Assessment of Water Requirement for Agricultural area by Using GIS

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Abstract: Phitsanulok province usually faces problems of flood and drought. The water demand and water supply, analyzed by using GIS, were considered in this study to assess water requirement for Tambols in Phitsanulok. Water demand was crop water requirement whereas water supply was water budget which was calculated from runoff and soil water quantities. Tambols were defined into 2 categories: (1) insufficient water supply and (2) sufficient-excess water supply. The results showed that numbers of Tambol in each groups were 56 (60.22%) and 37 (39.78%) respectively. Thirty seven Tambols having more supply than demand had excess water budget of 263,780,145 m^3/year and 486,665 rais of agricultural area could be increased. Fifty six Tambols having more demand compared to supply lack water budget of 599,071,991 m^3/year and 2,249,696 rais of agricultural area could be suffered from water shortage.
Keyword: Assessment, GIS, Demand-supply Balance, Water requirement

1. Introduction

Water development is necessary for developing countries which have agricultural products as main export goods. The agricultural area in Thailand has been facing both drought and flood problems. Phitsanulok is a province in north of Thailand. This province is also facing such problems. In May 2004, there were 2,792,307 rais of agricultural area in which rice crop and cultivation areas contributed for 2,424,307 rais and 368,000 rais respectively [1]. The main objective of this study was to analyze balance between water demand and water supply in agricultural area and to calculate balance of agricultural water requirement.

2. Study Area

Phitsanulok Province locates in the lower northern Thailand, about 390 km from Bangkok. The total area is approximately 10,815 square kilometers or 6,759,375 rais (1 rai = 0.16 hectare). This province composes of 9 districts (93 Tambols) (Fig. 1).

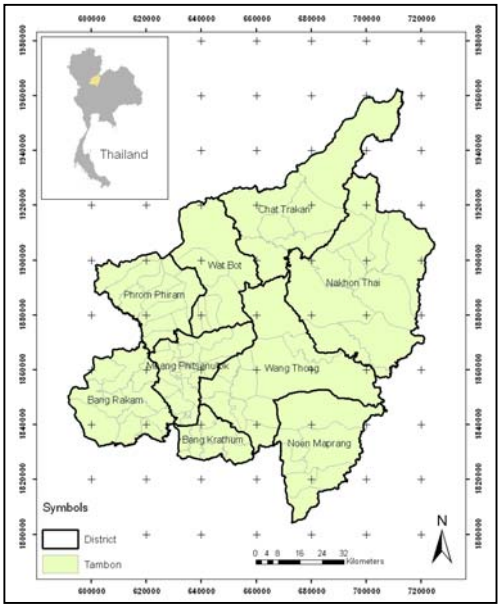


Fig. 1 Study area: 9 districts (93 Tambols) in Phitsanulok province

3. Materials

1) Vector Map of Boundary on a 1: 50,000 scale, produced by the Royal Thai Survey Department.
2) Vector Map of Village on a 1: 50,000 scale, produced by the Royal Thai Survey Department.
3) Vector Map of Soil on a 1: 50,000 scale, produced by the Land Development Department of Thailand.
4) Vector Map of Land use on a 1: 50,000 scale, produced by the Land Development Department of Thailand.
5) Vector Map of Water Resources on a 1: 50,000 scale, produced by the Royal Thai Survey Department.
6) Topographic maps on a 1: 50,000 scale, produced by the Royal Thai Survey Department.
7) Average rainfall (10 years) from 145 stations, produced by The Thai Meteorological Department.
8) Average Evaporation (10 years) from 14 stations, produced by The Thai Meteorological Department.
9) Crop Water Requirement produced by The Royal Thai Irrigation Department.
10) NRD2C Database year 2003 produced by The Thai Ministry of Interior.

4. Methods

1) Water Demand Data:

For this study, water demand was crop water requirement (CWR). CWR was estimated in GIS as following procedures.

1. Join data from Table 1 to land use map, particularly in agriculture area.
2. Select data of rice cropping number per year from NRD2C database.
3. Calculate CWR per year from land use data and number of crop per year, the calculation is shown in eq. (1)

$$\mathbf{CWR = CWR_c \times A \times N} \qquad \textbf{(1)}$$

where "CWR" is crop water requirement (m^3/rai/year), "CWR_c" is crop water requirement per crop (m^3/rai/year), "A" is area (rai), and "N" is number of crop per year.

Table 1. Crop Water Requirement

Crop Type	Crop Water Requirement per crop (m^3/rai/year)
Rice	1,101
Corn	445
Maize	550
Sweet Corn	424
Mung bean	333
Soybean	578
Peanut	582
Sugar cane	1,512

Source: [2]

2) Water Supply Data:

For this study, the water supply data was a summation of runoff and soil water. Each quantity was estimated in GIS as follows;

1. Runoff (R): Runoff was calculated from the 2 methods: 1) calculation from the elevation and 2) calculation from soil type and land cover type, as given in eq. (2) - eq. (5). To calculate runoff from percentage of elevation in GIS, DEM data was created from elevation data and was classified into 4 groups (Table 2).

$$\mathbf{Rc = (\mathit{a} \times P) + \mathit{b}} \qquad \textbf{(2)}$$

$$\mathbf{R_1 = P \times Rc \times A} \qquad \textbf{(3)}$$

where "R_1" is runoff from elevation (m^3/rai/year), "Rc" is runoff coefficient, "P" is rainfall (m^3/year), "*a*" is coefficient of equation, "*b*" is constant, and "A" is area (rai).

Table 2. Runoff Coefficient by using percent of elevation

Type	Slope	a	b
Flat area	0 – 5%	0.1293	- 6.2370
Gentle slope area	> 5 – 15%	0.1293	- 3.0540
Rolling area	>15 – 30%	0.1295	1.4890
Steep area	> 30%	0.1295	5.7160

Source: [3]

Next, SCS Curve Numbers (Table 3) relating to certain soil types and land cover types used to calculate runoff. The calculation are given in eq. (4) and eq. (5)

$$\mathbf{R_2 = ((P - 0.2S)^2 / (P + 0.8S)) \times A} \quad \mathbf{(4)}$$

$$\mathbf{S = (1000/CN) - 254} \quad \mathbf{(5)}$$

where "P" is less than 0.2S, "R_2" is Runoff depth (mm), "P" is rainfall (m^3/rai/year, "S" is maximum recharge capacity of watershed after 5 days antecedent rainfall (mm), "CN" is Curve Number and "A" is area (rai).

Table 3. SCS Curve Numbers

Type	Wasted Land	Vegetation	Rice	Orchards	Pasture	Forest	Community
A (sandy)	77	67	62	60	30	35	58
B (loamy)	86	76	73	72	58	60	73
C (sandy clay loam)	91	83	81	81	71	73	82
D (clay)	94	86	85	84	78	80	86

Source: [3]

Finally, total runoff from the 2 equations was calculated as in eq. (6).

$$\mathbf{R = R_1 + R_2} \quad \mathbf{(6)}$$

where "R" is total runoff (m^3/rai/year)

2. Soil Water (SW): Soil water was calculated by using water balance model (eq. 7). Soil water computed from eq. (7) was an average value within each Tambol in agricultural area.

$$\mathbf{SW = P - (R + D + E)} \quad \mathbf{(7)}$$

where "SW" is soil water (m^3/rai/year), "P" is rainfall (m^3/rai/year), "R" is total runoff (m^3/rai/year), "D" is soil percolation (m^3/rai/year), and "E" is evaporation (m^3/rai/year).

3. Water Budget (WB): Water budget was a summation of runoff and soil water as in eq. (8).

$$\mathbf{WB = R + SW} \quad \mathbf{(8)}$$

where "WB" is water budget (m^3/rai/year)

3) Water Demand-Supply Balance, DSB: the balance between water demand and water supply was calculated in eq. (9) as follow;

$$\mathbf{DSB = WB - CWR} \quad \mathbf{(9)}$$

where "DSB" is balance between water demand and water supply (m^3/rai/year)

4) Assessment of water requirement:

In this study, the area was classified into 2 categories; insufficient water and sufficient- excess water supply. The area where demand is higher than supply grouped as insufficient water supply. Since the water budget was inadequate in the former case, there are few suggestions to deal with this area; one is to decrease the numbers of

cultivation in order to provide sufficient amount of available. The other is changing crop types to ones that require less amount of water.

The area where demand is less than supply was labeled as sufficient-excess water. In this area, there is a potential for water reservoir development because of adequate water budget.

5. Results and Discussion

1) Water Demand: Fig. 2 shows the crop water requirement in agricultural area. Tambol Tha-ngam located in Wat Bot district had the highest average crop water requirement (1,263 m^3/rai/year). Most of the is used for growing sugar cane. Tambol Bo Phak located in Chat Trakan district had the lowest average crop water requirement (58 m^3/rai/year). Most of the area was used for growing sweet corn and maize.

2) Water Supply: Fig. 3 shows runoff volume in the study area. Tambol Wat Ta Yom located in Bang Krathum district had the highest average runoff (1,100 m^3/rai/year). Tambol Khui Muang located in Bang Rakham had the lowest average runoff (128 m^3/rai/year). Fig. 4 shows soil water volume. Tambol Noen Maprang located in Noen Maprang district had the highest average soil water (128 m^3/rai/year). Tambol Khui Muang located in Bang Rakham had the lowest average soil water (1 m^3/rai/year). Fig. 5 shows water budget volume. The highest (1,179 m^3/rai/year) and lowest (131 m^3/rai/year) average water budget volume were found in Tambol Wat Ta Yom (Bang Krathum distict) and Tambol Khui Muang (Bang Rakham district), respectively.

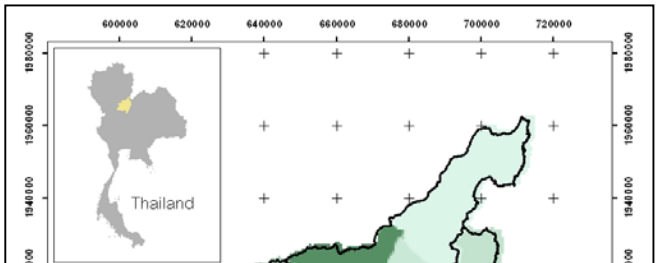
3) Demand-Supply balance: In Fig. 6, there were 37 Tambols where demand was less than supply. Tambol Chat Trakan located in Chat Trakan district had the highest demand-supply balance value (487 m^3/rai/year). In addition, there were 56 Tambols where demand was greater than supply. Tambol Khui Muang located in Bang Rakham district had the lowest demand-supply balance value (-900 m^3/rai/year). Thus, this area tends to have problem of water shortage for crop cultivation.

4) Assessment of water requirement: Fig.7 and 8 shows the assessment of water requirement. From DSB calculation, the 56 Tambols (60.22% of total 93 Tambols) had insufficient water supply as 599,071,991 m^3/year while the 37 Tambols (39.78% of total 93 Tambols) had sufficient-excess water supply as 263,780,145 m^3/year.

In the assessment of water requirement, the 486,665 rais of agricultural area classified as sufficient-excess water supply could be increased. On the other hand, 712,631 rais of agricultural area were considered “insufficient water supply” which could be suffered from water shortage. Table 4 presents amount of insufficient water supply, sufficient – excess water supply, and number of area to increase or decrease in all district for growing crop type.

Table 4. Agricultural areas of insufficient water supply and sufficient-excess water supply

District	Number of Tambols	Insufficient water supply (m^3/year)	Decreased Area (Rai)			Sufficient-excess water supply (m^3/year)	Increased Area (Rai)		
			Only Rice	Only Corn	Only Sugar cane		Only Rice	Only Corn	Only Sugar cane
Chat Trakan	6	7,465,996	6,781	16,778	4,938	35,435,909	32,185	79,631	23,436
Nakorn Thai	11	324,729	295	730	215	83,748,637	76,066	188,199	55,389
Noen Maprang	7	7,420,486	6,740	16,675	4,908	62,468,923	56,738	140,380	41,315
Bang Krathum	9	2,937,889	2,668	6,602	1,943	14,485,344	13,157	32,551	9,580
Bang Rakham	11	164,374,231	149,295	369,380	108,713	2,909,171	2,642	6,537	1,924
Phrom Phiram	12	143,228,666	130,090	321,862	94,728	-	-	-	-
Muang Phitsanulok	20	102,517,632	93,113	230,377	67,803	2,265,075	2,057	5,090	1,498
Wang Thong	11	108,530,179	98,574	243,888	71,779	35,617,749	32,350	80,040	23,556
Wat Bot	6	62,272,184	56,560	139,937	41,185	26,849,337	24,386	60,336	17,757



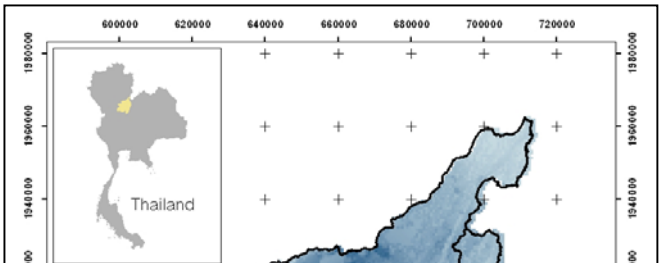


Fig. 2 Crop water requirement calculated from land use map, CWR_c and number of crop per year

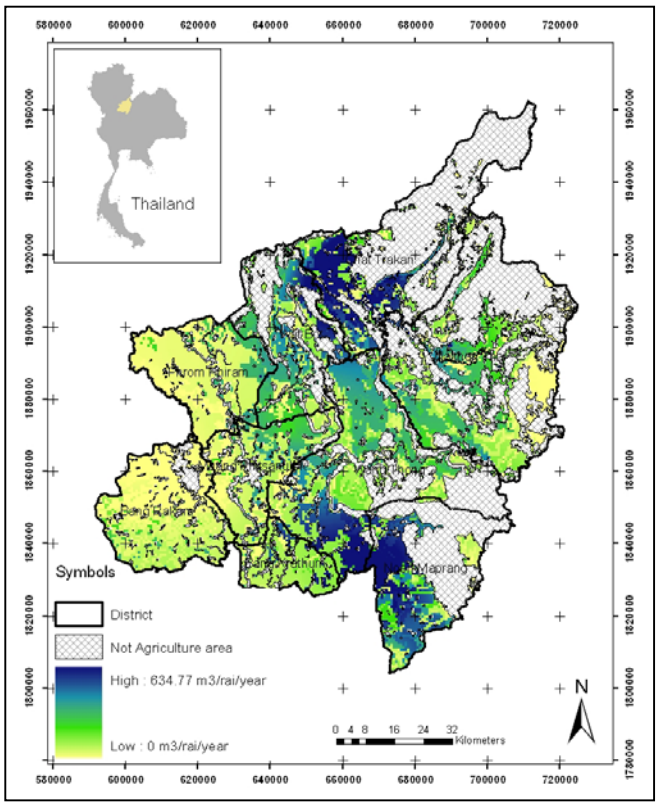


Fig. 3 Runoff calculated from soil type and elevation

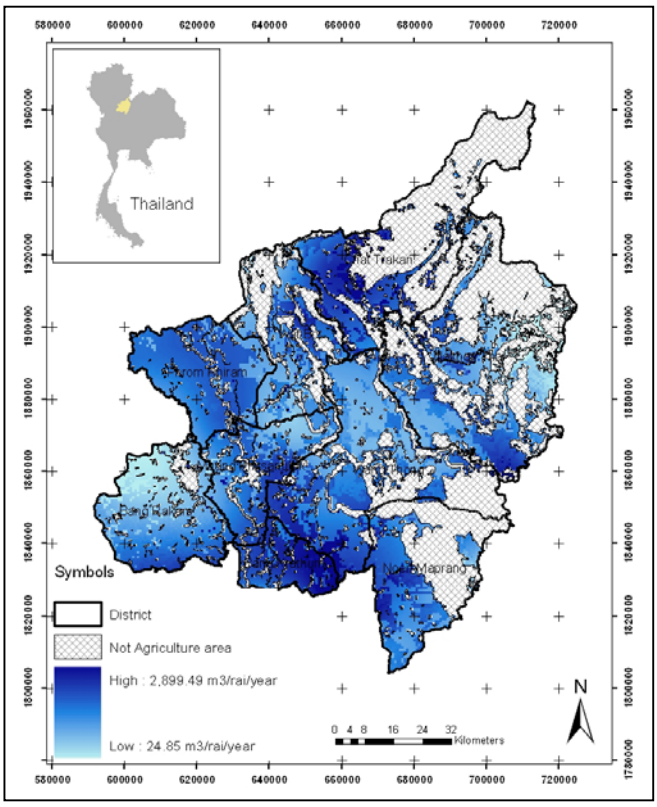


Fig. 4 Soil water content only in agricultural area

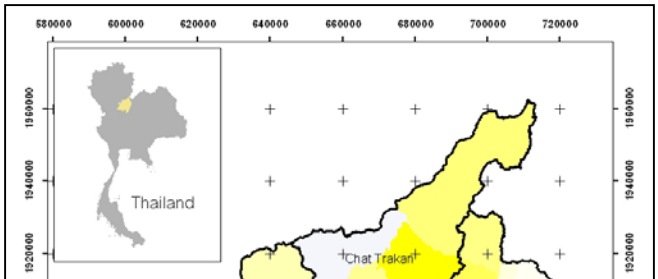


Fig. 5 Water budget calculated from runoff and soil water

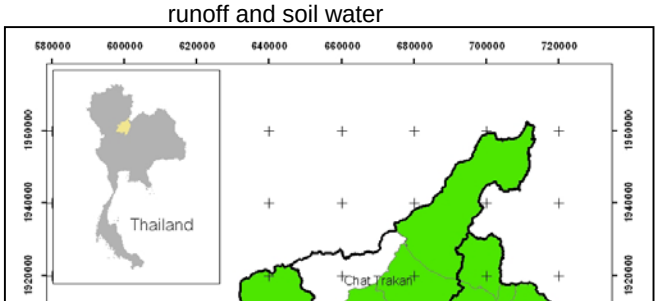


Fig. 6 Water Balance calculated by water budget and crop water requirement

Fig. 7 Assessment results of water requirement in Phitsanulok province

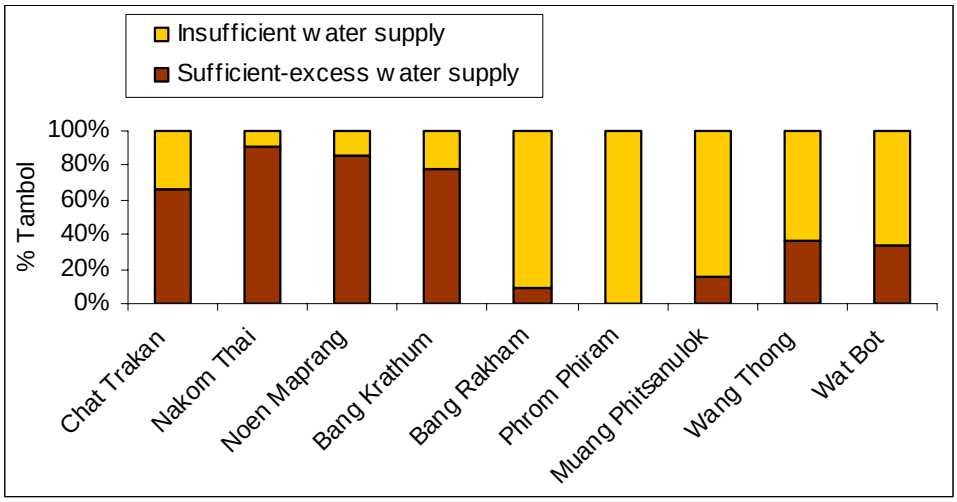


Fig. 8 Percentage from assessment of water requirement by District

6. Conclusion

The assessment result of water requirement by using demand-supply balance was categorized into 2 groups: insufficient and sufficient-excess water supply. From total of 93 Tambols, 56 Tambols (60.22%) were classified as insufficient water supply because these Tambols had demand-supply value as a negative value. The remaining 37 (39.78) Tambols were classified into sufficient-excess water supply with demand-supply balance value ranging form 0 to 487 m^3/rai/year. The result of this study could be used for supporting Tambol in order to make decision on water reservoir development at Tambol's level.

7. References

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