UNIVERSITÀ DEGLI STUDI FIRENZE

USE OF GIS SYSTEMS FOR WATER HARVESTING PLANNING AND DESIGN IN ARID AREAS

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Tunis, 14 December 2022

Regional gathering
Tunis, 12 – 16 December 2022

ITALIAN AGENCY FOR DEVELOPMENT COOPERATION

- Water Harvesting best siting: definition
- An example of water harvesting ponds in Nepal
- An example of Sand Dams in Angola

WATER HARVESTING BEST SITING:

The success of water harvesting systems depends heavily on the **identification of suitable sites**

Various methodologies have been developed for the **selection of suitable sites**

Field surveys are the most common method for selecting suitable sites for **small areas**

The selection of appropriate sites (**the so-called best siting**) for different water harvesting technologies in larger areas is a **great challenge**

WATER HARVESTING BEST SITING:

Typical approaches for best siting involve the use of **GIS systems**

Various factors such as **rainfall, land cover/use, topography, soil texture/depth, hydrology, socio-economics, ecology,** and **environmental effects** can be used for identifying suitable sites

Such an approach can be defined as **top-down** since there is no space for the involvement of the local population. Other approaches can be **defined bottom-up** when they involve a participatory process – but they can be **time-expensive**

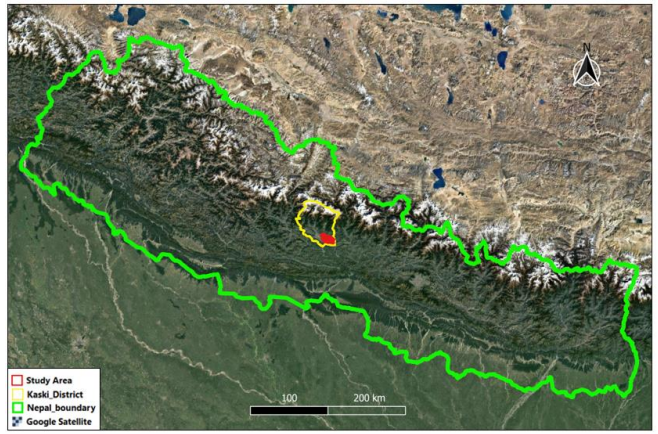
How to mix top-down and bottom-up approaches for water harvesting siting?

IDENTIFICATION OF SUITABLE SITES FOR TRADITIONAL *POKHARI* WATER HARVESTING IN RURAL NEPAL

Pokharis are traditional Nepalese ponds, used mainly for **cattle rearing** and **supplemental irrigation** of paddy fields. Their main characteristics are:

- Pond bottom lined with red mud (red clay) and compacted by cattle passage
- Lateral walls covered with stones and red mud
- Two accesses to the pond for animals

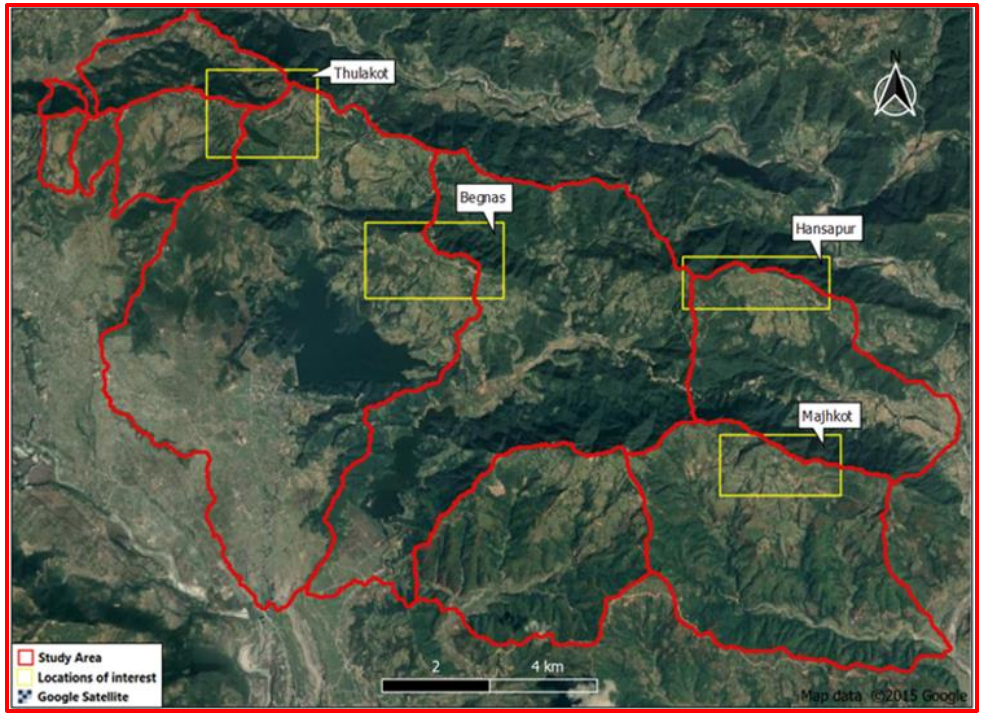
Study Area



Four tophills: Thulakot, Majhkot, Begnas and Hansapur communities

Central Nepal, Kaski District

- Hilly – montaneous region, altitude in study area ranges from 407 to 1443 m a.s.l.
- Climate is humid subtropical, the monsoon season lasts from June to September. Mean annual rainfall is 3900 mm.



DATA AND PROCESSING

Data	Data format	Source
Soil	Raster (250 m resolution)	Downloaded from Nepalese National Soil Science Research Center website https://soil.narc.gov.np/soil/soilmap/
Land use/ cover	Raster (100 m resolution and 10 m resolution)	Copernicus website https://land.copernicus.eu/global/_content/annual-100m-global-land-cover-maps-available ESA worldcover website https://esa-worldcover.org/en/data-access
Digital Elevation Model (DEM)	Raster (30 m resolution)	https://www.eorc.jaxa.jp/ALOS/en/aw3d30/index.htm
Water sources	Vector	Provided by IRHA

Through Qgis software, flow accumulation and elevation layers of the study area were **derived** from the DEM

DATA AND PROCESSING

Multi-criteria decision making (MCDM) is commonly used in best siting analysis. It allows to **compare** and relate **different kinds of data** through few simple steps:

- Each **dataset is converted into a spatial map** classified on a scale which is common to all kinds of data (usually 1-9 scale).
- Each layer is then given a **weight** according to the **influence** it will have on the final result.
- Each layer multiplied by its weight is summed to the other maps to obtain a **single** final **output**.

The result reports a **range of options** from "optimally suitable" to "not suitable" sites.

$$S = \sum w_i x_i$$

where S is the final suitability score, w_i is weight of factor i, and x_i is suitability score of factor i (Dile et al. 2016).

DATA AND PROCESSING

Criteria selected for this analysis were:

- Slope
- Land use (two maps, at 100m and 10m resolution)
- Flow accumulation
- Elevation
- Soil texture
- Distance from rivers and lakes

Data values/categories were **ranked** according to their suitability for *pokharis* best siting

Suitability score	**9**	**7**	**5**	**3**	**1**
Data value ranges	Optimal values/ best suitable data categories	Good values/ suitable data categories	Acceptable values/ suitable data categories	Scarcely acceptable values/ suitable data categories	Inadequate values/ suitable data categories

DATA AND PROCESSING

Weights of each layer are assigned according to their relative influence on the result.
No matter their distribution, the **sum** of all weights **must be 1**.

Criteria	Suitability score	Optimal value	Weight
Slope	1 (least suitable) – 9 (most suitable)	0 – 5 %	0.19
Land use		Open forest, Bareland, Herbaceous vegetation	0.19
Soil Texture		15 - 35 % Clay content	0.19
Flow accumulation		<200	0.19
Elevation		>1237	0.19
Distance from lakes and rivers		>4km	0.04

DATA AND PROCESSING

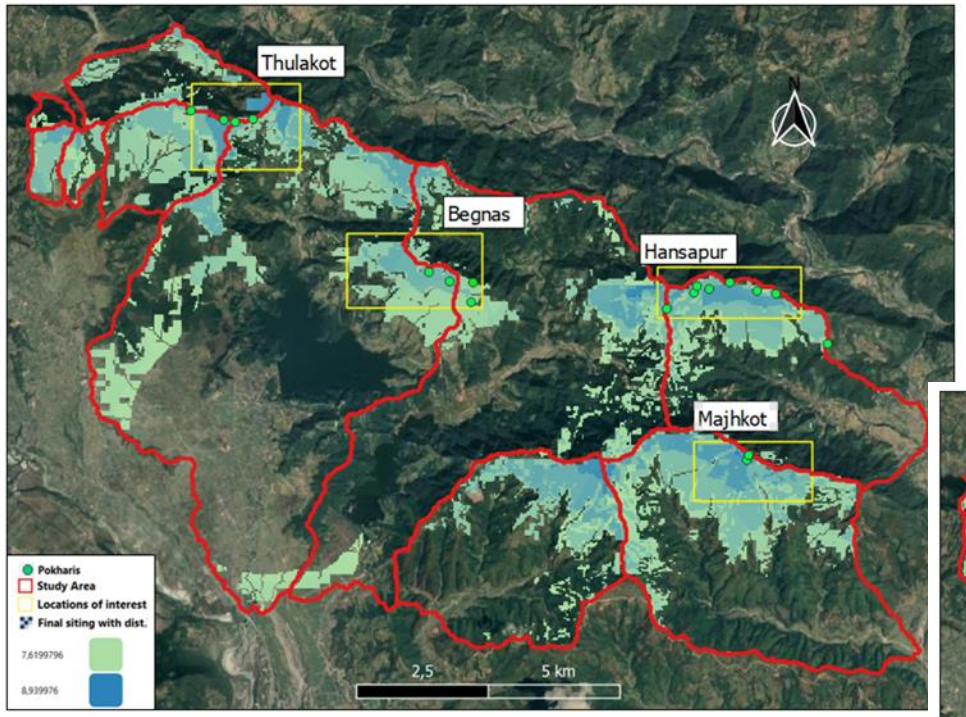
In October 2021, a **field visit** in the study area was carried out to **further analyse** the results obtained through Qgis software. In particular, three additional elements were inspected:

- selection of **best land use option** between the two maps available by checking real LULC in field
- real suitability of retrieved best sites (**validation**)
- **Participatory analysis of traditional criteria used for pokharis building**

Two main information were gathered in-site to refine the result:

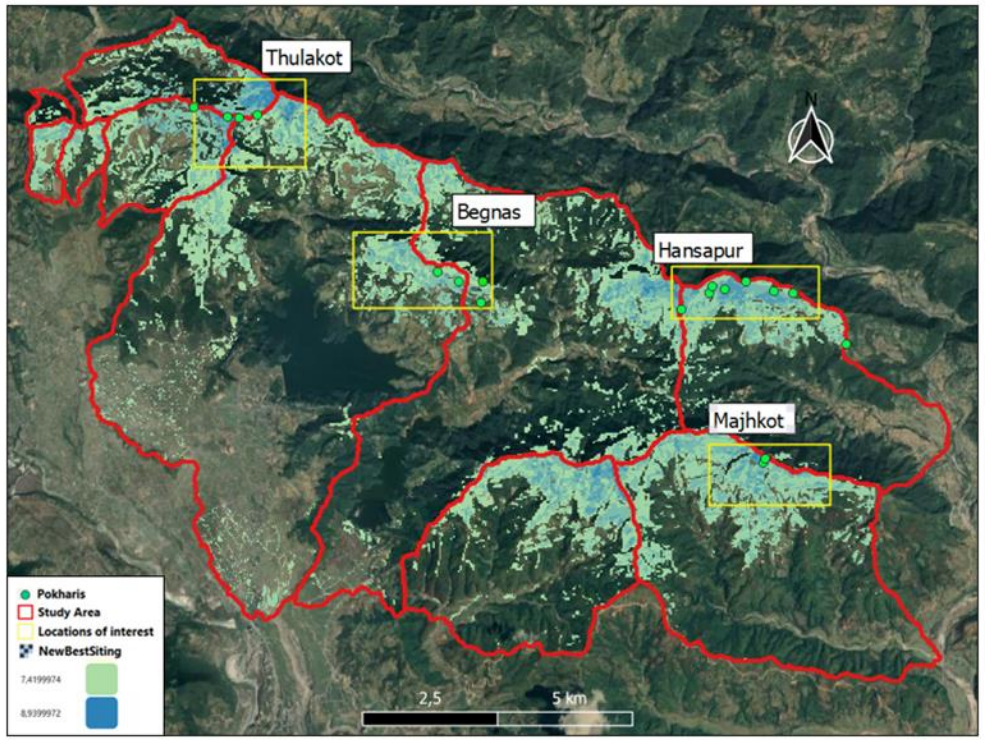
- Land property
- Terraces presence

RESULTS



Best siting map produced with 100 m resolution LULC

Best siting map produced with 10 m resolution LULC



RESULTS

Semi-structured interviews, submitted to local experts, report that **traditional criteria considered for *pok*haris** building are:

- Distance from villages (main criteria)
- Water accumulation over years during monsoons
- Distance from roads and tracks

RESULTS

The results were validated by overlaying GPS position of **existing *pokharis*** with the obtained maps.

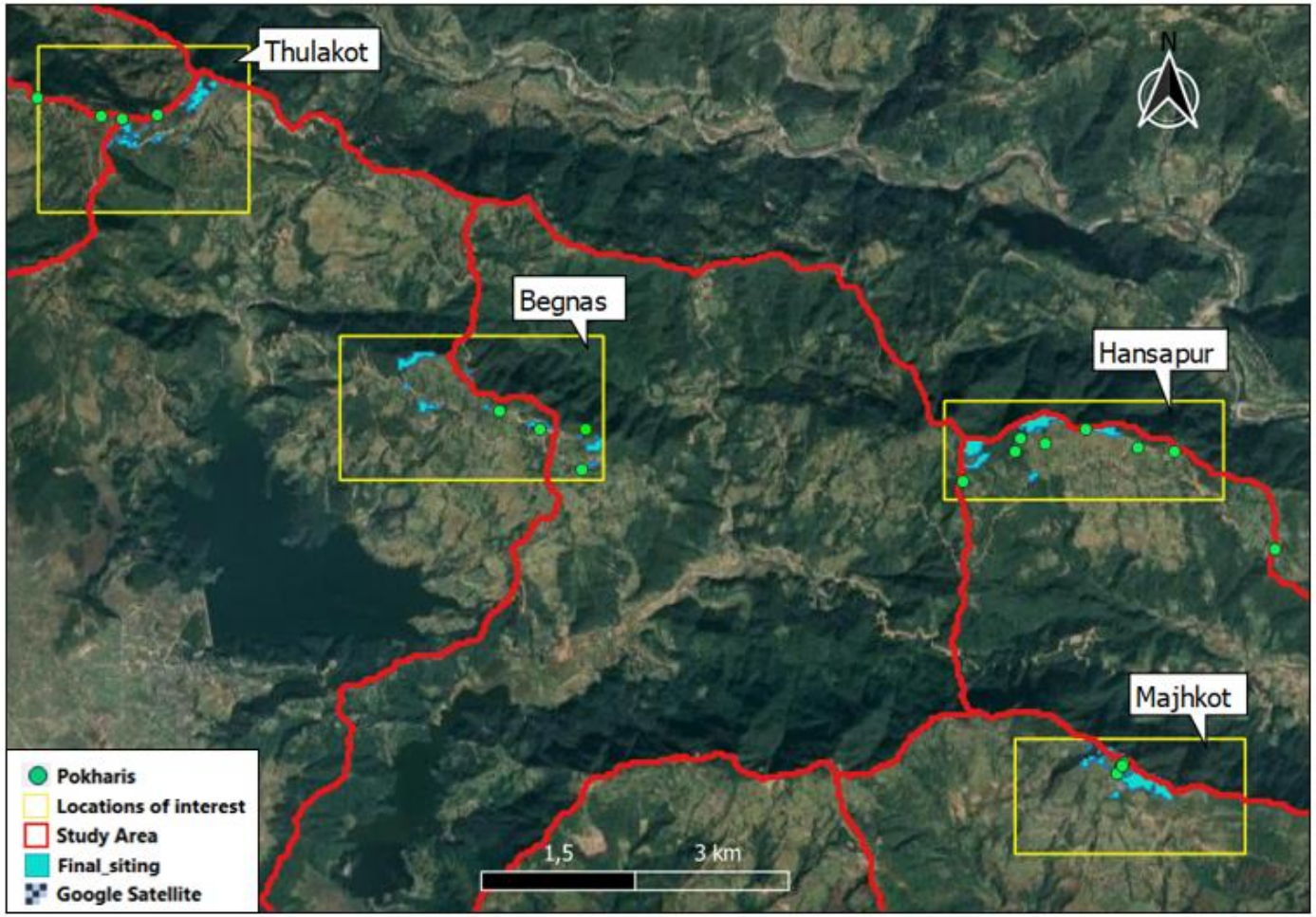
Suitability scores range was divided in quartiles as follows:

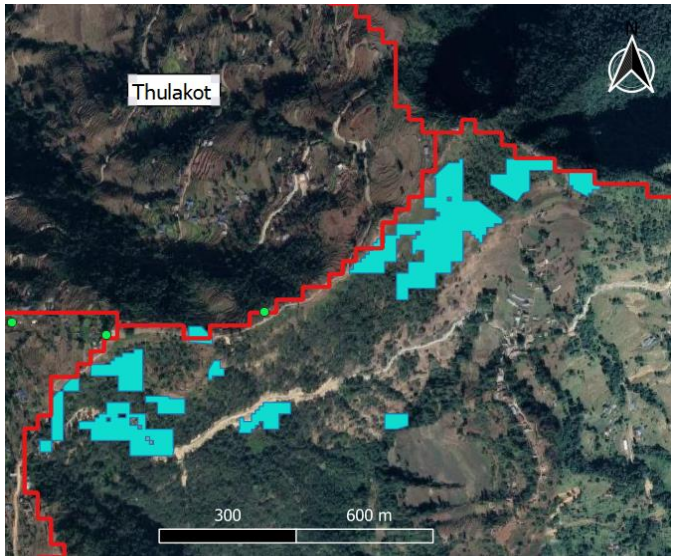
Quartile	Q1	Q2	Q3	Q4
range	2.74- 6.53	6.54-7.05	7.06-7.33	7.34-8.58

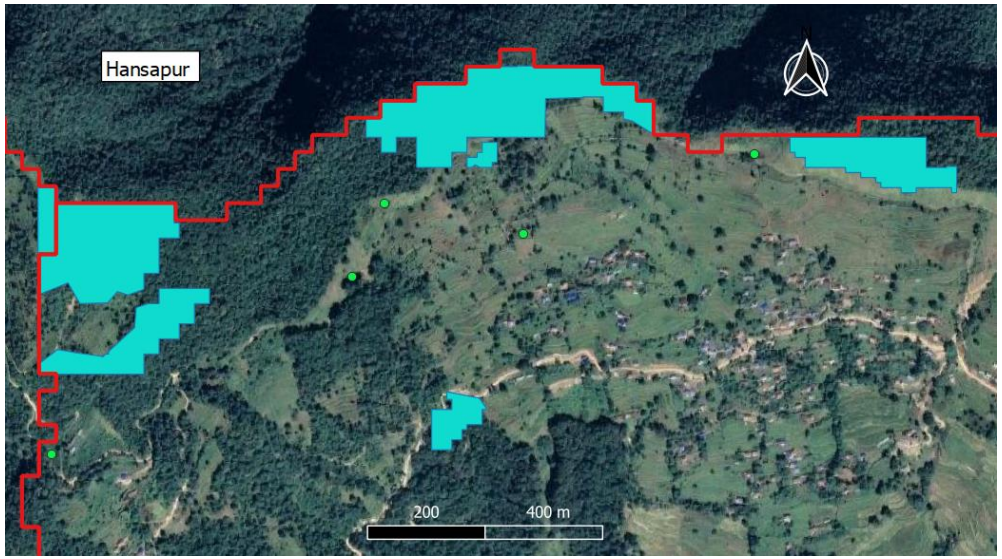
All but one existing pokharis resulted in Q4

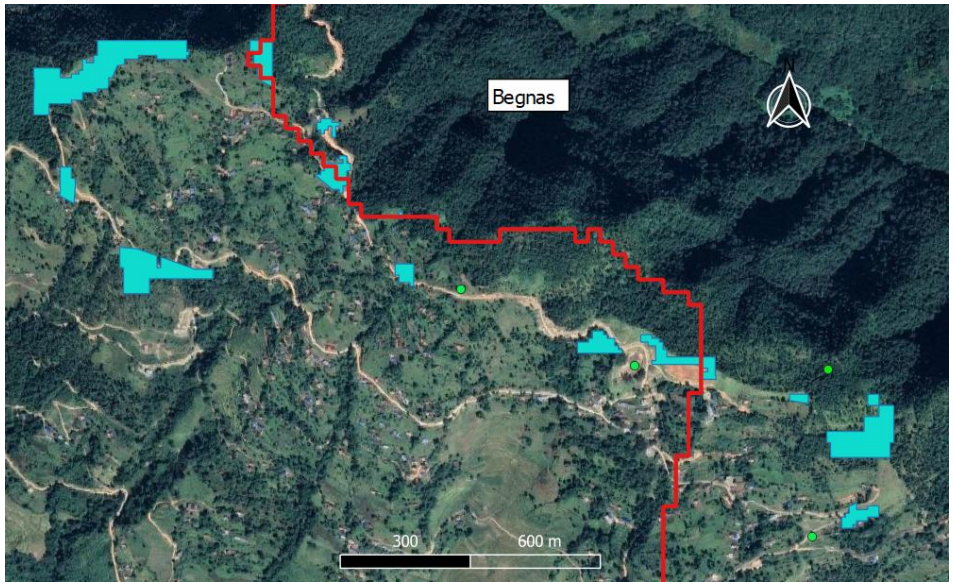
Final best siting- suitable areas excluding terraces, **private lands, and areas > 2km far from villages**

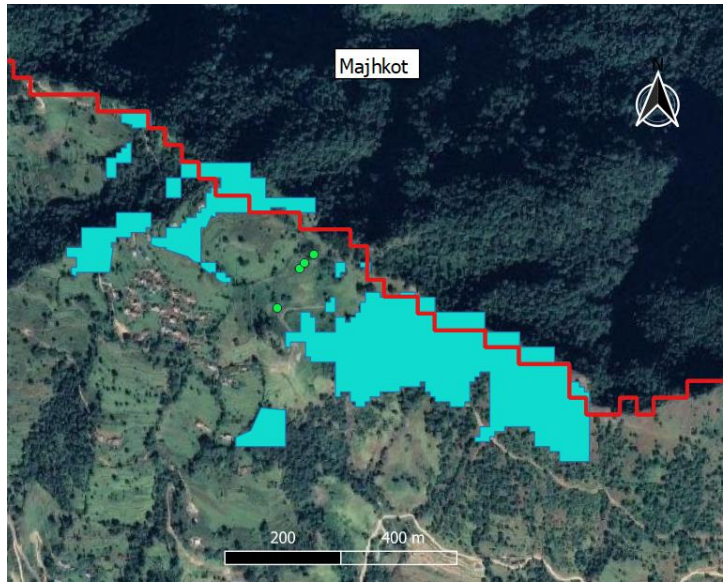
Participatory criteria




Thulakot
300
600 m


Hansapur
200
400 m


Begnas
300
600 m


Majhkot
200
400 m

CONCLUSIONS: NEPAL CASE STUDY

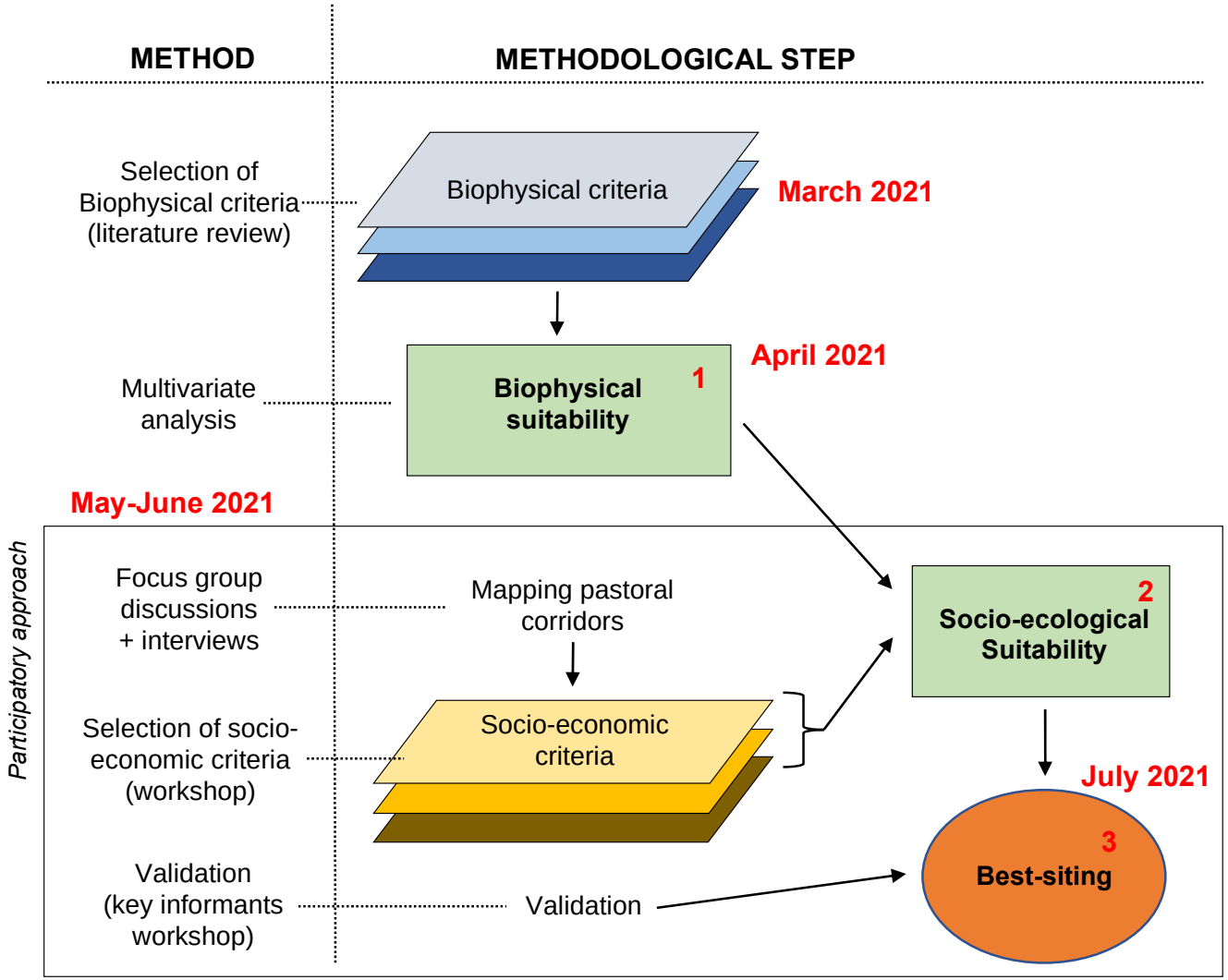
- The obtained map suggests best sites for pokharis building on the basis of a scientific methodology **consistent** with traditional criteria

- The map was successfully validated using already built structures and refined through field data, so it can be used in **water resources management and planning.**

- Resulting best spots should be checked on the field for land ownership and accessibility of the sites

BEST-SITING OF SAND DAMS WATER HARVESTING IN NAMIBE, ANGOLA

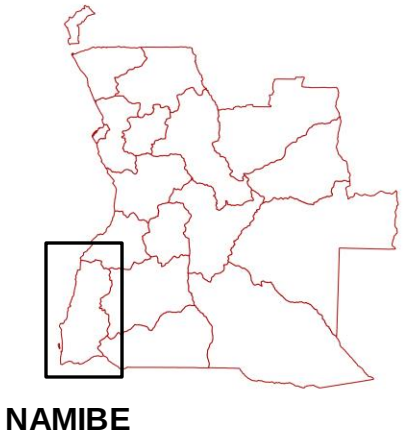
Sand dams are **concrete walls built on the bedrock of ephemeral sandy streams,** with the aim of filling the area behind the dam **with sand** carried by the seasonal runoff events and **store water in the sand voids to avoid evaporation.**


METHOD
METHODOLOGICAL STEP
Selection of Biophysical criteria (literature review)
Biophysical criteria
March 2021
Multivariate analysis
Biophysical suitability
1
April 2021
May-June 2021
Participatory approach
Focus group discussions + interviews
Mapping pastoral corridors
2
Socio-ecological Suitability
Selection of socio-economic criteria (workshop)
Socio-economic criteria
July 2021
3
Best-siting
Validation (key informants workshop)
Validation

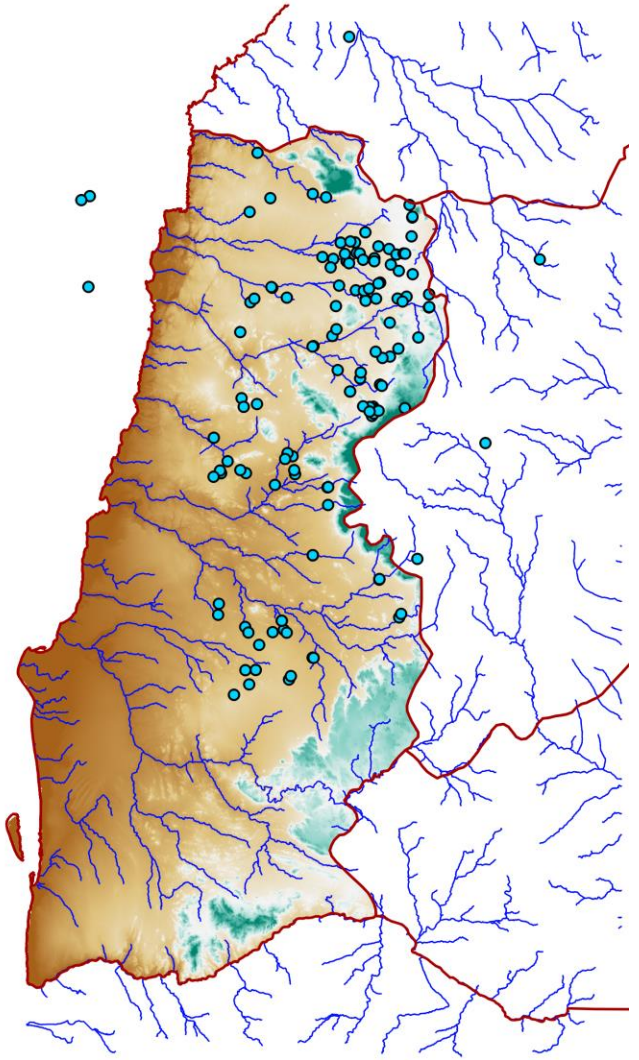
Biophysical criteria – where is the water going?

Selected from leterature

- **Drainage network**
- Slope
- Soil type



NAMIBE



Biophysical criteria – where is the water go

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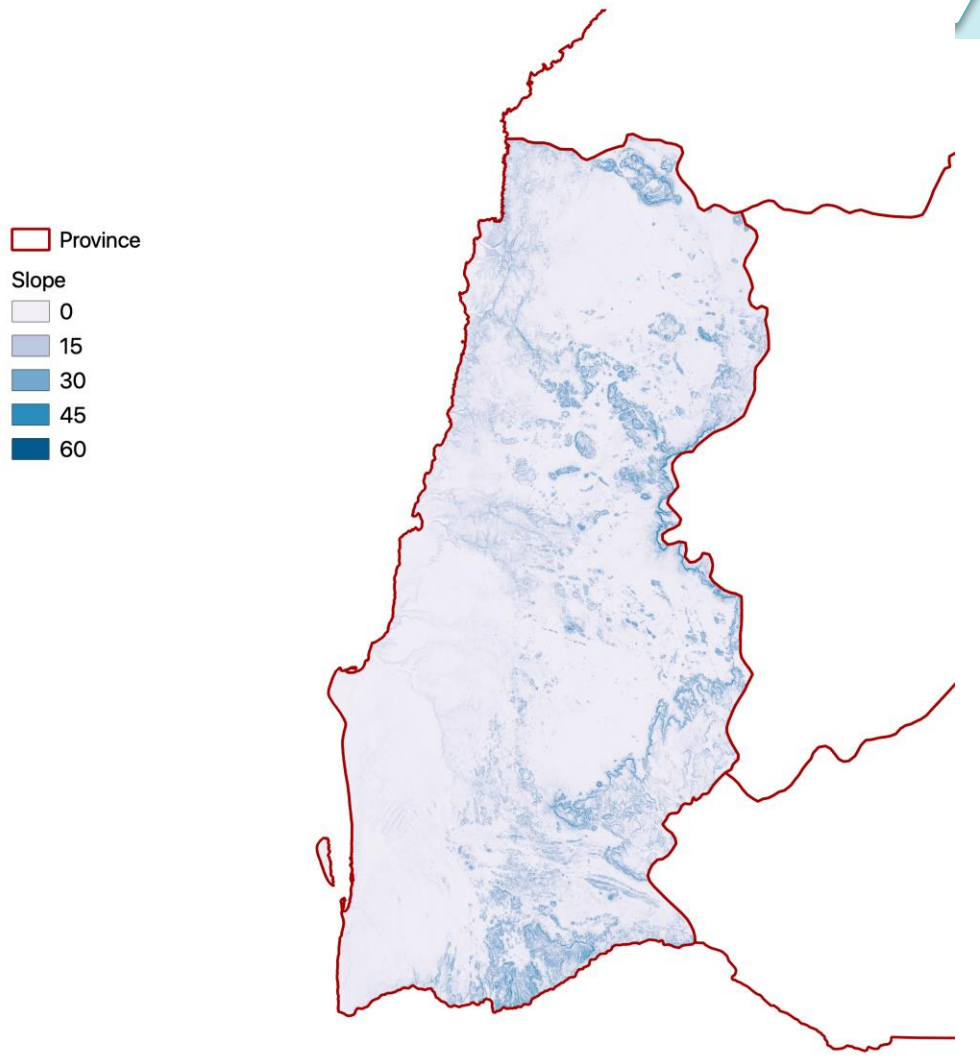

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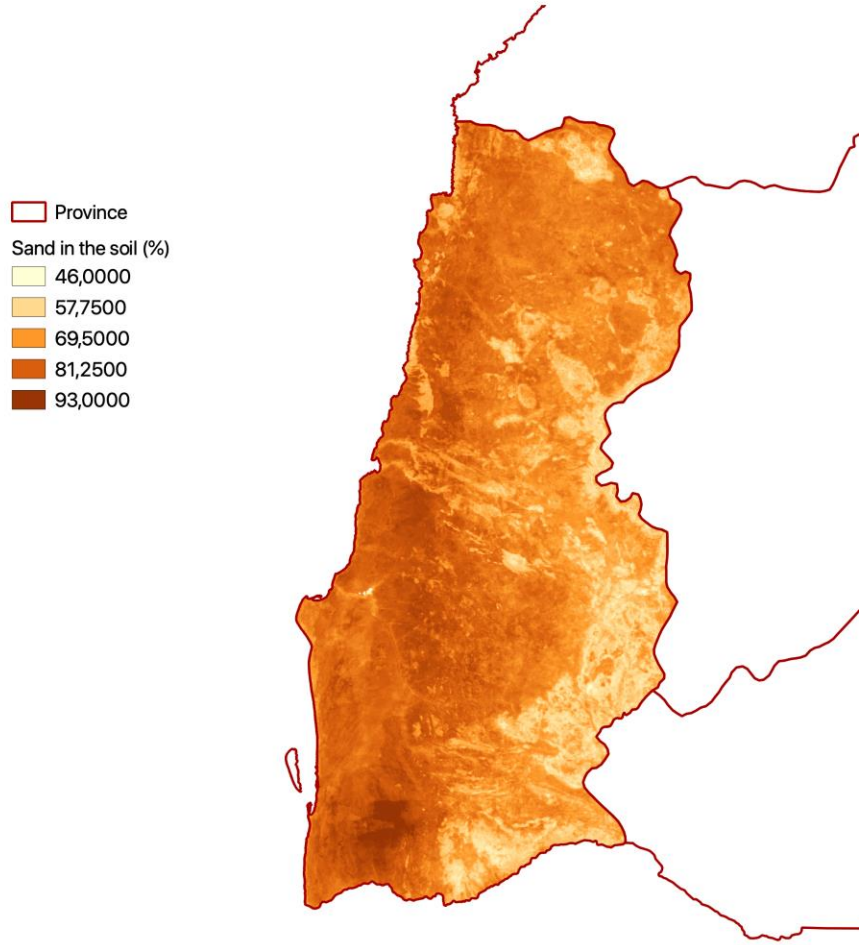
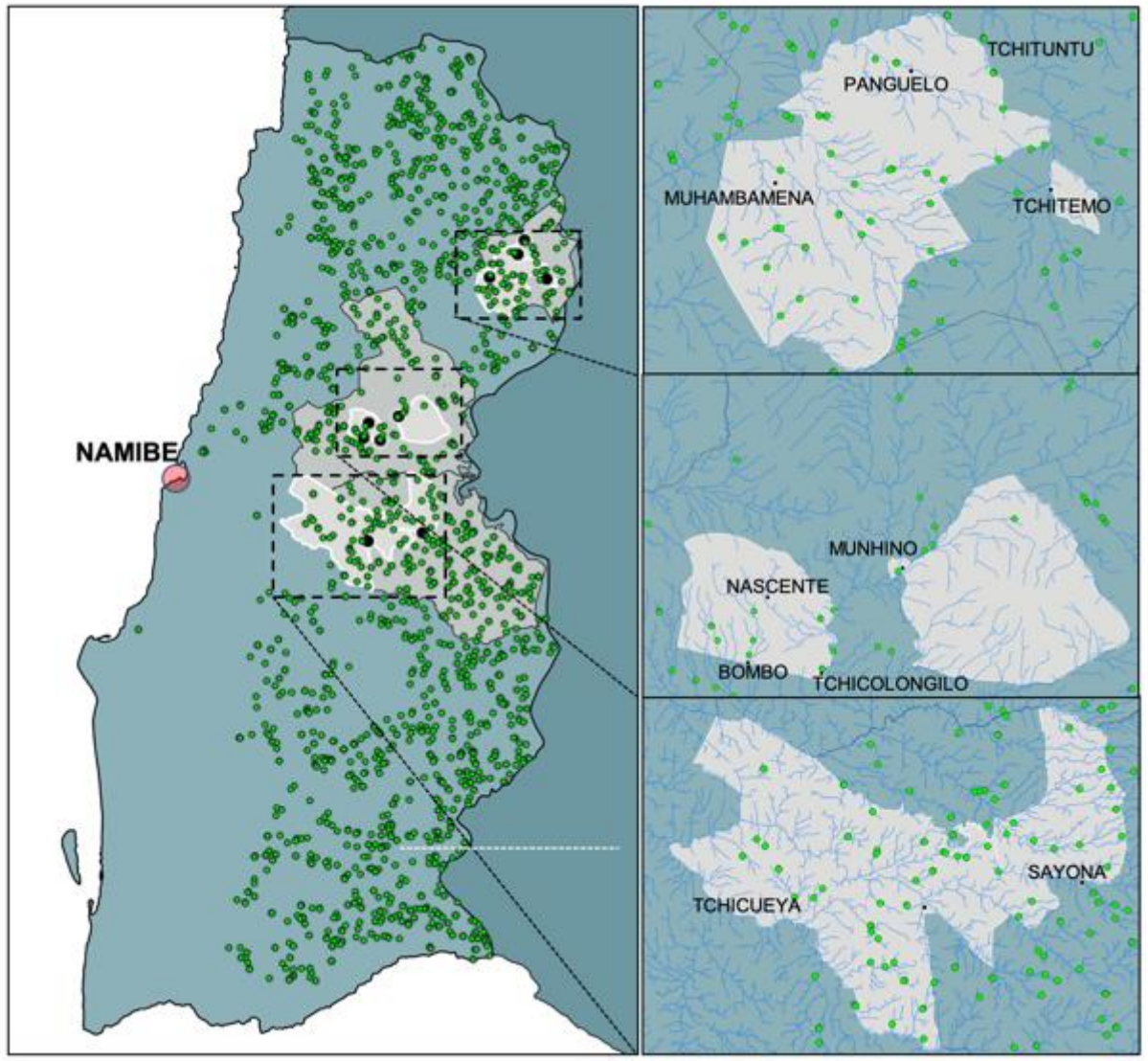


Selection of suitable points:

- On the **drainage network**
- Excluding the points located in areas with slope higher than 2 degrees
- Excluding stream order higher than 2
- Excluding soil salinity higher than 40Hz.

2.106 points in Namibe, 121 in the 10 project communities



Socio-economic criteria – where is the water needed?

Participatory approach

The participatory approach will involve:

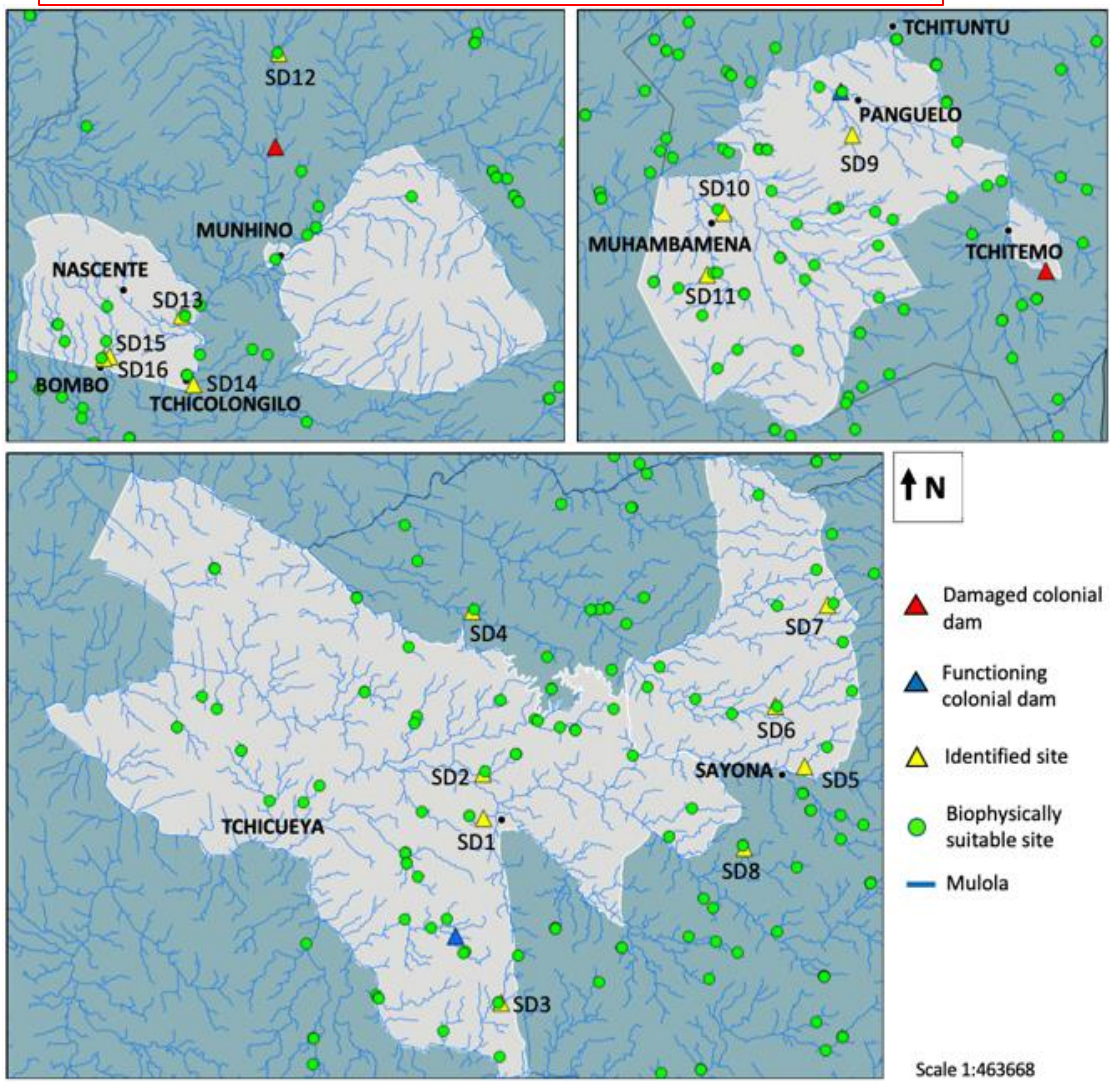
1. Focus group discussions and interviews to understand and possibly map the main pastoral corridors (participatory mapping)
2. Workshops to select the most relevant socio-economic criteria to include in the best-siting analysis.
3. Key informants interviews to validate the final best-siting maps

Based on the community-specific water-related problems, we identified the main conditions to account

Although the characteristic change depending on the local conditions and local population needs, they can be overall summarized in:

1. Important to plan for a location that can serve a **large part of the community**.
2. Proximity to **non-served locations**
3. Proximity to road : to allow **easy access for transporting materials mechanized vehicles**
4. Proximity to strategic places : for example, **located in pasture areas if the purpose is to serve animals** of local communities
5. Proximity to pastoral **transhumance routes**

Final selection (yellow triangles): 9 points



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