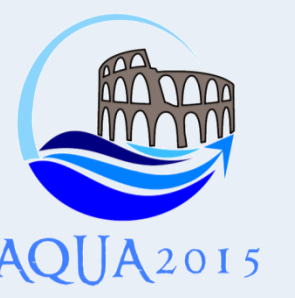
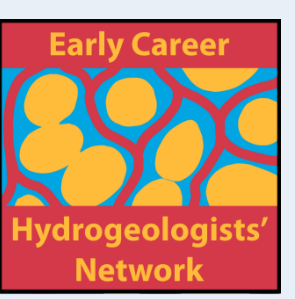


# REGIONAL MAPPING OF THE POTENTIAL OF MANAGING AQUIFER RECHARGE: A LANDSCAPE-BASED APPROACH



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## INTRODUCTION

Managed Aquifer Recharge (MAR) can be used to improve water security and resilience to droughts. In particular in areas coping with an increase in climate extremes, both in rainfall and in droughts, MAR can be a beneficial technique. The selection of most suitable MAR interventions may however not be straightforward. The experience is that it can be difficult to assess the full scope of possible interventions that would be suitable within one area. In order to provide an overview of most appropriate techniques and location for MAR interventions in the Merti aquifer, a landscape-based approach has been applied using remote sensing data and GIS analyses.

## STUDY AREA

The transboundary Merti aquifer, shared between Kenya and Somalia, is a large non-renewable aquifer that is one of the few reliable water sources in this semi-arid region. Both the local population and the growing number of refugees depend on the groundwater. Groundwater abstraction has increased rapidly last years; from ~1 million m<sup>3</sup> in 2002 to ~3 million m<sup>3</sup> in 2011 in Dadaab area (Mumma et al., 2011). One of the anticipated risks of continued and increased groundwater abstraction is groundwater depletion, which could have various negative consequences. The most relevant water-related risks for the Merti aquifer are drying up of wells and deterioration of water quality as a result of increasing salinity of the abstracted water. The Merti aquifer is confined and groundwater is found between 110 and 180 m below ground level. Near the surface, shallow, mainly seasonal, perched aquifers exist. Rainfall in the area is limited and is characterized by large temporal and spatial variability. Mean annual precipitation in the area is 300 mm yr<sup>-1</sup>. Potential evaporation in the area is large, up to 2600 mm yr<sup>-1</sup>, and surpasses the rainfall most months of the year.

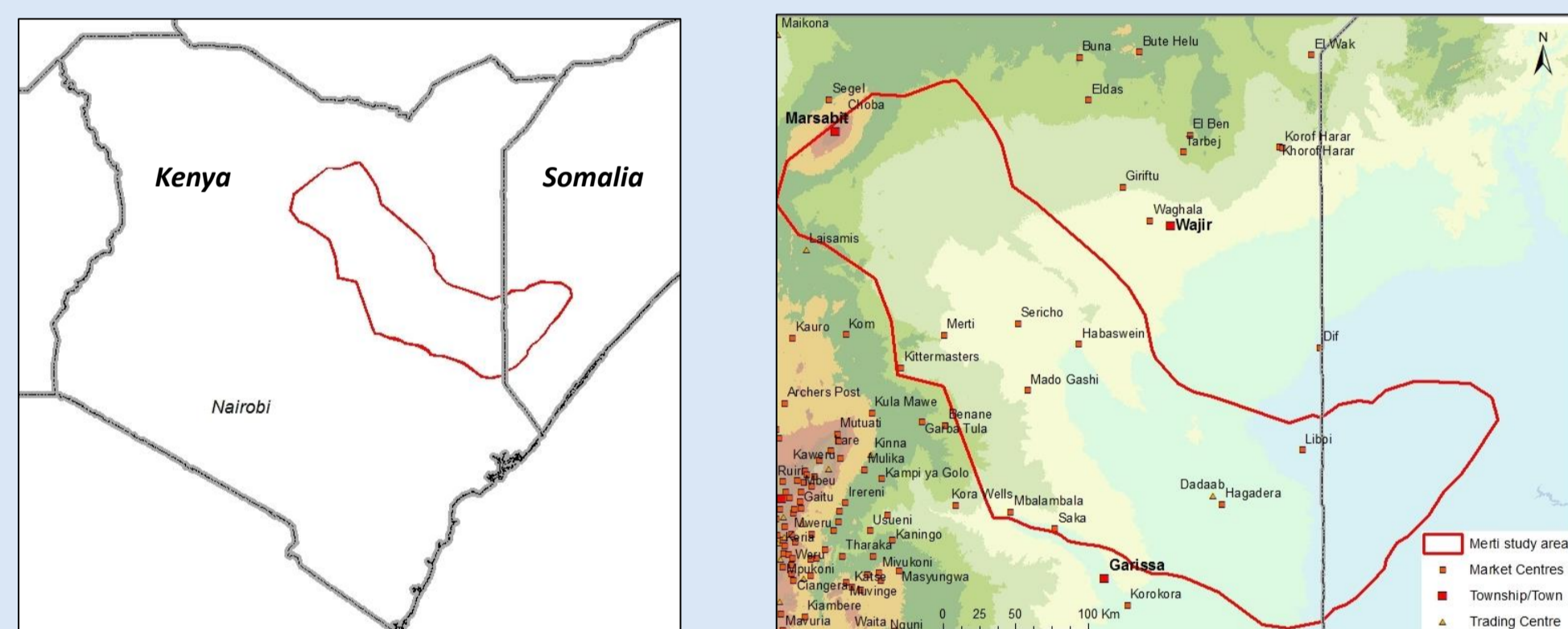


Figure 1. Location of the Merti aquifer study area

## METHODOLOGY

Satellite data and available data about e.g. geology, hydrogeology, climate and existing wells were collected and processed to obtain the key variables (also referred to as 'building blocks') that provide information about the geo-hydrological situation and the groundwater recharge for the Merti area. The combination and interpretation of these variables results in the indication of areas where seasonal runoff and river water is available and where shallow groundwater is likely to be present or can be replenished. The different MAR interventions were grouped in various categories according to the landscape's characteristics, resulting in a MAR potential map. Groundwater mapping in the deeper water-bearing layers required a different approach from mapping shallow groundwater and surface water sources. The available borehole data and geological literature were combined in order to create a conceptual model of the sub-surface. Groundwater dynamics and flow-patterns were derived from piezometric maps, based on borehole data and monitoring data.

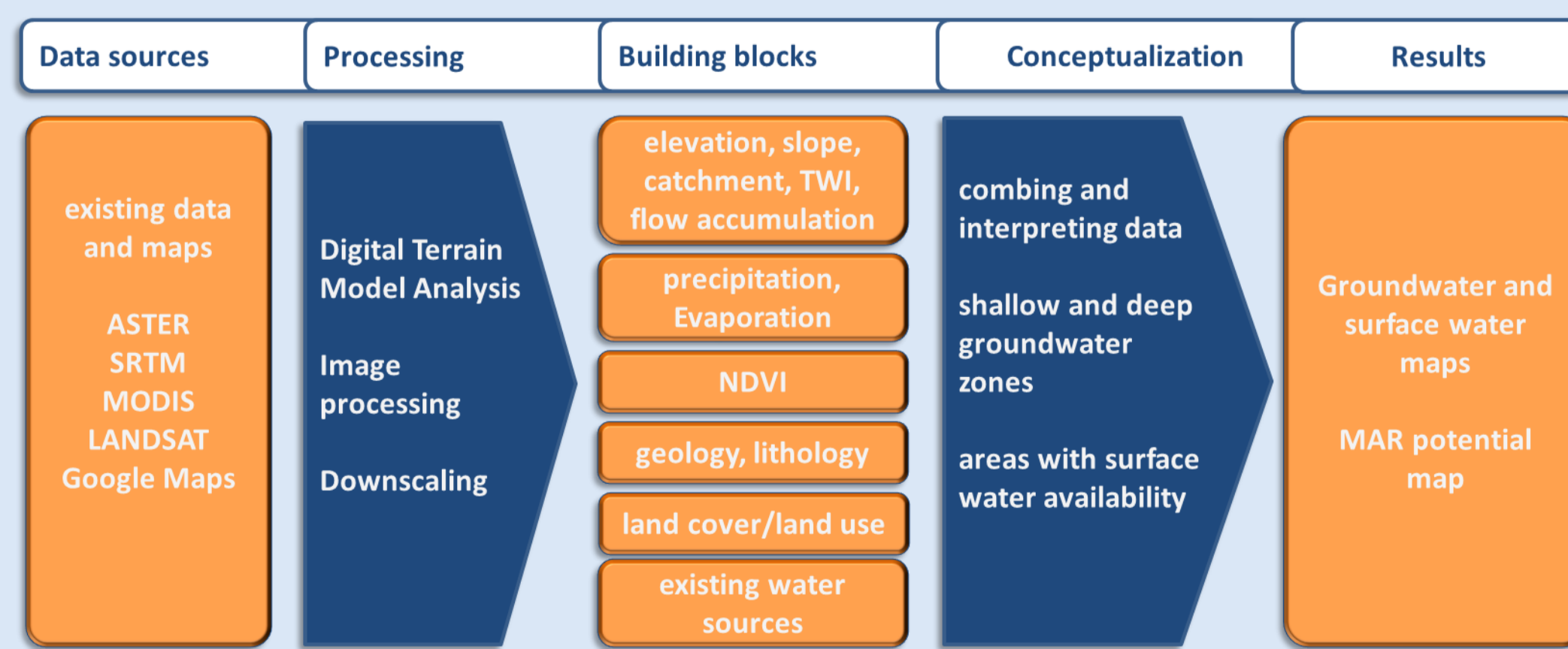


Figure 2. The methodology for the regional mapping of the potential of MAR based on remote sensing, existing water sources data and GIS analyses

## RESULTS

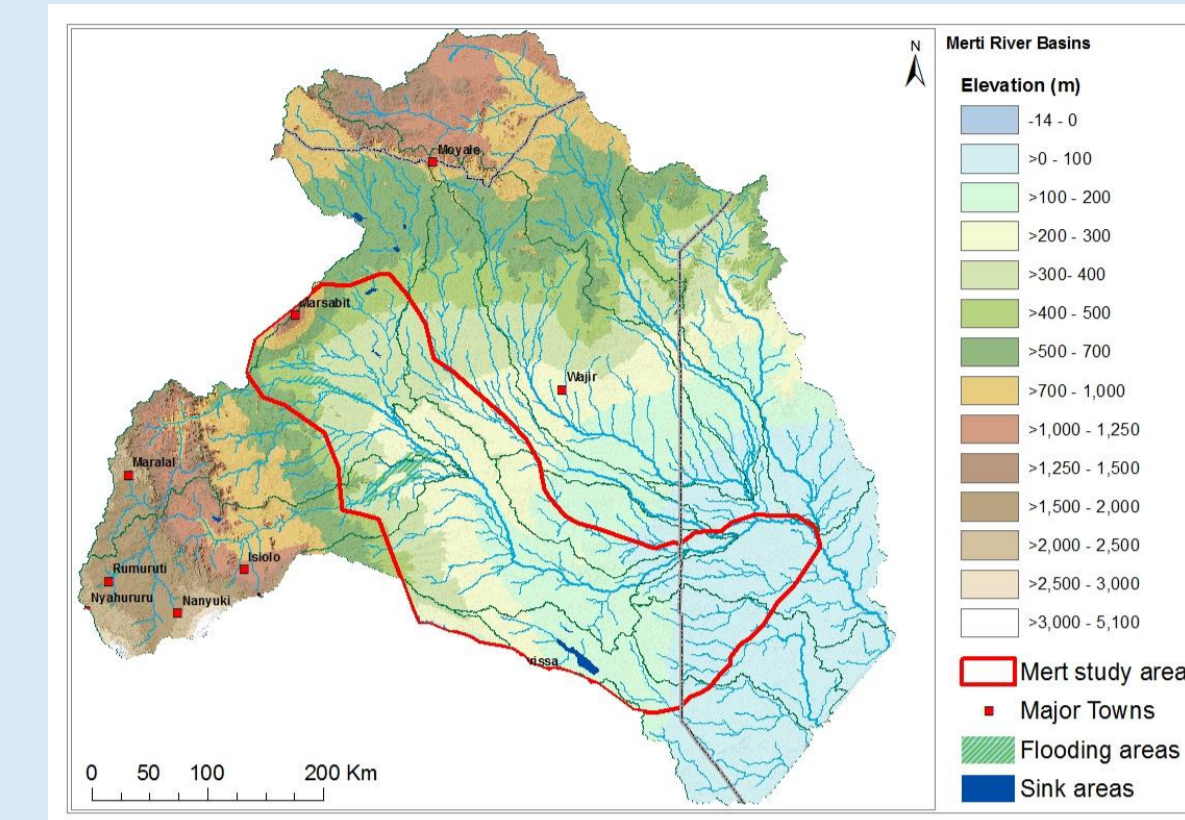


Figure 3. Surface water

The figure above shows the Merti aquifer with its watersheds, streams, sink areas and seasonal wetlands. Watersheds were determined for each river system based on the Digital Terrain Model (DTM). The flooding areas and depression sink areas could be interesting location for shallow MAR implementation, because of the water accumulation from surrounding catchment areas. This water could be used for MAR, instead of lost via evaporation.

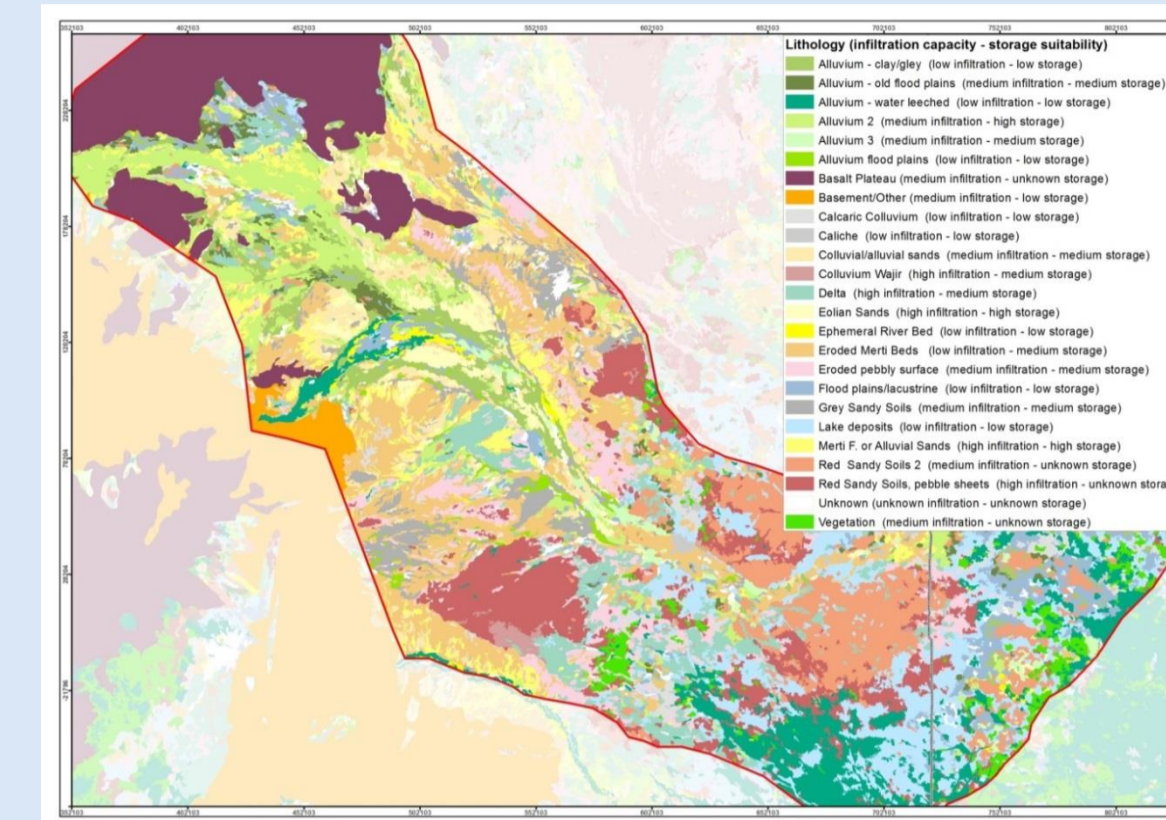


Figure 4. Lithology

A detailed lithology map was developed for the area using supervised classification of processed multi-spectral Landsat satellite imagery. The classification is based on remote sensing, complemented with existing studies. The identified map units provide lithological classes of the upper formation with three characteristics:

- lithology (25 litho-classes)
- Expected infiltration capacity of the top layer
- Expected groundwater storage capacity of the formation based on the permeability

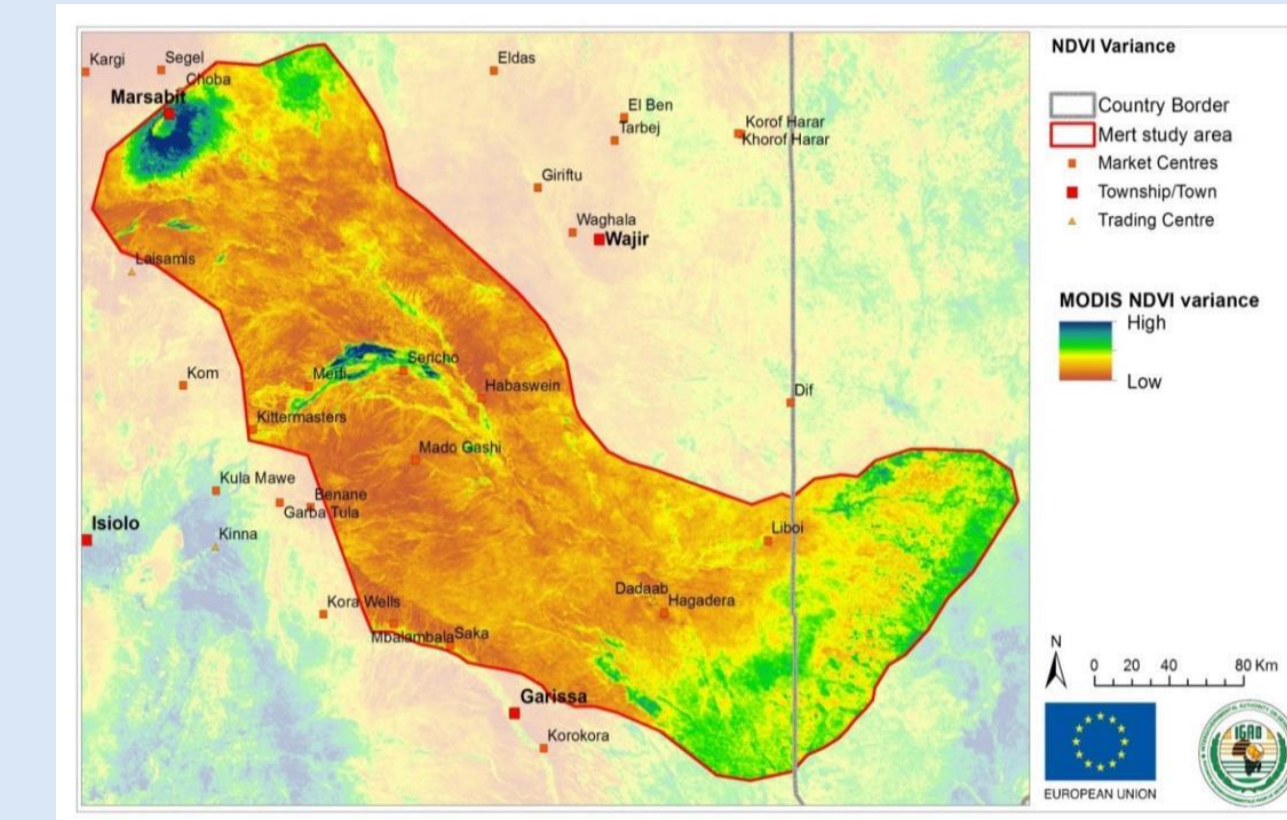


Figure 5. Normalized Difference Vegetation Index

The seasonal change in Normalized Difference Vegetation Index (NDVI) is an indication for the resilience of vegetation for extended periods of drought and the capacity of the soil to retain moisture. The NDVI variance was used to identify areas that flood regularly or occasionally. Areas with a high variance in vegetation indicates temporal availability of water, in most cases caused by seasonal flooding. These areas can seasonally provide large volumes of water for the application of MAR.

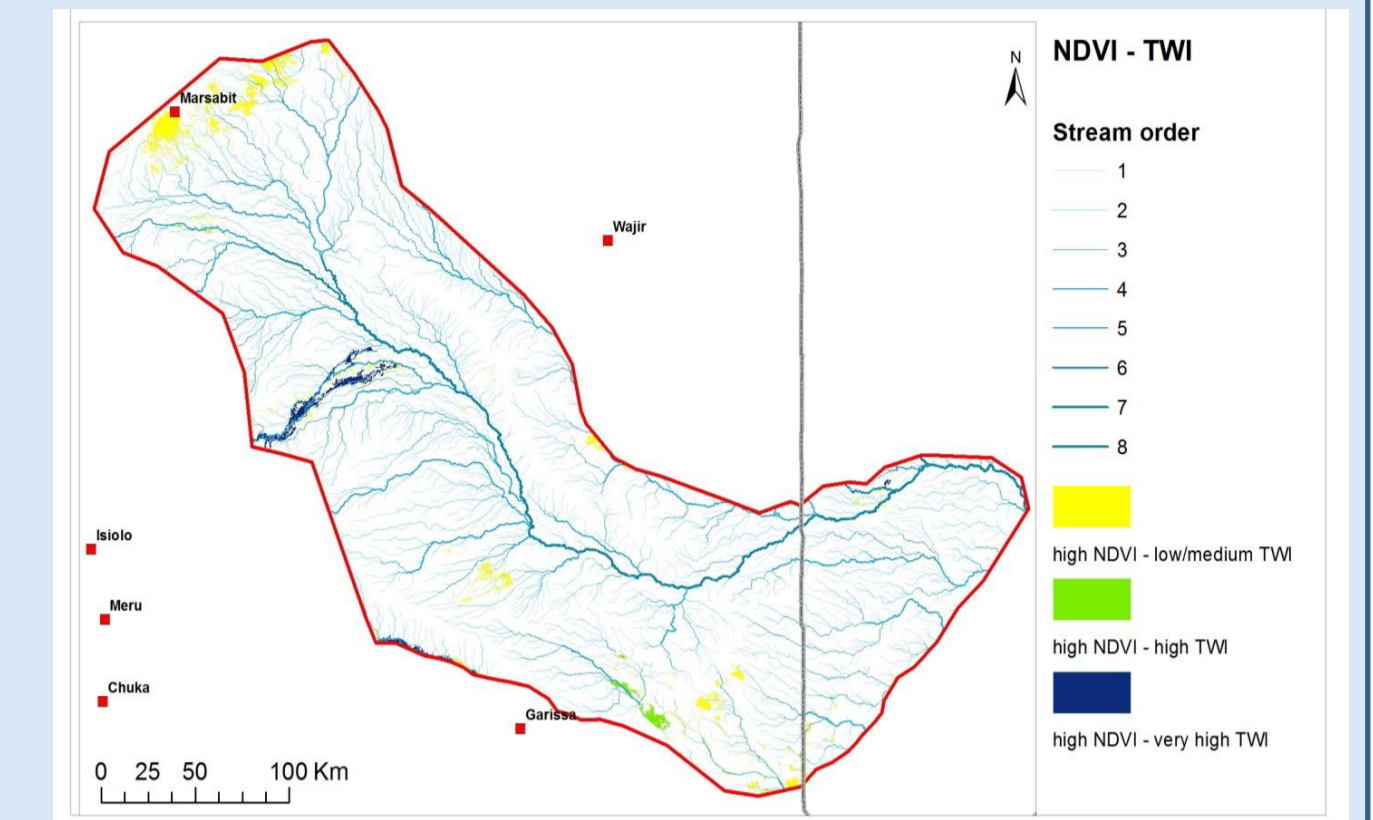


Figure 6. Potential occurrence of shallow groundwater

Topographic Wetness Index (TWI) can be used to identify shallow groundwater. TWI was determined based on the slope and flow accumulation. Areas with a high flow accumulation and gentle slopes have a higher TWI. Higher TWI values therefore represent drainage depressions, lower values represent crests and ridges. A combination of high NDVI and high TWI indicate the potential occurrence of shallow groundwater.

## MANAGE AQUIFER RECHARGE POTENTIAL MAP

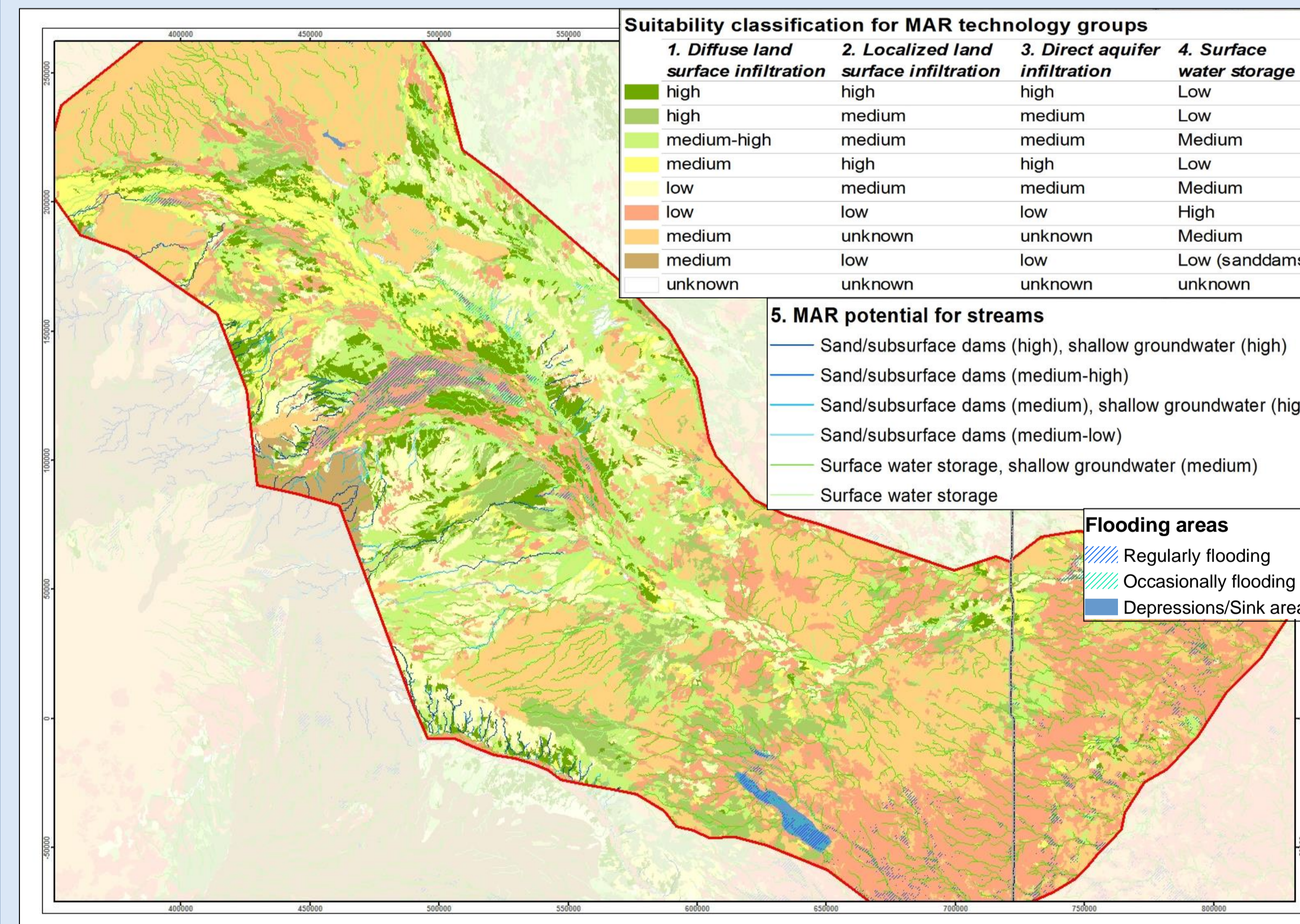


Figure 7. Land classification for shallow MAR based on remote sensing

The map provides a first identification of the potential of Managed Aquifer Recharge (MAR) of shallow groundwater in the Merti area. The suitability classification for shallow MAR is based on the infiltration capacity of the soil/top layer, and the storage potential for shallow groundwater of the formation, based on the permeability and likely presence of impermeable layer(s) that prevent deep infiltration. Streams and rivers have been classified based on NDVI of the riverbank and sand content of the riverbed. The study is based on remote sensing, complemented with existing water sources data. This map is prepared to provide an indicative and generic overview of the MAR suitability.

Figure 8. MAR for deep groundwater

Given the confined nature of the Merti aquifer, the best technique for MAR of the deep groundwater are injection wells. The geological formations of the Central Merti aquifer are technically favourable for MAR of the deep aquifer. The Central Merti Aquifer is depicted with the blue contour lines (figure on the right; after Oord, 2011). Best locations are near Habaswein and the Dadaab area, close to groundwater abstraction wells.

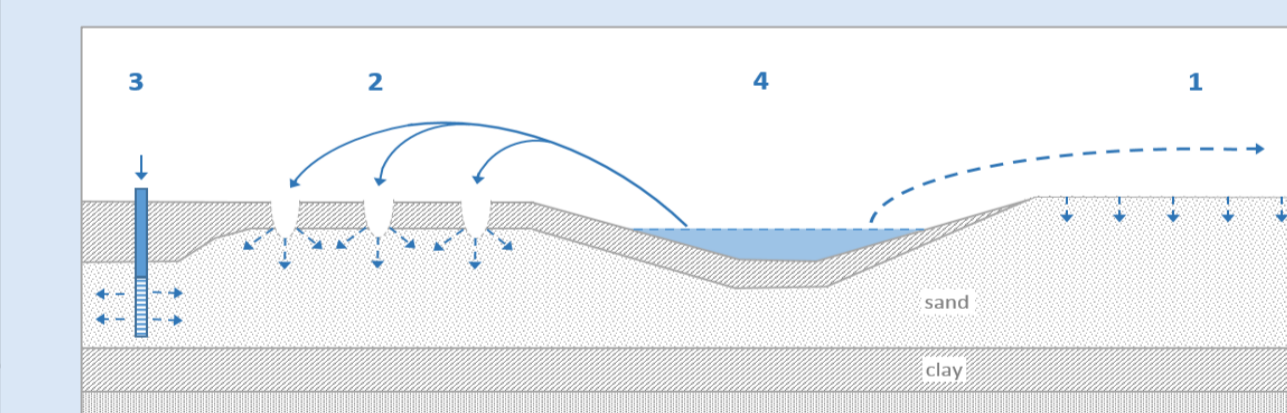
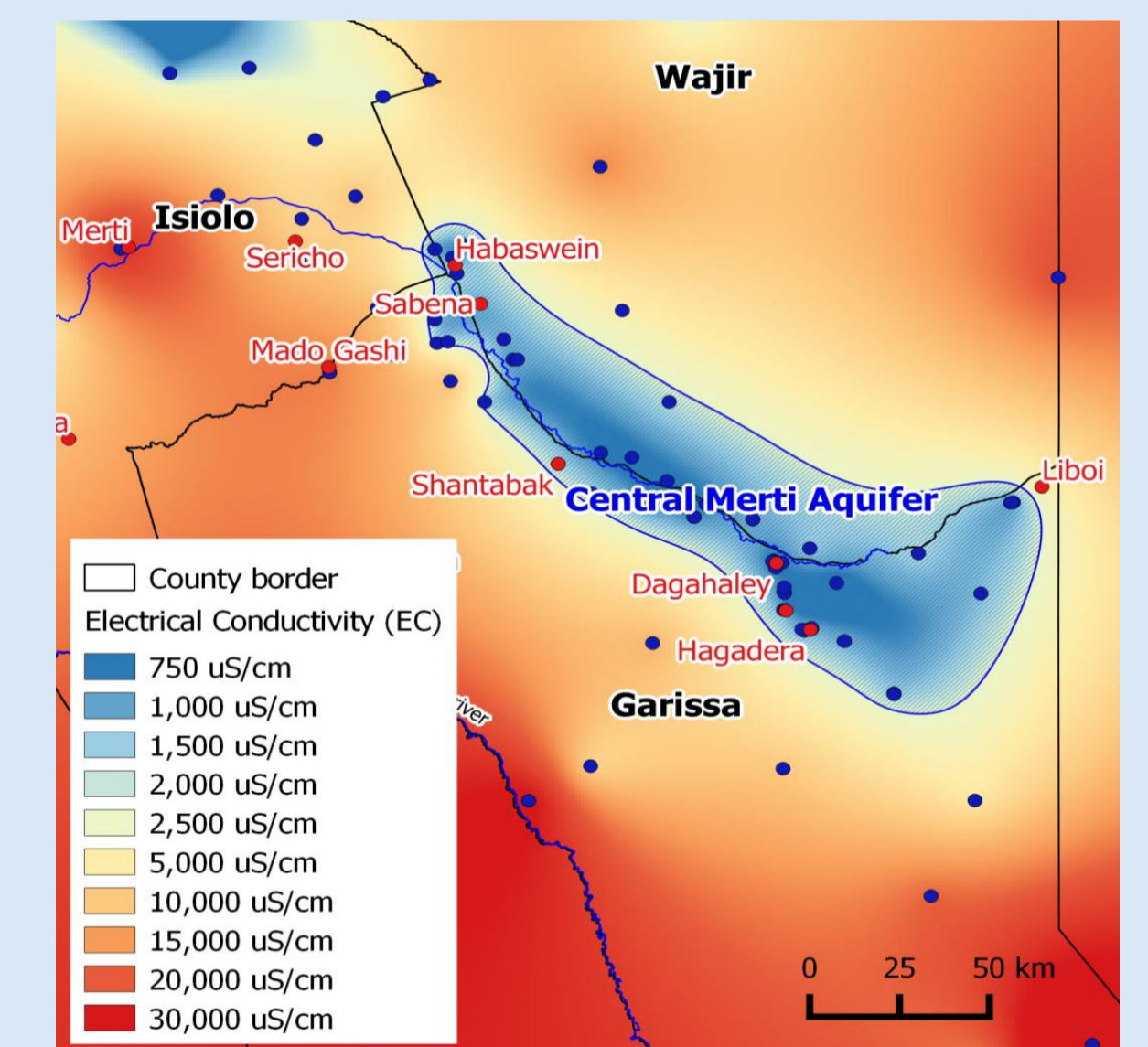


Figure 9. Schematic representation of the classification of different MAR technology groups



## CONCLUSIONS AND RECOMMENDATIONS

The study has shown that for the Merti aquifer both the water resources and landscape characteristics required for MAR interventions are available. The MAR suitability map indicates there is potential for MAR interventions for shallow and deep groundwater. Recharge of shallow aquifers will augment the availability of fresh water, and will thereby minimize the need for exploitation of deep groundwater. Recharge of the deep aquifer will help in ensuring inter-generational sustainability.

Recommended shallow MAR interventions include diffuse land surface infiltration, localized land surface infiltration, direct aquifer infiltration, surface water storage and in-stream storage such as sand dams and subsurface dams. Given the confined nature of the Merti aquifer, the best technique for MAR of the deep groundwater are injection wells.

The developed methodology could be applied for other arid and semi-arid regions, to assist policy on integrated water resource management, as well as a first guidance for technology selection for implementing parties.

### Literature cited

- 1] Mumma et al., (2011) Kenya: Groundwater Governance Case Study.
- 2] Oord (2011) Droogte in de Hoorn van Afrika Ontwikkeling van de Merti aquifer in noordoost Kenia. . Stromingen, 16(3).

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