Criteria for selection of technology to exploit groundwater in water scare area in Vietnam

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1. Introduction

The high mountainous and water-scarce regions of the North constitute the largest territorial area among the economic zones in Vietnam, concurrently holding immense significance in the socio-economic development and national security and defense. Due to the complex natural geographical conditions, water resources prospecting for consumption and production purposes poses significant challenges and complexities. To ensure the effective and sustainable operation of water exploitation projects, it is imperative to select appropriate extraction technologies and management practices tailored to the specific conditions of each water resource and other pertinent factors. However, the task of identifying suitable water extraction technologies for high mountainous and water-scarce areas to guarantee the long-term effectiveness and sustainability of projects is exceedingly arduous and contingent upon various factors, including rainfall, stream flow, thickness of cover layers, aquifer thickness, depth to groundwater level, water level depth, permeability coefficient, flow rate, exploitable reserves, water quality, distance to water usage points, distance to transportation routes, distance to road networks, terrain slope, land use, geological conditions, fracture density, population distribution/population density, and proximity to pollution sources (Enke Hou et al., 2018; Fanao Meng et al., 2021; Indrani Mukherjee et al., 2020; Yu W et al., 2019). Geographic Information Technology (GIS) has emerged as a crucial tool in water resource research due to its capabilities in spatial-temporal development and effectiveness in spatial data analysis and prediction (Ghayoumian et al., 2007). Numerous studies have been conducted to identify areas suitable for implementing sustainable water extraction technologies using GIS techniques. Most studies employ index calculation methods, utilizing GIS technology to create maps of areas suitable for implementing sustainable water extraction technology (Ghayoumian et al., 2007).

2. Materials and methods

To establish a map of areas suitable for implementing sustainable groundwater extraction technologies using drilled wells in the Northern region of Vietnam, a multi-parameter dataset including data on saturation thickness, water level depth, transmissivity coefficient of aquifer, exploitable reserves, distance to water usage points, terrain slope, population distribution/population density is provided by the National Center for Water Resources Planning and Investigation (Nawapi).

From the correlation equation between ground water level elevation and terrain elevation, calculate the ground water level depth by predicting ground water level elevation according to terrain elevation in the entire study area, then Then, subtract the underground water level from the terrain elevation to determine the underground water depth of the aquifers in the study area..

Base on the correlation equation between groundwater level elevation and terrain elevation, the groundwater depth can be calculated by predicting groundwater elevation according to terrain elevation across the entire research area. Subsequently, we calculate the depth to groundwater level within the aquifers in the research area by subtracting groundwater level elevation from terrain elevation.

The hydraulic transmissivities of the aquifers are compiled from the historical groundwater resource surveys conducted within the research area, provided by Nawapi. The safe yield of groundwater are quantified using the safe yield module (in the unit of $m^3/day/km^2$). Based on the consolidation of hydrogeological parameters of the aquifers, including aquifer thickness, storage coefficient, permeability, conductivity, and groundwater flow module, the author had come to the conclusion that the storage capacity, recharge rate, groundwater resource availability, and safe yield of groundwater approximately equaled to 30% of the groundwater availability within the aquifers in the studied area. Finally, the safe yield module is determined by dividing the safe yield by the extent area of the aquifer. All calculation steps and procedures mentioned above are executed using GIS tools included in ArcGIS software.

The terrain slope within the studied area is determined by the digital elevation model (DEM). Using the Slope tool in ArcGIS software, terrain slope levels have been established. Population distribution data, serving the assessment and identification of technological solutions for groundwater exploitation using drilled wells in high mountainous, water-scarce regions of the Northern provinces, is synthesized based on natural area and population status in the 2020 Statistical Yearbook of the provinces; and the population density within the study area is calculated subsequently.

To establish a map of areas applying sustainable groundwater exploitation technology through drilled wells in the Northern region of Vietnam, the weights of all seven different criteria grades have been calculated by using the Analytical Hierarchy Process (AHP) (Saaty, 1980) and determined using the weighted sum method in GIS. Seven thematic map layers corresponding to the standardized criteria are those with scores ranging from 1 to 5, representing levels from very poor sustainability to very sustainable.

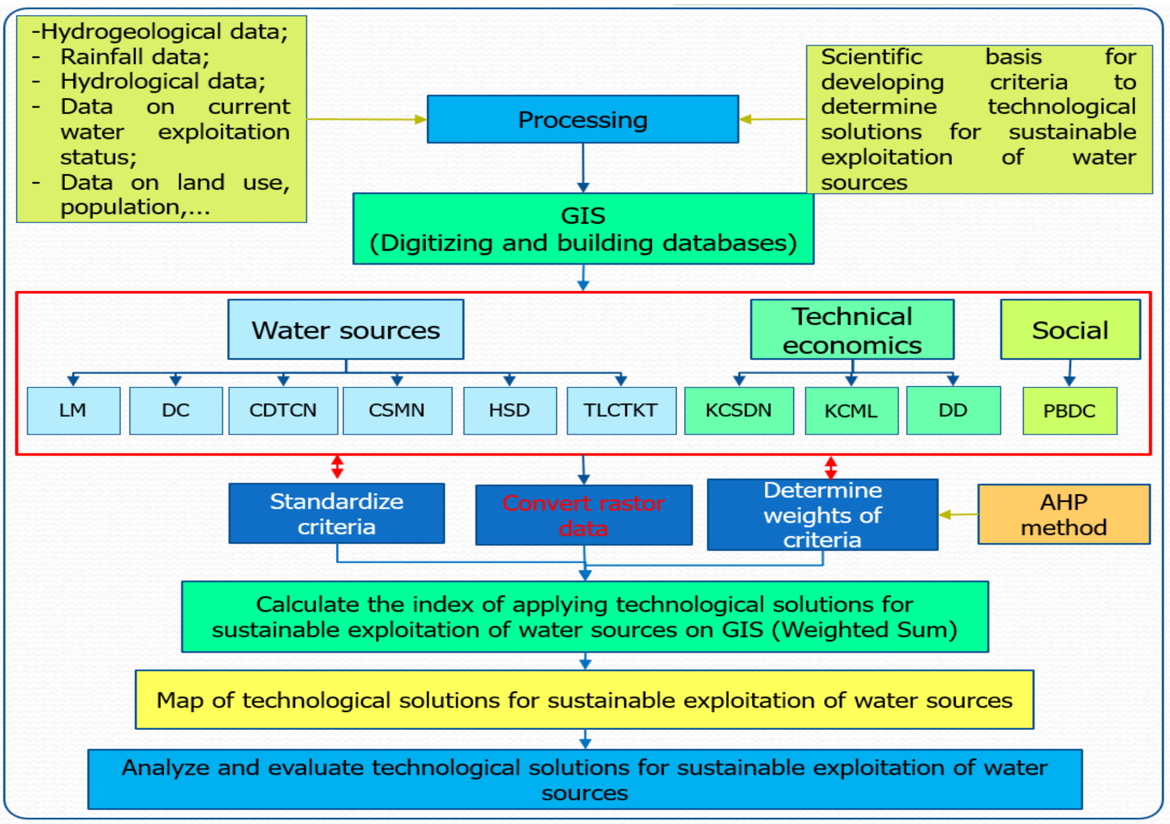

Figure 1. Diagram of methodology on identifying the locations applying sustainable groundwater exploitation technology solutions through drilled wells in the mountainous, water-scarce regions of the Northern area of Vietnam

Based on the index for implementing sustainable groundwater exploitation technology solutions through drilled wells in the mounteneous, water-scarce regions of the Northern area of Vietnam, it can be divided into 5 intervals: very unsustainabile; unstainable; moderate sustainabile; sustainable; and very sustainable.

3. Results and discussions

All the seven thematic layers of of saturation thickness (of aquifers), depth to groundwater level, transmissivity, Exploitable reserve, terain slope, distance to the water useage point, population distribution/density together with their patterns over the studied areas are presented in details as follow:

Depth to groundwater level

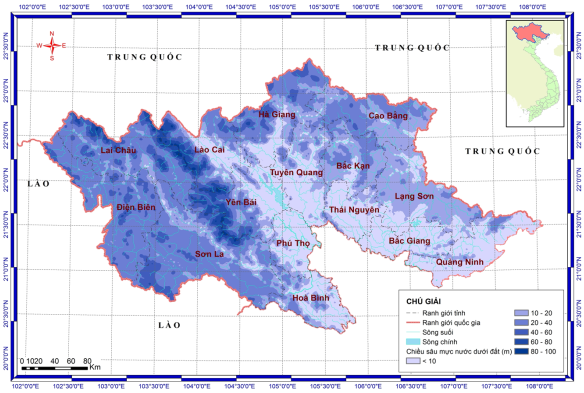

Figure 2. Distribution diagram of average depth of aquifers in high-mountainous and water-scarce regions in the North

Saturation thickness (of aquifers):

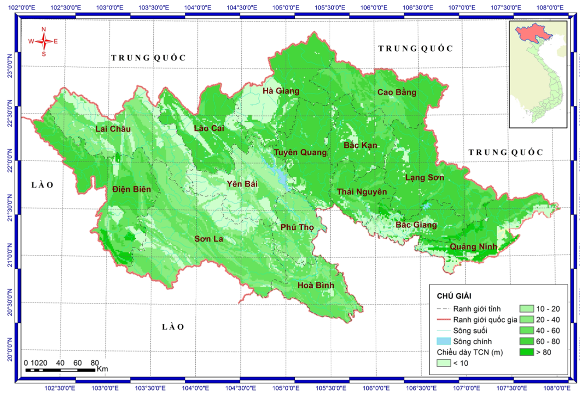

Figure 3. Distribution diagram of average thickness of aquifers in high-mountainous and water-scarce regions in the North

Aquifer's transmissivity

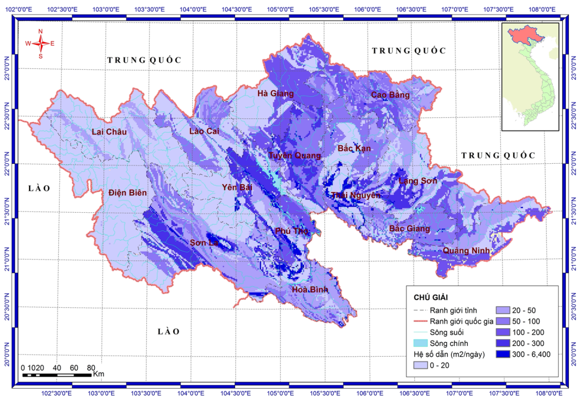

Figure 4. Distribution diagram of average transmissivity of aquifers in high-mountainous and water-scarce regions in the North

Exploitable reserve

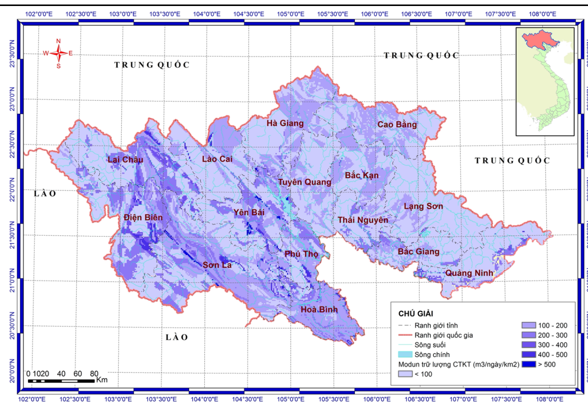

Figure 5. Distribution diagram of average Exploitable reserve of aquifers in high-mountainous and water-scarce regions in the North

Distance to the groundwater usage point

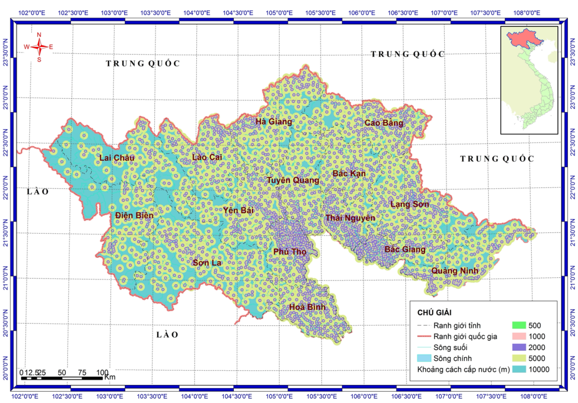

Figure 6. Distribution diagram of average Distance to the groundwater usage point in high-mountainous and water-scarce regions in the North

Groundwater exploitation technology

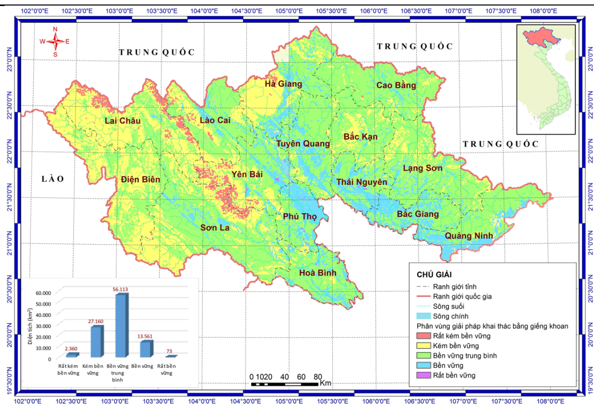

Figure 7. Distribution diagram for application of groundwater exploitation technology in high-mountainous and water-scarce regions in the North

4. Conclusion

The determination of area for applying suitable groundwater exploitation technologies by wells in the mountainous, water-scare areas in Northern Vietnam using GIS technique provided an effective solution for managing the sustainable explotation of water resources. The results show that the used criteria are suitable for the mountainous, water-scare areas and the weights of the established criteria ensure a consistent ratio (CR < 10%) according to the hierarchical analysis method. Additionally, the areas applying groundwater explotation technologies by wells for water supply at the levels of very sustainable and sustainable are distributed across 1,895 communes in 15 provinces with the total area of 13,634km^2 (accounting for 13.7% of the total study area).

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