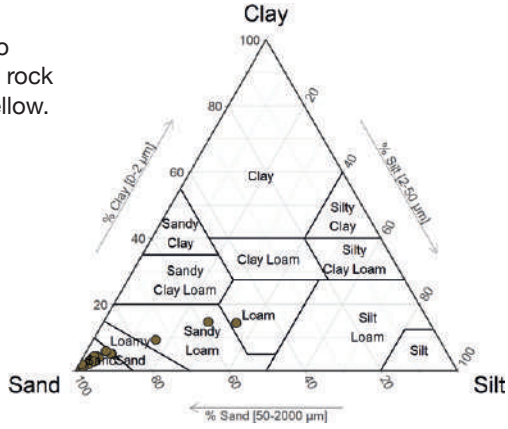


SOIL PROFILE DESCRIPTION

H1: 0 to 45 cm

Sandy soil, loose, single-grain to weakly structured; contains fine rock fragments and roots; reddish yellow.

SOIL TEXTURE

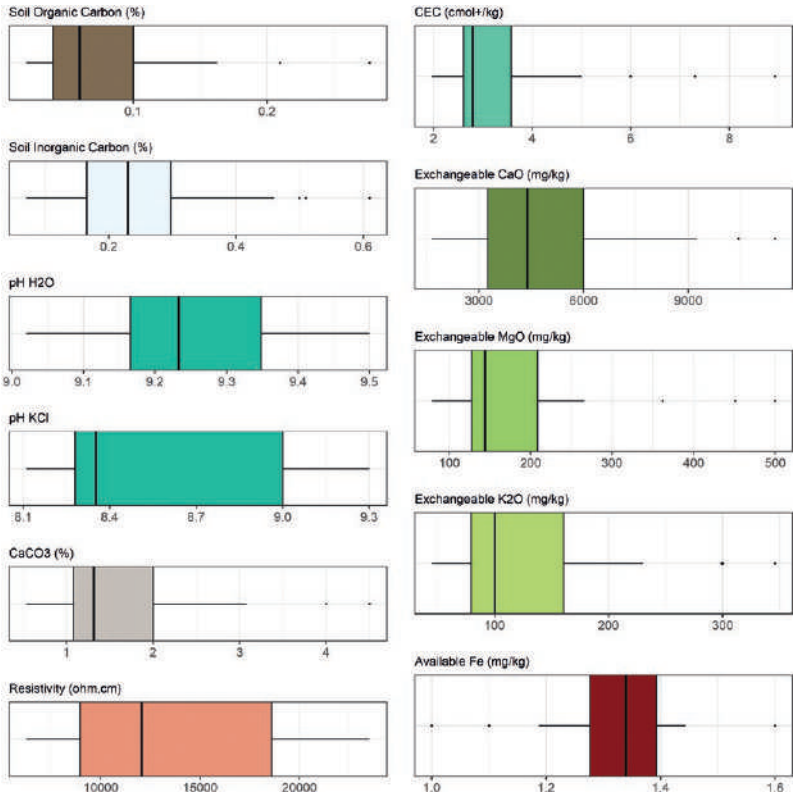


SOIL PROPERTIES

These soils are coarse-textured, ranging from sand to sandy loam, with a loose single-grain structure. Particle-size distribution is dominated by sand, with minimal silt and clay, resulting in high permeability and limited water- and nutrient-retention capacity.

The sandy texture, combined with arid conditions, contributes to extremely low soil organic carbon contents and very low cation exchange capacity. The soils are very strongly alkaline, reflecting intense evaporation and the concentration of soluble alkaline constituents in the soil solution, particularly bicarbonates. Although calcium carbonate contents are low, extractable calcium dominates the exchange complex, indicating a calcium-rich alkaline chemical environment (pH KCl ≈ 8.3). Electrical resistivity values indicate non-saline conditions.

These physicochemical conditions strongly constrain nutrient availability: high pH reduces iron solubility, while phosphorus availability is limited by precipitation as poorly soluble calcium phosphates. The dominance of exchangeable calcium may also contribute to nutrient imbalances affecting magnesium and potassium uptake. Overall, these weakly developed alluvial soils exhibit low natural fertility and limited capacity to support plant establishment.



5200 | GRAVEL WADIS

Formed through fluvial deposition and erosion, these soils occur downstream of stony and unstable relief features. The stony composition of these soils testifies the strength and turbulence of the floods. The stratification of the soil testifies to variations in the speed of the water current.

LANDSCAPE

Major landform: Valley floor (wadi) and plain
Minor landform: Valley floor (wadi) and plain
Topography: Flat, low gradient slope
Dominant bedrock: Gabbro, granitoids, schist, and Hadiyah Group.

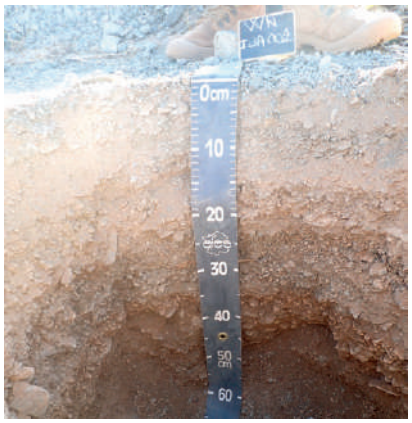


SOIL SURFACE

Land use: Natural
Coarse surface elements: Surface covered by various rock fragments
Salt: None



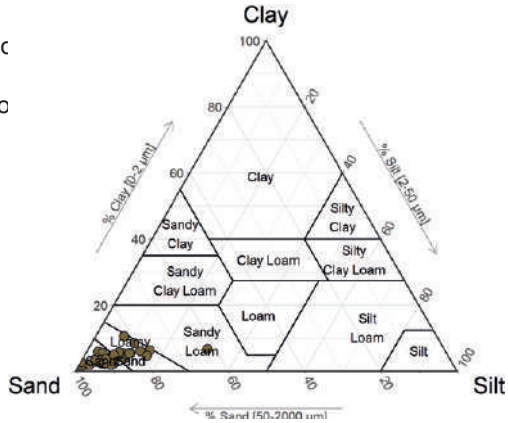
SOIL PROFILE



SOIL PROFILE DESCRIPTION

H1: 0 to 55 cm
Loamy Sand texture, layered and single grain structure, with rock fragments, compact, without roo
Greenish black

SOIL TEXTURE

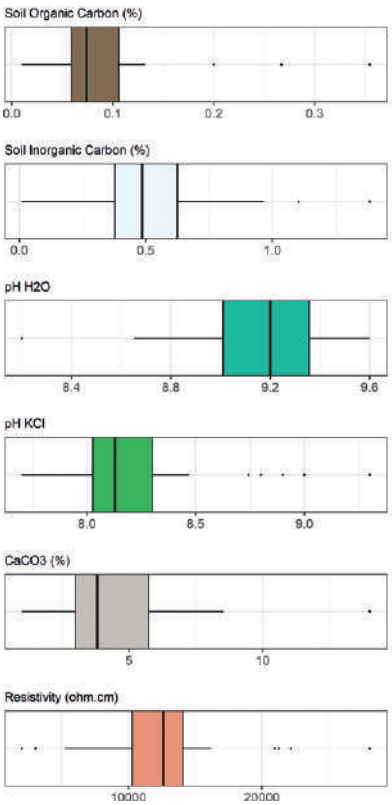


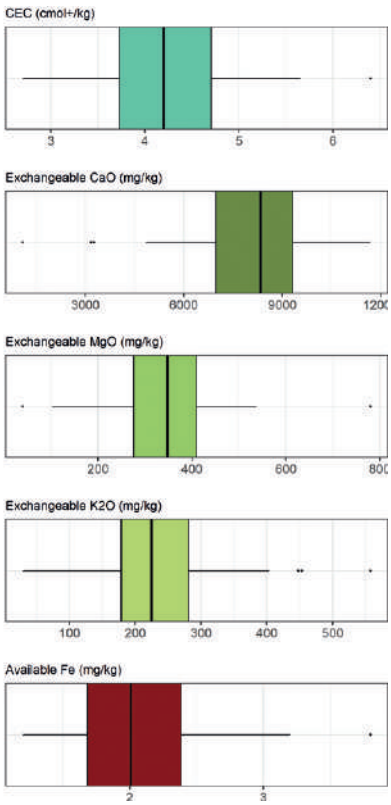
SOIL PROPERTIES

These soils occur in gravel wadis, where episodic floods redistribute coarse fluvial sediments across broad valley floors, producing heterogeneous sandy to loamy sand and sandy loam profiles with abundant coarse fragments.

Soil organic carbon is very low, reflecting weak biological activity under highly transient moisture conditions, while inorganic carbon remains low. The soils are very strongly alkaline, and the elevated pH H20 mainly reflects evaporation-induced concentration of soluble alkaline constituents, particularly bicarbonates, during dry periods following flood events, despite only low to moderate carbonate contents. Cation exchange capacity is very low because of the dominance of coarse sandy materials and the scarcity of clay colloids. Electrical resistivity indicates non-saline conditions, while rapid drainage and high permeability strongly limit moisture retention. Exchangeable calcium dominates the exchange complex, with subordinate magnesium and potassium derived from mixed lithological inputs within the drainage basin. Under strongly alkaline conditions, micronutrient availability, particularly iron, is markedly reduced, while phosphorus availability is limited through precipitation as poorly soluble calcium phosphates.

Overall, these weakly developed alluvial soils are characterized by coarse textures, poor nutrient retention, and strong hydrological constraints.





APPENDIX 4

FLORA NAMES

A list of all the plant names used in the manual with their family, authorities and commonly found synonyms. Complete synonymy is available in Stott et al., 2026. Nomenclature and taxonomic status follow World Flora Online unless otherwise stated in Stott et al., 2026. Taxa highlighted have been identified as of high conservation significance, based on national endemism, restricted range and rarity or their threatened status on the IUCN Red List.

Conservation status categories abbreviations: CR – Critically Endangered; EN – Endangered; VU – Vulnerable; NT – Near Threatened; LC – Least Concern; DD – Data Deficient; NE – Not Evaluated IUCN Red List status is global unless indicated as a regional assessment for the Arabian Peninsula.

SPECIES	FAMILY	SYNONYMS	IUCN STATUS	DISTRIBUTION	CONSERVATION PRIORITY
Abutilon bidentatum (Hochst.) A.Rich.	Malvaceae		NE	Widespread	
Achillea fragrantissima Sch.Bip.	Asteraceae		NE	Range-restricted; Egypt, Iraq, Jordan, Kuwait, Palestine, Lebanon, Syria, Saudi Arabia	
Agathophora alopecuroides (Delile) Fenzl ex Bunge.	Amaranthaceae		NE	Widespread	
Alcea striata Alef.	Malvaceae		NE	Range-restricted; Egypt (Sinai), Israel, Jordan, Lebanon, Palestine, Saudi Arabia, Syria, Turkey	Rare in KSA
Alkanna orientalis (L.) Boiss.	Boraginaceae		NE	Widespread	
Anarrhinum orientale Benth.	Plantaginaceae		NE	Widespread	
Anastatica hierochuntica L.	Brassicaceae		NE	Widespread	
Anthemis deserti Boiss.	Asteraceae		NE	Range-restricted; Egypt, Iraq, Jordan, Lebanon, Palestine, Saudi Arabia	
Anvillea garcinii DC.	Asteraceae	Buphthalmum arabicum Delile	NE	Widespread	
Artemisia judaica L.	Asteraceae		NE	Widespread	
Artemisia sieberi Besser.	Asteraceae		NE	Widespread	
Asphodelus tenuifolius Cav.	Asphodelaceae		NE	Widespread	
Astragalus caprinus L.	Fabaceae		NE	Widespread	
Astragalus echinus DC.	Fabaceae		NE	Range-restricted; Egypt (Sinai), Lebanon, Saudi Arabia, Syria	Rare in KSA
Astragalus spinosus (Forssk.) Muschl.	Fabaceae		NE	Widespread	
Ballota undulata (Sieber ex Fresen.) Benth.	Lamiaceae	*Pseudodictamnus undulatus* (Benth.) Salmaki & Siadati	NE	Range-restricted;Egypt, Jordan, Palestine, Saudi Arabia, Syria	
Bromus tectorum L.	Poaceae		NE	Widespread	

Cakile arabica Velen.	Brassicaceae		NE	Range-restricted; Iran, Iraq, Kuwait, Saudi Arabia	
Calligonum comosum L'Hér.	Polygonaceae		NE	Widespread	
Caroxylon villosum (Schult.) Akhani & Roalson.	Amaranthaceae	*Salsola vermiculata* L., *Salsola villosa* Schult.	NE	Widespread	
Centaurea sinaica DC.	Asteraceae		NE	Range-restricted;Egypt, Israel, Jordan, Oman, Qatar, Saudi Arabia, United Arab Emirates	
Citrullus colocynthis (L.) Schrad.	Cucurbitaceae		NE	Widespread	
Cymbopogon schoenanthus (L.) Spreng.	Poaceae		NE	Widespread	
Daphne mucronata subsp. *linearifolia* (Hart) Halda.	Thymelaeaceae			Range-restricted; Israel, Jordan, Palestine, Saudi Arabia	Rare in KSA
Diplotaxis acris (Forssk.) Boiss.	Brassicaceae		NE	Widespread	
Diplotaxis harra Boiss.	Brassicaceae		NE	Widespread	
Dodonaea viscosa Jacq.	Sapindaceae		LC	Widespread	
Ducrosia flabellifolia Boiss.	Apiaceae		NE	Range-restricted; Iraq, Jordan, Saudi Arabia	Rare in KSA
Echinops glaberrimus DC.	Asteraceae		NE	Range-restricted; Egypt, Israel, Jordan, Saudi Arabia	
Ephedra alata Decne.	Ephedraceae		LC	Widespread	
Ephedra ciliata Fisch. & C.A.Mey.	Ephedraceae	*Ephedra ciliata* Fisch. & C.A.Mey. var. *ciliata*, *Ephedra foliata* Boiss. ex C.A.Mey., *Ephedra foliata* var. *ciliata* (Fisch. & C.A.Mey.) Stapf	LC	Widespread	
Ephedra pachyclada subsp. *sinaica (*Riedl) Freitag & Maier-St.	Ephedraceae	*Ephedra sinaica* Riedl	NE	Range-restricted; Egypt (Sinai), Jordan, Saudi Arabia, Yemen	Rare in KSA. It has only been recorded from one locality in AlUla.
Euryops jaberiana Abedin & Chaudhary.	Asteraceae		NT	National endemic	Populations in AlWard are large, of global importance.

Fagonia bruguieri DC.	Zygophyllaceae	*Zygophyllum bruguieri* (DC.) Christenh. & Byng	NE	Widespread	
Fagonia glutinosa Delile.	Zygophyllaceae	*Zygophyllum glutinosum* (Delile) Christenh. & Byng	NE	Widespread	
Fagonia mollis Delile.	Zygophyllaceae	*Zygophyllum molle* (Delile) Christenh. & Byng	NE	Range-restricted; Egypt (Sinai), Israel, Jordan, Palestine, Saudi Arabia, Syria.	
Fagonia paulayana J.Wagner & Vierh.	Zygophyllaceae	*Zygophyllum paulayanum* (J.Wagner & Vierh.) Christenh. & Byng	NE	Widespread	
Farsetia aegyptia Turra.	Brassicaceae		NE	Widespread	
Farsetia burtonae Oliv.	Brassicaceae		NE	Range-restricted; Iraq, Kuwait, Saudi Arabia	
Farsetia longisiliqua Decne.	Brassicaceae	*Farsetia stylosa* T.Anderson	NE	Widespread	
Ferula sinaica Boiss.	Apiaceae		NE	Range-restricted; Egypt (Sinai), Israel, Jordan, Palestine, Saudi Arabia	Restricted distribution in KSA
Ficus palmata Forssk.	Moraceae		LC (Arabian Peninsula)	Widespread	
Ficus salicifolia Vahl	Moraceae	*Ficus cordata* subsp. *salicifolia* (Vahl) C.C.Berg	NE	Widespread	
Glaucium arabicum Fresen.	Papaveraceae		NE	Range-restricted; Egypt (Sinai), Israel, Iraq, Lebanon, Syria, Palestine, Saudi Arabia	Rare in KSA.
Gymnocarpos decander Forssk.	Caryophyllaceae		NE	Widespread	
Gypsophila capillaris (Forssk.) C.Chr.	Caryophyllaceae		NE	Widespread	
Haloxylon salicornicum (Moq.) Bunge ex Boiss.	Amaranthaceae		NE	Widespread	
Helianthemum lippii (L.) Dum.Cours.	Cistaceae		NE	Widespread	
Heliotropium digynum (Forssk.) Asch. ex C.Chr.	Boraginaceae		NE	Widespread	
Hyoscyamus pseudoalbus E.K. Harvey, A.Abdulkareem & T.Särkinen.	Solanaceae			National Endemic	National Endemic
Hyoscyamus viscosus E.K. Harvey & A.Abdulkareem.	Solanaceae			National Endemic	National Endemic

Iphiona scabra DC. ex Decne.	Asteraceae		NE	Widespread	
Kickxia aegyptiaca Nábelek.	Plantaginaceae		NE	Widespread	
Kickxia pseudoscoparia V.A.W.Sm & D.A.Sutton.	Plantaginaceae		DD	Range-restricted; Egypt (Sinai), Palestine, Saudi Arabia, Sudan-South Sudan. This species was assessed as a Saudi Arabia endemic in Forrest & Neale (2023). Records exist for other countries but these require verification following taxonomic study	
Launaea mucronata (Forssk.) Muschl.	Asteraceae		NE	Widespread	
Lavandula coronopifolia Poir.	Lamiaceae		NE	Widespread	
Leysera leyseroides Maire.	Asteraceae	.	NE	Widespread	
Lycium shawii Roem. & Schult.	Solanaceae		LC	Widespread	
Medicago laciniata (L.) Mill.	Fabaceae		NE	Widespread	
Monsonia nivea Webb.	Geraniaceae		NE	Widespread	
Morettia parviflora Boiss.	Brassicaceae		NE	Range-restricted; Bahrain, Egypt (Sinai), Israel, Jordan, Oman, Palestine, Saudi Arabia, Yemen, United Arab Emirates	
Nanorrhinum acerbianum (Boiss.) Betsche.	Plantaginaceae		NE	Widespread	
Nepeta sheilae Hedge & R.A.King.	Lamiaceae		DD	National endemic	National endemic
Neurada procumbens L.	Neuradaceae		NE	Widespread	
Noaea mucronata (Forssk.) Asch. & Schweinf.	Amaranthaceae		NE	Widespread	
Ochradenus baccatus Delile.	Resedaceae		NE	Widespread	
Pallenis hierochuntica (Michon) Greuter.	Asteraceae		NE	Widespread	
Panicum turgidum Forssk.	Poaceae		NE	Widespread	
Periploca aphylla Decne.	Apocynaceae		LC	Widespread	

Phlomis brachyodon (Boiss.) Zohary ex Rech.f.	Lamiaceae		NE	Range-restricted;Jordan, Palestine, Saudi Arabia	Rare in KSA
Pistacia khinjuk Stocks.	Anacardiaceae		LC (Arabian Peninsula)	Widespread	
Plantago afra L.	Plantaginaceae		NE	Widespread	
Plantago ovata Forssk.	Plantaginaceae		NE	Widespread	
Polycarpaea repens Asch. & Schweinf. ex Asch.	Caryophyllaceae		NE	Widespread	
Pterocephalus sanctus Decne.	Caprifoliaceae		NE	Range-restricted;Egypt (Sinai), Israel, Jordan, Palestine, Saudi Arabia	
Pulicaria undulata (L.) C.A.Mey. subsp. *Undulata.*	Asteraceae		NE	Widespread	
Ramaliella intricata (Boiss.) Zaika, Sukhor. & N.Kilian.	Asteraceae		NE	Range-restricted; Iran, Palestine, Saudi Arabia	Rare in KSA
Retama raetam (Forssk.) Webb & Berthel.	Fabaceae		NE	Widespread	
Rhanterium epapposum Oliv.	Asteraceae		NE	Widespread	
Rumex vesicarius L.	Polygonaceae		NE	Widespread	
Sageretia thea (Osbeck) M.C.Johnst.	Rhamnaceae		NE	Widespread	
Salvia deserti Decne.	Lamiaceae		NE	Range-restricted;Egypt (Sinai), Jordan, Israel, Palestine, Saudi Arabia	
Schismus barbatus (L.) Thell.	Poaceae		NE	Widespread	
Schouwia purpurea (Forssk.) Schweinf.	Brassicaceae		NE	Widespread	
Scrophularia deserti Delile.	Scrophulariaceae		NE	Widespread	
Scrophularia hypericifolia Wydler.	Scrophulariaceae	*Scrophularia syriaca* Benth.	NE	Widespread	
Senecio flavus (Decne.) Sch.Bip.	Asteraceae		NE	Widespread	
Silene arabica Boiss.	Caryophyllaceae		NE	Widespread	
Stachys aegyptiaca Pers.	Lamiaceae		NE	Range-restricted; Egypt (Sinai), Israel, Jordan, Palestine, Saudi Arabia	

Stipagrostis ciliata (Desf.) De Winter.	Poaceae		NE	Widespread	
Stipagrostis plumosa (L.) Munro ex T.Anderson.	Poaceae		NE	Widespread	
Stipellula capensis (Thunb.) Röser & Hamasha.	Poaceae	*Stipa capensis* Thunb.	NE	Widespread	
Teucrium polium L.	Lamiaceae		NE	Widespread	
Thymbra nabateorum (Danin & Hedge) Bräuchler.	Lamiaceae	*Satureja nabateorum* Danin & Hedge	E	Range-restricted; Jordan, Saudi Arabia	Threatened species - Abdulkarem et al, 2025
Trichodesma boissieri Post.	Boraginaceae		NE	Range-restricted; Jordan, Israel, Palestine, Saudi Arabia, Yemen	Rare in KSA
Trigonella stellata Forssk.	Fabaceae		NE	Widespread	
Vachellia gerrardi var. *najdensis* (Chaudhary) Ragup., Seigler, Ebinger & Maslin.		*Acacia gerrardi* Benth. subsp. *gerrardi*, *Acacia gerrardi* subsp. *negevensis* Zohary, *Acacia gerrardi* var. *najdensis* Chaudhary, *Acacia gerrardi* var. *negevensis*, *Vachellia gerrardi* (Benth.) P.J.H.Hurter subsp. *gerrardi*, *Vachellia gerrardi* subsp. *negevensis* (Zohary) Ragup., Seigler, Ebinger & Maslin	NE	Range-restricted; Iraq, Kuwait, Oman, Palestine, Saudi Arabia, Sinai, Yemen	
Vachellia oerfota (Forssk.) Kyal. & Boatwr.	Fabaceae	*Acacia oerfota* (Forssk.) Schweinf.	LC (Arabian Peninsula)	Widespread	
Vachellia tortilis (Forssk.) Galasso & Banfi.	Fabaceae	*Acacia tortilis* (Forssk.) Hayne	LC Global and regional		
Vachellia tortilis subsp. *raddiana* (Savi) Kyal. & Boatwr.	Fabaceae	*Acacia raddiana* Savi, *Acacia tortilis* subsp. *raddiana* (Savi) Brenan	NE	Widespread	
Vachellia tortilis (Forssk.) Galasso & Banfi subsp. *Tortilis.*	Fabaceae		NE	Widespread	
Verbascum shiqricum Hemaid.	Scrophulariaceae		VUD2	National endemic	National endemic, threatened
Withania somnifera (L.) Dunal.	Solanaceae		NE	Widespread	
Zilla spinosa (L.) Prantl.	Brassicaceae		NE	Widespread	
Zoegea purpurea Fresen.	Asteraceae		NE	Widespread	

APPENDIX 5

FAUNA NAMES

List of fauna used in the manual. Fauna classed as of high conservation value is highlighted. The list comprises the class, order, family, species name and common name. For each species, it is indicated if it is endemic (End) to the Arabian Peninsula or near endemic (NE – defined as >75% of the global range occurring within AIUla), geographically restricted (G.R. – i.e., species with very constrained area of occupancy or extent of occurrence). The regional IUCN status is also provided.

Conservation status categories abbreviations:

CR – Critically Endangered

EN – Endangered

VU – Vulnerable

NT – Near Threatened

LC – Least Concern

DD – Data Deficient

NA – Not Applicable

NE – Not Evaluated

CLASS	ORDER	FAMILY	SPECIES	COMMON NAME	END	G.R.	IUCN
Amphibia	Anura	Bufonidae	*Bufotes sitibundus*	Variable green toad	-	-	CR
Amphibia	Anura	Bufonidae	*Sclerophrys arabica*	Arabian toad	Yes	-	LC
Amphibia	Anura	Bufonidae	*Duttaphrynus dhufarensis*	Oman toad	Yes	-	VU
Amphibia	Anura	Dicroglossidae	*Euphlyctis ehrenbergii*	Arabian five-fingered frog	Yes	-	CR
Arachnida	Araneae	Araneidae	*Larinia chloris*	Slender orb-weaver spider	-	-	DD
Arachnida	Araneae	Gnaphosidae	*Zelotes sp.*	Ground spider	-	-	NE
Arachnida	Araneae	Lycosidae	*Hogna sp.*	Ferocious wolf spider	-	-	NE
Arachnida	Araneae	Lycosidae	*Lycosa piochardi*	Tarantula wolf spider	-	-	LC
Arachnida	Araneae	Oecobiidae	*Oecobius sp.*	Wall spider	-	-	NE
Arachnida	Araneae	Oecobiidae	*Uroctea cf. thaleri*	Bordered disc web spider	-	-	LC
Arachnida	Araneae	Palpimanidae	*Palpimanus gibbulus*	Common palp-footed spider	-	-	LC
Arachnida	Araneae	Philodromidae	*Thanatus cf. setiger*	False crab spider	-	-	LC
Arachnida	Araneae	Pholcidae	*Artema nephilit*	Giant daddy-long-leg spider	-	-	LC
Arachnida	Araneae	Pholcidae	*Holocnemus pluchei*	Marbled daddy long-legs spider	-	Yes	LC
Arachnida	Araneae	Salticidae	*Thyene imperialis*	Jumping spider	-	-	LC
Arachnida	Araneae	Selenopidae	*Selenops radiatus*	Palm wall crab spider	-	-	LC
Arachnida	Araneae	Theridiidae	*Latrodectus revivensis*	Desert widow spider	-	-	DD
Arachnida	Araneae	Theridiidae	*Steatoda cf. latifasciata*	False widow spider	-	-	DD
Arachnida	Araneae	Theridiidae	*Steatoda cf. paykulliana*	False widow spider	-	-	DD
Arachnida	Scorpiones	Buthidae	*Buthacus yotvatensis*	Yotvata sand scorpion	-	-	LC
Arachnida	Scorpiones	Scorpionidae	*Scorpio fuscus*	Dark large-clawed scorpion	-	-	LC
Aves	Accipitriformes	Accipitridae	*Aquila chrysaetos*	Golden Eagle	-	-	CR
Aves	Accipitriformes	Accipitridae	*Aquila fasciata*	Bonelli's Eagle	-	-	EN
Aves	Accipitriformes	Accipitridae	*Aquila verreauxii*	Verreaux's Eagle	-	-	CR
Aves	Accipitriformes	Accipitridae	*Buteo buteo*	Steppe Buzzard	-	-	NE
Aves	Accipitriformes	Accipitridae	*Buteo rufinus*	Long-legged Buzzard	-	-	EN
Aves	Accipitriformes	Accipitridae	*Circaetus gallicus*	Short-toed Snake-eagle	-	-	EN
Aves	Accipitriformes	Accipitridae	*Circus aeruginosus*	Western Marsh-harrier	-	-	VU
Aves	Accipitriformes	Accipitridae	*Torgos tracheliotos*	Lappet-faced Vulture	-	-	CR
Aves	Apodiformes	Apodidae	*Apus apus*	Common Swift	-	Yes	NE
Aves	Caprimulgiformes	Caprimulgidae	*Caprimulgus nubicus*	Nubian Nightjar	-	-	VU

Aves	Charadriiformes	Glareolidae	*Cursorius cursor*	Cream-coloured Courser	-	-	LC
Aves	Columbiformes	Columbidae	*Streptopelia turtur*	European Turtle-dove	-	Yes	NT
Aves	Falconiformes	Falconidae	*Falco concolor*	Sooty Falcon	-	-	CR
Aves	Falconiformes	Falconidae	*Falco peregrinus*	Peregrine Falcon/Barbary Falcon	-	-	EN
Aves	Galliformes	Phasianidae	*Alectoris chukar*	Chukar	-	-	LC
Aves	Galliformes	Phasianidae	*Coturnix coturnix*	Common Quail	-	-	LC
Aves	Passeriformes	Alaudidae	*Alaemon alaudipes*	Greater Hoopoe-lark	-	-	LC
Aves	Passeriformes	Alaudidae	*Ammomanes cinctura*	Bar-tailed Lark	-	Yes	LC
Aves	Passeriformes	Alaudidae	*Calandrella eremica*	Rufous-capped Lark	-	-	EN
Aves	Passeriformes	Alaudidae	*Eremalauda eremodites*	Arabian Lark	NE	-	LC
Aves	Passeriformes	Alaudidae	*Eremophila bilopha*	Temminck's Lark	-	-	LC
Aves	Passeriformes	Estrildidae	*Euodice cantans*	African Silverbill	-	-	LC
Aves	Passeriformes	Muscicapidae	*Monticola solitarius*	Blue Rock-thrush	-	-	LC
Aves	Passeriformes	Muscicapidae	*Oenanthe oenanthe*	Northern Wheatear	-	-	NE
Aves	Passeriformes	Muscicapidae	*Oenanthe xanthoprymna*	Kurdish Wheatear	-	Yes	NT
Aves	Passeriformes	Muscicapidae	*Phoenicurus ochruros*	Black Redstart	-	-	LC
Aves	Passeriformes	Ploceidae	*Ploceus galbula*	Rüppell's Weaver	-	-	NA
Aves	Passeriformes	Pycnonotidae	*Pycnonotus leucotis*	White-eared Bulbul	-	-	NA
Aves	Passeriformes	Sylviidae	*Curruca leucomelaena*	Arabian Warbler	-	-	LC
Aves	Passeriformes	Sylviidae	*Curruca melanocephala*	Sardinian Warbler	-	-	VU
Aves	Passeriformes	Sylviidae	*Curruca nana*	Asian Desert Warbler	-	-	LC
Aves	Passeriformes	Sylviidae	*Sylvia borin*	Garden Warbler	-	-	NE
Aves	Strigiformes	Strigidae	*Bubo ascalaphus*	Pharaoh Eagle-owl	-	-	VU
Aves	Strigiformes	Strigidae	*Otus brucei*	Pallid Scops-owl	-	Yes	CR
Insecta	Lepidoptera	Erebidae	*Anumeta spilota*	-	-	-	NE
Insecta	Lepidoptera	Erebidae	*Casama innotata*	-	-	-	NE
Insecta	Lepidoptera	Erebidae	*Drasteria flexuosa*	-	-	-	NE
Insecta	Lepidoptera	Erebidae	*Gnamptonyx innexa*	-	-	Yes	NE
Insecta	Lepidoptera	Erebidae	*Hypotacha ochribasalis*	-	-	-	NE
Insecta	Lepidoptera	Erebidae	*Ophiusa tirhaca*	-	-	-	NE
Insecta	Lepidoptera	Erebidae	*Pandesma robusta*	-	-	Yes	NE
Insecta	Lepidoptera	Erebidae	*Tathorhynchus exsiccata*	-	-	-	NE
Insecta	Lepidoptera	Geometridae	*Orthonama obstipata*	-	-	-	NE
Insecta	Lepidoptera	Geometridae	*Zamarada minimaria*	-	-	-	NE

Insecta	Lepidoptera	Hesperiidae	*Gegenes nostrodamus*	Mediterranean skipper	-	-	DD
Insecta	Lepidoptera	Hesperiidae	*Pelopidas mathias*	Black-branded swift	-	-	DD
Insecta	Lepidoptera	Lasiocampidae	*Streblote acaciae*	-	-	-	NE
Insecta	Lepidoptera	Lycaenidae	*Brephidium exilis*	Western pygmy blue	-	-	NA
Insecta	Lepidoptera	Lycaenidae	*Freyeria trochylus*	Grass jewel	-	-	DD
Insecta	Lepidoptera	Lycaenidae	*Leptotes pirithous*	Lang's short-tailed blue	-	-	LC
Insecta	Lepidoptera	Lycaenidae	*Zizeeria karsandra*	Dark grass blue	-	-	DD
Insecta	Lepidoptera	Noctuidae	*Agrotis ipsilon*	-	-	Yes	NE
Insecta	Lepidoptera	Noctuidae	*Agrotis segetum*	-	-	-	NE
Insecta	Lepidoptera	Noctuidae	*Hecatera dysodea*	-	-	-	NE
Insecta	Lepidoptera	Noctuidae	*Helicoverpa armigera*	-	-	Yes	NE
Insecta	Lepidoptera	Noctuidae	*Heliothis nubigera*	-	-	Yes	NE
Insecta	Lepidoptera	Nymphalidae	*Junonia hierta*	Yellow pansy	-	Yes	LC
Insecta	Lepidoptera	Nymphalidae	*Junonia orithya*	Blue pansy	-	Yes	LC
Insecta	Lepidoptera	Pieridae	*Colotis chrysonome*	Golden arab	-	Yes	LC
Insecta	Lepidoptera	Pieridae	*Colotis danae*	Crimson tip	-	-	LC
Insecta	Lepidoptera	Pieridae	*Colotis halimede*	Yellow patch white	-	-	DD
Insecta	Lepidoptera	Pieridae	*Colotis liagore*	Desert orange tip	-	-	LC
Insecta	Lepidoptera	Pieridae	*Euchloe belemia*	Green-striped white	-	-	DD
Insecta	Lepidoptera	Sphingidae	*Daphnis nerii*	-	-	-	NE
Insecta	Lepidoptera	Sphingidae	*Hyles livornica*	-	-	Yes	NE
Insecta	Odonata	Libellulidae	*Sympetrum fonscolombii*	Red-veined darter	-	-	LC
Mammalia	Artiodactyla	Bovidae	*Capra nubiana*	Nubian ibex	-	Yes	EN
Mammalia	Artiodactyla	Bovidae	*Gazella arabica*	Arabian gazelle	Yes	-	EN
Mammalia	Artiodactyla	Bovidae	*Oryx leucoryx*	Arabian oryx	Yes	-	EN
Mammalia	Carnivora	Canidae	*Canis lupus*	Grey wolf	-	-	EN
Mammalia	Carnivora	Canidae	*Vulpes cana*	Blanford's fox	-	-	NT
Mammalia	Carnivora	Felidae	*Felis lybica*	Afro-Asiatic wildcat	-	-	NT
Mammalia	Chiroptera	Pteropodidae	*Rousettus aegyptiacus*	Egyptian rousette	-	Yes	LC
Mammalia	Chiroptera	Rhinopomatidae	*Rhinopoma cystops*	Arabian mouse-tailed bat	-	-	LC
Mammalia	Chiroptera	Vespertilionidae	*Barbastella leucomelas*	Eastern barbastelle	-	-	VU
Mammalia	Chiroptera	Vespertilionidae	*Hypsugo ariel*	Fairy pipistrelle	-	-	NT

Mammalia	Chiroptera	Vespertilionidae	*Pipistrellus kuhlii*	Kuhl's pipistrelle	-	Yes	LC
Mammalia	Chiroptera	Vespertilionidae	*Plecotus christii*	Christie's big-eared bat	-	-	NT
Mammalia	Lagomorpha	Leporidae	*Lepus capensis*	Cape hare	-	-	NT
Mammalia	Rodentia	Dipodidae	*Jaculus loftusi*	Arabian jerboa	NE	-	LC
Mammalia	Rodentia	Gliridae	*Eliomys melanurus*	Black-tailed garden dormouse	-	-	NT
Mammalia	Rodentia	Muridae	*Gerbillus cheesmani*	Cheesman's gerbil	Yes	-	LC
Mammalia	Rodentia	Muridae	*Gerbillus dasyurus*	Wagner's gerbil	NE	-	LC
Mammalia	Rodentia	Muridae	*Psammomys obesus*	Fat sand rat	-	Yes	LC
Reptilia	Squamata	Agamidae	*Pseudotrapelus sinaitus*	Sinai agama	-	-	LC
Reptilia	Squamata	Agamidae	*Uromastyx aegyptia*	Egyptian mastigure	-	-	NT
Reptilia	Squamata	Agamidae	*Uromastyx ornata*	Ornate mastigure	-	-	NT
Reptilia	Squamata	Colubridae	*Lytorhynchus diadema*	Crowned leafnose snake	-	-	LC
Reptilia	Squamata	Colubridae	*Platyceps elegantissimus*	Elegant racer	-	-	LC
Reptilia	Squamata	Colubridae	*Platyceps saharicus*	Saharan racer	-	Yes	LC
Reptilia	Squamata	Colubridae	*Spalerosophis diadema*	Diadem snake	-	-	LC
Reptilia	Squamata	Colubridae	*Telescopus dhara*	Arabian cat snake	-	Yes	DD
Reptilia	Squamata	Gekkonidae	*Hemidactylus granosus*	Grainy house gecko	-	-	LC
Reptilia	Squamata	Gekkonidae	*Stenodactylus doriae*	Dune sand gecko	-	-	LC
Reptilia	Squamata	Gekkonidae	*Tropiocolotes yomtovi*	Yom-Tov's sand gecko	-	-	LC
Reptilia	Squamata	Lacertidae	*Acanthodactylus boskianus*	Bosk's fringe-fingered lizard			LC
Reptilia	Squamata	Lacertidae	*Acanthodactylus schmidti*	Schmidt's fringe-fingered lizard	-	-	LC
Reptilia	Squamata	Lacertidae	*Acanthodactylus tilburyi*	Tilbury's fringe-fingered lizard	-	-	DD
Reptilia	Squamata	Phyllodactylidae	*Ptyodactylus ananjevae*	Ananjeva's fan-fingered gecko	-	-	LC
Reptilia	Squamata	Psammophiidae	*Psammophis schokari*	Schokari sand racer	-	-	LC
Reptilia	Squamata	Scincidae	*Chalcides ocellatus*	Ocellated bronze skink	-	-	LC
Reptilia	Squamata	Scincidae	*Scincus conirostris*	Sandfish skink	-	-	LC
Reptilia	Squamata	Varanidae	*Varanus griseus*	Desert monitor	-	-	LC
Reptilia	Squamata	Viperidae	*Cerastes gasperettii*	Gasperetti's viper	-	-	LC

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