Site suitability mapping for 'Managed Aquifer Recharge (MAR)' implementation in Poralai and Hingol, the coastal basins of Baluchistan, Pakistan

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József & Erzsébet Tóth Endowed Hydrogeology Chair and Foundation

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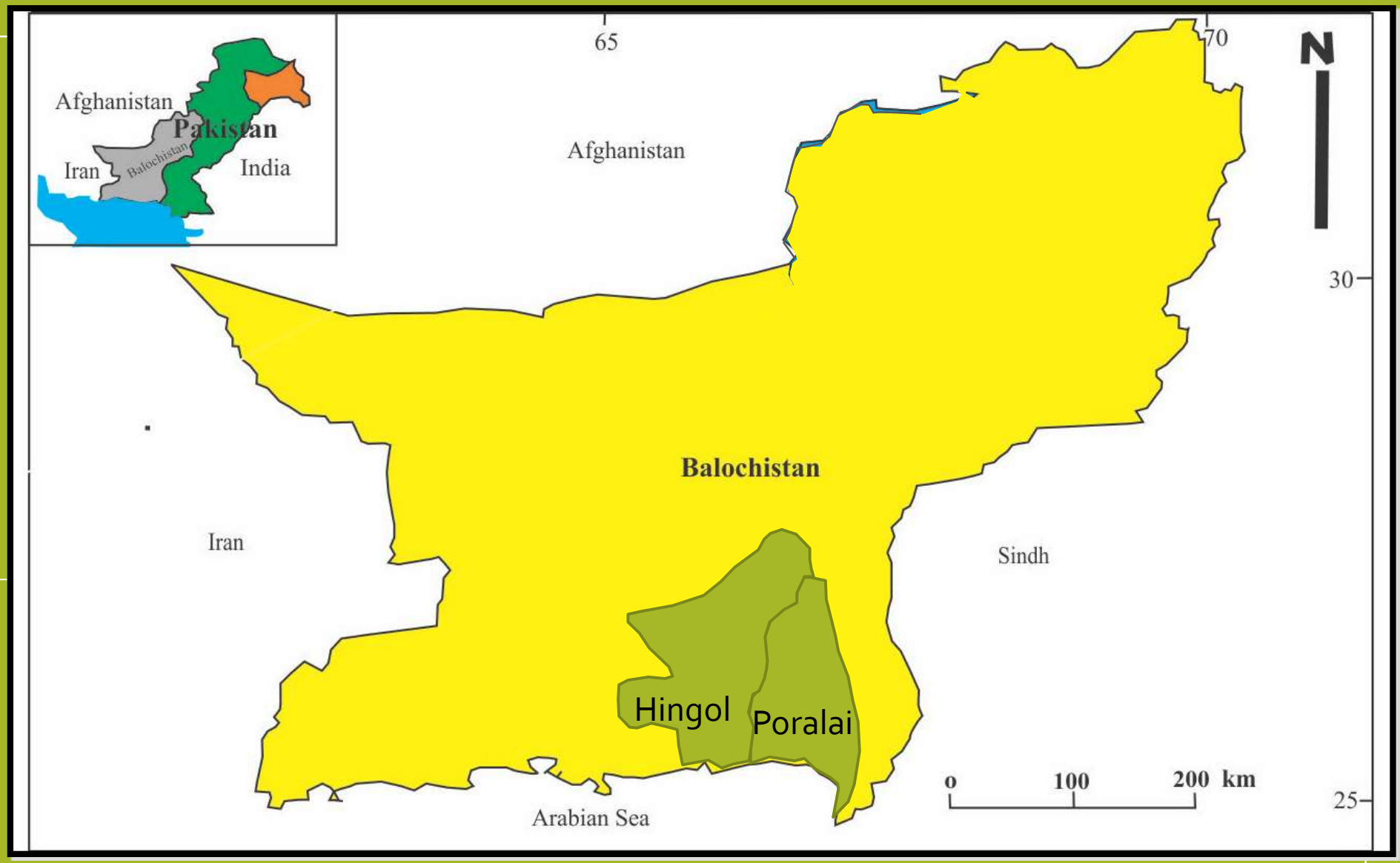
Goal

To revise the development of managed aquifer recharge (MAR) techniques in Baluchistan (Pakistan) and produce MAR suitability map for Hingol and Poralai basins.



Map of Baluchistan province (Pakistan) while the Hingol and Poralai Basins (where the MAR suitability mapping is conducted in the present study) are shown in green.

Silt deposited in delay action dam

Ditch

Leaky dam near Quetta

Terraces

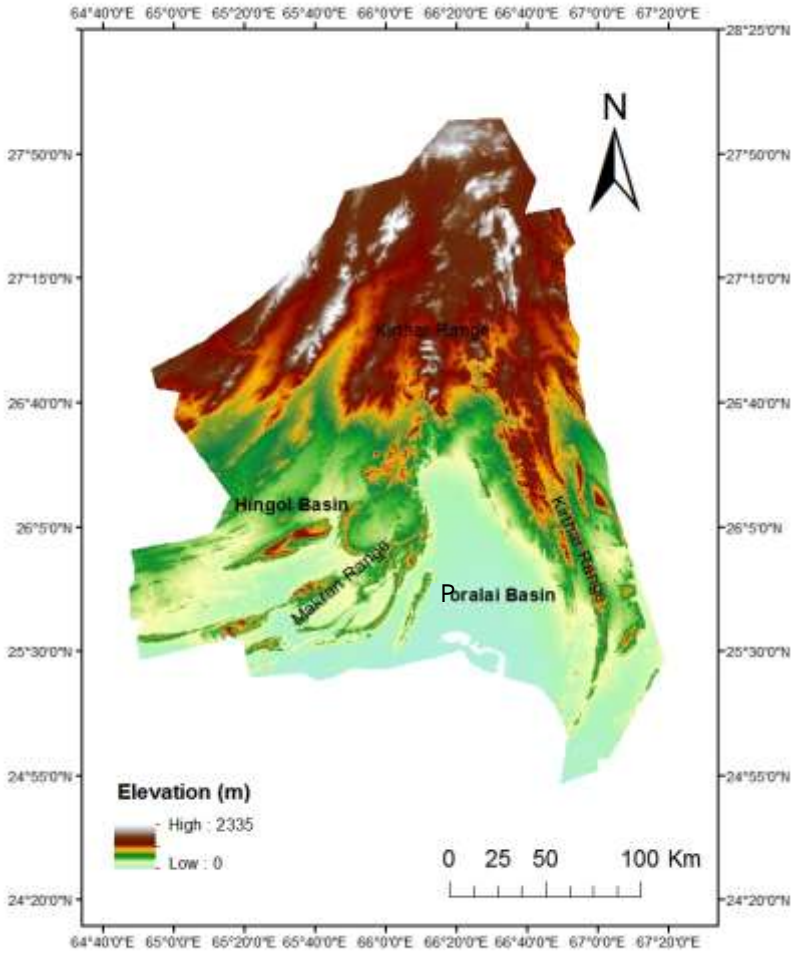
Trenches

Inverted well

Applied MAR Methods in Baluchistan

Non-palatable shrubs

MAR Suitability Mapping for Hingol and Poralai Basins



- Hingol and Loralai are the coastal basins of Baluchistan
- Elevation ranges from 0 to 2335 m. Elevation increases towards north. Makran Ranges separate the two basins.

Hingol and Loralai are chosen for MAR suitability mapping because:

1) Migration from rural areas and neighboring country Afghanistan intensified the water problems.

2) Sea water intrusion problem is aggravating in the coastal areas of Baluchistan (IUCN, 2000)

3) China Pakistan Economic Corridor and development of Gawadar Port is predicted to result in rapid increase in population and industries which will further aggravate the already declining water table.

Use of INOWAS Platform

In the online INOWAS platform (https://dss.inowas.com/tools) the option of 'MAR method selection' is used to identify suitable MAR options by choosing 1) Source of Water, 2) Soil type, 3) Land use, 4) Purpose, 5) Typical scale.

Some methods suggested by INOWAS are suitable and some are not, based on the climatic conditions of Hingol and Poralai Basins.

Infiltration ponds and basins: not suitable

- Temperature in the study area is high which will result in rapid evaporation

Dune Filtration: not suitable

- No sand dunes are present in the study area.

Subsurface Dams: not suitable

- Water table is deep (15 to 30 m), so not feasible.

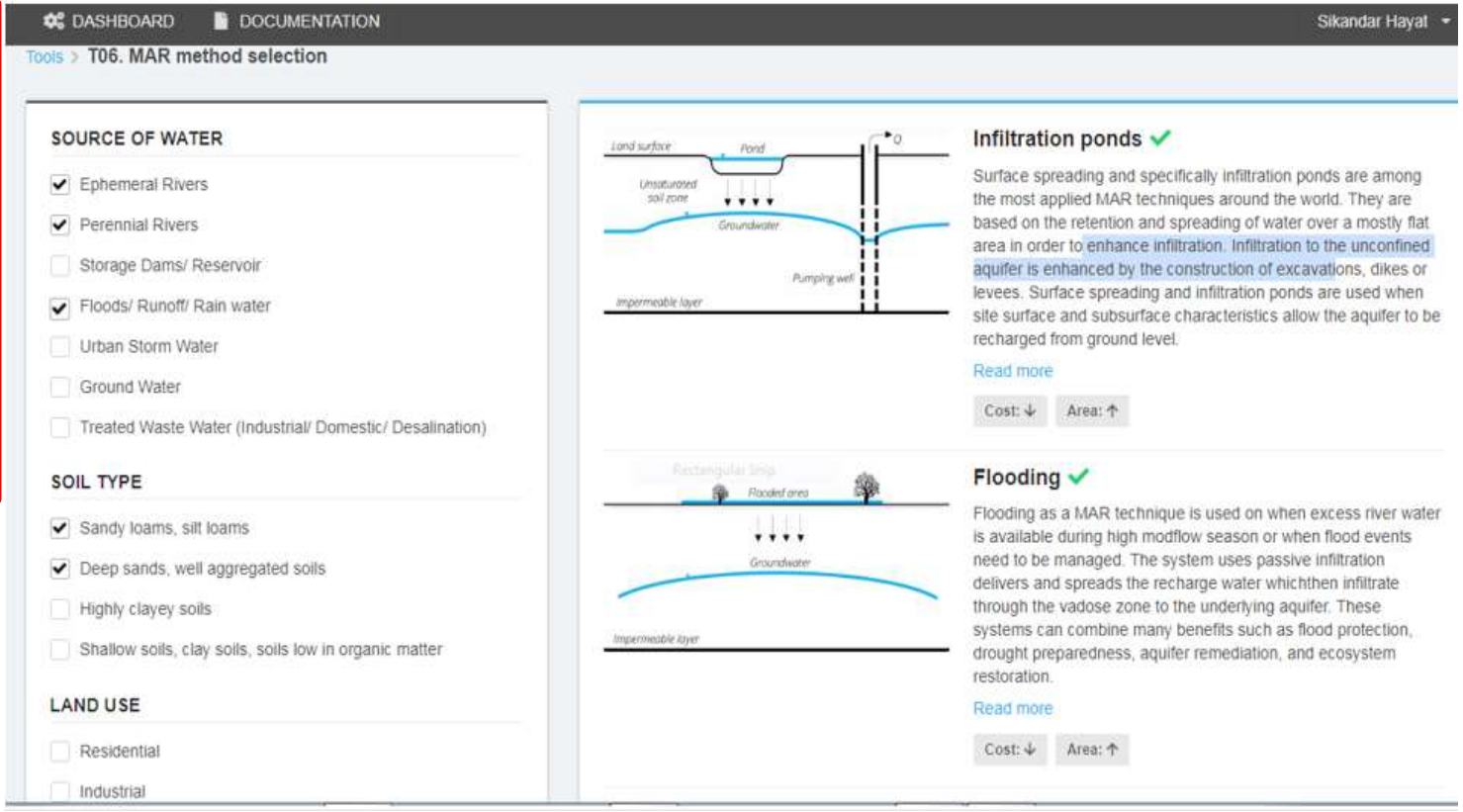
Flooding: Suitable

Trenches: Suitable

Ditches and furrows: Suitable

Rooftop harvesting: Suitable

Leaky dam: It is also a suitable method and already being used in Quetta but INOWAS did not suggest that method.



Preview of the 'MAR method selection' tool in INOWAS

Geographic Information System Multi-Criteria Decision Analysis (GIS-MCDA)

- GIS-MCDA is a combination of tools and methods to transform and integrate geographical data and value judgements to assist us in wise decision making (Malczewski, J. 2015)

Following steps are involved: (Rahman et al., 2012; Valverde et al., 2016)

1) Defining a Goal:

Identification of sites which are suitable for MAR implementation. (Ditches, Flooding, Furrows, Trenches)

2) Screening of suitable area

a) Areas with more than 40 % slope are considered unsuitable for MAR

b) Urban areas are also considered unsuitable

3) Process of Suitability Mapping

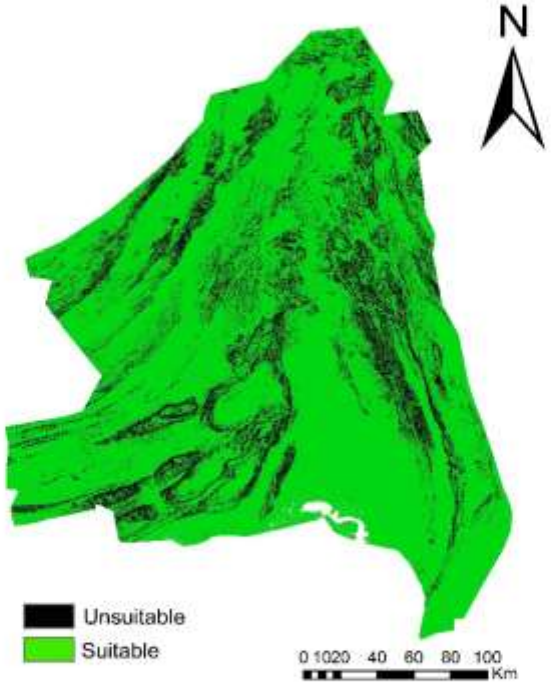
Selection of Criteria: Based on available data and the importance of the influence following criteria are chosen:
Slope, Geology, Soil, Precipitation, Drainage density, Land Cover

Weight assignment to each criterion:
MIF Multi-Influencing factor method

Common Scale:
Different criteria have different units. A common scale is used to show the relative level of the criteria. (from 0 to 1)

Weighted Overlay Analyses:
Weighted linear combination is used to overlay the criteria to find and rank suitable areas.

Constraint Mapping

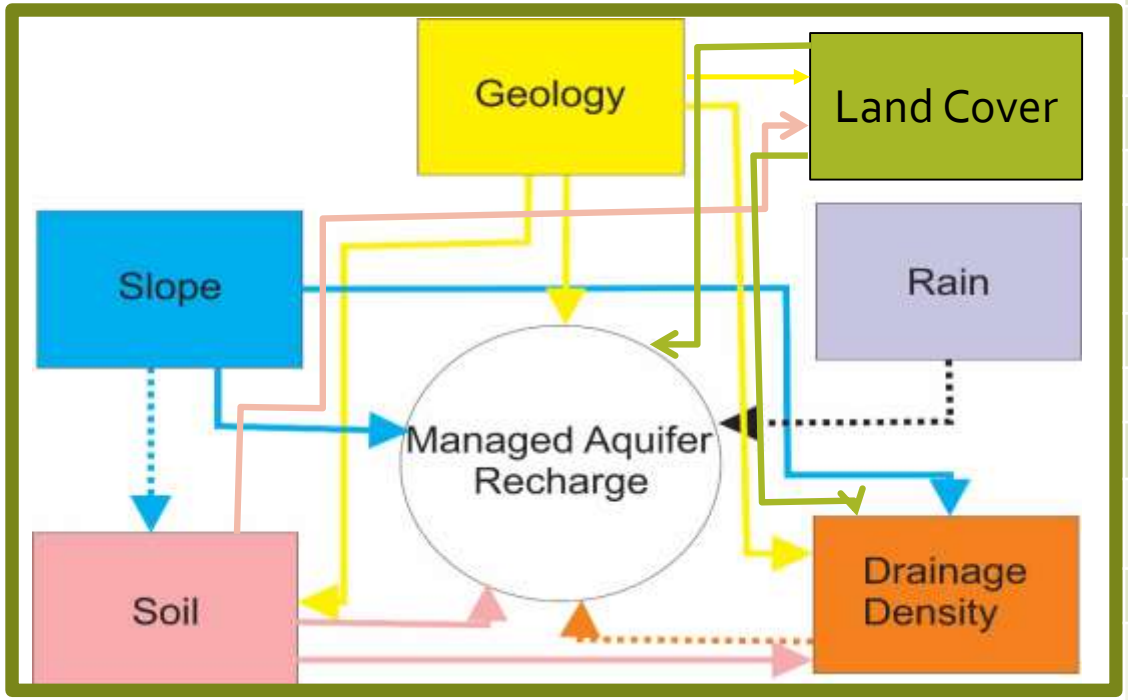


Constraint Map for Slope

Constraint Map for Land Cover

Weight Assignment: MIF method

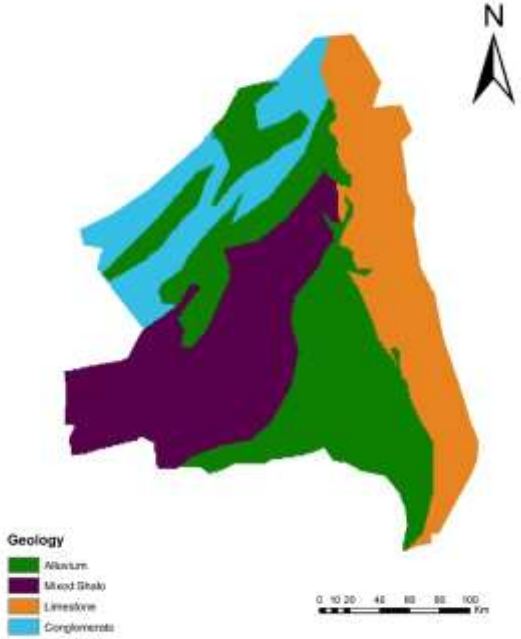
- Interaction between criteria for MIF method
- Solid arrows represent major influence
- Dash arrows represent minor influence

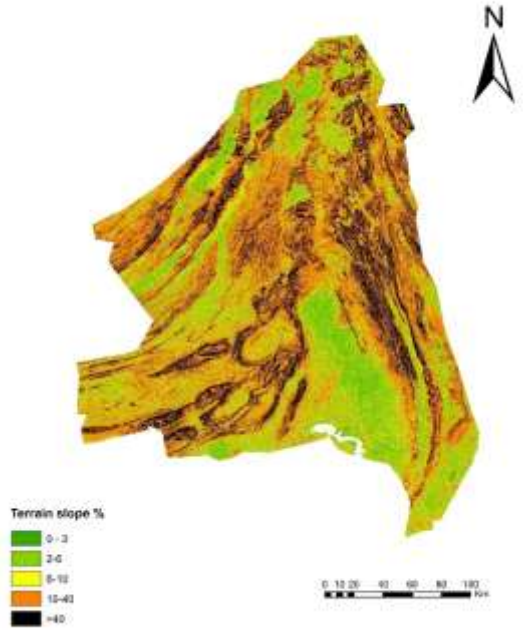


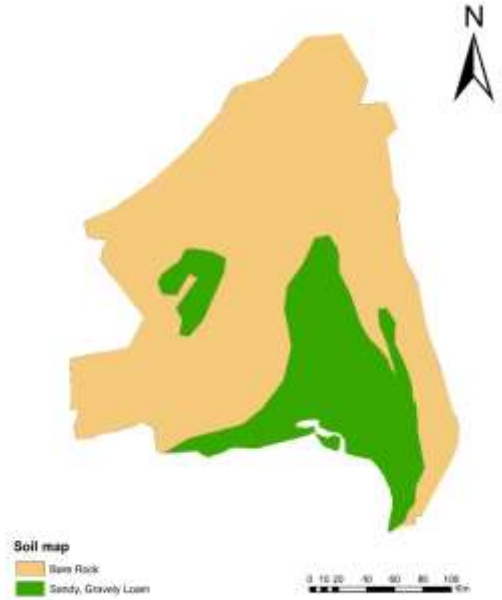
Calculation of criterion weight Using MIF method

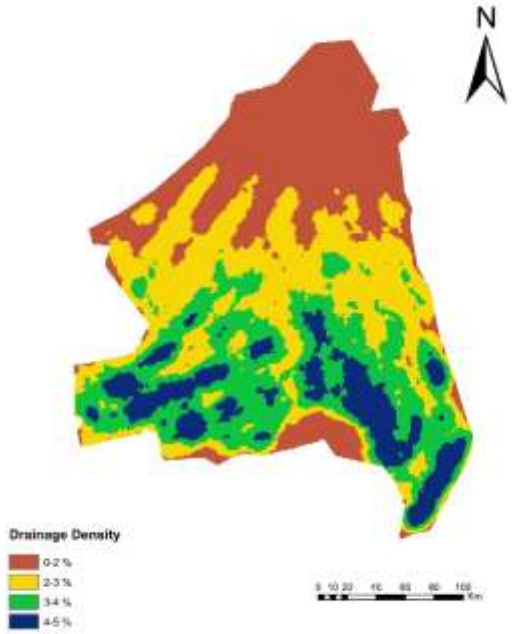
Criterion	Score	Weight
Geology	1 + 1 + 1 +1= 4	32 %
Slope	1 + 1 + 0.5 = 2.5	20 %
Drainage Density	0.5	4 %
Soil	1 + 1 + 1 = 3	24 %
Rain	0.5	4 %
Land Cover	2	16 %
Total	**12.5**	**100 %**

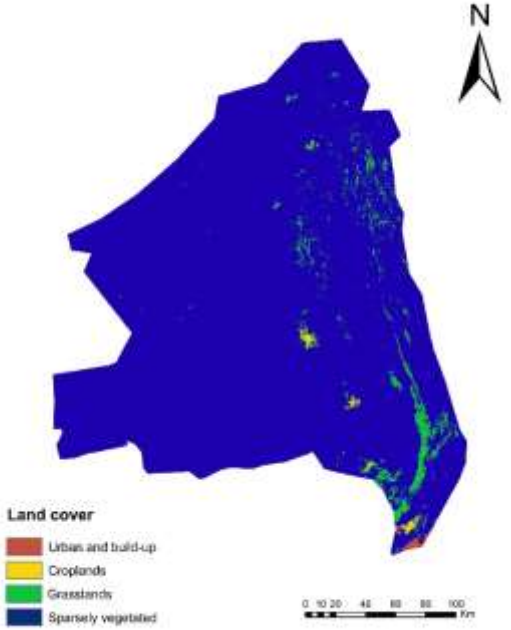
Criteria	Domain of Affect	Common Scale
Geology	Alluvium	0.9
	Limestone, Fractured	0.7
	Conglomerate	1
	Mixed Shale	0
Slope %	0-2	1
	2-6	0.8
	6-10	0.5
	10-40	0.2
	>40	0
Soil	Sandy, Gravely Loam	1
	Bare Rock	0.2
Drainage Density %	0-2	1
	2-3	0.6
	3-4	0.3
	4-5	0.1
Mean Annual Rainfall (mm)	100-200	0.6
	< 100	0.5
Land Cover	Sparsely vegetated	1
	Grassland	0.8
	Cropland	0.5
	Urban/ built-up	0


N
Geology
Alluvium
Mixed Shale
Limestone
Conglomerate
0 10 20 40 60 80 100
Km

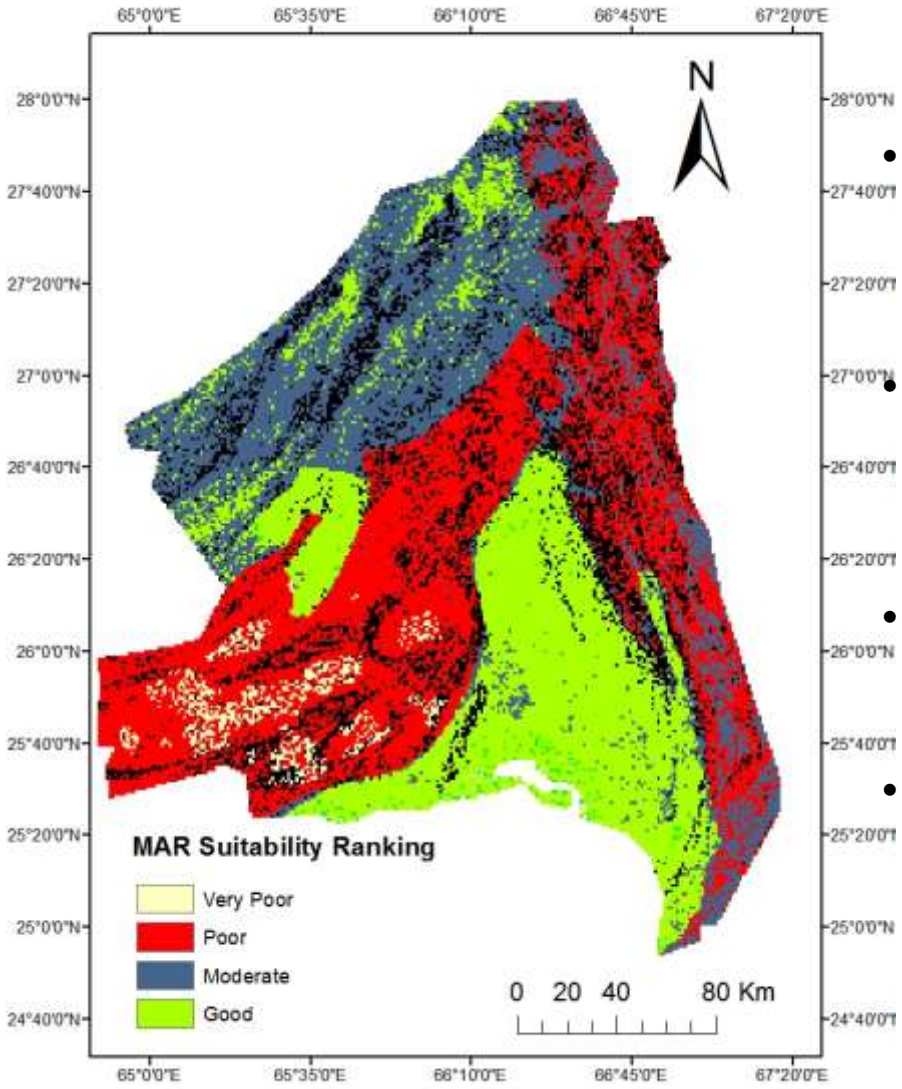

N
Terrain slope %
0 - 3
3-5
5-10
10-40
>40
0 10 20 40 60 80 100
Km


N
Soil map
Bare Rock
Sandy, Gravely Loam
0 10 20 40 60 80 100
Km


N
Drainage Density
0-2 %
2-3 %
3-4 %
4-5 %
0 10 20 40 60 80 100
Km


N
Land cover
Urban and build-up
Croplands
Grasslands
Sparsely vegetated
0 10 20 40 60 80 100
Km


N
Mean annual rainfall mm
<100
100-200
0 10 20 40 60 80 100
Km



Suitability Map

- Geology, slope, precipitation, drainage density, and Soil maps are overlaid by Weighted Linear Combination method (Rahman et al., 2012; Valverde et al., 2016) to obtain final MAR suitability map.
- The MAR suitability map shows that Poralai Basin has high suitability for the implementation of MAR techniques while Hingol Basin has relatively few suitable areas to implement MAR.
- The GIS analysis is intended to be used as guidance and screening tool to focus site studies.
- According to Government of Baluchistan water of Hingol basin is suitable for recharge but for MAR implementation detailed quality analysis would be needed.

Conclusions

- MAR is being practiced in Baluchistan successfully. Delay action dams are not successful but effective watershed management can reduce the erosion and sedimentation and increase their efficiency.
- Integration of remote sensing and GIS is efficient for quick and wise decision making for groundwater resources management while minimizing the labor, money and time.
- Weighted linear combination overlay analysis shows that most of the Poralai Basin and a small area of Hingol Basin is suitable for MAR implementation especially trenches, ditches, flooding and furrows.
- Flooding, water shortage, and Sea water intrusion problem can be solved using MAR techniques
- The INOWAS platform is found useful to narrow down the MAR methods for the study area but it could be made more accurate by adding the options 1) temperature of the area, 2) precipitation and 3) depth to the water table under the tab of 'MAR method selection'.
- This study provides a broad overview of suitable areas for MAR implementation. For the development of a MAR site many other factors such as ecology, economics and management/politics should also be considered.

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