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5.1
Modelling as a tool of groundwater assessment

Application of GIS techniques for determining suitable areas for managed aquifer recharge in the lower Ping-Yom river basin, Thailand

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ABSTRACT

Due to the year-round high water needs for growing rice in Thailand, farmers are drawing heavily upon the groundwater from the shallow aquifers located in the alluvium and alluvium fan deposits of the Ping - Yom River Basin. The average groundwater level has declined to about 7 to 10 meters below the ground surface; levels that are considered critical for pumping by farmers. The Department of Groundwater Resources, Thailand realizes that subsurface storage of some of the seasonally abundant surface water resource into the aquifers may be useful for the farmers and for restoring the water balance of the groundwater basin. Managed Aquifer Recharge (MAR) using ponding methods of recharge may be one of the cheapest method of recharge, and is proposed to be applied within this area. Therefore the objective of this study is to determine the suitable areas using MAR-based ponding systems. There are four significant groups of parameters to consider for selecting areas suitable for MAR, namely hydrogeology, geomorphology, soils, and slope. Thematic layers for all information were classified, weighted and analyzed by a Geographical Information System (GIS) using ArcGIS software. Weighted Index Overlay Analysis (WIOA) is used for the selection of potential MAR areas. Finally suitability of the integrated classes for artificial recharge is identified as (a) very suitable, (b) suitable, (c) moderately suitable, and (d) unsuitable. The result of the study indicates that about 1,900 km^2 (9%) of the study area is considered as very suitable for MAR. It is recommended that more detailed subsurface investigations be performed in order to validate the GIS approach.

INTRODUCTION

Extensive use of shallow groundwater for rice growing in the Lower North Region River Basin of Thailand has caused groundwater levels to decline from 1-2 m below ground surface in previous decades to 7-10 m at the present time. Artificial recharge is an effective technique for the restoration and augmentation of groundwater resources. Ponding systems may be one of the simplest and cheapest methods of artificial recharge, and is proposed to be applied to raise the groundwater levels within this area. The objective of the study is to identify the most suitable areas for managed aquifer recharge (MAR) using ponding system by application the Geographic Information Systems (GIS) techniques.

The study area is located in the Lower North Region River Basin, Thailand. It occupies three provinces, namely, Sukhothai, Pichit and Pitsanulok (Fig. 1) covering an area of about 21,312 km^2.

Geographically, the western part is located in the Yom river basin, whereas the eastern part is a part of the Nan River basin. Northern and northeastern part has high topography (up to 2,102 meters above sea level) at Phu Soi Dao, Amphoe Chat Trakan, Pitsanulok Province) and gradually flattening terrain in the central part with an average elevation of 33-46 m above MSL. The average temperature is about 28°C, the annual rainfall and potential evaporation are about 1,350 mm and 1,200 mm respectively.

The study area is underlain by thick sequences of unconsolidated rocks in the central part and igneous and sedimentary rocks in the north and northeastern sediments (Department of Mineral Resources, 1983, Figure 2).

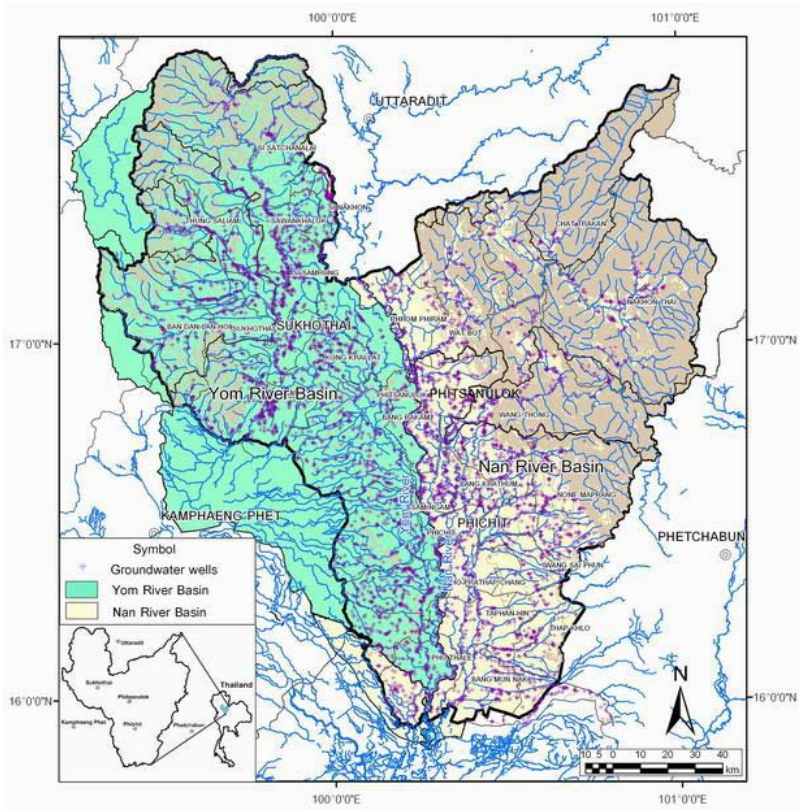

Figure 1. Location of the study area, the Lower North Region River Basin, Thailand (Department of Groundwater Resources, 2009).

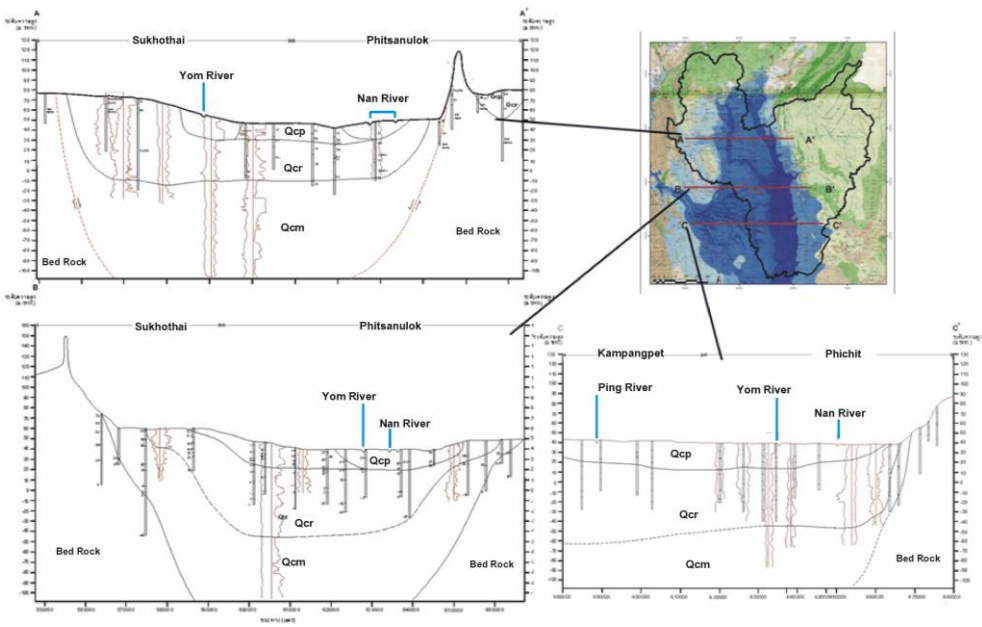

Figure 2. Hydrogeological map of the Lower North Region River Basin (modified from Department of Mineral Resources, 1983.

The unconsolidated sequence consists of (1) Recent flood plain deposits (Qfd) or Chao Phraya Aquifer (Qcp); consisting of sand and gravel interbeded with clay; with an average thickness of about 0- m and well yields ranging from 15-2 m^3 hr (2) Low terrace deposits (Qlt) or Chiang Rai Aquifer (Qcr) consisting of clay, silt, interbeded with sand and gravel (10-60 m thick) and well yields ranging from 15-20 m^3 hr , (3) High terrace deposits (Qht) or Chiang Mai Aquifer (Qcm) consisting of gravel, sand, and rock fragment with well yields ranging from 30-50 m^3/hr. The consolidated rocks are mainly limestone; interbeded with shale and sandstone with well yields ranging from 2-5 m^3/hr and metamorphic and Igneous rocks with well yields ranging from 1-5 m^3/hr.

METHODOLOGY

In determining the areas most suitable for MAR, there are four main groups of parameters to consider, namely geology, geomorphology, soil, and slope which are compiled and analyzed as a thematic derivative maps as shown in Figures 3 to 6.

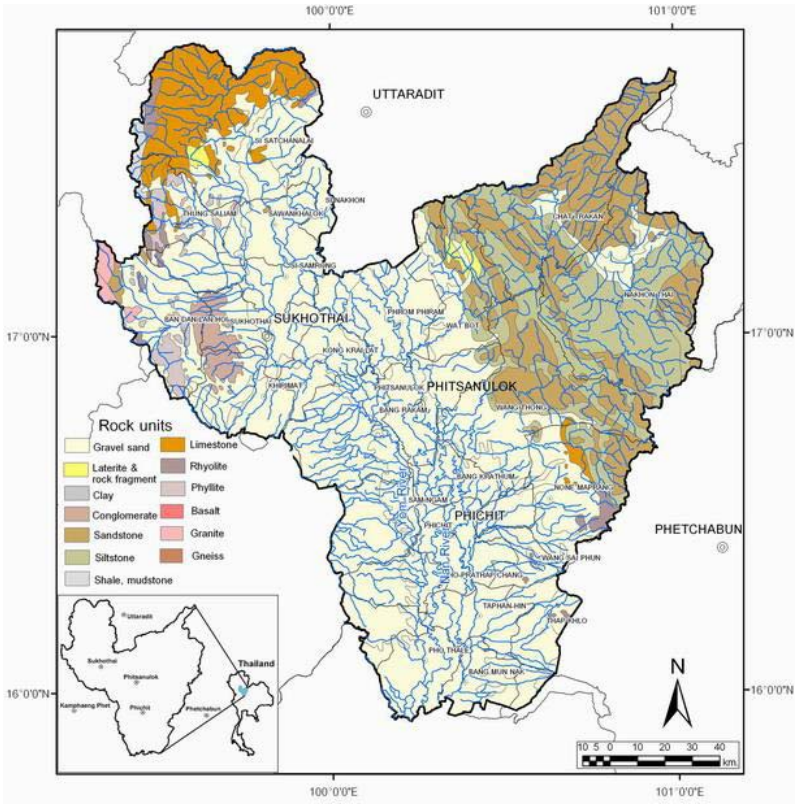

Figure 3. Geological map of the Lower North Region River Basin (modified from Department of Mineral Resources, 1976).

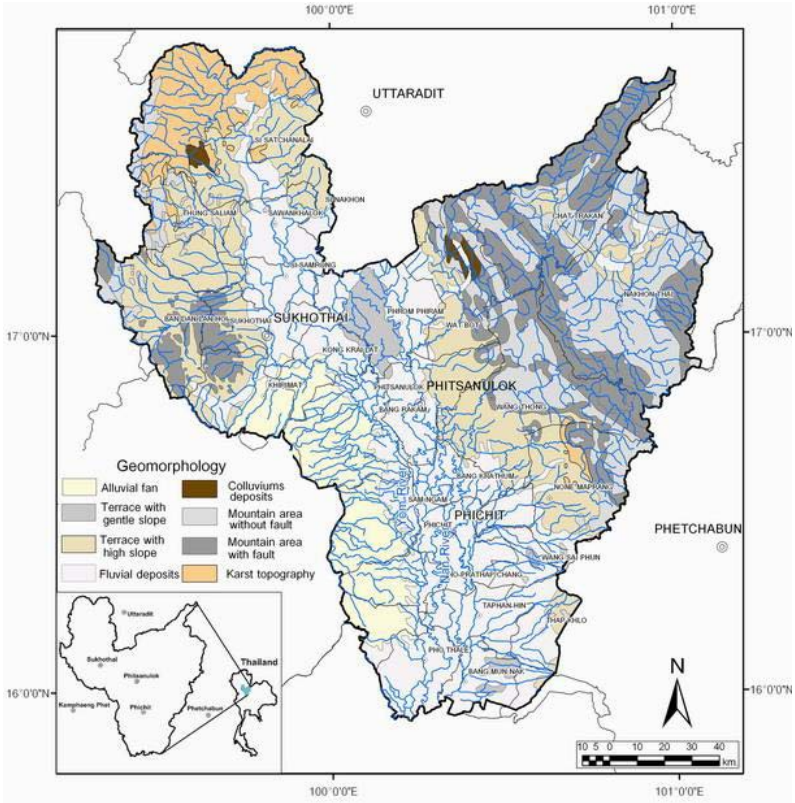

Figure 4. Geomorphological map of the Lower North Region River Basin.

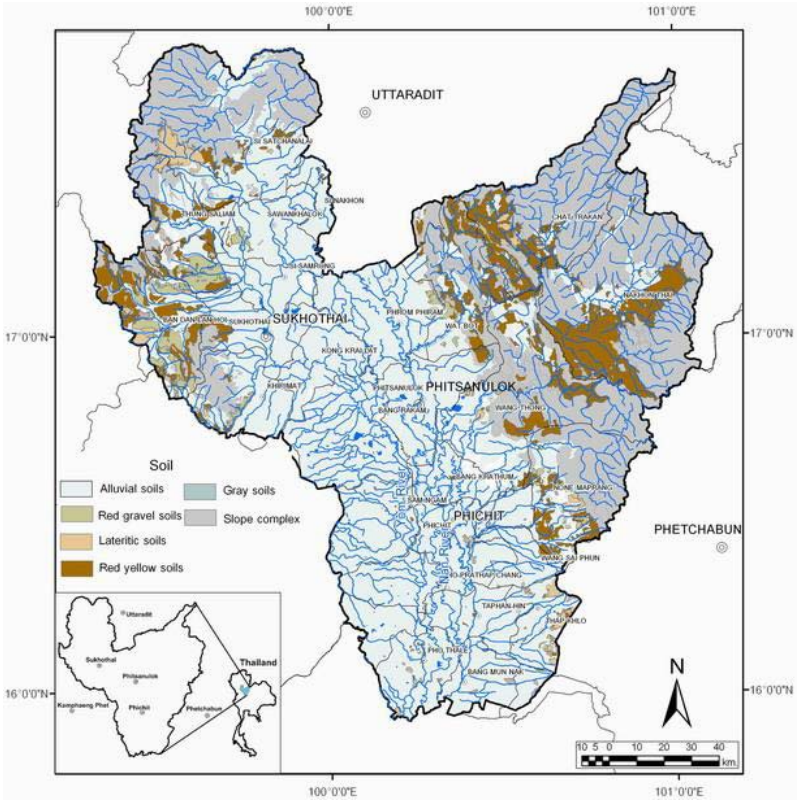

Figure 5. Soil map of the Lower North Region River Basin (modified from Land Development Department, 2000).

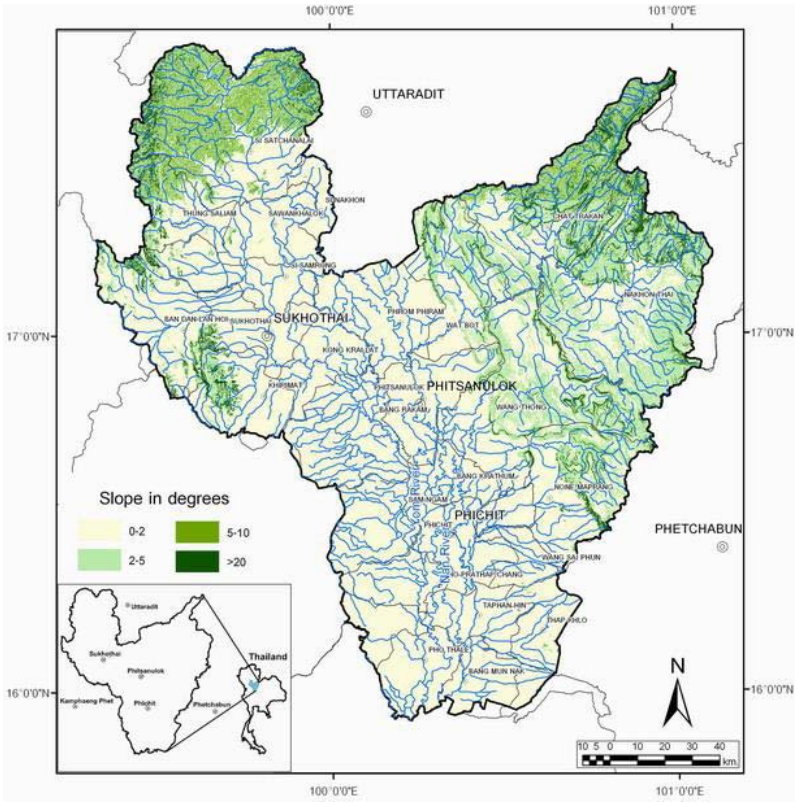

Figure 6. Slope map of the Lower North Region River Basin.

Geologic database is constructed using 1:250,000 scale geologic map (Department of Mineral Resources, 1976). Geomorphologic database is developed from topographical maps 1:250,000 scale (Royal Thai Survey Department, 2006) and hydrogeological map 1:100,000 scale (Department of Mineral Resources, 1983). Soil database is constructed using 1:50,000 scale provincial soil map (Land Development Department, 2000). Slope database is developed from topographical maps 1:50,000 scale (Royal Thai Survey Department, 2006). Classification, score and weight of each group of parameters were assigned for each thematic map based on the field evidence and previous works (Saraf, et. al, 2004) and shown in Table 1.

Table 1. Weighted indices for selecting potential MAR areas.

Thematic layers	Classes	Score	Weight
1. Geology	1.1 Gravel, sand	5.0	0.6
	1.2 Laterite & rock fragment	4.0	
	1.3 Clay	4.0	
	1.4 Conglomerate	1.5	
	1.5 Sandstone	1.5	
	1.6 Siltstone	1.5	
	1.7 Shale, Mudstone	1.5	
	1.8 Limestone	1.5	
	1.9 Rhyolite	1.5	
	1.10 Phyllite	1.0	
	1.11 Basalt	1.5	
	1.12 Gramite	0.5	
	1.13 Gneiss	0.5	
2. Geomorphology	2.1 Alluvial fan	5	0.7
	2.2 Terrace with gentle slope	3	
	2.3 Terrace with high slope	1	
2. Geomorphology (Cont.)	2.4 Fluvial deposits	1	0.7
	2.5 Colluviums deposits	1	
	2.6 Mountain area without fault	1	
	2.7 Mountain area with fault	2	
	2.8 Karst topography	5	
3. Soils	3.1 Red gravelly soils	5	0.5
	3.2 Alluvial soils	4	
	3.3 Lateritic soils	3	
	3.4 Red yellow soils	2	
	3.5 Gray soils	2	
	3.6 Slope complex	1	
4. Slopes	4.1 Range 0 - 2	4	0.4
	4.2 Range 2 - 5	5	
	4.3 Range 5 - 10	3	
	4.4 Range 10 - 20	2	

Suitable areas for managed aquifer recharge (MAR) were determined by an overlay technique with the Geographic Information System using ArcGIS software by the Weighted Index Overlay Analysis (WIOA) (Saraf, et. al, 2004). The overall methodologic framework is shown in Figure 7. All maps are presented at a resolution of 2.3 Mega pixels.

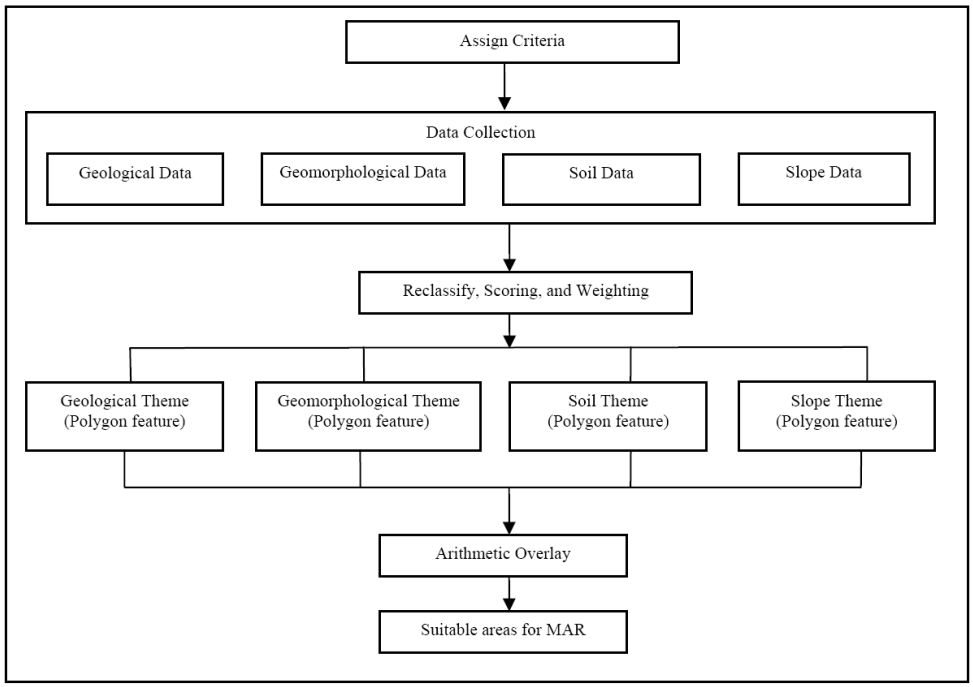

Figure 7. Flow chart illustrating the methodogy used in this study.

RESULTS

Suitable areas for managed aquifer recharge (MAR) can be determined and classified into 4 zones, (1) very suitable, (2) suitable, (3) moderately suitable, and (4) unsuitable as depicted in Figure 8.

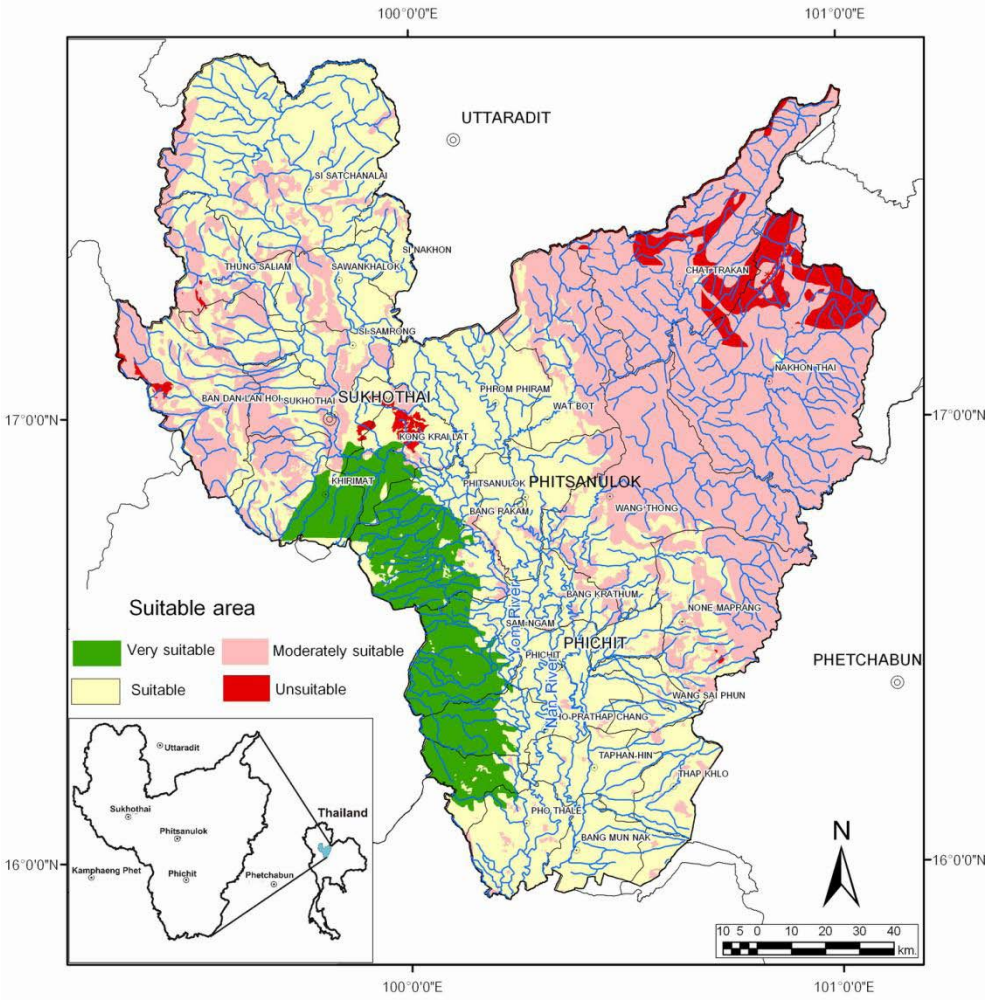

Figure 8. Suitable areas for MAR in the Lower North Region River Basin.

1. Very suitable area for MAR by using ponding methods is located in the southwest region of the Lower Region River Basin and covers area of about 1,900 km^2 (9% of the study area), in Amphoe Bangrakham, some part of Amphoe Kirimas and Kongkrilas, Pitsanulok Province, and Amphoe Samngam, Amphoe Vachira Baramee, Amphoe Popratapchang, Pichit Provinces. The most suitable areas are overlain by gravel and sand, alluvial fan, red gravelly soils, and have slopes of 2-5 degrees.

2. Suitable areas are located in the centre of the basin and cover an area of about 10,400 km^2 (48% of the study area), in Amphoe Sri Satchanalai, Amphoe Sri Samrong, Amphoe Sawankalok, Amphoe Phrom Phiram, Amphoe Wat Bot, Amphoe Muang, Amphoe Bang Kra tum, and parts of Amphoe Wangtong, Pitsanulok province, and parts of Amphoe Samngam, Amphoe Muang, Amphoe Taphanhin, Amphoe Bangmunnak, Amphoe Wangsaipoon, and Amphoe Tabkhlor, Pichit Province, respectively.

3. Moderately suitable areas cover an area of about 8,200 km^2 (39% of the study area) in the northwest and northeast regions where are the relatively high topographic terrain.

4. Unsuitable areas cover an area of about 800 km^2 (4% of the study area) and mainly situated in the high terrain regions in the north east as shown in Figures 8 and 9.

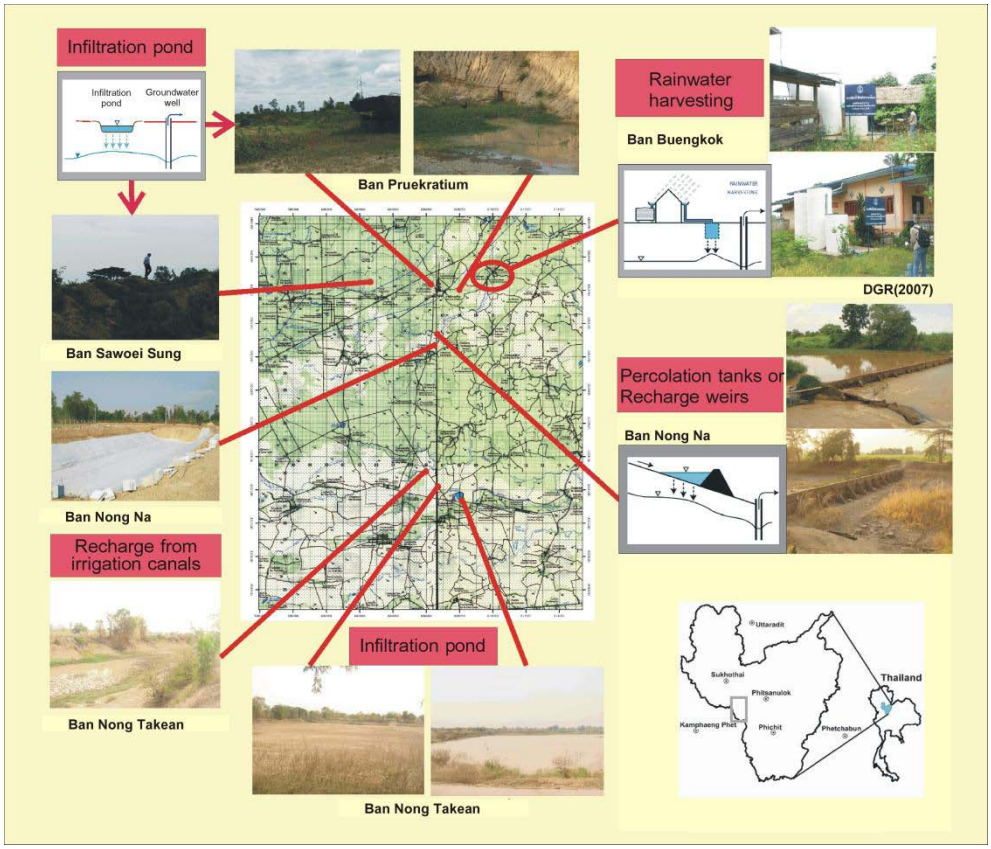

Figure 9. Topographic terrain of the suitable area, with the sand and gravel pits located in the Bangrakam area, Pitsanulok Provinces (Department of Groundwater Resources, 2009).

CONCLUSIONS AND RECOMMENDATIONS

A diverse and complex array of criteria determine the suitability areas for MAR. This study has demonstrated that GIS-based approaches can usefully delineate such areas. Verification of the approach is required by more in-depth site investigations for one or more suitability classes.

The technique described here can also be adapted and employed to determine the suitability other MAR techniques, such as trenching, rainwater harvesting, recharge weir, and Aquifer Storage and Recovery (ASR) in future studies (Figure 9).

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