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Land use and hydrologic soil group classification for the Yang River basin in Northeast Thailand

Naroumon Poomkhonsan and Supasit Konyai*

Department of Agricultural Engineering, Faculty of Engineering, Khon Kaen University, Khon Kaen, Thailand, 40002

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Abstract

The Yang River Basin is one of the rarest watersheds in Northeast Thailand that has not been destructively modified by dam construction. The river is always subjected to flood in the rainy season and drought in dry season. To overcome these problems, good river basin management is needed. The most important basic task for good management is to identify geographic feature affecting hydrology of the watershed. The aim of this paper is to present methods to classify land uses and hydrologic soil groups (HSG) of the Yang Basin. Land use and HSG are the two most essential factors for water resource management analyses. Geographic Information System (GIS) was used and guided by the Curve Number, NRCS method. The entire basin can be classified in terms of: Agriculture land, forest land, residential, water resource, irrigation area, meadow, and other area and these classifications were 71.03%, 21.98%, 2.46%, 1.38%, 1.13%, 0.23% and 1.79% respectively. Additionally, the hydrologic soil groups in the whole area have been characterized by using soil texture and soil properties such as hydraulic conductivity and infiltration rate. The HSG of separate group types: A, B, C and D were 27.95%, 12.56%, 52.75% and 6.74% respectively.

Keywords: Geographic information system (GIS), Hydrologic soil groups (HSG), Water resource management

*Correspondent author Tel.: +66 4336 2148; fax: +66 4336 2149

Email address: supako@kku.ac.th

1. Introduction

Land use is an important characteristic of the runoff process that affects infiltration, erosion, and evapotranspiration. Hydrologic models, distributed models in particular, need specific data on land use and it is location within the basin.

In terms of spatial domain, the model can be classified as lumped or distributed model. A lumped model typically assumes that rainfall and hydrologic factors are uniform over the watershed. It might miss some local processes that affect the overall response of the system. To overcome this deficiency, spatially distributed models, in which the watershed is divided into grid cells with spatially specific hydrologic parameters, have been developed [1].

Most of the previous work on adapting remote sensing to hydrologic modeling has involved the Natural Resources Conservation Service (NRCS) runoff curve number (CN) model. This involved using remote sensing data as a substitute for land cover maps which had been obtained by conventional means.

The geographic information system (GIS) is a computer base data tool to display, store, analyze, retrieve and generate spatial and attribute data [2]. The GIS technology provides suitable alternatives for efficient management of large and complex databases. It is used in hydrologic models such as SWAT and MODFLOW model to facilitate processing, measurable watershed area, physical features of the land use and interpretation of hydrologic data. Several studies have been done to incorporate GIS into hydrologic modeling. Land use hydrologic soil groups (HSG) are an important characteristic of surface runoff, infiltration, evapotranspiration, and erosion. Hydrologic models require specific data on land use and its location within the basin.

The objective of this study is to analyze land use interpreted from aerial photographs and compare with that obtained from maps. The entire basin can be classified in this way. In this method, the hydrologic soil groups in the entire area have been determined by using soil texture and soil properties. The HSG of separate group types: A, B, C and D, are obtained.

2. Materials and methods

2.1 The study area

The Yang basin was selected as the study area. It is a sub-watershed of the Chi basin in Northeast, Thailand, and includes portions of five provinces: Mukdahan, Yasothon, Roi Et, Kalasin and Sakon Nakhon. The area of the basin is 4,145 square kilometers (figure 1.) or 2,590,625 acres [3]. The Yang sub-basin comprises 8.38 percent of Chi basin.

The Yang basin is located in the eastern part of the Chi basin. The watershed divide of the Yang basin is in the north of Sakon Nakhon Province. The watershed demarcation then follows the Phu Phan mountain range around the Khao Wong district of Kalasin province. The area from the middle of the basin until the outlet is a flood plain. The elevation of the basin ranges from 100-130m (MSL.) the origin of yang basin is the Kalasin province. The Climate is defined by the southwest and the northeast monsoons.

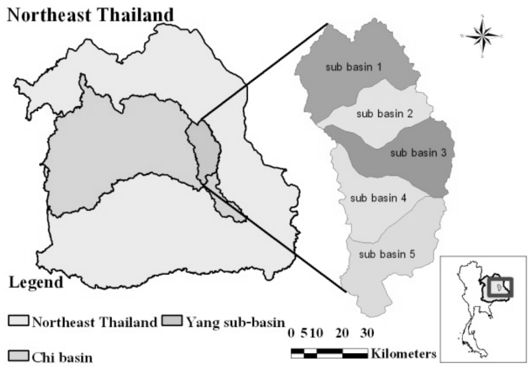


Figure 1 Yang sub-basin of the Chi basin in Northeast Thailand

2.2 Land use classification

Land cover complex classification depends on three factors: land use, treatment, and hydrologic condition. Land use is watershed cover; it includes all agricultural and non-agricultural lands. Land treatment refers mainly to mechanical practices and management practices. The hydrologic condition reflects the level of land treatment and is divided into three classes: poor, fair, and good. The Antecedent Moisture Condition (AMC) is an indicator of watershed wetness and availability of soil storage prior to a storm. Three levels of AMC are used: AMC-I for dry, AMC-II for normal, and AMC-III for wet conditions. NRCS curve numbers for AMC II are shown for various land uses and HSGs in table 1.

2.3 Hydrologic soil group

Soils are classified to indicate the minimum infiltration of bare soil that is thoroughly wetted. The classifications are A, B, C, or D and the four hydrologic soil group (HSG) are defined by the NRCS. Soils in group A have lowest runoff potential, soils in group B have moderately low runoff potential, soils in group C have moderately high runoff potential and group D soils have the highest runoff potential.

Table 2 gives characteristics and minimum infiltration rates for the various HSGs. These values were based on in-situ soil that have an undisturbed profile. The texture of the disturbed soil is described as shown in tables 3 and 4. These tables are used to determine the characteristics of HSGs for Thailand. This method assumes that significant compaction of the soil has not occurred.

2.4 Overlay data

Management Information Systems (MIS) and Geographic Information Systems (GIS) are spatial databases (Spatial Database System) and the descriptive information (Attribute Data System).

GIS is a system designed to collect, store, analyze, search data and show geographic information. It is designed to display information on the basin on computer hardware. In order to do so, there is the ability to import data from a spatial data management system for data processing. Analysis is then undertaken and the results used for decision making [7].

Table 1 Curve number, cn for antecedent soil moisture condition II, AMCII case I_a = 0.2S [4]

Land Use Description		Hydrologic Soil Group			
		A	B	C	D
Cultivated land: without conservation treatment		72	81	88	91
with conservation treatment		62	71	78	81
Pasture or range land: poor condition		68	79	86	89
good condition		39	61	74	80
Meadow: good condition		30	58	71	78
Wood or forest land: thin stand, poor cover, no mulch		45	66	77	83
good cover		25	55	70	77
Open Spaces, lawns, parks, golf courses, cemeteries, etc.					
good condition: grass cover on 75% or more of the area		39	61	74	80
fair condition: grass cover on 50% to75% or more of the area		49	69	79	84
Commercial and business areas (85% impervious)		89	92	94	95
Industrial districts (72% impervious)		81	88	91	93
Residential:					
Average lot size	Average % impervious				
1/8 acre or less	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
Paved parking lots, roofs, driveways, etc.	98	98	98	98	
Streets and roads:					
Paved with curbs and storm sewers	98	98	98	98	
Gravel	76	85	89	91	
Dirt	72	82	87	89	

Table 2 Characteristics and minimum infiltration rates for HSG [5]

Group	Characteristics	Minimum infiltration rate (in/hr)
A	High infiltration rate (low runoff potential); well to excessively drained deep sand or gravel; deep loess; aggregated silts	Greater than 0.30
B	Moderate infiltration rates when thoroughly wetted; moderately deep to deep; moderately well to well drained; moderately fine to moderately course textures; shallow loess; sandy loam	0.105 to 0.30
C	Low infiltration rates when thoroughly wetted; soils with a layer that impedes downward water moment; moderately fine to fine texture; clay loams; shallow sandy loams; soil low in organic content; soils usually high in clay	0.05 to 0.15
D	Very low infiltration rates (high runoff potential) when thoroughly wetted; clay soils with high swelling potential; permanent high water table; clay pan or clay layer at or near the surface; heavy plastic clays; certain saline soils	0 to 0.05

Table 3 Hydrologic soil groups in Thailand [6]

Hydrologic Soil Group (HSG)	Texture Description	Soil Group rate
A (High infiltration)	Sand, Loamy Sand or Sandy Loam	26,27,28,29,30,31, 32,35,36,38,39,40, 43,44,45,46,47,50, 51,52,54,56
B (Moderately high infiltration)	Silt Loam or Silt	33,34,37,41,42,48, 49,53,55,60,61,62
C (Moderately low infiltration)	Sandy Clay or Loam	7,15,17,19,20,21,2 2,24,25
D (Low infiltration)	Clay Loam, Silty Clay, Sandy Clay, Silty Clay , Clay	1,2,3,4,5,6,8,9,10, 11,12,13,14,16,18, 23,57,58,59

Table 4 Texture description for hydrologic soil groups [6]

Group	Texture Description
A	Sand, loamy sand, or sandy loam
B	Silt loam or silt
C	Sandy clay or loam
D	Clay loam, silty clay loam, sandy clay, silty clay, or clay

The system displays the status of water resources and water management for the area. The relationship between water resources and water management in the area presented in the database is divided into three parts: i) a common database which is required to allow the plan to manage water effectively and provide the tools to do that, ii) the geographic information system (GIS), shown in the picture graphic map associated with descriptive information and iii) the database linking the two types data together. This allows users to display both data at the same time [8].

Geographic Information Systems are very well adapted for spatial data organization, visualization, querying, analysis and are very useful in the context of hydrologic simulation and modeling of spatial phenomena (figure 2) (e.g. floods, overland flow, subsurface flow and groundwater flow) [9, 10]. Streamflow and precipitation are the major basin-scale phenomenon in the hydrologic cycle. Streamflow derives integrated results from various upland flow sources in response of rainfall and other water inputs. The large variation and behavior of drainage basins causes difficulties to produce general relationships, to identify and quantify the physical geographic characteristics that result in a simulated hydrograph [11].

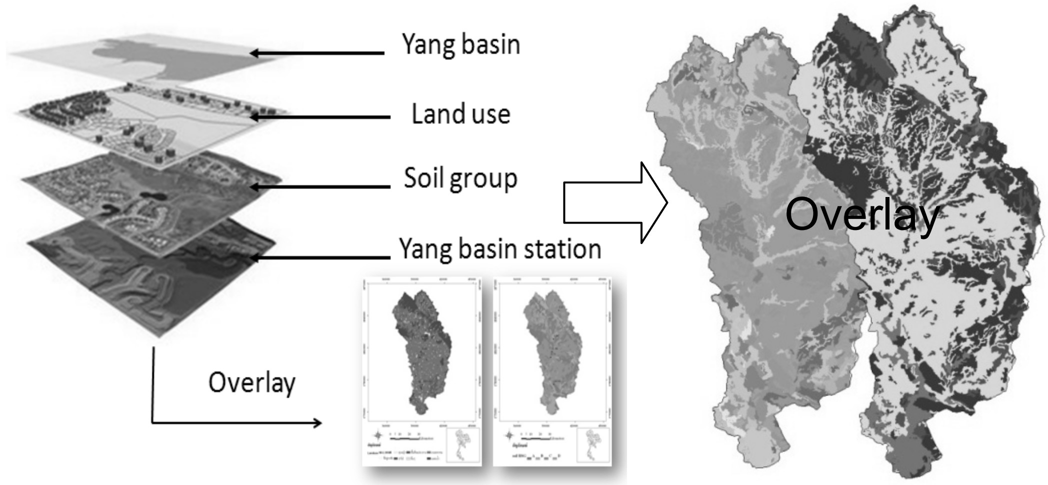


Figure 2 Overlay data method

2.5 Sub basin classification

The distribution of sub basins related to rainfall and runoff stations is shown in figure 3.

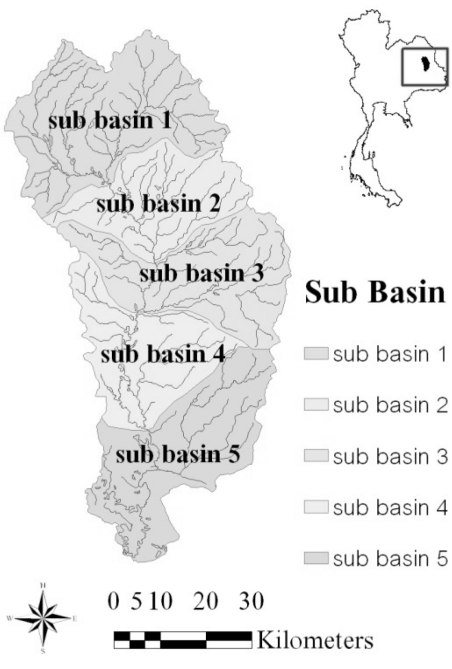


Figure 3 Sub-basin on Yang basin

2.6 NRCS runoff curve number method

In the NRCS runoff equation, the ratio of the amount of actual retention to watershed storage is assumed to be equal to the ratio of actual direct runoff to the effective rainfall [12], [13].

$$Q = \frac{(P-0.2S)^2}{(P+0.8S)} \quad (P > 0.2S) \tag{1}$$

Where; Q = actual direct runoff (mm), P = total rainfall (mm) and S = watershed storage (mm)
The parameter S is related to CN by

$$S = \frac{25400}{CN} - 254 \tag{2}$$

The CN method is able to reflect the effect of changes in land use on runoff. The CN values range between 1 and 100. Higher values of CN indicate higher runoff. The NRCS runoff equation is widely used in estimating direct runoff because of its simplicity, flexibility and versatility.

3. Results and discussion

3.1 Land use

The Yang basin study area is 4,145 square kilometers and a tributary of the Chi basin. The selected rainfall stations were 11053, 11230, 11062, 49062, and 49272, and runoff stations were E.54, E.57, E.70, E.33A, and 042003. They are located in the watershed area and were used for hydrological data collection. The distribution of land use within the basin such as residence, meadow, forest, Irrigation area, agriculture land and other is shown in table 5 and figure 4.

Table 5 Land use in Yang basin

Number	Land use	Area (KM²)	% Area
1	Agriculture land	2948.68	71.03
2	Forest land	912.523	21.98
3	Residential	102.096	2.46
4	Water resource	57.133	1.38
5	Irrigation area	47.009	1.13
6	Meadow	9.525	0.23
7	Other	74.379	1.79
	Total	4151.345	100

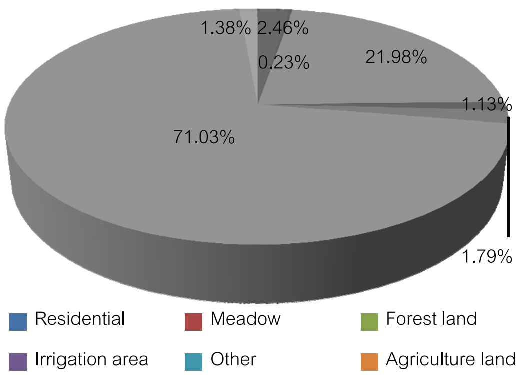


Figure 4 Proportion of land uses in Yang basin

3.2 Hydrologic soil groups (HSG)

There are 20 separate soil groups in the Yang basin, i.e.: 2, 3, 6, 7, 17, 18, 20, 22, 24, 25, 33, 35, 40, 41, 44, 48, 49, 56, 61, and 62 respectively. The percentage area associated with HSGs A, B, C, and D. are 27.95, 12.56, 52.75, and 6.74% respectively as shown in table 6 and figure 5.

Table 6 Hydrologic soil group (HSG)

HSG	Area (KM²)	% Area
A	1160.37	27.95
B	521.47	12.56
C	2189.69	52.75
D	279.81	6.74
Total	4151.35	100

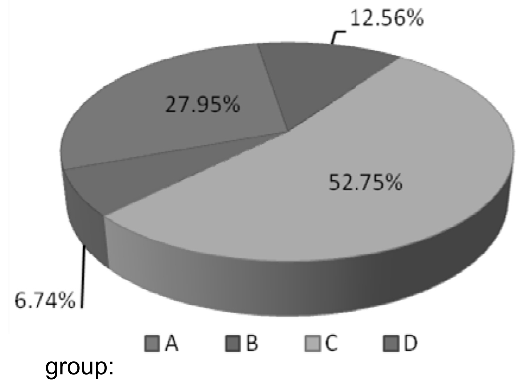


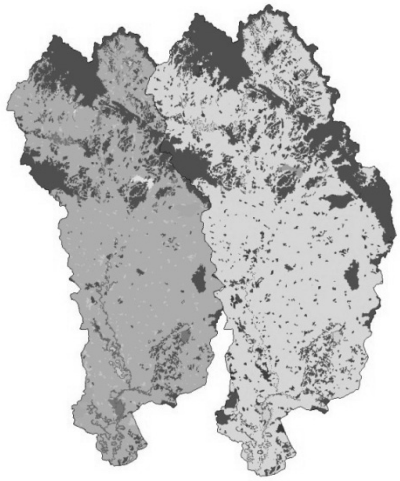
Figure 5 Proportion of HSG in Yang basin

3.3 The data layer and application NRCH method

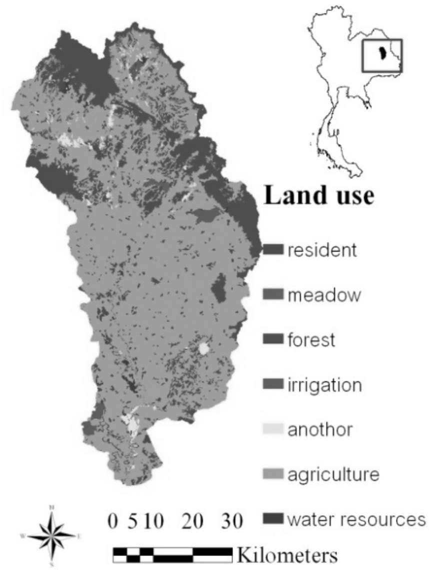
The data in the database developed from all data sources were analyzed in several layers using Arc GIS. These layers were watershed, contour, provinces, district, contour line for rainfall and runoff, forest area, soil group, land use, etc. The layers were used to classify land use and hydrologic soil groups in Yang basin by using Thiessen and NRCS method which are shown in figure 6.

3.4 Sub basin classified

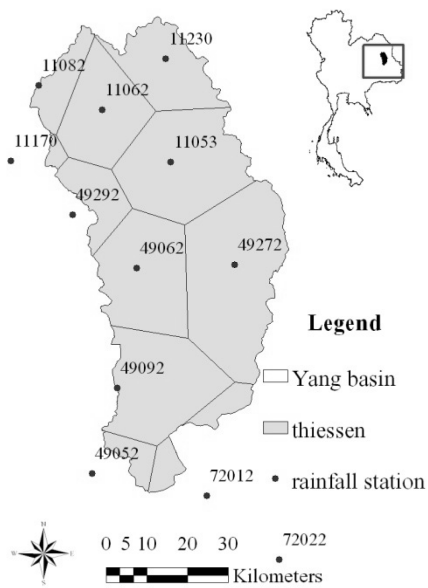
The Yang sub-basin was classified by percentage areas for land use and soil group. For this study, this information was calculated from Hydrologic Response Units (HRU). So this determination depends on land use and soil group for the sub basin. For this sub basin the areas and percent areas for the various land uses and hydrologic soil groups are shown in figure 7 and table 7.



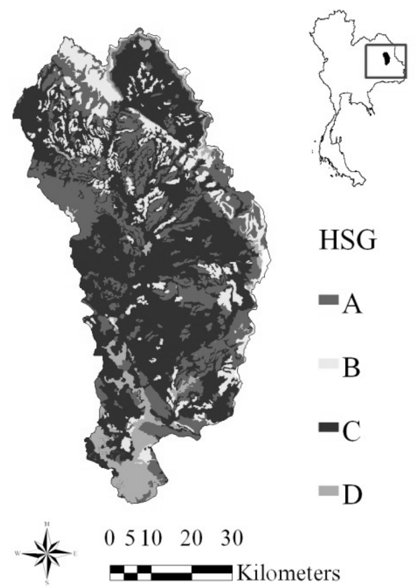
(a) Overlay data in GIS.



(b) Land use in Yang basin.



(c) Average rainfall by Thiessen method.



(d) Soil group in Yang basin.

Figure 6 Classify land use and hydrologic soil group

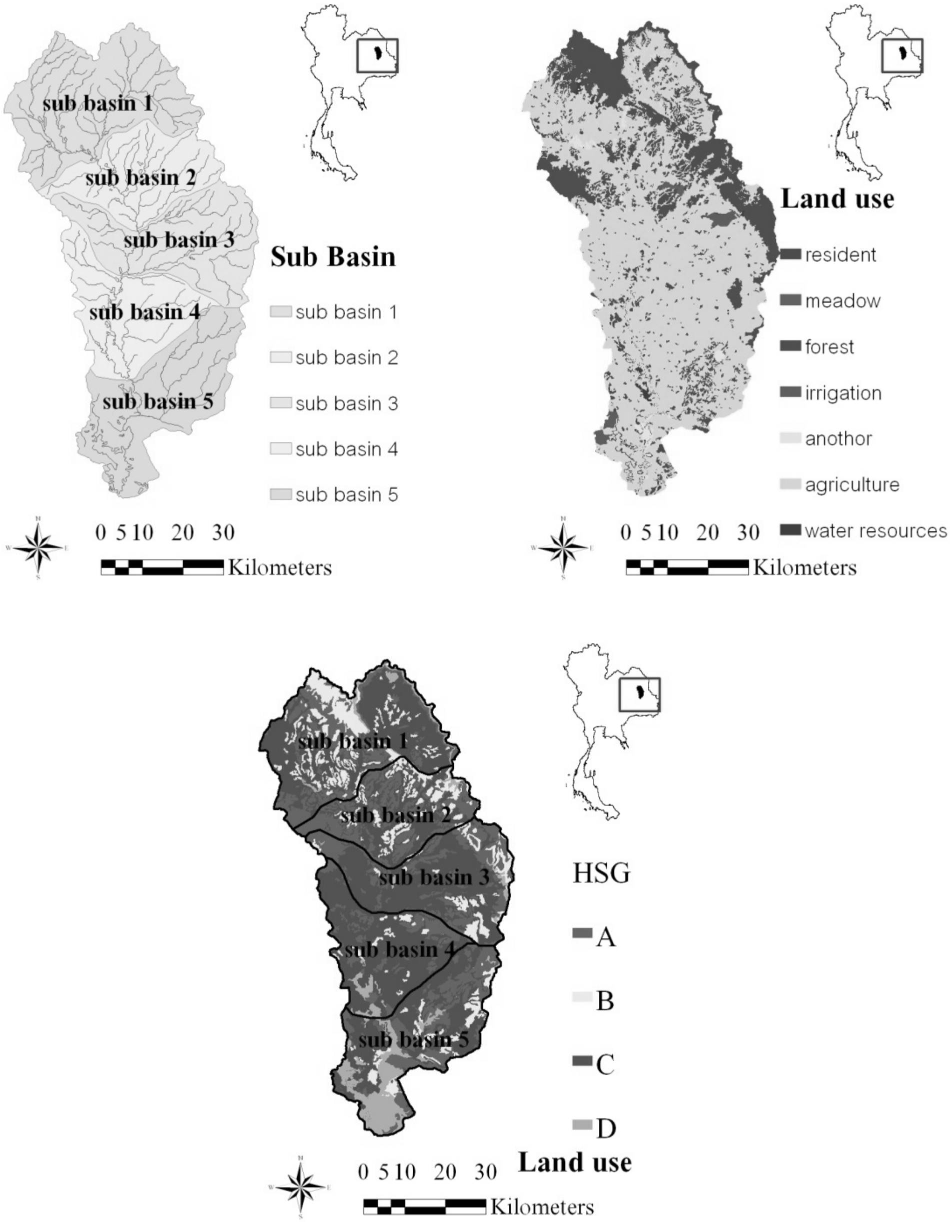


Figure 7 Classify land use and hydrologic soil group of Yang Sub

Table 7 Land use classified and soil group (HRU)

Land use	Sub Basin 1		Sub Basin 2		Sub Basin 3		Sub Basin 4		Sub Basin 5	
	Area (KM^2)	% Area	Area (KM^2)	% Area	Area (KM^2)	% Area	Area (KM^2)	% Area	Area (KM^2)	% Area
Agriculture land	584.90	55.06	343.90	53.47	612.22	77.84	646.09	92.60	761.46	79.25
Forest land	404.38	38.07	267.92	41.66	128.16	16.29	17.15	2.00	94.21	9.80
Residential	17.72	1.67	10.84	1.69	19.64	2.50	25.16	2.46	28.73	2.99
Irrigation area	8.58	0.81	0.00	0.00	18.40	2.34	0.00	0.00	20.02	2.08
Meadow	0.39	0.04	9.03	1.40	0.00	0.00	0.11	0.02	0.00	0.00
Other	35.13	3.31	9.46	1.47	3.34	0.42	0.62	0.09	25.83	2.69
HSG					Soil Group (HRU)					
A	256.78	24.00	276.66	43	228.29	29	130.52	19	267.62	28
B	212.97	20	115.23	18	82.02	10	22.47	3	88.50	9
C	550.78	52	245.24	38	459.75	59	522.48	75	411.43	43
D	41.75	4	5.99	1	16.50	2	22.24	3	193.28	20
Total	1062.28	100	643.12	100	786.55	100	697.70	100	960.83	100

4. Conclusion

The classified land use and hydrologic soil groups in the Yang sub-basin are similar to those of Thailand as shown by the land use and soil group overlay in the geographic information system. The results show land use interpreted from aerial photograph and compared with maps were classified in areas: Agriculture land (71.03%), forest land (21.98%), residential (2.46%), water resource (1.38%), irrigation area (1.13%), Meadow (0.23%), and other (1.79%) respectively. Additionally, the hydrologic soil groups in the whole area have been scrutinized by using soil texture and soil properties. The HSG of separate group types were: A (27.95%), B (12.56%), C (52.75%), and D (6.74) respectively. This data is important for water resource management and design of irrigation systems.

5. Acknowledgements

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