The Changes of Soil Properties and Moisture Regime under Orchard in Comparison with the Forest

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Abstract: Cultivation of fruit trees and shrubs as an alternative for replacing shifting cultivation in the highlands has been promoted in northern Thailand for long time, with the belief that the orchards are better than shifting cultivation in watershed functions. This belief was examined by studying the changes of soil physical properties and soil moisture regime in well-established litchi orchards (*Litchi chinensis*), in comparison with the forest and shifting cultivation fields.

Two sites in mountainous areas in Chiang Mai, northern Thailand were studied. Each site consists of three different landuses: a mixed deciduous forest with limited disturbance of human and livestock activities, a shifting cultivation field with short fallow cycle and a twenty year old litchi orchard. The following properties of soil profiles were measured: bulk density, aeration porosity, saturated hydraulic conductivity and aggregate stability. Soil moisture profiles up to one-meter depth were monthly monitored for two years.

Permanent cultivation of litchi orchard has caused more compaction of the topsoil than shifting cultivation of annual crops. Although the compaction was still far below the critical point directly affecting plant growth, it was enough, however, to lower down the infiltration of rain and enhance run-off, consequently increase the wet season flow in streams.

The whole soil profiles under the orchards were much drier than those under the forest and shifting cultivation fields for both wet and dry seasons. This could be the effect of the higher and continuous water consumption of the evergreen orchards. The finding suggests that the orchard would reduce the base flow in streams during the dry season.

Although orchards permanently cover the soil, this study indicates that the fruit tree plantations are not better than shifting cultivation fields in the hydrological function of watershed if the top layer of the soils in the plantations were compacted. Therefore, measures should be taken to minimize the compaction of topsoil layer in the orchards. In addition, establishing orchards in sensitive watershed areas should be limited.

Keywords: mountainous areas, orchard, forest, shifting cultivation, soil moisture regime

1 Introduction

Cultivation of fruit trees and shrubs as an alternative for replacing shifting cultivation in the highlands has been promoted in northern Thailand for long time, with the belief that the orchards are better than shifting cultivation in watershed functions. This belief was examined by studying the changes of some soil physical properties and soil moisture regime in well-established litchi orchards (*Litchi chinensis*) in comparison with the forest and shifting cultivation fields.

2 Material and methods

2.1 Studied sites

Two sites in mountainous areas in Chiang Mai, northern Thailand were studied. The first site locates on a slope near Mae Sa Mai villages and another site locates on a slope near Nong Hoi villages. Both villages, established for more than 50 years, are the villages of Hmong ethnic minority who have practiced short fallow shifting cultivation together with modern intensive farming for market. Each site consists of three different landuses: a mixed deciduous forest with limited disturbance of human and livestock activities, a shifting cultivation field with short fallow cycle and a twenty year old litchi orchard without under cover (except litter fall). Litchi trees in the orchards were fully growth in the planting space of 8—10 m. Cropping system in the shifting cultivation was the growing of upland rice, corn or soybean for two years and leaving fallow for 2—3 years. During the study period upland rice was grown in the fields. Table 1 shows some features of the sites.

Table 1 Some features of the two studied sites

Features	Mae Sa Mai Site	Nong Hoi Site
Soil Type	Clayey Kaolinitic family of Oxic Paleustults	Clayey Kaolinitic family of Oxic Paleustults
Degree of slope	20%—25%	20 %—25 %
Altitude	1,000 m	1,100 m
Position on slope	Middle	middle

2.2 Measuring of some physical properties

In each landuse of each studied site four sampling plots of 1.5 by 1.5 m were selected. The sampling plots were located at any available area about 1 m away from tree trunks in the forest, at the mid-way between litchi trunks and the rims of their canopies in the orchards and any normal area in the shifting cultivation fields. In each plot 12-core samples, with the cores of 7.5 cm diameter and 4 cm depth, from each of the depth 0—10 cm, 10 cm—20 cm, 20 cm—30 cm and 30 cm—40 cm were taken. Bulk density, saturated hydraulic (Klute and Dirksen, 1986) and air-filled porosity (the percentage of pore space filled with air when the core samples were in equilibrium with the suction of 100 cm, McIntyre, 1974) were measured from the core samples. A disturbed soil sample from the depth 0—5 cm of each plot was taken for the measuring of aggregate stability (Kemper and Rosebau, 1986). Ten replications were done. The soil samples were taken at the beginning of rainy season, 1994.

2.3 Monitoring of soil moisture profiles

Soil moisture profiles of the depth 0-100 cm were monitored at 1–2 month intervals for two years, from the beginning of rainy season, 1994 till the end of dry season, 1996. In each monitoring time four points for auger holes were randomly selected in each landuse. The points were 1.5—2.0 m away from trunks in the forest and orchards. Soil samples at the depths of 0-5 cm, 5 cm-10 cm, 10 cm—15 cm, 15 cm—20 cm, 20 cm—30 cm, 30 cm—40 cm, 40 cm–50 cm, 50 cm—60 cm, 60 cm—70 cm, 70 cm—80 cm, 80 cm—90 cm and 90 cm—100 cm were taken with a Dutch auger. The auger holes were filled after the samples were taken each time. Soil samples from the same depths of the four profiles were mixed before measuring of soil moisture gravimetrically. The daily rain records were taken from Mae Sa Mai Royal project station, about 2—4 km away from the studied sites.

3 Results and discussion

3.1 The changes of some physical properties

Table 2 shows bulk density, saturated hydraulic conductivity and air-filled porosity of the soils at the depth of 0—40 cm of the three landuses. It is obviously seen that the soils up to the depth of 40 cm under orchards were more compact than those under the shifting cultivation fields and the forest. While the soils in the shifting cultivation fields were relatively not different from those in the forests. Therefore, permanent cultivation of litchi orchard has caused more compaction in the topsoil than shifting cultivation of annual crops. The erosion of well structure top layer and farmers' activities in cultivation, particularly harvesting of litchi which had been done in wet season, could be the primary causes of the soil deterioration.

Bowen (1981) has given a general rule-of-thumb that bulk densities of 1.55—1.85 Mg/m^2 will severely impede root growth and thus reduce yield of crops grown on clay loam to loamy fine sand. Therefore, the degree of compaction in the orchards was still far below the critical point directly affecting plant growth. It was enough, however, to lower down the infiltration of rain and enhance run-off, consequently increase the wet season flow in streams.

The aggregate stability of the soil at the top layer of the three landuses was 94.4%, 96.0% and 96.3 % for orchard, shifting cultivation and forest, respectively. Thus, the landuses have not effected the stability of soil aggregate.

Table 2 Some physical properties of the soils under different landuses

Depth, cm	Bulk Density, Mg/m^3			Saturated Hydraulic Conductivity, mm/minute			Air-filled Porosity[1], %		
	Orchard	Shifting Cultivation	Forest	Orchard	Shifting Cultivation	Forest	Orchard	Shifting Cultivation	Forest
0—10	1.04a	0.95b	0.82b	11.73a	75.62b	203.60b	9.96a	21.81b	24.68b
10—20	1.25a	0.98b	0.96b	10.93a	57.98b	133.24b	13.80a	22.67b	22.67b
20—30	1.21a	0.98b	1.02b	17.17a	64.42ab	117.56b	13.94a	20.64b	21.56b
30—40	1.24a	1.00b	1.03b	12.94a	33.49a	90.07b	11.80a	20.59b	23.22b

Means of the same properties in the same depth follow by the same letter are not different at 5 % level.

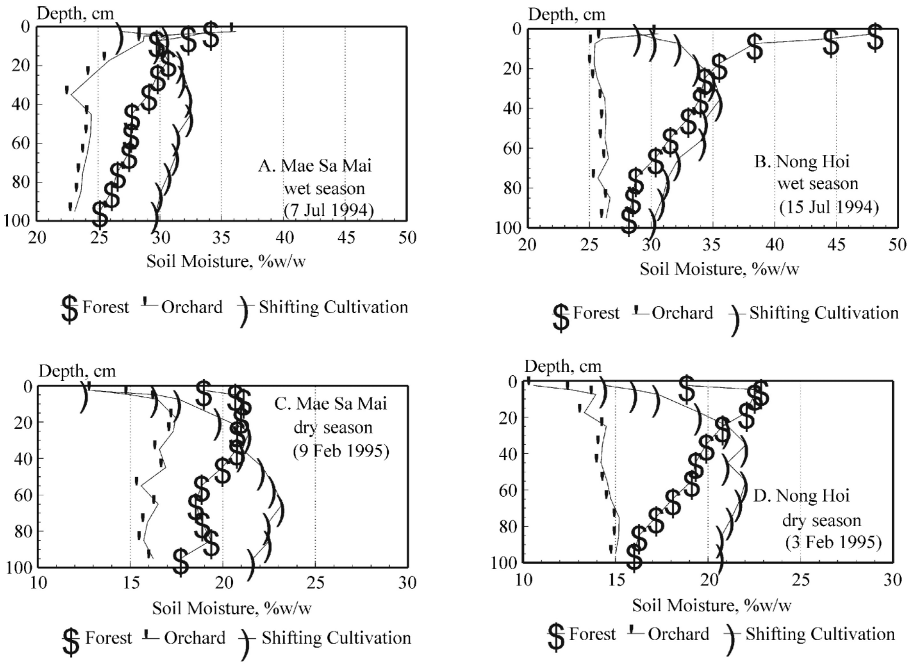

Fig.1 Soil moisture profiles in the three landuses at the middle of wet and dry season in the first year

[1] CV of bulk density = 11.4%—17.3 %, CV of saturated hydraulic conductivity = 89.3%—119.7%, CV of air-filled porosity = 15.9%—27.3%

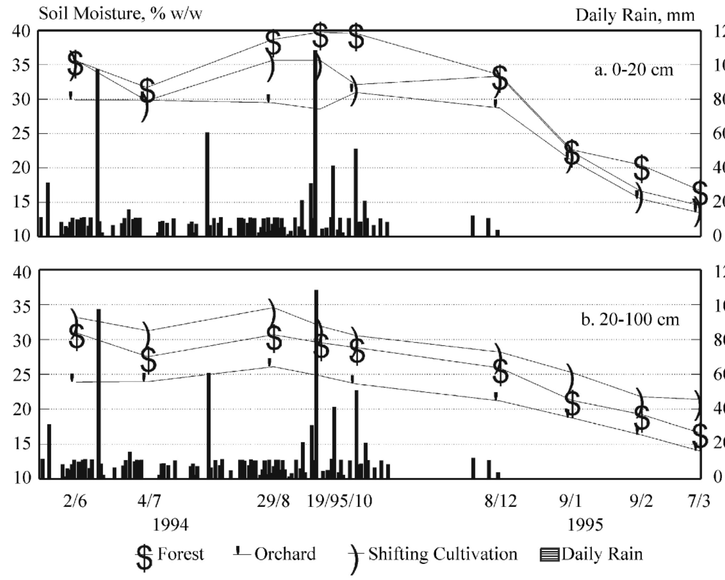

Fig.2 Average soil moisture content of mae Sa mai site, 1994—1995

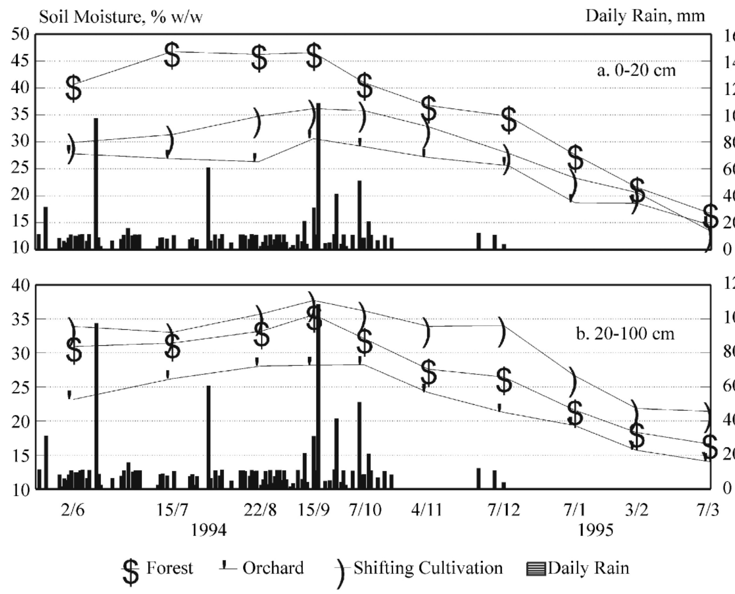

Fig.3 Average soil moisture content of Hong Hoi site, 1994—1995

3.2 The changes of soil moisture regimes

Figure 1 shows soil moisture profiles in the three landuses of both sites at the middle of wet and dry season in the first year of the study. Figure 2 and 3 show the average moisture content at the depth of 0-20 cm and 20 cm—100 cm at various times of the monitoring in the first year, together with the amount of daily rain. The figures of the second year were not presented since they were similar to the first year.

In general, the trends of soil moisture regimes of both sites were relatively similar. During the dry season, the top 20 cm of the shifting cultivation fields have drier than the forest, while the opposite was true for the deeper layers. The average moisture content of the depth 20 cm—100 cm of shifting cultivation fields were 5%—8% w/w higher than those of the orchards, and 3%—5% w/w higher than those of forest. The direct exposing to sunlight due to the absence of canopy resulted in the higher water evaporation from the top layer, while the absence of root activities during the dry season resulted the lesser water extraction from the deeper layers of the shifting cultivation field.

The whole soil profiles (up to one-meter depth) under the orchards were much drier than those under the forest and shifting cultivation fields for both wet and dry seasons. This could be the effect of the higher and continuous water consumption of the evergreen orchards. Wilson (1998) also found that soils under trees dried faster than that under pasture, particularly in the depth of 10 cm—50 cm. The finding suggests that the orchard would reduce the base flow in streams during the dry season, in addition to the tendency of increasing the wet season flow due to reduction of infiltration as the consequence of the compaction of topsoil in the orchards.

4 Conclusion

Although orchards permanently cover the soil, this study indicates that the fruit tree plantations are not better than shifting cultivation fields in the hydrological function of watershed if the top layer of the soils in the plantations were compacted. Therefore, measures should be taken to minimize the compaction of topsoil layer in the orchards. In addition, establishing orchards in sensitive watershed areas should be limited.

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