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Research Paper

Effect of forest ecosystem on soil properties: A case study in the Royally-Initiated Khao Cha-Ngum deteriorated area development project, Thailand

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Abstract

This study aims to evaluate the effect of forest ecosystem on soil properties in a natural reforestation area of Thai Royally-Initiated Khao Cha-Ngum deteriorated area. The forest ecosystem has changed tremendously over 20 years. It changed from degraded forests to dry dipterocarp forests (flat ground and south) and mixed deciduous forests (north, east and west). Soil in the west is different from others because tree species in the west aspect area is more diverse than others. It has equal accumulation of organic matter throughout the soil profile; whereas the accumulation of organic matter of others is in A horizon. Mineral composition of the south, east and west soils contained goethite indicating that these soils were more humid than the flat ground and north soils. Soil micromorphological characteristics indicated that all soils had highly activities of soil organisms. Natural reforestation for a long time has a distinct effect on soil formation in relation to the variety of trees because trees affect the soil moisture, quality and quantity of the litter.

Keywords: Secondary forest succession; Abandoned farmland; Tree species; Forest soils; Soil organic carbon

Introduction

Around fifty years ago, an enormous amount of total deforestation occurred in Khao Cha-Ngum district. Farmers used these lands for an intensive agriculture. The lands had turned to be a low productivity land, then these degraded farmlands were abandoned. Some farmers designed to give these damaged lands to His Majesty The Late King Bhumibol Adulyadej. He has assigned relevant government agencies, included Land Development Department, to improve degraded soil constituting on area 139 ha in Khao Cha-Ngum district, Ratchaburi province since 1986. Over the last few decades, natural reforestation has replaced this abandoned agricultural land. Agricultural land abandonment causes a momentous change of biodiversity and landscape features. Forest succession refers to changes in plant species composition of an area with a constant climate over a period of time (Finegan, 1984). Tree species composition, biomass, diversity and productivity are generally considered factors in a forest succession (Connell and Slatyer, 1977). The secondary forest succession has concrete effects in the long term as forest affects soil properties (Benayas *et al*., 2007). It is capable of improving soil health due to root system action and organic matter addition by litterfall. The processes of the carbon cycle consist of litterfall and root turnover (Sharma and Sharma 2004; Andivia *et al*., 2016). Carbon accumulation mechanisms in forest soil depend on tree species composition due to quantity and quality above and below ground litter inputs (Berg, 2000; Hansson *et al*., 2013). The litter decomposition and recycling of nutrients made soil physico-chemical and biological properties suitable for plant growth (Sharma and Sharma, 2004). The multi-species are more promote soil carbon sequestration than mono-specie (Augusto *et al*., 2015). This study aimed to evaluate the effect of natural reforestation and soil properties in The Royally-Initiated Khao Cha-Ngum deteriorated area development project area where agricultural land has been abandoned and overgrown by trees and bushes.

Materials and Methods

The study area was located at the pavilion in the project area of the Royally-Initiated Khao Cha-Ngum deteriorated area development project, Thailand. The studied area ranges in altitude at 85 above mean sea level, in mean annual temperature from 28°C and in annual precipitation from 1200 mm (average precipitation 100 days). The forest was degraded without topsoil and it was restored for over 20 years.

Plant community

We used the primary data from the second-generation forest ecology report which was collecting data between June to July 2014 in 5 plots of size 40x40 m (Pruaksakorn and Glumphabutr, 2015). The four permanent plots in 4 aspects included north, south, east and west of the pavilion and the other was at flat ground near the pavilion (Figure 1).

The collecting data was following steps below:

1. Dividing the forest area at 85 above mean sea level into five zones based on the aspects of the pavilion.
2. Laying the squares on the compass line alternately (Figure 1).
3. The square size of each aspect is 40 x 40m (Figure 2).
4. Collecting data of plant species was carried out on tree habitus plant species (>1.3 m height and diameter >4.5 cm) with a square size of 10x10 m, sapling (> 1.3 m height and diameter <4.5 cm) with a size of 4x4 m, seedling with a size of 1x1 m and litterfall trap with a size of 1x1 m (Figure 2).

Soil properties

Soil and litterfall samples were collected from the four permanent plots in 4 aspects included north, south, east and west of the pavilion and the other was at flat ground near the pavilion. All soils were sampling on 12th February 2019. Disturbed soil samples were air-dried and sieved through 2 mm prior to determination of soil texture, soil reaction (pH), electrical conductivity (EC), organic matter (OM), available phosphorus (Avail. P), cation exchange capacity (CEC) and exchangeable cations (Ex. K, Na, Mg and Ca) (National Soil Survey Center, 1996). Ground whole soil samples were used for mineralogical analysis using XPert^3 powder diffractometer with Pixel detector (CuKα, 45 kV, 40 mA) scanned from 5 to 70◦ 2θ, a step size of 0.015◦ 2θ and a scan speed of 0.02◦ 2θ s^{-1} (Brindley and Brown, 1980). Undisturbed soil samples were used for soil micromorphological analysis on thin section of resin impregnated soils by polarizing microscope (Bullock *et al*., 1985).

Statistical analysis

Analytical data were statistically analyzed using factor analysis and principal component analysis with the Statistica Program (Version 8.0) (Statsoft Inc. 2007).

Results

Plant community

The dominant tree, sapling and seedling species were shown in Tables 1 to 3. The important tree species of this natural forest re-growth were based on the aspect. The important tree species of flat ground, north and south, east and west aspect soils were *Shorea obtusa* Wall., *Shorea siamensis* Miq. and *Xylia xylocarpa* (Roxb.), respectively (Table 1). The tree species diversity index indicated that the tree species of west aspect soil were more diverse than the others. The important sapling species were *Atalantia monophylla* DC. (flat ground), *Millettia brandisiana* Kurz. (north), *Arfeuillea arborescens* Pierre. (south); *Ochna integerrima* **(**Lour.) Merr. (east) and *Ellipanthus tomentosus* Kurz. (west). The west aspect area had the highest sapling species diversity (Table 2). The seedling results was shown in (Table 3). *Memecylon edule* Roxb. (flat ground), *Buchanania latifolia* Roxb. (north), *Atalantia monophylla* DC. (south and west), *Bauhinia saccocalyx* Pierre. (east) were the important seedling species. The amounts of litterfall result 2014 was presented in Table 4. The litterfall amount of flat ground area was higher than the others whereas the leaf litterfall amount of west aspect area is higher than the others.

Soil properties

Each soil has similar characteristics such soil type, parent material, and slope; therefore, tree species diversity is the main factor between selected areas. Different tree species affect soil organic carbon distribution within the soil profiles (Chapi, 2003). The influence of tree species and forest on soil properties was more in topsoil than in the subsoil (Sharma and Sharma, 2004). The results showed that these forest soils are characterized by a sandy loam texture and a brown to strong brown color (Table 5). Various sizes of plant roots present in all soil horizons (Table 5). The results revealed that all soils were generally acidic (pH<7) (Table 6). Forest floor layer and A horizon were related to the litterfall. The pattern of organic matter accumulation of west aspect soil was different from others (Figure 3). It was probably that the carbon stock in the mineral soil (BC horizon) of the west aspect soil was linked to root turnover. The different plant species and variation might enhance soil organic matter accumulation and stabilization in BC horizon (Andivia *et al*., 2016) because the difference in dominant tree species differ in litter quality and root exudates (Chandra *et al*., 2016). The organic matter accumulation of the others was enriched with vast organic matter in A horizon and decreased gradually in BC horizon due to the decomposition processes of the plants litter.

Principal component analysis was used to determine soil properties and also to group soil samples. Around eighty one percent of the variation in data for all soils was explained by the first two factors (Figure 4). Sand fraction and organic matter play an important role for these soils especially of A horizon therefore A horizon results should be eliminated. Around eighty percent of the variation in data for mineral horizon (BC horizon) was elucidated by the first two factors (Figure 5). All mineral horizons were quite similar except for the BC horizons of the soil from north and west aspect. The BC horizon of west aspect soil had high organic matter content whereas the BC horizon of north aspect soil had high clay content. The mineralogical composition of the whole soil samples was shown in Table 7. Quartz was the dominant mineral of whole soil sample. Kaolinite and illite were a minor mineral. Hematite presented in all studied soils whereas goethite occurred in the south, east and west aspect soils. The nature of soil micromorphology has been investigated by observation of thin sections using optical microscopy. Some of the micromorphological features of these soils are illustrated in Figure 6. The micromorphological properties of all soils were affected by plant roots and tissues and organic matter. Obviously, all of them explained soil organisms and biological activities. Fungi directly linked between roots of plants and the soil fabric (Figure 6a) because they play key roles in soil and plant interactions. Bacteria directly accumulated to organic matter in soil (Figure 6b).

Table 1 Important value index (IVI) (Top 5) and diversity index of tree.

Aspect	No of species	Dominant tree species	IVI	Fisher's alpha Index	Shannon-Wiener (H) Index
Flat ground	39	1. *Shorea obtusa* Wall.	38.18	11.88	4.61
		2. *Bauhinia saccocalyx* Pierre.	17.15		
		3. *Memecylon edule* Roxb.	16.17		
		4. *Aporusa villosa* Lindl. Baill.	15.79		
		5. *Ellipanthus tomentosus* Kurz.	14.60		
North	28	1. *Shorea siamensis* Miq.	47.38	8.88	3.96
		2. *Pterocarpus macrocarpus* Kurz.	44.60		
		3. *Xylia xylocarpa* (Roxb.)	35.01		
		4. *Vitex pinnata* L.	21.42		
		5. Shorea obtusa Wall.	15.21		
South	42	1. *Shorea siamensis* Miq.	62.30	13.62	4.39
		2. *Bauhinia saccocalyx* Pierre.	22.07		
		3. *Schleichera oleosa* (Lour.) Oken	19.63		
		4. *Ellipanthus tomentosus* Kurz.	17.85		
		5. *Shorea obtusa* Wall.	14.71		
East	31	1. *Xylia xylocarpa* (Roxb.)	59.81	8.35	3.69
		2. *Shorea siamensis* Miq.	53.89		
		3. *Vitex pinnata* L.	18.20		
		4. *Melanorrhoea usitata* Wall.	17.93		
		5. *Canarium subulatum* Guill.	15.23		
West	45	1. *Xylia xylocarpa* (Roxb.)	39.92	14.47	4.44
		2. *Shorea siamensis* Miq.	32.88		
		3. Ellipanthus tomentosus Kurz.	25.57		
		4. Shorea obtusa Wall.	20.28		
		5. *Canarium subulatum* Guill.	12.96		

Table 2 Important value index (IVI) (Top 3) and diversity index of sapling.

Aspect	No of species	Dominant sapling species	IVI	Fisher's alpha Index	Shannon-Wiener (H) Index
Flat ground	19	1. *Atalantia monophyla* DC.	94.73	6.40	2.85
		2. *Bauhinia saccocalyx* Pierre.	62.51		
		3. *Croton acutifolius* Esser.	29.01		
North	10	1. *Millettia brandisiana* Kurz.	59.01	11.41	3.20
		2. *Sterculia foetida* L.	43.01		
		3. Vitex pinnata L.	38.01		
South	25	1. *Arfeuillea arborescens* Pierre.	59.4	12.04	3.66
		2. *Atalantia monophyla* DC.	38.13		
		3. *Ellipanthus tomentosus* Kurz.	28.47		
East	19	1. *Ochna integerrima* (Lour.) Merr.	46.86	9.71	3.83
		2. *Flacourtia indica* (Burm.f.) Merr.	39.18		
		3. *Ellipanthus tomentosus* Kurz.	34.38		
West	25	*1. Ellipanthus tomentosus* Kurz.	33.49	20.44	4.30
		2. Buchanania latifolia Roxb.	29.11		
		3. *Senna spectabilis* (DC.) Irwin & Barneby.	24.68		

Table 3 Important value index (IVI) (Top 3) and diversity index of seedling.

Aspect	No of species	Dominant seedling species	IVI	Fisher's alpha Index	Shannon-Wiener (H) Index
Flat ground	9	1. *Memecylon edule* Roxb.	68.57	3.06	2.29
		2. *Atalantia monophylla* DC.	62.34		
		3. *Bauhinia saccocalyx* Pierre.	25.19		
North	9	1. *Buchanania latifolia* Roxb.	41.43	9.50	3.01
		2. *Millettia leucantha* Kurz.	34.29		
		3. *Vitex pinnata* L.	27.62		
South	12	1. *Atalantia monophylla* DC.	77.64	5.61	2.62
		2. *Arfeuillea arborescens* Pierre.	41.20		
		3. *Bauhinia saccocalyx* Pierre.	13.46		
East	8	1. *Bauhinia saccocalyx* Pierre.	72.86	7.76	2.56
		2. *Atalantia monophylla* DC.	24.29		
		3. *Shorea siamensis* Miq.	17.14		
West	7	1. *Atalantia monophylla* DC.	72.87	4.00	2.31
		2. *Bauhinia saccocalyx* Pierre.	44.13		
		3. *Ellipanthus tomentosus* Kurz.	31.17		

Table 4 The amounts of litter of the studied area year 2014.

Aspect	Litterfall (kg ha^{-1} $annual^{-1}$)				
	Leaf	Branch	Reproductive organ	Others	Total
Flat ground	127	20.6	2.9	25.6	176
North	96	18.1	1.8	16.5	132
South	133	7.7	4.8	15.5	161
East	106	18.4	1.0	15.8	141
West	135	9.0	1.1	18.6	164

Table 5 Soil samples, coordination, soil morphology and soil reaction.

Aspect	Coordination	Horizon	Depth (cm)	Color	Features	pH
Flat ground	47Q 0576169 E 1516673 N	A	0-15	Brown (7.5YR 4/3)	many very fine to fine and common medium and few coarse roots	7.0
		BC1	15-33	Strong brown (7.5YR 5/6)	common fine and medium roots	6.0
		BC2	33-50	Strong brown (7.5YR 5/6)	common fine and medium roots	5.0
North	47Q 0576379 E 1516732 N	A	0-5	Brown (7.5YR 4/3)	common very fine to medium and few coarse to very coarse roots	5.5
		BC	5-40	Strong brown (7.5YR 5/6)	common fine to coarse and few very coarse roots	5.5
South	47Q 0576282 E 1516596 N	A	0-5/10	Brown (7.5YR 4/3)	common very fine to medium roots	5.0
		BC1	5/10/1930	Strong brown (7.5YR 5/6)	common fine and medium roots	6.5
		BC2	30-50	Strong brown (7.5YR 5/6)	common fine and medium roots	7.0
East	47Q 0576383 E 1516679 N	A	0-5	Brown (7.5YR 4/3)	common fine to coarse roots	5.5
		BC	5-40	Strong brown (7.5YR 5/6)	common fine to medium and few very coarse roots	5.0
West	47Q 0576226 E 1516753 N	A	0-10	Brown (7.5YR 4/3)	many fine and common medium and few coarse roots	5.5
		BC	10-40	Strong brown (7.5YR 5/6)	common fine to medium and few coarse roots	5.0

Table 6 Physico-chemical properties of the studied soils.

Aspect	Horizon	Depth	Sand	Silt	Clay	pH (1:1)	EC	OM	Avail P	CEC	Exch Ca	Exch Mg	Exch Na	Exch K
		(cm)	(-----------%---------)			H_2O	(dS m^{-1})	%	(mg kg^{-1})	(------------------cmol kg^{-1}--------------)				
Flat ground	A	0-15	72.8	12.2	15.0	6.1	0.02	2.04	3.8	5.43	3.11	1.19	nd	0.18
	BC1	15-33	72.3	13.2	14.5	5.8	0.01	0.45	1.4	2.55	0.96	0.51	nd	0.07
	BC2	33-50	70.3	14.2	15.6	5.9	0.01	0.74	1.4	3.04	1.40	0.67	nd	0.08
North	A	0-5	50.2	21.6	28.2	6.3	0.05	6.31	10.4	13.00	7.43	1.97	nd	0.56
	BC	5-40	45.9	19.8	34.2	6.1	0.02	2.07	3.6	7.05	3.99	1.21	0.07	0.18
South	A	0-5/10	63.3	21.1	15.6	6.0	0.05	5.10	18.3	11.23	7.29	2.01	nd	0.28
	BC1	5/10-30	65.3	17.4	17.3	5.5	0.01	1.11	9.5	4.08	1.76	0.35	nd	0.08
	BC2	30-50	66.9	17.2	15.9	6.0	0.01	1.11	8.4	4.02	2.04	0.51	nd	0.08
East	A	0-5	58.9	27.1	14.0	5.0	0.05	9.52	12.1	13.43	3.69	1.62	nd	0.25
	BC	5-40	67.3	19.1	13.6	5.2	0.01	0.74	2.8	3.17	0.20	0.60	nd	0.06
West	A	0-10	69.2	19.5	11.3	5.5	0.03	3.43	8.2	6.99	3.06	0.86	nd	0.18
	BC	10-40	71.4	14.5	14.1	6.0	0.04	2.43	8.2	6.02	3.91	0.62	nd	0.11

Table 7 Mineral components of bulk soil samples.

Aspect	Horizon	Depth(cm)	Major minerals	Minor minerals
Flat ground	A	0-15	Q(xxxx); Ill(x)	Kao(tr)
	BC1	15-33	Q(xxx); Ill(x)	Hem(tr); Kao(tr)
	BC2	33-50	Q(xxxx); Kao(x); Ill(x)	Hem(tr)
North	A	0-5	Q(xxxx); Kao(x); Ill(x)	Hem(tr)
	BC	5-40	Q(xxxx); Kao(x); Ill(x)	Hem(tr)
South	A	0-5/10	Q(xxx); Ill(xx); Kao(x)	Goe(tr); Micro(tr)
	BC1	5/10-30	Q(xxxx); Ill(xx)	Mag(tr); Hem(tr); Goe(tr); Anat(tr); Kao(tr)
	BC2	30-50	Q(xxxx); Kao(x); Ill(x)	-
East	A	0-5	Q(xxxx): Kao(x); Ill(x)	Hem(tr); Anat(tr)
	BC	5-40	Q(xxxx); Kao(x); Ill(x)	Goe(tr)
West	A	0-10	Q(xxxx); Kao(x)	Mag(tr); Hem(tr); Goe(tr); Ill(tr)
	BC	10-40	Q(xxxx); Kao(x)	Ill(tr)

xxxx = Dominant (60%)
x = Small (5-20%)
Q = Quartz
Hem = Hematite
Mag = Magnetite
xxx = Large (40-60%)
tr = Trace (<5%)
Ill = Illite
Goe = Goethite
Ant = Anatase
xx = Moderate (20-40%)
\- = Not detected
Kao = Kaolinite
Micro = Microcline

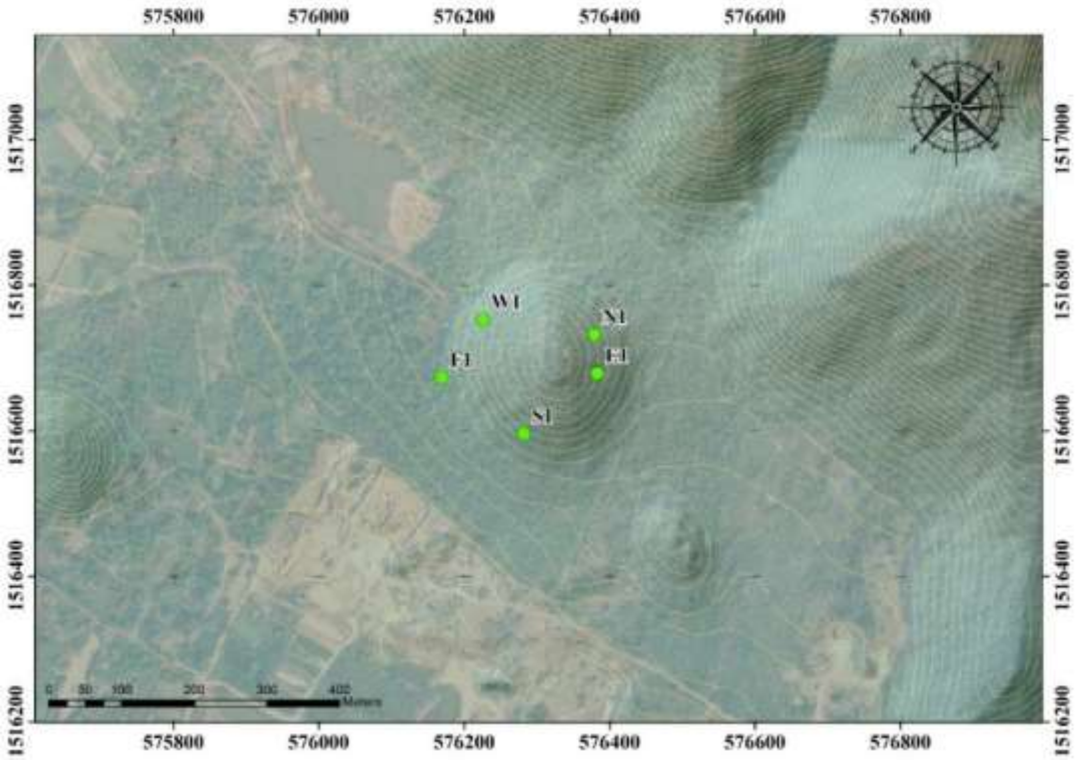

Figure 1 The location of the studied area.

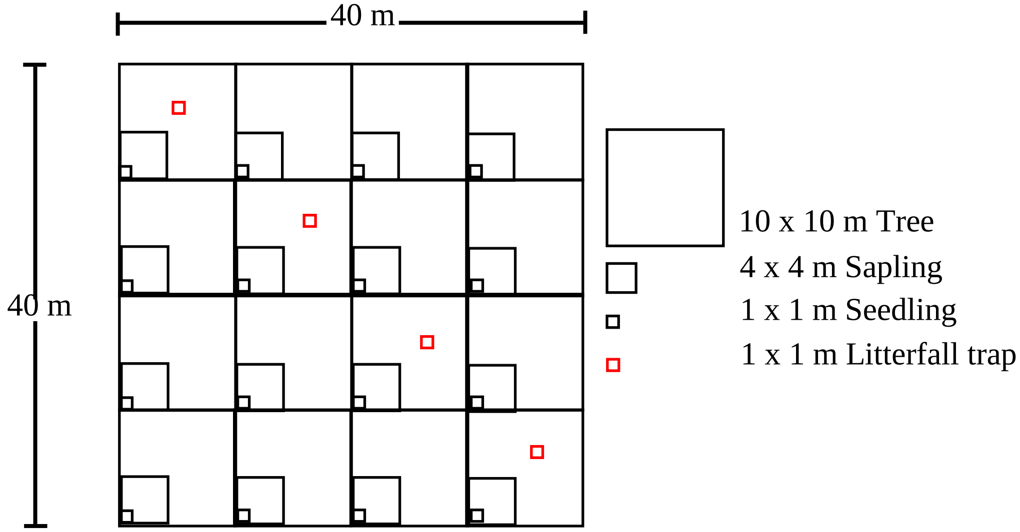

Figure 2 The permanent plots for tree species, sapling, seedling identity and litterfall trap size.

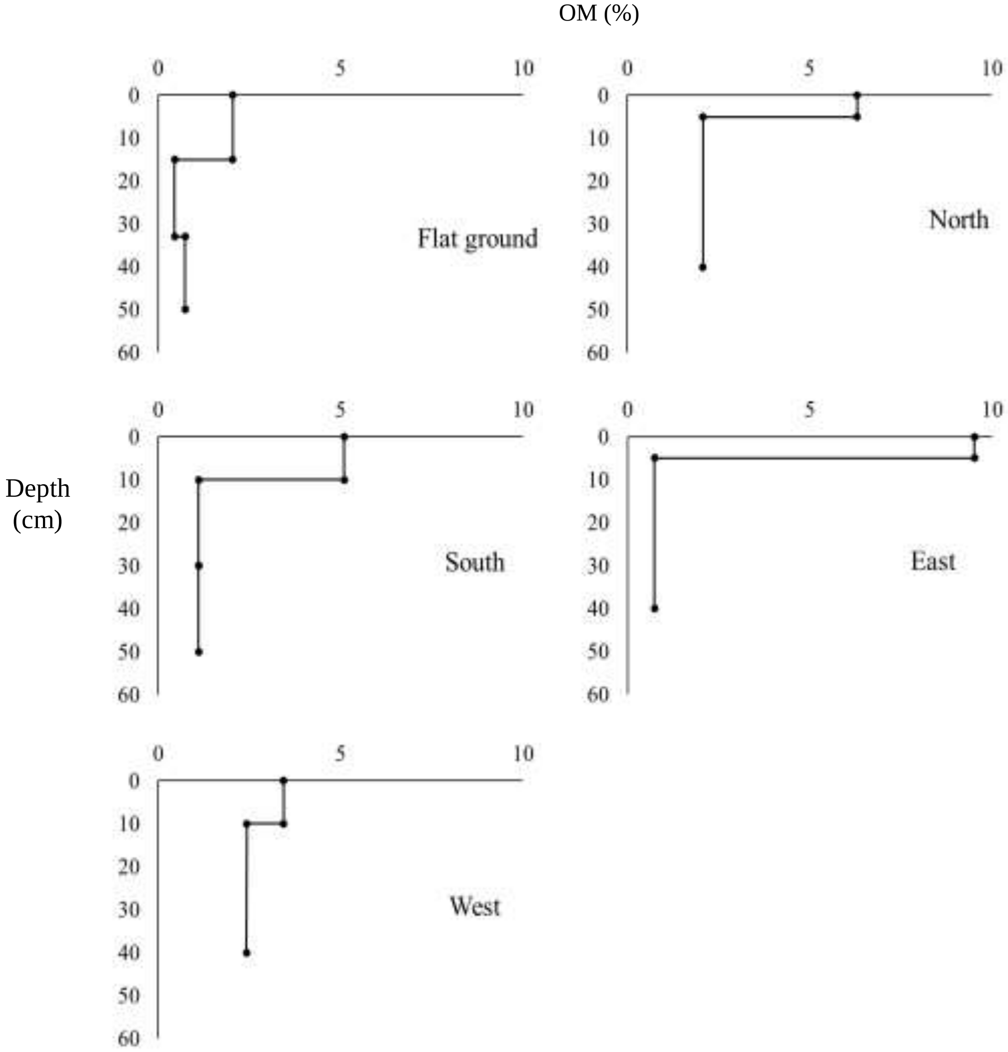

Figure 3 Organic matter content (%) versus soil depth (cm).

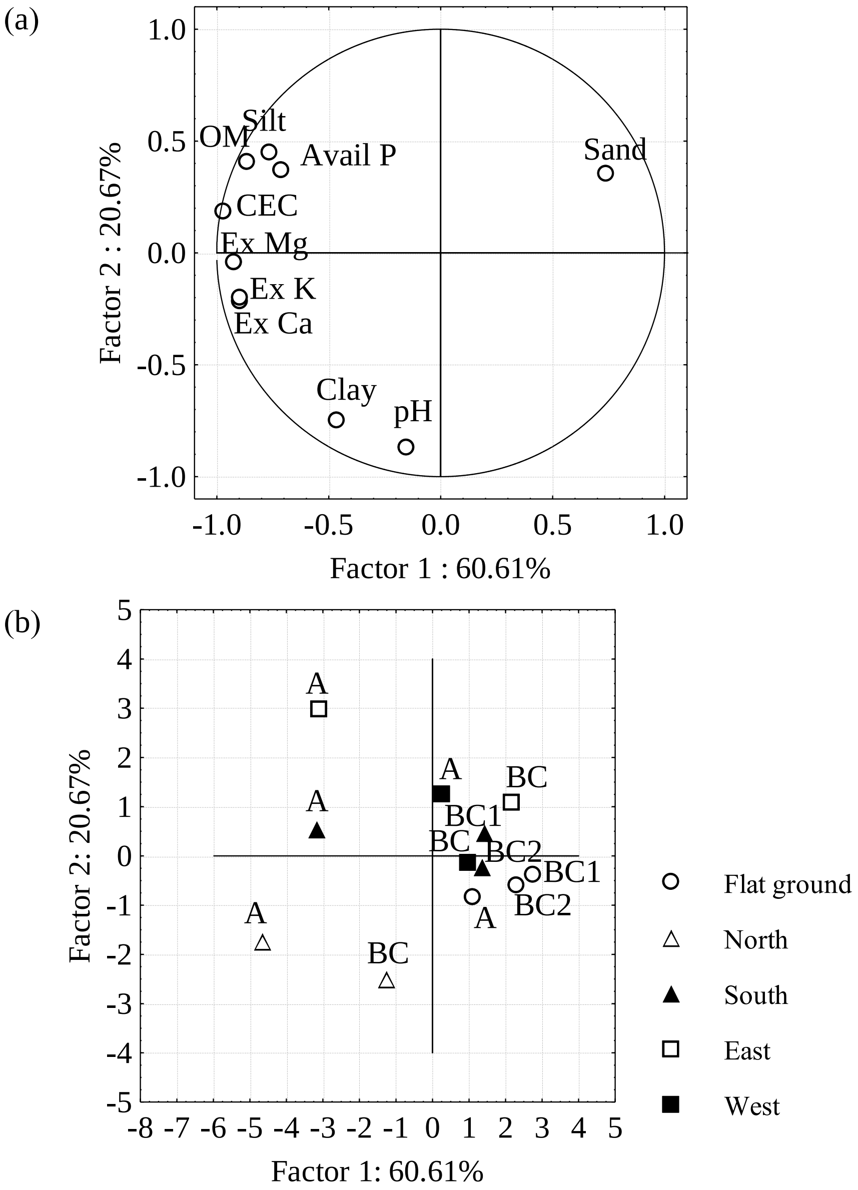

Figure 4 Factor analysis for soil properties (a) distribution of soil properties (variables) (b) distribution of topsoil and subsoil samples (cases).

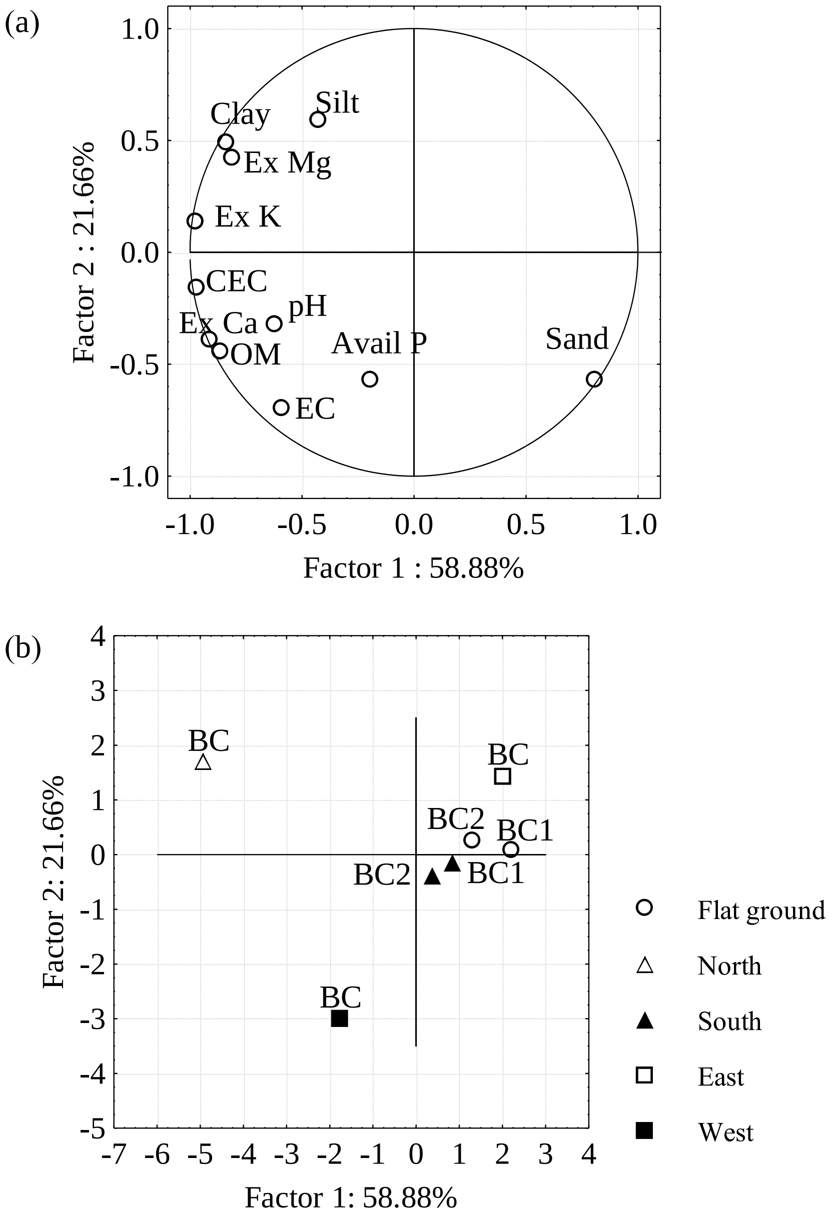

Figure 5 Factor analysis for soil properties (a) distribution of soil properties (variables) (b) distribution of subsoil samples (cases).

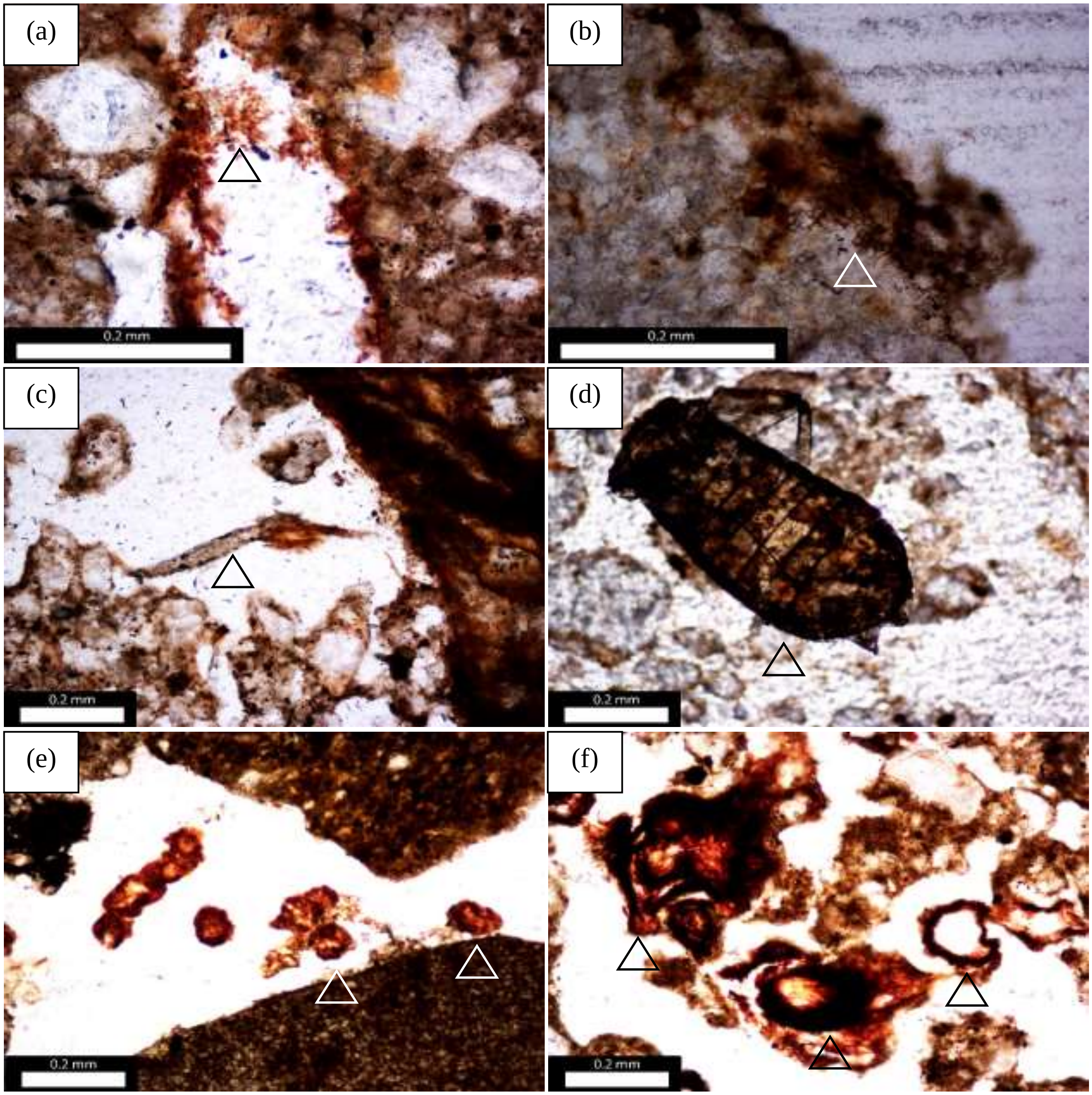

Figure 6 Micromorphology of the soil horizons (a) fungi of north aspect soil, A horizon (0-5 cm); (b) bacteria of north aspect soil, BC horizon (5-40 cm); (c) nematode of flat ground soil, A horizon (0-15 cm); (d) arthropod of east aspect soil, BC horizon (5-40 cm); (e) excrement of north aspect soil, A horizon (0-5 cm) and (f) various decomposed plant tissues of north aspect soil, A horizon (0-5 cm).

Conclusion

Natural regeneration was studied in abandoned farmland after intensive agricultural land use in the Royally-Initiated Khao Cha-Ngum deteriorated area. Evaluation of soil properties under natural reforestation revealed impact on soil health especially soil organic carbon because land cover and input change. The driving factor in biological activity in these soils is the amount of organic matter present. Litter is the main source of soil organic carbon and plant nutrient cycling. Litterfall and root decomposition add organic matter to soil. Natural-reforestation is recommended as a great low input strategy of regenerating degraded lands.

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