Improvement of soil suitability mapping for teak plantations in Northeast Thailand

Somsak Sukchan[1)*], Iwao Noda[2)]

[1)] Office of Soil Resources Survey and Research, Land Development Department, MOAC, Bangkok 10900, Thailand
[2)] Japan International Research Center for Agricultural Sciences, 1-1 Ohwashi, Tsukuba, Ibaraki 305-8686, Japan
* *Corresponding author; e-mail: somsaksc@hotmail.com*

Abstract

This study aimed to improve soil suitability mapping for teak (*Tectona grandis*) plantation in northeast Thailand. The study areas were in Udon Thani and Nong Bua Lam Phu Provinces. We checked soil properties and classified teak growth class by field surveys, and compared the soil suitability class with the teak growth class. The soil suitability classes were revised from three classes to five classes. The results of Udon Thani Province showed that moderately suited areas accounted for 42.3% (462,086 ha) mostly in the east part of Province, and not suited area 23.6% (257,626 ha) mainly in the central part. Nong Bua Lam Phu Province showed that moderately suited and more suited areas accounted for 37.4% (151,524 ha) mainly in north and central part of Province, and unsuited areas 29.1% (118,046 ha) mostly in the south part. But the ratio of suited areas was supposed higher in Nong Bua Lam Phu Province, due to more mountain area than Udon Thani Province.

The map accuracy was investigated by comparing the revised soil suitability class from soil group with actual teak growth class, and resulted that 20 sites were accord (69 %), five sites were underestimated (17 %) and four sites were overestimated (14 %). The map accuracy remained at 69 % to be acceptable. The farmer's management was supposed as an important factor, which affected to raise the teak growth class than corresponding to the revised soil suitability class.

Keywords: teak plantation, site suitability, soil group, mapping, farmer

Introduction

Teak is the well-known and valuable timbers of the world (White 1992; Kaosa-ard 1998; Robertson 2002 etc.) Its timber qualities include attractiveness in color and grain, durability, lightness with strength, ease of seasoning without splitting and cracking, ease of working and carving, resistance to termite, fungus, and weathering, etc.(Kaosa-ard 1998). Teak plantations have been widely established throughout the tropics with the main objectives to produce high quality timber. However, there are many factors limiting the success of teak plantation establishment, especially three main factors of site quality, seed supply and silvicultural management, affect growth and quality of the plantation (Kaosa-ard 1998).

On the basis of previous studies, Kaosa-ard (1998) said that teak grows best on deep, well-drained alluvial soils derived from limestone, schist, gneiss, shale. The species performs very poorly, in terms of growth and stem form, on dry sandy soil, shallow soil, acidic soil derived from laterite or peat bog, and on compacted or waterlogged soil (Kaosa-ard 1981 etc.). Roots were stunted and the taproot was very poorly developed in waterlogged alluvial soils and clay soils (Kadambi 1972). Teak requires relatively large amounts of calcium for its growth and development. Also soil pH is another factor limiting the distribution and stand development of the species, the optimum pH range for better growth and quality is between 6.5-7.5 (Seth and Yadav 1959; Kaosa-ard 1981; Tewari 1992). Teak can grow naturally over a wide range of climatic condition, but annual rainfall is required between 1,200 and 2,500 mm with a dry season of 3-5 months, for high quality wood production with optimum growth (Kaosa-ard 1981; Keogh 1987).

Sukchan and Sakai (2009) classified the soil suited for teak plantation in Udon Thani, Nong Bua Lam Phu and Buri Ram Provinces on the basis of soil properties; sub-soil texture, drainage, soil depth, pH, and fertility, from the soil group map (Land Development Department (LDD) 2004). However, Sukchan and Sakai (2009) showed that some suitability classes were required to be improved after some cross-checks in the field, and the soil suitability classes were recommended to do field checking and reclassifying. Therefore, this study aimed to improve the soil suitability

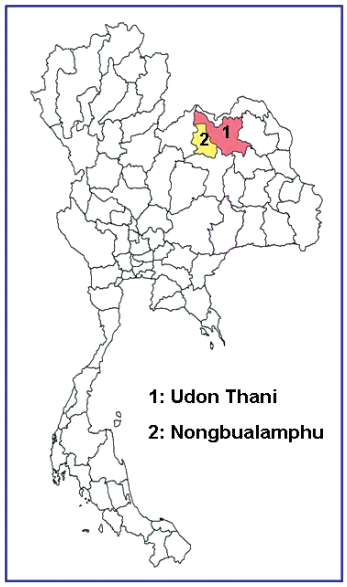

Fig. 1. Location of Udon Thani and Nong Bua Lam Phu Provinces

mapping for teak plantation in northeast Thailand.

Materials and methods

1. Study area

The study areas were Udon Thani and Nong Bua Lam Phu Provinces located in upper northeast of Thailand. Udon Thani Province is located in Khorat Plateau, northeast region of Thailand, between Khon Kaen Province in the south and Nong Khai Province in the north (Fig. 1). The area is 11,730.3 km^2 between N16^o 45' – N18^o 10' and E 102^o 00' – E103^o 30'. Mean annual rainfall is approximate 1520 mm and mean annual temperature is 26.1^{o}C. Three seasons are rainy season (May – October), cold season (November – February), and summer season (March – April). Nong Bua Lam Phu Province is located in the west part of Udon Thani (Fig. 1). The area is 3,859 km² between N16^o 43' – N17^o 39' and E101^o 58' – E102^o 42'. Annual rainfall ranges from 1,016 to 1,844 mm (1995-2002), and mean annual temperature is 26.7^{o}C.

2. Soil in the study area

From soil group map data (1:50,000), The Udon Thani has 33 soil groups and 66 soil groups association (as mapping unit 35/24). The Nong Bua Lam Phu has 20 soil groups and 66 soil groups association. Soil group no. 1 – 13 and no. 59 are low land clayey soil, no.16 – 25 are lowland salty, loamy and sandy soil. Soils are mostly poorly drained. Soil group no. 28 – 31 are upland clayey well drained soil, no. 33 – 38 are upland fine loamy well drained soil, no. 40 – 44 are upland coarse-loamy and sandy well drained soil, no. 45 – 61 are upland shallow soil, no. 54 is upland alkaline soil and no. 62 is mountainous areas. The details of each soil group are in Table 1.

Table 1. Soil group properties in Udon Thani and Nong Bua Lam Phu Provinces

Soil group	Subsoil Texture	Drainage	Soil depth	pH	Fertility
1	C	PD	deep	6.0 – 7.5	moderate
2	C	PD	deep	4.5 – 5.5	moderate
3	C	PD	deep	7.5 – 8.0	moderate
4	C	PD	deep	7.0 – 8.0	moderate
6	C	PD	deep	4.5 – 5.5	low
7	C	PD	deep	6.0 – 7.0	moderate
9	C	PD	deep	7.0 – 8.5	low
13	C	PD	deep	7.0 – 8.0	low
16	Sil	PD	deep	5.0 – 6.0	low
17	SCL	SWPD	deep	4.5 – 5.5	low
18	SCL	PD	deep	6.0 – 7.0	low
20	SCL	PD	deep	6.0 – 7.0	low
21	L	MWD	deep	5.5 – 7.0	moderate
22	SL	PD	deep	4.5 – 5.5	low
24	S	SWPD	deep	5.5 – 6.5	low
25	SL/C	SWPD	shallow	4.5 – 5.5	low
28	C	WD	deep	7.0 – 8.0	moderate
29	C	WD	deep	4.5 – 5.5	low
31	C	WD	deep	5.5 – 6.5	moderate
33	Si/L	WD	deep	5.5 – 6.5	moderate
35	SCL	WD	deep	4.5 – 5.5	low
36	CL	WD	deep	6.0 – 7.5	low
38	L	WD	deep	5.0 – 7.0	moderate
40	SL	WD	deep	4.5 – 5.5	low
41	LS	WD	deep	4.5 – 5.5	low
43	S	WD	deep	5.5 – 7.0	low
44	LS	WD	deep	5.5 – 7.0	low
45	gC	WD	shallow	4.5 – 5.5	low
46	gC	WD	shallow	5.5 – 6.5	low
47	gC	WD	shallow	5.0 – 7.0	low
48	gSL	WD	shallow	5.0 – 6.0	low
49	gC	MWD	shallow	5.0 – 6.5	low
54	C	WD	moderate	8.0 – 8.5	moderate
56	gSL	WD	moderate	5.0 – 6.0	low
59	C	PD	deep	5.0 – 6.0	low
60	LS	WD	deep	5.0 – 6.0	low
61	Sl	WD	shallow	4.5 – 5.5	low
62	-	-	-	-	-

Remarks) Subsoil texture is shown as C : Clay, SiL : Silt Loam, CL : Clay Loam, SCL: Sandy Clay Loam, SL : Sandy Loam, LS : Loamy Sand, gC : gravelly Clay, gSL : Gravelly Sandy Loam. Drainage is shown as PD: Poorly Drained, SWPD : Some What Poorly Drained, WD: Well Drained, MWD: Moderately Well Drained.

3. Methods

We collected the data of soil group map and soil suitability map for teak plantation in Udon Thani and Nong Bua Lam Phu Provinces, and also collected the teak plantation sites position data from Royal Forest Department (RFD). The soil suitability maps (Sukchan and Sakai 2009) were overlaid with teak plantation sites for selecting observation plantations. In field observations at teak plantations, we observed teak growth class by dominant tree height and trees stem features. We collected three soil samples per site by depth using an auger. The field observations were done in rainy season (July and August, 2010) at 29 sites. We observed the landform and soil

properties to describe actual soil features of limitations, and reclassified the relationship between the actual soil features and teak growth class to revise the soil suitability. The revised soil suitability classes for teak plantation from soil groups were mapped for Udon Thani and Nong Bua Lam Phu Provinces. Finally, the accuracy was investigated by comparing the revised soil suitability class by the field observation with the actual teak growth class.

Result and discussion

1. Reclassification of soil suitability classes for teak plantation

Due to lack of information for soil suitability of teak plantation in Udon Thani, Sukchan and Sakai (2009) applied for teak plantation, the set of soil suitability classification which LDD (1990) had made from other economic crop trees information and information on soil survey. The soil properties which were considered for soil suitability were subsoil texture, drainage, soil depth, soil pH and natural soil fertilities. Sukchan and Sakai (2009) classified the soil suitability into three classes as well suited, moderately suited, and unsuited. However, from our field surveys in Udon Thani, Nong Bua Lam Phu and Loei Provinces, we found that soil suitability classes should be extended from three classes to five classes for better estimation as follows;

1: Soil very well suited,
2: Soil well suited,
3: Soil moderately suited,
4: Soil poorly suited,
5: Soil unsuited.

The soil suitability class was denoted with the rank of classes and the limitation of soil, according to LDD (1990). We used the limitations of LDD (1990) in the same way as Sukchan and Sakai (2009);

a : slightly acid,
d : drainage problem or too wet,
f : flood problem,
g : gravel mixed in soil or shallow soil,
n : nutrient status,
s : soil texture is not suited as very sandy soil or low natural fertilities.

The limitation shows inadequate feature up until next superior soil suitability class. For example, 2n means that the soil suitability class could advance to the 1st class, if the soil didn't have nutrient status problem.

In the field, we evaluated a teak growth class as an expert score of a survey team (1 : very good, 2 : good, 3 : moderate, 4 : poor and 5 : very poor). We revised the old suitability three classes; 1, 1a, 2d, 2g, 2s, 3d, 3g, 3f, SC, W, with five classes. Each class of soil suitability was set to correspond to two classes of the teak growth. Relationship between the revised soil suitability class and teak growth class was set as Table 2. No soil group accounts for mountain area of SC and water body of W, because soil group data was historically made for cash crops cultivation on agricultural lands.

Table 2. Relationship between the revised suitability class and teak growth class

Revised soil suitability class	Teak growth class	Remarks
1	1-2	
2n	2-3	
3d	3-4	
3g	3-4	
3s	3-4	
4d	4-5	
4g	4-5	
5f	5	
SC	-	Mountain area
W	-	Water body

The representative soil series for each soil suitability class in Udon Thani, Nong Bua Lam Phu Provinces were as follows;

1 : very well suited soil, representative soil series were Loei series (Lo), Wanghi series (Wi), Chieng Mai series (Cm), Tha Muang series (Tm), Si khu series (Si),

2n : well suited soil, but soil pH slightly low for teak; representative soil series were Korat series (Kt), Satuk series (Suk),Warin series (Wn), Yasothon series (Yt), Pakchong series (Pc), Chokchai series (Ci),

3s : moderately suited soil with limitation that soil texture was not suited as very sandy soil or low natural fertilities; representative soil series were Chum Puang series (Cpg), Chakkarat series(Ckr), Ban Phai series (Bpi), Mahasakham series (Msk), Nampong series (Ng),

3g : moderate suited soil with limitation of gravel mixed soil or shallow soil in; representative soil series are Chieng Khan series (Ch), Phon Pisai series (Pp), Sakon series (Sk), Phon Ngam series (Png), Lat Ya series (Ly),

4g : poor suited soil with limitation of bedrock or thick gravel mixed in soil; representative soil series were Tha Yang series (Ty), Mae Rim series (Mr),

4d : poor suited soil with limitation of drainage or wet for teak; representative soil series were Ubon series (Ub), Phen series (Pn),

5f : non suited soil with limitation of flooding; representative soil series were Buri Ram series (Br), Pimai series (Pm), Ratchaburi series (Rb), Chum Saeng series (Cs), Nakhorn Panom series (Nn), Roi Et series (Re), Renu series (Rn), Kula Ronghi series (Ki), Udon series (Ud) (LDD 2004).

The legend of soil suitability class followed the association system the same as soil group map. The legend of soil group map is sometimes built up with association of the soil groups (LDD 1990). For example, the associated soil groups 31/49 means soil group 31 associated with 49. It means they can't separate to single unit due to the limitation of map scale etc., but the front soil group 31 is dominant.

Table 3. Area of soil suitability classes for teak plantation in Udon Thani Province

Revised soil suitability class	Area (ha)	%	Remark
1	5,853	0.5	21,009 ha
1/3g	14,825	1.4	1.9%
1/3s	10	0.0	
1/4g	321	0.0	
2n	36,552	3.3	132,005 ha
2n/3g	8,347	0.8	12.1%
2n/3s	86,603	7.9	
2n/4g	93	0.0	
2n/5f	410	0.0	
3g	234,090	21.4	462,086 ha
3s	213,609	19.6	42.3%
3s/3g	11,358	1.0	
3s/4g	3,029	0.3	
4d	60,385	5.5	130,443 ha
4d/3g	33,366	3.1	12.0%
4g	36,682	3.4	
5f	247,524	22.7	257,626 ha
5f/2n	728	0.1	23.6%
5f/3g	2,223	0.2	
5f/3s	7,151	0.7	
SC	12,254	1.1	Mountain area
W	76,059	7.0	Water body
Total	1,091,475	100.0	

Table 4. Area of soil suitability classes for teak plantation in Nong Bua Lam Phu Province

Revised soil suitablility class	Area (ha)	%	Remark
1	2,689	0.7	7,816 ha
1/3g	5,127	1.3	1.9%
2n	13,272	3.3	77,316 ha
2n/3g	35,061	8.7	19.1%
2n/3s	26,376	6.5	
2n/4g	2,607	0.6	
3g	23,001	5.7	66,392 ha
3g/4g	16,575	4.1	16.4%
3s	19,445	4.8	
3s/3g	5,171	1.3	
3s/4g	2,200	0.5	
4d	2,441	0.6	85,754 ha
4d/2g	473	0.1	21.2%
4d/3g	50,986	12.6	
4g	31,854	7.9	
5f	98,383	24.3	118,046 ha
5f/2n	5,860	1.4	29.1%
5f/3g	543	0.1	
5f/3s	12,218	3.0	
5f/4d	1,042	0.3	
SC	40,719	10.0	Mountain area
W	9,270	2.3	Water body
Total	405,311	100.0	

We interpreted that the soil group 31 and 49 were related to the soil suitability class 1 and 3g, respectively. Therefore, the soil suitability 1/3g meant the association of two classes, and the class 1 was dominant.

2. Mapping of soil suitability class for teak plantation

As for Udon Thani Province, the results showed very well suited areas were 21,009 ha (1.9 %) in the northwest part of Province as Na Yung and Nam Som Districts (Table 3). Well suited areas were 132,005 ha (12.1 %) mainly in Kudchab, Nong Wua So, Nong Saeng and Wang Sam Mo Districts. Moderate suited areas were 462,086 ha (42.3 %). Poorly suited areas were 130,443 ha (12.0 %) and unsuited areas were 257,626 ha (23.6 %) as detail in Table 3 and Fig. 2. Mountain area and water body were 1.1 % and 7.0 %, respectively.

As for Nong Bua Lam Phu Province, the results showed very well suited areas were 7,816 ha (1.9 %) in the northwest part of the Province as Suwan Khuha District (Table 4). Well suited areas were 77,316 ha (19.1 %) mainly in Na Klang, Si Bun Ruang and Mueang Districts. Moderately suited areas were 66,392 ha (16.4 %). Poorly suited areas were 85,754 ha (21.2 %), and unsuited areas were 118,046 ha (29.1 %) as detail in Table 4 and Fig. 3. Mountain area and water body were 10.0 % and 2.3 %, respectively. In general, teak can grow better on slope area than flat area. Therefore, the mountain area must be potentially suitable for teal plantations, and Nong Bua Lam Phu was supposed to be higher ration of soil suited soil classes than the Udon Thani, if we involve the mountain area.

3. Accuracy test of soil suitability for teak plantation

We compared the revised soil suitability class with actual teak growth class (Table 5). The revised soil suitability class was evaluated by the field observation. The result of comparison showed that 20 sites were accord (69 %), five sites were underestimated (17 %) and four sites were overestimated (14 %). The detail of comparisons was shown in Table 3. From interviews with farmers, teak plantations managed with watering or fertilizing etc. showed better teak growth class than the revised soil suitability. Therefore, the teak management was supposed to be an important factor which affected to raise teak growth class than corresponding to the soil suitability class.

Conclusion

The soil suitability classes for teak plantation in northeast Thailand were classified into five classes as soil

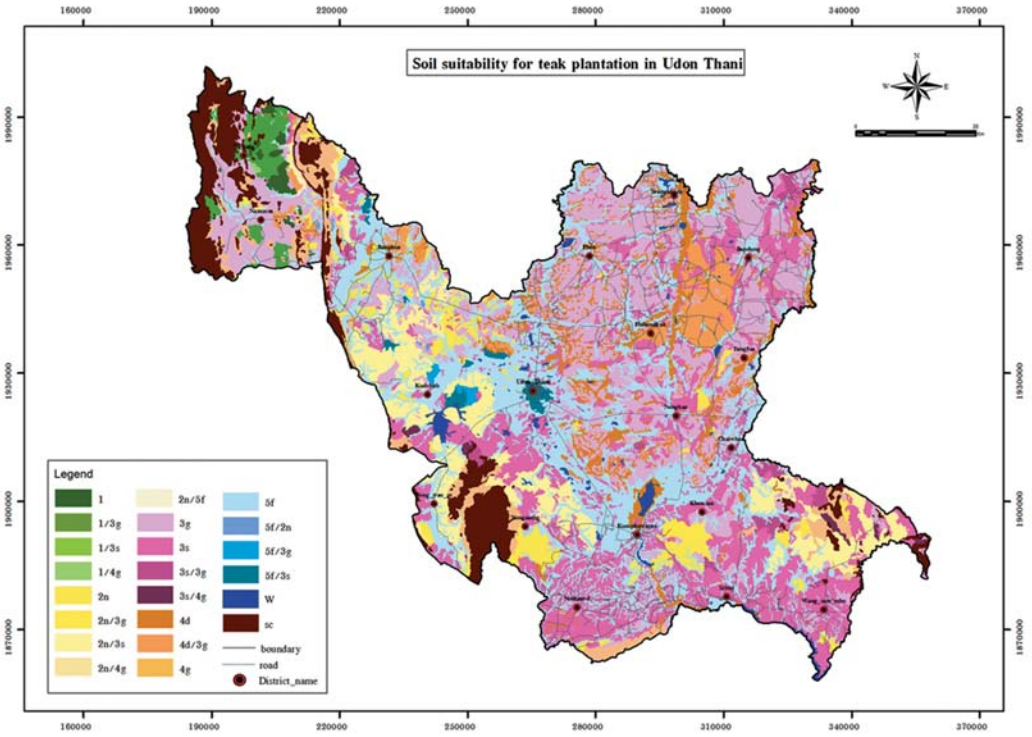

Fig. 2. Revised soil suitability map for teak plantation in Udon Thani Province

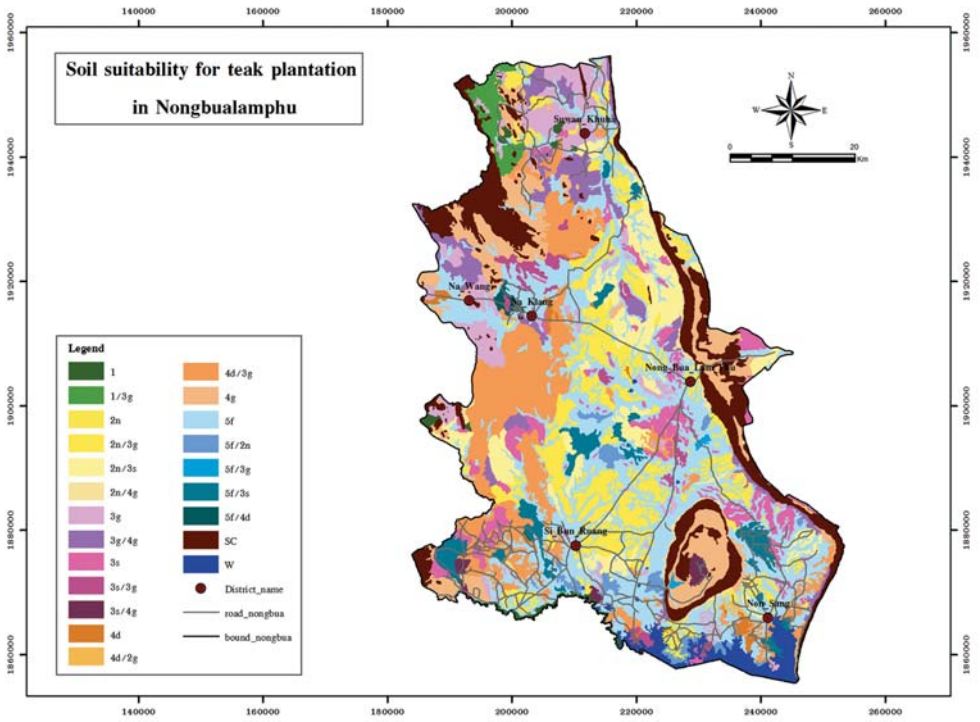

Fig. 3. Revised soil suitability map for teak plantation in Nong Bua Lam Phu Province

Table 5. The comparisons of the revised soil suitability class with actual teak growth classes

No.	Observed sitecode	Revised soil suitability class	Actual teak growth class	Result of comparison
1	NS1	1	1-2	accord
2	NS2	3g	2-3	accord
3	NS3	3g	2-2.5	underestimated
4	NS4	3g/4d	4	accord
5	NS5	3g	2-2.5	underestimated
6	NS6	3g	3-3.5	accord
7	NS7	3g	3.5-4	accord
8	NY1	SC	1-2	accord
9	NY2	1/3g	2-2.5	accord
10	NY3	1/3g	3	accord
11	NY4	3g	3-3.5	accord
12	NS9	3g	3.5-4	accord
13	BP1/1	4d/3g	4.5-5	accord
14	BP2	2n/3g	1-2	accord
15	Nbm5	2n	3.5	overestimated
16	Nbm6	2n	4	overestimated
17	Nbm7	5f	3-4	underestimated
18	Nbm8	5f	2-2.5	underestimated
19	Nbm4	3s/3g	5	overestimated
20	Nbm3	3s/3g	4	accord
21	Nbm2	5f	4.5-5	accord
22	Nbm1	2n/3s	5	overestimated
23	Nb s1	1/3g	1-1.5	accord
24	Nb s2	1/3g	2	accord
25	Nb s3	1/3g	3-4	accord
26	Nb n1	4d/3g	3	accord
27	Nb n2	4g	4	accord
28	Nb n3	5f/4d	4	accord
29	Nb n4	5f/4d	1	underestimated

very well suited, soil well suited, soil moderately suited, soil poorly suited and soil unsuited. We conducted the map accuracy test by the comparisons of the revised soil suitability with teak growth class. As the result, 69 % was accord, 17% was underestimated, and 14% was overestimated.

This study selected two Provinces in upper parts of northeast Thailand. The areas were not the representative of whole northeast. Also teak plantation management was supposed to be a significant factor affecting on teak growth with the exception of the revised soil suitability class. Another study should be conducted to survey and take samples from middle and south parts of northeast for more complete conclusion covering the whole northeast region.

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Reference

Kadambi K (1972) Silviculture and management of Teak. Bulletin 24, School of Forestry Stephen F. Austin State University Nacogdoches, Texas

Kaosa-ard A (1981) Teak (*Tectona grandis* L.f.) - Its natural distribution and related factors. Natural History Bulletin of the Siam Society, 19: 55-74.

Kaosa-ard A (1998) Overview of problems in teak plantation establishment. *In*: Teak for the Future - Proceedings of the Second Regional Seminar on Teak. FAO, pp 49-60

Keogh R (1987) The Care and Management of Teak (*Tectona grandis* L.f.) Plantations. Universidad Nacional, Heredia, Costa Rica

Land Development Department (1990) Report of land use for economic crops in Udon Thani Province (in Thai). Technical Number 153, Soil survey and classification division, Land development department, MOAC, Bangkok

Land Development Department (2004) Characterization of Established Soil Series in the Northeast Region of Thailand Reclassified According to Soil Taxonomy 2003 .Technical Number 552, Office of soil survey and land use planning, Land Development Department, MOAC, Bangkok

Robertson B (2002) Growing Teak in the Top End of the NT. Agnote. No. G26: 1-5

Seth SK, Yadav JPS (1959) Teak soils. Indian Forester, 85 (1): 2-16

Sukchan S, Sakai M (2009) Mapping of suitable soil for teak plantation in Udon Thani, Nong Bua Lam Phu and Buri Ram provinces. Report of RFD-JIRCAS joint research project, 6 pp

Tewari DN (1992) A monograph on teak (*Tectona grandis* Linn. f.). Dehra Dun, India, International Book Distributors

White KJ (1991) Teak. Some aspects of Research and Development. FAO Regional Office for Asia and the Pacific (RAPA), Bangkok