Glomalin-related soil protein influence on soil aggregate stability in soils of cultivated areas and secondary forests from Northern Thailand.

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Abstract
Types of land use and soil cultivation are important to maintain soil fertility. This project aimed to identify the relationships between glomalin – related soil protein contents and aggregate stability of various land uses from mountainous areas in Northern Thailand. Soil aggregate and glomalin-related soil protein components responded to land use intensity and landscape characteristics. Land use type with shifting cultivation that occurrs in mountainous areas showed the highest aggregate stability and amount of glomalin-related soil protein, due to lack of tillage and least disturbing managements. This study found positive relationship between soil aggregate stability and easily extractable glomalin content.

Key Words
Glomalin-related soil protein, soil aggregate stability, Northern Thailand.

Introduction
The mountain areas of Northern Thailand are considered the origin of important natural resources. The prevailing land management practices of the ethnic tribes in the sloping areas, mainly shifting cultivation and zero tillage made it appear that the land was undisturbed (Aumtong *et al.* 2009). Glomalin-related soil protein component is produced by arbuscular mychorrrihza (Rillig 2004;Wright *et al.* 1998), and as a stable glue the hyphae (Wright and Upudhyaya 1998) has an important role in soil aggregate stabilization. Wright and Anderson (2000) indicated that glomalin produced from some crop rotation cropping system could promote aggregate stability. The quantification of glomalin can be divided into two fractions; first, easily extractable glomalin and second, total glomalin. Both of them show different responses to land use change (Wright and Upadhyaya 1998). Wright *et al.* (1999) indicated that arbuscular mycorrhiza (AM) fungi have been related to aggregate formation and stability. Arbuscular mycorrhizal fungi (AMF) occur in the soil of most ecosystems, including polluted soils. AMF form symbiotic networks with host plant roots. The fungi scavenge nutrients from soils and transfer these nutrients to the host plant in exchange for carbohydrates. Host plants rely upon mycorrhizal fungi to acquire nutrients such as phosphorus and nitrogen for growth. The screening of native host plants e.g. weed, shrub and tree in various ecosystems could be done. The benefit from plant hosts at a practical level could then be as a cover crop in agro-ecosystems or agro- forestry systems.

Because AMF infect about 80 % of vascular host plant species and are found in almost every soil type, glomalin is detected in large amounts in numerous soils. Glomalin is defined as organic substance glycoprotein copiously produced by all AMF, measured operationally in soils as glomalin-related soil protein (GRSP) (Rillig 2004). Glomalin is firmly incorporated into the hyphae and spore wall in large amounts (Diver *et al.* 2005) and is highly positively correlated with soil aggregate stability (Wright and Upadhyaha 1998). However, the relationship between the content of glomalin and other soil properties should be studied. The objective of this project is to identify the relationships between glomalin –related soil protein contents and aggregate stability for various land uses in a mountainous area of Northern Thailand.

Methods
The study was carried out in Khiud Chang Watershed (KCW), Ban Pong and Maejo in Chiangmai Province, Northern Thailand. The mean annual rainfall of this area from 1998 to 2009 was about 1200 mm. The mean monthly air temperature was about 29°C. Being mountainous, it has an undulating landscape. KCW is a tributary of Mae Nam Mae Rim watershed and is located in an area that has an elevation of 300 to 1,100 meters above sea level (ASL).

Land uses
From each site, a composite soil sample of 8-10 subsamples was collected from each land-use. Samples were taken at a depth of 0-15 cm at 39 sites.

Table 1 shows the characteristics of the main land uses in the area.

Land use	Abbrevation	Number of replications	Characteristics
Secondary conservation forests	(SCF)	4	15 years old, much of the plant cover is bamboo and has nearly 50 % closed canopy. Some villagers harvest nontimber forest products (NTFP's).
Fruit tree plantations	(FTP)	12	mostly longan, mango and lychee (*Litchi chinensis)*, which are now 7 to 30 years old.
Fallow areas	(FA)	4	covered with bush and grass; free of agricultural activities for 1- 4 years.
Afforestated areas	(Teak)	4	young 15 year old teak (*Tectona grandis*) areas.
Wetland rice (Paddy soil)	(PAD)	4	a practice that started about 30-years ago, wetland rice is grown using machine tillage in soil preparation.
Upland rice	(UPR)	3	planted upland rice for home consumption, and maize for livestock feed, annually or rotated.
Vegetable	(VEC)	8	planted vegetable and ornamental crop for selling and consumption, high input of chemical fertilizer and frequency of land use.

Glomalin related soil protein analysis

Easily-extractable and total glomalin related soil protein were extracted by procedure adjusted from Wright and Upadhyaya (1998). One gram of air dried soil was placed into a 50 ml centrifuge tube and mixed with 8 mL of 50 mM sodium citrate buffer (pH = 8), then samples were autoclaved for 30 minutes. The supernatant was collected by centrifugation at 2510 g for 15 minutes. Total glomalin related soil protein was extracted with 8 mL of 50 mM sodium citrate buffer (pH = 8), then samples were autoclaved for 90 minutes. The supernatant was determined for related- soil protein as glomalin by the Bradford assay with bovine serum albumin standard.

Aggregate stability

The soil was transferred along with the filter paper into an aluminum can and dried at 105 °C for 24 hours. The oven-dry soil aggregates (5 g) were transferred into the wet sieving apparatus. The dispersing agent of 10 ml of 5 percent solution of sodium hexametaphosphate and enough distilled water were added to fill the cup to within 4 cm of the rim, and then the suspension was stirred for 5 minutes. Aggregate stability is the amount of aggregated soil > 0.25 mm remaining after 5 min of wet sieving (Kemper and Rosenau 1986).

Soil organic carbon (SOC)

Soil organic carbon content was determined after sieving (0.5 mm) by the wet combustion method described in Nelson and Sommers (1986).

Statistical analysis

The amounts of glomalin, SOC and aggregate stability differed among land-use types were analyzed by one way ANOVA. Evaluation of the relationships between glomalin and other soil indicators was by regression analysis.

Results

The results showed that the amount of total glomalin was lowest in paddy soils or soils that were intensively disturbed by tillage (Table 2.). The tillage practice caused loss of soil organic matter leading to low soil biological activity. Microbial activity could include mychorrhizal fungi activity. Meanwhile, the upland soil planted with rice or less cultivated and disturbed than other arable soils, showed high amounts of easily extractable glomalin and total glomalin. Wright and Anderson (2000) indicated that glomalin changes quickly in response to tillage practices and crop rotation. The basic method for planting field crops such as corn for animal feed and upland rice, involved dropping seeds directly into a hole in the soil. These practices seen as economical in terms of seeds, convenient in terms of the sloping land characteristics, were an important local wisdom to manage production factors, and may be a means to protect and maintain soil resources besides preventing soil erosion. From the high content of glomalin upland rice, the upland rice plantation could be considered as a non-tillage practice for mountainous area in Northern Thailand, and could be included in the shifting cultivation cropping system. Crop rotation and non-tillage could be found in

this area. The transformation of agricultural land (e.g. upland rice) to fallow area and secondary forest is the pattern of land use change in shifting cultivation. This pattern agrees with the diversity of host plants that produce glomalin. This study found a significant positive relationship between soil aggregate stability and easily extractable glomalin content (Figure 1).

Table 2. Land use types affected on amount of easily-extractable glomalin and total glomalin related soil protein, soil organic carbon and aggregate stability for soils from a mountainous area northern Thailand.

Land use (see Table 1)	Number of samples	Easily-extractable glomalin	Total glomalin	SOC (%)	Aggregate Stability (%)
		(mg/kg)			
VEC	8	6.16 cd	7.16 b	1.36 cd	29.69 cde
PAD	4	5.70 cd	6.30 b	1.55 bcd	21.35 e
UR	3	8.77 a	11.22 a	1.73 bc	51.75 b
FT	12	7.31 b	10.37 a	1.62 bc	35.51 c
Teak	4	5.65 cd	7.63 b	1.11 d	28.13 cde
FA	4	6.81 bc	8.19 b	2.04 b	34.20 cd
SCF	4	7.96 ab	10.81 a	4.31 a	78.16 a

For each variable different letters are indicative of statistical differences (P<0.05)

Conclusion

The level of disturbed land uses affected the soil quality due to the decreasing soil organic carbon and amount of glomalin related soil protein. These fractions could be related to soil aggregate stability. The land use types minimally disturb soils, like upland rice cultivation in a mountainous landscape, had the highest amount of easily extractable and total glomalin. Meanwhile, the land use of the highly accessible lowland had the lowest glomalin contents of soils which showed positive relationships between soil aggregate stability and easily extractable glomalin content.

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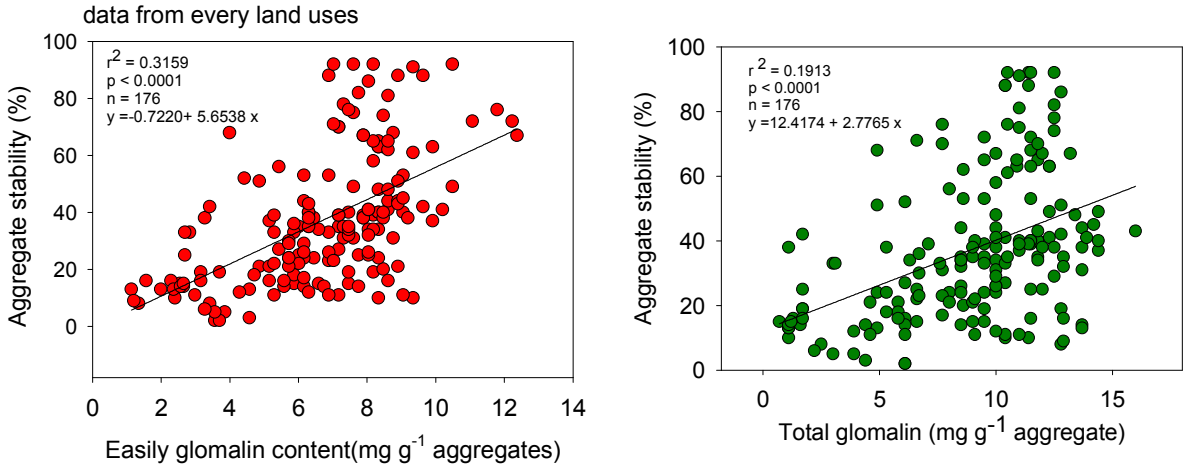

Figure 1. Relationship between easily extractable, total glomalin and stability of 1-2 mm size aggregates in 0-15 cm soil samples for a variety of land uses in Chiang Mai province, Northern Thailand.

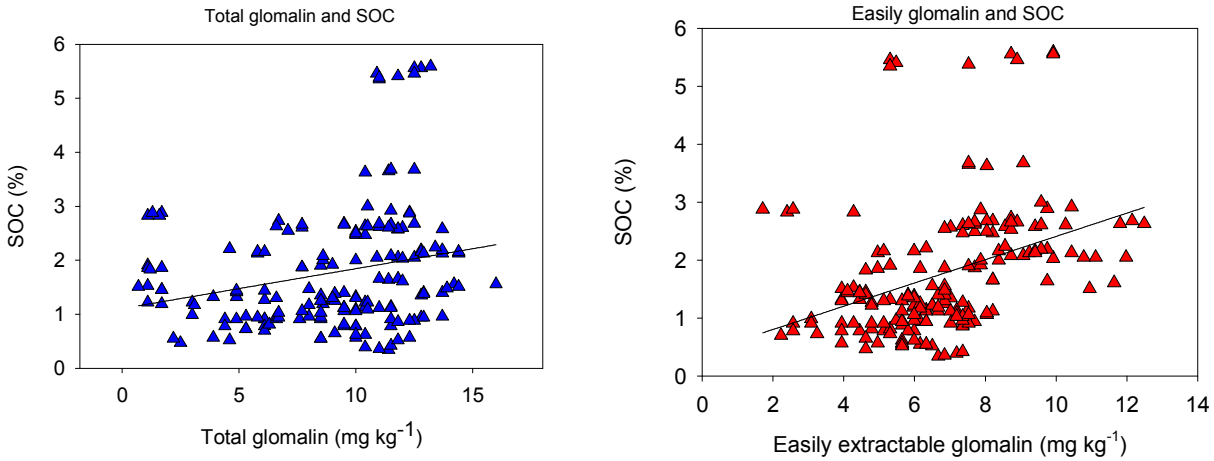

Figure 2. Relationship between easily extractable glomalin, total glomalin and SOC in 0-15 cm soil samples for a variety of land uses in Chiang Mai province , Northern Thailand.

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