Journal of Global Change Data & Discovery. 2025, 9(3): 247-261
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Global Change Research Data Publishing & Repository

Global Oases Distribution Dataset and its Cataloging System

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Abstract: Oases are non-zonal geographical units formed on a desert matrix in arid regions driven by stable water sources. They serve as crucial habitats for biodiversity, bases for human livelihoods, and important pillars of human civilization. Oases play a pivotal role in maintaining the stability of terrestrial ecosystems in arid zones, preventing land degradation, regulating local climates, and enhancing ecological well-being. However, fundamental research on the global distribution digital data of oases is still lacking, and systematic global oasis cataloging has not yet been established. This has caused significant discrepancies and gaps in the available data, resulting in inconsistencies and inaccuracies in numerous related studies, thereby hindering the progress in oasis science. To fill this gap, this data product, based on high-resolution remote sensing imagery provided by the Google Earth Pro platform, manually delineated global oasis boundaries through visual interpretation. A global oasis dataset was created using 2020 as the baseline year, and the first comprehensive global oasis catalog was systematically completed. The dataset, comprising a total of 54 files, has been published in the Global Change Research Data Publishing & Repository the regular member of World Data System of the International Science Council and is freely available for download globally. The research results show that oases are distributed across 5 continents and 54 countries, covering a total area of 2,482,193.27 km² and encompassing 4,850 oases. Among them, China has the largest area (275,535.39 km²) of oases, containing 1,398 oases. Based on this high-precision dataset, we selected the most relevant four attributes (continent, country, river, and oasis area)—to code the global oases. Each oasis larger than 1 km² was assigned a unique ID, thereby establishing a clear 'identity' for each oasis and addressing the long-standing absence of a global cataloging system. Moreover, regular future updates related to the catalog information will enable the precise tracking of dynamic processes such as oasis expansion and contraction, providing a quantitative basis for the scientific assessment of ecosystem health and evolutionary trends.

Received: 05-06-2025; **Accepted:** 27-08-2025; **Published:** 25-09-2025

Foundations: Chinese National Committee for Man and the Biosphere Programme, UNESCO (2023); Xinjiang Uygur Autonomous Region (2023TSYCLJ0049); National Natural Science Foundation of China (42361144792)

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Citation: Gui, D. W., Lin, J. W., Liu, Y. F., *et al*. Global oases distribution dataset and its cataloging system [J]. *Journal of Global Change Data & Discovery*, 2025, 9(3): 247–261. https://doi.org/10.3974/geodp.2025.03.01.

Keywords: oasis; global; spatial distribution; cataloging; dataset

DOI: https://doi.org/10.3974/geodp.2025.03.01

1 Introduction

Arid zone constitutes a critical component of the Earth's geographical system, covering approximately 41% of the global land surface and supporting the survival of more than 2.5 billion people[1]. Within these regions, oases represent unique socio-ecological landscapes[2], formed on desert matrices due to stable water sources[3]. Oases hold significant ecological, social, and cultural value globally, playing irreplaceable roles in sustaining biodiversity, maintaining ecological integrity, and preserving cultural heritage[4]. Their stability is essential not only for the well-being of local communities but also for regional ecosystem health and economic sustainability[5]. Given their high degree of local specificity, global conservation strategies for oases are urgently needed, consistent with the principles promoted by UNESCO, UNEP (2002), the Millennium Ecosystem Assessment (2005), and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (2019)[6].

Despite their importance, global research on oases remains insufficient. The most pressing challenge lies in the unresolved question of their global distribution, which has led to an unclear baseline and inconsistent data. Existing studies primarily focus on specific river basins[7,8] or individual countries[9,10], leaving the exact global number, area, and spatial distribution of oases largely unknown. Furthermore, the absence of publicly available, freely accessible global datasets has significantly limited quantitative analyses and hindered the systematic development of oasis science.

Systematic classification and cataloging of geographical units constitute the foundation of geographical research and are prerequisites for understanding spatial distribution and evolutionary patterns[11]. As non-zonal geographical units in arid regions, oases also require systematic cataloging. Such cataloging effectively establishes an "oasis register", documenting the location, extent, and core hydrological and ecological attributes of each oasis. These baseline data are essential for analyzing oasis ecosystem structures, their functional dynamics, and their interactions with surrounding desert environments. At a broader scale, cataloging can uncover potential linkages among dispersed patches of oasis, providing evidence for ecological corridor planning, species migration, and gene flow[12]. This contributes to enhancing connectivity and resilience within regional ecological networks and mitigating habitat fragmentation risks under climate change. However, the lack of baseline data has long prevented systematic cataloging at the global scale, leaving the framework of oasis science incomplete.

To address this issue and bridge the gap, the current study adopted 2020 as the baseline year and utilized high-resolution summer imageries from Google Earth Pro as the primary data source. Over a span of 5-years, more than 30 geographers conducted detailed visual interpretation to delineate oasis boundaries, resulting in the construction of a global oasis dataset with high precision. This dataset comprehensively clarifies the number and area of oases worldwide, thereby providing reliable baseline information for subsequent ecological research and management. Based on this dataset, we developed systematic coding rules to establish the first global oasis catalog, thereby filling a long-standing gap in oasis research. Importantly, the dataset and cataloging results are freely available under the framework of the "Open Science" initiative, making a significant contribution to the advancement and enrichment of oasis science.

2 Methods

2.1 Data Sources

The data used in this study mainly included remote sensing imageries, global arid zoning data, national administrative boundary data, global watershed data, and global vegetation cover data. The remote sensing imageries are primarily sourced from Google Earth Pro, which provides a very high spatial resolution, reaching sub-meter levels. The global arid zoning data were obtained from the United Nations Environment Programme World Conservation Monitoring Centre[1], offering an authoritative basis for the regional division of arid zones. The national administrative boundary data were derived from the Global Administrative Unit Layers (GAUL) database[2], which provided detailed administrative boundary information for countries and regions worldwide. It should emphasize that this boundaries for scientific research reference only, not for politics argument between countries. The global watershed data were taken from relevant research published in *Scientific Data*[13], covering watershed information on a global scale. The global land cover data were sourced from the European Space Agency (ESA) global land cover product[3], with a spatial resolution of 10 m, which effectively supports the monitoring and analysis of land use and environmental change.

2.2 Data Extraction Method

Although existing studies have proposed semi-automatic[14,15] or fully automatic[16,17] methods for feature extraction, these technologies still face challenges such as unstable classification accuracy and blurry boundaries when dealing with the spatial heterogeneity of internal vegetation types within oases (e.g., mixed distribution of different crop types, shrubs, and trees) and the morphological diversity of oasis boundary patterns (e.g., gradual transition zones along river edges, intermingled zones between farmland and desert). To ensure the consistency and high quality of the oasis boundary data, the visual interpretation method[18], combined with spatial validation in a Geographic Information System (GIS), was ultimately adopted to establish a rigorous technical workflow (Figure 1).

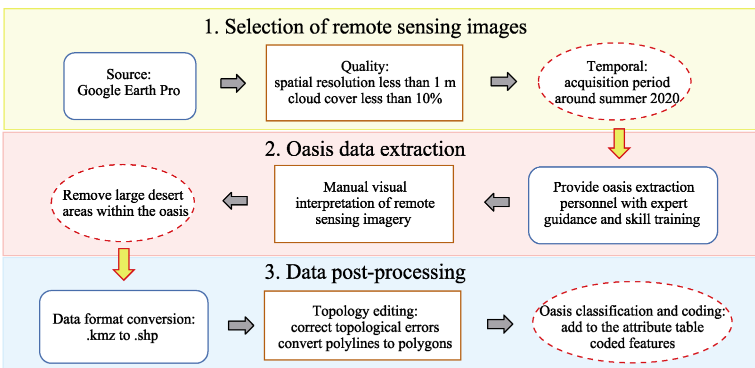

Figure 1 Technical roadmap of the dataset development

The workflow of the dataset development is shown as follows:

(1) Image selection: Summer remote sensing images of 2020 were selected because this period

[1] WCMC. https://www.wcmc.org.uk/.

[2] GADM. https://gadm.org/.

[3] ESA. https://esa-worldcover.org/.

featured vigorous vegetation growth with a high Leaf Area Index (LAI) and no snow interference, providing a high-contrast visual basis for visual interpretation.

(2) Image examination: The images were examined using multi-level zooming on the Google Earth Pro platform, with a requirement that the viewing altitude be below 1.5 km and the spatial resolution better than 1 m to clearly display the fine details of the oasis edge (such as the crown morphology of vegetation and farmland boundaries).

(3) Pixel-by-pixel interpretation: Based on the actual ground conditions and with vegetation cover data as auxiliary information, each pixel was interpreted to classify different land use types (e.g., water bodies, bare land, farmland, desert). Control points were precisely set using the platform's mapping tools, and the oasis boundary was exported in .kmz format.

(4) GIS validation and conversion: The .kmz file was then imported into ArcGIS 10.8, converted into a .shp format vector file, and a spatial topological relationship check was executed.

(5) Final processing: The validated polyline boundary data was subsequently converted into a polygonal (polygon) file. Basic geographic information was added to the attribute table, and patches smaller than 0.01 km^2 were removed to eliminate noise interference, thereby more accurately representing the overall spatial extent and geographic characteristics of the oasis.

2.3 Coding System

To enable the scientific identification, classification, and management of global oases, this study developed a multi-level and multi-dimensional coding system, assigning a unique ID to each oasis. Considering that very small oases are highly vulnerable to environmental changes and tend to display greater randomness in their evolution, only oases with an area larger than 1 km^2 were selected for coding in order to improve the accuracy and practicality of the system.

During the selection of coding fields, several alternative designs were initially evaluated. For example, a "water source" field could have been introduced to distinguish between oases primarily driven by surface water and those sustained by groundwater. Similarly, a "climate attribute" field could have been considered to differentiate oases in cold desert versus hot desert environments. However, these attributes were not adopted because they are difficult to define consistently across all oases and may introduce ambiguity.

Following expert consultation, the final oasis ID was generated through hierarchical coding based on four of the most representative attributes: continent, country, basin, and area (Figure 2).

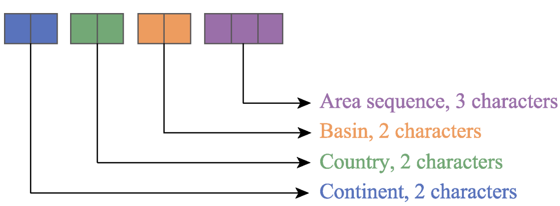

Figure 2 Schematic of global oasis coding system

Continent field (2 characters): This is the first-level and highest hierarchical field, directly indicating the continent in which the oasis is located. As a geographic unit above the national level, the continent field not only establishes a clear hierarchical framework but also enables progressive aggregation and drill-down analyses from the continental to the national level in both statistical and spatial queries. This significantly improves the efficiency of data aggregation and retrieval. Furthermore, defining this field avoids ambiguities arising from countries that span multiple continents or special geographic divisions, thereby reducing redundancy caused by repeated mapping logic. Globally, oases are distributed across Asia, Africa, North America, South America, and Oceania, with the corresponding codes in the oasis ID being AS, AF, NA, SA, and OA, respectively.

Country field (2 characters): This is the second-level field, specifying the country or countries containing the specific oasis. The inclusion of the country field highlights the central role of the national level in the governance and development of oases. National boundaries define the administrative affiliation and spatial extent of each oasis, forming the institutional foundation for its internal and external spatial organization. Globally, oases are distributed across 54 countries, including typical oasis regions such as China, the United States, Egypt, and Pakistan. In the coding process, each country is represented by a two-letter English code defined by the International Organization for Standardization (ISO), ensuring both standardization and international compatibility of the data structure. In cases where an oasis spans multiple countries, the first character of this field denotes the number of countries involved, while the second character is encoded sequentially according to the relative geographic positions of the countries, following an order from northeast to southwest (Table 1).

Table 1 Oasis ID country code system

Country name	Country ID	Country name	Country ID
Algeria	DZ	Tajikistan	TJ
Egypt	EG	Turkey	TR
Ethiopia	ET	Turkmenistan	TM
Angola	AO	Uzbekistan	UZ
Kenya	KE	Syria	SY
Libya	LY	Armenia	AM
Mali	ML	Yemen	YE
Mauritania	MR	Iraq	IQ
Namibia	NA	Iran	IR
Sudan	SD	Israel	IL
Somalia	SO	Jordan	JO
South Africa	ZA	China & Kazakhstan	2A
Afghanistan	AF	Turkmenistan & Uzbekistan	2B
Kyrgyzstan	KG	Turkmenistan & Afghanistan	2C
Kuwait	KW	Afghanistan & Tajikistan	2D
Lebanon	LB	Afghanistan & Iran	2E
Tunisia	TN	Pakistan & Iran	2F
Niger	NE	Azerbaijan & Iran	2G
Nigeria	NG	Kuwait & Saudi Arabia	2H
Senegal	SN	Syria & Jordan	2I
Chad	TD	Israel & Jordan	2J
Argentina	AR	United Arab Emirates & Saudi Arabia	2K
Bolivia	BO	United Arab Emirates & Oman	2L
Peru	PE	Oman & Saudi Arabia	2M
Chile	CL	Saudi Arabia & Yemen	2N
United States	US	Egypt & Libya	2O
Mexico	MX	Algeria & Tunisia	2P
Australia	AU	Algeria & Morocco	2Q
Eritrea	ER	Eritrea & Sudan	2R

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Country name	Country ID	Country name	Country ID
Cape Verde	CV	Ethiopia & Somalia	2S
Djibouti	DJ	Niger & Mali	2T
Cameroon	CM	Mali & Mauritania	2U
Morocco	MA	Mauritania & Senegal	2V
United Arab Emirates	AE	Namibia & South Africa	2W
Oman	OM	United States & Mexico	2X
Azerbaijan	AZ	Syria & Israel & Jordan	3A
Pakistan	PK	Kazakhstan & Kyrgyzstan & Uzbekistan & Tajikistan	4A
Bahrain	BH	Uzbekistan & Tajikistan & Afghanistan & Turkmenistan	4B
Kazakhstan	KZ	Turkey & Armenia & Azerbaijan & Iran	4C
Qatar	QA	Niger & Chad & Cameroon & Nigeria	4D
Mongolia	MN	Iran & Iraq & Kuwait & Turkey & Syria & Lebanon	6A
Saudi Arabia	SA		

Basin field (2 characters): This is the third-level field, used to further identify the watershed to which an oasis belongs. The rationale for selecting the watershed as a coding field lies in the fundamental importance of water resources as water is the lifeline of oases, shaping their ecosystems, sustaining vegetation cover, and supporting human society. In practice, an oasis is typically associated with one or multiple watersheds. For consistency and clarity, this study designated the primary watershed that sustains the oasis as the identifier for this field. The coding rules for watersheds are adapted from existing global watershed classification systems, with necessary modifications to address the specific characteristics and requirements of oases. The correspondence between global watershed codes and the oasis codes applied in this study is presented in Table 2.

Table 2 Global basin code and oasis ID code cross-reference

Global basin code	Oasis ID code	Global basin code	Oasis ID code	Global basin code	Oasis ID code	Global basin code	Oasis ID code
21A	01	53A	27	25G	14	55A	40
22B	02	53B	28	25H	15	55B	41
23A	03	53D	29	25I	16	56A	42
24A	04	53E	30	25J	17	56B	43
24B	05	53F	31	42B	18	56C	44
24C	06	53G	32	42C	19	64A	45
24D	07	53H	33	42F	20	65A	46
25A	08	53J	34	42G	21	72B	47
25B	09	53K	35	43B	22	72C	48
25C	10	54A	36	43C	23	73D	49
25D	11	54C	37	45A	24	73I	50
25E	12	54D	38	45B	25	75A	51
25F	13	54E	39	45C	26		

Area field (3 characters): This is the fourth and final hierarchical field. Since a single watershed may contain multiple oases, a three-character format is adopted to accommodate cases where numerous oases exist within the same watershed. Within each watershed, oases are ranked by area, with the largest assigned the code 001, followed sequentially by smaller ones. This field ultimately defines the relative status of an oasis within its watershed.

The area field was selected because the size of an oasis is a critical determinant of its significance. It serves not only as a spatial quantitative indicator but also as an important parameter with cross-disciplinary relevance in ecology, sociology, and resource management. For example, the area of an oasis influences its capacity to sustain ecosystems and is directly related to the distribution and availability of water resources. In contrast, smaller oases are more vulnerable in terms of water resource allocation and carrying capacity, making them more susceptible to external environmental changes.

3 Results

3.1 The Global Oases Dataset

This study produced a total of 54 oasis datasets[18–71] and a global oasis code table. The datasets are archived in .kmz and .shp formats. All datasets have been published on the Global Change Research Data Publishing & Repository and are available for free download globally. The specific list of datasets is shown in Table 3.

Table 3 Overview of global oasis entries publication

Oasis Name	DOI	Data size	Data formats
Egyptian Oasis	10.3974/geodb.2025.02.10.V1	649 MB	.kmz, .shp
Ethiopian Oasis	10.3974/geodb.2025.03.10.V1	22.5 MB	.kmz, .shp
Algerian Oasis	10.3974/geodb.2025.04.07.V1	730 MB	.kmz, .shp
Angolan Oasis	10.3974/geodb.2025.04.08.V1	31 MB	.kmz, .shp
Libyan Oasis	10.3974/geodb.2025.04.09.V1	255 MB	.kmz, .shp
Malian Oasis	10.3974/geodb.2025.04.10.V1	60.8 MB	.kmz, .shp
Mauritanian Oasis	10.3974/geodb.2025.04.11.V1	94.4 MB	.kmz, .shp
Kenyan Oasis	10.3974/geodb.2025.04.12.V1	15.1 MB	.kmz, .shp
Namibian Oasis	10.3974/geodb.2025.05.03.V1	7.98 MB	.kmz, .shp
South African Oasis	10.3974/geodb.2025.05.04.V1	10.6 MB	.kmz, .shp
Sudanese Oasis	10.3974/geodb.2025.05.06.V1	392 MB	.kmz, .shp
Somali Oasis	10.3974/geodb.2025.05.07.V1	12.3 MB	.kmz, .shp
Tunisian Oasis	10.3974/geodb.2025.06.02.V1	180 MB	.kmz, .shp
Afghan Oasis	10.3974/geodb.2025.06.03.V1	680 MB	.kmz, .shp
Kyrgyzstani Oasis	10.3974/geodb.2025.06.04.V1	249 MB	.kmz, .shp
Kuwaiti Oasis	10.3974/geodb.2025.06.06.V1	28.1 MB	.kmz, .shp
Lebanese Oasis	10.3974/geodb.2025.06.07.V1	9.20 MB	.kmz, .shp
Peruvian Oasis	10.3974/geodb.2025.06.08.V1	332 MB	.kmz, .shp
Chilean Oasis	10.3974/geodb.2025.06.09.V1	84.9 MB	.kmz, .shp
Argentine Oasis	10.3974/geodb.2025.07.05.V1	116 MB	.kmz, .shp
Australian Oasis	10.3974/geodb.2025.07.06.V1	123 MB	.kmz, .shp
Bolivian Oasis	10.3974/geodb.2025.07.07.V1	7.29 MB	.kmz, .shp

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Oasis Name	DOI	Data size	Data formats
Mexican Oasis	10.3974/geodb.2025.07.08.V1	262 MB	.kmz, .shp
Syrian Oasis	10.3974/geodb.2025.07.09.V1	32.6 MB	.kmz, .shp
Yemeni Oasis	10.3974/geodb.2025.07.10.V1	202 MB	.kmz, .shp
Israeli Oasis	10.3974/geodb.2025.07.11.V1	21.3 MB	.kmz, .shp
Southwestern American Oasis	10.3974/geodb.2025.07.12.V1	1.04 GB	.kmz, .shp
United Arab Emirates Oasis	10.3974/geodb.2025.07.13.V1	52.6 MB	.kmz, .shp
Omani Oasis	10.3974/geodb.2025.07.14.V1	121 MB	.kmz, .shp
Azerbaijani Oasis	10.3974/geodb.2025.07.15.V1	11.6 MB	.kmz, .shp
Pakistani Oasis	10.3974/geodb.2025.08.05.V1	670 MB	.kmz, .shp
Bahraini Oasis	10.3974/geodb.2025.08.06.V1	41.6 MB	.kmz, .shp
Eritrean Oasis	10.3974/geodb.2025.08.11.V1	28.7 MB	.kmz, .shp
Cape Verdean Oasis	10.3974/geodb.2025.08.12.V1	6.57 MB	.kmz, .shp
Djiboutian Oasis	10.3974/geodb.2025.08.13.V1	5.03 MB	.kmz, .shp
Kazakhstani Oasis	10.3974/geodb.2025.08.14.V1	727 MB	.kmz, .shp
Qatari Oasis	10.3974/geodb.2025.08.15.V1	6.44 MB	.kmz, .shp
Mongolian Oasis	10.3974/geodb.2025.08.16.V1	80.9 MB	.kmz, .shp
Saudi Arabian Oasis	10.3974/geodb.2025.08.17.V1	879 MB	.kmz, .shp
Turkish Oasis	10.3974/geodb.2025.08.18.V1	90.4 MB	.kmz, .shp
Turkmen Oasis	10.3974/geodb.2025.08.19.V1	116 MB	.kmz, .shp
Uzbek Oasis	10.3974/geodb.2025.08.20.V1	199 MB	.kmz, .shp
Armenian Oasis	10.3974/geodb.2025.08.21.V1	11.1 MB	.kmz, .shp
Iraqi Oasis	10.3974/geodb.2025.08.22.V1	139 MB	.kmz, .shp
Iranian Oasis	10.3974/geodb.2025.09.03.V1	2.18 GB	.kmz, .shp
Jordanian Oasis	10.3974/geodb.2025.09.04.V1	40 MB	.kmz, .shp
Chadian Oasis	10.3974/geodb.2025.09.05.V1	6.35 MB	.kmz, .shp
Cameroonian Oasis	10.3974/geodb.2025.09.07.V1	1.77 MB	.kmz, .shp
Moroccan Oasis	10.3974/geodb.2025.09.08.V1	621 MB	.kmz, .shp
Nigerien Oasis	10.3974/geodb.2025.09.09.V1	26.5 MB	.kmz, .shp
Nigerian Oasis	10.3974/geodb.2025.09.10.V1	19.5 MB	.kmz, .shp
Senegalese Oasis	10.3974/geodb.2025.09.11.V1	75.8 MB	.kmz, .shp
Tajik Oasis	10.3974/geodb.2025.09.12.V1	134 MB	.kmz, .shp
Chinese Oasis	10.3974/geodb.2025.09.13.V1	763 MB	.kmz, .shp

3.2 Statistics of Global Oases by Continent

As shown in Figure 3, the geographic extent of global oases ranges from 34°9′5.95″S to 50°55′8.14″N, and from 122°24′35.25″W to 110°12′42.16″E. The easternmost point is located in Victoria, Australia, and the westernmost in California, USA. The northernmost point lies at Lake Uvs Nuur in Mongolia, while the southernmost point is situated on the eastern slopes of the Andes Mountains in South America.

In 2020, the total global oasis area, calculated using the Albers projection, was 2,482,193.27 km^2, comprising 4,850 oases, of which 3,274 were larger than 1 km^2. Statistical analysis of the dataset revealed a pronounced regional concentration in oasis distribution. At the continental scale, Asia contains the largest oasis area, totaling 1,666,863.36 km^2 (67.15% of the global total), and also the highest number of oases (2,701), reflecting the strong aggregation of oases in its arid and semi-arid regions. Africa ranks second, with an oasis area of 432,312.48 km^2 (17.42%) and 1,289 oases, most of which are concentrated around the Sahara Desert.

In contrast, oases in North America, Oceania, and South America cover comparatively smaller areas: 233,638.00 km^2 (9.41%), 93,648.42 km^2 (3.77%), and 55,731.01 km^2 (2.25%), with 654, 49, and 157 oases, respectively. The ratio of quantity to area highlights clear differences in spatial distribution: North American oases are relatively numerous but dispersed in area; South American oases are moderate in number but small in size; while Oceania hosts fewer oases, though they are relatively large in extent (Table 4).

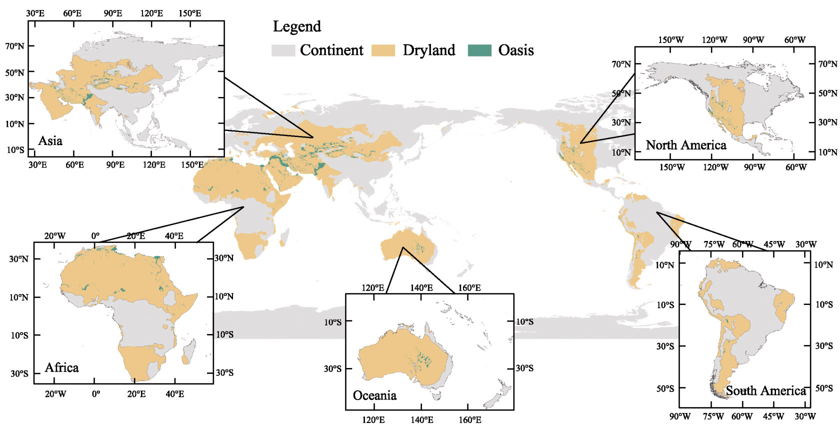

Figure 3 Map of global oasis distribution (2020)

Table 4 Statistics of global oasis areas and number by continent

Continent	Oasis area（km^2）	Oasis number
Asia	1,666,863.36	2,701
Africa	432,312.48	1,289
North America	233,638.00	654
Oceania	93,648.42	49
South America	55,731.01	157

3.3 Statistics of Global Oases by Country or Region

As shown in Table 5, the top ten countries with the largest global oasis area distribution are China, Pakistan, Iran, the United States, Kazakhstan, Iraq, Uzbekistan, Australia, Saudi Arabia, and Egypt.

China has the largest oasis area, covering 275,535.39 km^2 with a total number of 1,398 oases. These oases are widely distributed, particularly in the arid regions of the western provinces such as Xinjiang, Gansu, and Inner Mongolia. They serve not only as critical resources for agricultural production but also play vital roles in ecological protection and water resource management.

This is followed by Pakistan, which has an oasis area of 267,969.51 km^2 and 67 oases. The oases in Pakistan are primarily located in its western arid regions, such as Balochistan Province. Although the number of oases is significantly smaller than that of China, their total area remains substantial.

Iran ranks third with an oasis area of 239,371.98 km^2 and 494 oases. Despite the relatively high number of oases, they are dispersed across vast desert areas, making efficient water resource utilization crucial for the country.

The United States has an oasis area of 183,177.03 km^2, with 512 oases mainly concentrated in California and Nevada. Although the total oasis area is not as large as in the aforementioned countries, the relatively high number and even distribution of oases provide a solid foundation for water resource management and agricultural irrigation in the U.S.

Kazakhstan possesses an oasis area of 152,213.99 km^2 with 24 oases, primarily located in the arid zones of its western and southern regions. Although the number of oases is not large, they are of great significance for local agriculture and ecological protection, especially in remote areas where they serve as key sources of sustenance.

Other countries, such as Iraq (151,340.55 km^2), Uzbekistan (111,055.10 km^2), and Australia (93,648.42 km^2), also have substantial oasis areas but relatively fewer oases. Their oases are mainly concentrated in specific regions, resulting in relatively localized distributions.

The oases in Egypt (82,453.44 km^2) and Saudi Arabia (78,730.10 km^2) also play significant roles within their respective arid zones, particularly in agricultural irrigation and water resource utilization.

Table 5 Statistics of global oasis areas and number by country

Country	Oasis area (km^2)	Number of oases	Country	Oasis area (km^2)	Number of oases
China	275,535.39	1,398	Argentina	15,698.77	60
Pakistan	267,969.51	67	Bolivia	14,626.14	7
Iran	239,371.98	494	Chad	14,498.03	62
United States	183,177.03	512	Tajikistan	13,662.60	26
Kazakhstan	152,213.99	24	Oman	12,504.42	79
Iraq	151,340.55	1	Mauritania	10,855.64	68
Uzbekistan	111,055.10	19	Jordan	9,210.02	39
Australia	93,648.42	49	Niger	8,371.91	12
Egypt	82,453.44	168	Senegal	8,289.08	3
Saudi Arabia	78,730.10	264	Ethiopia	7,865.62	8
Syria	76,873.99	4	Kenya	7,829.66	12
Turkmenistan	65,661.65	27	Kuwait	5,639.11	21
Sudan	54,463.08	46	Qatar	5,584.19	1
Afghanistan	53,891.97	46	Israel	4,000.97	26
Mexico	50,460.97	142	Chile	3,548.53	41
Mali	49,979.07	24	Armenia	3,028.22	1
Turkey	48,815.65	11	Eritrea	2,228.50	14
Tunisia	46,506.30	77	Cameroon	2,035.32	1
Algeria	46,119.34	448	Somalia	1,689.99	15
Morocco	36,161.74	111	Lebanon	1,607.14	1
Libya	30,955.73	131	Azerbaijan	1,066.61	9
Kyrgyzstan	26,414.91	58	Angola	835.04	20
United Arab Emirates	24,825.24	14	South Africa	676.01	8
Peru	21,857.57	49	Bahrain	570.99	1
Mongolia	19,937.56	23	Namibia	231.51	15
Nigeria	19,932.49	12	Djibouti	167.72	4
Yemen	17,351.50	47	Cape Verde	167.26	30

3.4 Top 10 Oases in the World

According to the oasis coding system established in this study, Table 6 presents the top ten largest oases in the world by area. The combined area of these top ten oases is 1,062,883.77 km^2, accounting for approximately 42.82% of the global oasis area. In other words, less than 0.2% of individual oasis units worldwide contain nearly half of the total oasis area, fully demonstrating the "dominant effect" of the oasis landscape. Among them, 2 oases, AS6A04001 and ASPK05001 have a combined area of 548,876.35 km^2, representing 22.12% of the global total, underscoring their immense significance.

In terms of continental distribution, Asia and Africa hold absolute dominance: 6 of the top 10 largest oases are located in Asia, with a total area of 846,390.19 km^2, while 4 are located in Africa, with a total area of 216,493.59 km^2. From a national or transnational perspective, the Central Asia-West Asia region constitutes the core belt of global oases. For example, transnational oases such as the six-country combination in West Asia (AS6A04001), the four-country combination in Central Asia (4A), Central Asia plus Afghanistan (4B), and Egypt and Libya (2P) all rank among the top ten. This indicates that the formation and maintenance of oases in this region frequently transcend national boundaries, reflecting not only their geographical connectivity but also the inherent complexity of transnational water resource management in oasis governance.

Table 6 Top 10 of the global oases

Oasis ID	Continent	Country	Basin	Area (km^2)
AS6A04001	Asia	Iran & Iraq & Kuwait & Turkey & Syria & Lebanon	04	300,023.58
ASPK05001	Asia	Pakistan	05	248,852.77
AS4A10001	Asia	Kazakhstan & Kyrgyzstan & Uzbekistan & Tajikistan	10	127,200.28
AF2P27001	Africa	Egypt & Libya	27	75,328.00
AS4B10002	Asia	Uzbekistan & Tajikistan & Afghanistan & Turkmenistan	10	71,848.91
ASCN12001	Asia	China	12	52,719.28
AFSD27002	Africa	Sudan	27	48,430.33
AF2U28001	Africa	Niger & Mali	28	47,756.96
ASKZ11001	Asia	Kazakhstan	11	45,745.37
AF2Q32001	Africa	Algeria & Tunisia	32	44,978.29

4 Discussion and Conclusion

This study, based on Google Earth Pro imagery by employing manual visual interpretation, successfully constructed the world's first high-precision global oasis dataset through the collective efforts of over 30 geographers over a span of five-years. Although this dataset contains certain human-induced errors and requires further refinement, it comprehensively depicts the spatial distribution of global oases in 2020, marking a new phase in oasis research by advancing from qualitative to quantitative analysis and providing novel perspectives and methodologies for oasis science. All global oasis distribution data are freely available for download and use, fully aligning with the "Open Science" initiative proposed by UNESCO and representing a significant contribution to the advancement of oasis science.

Nevertheless, although these data are highly accurate, their acquisition has required considerable time and human resource input. To achieve continuous updates and ensure the long-term applicability of the data, the development of intelligent automated extraction technologies for oasis boundaries is of critical importance. Reaching this goal demands technological breakthroughs, and more importantly, broader participation of scholars, particularly experts in artificial intelligence and inter disciplinary collaborative research to improve both the efficiency and practical value of oasis science.

Oasis cataloging fills a long-standing gap in oasis science and represents a pioneering contribution to the field. However, cataloging is not a static, one-time task but a dynamic, systematic endeavor that requires sustained investment, regular updates, and constant refinement. Once breakthroughs in intelligent boundary extraction are achieved, real-time updates of global oases will become feasible, with changes in oasis area and land use promptly reflected in the cataloging system. Ideally, cataloging should be updated annually to ensure data timeliness and accuracy; however, if costs are prohibitive, a comprehensive update at least every five years should be guaranteed.

It should also be emphasized that the attributes represented in oasis cataloging can be continuously expanded and enriched. Each oasis corresponds to a unique code, enabling the establishment of a dynamically updated attribute database. As research advances, additional natural and socio-economic attributes such as species counts, numbers of endangered species, population, GDP, educational levels, and industrial structures can be incorporated. With the progressive enrichment and refinement of this information, the future development of oases will be supported by increasingly precise databases, allowing for more targeted and feasible policy and management solutions. Given the escalating challenges of climate change and the increasing conflicts between human activities and natural resources, it is crucial to enhance the breadth, depth, and precision of oasis cataloging. Additionally, establishing standardized, regulated national- and regional-level oasis databases and information-sharing mechanisms should be prioritized. True promotion of sustainable oasis development can only be achieved by generating and sharing more comprehensive oasis data.

Author Contributions

Gui, D. W. and Liu, C. were responsible for the overall design of the paper framework; Lin, J. W. collected and processed the data; Liu, Q. and Liu, Y. F. provided guidance and made revisions to the paper; Abd-Elmabod, S. K. and Ahmed, Z. conducted data validation; Gui, D. W. and Lin, J. W. wrote the paper.

Acknowledgments

Sincere gratitude is extended to the Institutes of Science and Development, Chinese Academy of Sciences, the Xinjiang Uygur Autonomous Region, and the National Natural Science Foundation of China for their financial support of this research. Furthermore, we extend our thanks to Dr. Shi, R. X. from the Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, for her valuable suggestions and meticulous corrections during the global oasis data review process.

Conflicts of Interest

The authors declare no conflicts of interest.

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