




Rangelands of Saudi Arabia: a review

Osama H. Sayed¹ , Yahya S. Masrahi² , Moochikkal Remesh³ 

Biology Department, Jazan University, Jazan, Saudi Arabia, email: oshsayed@gmail.com (author for correspondence)

Received: May 7, 2025 | Accepted: June 24, 2025 | Published: February 3, 2026

Abstract

The rangelands of Saudi Arabia are important for the livelihood of local pastoral communities. Lowland rangelands cover huge areas in the saline saltmarshes, dry sand dunes and arid desert plains, with noticeable latitudinal and edaphic gradients, marked floristic zonation, and vegetation influenced by limited water availability. Highland rangelands display altitudinal gradients, mild wet conditions and plentiful pastoral output. This review provides insights into those rangelands' geodiversity, distribution, characteristics, and phytodiversity in relation to climatic conditions and species acclimatization potential. It also provides analysis of soil erosion, overgrazing, alien and invasive plants, urban sprawl, and intrusive recreational activities, as serious threats facing rangelands. A discussion of the necessary monitoring and management measures is also presented in terms of environment management goals.

Keywords

Saudi Arabian rangelands, characteristics, distribution, geodiversity, management, monitoring, phytodiversity, threats

Citation

Sayed, O.H., Masrahi, Y.S., Remesh, M. 2026. Rangelands of Saudi Arabia: a review. – *Phytologia Balcanica*. 32: 27-39 -- ISSN 1310-7771 (print), 1314-0027 (online).

Introduction

Saudi Arabia occupies a large part of the Arabian Peninsula, with a long maritime perimeter along the Red Sea and Arabian Gulf coasts. Climate is cold to moderate in winter and hot in summer, with scarce erratic rainfalls, protracted droughts, severe aridity, and strong sand storms (Butt & Mashat 2018; Sayed & Masrahi 2023). Its diverse coastal topography features sandy shores, saline saltmarshes and dry coastal sand dunes. Deeper inland, expansive arid desert plains form vast sand seas with barchans, desert pavements and ancient basaltic lava fields (Moufti & Németh 2016; Sayed & Masrahi 2023). The highlands with their wet and mild conditions offer rich phytodiversity. The cool mild conditions and ample rainfalls in the mountains support thriving pasture and

terraced agriculture (Sayed & al. 2019; Al-Turki & al. 2020; Khemira & al. 2023; Sayed & Masrahi 2023; Sayed & Masrahi 2025).

Saudi Arabian rangelands cover huge areas of saline saltmarshes, dry sand dunes, arid desert plains, and cool mountains. They are important for livestock breeding and support of pastoral communities. They also play crucial ecological role in preventing soil degradation and enhancing carbon sequestration (Al-Rowaily & al. 2018; Alhaithloul 2019; Alzarrah & al. 2021). In line with the way the early inhabitants used to graze their herds for centuries, sustainability of the rangelands has been achieved by voluntary grazing restrictions due to the movement of nomadic tribes thus imposing intermittent respite to the rangelands. However, urbanization and anthropogenic activities brought about formidable challenges, with se-

rious consequences of soil erosion, floristic degradation, and rangelands deterioration (Al-Rowaily & al. 2015; As-seeed & al. 2019). This review offers an insight into the Saudi Arabian rangelands geodiversity, distribution, characteristics, and phytodiversity in relation to climatic conditions and species acclimatization potential. It provides an elaborate analysis of soil erosion, overgrazing, alien and invasive plant incursions, urban sprawl, and intrusive outdoor recreational activities as major challenges for rangelands deterioration. It also discusses the necessary measures for tackling these challenges, with an emphasis on the rangelands' monitoring and management.

1. Distribution and phytodiversity

1.1 Northern Region rangelands

The Northern Region covers large areas of An-Nafud Desert remarkable for its vast arid desert plains, aeolian reddish sand, crescent-shaped barchans, and extreme aridity (Fig. 1). Its climate is cold in winter and mild in summer, with mean annual temperatures of 10°C and 35°C, respectively, and winter precipitation of about 40 mm (Table 1). During the rainy season in winter, large transient pools in shallow silty depressions host rich annual vegetation (Hasanean & Almazroui 2015).

The northern parts of An-Nafud Desert enclose vast desert plains with *Vachellia flava*-*Vachellia tortilis* and *Panicum turgidum*-*Artemisia monosperma* communities,

vegetation of Saharo-Arabian/Irano-Turanian chorology, and mainly therophyte and chamaephyte life forms (Table 2). The rangelands comprise thorn scrubs (*Vachellia flava*, *V. tortilis* - *Fabaceae*) and cool-adapted grasses such as *Aegilops kotschyi*, *Alopecurus myosuroides*, *Avena byzantina*, *Avena sterilis*, *Bromus scoparius*, *Dactylis glomerata*, *Poa sinaica*, and *Stipa parviflora* (*Poaceae*) (Masrahi & al. 2012; Sayed & Masrahi 2025). The cool-adapted annuals and perennials include *Anvillea garcinii* (*Asteraceae*), *Astragalus spinosus* (*Fabaceae*), *Calligonum polygonoides* (*Polygonaceae*), *Paronychia arabica* (*Caryophyllaceae*), and *Reseda pruinosa* (*Resedaceae*) (Fakhry & AlAnazi 2017; Hosny & al. 2018; Basahi 2018).

The southern parts of An-Nafud Desert encompass barchans, which host *Haloxylon persicum*-*Stipagrostis drarii* and *Pulicaria undulata*-*Citrullus colocynthis* communities, vegetation of Saharo-Arabian/Sudano-Zambezian chorology with some Irano-Turanian elements, and mainly therophyte and chamaephyte life forms (Table 2). The rangelands contain thorn scrubs (*Vachellia flava*, *V. tortilis* - *Fabaceae*) and a blend of cool- and warm-adapted grasses, such as *Ammochloa palaestina*, *Bromus danthoniae*, *Oryzopsis miliacea*, *Centropodia forskalii*, *Enneapogon lophotrichus*, *Eragrostis aspera*, *Digitaria pennata*, and *Echinochloa frumentacea* (*Poaceae*) (Masrahi & al. 2012; Sayed & Masrahi 2025). Common species include *Anthemis deserti* (*Asteraceae*), *Horwoodia dicksoniae* (*Brassicaceae*), *Plantago boissieri* (*Plantaginaceae*), *Polycarpaea repens* (*Caryophyllaceae*), and *Savignya parviflora* (Hosny & al. 2018; Abdein & Osman 2020; Elmefregy & El-Sheikh 2020; El-Sheikh & al. 2021).

Fig. 1. Map of different regions of Saudi Arabia. (<https://www.worldmap1.com/saudi-arabia-map.asp>).



Table 1. Saudi Arabian rangelands' distribution and geodiversity

Region	Territory	Features					
		Altitude (m)	Topography	Climate	Temp. (°C)	Rainfall (mm)	Aridity
Northern	An-Nafud Desert	500	Desert plains Sand dunes	Cold winter Mild summer	Min. 10 Max. 35	Winter 40 mm	Hyper-arid
Central	Najd Plateau Northern Parts	800-1000	Barchans Wadis	Cold winter Warm summer	Min. 15 Max. 30	Winter 100 mm	Arid
	Najd Plateau Southern Parts	600	Desert plains Wadis	Mild winter Hot summer	Min. 20 Max. 40	Winter 20 mm	Hyper-arid
Eastern	Northern Parts	0-500	Saltmarshes Sand dunes	Cold winter Hot summer	Min. 15 Max. 45	Winter 70 mm	Arid
	Southern Parts	0-500	Saltmarshes Sand dunes	Mild winter Warm summer	Min. 20 Max. 45	Winter 70 mm	Arid
	Al-Ahsa Oasis	150	Desert plains Wadis	Mild winter Hot summer	Min. 25 Max. 45	Winter 70 mm	Arid
	Empty Quarter	800	Barchans Desert plains	Cold winter Hot summer	Min. 10 Max. 50	Spring 10 mm	Hyper-arid
Western	Northern Tihama	0-700	Saltmarshes Sand dunes Desert plains	Cold winter Mild summer	Min. 10 Max. 20	Winter 25 mm	Arid
	Central Tihama	0-500	Saltmarshes Sand dunes Desert plains	Mild winter Hot summer	Min. 20 Max. 30	Winter/ spring 70 mm	Arid
	Southwestern Lowlands	0-500	Saltmarshes Sand dunes Desert plains	Mild winter Hot summer	Min. 25 Max. 35	Summer 100 mm	Hyper-arid
Southwestern	Highlands	500-1000	Highlands	Mild winter Hot summer	Min. 20 Max. 30	Summer 200 mm	Arid
	Mountains	>1000	Mountains	Cold winter Mild summer	Min. 10 Max. 20	Summer 300 mm	Semi-arid

1.2 Central Region rangelands

The Central Region falls within the elevated Najd Plateau, with its dry desert plains, arid desert pavements, crescent-shaped barchans, meadows, and wadis (Fig. 1). Najd Plateau reaches an altitude of 1000 m in the west and slopes down gently eastward to about 800 m, with many fertile areas within the Tuwaiq Escarpment Jurassic stratigraphic sequence (Alghamdi & al. 2018; Mseddi & al. 2021; Sayed & Masrahi 2023). Climate shows north-south temperature variations, with cold winter in the

northern parts, mild winter in the southern parts, and mean annual temperatures of 15°C and 20°C, respectively. Summer is warm in the northern parts and hot in the southern parts, with mean annual temperatures of 30°C and 40°C, respectively (Table 1). The rainy season in winter brings total annual precipitation of 100 mm in the northern parts and 20 mm in the southern parts (Hasanean & Almazroui 2015; Alotaibi & al. 2018).

The Central Region rangelands cover vast areas of the Najd Plateau dry sand dunes, arid desert pavements and wadis with aquifers and ample pastoral output. They

Table 2. Saudi Arabian rangelands' characteristics and phytodiversity

Region	Territory	Altitude (m)	Phytodiversity			
			Mangroves	Thorn scrubs	Juniperious woodlands	Species Tendency Chorology
Northern	Nafud Desert Northern Part	500	-	<i>Vachellia flava</i> <i>V. tortilis</i>	-	Cool-adapted Saharo-Arabian/ Irano-Turanian
	Nafud Desert Southern Part	500	-	<i>Vachellia flava</i> <i>V. tortilis</i>	-	Cool-adapted Warm-adapted Saharo-Arabian/ Irano-Turanian
Central	Najd Plateau Northern Part	800-1000	-	<i>Vachellia flava</i> <i>V. oerfota</i> <i>V. tortilis</i>	-	Cool-adapted Saharo-Arabian/ Irano-Turanian
	Najd Plateau Southern Part	600	-	<i>Vachellia flava</i> <i>V. oerfota</i> <i>V. tortilis</i>	-	Warm-adapted Arid-adapted Saharo-Arabian/ Irano-Turanian
Eastern	Northern Part	0-500	<i>A. marina</i>	<i>Vachellia flava</i> <i>V. tortilis</i>	-	Salt-tolerant Saharo-Arabian/ Irano-Turanian
	Southern Part	0-500	<i>A. marina</i>	<i>Vachellia flava</i> <i>V. tortilis</i>	-	Salt-tolerant Saharo-Arabian/ Irano-Turanian
	Al-Ahsa Oasis	150	-	<i>Vachellia flava</i> <i>V. tortilis</i>	-	Warm-adapted Arid-adapted Saharo-Arabian/ Irano-Turanian
	Empty Quarter	800	-	<i>Senegalia hamulosa</i> <i>Vachellia flava</i> <i>V. oerfota</i> <i>V. tortilis</i>	-	Drought-tolerant Saharo-Arabian/ Irano-Turanian
Western	Northern Tihama	0-700	<i>A. marina</i>	<i>Vachellia flava</i> <i>V. tortilis</i>	-	Salt-tolerant Cool-adapted Saharo-Arabian/ Irano-Turanian with some Mediterranean elements
	Central Tihama	0-500	<i>A. marina</i>	<i>Vachellia flava</i> <i>V. tortilis</i>	-	Salt-tolerant Cool-adapted Warm-adapted Saharo-Arabian/ Sudano-Zambeian with some Saharo-Arabian/ Irano-Turanian elements
	Southwestern Lowlands	0-500	<i>A. marina</i> <i>R. mucronata</i>	<i>Vachellia flava</i> <i>V. tortilis</i>	-	Salt-tolerant Warm-adapted Arid-adapted Saharo-Arabian/ Sudano-Zambeian with some Saharo-Arabian/ Irano-Turanian elements
South-western	Highlands	500-1000	-	<i>Senegalia asak</i> <i>Vachellia flava</i>	-	Cool-adapted Warm-adapted Saharo-Arabian/ Irano-Turanian
	Asir Mountains	>1000	-	<i>Senegalia asak</i> <i>V. etbaica</i> <i>A. gerrardii</i> <i>A. origina</i>	<i>Juniperus procera</i>	Cool-adapted Irano-Turanian/Euro-Siberian

contain thorn scrubs, cool-adapted annual and perennial species in the northern parts, and an assemblage of warm- and arid-adapted annual and perennial species in the southern parts (Hosny & al. 2018; Alhaithloul 2019; Rauf & al. 2022).

The sand dunes host *Artemisia monosperma*-*Haloxylon salicornicum* and *Leptadenia pyrotechnica*-*Haplophyllum*

tuberculatum communities, vegetation of Saharo-Arabian/Irano-Turanian chorology, and mainly therophyte and chamaephyte life forms (Table 2). Grasses include cool- and warm-adapted species, such as *Brachiaria ramosa*, *Bromus rubens*, *Bromus tectorum*, *Cenchrus gracilimus*, *Chrysopogon plumulosus*, *Cutandia memphitica*, *Tetrapogon villosus*, and *Tragus racemosus* (*Poaceae*).

Common species include *Polycarpha repens* (Caryophyllaceae), *Senna italica* (Fabaceae), *Horwoodia dicksoniae* (Brassicaceae), and *Neurada procumbens* (Nuradaceae) (Sayed & Masrahi 2023; Sayed & Masrahi 2025).

Desert pavements host *Vachellia tortilis*-*Rhazya stricta* communities, vegetation of Saharo-Arabian/Sudano-Zambezian chorology with some Irano-Turanian elements, and mainly phanerophyte and therophyte life forms (Table 2). They enclose thorn scrubs (*Vachellia flava*, *V. oerfota*, and *V. tortilis* - Fabaceae) and warm-adapted grasses, such as *Dactyloctenium aegyptium*, *Ochthochloa compressa*, and *Panicum turgidum* (Poaceae) (Masrahi & al. 2012; Hosny & al. 2018; Sayed & Masrahi 2025). The major perennial species include *Corchorus depressus* (Tiliaceae), *Helianthemum kahiricum* (Cistaceae) and *Senna italica* (Fabaceae). Winter rainfalls create ephemeral pools that encourage such annual species as *Bassia muricata* (Amaranthaceae), *Paronychia arabica* (Caryophyllaceae) and *Pycnocycla nodiflora* (Apiaceae) (Alghamdi & al. 2018; Alsharif & al. 2022; Sayed & Masrahi 2023; Almarr & al. 2024).

1.3 Eastern Region rangelands

The Eastern Region covers large areas along the hot and humid Arabian Gulf coast and extends into the southeastern hot hyper-arid Empty Quarter (Fig. 1). The climate of coastal areas shows north-south temperature variations, with cold winter in the northern parts, mild winter in the southern parts, mean annual temperatures of 15°C and 20°C, respectively, and winter rainfalls of about 70 mm (Table 1). However, summer is predominantly hot there, with mean annual temperature of 45°C (Almazroui 2020). These coastal areas host *Avicennia marina* (Acanthaceae) mangrove swamps, where camel herding is common, and as they extend inland into the saline littoral saltmarshes, they host halo-succulents shrubs and salt-tolerant grasses (Sayed 1995, Sayed & Masrahi 2023). As these rangelands extend further inland into the sand dunes and desert plains, they exhibit edaphic gradients of decreased soil salinity and water content and a floristic shift towards drought-tolerant annual and perennial species.

The saltmarsh rangelands along the Arabian Gulf coast host *Haloxylon salicornicum*-*Zygophyllum qatarense* and *Aeluropus lagopoides*-*Halopeplis perfoliata* communities, vegetation of Saharo-Arabian/Irano-Turanian chorology, and mainly chamaephyte and hemicryptophyte life forms (Table 2). Halo-succulents include *Anabasis setifera*, *Arthrocnemum macrostachyum*, *Halocnemum strobilaceum*, *Salicornia sinus-persica*, and *Seidlitzia rosmarinus* (Amaranthaceae). Grasses include *Centropodia fragilis*, *Lasurus scindicus*, *Phragmites australis* and *Stipagrostis plumosa* (Poaceae) (Masrahi & al. 2012; Sayed & Masrahi 2025). Common species include *Mesembryanthemum forsskalii* (Aizoaceae), *Plantago boissieri* (Plantaginaceae) and *Suaeda aegyptiaca* (Amaranthaceae) (Sayed 1993, 1994, 1995, 1996; Al-Turki & al. 2017; Almahasher 2021; Sayed & Masrahi 2023).

The Eastern Region rangelands also extend into the desert plains of Al-Ahsa Oasis, with its thriving agriculture supported by groundwater from complex aquifers and numerous springs (Salih & al. 2021, Khogali & al. 2024). Climate there is mild in winter and hot in summer, with mean annual temperatures of 25°C and 45°C, respectively, and winter rainfalls of about 70 mm (Table 1). That area hosts *Seidlitzia rosmarinus*-*Suaeda pruinoso-Zygophyllum decumbens* and *Haloxylon salicornicum*-*Cornulaca monacantha*-*Salsola baryosma* communities, vegetation of Saharo-Arabian/Irano-Turanian chorology, and mainly phanerophytes and therophyte life forms (Table 2). It also encloses thorn scrubs (*Vachellia flava*, *V. tortilis* - Fabaceae), vegetation of warm- and arid-adapted annuals and perennials, and vast areas of cultivated date palms (*Phoenix dactylifera* - Arecaceae) and Hassawi rice (*Oryza sativa* L. cv. Hassawi - Poaceae) (Al-Turki & Basahi 2015; Hosny & al. 2018; Al-Mssallem & al. 2024).

Furthermore, the southeastern parts of the Eastern Region rangelands fall within the hot hyper-arid Empty Quarter's vast desert plains and crescent-shaped barchans. Climate there is cold in winter and hot in summer, with mean annual temperatures of 10°C and 50°C, respectively (Table 1). Short spring rainy spells bring a total annual rainfall of only 10 mm (Almazroui 2019; Sayed & Masrahi 2023). That hyper-arid region hosts *Haloxylon salicornicum*-*Vachellia tortilis* and *Halophyllum tuberculatum*-*Vachellia oerfota* communities, and vegetation of Saharo-Arabian/Irano-Turanian chorology (Table 2). It enfolds scattered thorn scrub woodlands (*Senegalia hamulosa*, *Vachellia flava*, *V. oerfota*, and *V. tortilis* - Fabaceae) and tree species, such as *Commiphora myrrha* (Burseraceae), *Maerua crassifolia* (Capparaceae), *Moringa peregrina* (Moringaceae), and *Ziziphus spinachristi* (Rhamnaceae). Vegetation includes warm-adapted and drought-tolerant perennial shrubs, such as *Ephedra foliata* (Ephedraceae) and *Haloxylon salicornicum* (Amaranthaceae), herbaceous species, such as *Dipterygium glaucum* (Cleomaceae), *Haplophyllum tuberculatum* (Rutaceae), *Leucas inflata* (Lamiaceae), and *Limeum arabicum* (Limeaceae), and few perennial grasses, such as *Panicum turgidum* (Poaceae). Annual species, such as *Astragalus hauarensis* (Fabaceae), *Cleome amblyocarpa* (Cleomaceae), *Monsonia nivea* (Geraniaceae), *Polygala erioptera* (Polygalaceae), and *Aristida adscensionis* (Poaceae), occur only after the spring rainfalls (Hall & al. 2010; Sayed & Masrahi 2023).

1.4 Western Region rangelands

The Western Region rangelands stretch parallel to the Red Sea coast, enclosing parts in northern Tihama, central Tihama, and southwestern lowlands (Fig. 1). Their wide latitudinal span (32°-17°N) entails a pronounced temperature gradient, with cold winter in the north and mild winter in the central parts and southern lowlands, with mean annual temperatures of 10°C, 20°C, and 25°C, respectively. Summer is mild in the north, warm

in the central parts, and hot in the southern lowlands, with mean annual temperatures of 20°C, 30°C, and 35°C, respectively (Table 1). Rainfalls occur in winter in the north, in winter and early spring in the central parts, and in summer in the southern lowlands (Hasanea & al. 2015; Hasanean & Almazroui 2015; Butt & Mashat 2018; Almazroui 2020; Rauf & al. 2022; Sayed & Masrahi 2023). The total annual precipitation shows a north-south rise, with 25 mm in the north, 70 mm in the central parts, and 100 mm in the southern lowlands (Almazroui 2019; Rauf & al. 2022; Sayed & Masrahi 2023). However, despite that north-south increase in the rainfalls, aridity manifests a notable north-south rise, due to the fact that that rainfalls occur during the hot summers, which increases demand for evapotranspiration in the southern lowlands (Almazroui & al. 2017; Almazroui 2020; Sayed & Masrahi 2023; Sayed & Masrahi 2025). Those rangelands comprise saline littoral saltmarshes, dry coastal sand dunes, and extend inland into the arid Tihama Desert plains. Such inland transition inflicts an edaphic gradient, with a marked decline of soil salinity and water content, and a floristic shift from the shoreline mangrove swamps to wet saline saltmarshes with halo-succulent shrubs and salt-tolerant grasses, and to arid desert plains dominated by drought-tolerant perennials (Remesh & al. 2020; Sayed & Masrahi 2023). While, the mangrove swamps host *Avicennia marina* (Acanthaceae) along the Red Sea coast, *Rhizophora mucronata* (Rhizophoraceae) is restricted to the southern Red Sea coralline islands and the Farasan Archipelago (Al-Qthanin & Al-Yasi 2021; Sayed & Masrahi 2023).

The northern Red Sea littoral saltmarshes host *Suaeda fruticosa*-*Juncus rigidus* and *Zygophyllum coccineum*-*Cyperus conglomeratus* communities, vegetation of Saharo-Arabian/Irano-Turanian chorology with some Mediterranean elements, and mainly therophyte and chamaephyte life forms (Table 2). The rangeland plants include halo succulents, such as *Arthrocnemum macrostachyum* and *Suaeda fruticosa* (Amaranthaceae), and salt-tolerant grasses, such as *Aeluropus littoralis*, *Echinochloa colona*, *Eragrostis lepida*, *Leptochloa fusca*, and *Saccharum ravennae* (Poaceae) (Masrahi & al. 2012; Basahi 2018; Sayed & Masrahi 2023; Sayed & Masrahi 2025).

The central Red Sea littoral saltmarshes host *Atriplex farinosa*-*Anabasis setifera* and *Suaeda pruinosa*-*Panicum turgidum* communities, vegetation of Saharo-Arabian/Sudano-Zambezian chorology with a few Irano-Turanian elements, and therophyte and chaemophyte life forms, with some hemicryptophytes and geophytes (Table 2). The rangeland plants include halo-succulents, such as *Anabasis setifera*, *Salsola baryosma* and *S. tetrandra* (Amaranthaceae), and grasses such as *Aeluropus lagopoides*, *Aristida funiculata*, *Panicum antidotale*, and *Panicum turgidum* (Poaceae) (Masrahi & al. 2012; Sayed & Masrahi 2023; Sayed & Masrahi 2025).

The southern Red Sea littoral saltmarshes host *Aeluropus lagopoides*-*Cyperus conglomeratus* and *Suaeda monoica*-*Panicum turgidum* communities, vegetation

of Saharo-Arabian/Sudano-Zambezian chorology, and mainly therophyte and chamaephyte life forms. The rangeland plants include halo-succulents, such as *Sesuvium verrucosum* (Aizoaceae) and *Suaeda monoica* (Amaranthaceae), and salt-tolerant grasses, such as *Aeluropus lagopoides*, *Desmostachya bipinnata*, *Halopyrum mucronatum*, *Panicum repens*, *Sporobolus helvolus*, *S. spicatus*, and *Urochondra setulosa* (Poaceae) (Masrahi & al. 2012; Sayed & Masrahi 2023; Sayed & Masrahi 2025).

The Western Region rangelands also extend inland into the dry arid desert plains with north-south floristic transition manifested by prevalence of cool-adapted species in the cool northern parts, cool- and warm-adapted species in the warm central parts, and warm- and arid-adapted species in the hot hyper-arid southwestern lowlands. Vegetation chorology also changes from Saharo-Arabian/Irano-Turanian with a few Mediterranean elements in the northern parts, to Saharo-Arabian/Sudano-Zambezian with some Saharo-Arabian/Irano-Turanian elements in the central parts, and Saharo-Arabian/Sudano-Zambezian in the southwestern lowlands (Al-Gifri & al. 2018; Al-Gifri & al. 2019; Khormy & al. 2019; Remesh & al. 2019; Sayed & al. 2020; Alharthi & al. 2023; Sayed & Masrahi 2023; Sayed & Masrahi 2025).

The northern cool desert plains host *Vachellia tortilis*-*Vachellia flava*, *Vachellia tortilis*-*Stipagrostis plumosa*, *Vachellia tortilis*-*Lycium shawii*, *Tamarix aucheriana*-*Juncus rigidus*, and *Capparis decidua*-*Zygophyllum simplex* communities, and vegetation of Saharo-Arabian/Irano-Turanian chorology with a few Mediterranean elements (Table 2). The rangeland grasses are mainly cool-adapted, such as *Ammochloa palaestina*, *Bromus dianthus*, *Ehrharta erecta*, *Hordeum murinum*, *Ochthochloa compressa*, *Poa annua*, and *Stipa capensis* (Alharthi & al. 2020; Sayed & Masrahi 2023; Sayed & Masrahi 2025).

The central warm desert plains host *Reichardia tingitana*-*Heliotropium aegyptiacum* and *Vachellia flava*-*Abutilon pannosum* communities, and vegetation of Saharo-Arabian/Sudano-Zambezian chorology with a few Irano-Turanian elements (Table 2). The rangeland grasses are mainly warm-adapted, such as *Cenchrus ciliaris*, *Lasiurus scindicus*, *Panicum turgidum*, and *Pennisetum divisum* (Poaceae) (Masrahi & al. 2012; Alharthi & al. 2023; Sayed & Masrahi 2023; Sayed & Masrahi 2025).

The hot hyper-arid desert plains of the southern lowlands host *Salvadora persica*-*Suaeda monoica*, *Tamarix aphylla*-*Cyperus conglomeratus* and *Ziziphus spinachristi*-*Vachellia tortilis* communities, and vegetation of Saharo-Arabian/Sudano-Zambezian chorology. The rangeland grasses are warm- and arid-adapted, such as *Eleusine indica*, *Eragrostis ciliaris*, *Digitaria velutina*, *Odysea mucronata*, *Paspalum dilatatum*, *Schoenefeldia gracilis*, and *Sporobolus festivus* (Masrahi & al. 2012; Sayed & Masrahi 2025).

1.5 Southwestern Region rangelands

Large parts of the Southwestern Region rangelands

are located in the highlands, reaching 1000 m a.s.l., and along the mountain slopes, exceeding 2000 m a.s.l. (Fig. 1). Increased altitude imposes climatic gradients of lower mean annual temperatures from 30°C to 20°C, and higher total annual precipitation from 200 mm to 300 mm in the highlands and high-altitude peaks, respectively (Table 1). With increase of the altitude, floristic diversity of the rangelands also increases, with a marked shift from thorn scrubs with cool- and warm-adapted species in the highlands, to *Juniperus* woodlands with a rich diversity of cool-adapted species on the high-altitude peaks (El-Juhany 2015; Al-Turki & al. 2019; Shalabi & Masrahi 2019; Ellassal 2020).

Highlands host *Nicotiana glauca*-*Senegalia asak* and *Ochradenus baccatus*-*Dodonaea viscosa* communities, and vegetation of Saharo-Arabian/Irano-Turanian chorology (Table 2). The highlands also host thorn scrubs (*Senegalia asak* and *Vachellia flava* - *Fabaceae*), and tree species, such as *Ficus cordata*, *F. palmata*, *F. sycomorus* and *F. vasta* (*Moraceae*), *Salvadora persica* (*Salvadoraceae*) and *Ziziphus mucronata* (*Rhamnaceae*) (Masrahi et al. 2017; Hosny & al. 2018; Sayed and Masrahi 2023). The shady wet understory of those trees encourages many annuals and perennials, some of aromatic and medicinal usage, such as *Senna occidentalis* and *Tamarindus indica* (*Fabaceae*), *Lavandula coronopifolia* and *Ocimum filamentosum* (*Lamiaceae*), *Jasminum grandiflorum* and *Olea europaea* (*Oleaceae*). The rangelands' cool-adapted grasses include *Avena ventricosa*, *Brachypodium fasciculatus*, *Ehrharta erecta*, *Eremopyrum bonapartii*, and *Stipa capensis*, and warm-adapted grasses, such as *Enneapogon persicus*, *Eragrostis barrelieri*, *Panicum coloratum*, and *Paspalum dilatatum* (Masrahi & al. 2012; Masrahi & al. 2017; Sayed & Masrahi 2025).

The mountain peaks reaching 1500 m a.s.l. host vegetation of Saharo-Arabian/Irano-Turanian chorology with a few Euro-Siberian elements, and therophyte, chamaephyte, hemicryptophyte, and phanerophyte life forms (Table 2). The thorn scrubs population includes *Senegalia asak*, *Vachellia etbaica* and *V. origena* (*Fabaceae*). However, the peaks exceeding 2000 m a.s.l. host conifer *Juniperus procera* (*Cupressaceae*) forests, cool-adapted species, such as *Achyranthes aspera* (*Amaranthaceae*), *Launaea massauensis*, *Pulicaria schimperi* (*Asteraceae*), *Triumfetta flavescens*, and *Sida alba* (*Malvaceae*), and cool-adapted grasses such as *Brachypodium retusum*, *Bromus pulchellus*, *Festuca arundinacea*, *Gastridium phleoides*, *Lamarckia aurea*, and *Trisetaria chaudharyana* (El-Juhany 2015; Hosny & al. 2018; Sayed & Masrahi 2025).

2. Threats

2.1 Soil erosion

Soil is the medium for root anchorage and plant support, source of water and nutrients, and habitat for organisms engaged in nitrogen fixation and decomposition

of litter. Soil erosion in the Saudi Arabian rangelands is connected with the inherent arid nature of the soil, high wind speed and fast surface runoff (Abd El-Salam & Elhakem 2016; Alghamdi 2017). Studies relating rangeland vegetation intensity to soil texture and moisture have indicated that while silt-loam soils with high water-holding capacity support rich vegetation and flourishing pastures, sandy soils host poor vegetation with frequently degraded patches. Strong storms common of the arid regions are also reported to increase sand soil loss, aggravate soil erosion and intensify rangelands degradation (Arishi 2020; Alzahrani & al. 2024, Al-Hajji & al. 2025). Plant cover deterioration is, in turn, reported to adversely affect rangeland soils, due to root system degradation, which entails increased soil compaction and runoff speed (Abd El-Salam & Elhakem 2016). Therefore, robust root systems are important for enhancing soil cohesion and improving arid rangeland soil properties (Alghamdi 2017; Al-Rowaily & al. 2018; Alzarah & al. 2021). Along these lines, intertwined grass fibrous roots and rhizomes develop shallow intensive networks that increase soil cohesion and stability (Abd El-Salam & Elhakem 2016; Elmefregy & El-Sheikh 2020; El-Sheikh & al. 2021; Salih & al. 2021). Furthermore, burial-resistant species, such as *Cadaba rotundifolia* (*Capparaceae*) and *Salvadora persica* (*Salvadoraceae*), contribute to sand dunes stabilization. When covered by sand, those burial-resistant hillock-forming species start new branches and develop phyto-genic hillocks, which slow down wind speed and create drainage paths that decelerate surface runoff (Elmefregy & El-Sheikh 2020; Remesh & al. 2020; El-Sheikh & al. 2021). Therefore, encouraging proliferation of grasses and burial-resistant species should be an integral part of the rehabilitation programs aimed at enhancing rangeland soil properties.

2.2 Overgrazing

Overgrazing in Saudi Arabian rangelands pertains to intensive herding without respites needed for vegetation recovery. It reduces pasture output, lowers litter deposition, diminishes native species persistence, and encourages encroachment of alien plants. Ultimately, it leads to increased soil compaction, reduced soil water infiltration, and reduced soil water-holding capacity (Al-Rowaily & al. 2018; Alhaithloul 2019; Alzarah & al. 2021). Therefore, rangeland maintenance should target analysis of the spatiotemporal vegetation dynamics, evaluation of pasture carrying capacity, and adoption of controlled livestock density. It is also important to enforce grazing rotation measures and conduct intensive public awareness campaigns (Azaiez & al. 2023; Almarri & al. 2024; Al-Huqail & al. 2025a).

2.3 Alien and invasive plants

While alien plants are non-native rangeland invaders, invasive plants can be alien or native species. These plants can outnumber the palatable species, alter vegeta-

tion structure and modify seed bank reserve. Harmful effects of the alien species also relate to their ability for comebacks that encourage their dominance over the native species, develop non-palatable alien plant stands, and produce litter biomass with allelopathic attributes, which suppress emergence, survival and recruitment of the native species' seedlings (Abbas & al. 2023; Abdelmalik & al. 2023). The alien plants of Saudi Arabian rangelands include several species, of which most damaging are *Argemone mexicana* (Papaveraceae), *Argemone ochroleuca* (Papaveraceae), *Ipomoea carnea* (Convolvulaceae), *Nicotiana glauca* (Solanaceae), *Cylindropuntia rosea*, *Opuntia stricta*, *Opuntia ficus-indica* (Cactaceae), *Parthenium hysterophorus* (Asteraceae), *Prosopis juliflora* (Fabaceae), and *Trianthema portulacastrum* (Aizoaceae) (Masrahi & al. 2015; Thomas & al. 2016; Masrahi & Sayed 2017; Masrahi & al. 2017; Alfarhan & al. 2021; Aljeddani & al. 2021; Assaeed & al. 2021; Sayed and Masrahi 2023). The native species of ominous invasive nature include *Arundo donax*, *Avena sterilis*, *Cenchrus echinatus*, *Chloris barbata*, *Digitaria ciliaris*, *Imperata cylindrica*, *Panicum antidotale*, and *Paspalum dilatatum* (Alharthi & al. 2020; Sayed & Masrahi 2025). Combating these alien and invasive species by physical harvesting, solarization of infested seed banks, and application of selective herbicides produces only short-term results. Long-term invasion control requires spatiotemporal monitoring, updated vegetation maps, analysis of invasion patterns, and biological control techniques. Lining up goals for herders, administrative bodies and ecological agencies is also imperative for eliminating the conflicts of interest and maximizing the control results (El-Juhany & al. 2022; Baharvandi & al. 2022; Almarri & al. 2024; Al-Huqail & al. 2025b).

2.4 Urban sprawl

Urban sprawl is an impactful socioeconomic process that alters land use, encourages rural-urban migration, and causes rangeland degradation. The reduced pastoral output of Saudi Arabian rangelands has been attributed to the accelerated growth of urban clusters and expansion of urban edge into the rangelands' natural framework (Almazroui & al. 2017; Aina & al. 2019; Alqadhi & al. 2021; Aljaddani & al. 2022). Therefore, monitoring urban expansion and controlling land use are important measures for curbing the damaging effects of urban sprawl. It is also important to consider setting of appropriate boundaries for urban expansion and enforcing legislation aimed at achieving the optimal urban growth, while protecting the rangelands' natural environment. Legal framework defining the urban boundaries is also important to align the urban expansion limits to environmental protection objectives (Aljaddani & al. 2022; Alsharif & al. 2022; Almarri & al. 2024, Alshayeb 2025).

2.5 Outdoor recreational activities

Outdoor recreational activities in Saudi Arabia en-

compass a rich tapestry of desert sports interwoven with heritage, culture and modernity. Among these, falconry, hunting, camping, and off-road driving are most popular. However, these nature-based activities often interfere with the natural desert environment and include intrusive practices that pose serious threats to the fragile rangeland ecosystems (Alatawi 2022, Alrawaf & al. 2023; Barichiev & al. 2018). Desert camping is also related to alarming pollutants and plastic waste accumulation, with hazardous microplastic compounds that retard plant growth and reduce rangeland forage quality (El-Bana & Aldakhil 2015; Alzarah & al. 2021; Alrawaf & al. 2023). Furthermore, off-road driving is one of the most environmentally destructive outdoor activities. It changes gravely the rangeland hydrological pattern by creating salient driving tracks that alter soil texture, increase soil compaction, and reduce soil water retention. It also fragmentizes the grazing sites and encourages the invasive species' incursion and alien species' encroachment (El-Bana & Aldakhil 2015; Ayachi & Jaouadi 2017; Al-Dousari & al. 2019; Assaeed & al. 2019; Al-Huqail & al. 2025b). Along these lines, the term "ecotourism" describes some nature-based activities that harmonize recreation with environmental protection so as to achieve adequate touristic experience with minimal impact on nature. Therefore, sustainable nature-based activities can be achieved by upgrading the rangeland workers' training, public awareness campaigns and updating the national curricula with environmental protection themes (Al-Tokhais & Thapa 2019; Ellassal 2020; AlAli & al. 2024).

3. Monitoring

Monitoring of natural resources involves continuous assessment aimed at developing and updating the information which reflects the current status, anticipates future changes and reveals long-term trends. It also helps assess validity of the management programs and achieve sustainability objectives. Therefore, monitoring is important for understanding the rangeland dynamics and providing information necessary for management and decision-making (Alghamdi 2017; Assaeed & al. 2018). Monitoring the Saudi Arabian rangelands has recently gained momentum by establishing some genetic diversity centers and seed gene banks to regulate the rangelands' genetic dependability and consistency (Al-Turki & al. 2020; Assaeed & al. 2021). It has also been improved by introducing some advanced tools that facilitate spatiotemporal monitoring, such as GIS applications useful for evaluation of soil erosion, identification of degraded rangelands and exploration of groundwater reserves (Abdullah & al. 2015; Alzarah & al. 2021; Mobarak & al. 2022; Shrahily & al. 2022; Abdullah & al. 2023). Advanced remote-sensing and satellite-based approaches also offer robust tools for real-time spatiotemporal imagery and updated vegetation maps (Al-Rowaily & al. 2018; Alzarah & al. 2021; Alsharif & al. 2022; Mobarak & al.

2022; Shrahily & al. 2022). Such innovations as Artificial Intelligence (AI), Internet of Things (IoT), Machine Learning (ML), and autonomous Unmanned Aerial Vehicles (UAVs) have also been adopted in the Saudi Arabian rangeland monitoring programs. Of these tools, UAVs have been effectively used to determine the rangeland vegetation phenology and monitor the grazing animal biometrics and feeding behaviors. Artificial Intelligence Neural Networks augmented with Machine Learning algorithms has also proved effective in assessing and predicting the rangelands' soil erosion (Alanezi & al. 2022; Alqadhi & al. 2023).

4. Management

Overexploitation pressures have currently caused rangeland decline at unprecedented critical levels. These pressures call for implementation of management programs aimed at sustainably operated rangelands, protection of their quality and keeping of their consumption-sustainability balance. The required comprehensive management programs should address the herding practices, livestock characteristics, stocking rates, and animal grazing behavior, as well as other rangeland resources such as soil, water and vegetation. These programs should also be flexible and responsive to the rangelands' dynamic nature, which calls for corrective actions (Abdullah & al. 2015; Barichiev & al. 2018; El-Juhany & al. 2022).

Saudi Arabian rangelands are facing multiple issues, of which selective livestock grazing, protracted drought and plant cover deterioration are most damaging. Selective grazing targets individual species and particular grazing patches, which depletes palatable species and encourages invasive plants. Therefore, management programs should enforce rotational grazing measures to alleviate the adverse effects of selective grazing (Abdullah & al. 2015; Alanezi & al. 2022, FAO 2022; Alqadhi & al. 2023). Furthermore, protracted droughts limit rangeland vegetation in the arid regions and demand adoption of water management approaches that target high rainwater use efficiency (Abbas & al. 2022; Alotaibi & al. 2023). Along these lines, dams built at desert depressions create water reservoirs for recharge of aquifers and support of desert agriculture (Abu-Abdullah & al. 2020; Sayed & al. 2020). Therefore, management programs should also address the use of these huge water reserves for planned irrigation of the arid rangelands during prolonged droughts. Several studies have proved effectiveness of controlled irrigation in enhancing the arid rangelands productivity (Sayed 1994; Al-Rowaily & al. 2015; Assaeed & al. 2019; Mohamed & al. 2024). Studies have also revealed grave plant cover deterioration owing to rangeland overexploitation and have indicated a need for building up recurrently fenced enclosures to enhance vegetation recovery (Barichiev & al. 2018; Assaeed & al. 2019). However, physical fencing alters the processes of natural ecosystems, modifies grazing animal behavior, and interferes with the wild ani-

mals' migratory routes. Conversely, virtual fencing technologies make possible the establishment of rangelands enclosures without physical barriers and do not interfere with the wild animals' migratory routes. Wireless sensors and smart collars could confine the animals' movement within the virtual enclosures by producing sound as animals approach the virtually fenced boundaries (Ilyas & Ahmad 2020; Azaiez & al. 2023). Finally, involvement of stakeholders is also crucial for successful rangeland management. Assessing the local herders' perception of the management programs can help identify the barriers, reveal constraints and produce recommendations for successful management (FAO 2017; Baharvandi & al., 2022; El-Juhany & al. 2022; Alotaibi & al. 2023).

5. Future

Rangeland deterioration takes place at serious environmental, economic and social costs. Updating the rangelands' sustainability regulations and enforcing protection legislation are urgent measures needed for rangelands conservation (Al-Tokhais & Thapa 2019; Azaiez & al. 2023; Almarri & al. 2024). Future conservation of the Saudi Arabian rangelands is expected to incorporate standardized conservation indicators, normalized assessment markers and clear benchmarks. It is also important to shift the public attitudes from risk to opportunity and change priority from consumption to a supply-demand balance. These measures form a comprehensive set of prerequisites for keeping up with the guidelines of the Saudi and Middle East Green Initiative 2021 and the ambitious directives of the Kingdom Vision 2030.

Conclusions

Saudi Arabian rangelands encompass a wide range of habitats. As they extend from coastal areas into the desert plains, they exhibit edaphic gradients with floristic zonation involving transition from wet saline locations dominated by halo-succulents and salt-tolerant species to dry arid locations hosting drought-evading annuals and drought-tolerant perennials. The rangelands' vast latitudinal gradient involves transition from the cool northern regions hosting cool-adapted species of Saharo-Arabian, Irano-Turanian, and Mediterranean chorology to hot arid southern lowlands hosting warm- and arid-adapted species of Saharo-Arabian, Sudano-Zambeian, and Tropical chorology. Mountainous southwestern rangelands exhibit an altitudinal gradient with a shift from hot low-altitude locations hosting warm- and arid-adapted species of Saharo-Arabian and Irano-Turanian chorology to cool high-altitude locations hosting cool-adapted species of Irano-Turanian and Euro-Siberian chorology. These rangelands face challenges of soil erosion, overgrazing, invasive species incursion, and alien species encroachment, urban sprawl, and intrusive practices as-

sociated with outdoor recreational activities. Such challenges call for prompt measures of constant monitoring based on standardized indicators, defined assessment markers and precise benchmarks. Updated management programs, enforced protection legislation and urban ex-

pansion control are also important elements for incorporation into the rangelands' long-term sustainability action plans. Conservation efforts should also address shifting the public attitudes from risk to opportunity and from consumption to supply-demand balance.

References

- Abbas, A.M., Al-Kahtani, M.A., Alfaifi, M.Y., Elbehairi, E.I. & Badry, M.O. 2020. Floristic diversity and phytogeography of Jabal Fayfa: A subtropical dry zone, South-West Saudi Arabia. – *Diversity*, **12**(9): 345. <https://doi.org/10.3390/d12090345>
- Abbas K., Qasim, M.Z., Song, H., Murshed, M., Mahmood, H. & Younis, I. 2022. A review of the global climate change impacts, adaptation, and sustainable mitigation measures. – *Environ. Sci. Poll. Res.*, **29**: 42539-42559. <https://doi.org/10.1007/s11356-022-19718-6>
- Abbas, A.M., Alomran, M.M., Alharbi, N.K. & Novak, S.J. 2023. Suppression of seedling survival and recruitment of the invasive tree *Prosopis juliflora* in Saudi Arabia through its own leaf litter: Greenhouse and field assessments. – *Plants*, **12**(4): 959. <https://doi.org/10.3390/plants12040959>
- Abdein, M.A. & Osman, A.K. 2020. Plant diversity assessment of Wadi Al-Hilali, Northern Border Region, Saudi Arabia. – *Int. J. Botany Stud.*, **5**: 87-9.
- Abdelmalik, A.M., Alshahrani, T.S., Alqarawi, A.A. & Ahmed, E.M. 2023. Allelopathic potential of *Nicotiana glauca* aqueous extract on seed germination and seedlings of *Vachellia gerrardii*– *Diversity*, **16**(1): 26. <https://doi.org/10.3390/d16010026>
- Abd El-Salam, M.M. & Elhakem, A.H. 2016. Desertification and its effect on the erosion of vegetation in the south-western region of Saudi Arabia. – *Environ. Monit. Assess.*, **188**(3): 164. <https://doi.org/10.1007/s10661-016-5164-z>
- Abdullah, A., Bakhshwain, A., Basuhail, A. & Aslam, A. 2015. An integrated framework for predicting long-term productivity of pastures in the Kingdom of Saudi Arabia. *Arab J. Sci. Engin.*, **40**: 3567-3582. <https://doi.org/10.1007/s13369-015-1841-4>
- Abdullah, W.S., Zerouali, B., Elbeltagi, A., Alwetaishi, A., Wong, Y.J., Bailek, N., AlSaggaf, A.A., Abd Elrahman, S.I.M. & Majrashi, A.A. 2023. Enhancing sustainable urban planning through GIS and multiple-criteria decision analysis: A case study of green space infrastructure in Taif Province, Saudi Arabia. – *Water*, **15**(17): 3031. <https://doi.org/10.3390/w15173031>
- Abu-Abdullah, M.M., Youssef, A.M., Maerz, N.H., Abu-ALFadail, E., Al-Harbi, H.M. & Al-Saadi, N.S. 2020. A flood risk management program of Wadi Baysh Dam on the downstream area: An integration of hydrologic and hydraulic models, Jizan Region, KSA. – *Sustainability*, **12**(3): 1069. <https://doi.org/10.3390/su12031069>
- Aina, Y.A., Wafer, A., Ahmed, F. & Alshuwaikhat, H.M. 2019. Top-down sustainable urban development? Urban governance transformation in Saudi Arabia. – *Cities*, **90**: 272-281. <https://doi.org/10.1016/j.cities.2019.03.003>
- AlAli A.M., Hassan, T.H., & Abdelmoaty, M.A. 2024. Tourist values and well-being in rural tourism: Insights from biodiversity protection and rational automobile use in Al-Ahsa Oasis, Saudi Arabia. – *Sustainability*, **16**(11): 4746. <https://doi.org/10.3390/su16114746>
- Alanezi, M.A., Mohammad, A., Sha'aban, Y.A., Boucekara, H.R. & Sha, M.S. 2022. Auto-encoder learning-based UAV communications for livestock management. – *Drones*, **6**(10): 276. <https://doi.org/10.3390/drones6100276>
- Alatawi, A.S. 2022. Conservation action in Saudi Arabia: Challenges and opportunities. – *Saudi J. Biol. Sci.*, **29**(5): 3466-3472. <https://doi.org/10.1016/j.sjbs.2022.02.031>
- Al-Dousari, A.M., Alsaleh, A., Ahmed, M., Raafat, M., Al-Dousari, N., Al-Shatti, F., Elrawi, M., & Teena, W. 2019. Off-Road vehicle tracks and grazing points in relation to soil compaction and land degradation. – *Earth Syst. Environ.*, **3**: 471-482. <https://doi.org/10.1007/s41748-019-00115-y>
- Alfarhan, A.H., Thomas, J. & Rajakrishnan, R. 2021. Impact assessment and management of invasive species in plant diversity centers and agriculture fields of Saudi Arabia. In: Pullaiah T. & Ielmini, M.R. (eds.), *Invasive Alien Species: Observations and Issues from Around the World*, pp. 207-225. Wiley-Blackwell, New York.
- Alghamdi, A.A. 2017. Quantifying the level of degradation in two adjacent rangeland areas in Ha'il district. – *IJAR*, **3**(3): 275-279.
- Alghamdi, A., Mseddi, K., Abdelgadir, M. & Sharawy, S. 2018. Inaccessible zones of Jabal Salma, Ha'il Region in Saudi Arabia: A reservoir for native seed species. – *J. Exp. Biol. Agric.*, **6**(3): 572-581. [https://doi.org/10.18006/2018.6\(3\).572.581](https://doi.org/10.18006/2018.6(3).572.581)
- Al-Gifri, A.N., Kasem, W.T. & Shalabi, L.F. 2018. Vegetation structure and diversity of Wadi Wasaa, Jazan, Saudi Arabia. – *J. Adv. Biol. Biotechnol.*, **18**(4): 1-16.
- Al-Gifri, A.N., Kasem, W.T., Shehata, R.S., & Eldemerdash, M.M. 2019. The African Paleotropical influence on the biogeography of the flora of Jazan, KSA. – *Asian J. Soil Sci. Plant Nut.*, **4**(1): 1-10.
- Al-Hajji Z., Munir S., Al-Qahtani J., Alexiou I. & Hafez M.A. 2025. Study of spatial and temporal variations of climatic variables during sand and dust storm events in Riyadh using in-situ observations. – *Int. J. Environ. Clim.*, **15**: 381-399. <https://doi.org/10.9734/ijec/2025/v15i34780>
- Alhaithloul, H.A.S. 2019. Environmental and genetic diversity of rangeland plant species in Saudi Arabia. – *World J. Environ. Biosci.*, **8**(3): 45-55.
- Alharthi, A., El-Sheikh, M.A., Elhag, M., Abdulrahman, A., Alatar, A.A., Abbadi, G.A., Abdel-Salam, E.M., Arif, I.A., Baeshen, A.A., Ebrahim, M. & Eid E.M. 2020. Remote sensing of 10 years changes in the vegetation cover of the northwestern coastal land of Red Sea, Saudi Arabia. – *Saudi J. Biol. Sci.*, **27**: 3169-3179. <https://doi.org/10.1016/j.sjbs.2020.07.021>
- Alharthi, S.T., El-Shiekh, M.A. & Alfarhan, A.A. 2023. Alien plant invasions of the natural habitat in the Western Region of Saudi Arabia: Floristic diversity and vegetation structure. – *Diversity* **15**: 309. <https://doi.org/https://doi.org/10.3390/d15030309>
- Al-Huqail, A.A., Al-Harbi, H.F., Alowaiifeer, A.M., El-Sheikh, M.A., As-saeed, A.M., Alsaleem, T.S., Kassem H.S., Azab O.M., Dar B.A., Malik J.A. & Ahmed M. Abd-ElGawad A.M. 2025a. Correlation between

- aboveground vegetation composition and soil seed bank of Raudhat desert habitat: a case study of Raudhat Alkhafs, Saudi Arabia. – *BMC Plant Biol.*, **25**: 136. <https://doi.org/10.1186/s12870-025-06162-0>
- Al-Huqail, A.A., Alghanem, S.M.S., Al-Robai, S.A., Mohamed, H.Y., Khalaf, M.H., Alsobeai, S.M., Abeer A.H.A. & Hassan M.O.** 2025b. Alien *Euphorbia hirta* L. induces soil sickness and reduces cover and diversity of native species. – *J. Soil Sci. Plant Nutr.*, **25**: 922-933. <https://doi.org/10.1007/s42729-024-02175-0>
- Ali, J., Khwaja M.G., Alsolamy M., Aljehani S., Alblowi K. & Majed G. Alotaibi M.G.** 2024. Assessing dynamics of ecotourism using multi-methods analysis. – *J. Ecotourism*, 2024: 1-21. <https://doi.org/10.1080/014724049.2024.2414822>
- Aljaddani, A.H., Song, X-P. & Zhu, Z.** 2022. Characterizing the patterns and trends of urban growth in Saudi Arabia's 13 capital cities using a Landsat Time Series. – *Remote Sens.*, **14**(10): 2382. <https://doi.org/10.3390/rs14102382>
- Aljeddani, G.S., Al-Harbi, N.A., Al-Qahtani, S.M., El-Absy, K.M., Abdullatif, B. & Dahan, T.E.** 2021. Inventory of some introduced and invasive plant species in some governorates of the Kingdom of Saudi Arabia. – *App. Ecol. Environ. Res.*, **19**(6): 4373-4388. https://doi.org/10.15666/aer/1906_43734388
- Almahasheer, H.** 2021. Assessment of coastal salt marsh plants on the Arabian Gulf region. – *Saudi J. Biol. Sci.*, **28**(10): 5640-5646. <https://doi.org/10.1016/j.sjbs.2021.06.002>
- Almarri, N.B., Ahmad, S. & Elshal, M.H.** 2024. Diversity and conservation of plant genetic resources in Saudi Arabia. In: **Al-Khayri, J.M., Jain S.M. & Penna S.** (eds.), *Sustainable Utilization and Conservation of Plant Genetic Diversity*, pp. 1009-1031. Springer, Singapore.
- Almazroui, M.** 2019. Assessment of meteorological droughts over Saudi Arabia using surface rainfall observations during the period 1978–2017. – *Arab. J. Geosci.*, **12**: 22. <https://doi.org/10.1007/s12517-019-4866-2>
- Almazroui, M.** 2020. Changes in temperature trends and extremes over Saudi Arabia for the period 1978–2019. – *Adv. Meteorol.*, **2020**: 8828421. <https://doi.org/10.1155/2020/8828421>
- Almazroui, M., Mashat, A., Assiri, M.E. & Butt, M.J.** 2017. Application of Landsat Data for urban growth monitoring in Jeddah. – *ESEV*, **1**(2): 25. <https://doi.org/10.1007/s41748-017-0028-4>
- Al-Mssallem, M.Q., Al-Khayri, J.M., Alessa, F.M., & Al-Shalan, H.Z.** 2024. Contribution of Hassawi rice to food and nutritional security in Saudi Arabia. In: **Ahmed, A.E., Khayri, J.M., & Elbushra, A.A.** (eds.), *Food and Nutrition Security in the Kingdom of Saudi Arabia, Macroeconomic Policy and Its Implication on Food and Nutrition Security*, Vol. 2, pp. 321-336. Springer Intl. Publ., Cham.
- Alotaibi, K., Ghumman, A.R., Haider, H., Ghazaw, Y.M. & Shafiqzaman, M.D.** 2018. Future predictions of rainfall and temperature using GCM and ANN for Arid Regions: A case study for the Qasim Region, Saudi Arabia. – *Water*, **10**: 1260. <https://doi.org/10.3390/w10091260>
- Alotaibi, B.A., Abbas, A., Ullah, R., Azeem, M.I., Samie, A., Mudassir, M., Dabiah, A.T., Raid, M. & Sadaf, T.** 2023. Dynamics and determinants of farmers' perceptions about causes and impacts of climate change on agriculture in Saudi Arabia: Implications for adaptation, mitigation, and sustainability. – *Atmosphere*, **14**(6): 917. <https://doi.org/10.3390/atmos14060917>
- Alqadhi, S., Mallick, J., Balha, A., Bindajam, A., Kumar, C., Pham, S., & Hoa V.** 2021. Spatial and decadal prediction of land use/land cover using multi-layer perceptron-neural network (MLP-NN) algorithm for a semi-arid region of Asir, Saudi Arabia. – *Earth Sci. Inform.*, **14**(3): 1547-1562. <https://doi.org/10.1007/s12145-021-00633-2>
- Alqadhi, S., Mallick, J., Talukdar, S., & Alkahtani, M.** 2023. An artificial intelligence-based assessment of soil erosion probability indices and contributing factors in the Abha-Khamis watershed, Saudi Arabia. – *Front. Ecol. Evol.*, **11**: 1189184. <https://doi.org/10.3389/fevo.2023.1189184>
- Al-Qathanin, R. & Al-Yasi, H.** 2021. Progress towards an updated checklist of the Farasan Archipelago flora. – *J. Arid Environ.*, **189**: 104488. <https://doi.org/10.1016/j.jaridenv.2021.104488>
- Alrawaf, T.I., Abubakar, I.R., Alshabibi, N.M., Al-Matar, K.M., Dano, U.L., Elhadi, E.M.A., Farooqi, M.A., Alshihri, F.S., Alzenifeer, B.M. & Al-Odah, M.A.** 2023. The distribution of ecotourism activities and potential consequences for the Saudi desert ecosystem. – *J. Arid Environ.*, **213**: 104950. <https://doi.org/10.1016/j.jaridenv.2023.104950>
- Al-Rowaily, S.L., El-Bana, M.I., Al-Bakre, D.A., Assaeed, A.M., Hegazy, A.K. & Ali, M.B.** 2015. Effects of open grazing and livestock exclusion on floristic composition and diversity in natural ecosystem of Western Saudi Arabia. – *Saudi J. Biol. Sci.*, **22**(4): 430-437. <https://doi.org/10.1016/j.sjbs.2015.04.012>
- Al-Rowaily, S.L., Assaeed, A.M., Al-Khateeb, S.A., Al-Qarawi, A.A. & Al Arifi, F.S.** 2018. Vegetation and condition of arid rangeland ecosystem in Central Saudi Arabia. – *Saudi J. Biol. Sci.*, **25**(6): 1022-1026. <https://doi.org/10.1016/j.sjbs.2016.12.015>
- Alsharif, M., Alzandi, A.A., Shrahily, R. & Mobarak, B.** 2022. Land use land cover change analysis for urban growth prediction using Landsat Satellite Data and Markov Chain Model for Al Baha Region Saudi Arabia. – *Forests*, **13**(10): 1530. <https://doi.org/10.3390/f13101530>
- Alshayeb, M.J.** 2025. Evaluating ecosystem service trade-offs and recovery dynamics in response to urban expansion: Implications for sustainable management strategies. – *Sustainability*, **17**(5): 2194. <https://doi.org/10.3390/su17052194>
- Al-Tokhais, A. & Thapa, B.** 2019. Stakeholder perspectives towards national parks and protected areas in Saudi Arabia. – *Sustainability*, **11**(8): 2323. <https://doi.org/10.3390/su11082323>
- Al-Turki, T.A. & Basahi, M.A.** 2015. Assessment of ISSR based molecular genetic diversity of Hassawi rice in Saudi Arabia. – *Saudi J. Biol. Sci.*, **22**(5): 591-599. <https://doi.org/10.1016/j.sjbs.2015.06.027>
- Al-Turki, T.A., Swarupnandan, K. & Davy, A.Y.** 2017. A re-examination of the Salicornias (Amaranthaceae) of Saudi Arabia and their polymorphs. – *Saudi J. Biol. Sci.*, **24**:1588-1600. <https://doi.org/10.1016/j.sjbs.2016.01.040>
- Al-Turki, T.A., Al-Namazi, A.A. & Masrahi, Y.S.** 2019. Conservation of genetic resources for five traditional crops from Jazan, SW Saudi Arabia, at the KACST Gene-Bank. – *Saudi J. Biol. Sci.*, **26**:1626–1632. <https://doi.org/10.1016/j.sjbs.2018.09.007>
- Al-Turki, T.A., Al-Namazi, A.A., Al-Ammari, B.S., Al-Mosallam, M.S. & Basahi, M.A.** 2020. *Ex-situ* conservation of wheat genetic resources from Saudi Arabia. – *Saudi J. Biol. Sci.*, **27**(9): 2318-2324. <https://doi.org/10.1016/j.sjbs.2020.04.015>
- Alzarrah, M.I., Hassaballa, A.A. & Salih, A.** 2021. Spatial analysis of rangeland's vegetation intensity as related to selected physical soil variables over ABQAIQ municipality of Saudi Arabia. – *Saudi J. Biol. Sci.*, **28**(2): 1336-1347. <https://doi.org/10.1016/j.sjbs.2020.11.060>
- Arishi, A.A.** 2020. Classification of sandstorms in Saudi Arabia. – *Atmospheric and Climate Sci.*, **11**(1): 177-193. <https://doi.org/10.4236/acs.2021.111012>

- Assaeed, A.M., Al-Faifi, S.A., Migdadi, H., El-Bana, M.I., Al Qarawi, A.A. & Khan, M.A. 2018. Evaluation of genetic diversity of *Panicum turgidum* Forssk. from Saudi Arabia. – Saudi J. Biol. Sci., 25(1): 123-129. <https://doi.org/10.1016/j.sjbs.2017.04.002>
- Assaeed, A.M., Al-Rowaily, S.A., El-Bana, M.I., Abood, A.A.A., Dar, B.A.M. & Hegazy, A.K. 2019. Impact of off-road vehicles on soil and vegetation in a desert rangeland in Saudi Arabia. – Saudi J. Biol. Sci., 26(6): 1187-1193. <https://doi.org/10.1016/j.sjbs.2018.05.001>
- Assaeed, A.M., Alharthi, A.S. & Abd-ElGawad, A.M. 2021. Impacts of *Nicotiana glauca* Graham invasion on the vegetation composition and soil: A case study of Taif, western Saudi Arabia. – Plants, 10(12): 2587. <https://doi.org/10.3390/plants10122587>
- Ayachi, H. & Jaouadi, S. 2017. Problems and perspective of ecotourism in the Island of Farasan: An empirical study based on survey data. – Soc. Bus. Rev., 12(2): 235-251. <https://doi.org/10.1108/SBR-10-2016-0056>
- Azaiez, O.B., Alharbi, M., Alhajoj, A., Alruwaili, F. & Njeru, J. 2023. Effects of community camel and sheep grazing on vegetation cover in Al-Mayla rangeland in northern Saudi Arabia. – Range Manag. Agrofor., 44(2): 226-232. <https://doi.org/10.59515/rma.2023.v44.i2.02>
- Baharvandi, M., Abdi, N., Ahmadi, A., Zar, H.T. & Rezaei, S.G. 2022. The effectiveness of rangeland management plans from the viewpoints of beneficiaries, experts, and managers. – Arabian J. Geosci., 15: 699. <https://doi.org/10.1007/s12517-022-09952-0>
- Barichiev, C., Sheldon, R., Wachter, T., Llewellyn, O., Al-Mutairy, M. & Alagaili, A. 2018. Conservation in Saudi Arabia; moving from strategy to practice. – Saudi J. Biol. Sci., 25(2): 290-292. <https://doi.org/10.1016/j.sjbs.2017.03.009>
- Basahi, R.A. 2018. Plant diversity of the coastal regions of Gulf of Aqaba, Saudi Arabia. – Ann. Res. Rev. Biol., 26(3): 1-11. <https://doi.org/10.9734/ARRB/2018/41212>
- Butt, M.J. & Mashat, A.S. 2018. MODIS satellite data evaluation for sand and dust storm monitoring in Saudi Arabia. – Int. J. Remote Sens., 39(23): 8627-8645. <https://doi.org/10.1080/01431161.2018.1488293>
- Ellassal, M. 2020. Geomorphological heritage attractions proposed for geotourism in Asir Mountains, Saudi Arabia. – Geoheritage, 12: 78. <https://doi.org/10.1007/s12371-020-00505-z>
- El-Bana, M. & Aldakhil, M. 2015. Effect of human recreation on vegetation composition and diversity of inland desert dunes in Al-Ghada Nature Reserve, Central Saudi Arabia. – Catrina, 11(1): 41-50.
- El-Juhany, L.I. 2015. The magnitude of dieback on *Juniperus procera* trees in the natural forests in the Southwestern Region of Saudi Arabia. – Biosci. Biotechnol. Res. Asia, 12(1): 219-230. <https://doi.org/10.13005/bbra/1655>
- El-Juhany, L., Ahmad, I., Baig, M.B. & Nawaz, M.F. 2022. Fostering the sustainable forest management in Saudi Arabia from resilience and mitigation perspectives. In: Behnassi, M., Gupta, H., Baig, M.B. & Noorka, I.R. (eds.), The Food Security, Biodiversity, and Climate Nexus, pp. 287-308. Springer, Cham.
- Elmefregy, M. & El-Sheikh, M.A. 2020. Ecological status of sand binder plant white saxaul (*Haloxylon persicum*) at the managed area of Al-Qassim, Saudi Arabia: Plant associations and population structure. – App. Ecol. Environ. Res., 18(2): 2781-2794. https://doi.org/10.15666/aer/1802_27812794
- El-Sheikh, M.A., Thomas, J., Arif, I.A. & El-Sheikh, H.M. 2021. Ecology of inland sand dunes “Nafuds” as a hyper-arid habitat, Saudi Arabia: Floristic and plant associations diversity. – Saudi J. Biol. Sci., 28(3): 1503-1513. <https://doi.org/10.1016/j.sjbs.2020.12.002>
- Fakhry, A.M. & AlAnazi, H.K. 2017. Floristic diversity and vegetation structure of Al-Dissah area northwestern Saudi Arabia. – Egypt. J. Exp. Biol., 13(2): 447-457. <https://doi.org/10.5455/egyjebb.20171009105256>
- FAO, 2017. The future of food and agriculture – trends and challenges, FAO, Rome.
- FAO, 2022. Strategies for strengthening feed and forage and feeding systems for a sustainable small ruminant livestock production in KSA. FAO, Riyadh.
- Hall, M., Llewellyn, O.A., Miller, A.G., Al-Abbasi, T.M., Al-Wetaid, A.H., Al-Harbi, R.J. & Al-Shammari, K.F. 2010. Important plant areas in the Arabian Peninsula: 2. Farasan Archipelago. – Edinb. J. Bot., 67(2): 189-208. <https://doi.org/10.1017/S0960428610000089>
- Hasanean, H. & Almazroui, M. 2015. Rainfall: Features and variations over Saudi Arabia. A Review. – Climate, 3(3): 578-626. <https://doi.org/10.3390/cli3030578>
- Hosny, A.M., Shawky, R.A. & Hashim, A.A. 2018. Size structure and floristic diversity of *Acacia* trees population in Taif Area, Saudi Arabia. – J. Biodivers. Endanger. Species, 6(210): 2. <https://doi.org/10.4172/2332-2543.1000210>
- Ilyas, Q.M. & Ahmad, M. 2020. Smart farming: An enhanced pursuit of sustainable remote livestock tracking and geofencing using IoT and GPRS. – Wirel. Commun. Mob. Comput., 2020(1): 6660733. <https://doi.org/10.1155/2020/6660733>
- Khemira, H., Mahdhi, M., Afzal, M., Oteef, M.D.Y., Tounekti, T., Al-Faifi, Z. & Alsolami, W. 2023. Assessment of genetic diversity and phylogenetic relationship of local coffee populations in southwestern Saudi Arabia using DNA barcoding. – PeerJ, 11: e16486. <https://doi.org/10.7717/peerj.16486>
- Khogali, A., Chavanidis, K., Stampolidis, A., Kirmizakis, P., Yassin, M., Abu-Mahfouz, I.S., Al-Shaibani, A., Tawabini, B., Pantelis & Soupios, P. 2024. Subsurface complexity controls the aquifer heterogeneity: A case study from the Al-Hassa oasis, Eastern Saudi Arabia. – Groundw. Sustain. Dev., 27: 101322. <https://doi.org/10.1016/j.gsd.2024.101322>
- Khormy, O.F., Remesh, M., Masrahi, Y.S. & Sayed, O.H. 2019. Functional attributes of range grasses in arid desert habitat. – Ecol. Environ. Conserv., 25:S5-S9.
- Masrahi, Y.S. & Sayed, O.H. 2017. Invasive *Opuntia stricta*: Case study in Southwestern Saudi Arabia. – Ecol. Environ. Conserv., 23(4): 195-201.
- Masrahi, Y.S., Al-Turki, T.A. & Sayed, O. H. 2012. Geographical distribution and chorology of grasses in the Arabian Peninsula. – Flora, 207(4): 250-256. <https://doi.org/10.1016/j.flora.2011.11.007>
- Masrahi, Y.S., Sayed, O.H. & Al-Turki, T.A. 2015. Alien Invasive *Opuntia stricta* in Jazan Region: Status Report. – J. Jazan Univ., 4: 15-22.
- Masrahi, Y.S., Remesh, M. & Sayed, O.H. 2017. Enumeration of the flora of Wadi Lajab Saudi Arabia. – Ecol. Environ. Conserv., 23(1): 99-106.
- Mobarak, B., Shrahily, R., Mohammad, A. & Alzandi, A.A. 2022. Assessing green infrastructures using GIS and the multi-criteria decision-making method: The case of the Al Baha Region (Saudi Arabia). – Forests, 13(12): 2013. <https://doi.org/10.3390/f13122013>
- Mohamed, B., Harbi, M.A., Mohammed, A. & Alrizqi, A.M. 2024. Rainwater harvesting for degraded rangeland rehabilitation in the Abu Fihil Sub-basin, Riyadh, Saudi Arabia. – J. Environ. Sci. Engin. B13: 211-226. <https://doi.org/10.17265/2162-5263/2024.06.00>
- Moufti, M.R. & Németh K. 2016. Geohéritage of volcanic Harrats in Saudi Arabia. Springer, Switzerland.

- Mseddi, K., Alghamdi, A., Abdelgadir, M., Sharawy, S., Chaieb, M. & Miller, T. 2021. Phytodiversity distribution in relation to altitudinal gradient in Salma Mountains - Saudi Arabia. – *Global Ecol. Conserv.*, **27**: e01525. <https://doi.org/10.1016/j.gecco.2021.e01525>
- Rauf, A., Ahmad, N., Ajmal, M., Abdul, M. & Zia R. 2022. Meteorological trend analysis for Najd and Hejaz regions, Saudi Arabia. – *Meteorol. Atmos. Phys.*, **143**: 35. <https://doi.org/10.1007/s00703-022-00873-x>
- Remesh, M., Masrahi, Y.S. & Sayed, O.H. 2019. *Phragmites australis* (Poaceae): New addition to the flora of Southwestern Saudi Arabia. – *Saudi J. Biol. Sci.*, **26**(7): 1563-1566. <https://doi.org/10.1016/j.sjbs.2018.11.001>
- Remesh, M., Masrahi, Y.S. & Sayed, O.H. 2020. Plant functional types on red sea coastal sand dunes. – *Ecol. Environ. Conserv.*, **26**(2): 599-605.
- Salih, A., Hassaballa, A.A., & Ganawa, E. 2021. Mapping desertification degree and assessing its severity in Al-Ahsa Oasis, Saudi Arabia, using remote sensing-based indicators. – *Arab. J. Geosci.*, **14**: 192. <https://doi.org/10.1007/s12517-021-06523-7>
- Sayed, O.H. 1993. Ecophysiological characteristics, distribution, and nutritional value of desert range plants in Qatar. – *Qatar Univ. Sci.*, **13**(2): 243-246.
- Sayed, O.H. 1994. Condition and trend of a depression-type habitat in rainfed desert rangelands of Qatar in response to fertilizer application. – *Qatar Univ. Sci. J.*, **14**(3): 289-292.
- Sayed, O.H. 1995. Effect of the expected sea level rise on *Avicennia marina* L. A case study in Qatar. – *Qatar Univ. Sci. J.*, **15**(1): 91-94.
- Sayed, O.H. 1996. Adaptational responses of *Zygophyllum qatarense* Hadidi to stress conditions in a desert environment. – *J. Arid Environ.*, **32**(4): 445-452. doi: <https://doi.org/10.1006/jare.1996.0037>
- Sayed, O.H. & Masrahi, Y.S. 2023. Climatology and phytogeography of Saudi Arabia. A Review. – *Arid Land Res. Manag.*, **37**(3): 1-58. <https://doi.org/10.1080/15324982.2023.2169846>
- Sayed, O.H. & Masrahi, Y.S. 2025. Grasses of Saudi Arabia: A Review. – *Grass Forage Sci.*, **79**(4): e12705. <https://doi.org/10.1111/GFS.12705>
- Sayed, O.H., Masrahi, Y.S., Remesh, M. & Al-Ammari, B.S. 2019. Coffee production in southern Saudi Arabian highlands: Current status and water conservation. – *Saudi J. Biol. Sci.*, **26**(7): 1911-1914. <https://doi.org/10.1016/j.sjbs.2019.03.002>
- Sayed, O.H., Masrahi, Y.S. & Remesh, M. 2020. Environmental impact of desert dam reservoir in arid habitat. – *Asian J. Plant Sci.*, **19**: 191-199. <https://doi.org/10.3923/ajps.2020.191.199>
- Shalabi, L.F. & Masrahi Y.S. 2019. Floristic composition, life forms and phytogeography of Al Hashr Mountain, Jazan region, SW Saudi Arabia. – *Egypt. J. Exp. Biol.*, **15**(1): 73-85. <https://doi.org/10.5455/egyjebb.20190301092631>
- Shrahily, R.Y., Alsharif, M.A., Mobarak, B.A., Mobarak, B.A. & Alzandi A.A. 2022. Land cover mapping using GIS and remote sensing databases for Al Baha Region Saudi Arabia. – *App. Sci.*, **12**(16): 8115. <https://doi.org/10.3390/app12168115>
- Thomas, J., El-Sheikh, M.A., Alfarhan, A.H., Alatar, A.A., Sivadasan, M., Basahi, M., Al-Obaid, S. & Rajakrishnan R. 2016. Impact of alien invasive species on habitats and species richness in Saudi Arabia. – *J. Arid Environ.*, **127**: 53-65. <https://doi.org/10.1016/j.jaridenv.2015.10.009>