



مؤتمر الخليج الخامس عشر للمياه
The 15th Gulf Water Conference

وزارة البيئة والمياه والزراعة
Ministry of Environment Water & Agriculture



Hydrological Assessment of the Weather Event “Madar 22”: Implications for Water Resources Management" in the Kingdom of Saudi Arabia

Dr. Yousry Mattar

*Senior Advisor of Water Resources
United Nations Development Program*

Ministry of Environment, Water & Agriculture (MEWA)

yousrymattar@hotmail.com





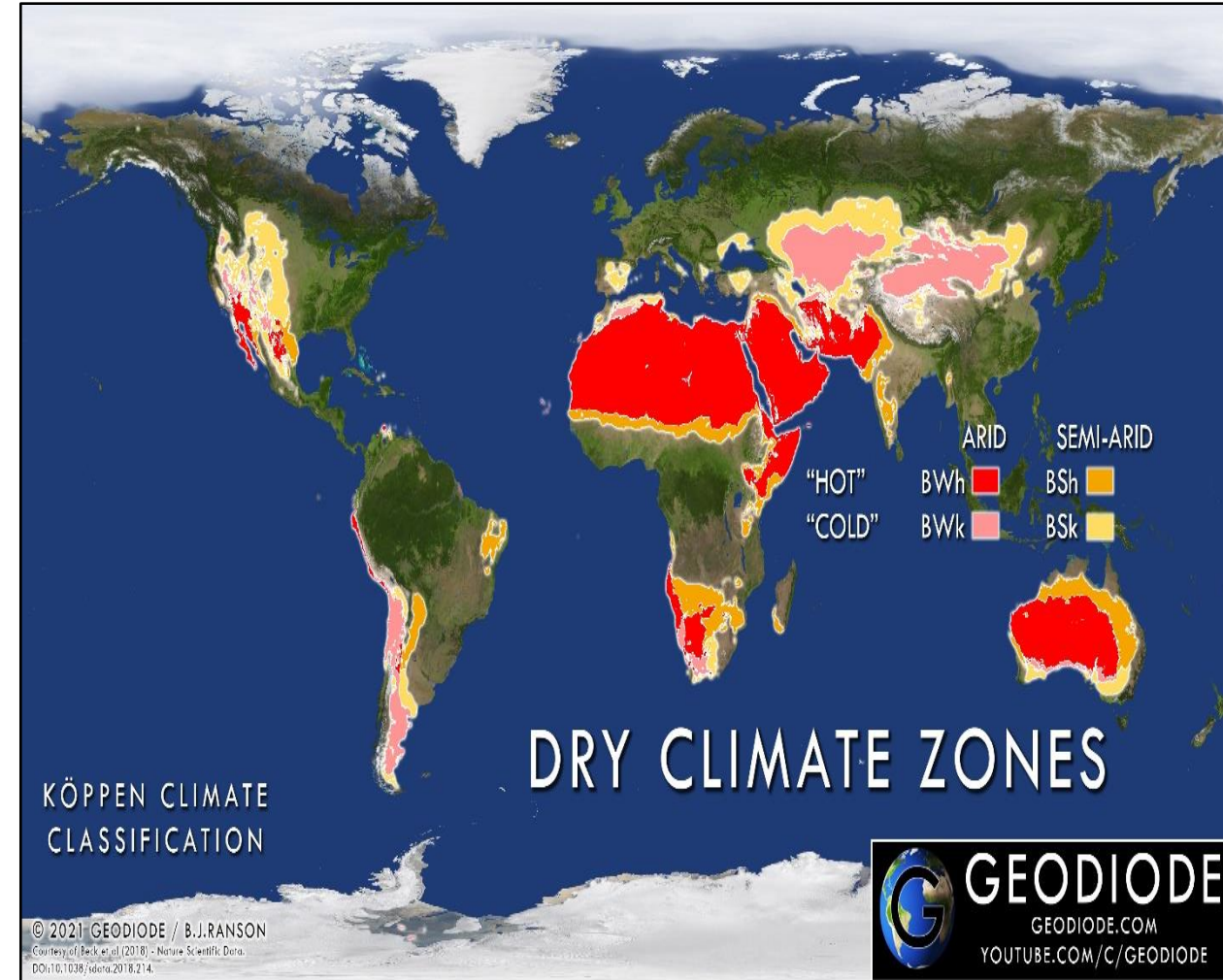
Overview

- **Introduction.**
- **Aim and Objectives of Study.**
- **Study Area.**
- **Methodology & Data Collection.**
- **Rainfall statistical analyses.**
- **Results.**
- **Conclusion & Recommendations.**



Introduction

- GCC are situated in arid Zone (BW).
- In Arid Zone, the rainfall storms exhibit **strong variability both in spatial distribution and intensity.**
- Some Distinctive Summer Rainy Weather Events occasionally occurred in GCC.
- The precipitation during these Weather Events plays very important role in enhancing the renewable **surface water** to meet various demands.



Dry Climate Zones in the World (Köppen (1936) and Geiger (1961))



Madar 22 Weather Event in Saudi Arabia

Many Distinctive rainy Summer Weather Events occasionally occurred in the Kingdom of Saudi Arabia and Gulf Council Countries.

The most important Weather Events have been occurred in 1957, 1960, 1983, 1988, 1992, 2016, 2018, 2020 and finally in 2022.

Most of the rainy summer weather event have been associated with recording negative values for the Indian Ocean Coefficient (IOD) coincides with the activity of the La Nina climate phenomenon

The Summer Weather Events have accompanied with heavy rains causing flash foods and runoff in many wadies.

The resulted Runoff during these Summer Weather Events have directly enhanced the storage volume of the retained surface water behind dams and also the renewable underground aquifers recharge.

Al Rabab Weather Event (from 28 July to 3 August 2016, 7 days)

Rahw Weather Event (24 July to 10 August 2020, 18 days).



North Riyadh, August 2022



Makka, August 2022



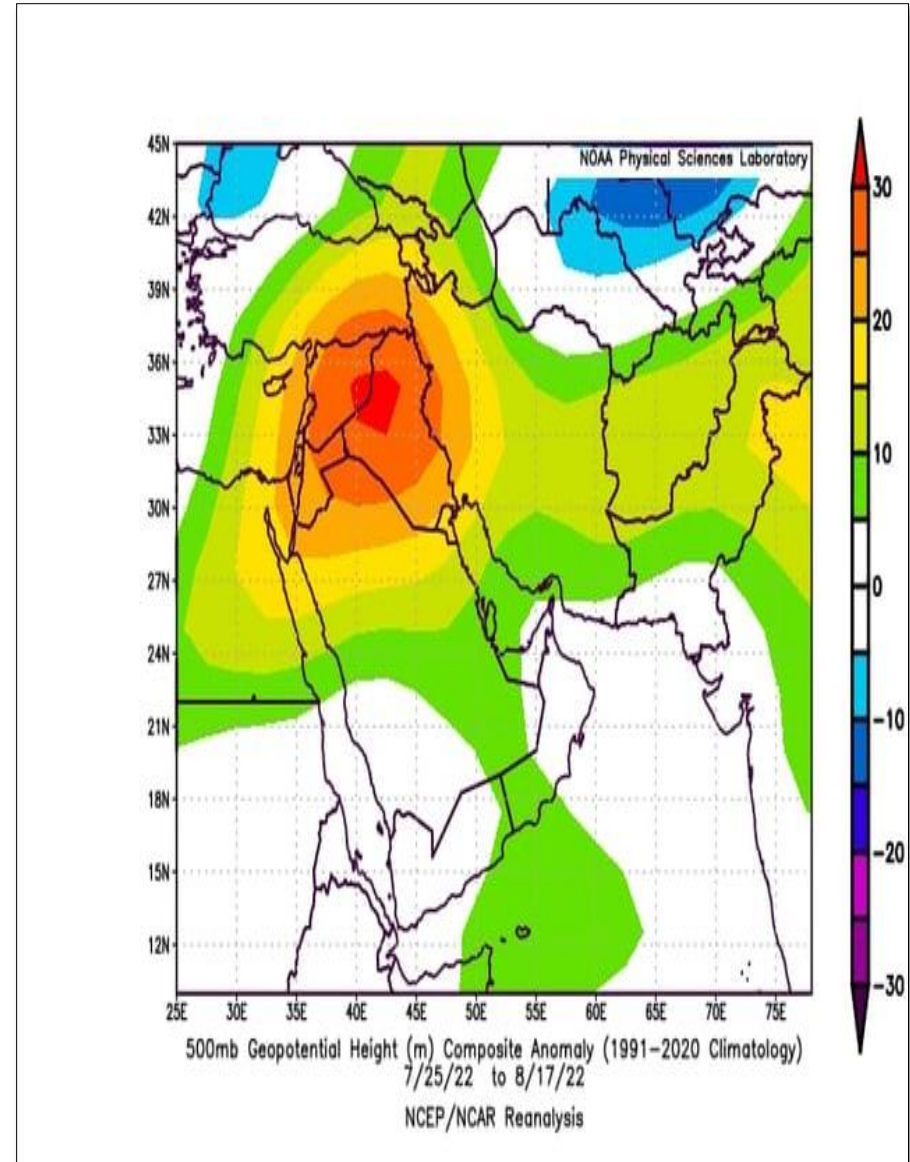
Introduction

Rare Distinctive summer weather event has affected the Arabian Gulf countries, Yemen, and western Iran between 23 July, extended to 21 August 2022 (Lasted to 30 days).

The Kingdom of Saudi Arabia has been affected with this tropical weather event, including major cities such as Riyadh, Jeddah, Al Qassim, Dharan, Najran, Asir, Jazan and Al Baha.

The nomination committee for distinctive climate conditions (Tasmyat) in Saudi Weather and Climate Association (wcaorg) has approved the name # Madar_22 to this rare summer tropical weather event.

This tropical weather event, resulted in medium to very heavy daily precipitation.



Madar 2022

"Madar 22", is considered as a rare and **distinctive historical summer** weather event in terms of its spatial distribution and Rainfall intensity in the Kingdom of Saudi Arabia and Arabian Gulf countries.

The precipitation rates during "Madar 22" are considered unprecedented **in July and August** within **the last 30 years** in the Arabian Gulf countries since the summer of 1992.



Madar 22 Weather Event in UAE & Oman

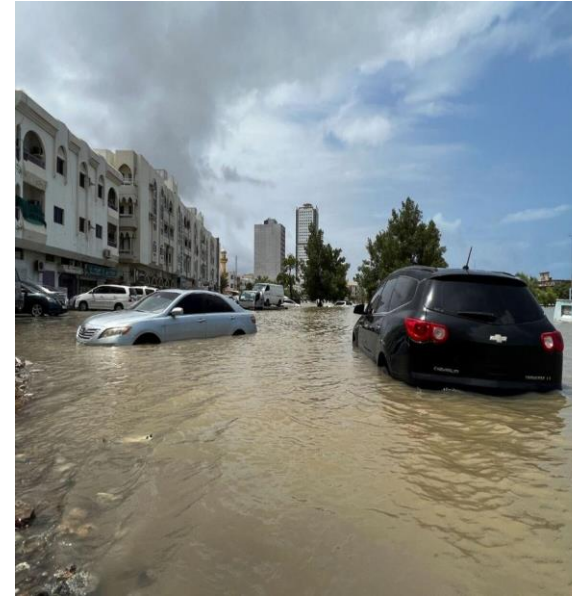
On Wednesday 27 July 2022, several regions in the UAE, such as Sharjah, Ajman, Ras Al Khaimah, Khor Fakkan, and Umm Al Quwain, recorded unprecedented heavy rainstorms.

Al Fujairah Port station has received 255.2 mm which was the highest in the UAE during the month of July recorded in the last 27 years, surpassing the 175.6 mm of rain received in Khor Fakkan (Sharjah) in 1995.

The second highest was recorded in Masafi (on the border between Al **Fujairah** and **Ras Al Khaimah** at 209.7mm

The third highest was noted in Al Fujairah Airport with 187.9mm.

Heavy rainfall exceeding 300 mm in 24 hours was recorded in Oman.



Impact of Madar 22 Weather event in UAE, 28 Jul 2022



Impact of Madar 22 Weather event in Oman & Iran Jul 2022



Madar 22 Weather Event in Qatar & Iran



On Thursday morning 28 July 2022, various regions of **Qatar** have witnessed, large amounts of rain causing flash floods in some parts.



According to the director of Meteorology Department at Qatar's Civil Aviation Authority (QCAA), **it was the first time to see such rains in Qatar in July since 1962.**



According to the Qatar News Agency (QNA), **Doha** had recorded 38mm, and 29.8mm in Al-Wakrah by (07:00) GMT.



Qatar average annual precipitation is ranging between 55.5–99 mm/year



Also, **western Iran** also experienced flash floods, and at least 53 persons were killed with "Madar 22" weather event .



Impact of Madar 22 Weather event, 28 July, 2022 in Qatar



Impact of Madar 22 Weather event, July 2022 in Qatar

Aim of Study



Understanding the rainfall pattern of "Madar_22" weather event



Evaluate the hydrological implications of the "Madar 22" event on water resources management in the Kingdom of Saudi Arabia.



Correlation between the estimated rainfall and runoff depth and volumes with those collected in dam reservoirs during "Madar 22."



Suggesting runoff and shallow aquifer recharge coefficients in each region in Saudi Arabia during the "Madar 22" event.



Proposing suitable techniques to enhance rainfall harvesting and renewable water resources in the Kingdom of Saudi Arabia.



Methodology & Data Collection

Analyzing

Analyzing the daily and hourly records of the **hydrologic network's 570** stations of (MEWA).

Utilizing

Utilizing the spatial distribution maps of the weighted precipitation for all regions in KSA, using ARC GIS spatial analysis techniques.

Correlating

Correlating the daily and monthly rainfall records with the corresponding records for 50 years record (1972-2022).

Estimating

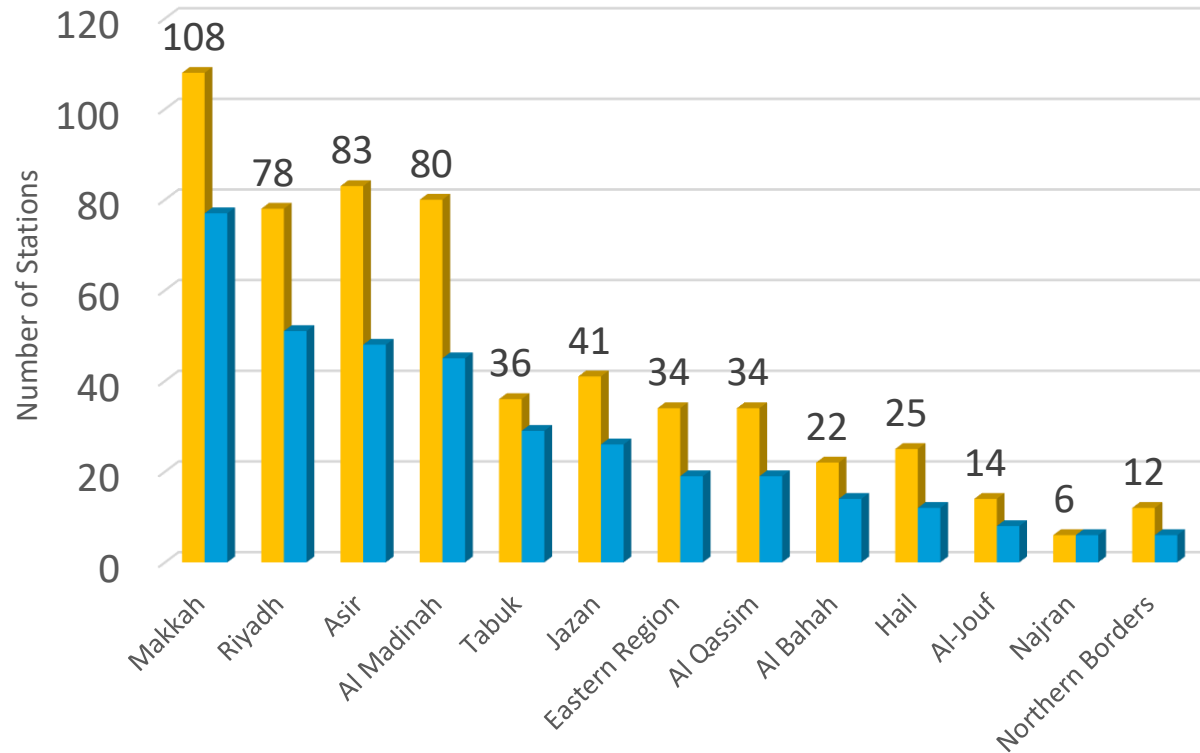
Estimating the rainfall harvesting in dams' reservoirs through Madar_22.

Introducing

New Regional Runoff and Recharge coefficients.

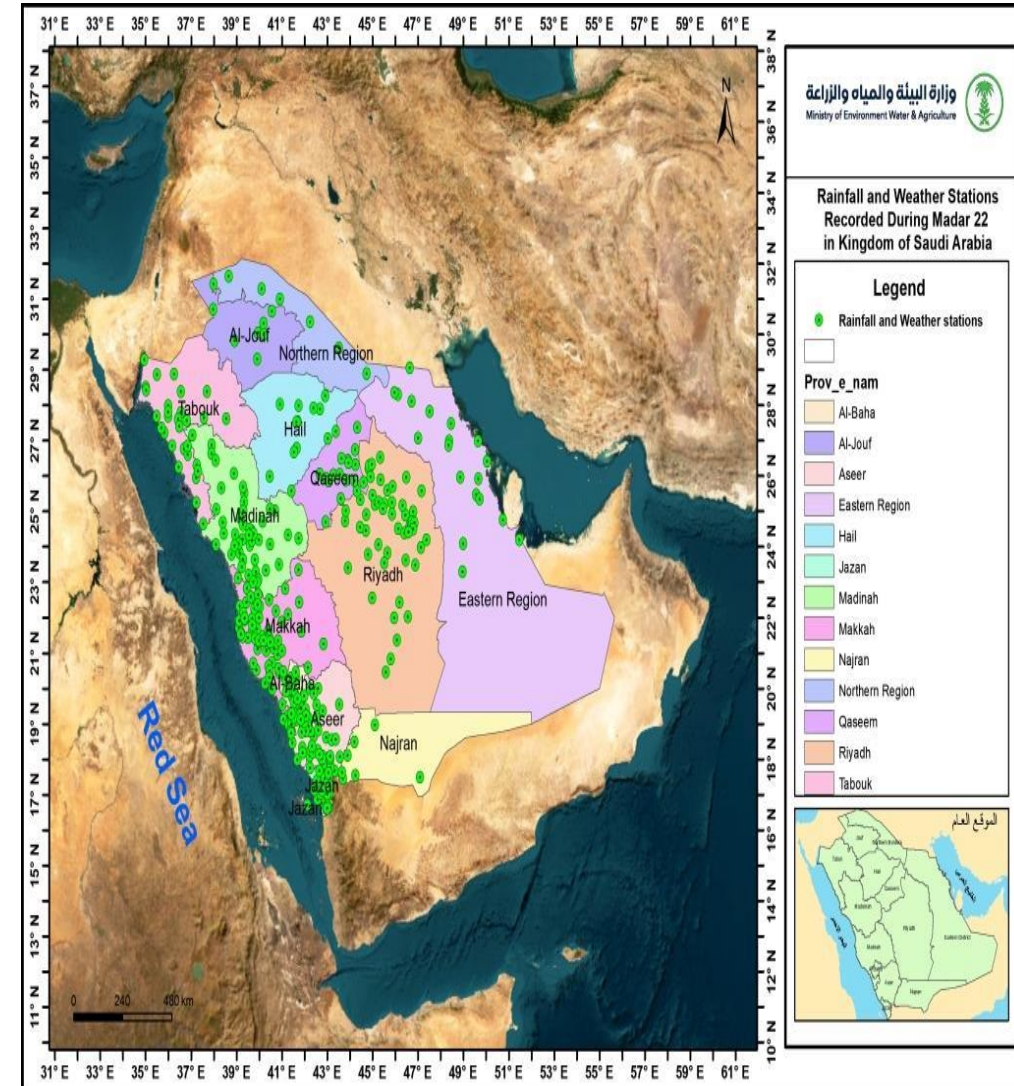
Data Collection

Comparison between Tota Number of hydrologic station and Tota Number of recorded station during Madar 2022 Weather Event



■ Number of weather and rainfall stations in MEWA hydrologic network

■ Number of hydrologic networks recorded rainfall during Madar 22



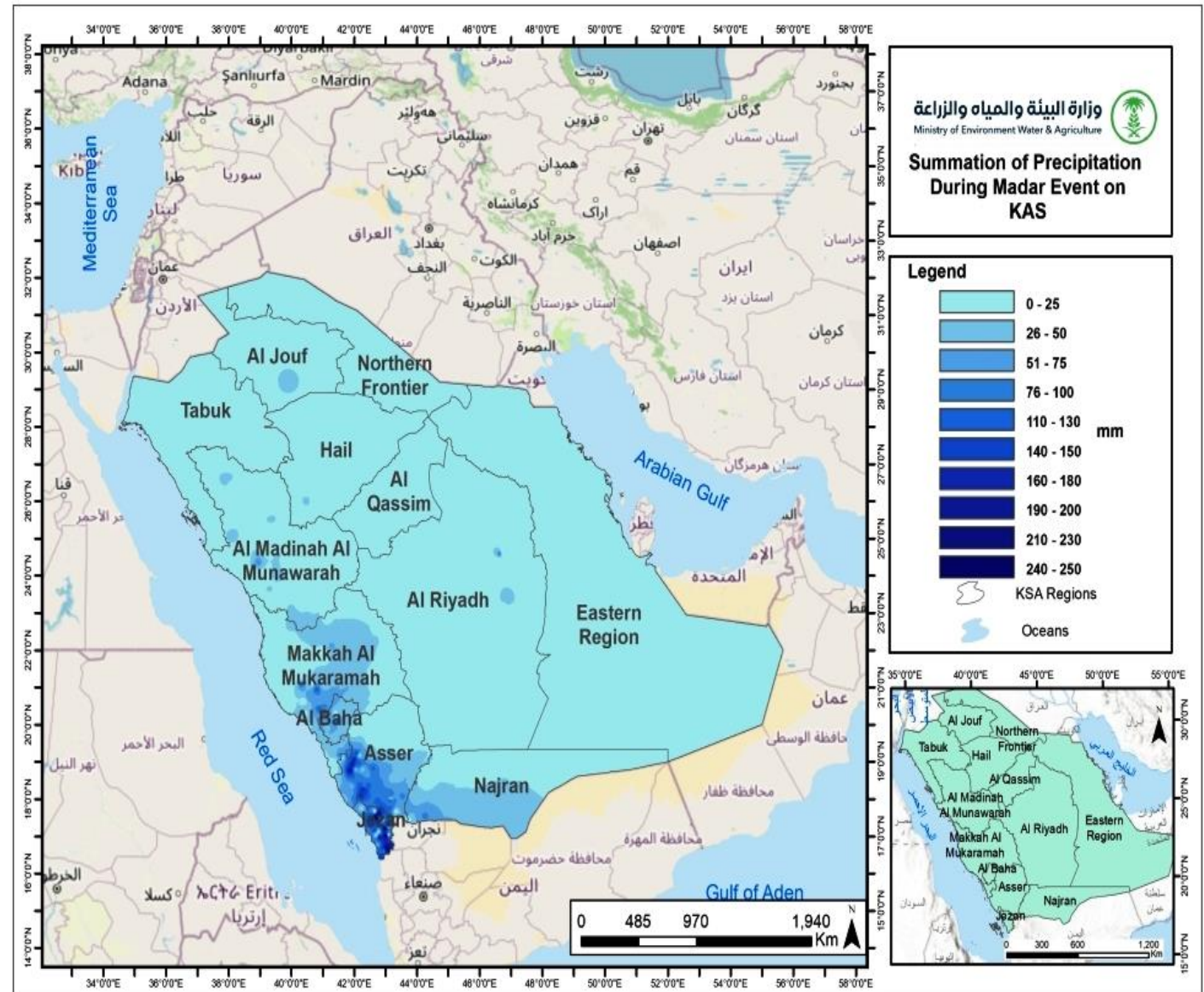
Location of MEWA hydrologic network stations recorded during Madar 22 event.

Rainfall Statistical analyses



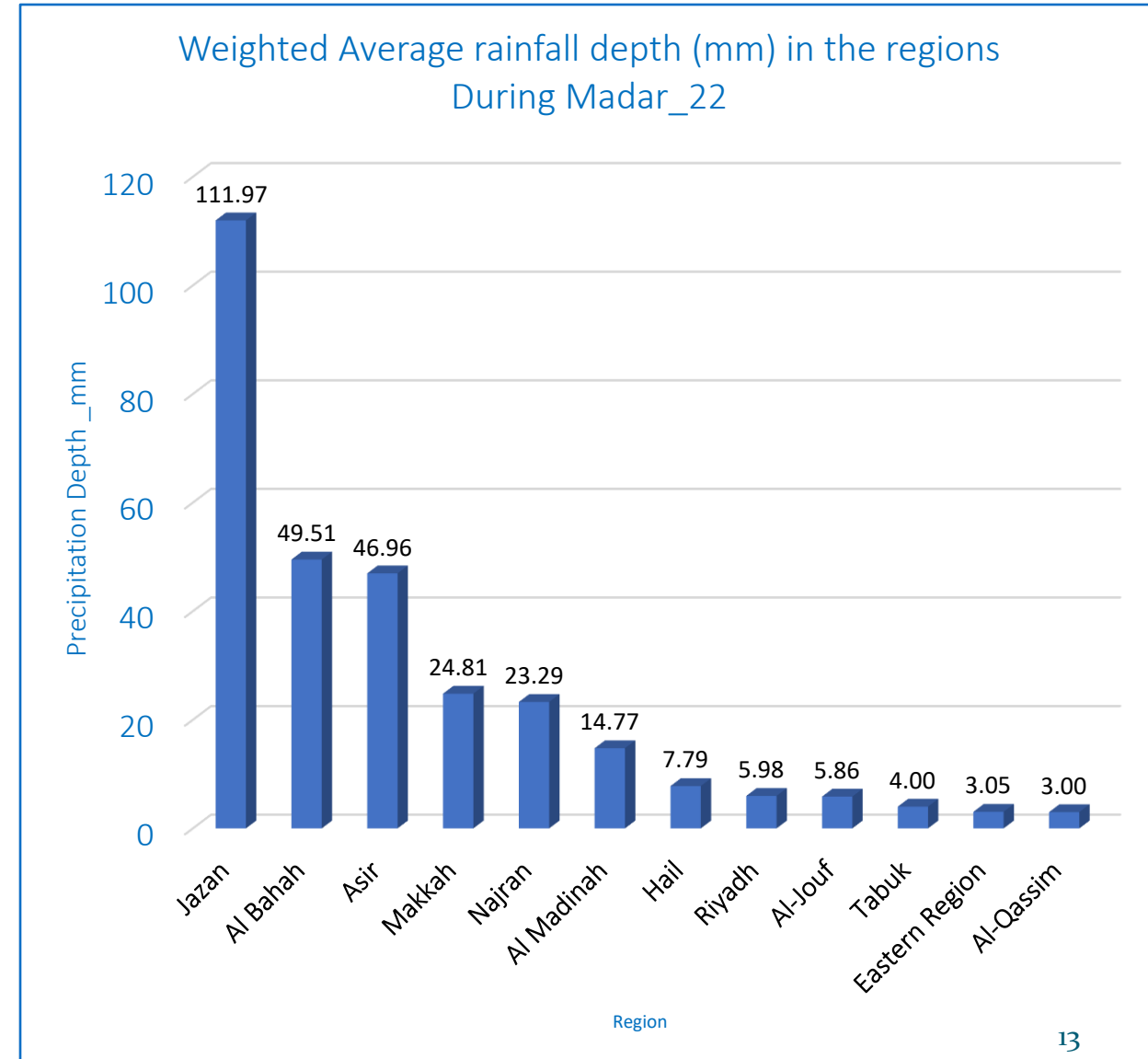
All obtained Rainfall data records from (365) MEWA Stations have been statistically analyzed using Spatial analyses tool in ARC GIS Application,

Isohyetal contour maps of the Spatial Distribution of the rainfall recorded during weather Event "Madar_22" have been produced in all affected regions.



Rainfall Statistical analyses

Region	Average Rainfall Depth (mm) within 50 y record	Average Rainfall Depth (mm) During Madar 22	Average Rainfall Depth During Madar 22 and The Average Annual Rainfall Depth for 50 y Record Ratio
Jazan	275	111.97	0.41
Asir	210	46.96	0.22
Al Bahah	200	49.51	0.25
Makkah	100	24.81	0.25
Al Qassim	90	3	0.03
Riyadh	85	5.98	0.07
Najran	75	23.29	0.31
Hail	70	7.79	0.11
Northern Borders	60	1.32	0.02
Al Madinah	53	14.77	0.28
Eastern Region	50	3.05	0.06
Al Jouf	40	5.86	0.15
Tabuk	35	4	0.11
Average	103.31	23.26	0.23



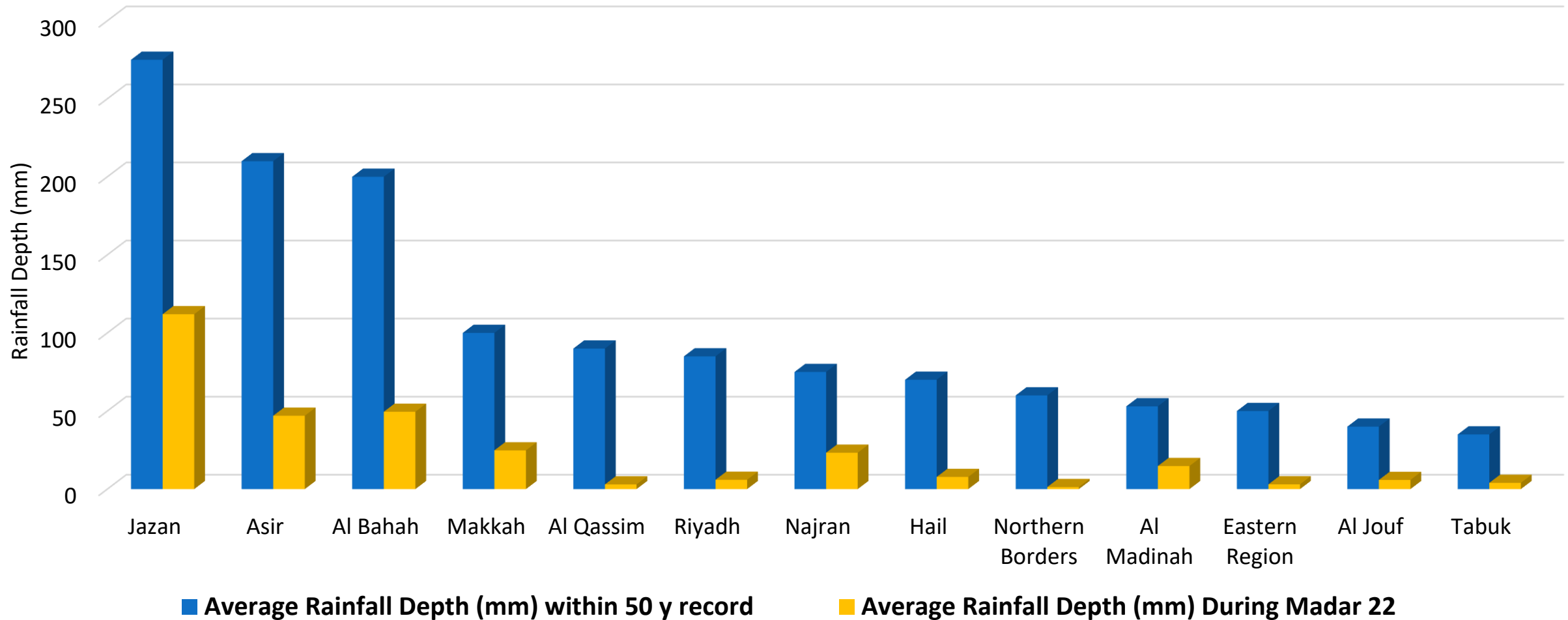


Results: Precipitation

- ❑ The **weighted rainfall** depth for all regions during Madar 22 amounted to **23.26 mm**, representing 23% of the average annual rainfall depth for all regions over a 50-year period.
- ❑ **Jazan** region recorded the highest weighted rainfall depth at **111.97 mm**, constituting approximately 41% of the annual rainfall depth over a 50-year period.
- ❑ **Asir** region recorded the maximum daily precipitation depth during Madar 22 in **79mm**.
- ❑ Jazan region recorded the **highest cumulative precipitation** depth during Madar 22 in **276 mm**
- ❑ The weighted **rainfall volume** amounted to **20.605 billion m³**, constituting approximately **18%** of the total annual rainfall volume for all regions over a 50-year period which is estimated as 166 billion m³ .
- ❑ **Asir region** recorded **the highest Precipitation** volume during the "Madar 22" event, with a total of **3.630 billion m³** represents 24% of the annual rainfall volume for a 50-year record in the Asir region.

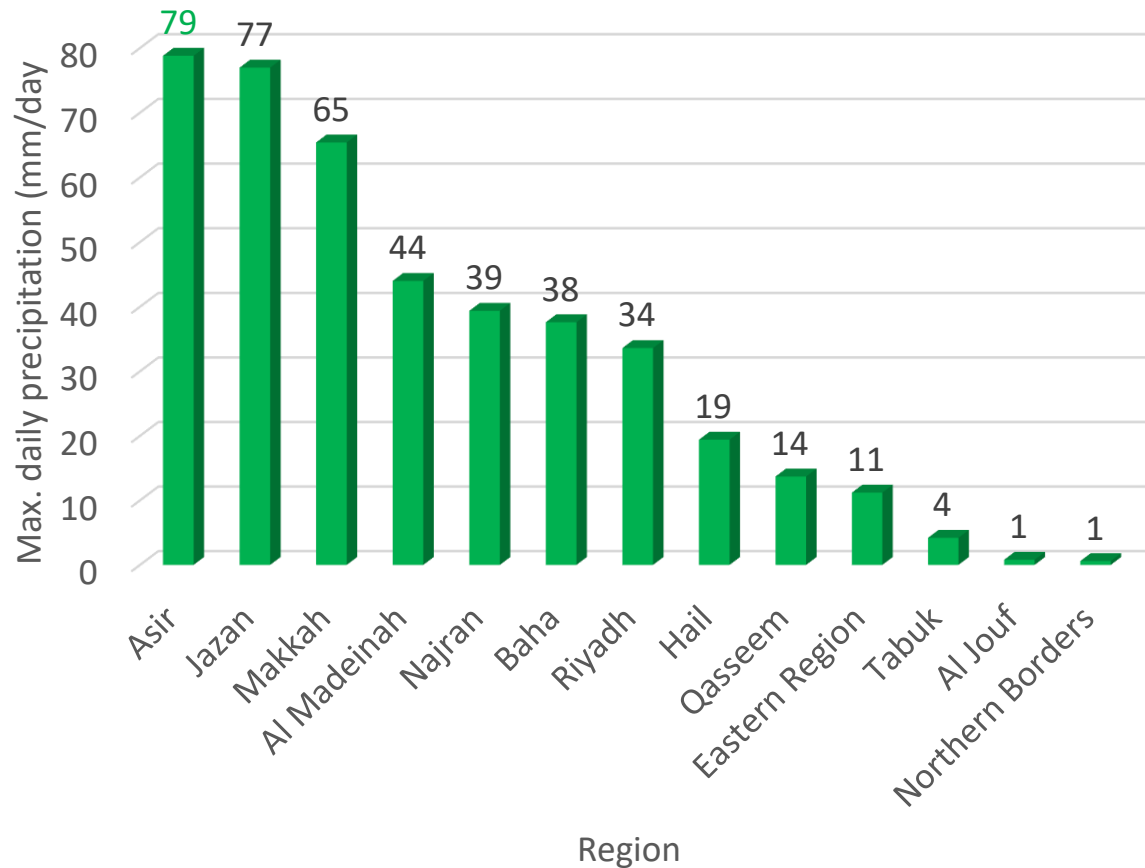
Results: Regions Average Rainfall

Comparison between the Average Annual rainfall depth (50 y) and the Average rainfall depth During Madar 22

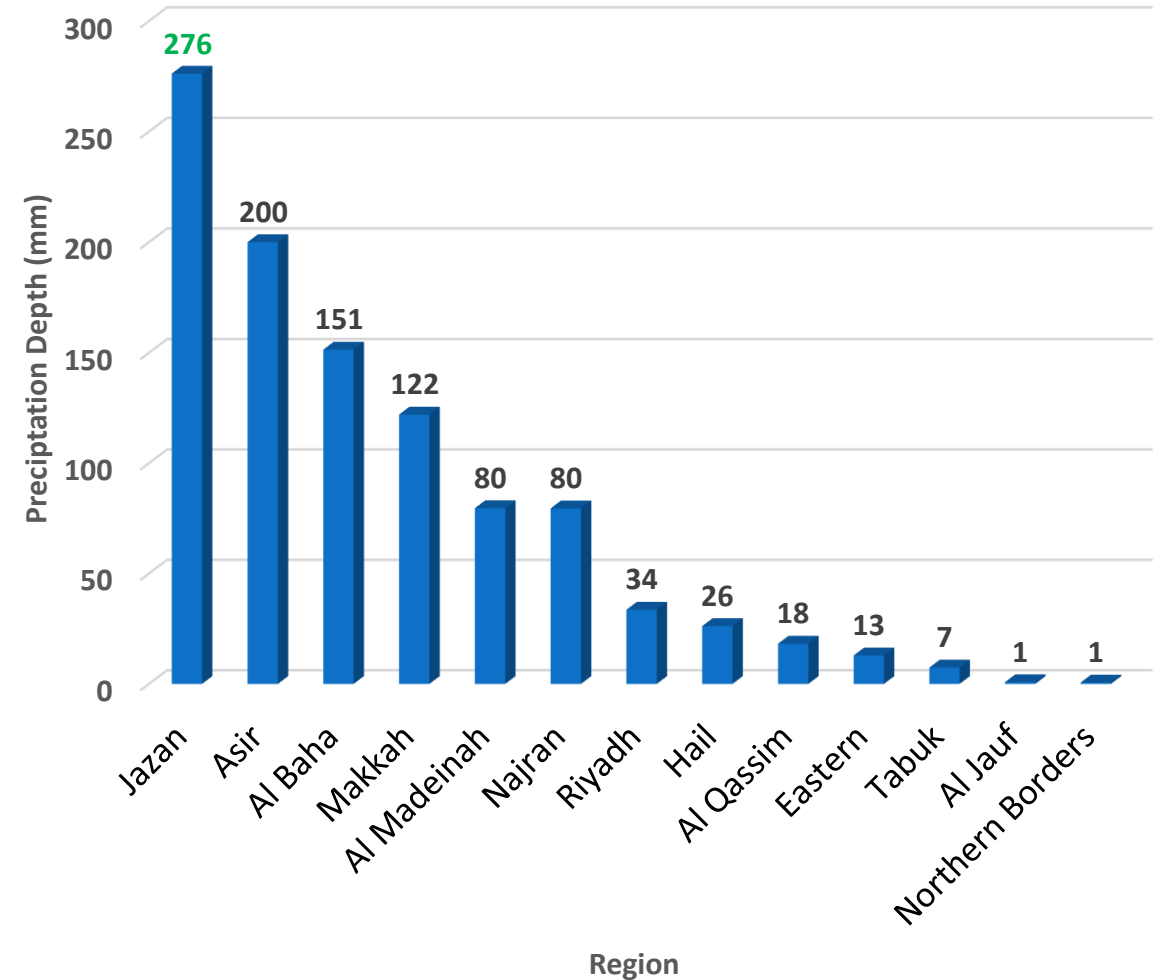


Results: Maximum Rainfall

Max daily Precipitation (mm/day) During Madar22 Rainstorm
Lasting
from (23/7/222 To 23/8/2022)
)



Maximum cumulative precipitation (mm) During Madar22



Rainfall Spatial Distribution and Isohyetal Maps for Regions

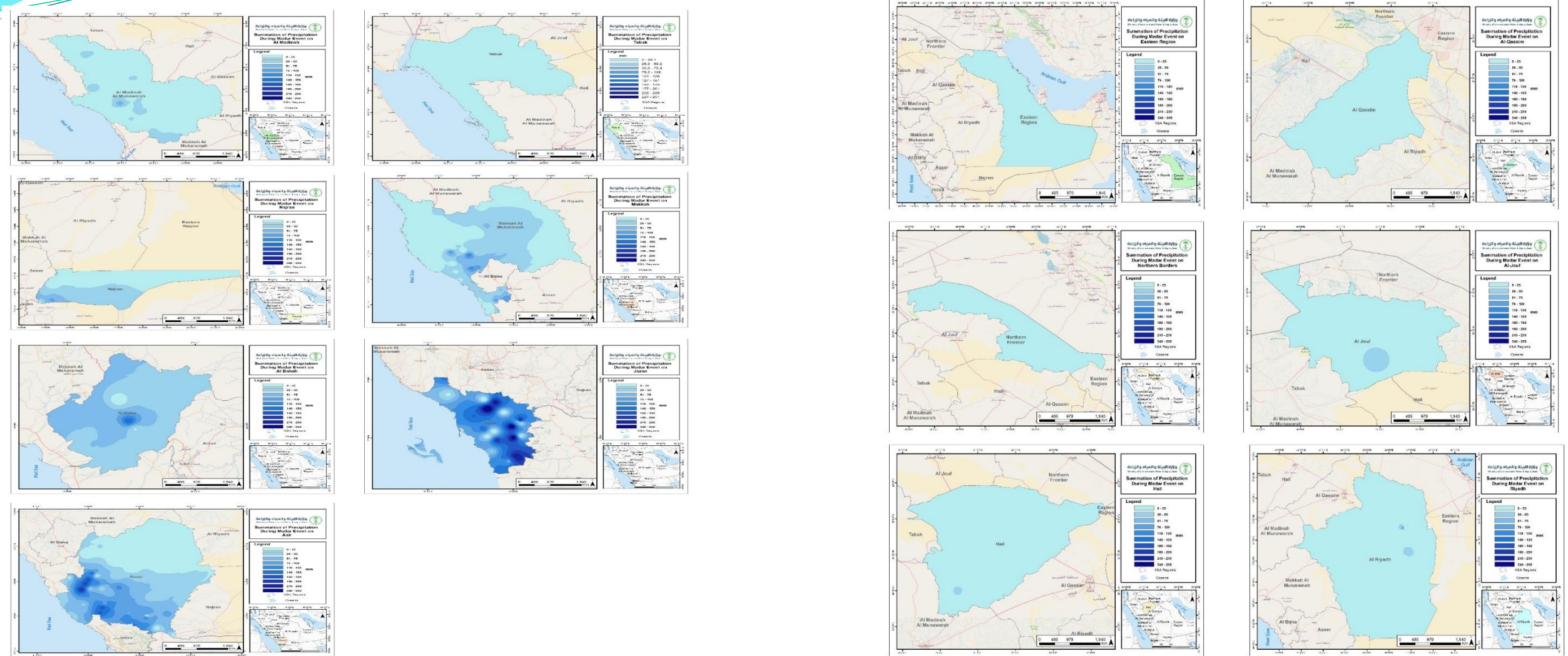
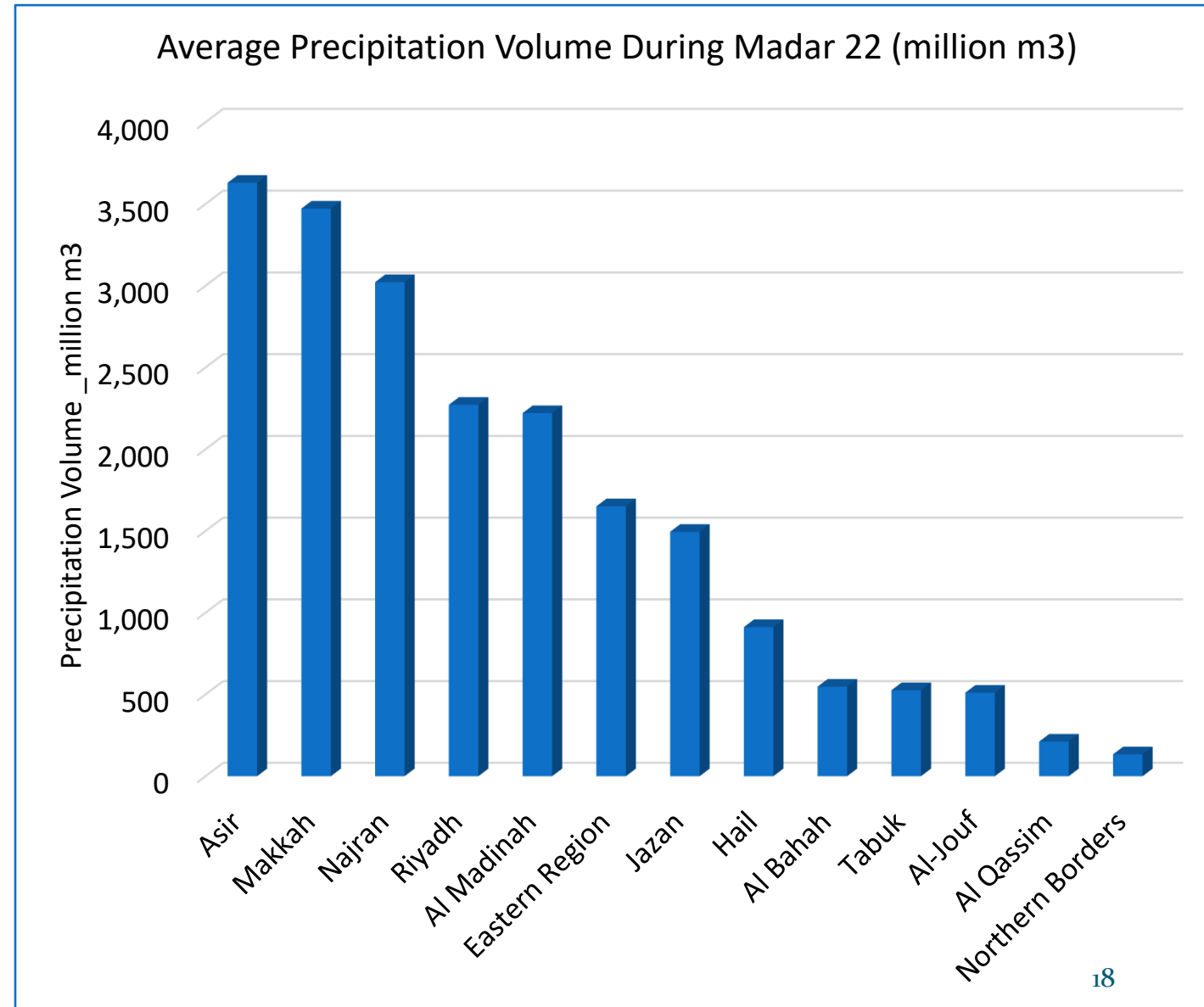


Figure. Rainfall distribution in Eastern Region, Al Qassim Region, Northern Borders Region, Al Jouf Region, Hail Region, and Riyadh Region during "Madar 22" weather event.

Results: Precipitation Depth & Volume

Region	Region Affected Area (km2)	Average Annual Rainfall Volume 50 y record (million m3)	Average Rainfall Volume During Madar 22 (million m3)	Ratio of Average Rainfall Volume During Madar 22 and 50 y record
Asir	77,297	15,390	3,630	0.24
Makkah	139,924	16,846	3,472	0.21
Najran	129,761	11,213	3,022	0.27
Riyadh	379,631	32,339	2,272	0.07
Al Madinah	150,320	8,055	2,221	0.28
Eastern Region	540,438	47,077	1,651	0.04
Jazan	13,356	2,918	1,495	0.51
Hail	117,086	7,584	912	0.12
Al Bahah	11,076	1,984	548	0.28
Tabuk	131,377	5,405	526	0.1
Al-Jouf	87,148	4,008	511	0.13
Al Qassim	70,661	5,224	212	0.04
Northern Borders	101,482	7,826	134	0.02
Total/Average	1,949,556	165,869	20,605	0.18



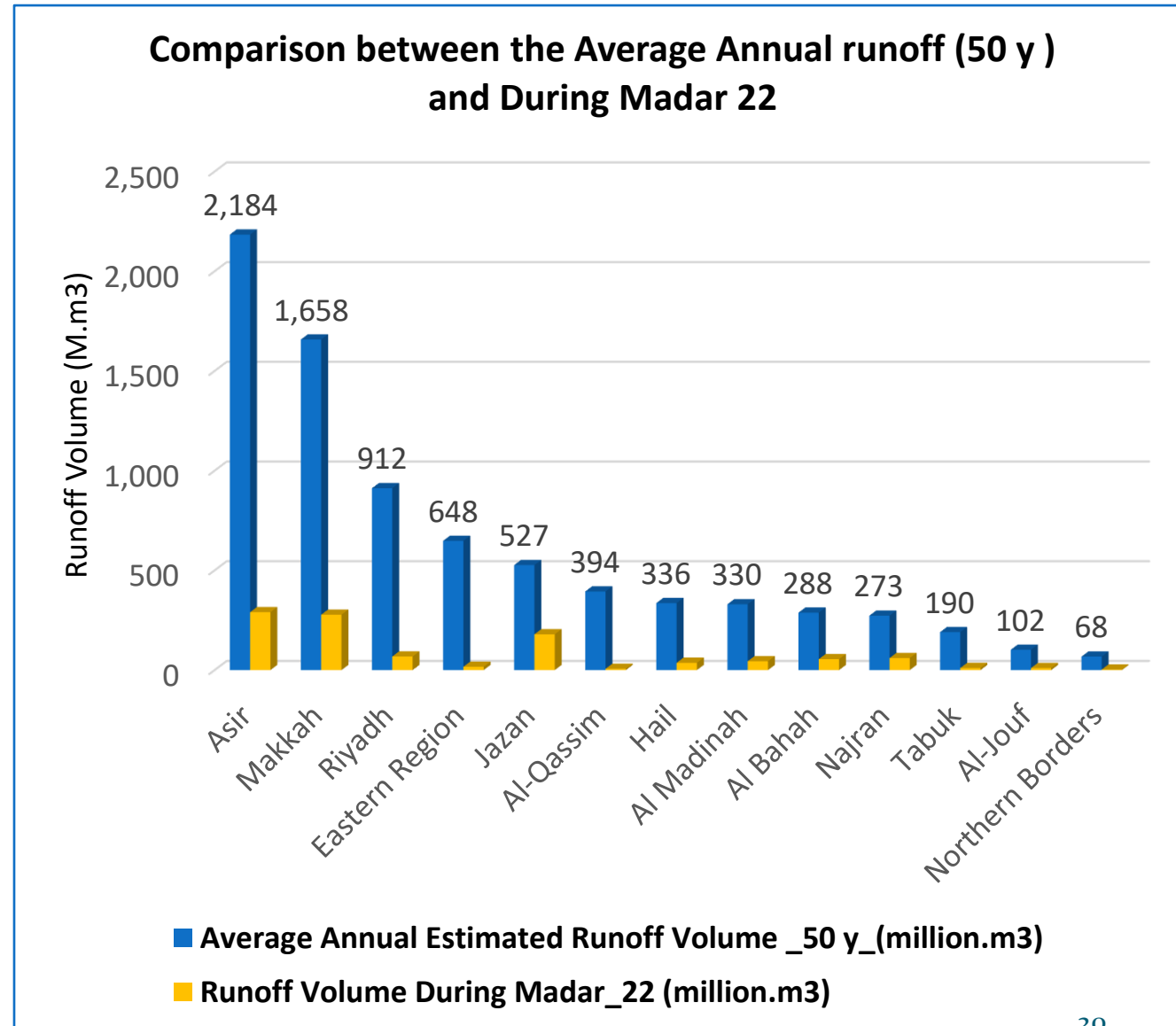


Results: Runoff Depth & Volume in Regions

- ❑ The **weighted average runoff depth** for all regions is estimated as **4.94 mm**, representing **4.8%** of the average annual precipitation depth **103mm** for all regions over a 50-year period.
- ❑ The weighted average runoff volume for all regions is estimated as **7.909 Bcm**, representing 4.8% of the average annual precipitation volume **165.869 Bcm** for all regions over a 50-year period.
- ❑ The weighted average runoff volume for all regions during Madar 22 is calculated as **1.058 bcm**, representing **12%** of the average annual precipitation volume for all regions over a 50-year period.
- ❑ **Asir region** recorded the highest weighted runoff volume at **290.41 M.m3**, constituting approximately 13% of the weighted annual runoff volume over a 50-year period.
- ❑ **Northern Borders** region recorded the **lowest weighted runoff volume** at **2.67 M.m3**, constituting approximately 4% of the weighted annual runoff volume over a 50-year period.

Results: Harvesting Runoff in Dam Reservoirs

Region	Region_ Annual_ Runoff Coefficient	Average Annual Estimated Runoff Volume_50 y_(million.m3)	Runoff Volume During Madar_22 (million.m3)	Average runoff During Madar_22 and 50 Years Record
Asir	0.08	2,184	290.41	0.13
Makkah	0.08	1,658	277.76	0.17
Riyadh	0.03	912	68.15	0.07
Eastern Region	0.01	648	16.51	0.03
Jazan	0.12	527	179.45	0.34
Al-Qassim	0.03	394	6.36	0.02
Hail	0.04	336	36.50	0.11
Al Madinah	0.02	330	44.41	0.13
Al Bahah	0.10	288	54.84	0.19
Najran	0.02	273	60.43	0.22
Tabuk	0.02	190	10.52	0.06
Al-Jouf	0.02	102	10.21	0.10
Northern Borders	0.02	68	2.67	0.04
Total	0.476	7,909	1,058.21	0.12

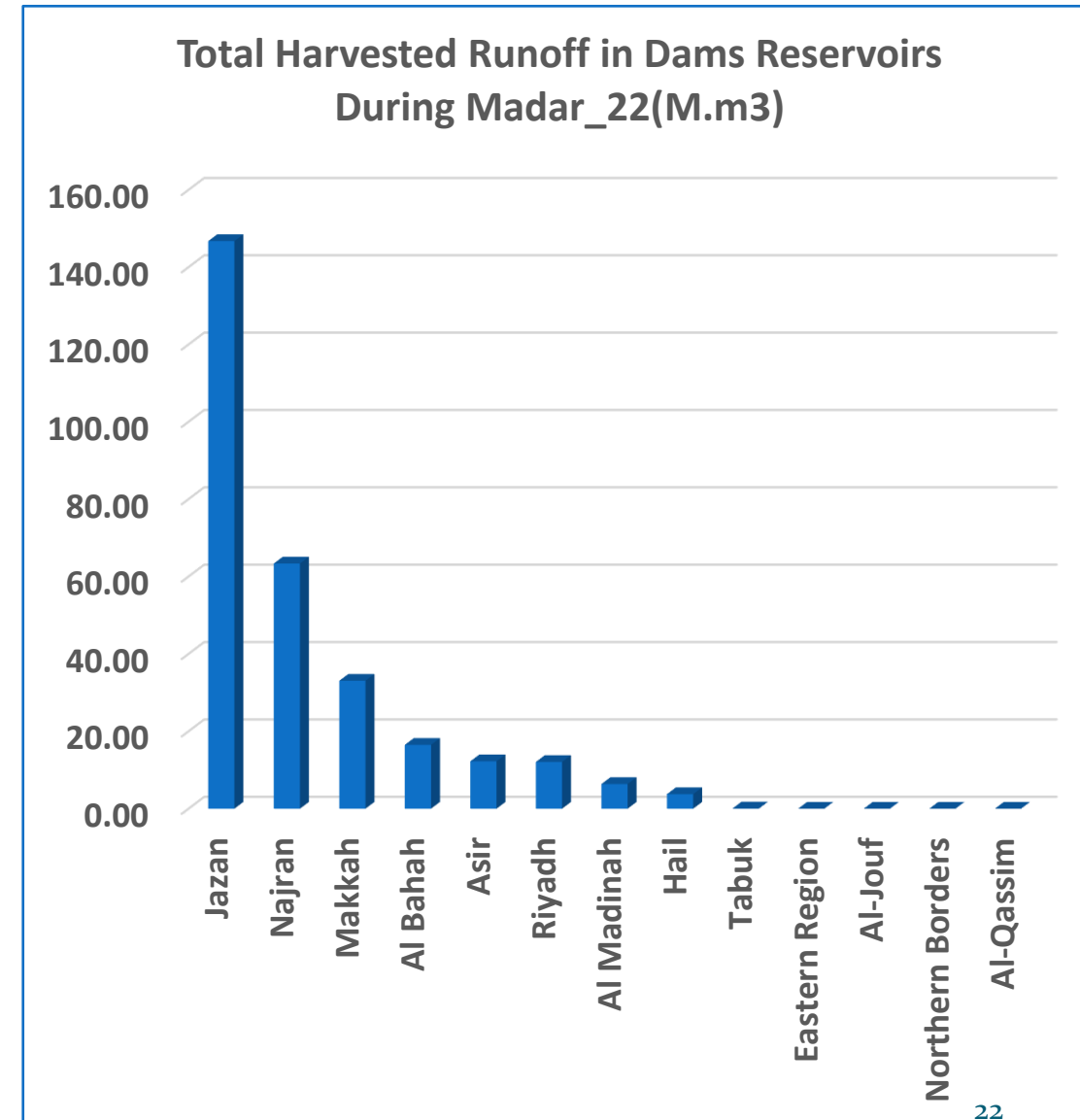


Results: Actual surface runoff received in dam reservoirs

- ❑ The actual surface runoff volume that entered dam reservoirs across all regions during "Madar 22" event was calculated and correlated with the estimated potential surface runoff for each region.
- ❑ The total volume of received floods in **(189) constructed dams** during "Madar 22" event attained **(294.11) M.cm**, representing only 21% of the total estimated surface runoff across all regions in the kingdom of Saudi Arabia.
- ❑ Relatively low received surface runoff in dam reservoirs indicates that 79% of the estimated floods flowed across wadis and drainage networks, which can be attributed to the insufficient number of constructed dams to harvest floods.
- ❑ **24 dams were spilled**, including 9 dams in Najran Region only.
- ❑ Surface runoff has reached **15 dams for the first time**, including 6 dams in Najran Region.
- ❑ **70 dams** were released, draining approximately **101.51 M.cm** of water downstream into wadis across eight regions.

Results: Harvested and Released Water in Dam Reservoirs

Region_Name	Total Harvested Runoff in Dams Reservoirs During Madar_22_M_m3	Number of Dams recived runoff During Madar	Number of Released Dams During Madar_22	Volume of Released water from dams During Madar_22_M_m3	Number of Spilled Dams During Madar_22	Number of Dams Recived Runoff For the first time During Madar_22
Jazan	146.7	8	5	13.4	5	0
Najran	63.3	22	9	56.7	9	6
Makkah	33.1	24	16	15.4	5	7
A-Bahah	16.5	31	5	4.9	0	0
Asir	12.2	56	9	3.6	0	0
Riyadh	12.1	16	9	4.0	0	0
Madeinah	6.4	23	10	2.6	5	2
Hail	3.8	7	7	1.1	0	0
Tabuk	0.054	2	0	0.0	0	0
Jouf	0	0	0	0.0	0	0
Northern Borders	0	0	0	0.0	0	0
Eastern District	0	0	0	0.0	0	0
Qaseem	0	0	0	0	0	0
Total	294.1	189	70	101.5	24	15



Results: Comparison between “Madar22” and “Rahw 2020” summer weather events

Correlation Item	Rahw 2020	Madar 22
Date started	24/7/2020	23/7/2022
Date completed	10/8/2020	21/8/2022
Duration (days)	18	30
Number of Affected Regions with the event	8	13
Total Affected area _km2 with the event	212,672	1,949,556
Number of Rainfall and Weather station recorded Rainfall	193	360
Average Precipitation _mm during the event	32.56	23.26
Maximum daily Precipitation _mm	83.10	78.80
Maximum Cumulative Precipitation _mm	306	276
The total Estimated Rainfall volume (M.m3)	10,894	20,605
The total Estimated Runoff volume (M.m3)	1,308	1,058
Number of dams received runoff	165	189
Total Runoff volume received in dam reservoirs	370	294
Total Runoff volume released from Dams	201	101

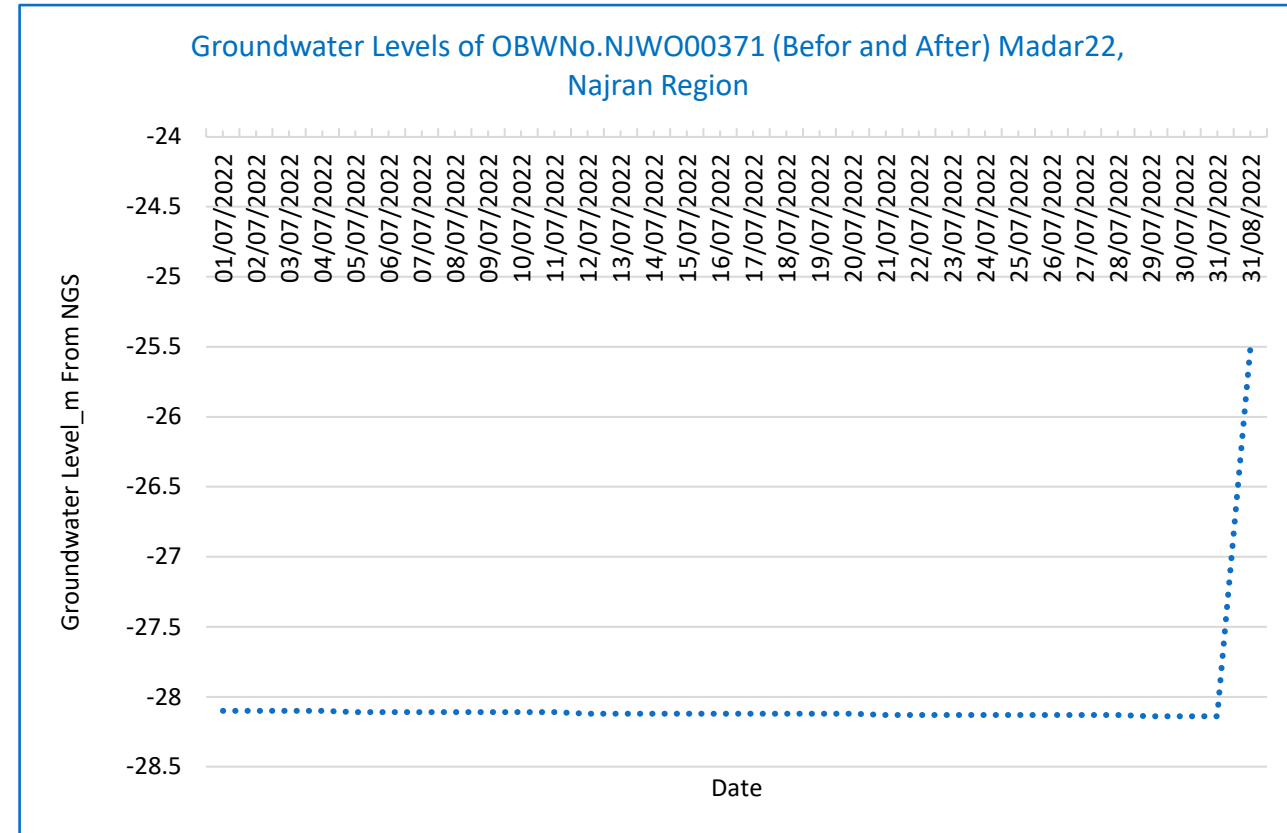
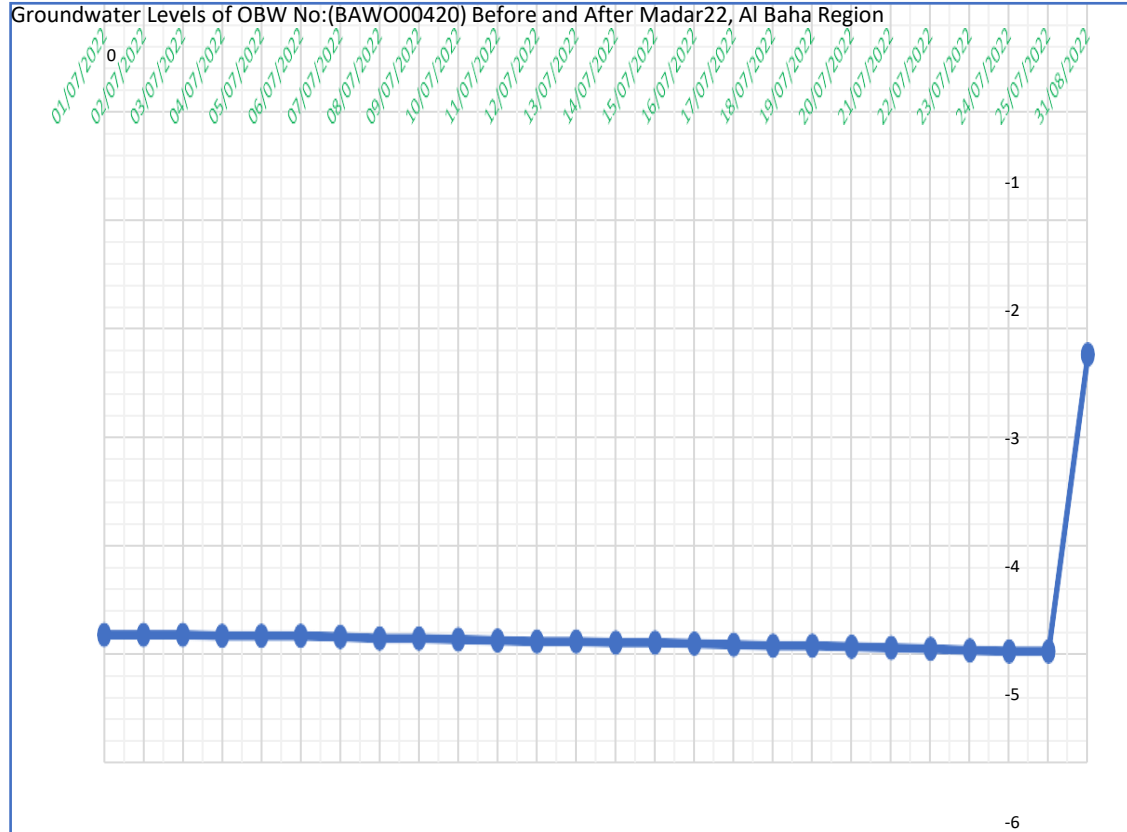
Results: Groundwater recharge in alluvium and basalt aquifers during Madar 22

Region	Average Annual Estimated Runoff Volume _50 y_M.m3	Regional Potential annual Recharge from Annual Runoff	Regional Potential annual Recharge Volume _50 y_M.m3	Region_ Estimated Recharge Volume During Madar_22_ M.m3	Regional Estimated Recharge from Annual Precipitation During Madar_22
Riyadh	912	0.27	246	18	0.008
Makkah	1,658	0.22	365	61	0.018
Al Madinah	330	0.28	92	12	0.006
Eastern Region	648	0.29	188	5	0.003
Asir	2,184	0.22	480	64	0.018
Najran	273	0.28	76	17	0.006
Jazan	527	0.18	95	32	0.022
Al-Jouf	102	0.28	29	3	0.006
Northern Borders	68	0.28	19	1	0.006
Al-Qassim	394	0.27	106	2	0.008
Tabuk	190	0.28	53	3	0.006
Al Bahah	288	0.20	58	11	0.020
Hail	336	0.26	87	9	0.010
Total	7,909	0.255	1895	239	0.010

Results: The groundwater levels in alluvium and basalt aquifers wells during Madar 22

Region	Total Observation Wells in Alluvium and Basalt	Recovered Wells During Madar 22	Range of net rising in groundwater levels	
			From	To
Al Baha	12	6	0.41	2.73
Al Jouf	4	1	0.15	0.15
Northern Borders	1	0	0.00	0.00
Riyadh	12	3	0.86	1.26
Qaseem	2	1	0.80	0.80
Al Madeinah	44	22	0.05	1.58
Tabuk	9	5	0.04	0.07
Jazan	17	4	0.09	1.14
Hail	2	0	0.00	0.00
Asir	18	11	0.03	1.55
Makkah	41	8	0.04	0.65
Najran	8	4	0.13	2.64
Total	170	65		

Results: Rising in Groundwater levels in alluvium and basaltic wells during Madar 22





Frequencies of "Madar_22 climate Event

The authors have the opinion that the "Madar_22" weather Event is considered as the frequency of "Al Rabab" Weather Event in 2016, and Rahw Weather Event 2020 but with longer period but with lower intensity.

1	<ul style="list-style-type: none"> • <u>Moghdeqah</u> • from 22 March to 21 April 2012 (31 days)
2	<ul style="list-style-type: none"> • <u>Al Baydaa</u> • from 25 April to 8 May 2013 (14 days)
3	<ul style="list-style-type: none"> • <u>Sabeghah</u> • from 22-26 November 2015 (5 days)
4	<ul style="list-style-type: none"> • <u>Al Rabab</u> • from 28 July to 3 August 2016 (7 days)
5	<ul style="list-style-type: none"> • <u>Joud</u> • from 11-18 February 2017 (8 days)
6	<ul style="list-style-type: none"> • <u>Ghadaq</u> • from 25 October to 20 November 2018 (27 days)
8	<ul style="list-style-type: none"> • <u>Rahw</u> • from 24 July to 10 August 2020 (18 days)

Conclusion

1. Madar_22 Event is considered as frequency of the summer weather events **Al Rabab, 2016 and Rahw, 2020.**
2. The monsoon depressions caused the “Madar 22” weather event will become more frequently and more severe in the future in summer months in the GCC, due to the climate change impacts.
3. The total volume of floods have been received in **189 constructed dam** reservoirs during "Madar 22" event reached **294.11 million** cubic meters, during "Madar 22" event across all regions in the kingdom of Saudi Arabia.
4. Relatively **low received surface runoff in dam** reservoirs can be attributed to the insufficient number of constructed dams to harvest floods.
5. Rainfall during these summer weather events in the **months of July and August** have **many beneficial for farmers' wells.**
6. **Significant rise in groundwater** tables in 65 observation wells distributed across several regions, during "Madar 22" weather event.
7. "Madar 22" weather event enhanced the **groundwater recharge within the alluvium and basalt aquifers.**

Recommendations



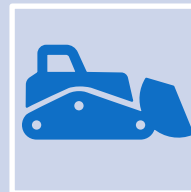
1- Update the operational and maintenance plans of Dams in KSA to meet with the summer weather events.



2- Keeping free storage volume in the dam's reservoirs corresponding to 50% of the total storage capacity of the dam to accommodate any runoff volumes that may reach the dam during rainstorms.



3-Continuous coordination with the Civil Defense and the emirates of the regions is highly recommended to warn citizens not to be near the wadi streams because of the possibility of opening the gates of the dams at any time.



4-Focusing on comprehensive studies and construction of additional rainfall harvesting techniques for in the Kingdom. This will contribute to maximizing the benefits from surface runoff water and groundwater recharge during rainy events.

Acknowledgements

- The authors extend their appreciation to H.E. Dr. Abdulaziz Alshaibani; the Deputy Ministry for Water in MEWA for his usual support and encouragement.

The authors are also grateful for H.E Eng Arif Al Kalai CTA for UNDP project in MEWA for his technical support.



مؤتمر الخليج الخامس عشر للمياه
The 15th Gulf Water Conference

وزارة البيئة والمياه والزراعة
Ministry of Environment Water & Agriculture



Thanks

Dr. Yousry Mattar

*Senior Advisor of Water Resources
United Nations Development Program*

Ministry of Environment, Water & Agriculture (MEWA)

yousrymattar@hotmail.com