Chapter 4

Result and discussion

4.1 Mandarin cultivation in Mae Soon sub-district

In this chapter, the general information of mandarin orchards of the farmers in Mae Soon sub-district, farmer practices for orchard management, general information about mandarin farmers and their knowledge about soil management were reported based on the data obtained from farmers' interviews (200 farmers) and field survey (50 orchards).

4.1.1 General information of mandarin orchards of the farmers in Mae Soon sub-district

1) Mandarin plant materials

Table 4.1 Mandarin plant materials used in the farmers' orchards in Mae Soon sub-district

Type of plant materials	General orchards		Productive selected orchards	
	No. of orchards	%	No. of orchards	%
air layering	156	78	46	92
air layering and grafted plant	44	22	4	8
Total no. of farmers	**200**	**100**	**50**	**100**

The information obtained from farmers' interviews indicated that majority of the interviewed farmers even the owners of productive orchards used air layered plant for planting there were about 22% of the total number interviewed farmer of 200 heads and 8% of the total numbers of the farmers who owned the productive orchards of 50 heads used both air layered and plant grafted plants as shown in table 4.1.

2) Ages of cultivated mandarin trees

Table 4.2 The ages of mandarin trees in the farmer orchards at Mae Soon sub-district

Ages of the trees (years)	**General orchards**		**Productive selected orchards**	
	No. of orchards	**%**	**No. of orchards**	**%**
4-6	12	6	2	4
6-8	28	14	14	28
8-10	94	47	14	28
>10	66	33	20	40
Total no. of farmers	**200**	**100**	**50**	**100**

About 47 percent of the total numbers of 200 orchards had mandarin trees with the ages about 8-10 years old and those with the trees more than 10 years old were about 33% (table 4.2). The productive orchards with the trees more than 10 years old were about 40% of the total numbers of the orchard and those with the trees about 6-8 and 8-10 years old were about 28%. According to Kuaprakone *et al.*(1999) which cited by Ounpo (2005), mandarin trees transplanted from air layering could be persisted up to 8 years old only. Thus, it was interesting observation that in the study area, the orchards with the trees more than 8 years old were still productive.

3) Land use history

Table 4.3 Land use history of mandarin orchards in Mae Soon sub-district

Cultivated crops before mandarin tree	General orchards		Productive selected orchards	
	No. of orchards	**%**	**No. of orchards**	**%**
paddy rice	60	30	2	4
litchi	30	15	4	8
litchi + paddy rice	52	26	37	74
forest following litchi	26	13	4	8
litchi, paddy rice, onion	8	4	2	4
litchi, onion, garlic	24	12	1	2
Total no. of farmers	**200**	**100**	**50**	**100**

About 60% of the total numbers of 200 orchards used to be paddy fields, the rest were previously litchi orchards. For the productive orchards about 82% used to be paddy field (table 4.3).

4) Topographical condition of mandarin orchards of the farmers

Table 4.4 Topographic condition of mandarin orchards in Mae Soon sub-district

Topographic condition	General orchards		Productive selected orchards	
	No. of orchards	**%**	**No. of orchards**	**%**
lowland	110	55	25	50
foothill	36	18	3	6
sloping land	54	27	22	44
Total no. of farmers	**200**	**100**	**50**	**100**

Fifty five percent of the total numbers of 200 orchards were in the lowland while 27% were on the sloping land and 18% were in the foothill. For the productive orchards, 50% were in the lowland and those on the sloping land and on the foothill were 44 and 6% respectively (table 4.4).

5) Availability of irrigated water

Table 4.5 Availability of the irrigated water for mandarin cultivation in Mae Soon sub-district

Availability of irrigated water	General orchards		Productive selected orchards	
	No. of orchards	%	No. of orchards	%
insufficient	84	42	12	24
sufficient	116	58	38	76
Total no. of farmers	**200**	**100**	**50**	**100**

Among the 200 interviewed farmers, 58% had sufficient water for mandarin cultivation while the rest had insufficient water. As to the productive orchards, 76% had sufficient water (table 4.5).

6) Famer practices for orchard management

Sixty nine percent of the total numbers of 200 farmers had never checked the qualities of the soils in their orchards neither 58% of the owners of the productive orchards (table 4.6).

Table 4.6 The numbers of mandarin farmers in Mae Soon sub-district who used to check the qualities of the soil in their orchards

Soil testing	General orchards		Productive selected orchards	
	No. of orchards	%	No. of orchards	%
check	62	31	21	42
never	138	69	29	58
Total no. of farmers	**200**	**100**	**50**	**100**

Various criteria were used by the mandarin farmers for fertilizer management in their orchards (table 4.7).

Table 4.7 Criteria of the mandarin farmers for fertilizer management in their orchard

Criteria	General orchards		Productive orchards	
	No. of orchards	%	No. of orchards	%
experience	118	59	34	68
recommendation of product dealers	6	3	1	2
results of soil testing	6	3	2	4
information of experience farmers + experience	28	14	9	18
information of experience farmers + experience + Agri.J.	8	4	1	2
experience + soil testing	4	2	3	6
recommendation of product dealers + experience	30	15	-	-
Total no. of farmers	**200**	**100**	**50**	**100**

Fifty nine percent of the total numbers of 200 farmers applied fertilizers to their mandarin trees according to their own experience and the same criteria were also used by 68% of the owners of the productive orchards. About 3-4 % of the total numbers of the interviewed farmers applied fertilizers based on the results of soil testing and 2-6 % applied fertilizers according to soil testing in combination with their own experiences. Not only their own experience, 14-18% of the interviewed farmers used the information obtained from the experience farmers or neighboring orchards for making decision on fertilizer usage in their orchards. In addition, 15% of the owners of the productive orchards applied fertilizers according to their own experiences together with the recommendations of the fertilizer dealers.

Table 4.8 Fertilizer grades used by mandarin farmers in Mae Soon sub-district

Fertilizer grades	General orchards		Productive orchards	
	No. of orchards	%	No. of orchards	%
46-0-0	4	2	2	4
46-0-0 + 13-13-21	8	4	3	6
46-0-0 + 13-13-21 + 15-15-15	6	3	4	8
46-0-0 + 13-13-21 + 15-15-15 + 0-46-0 + 0-0-60 + 15-0-0 + 0-52-34	80	40	14	28
46-0-0 + 15-15-15 +13-13-21 + others	10	5	1	2
46-0-0 + 15-15-15 + others	24	12	3	6
46-0-0 + others	8	4	2	4
13-13-21 + others	4	2	1	2
15-15-15	26	13	7	14
15-15-15 + 13-13-21 + 15-0-0	2	1	1	2
15-15-15 + 13-13-21 + others	8	4	4	8
15-15-15 + 15-0-0	4	2	2	4
15-15-15 + 15-0-0 + others	4	2	2	4
Total no. of farmers	**200**	**100**	**50**	**100**

Various fertilizer grades as shown in table 4.8 were used by mandarin farmers in Mae Soon sub-district. The most popular grades were 46-0-0, 13-13-21 and 15-15-15. The farmers who used fertilizers containing one primary plant nutrient (46-0-0, 15-0-0, 0-46-0, 0-0-60) were only 2-5% of the total number of interview farmers. Most of the farmers used two to three fertilizer grades. The commonly used fertilizer grades by mandarin farmers in Mae Soon sub-district were the same as those used by farmers in Fang district as reported by Srumsiri *et al.*(2008).

Table 4.9 Chemical fertilizer application rate (kg/tree) of mandarin farmers in Mae Soon sub-district

Chemical fertilizer application rate (kg/tree)	**General orchards**		**Productive orchards**	
	No. of orchards	**%**	**No. of orchards**	**%**
< 0.2	2	4	0	0
0.2-0.4	20	10	4	8
0.4-0.6	62	31	26	52
0.6-0.8	34	17	3	6
0.8-1.0	90	45	12	24
Total no. of farmers	**200**	**100**	**50**	**100**

In general, 45% of the interviewed farmers applied chemical fertilizer to mandarin trees at the rate of 0.8-1.0 kg/tree while 31% used the rate of 0.4-0.6 kg/tree. For the productive orchards, 52% of the interviewed farmers applied chemical fertilizer at the rate of 0.4-0.6 kg/tree and 24% applied at the rate of 0.8-1.0 kg/tree (table 4.9).

According to Srumsiri *et al.*(2008), the fertilizer application rate for mandarin trees is practically depended on the ages of the trees. The fertilizer application rates are generally increased with increasing of the tree ages. However, the rate of fertilizer application used in the 50 productive orchards seemed to be not depended on the ages of the tree as shown in table 4.10. It was therefore expected that the amount of fertilizer applied to the trees in those orchards might depend on the availability of the budget of each farmers.

Table 4.10 Rate of fertilizer application to mandarin trees with different ages by 50 interviewed farmers

Age of mandarin tree	Rate of fertilizer application kg/tree/M					Total no. of farmers
	<0.2	>0.2-0.4	>0.4-0.6	>0.6-0.8	>0.8-1.0	
4-6	0	0	2	0	0	2
6-8	0	1	5	1	7	14
8-10	0	1	10	0	0	14
>10	0	0	13	3	7	20

Table 4.11 Criteria of the farmers for foliar spraying of fertilizers in mandarin orchards

Criteria for nutrient spraying	General orchards		Productive orchards	
	No. of orchards	%	No. of orchards	%
1) when the trees show nutrient deficiency symptoms	16	8	14	28
2) for prevention of nutrient deficiency	98	49	35	70
3) both 1 + 2 cases	86	43	1	2
Total no. of farmers	**200**	**100**	**50**	**100**

Among the total numbers of 200 interviewed farmers, 49% applied nutrient spraying to prevent nutrient deficiencies of mandarin trees and the same management was used by 70% of the owners of productive orchards. Twenty eight percent of the total interviewed farmers used nutrient spraying when the trees showed nutrient deficiency symptom but that criterion was used by only 8% of the owners of the productive orchards. Furthermore, there were about 43% of the productive farmers who applied fertilizers by foliar spraying when the trees showed deficiency symptoms and for prevention (table 4.11).

In addition, most of the commonly used foliar fertilizers were Ca and Mg fertilizer and trance element fertilizer. The commercial fertilizer for secondary element (Ca and Mg) was a single fertilizer since the time needed for spraying of each element was different. Mg fertilizer was normally sprayed during leaf flush while Ca was needed during fruit setting particularly fruit enlargement stage. Trace element fertilizers commercially available are produced in the form of the mixture of all trace elements. The farmers normally sprayed trace elements to mandarin trees during leaf flush. In the case of Cu, In general, the farmers applied fungicides containing Cu compound in order to prevent disease infection thus the trees could get addition Cu from spraying of fungicide containing Cu.

Table 4.12 Occurrence of plant nutrient deficiency in mandarin orchards of the farmers at Mae Soon sub-district

Plant nutrient deficiencies	General orchards		Productive orchards	
	No. of orchards	%	No. of orchards	%
1) existing	186	93	45	90
Occurred symptom				
-A yellow leaves with invested V shape	16	8	3	7
-B yellow leaves with greening midrib	28	14	19	38
-C spitted fruit	13	26	7	16
-D symptom A + B	12	6	1	2
-E symptom A + C	16	8	5	10
-F symptom B + C	96	48	6	12
-G other...........	4	2	3	6
-H no information	2	1	1	2
2) Not exist	14	8	5	10
Total no. of farmers	**200**	**100**	**50**	**100**

The table 4.12 showed information about the occurrence of plant nutrient deficiency symptoms in mandarin orchards of the farmers in Mae Soon sub-district. Ninety to ninety three percent of the orchards had the trees showing plant nutrient deficiency symptoms. The most common symptoms observed in the total numbers of 200 orchards were yellow leaves with greening midribs and spitted fruits while those in the productive orchards were yellow leaves with greening midribs.

The yellow leaf with inverted V shape which can be observed in the mature leaf is the symptom of Mg deficiency while the yellow leaf with greening mid rib which can be observed in the young leaf is the symptom of Zn deficiency (Agropedia, 2010).

According to Storey et al. (2000), Ca is the important essential element involving with citrus fruit splitting because Ca is the component of plant cell wall. By foliar spraying of Ca, fruit spitting occurring in Chokun mandarin cultivar (*Citrus reticulata*) could be reduced from 52% to 5.6% (Sadudee and Jeewipah, 2005).

Table 4.13 Status of mandarin orchards evaluated by the farmers

Status of the orchards	General orchards		Productive orchards	
	No. of orchards	**%**	**No. of orchards**	**%**
1) collapses, have to change to the other crops	122	61	0	0
2) still productive for 2-3 more years	74	37	38	76
3) productive	18	9	12	24
Total no. of farmers	**200**	**100**	**50**	**100**

Among the total numbers of 200 interviewed farmers, 61 % considered that their orchards have been collapses and they had to change the cultivated crop from mandarin to the other crops (table 4.13). There were the orchards which were still productive for 2-3 years more while the orchards which were in a good condition were only 9%. As to the productive orchards, 76% were productive for 2-3 more years and those with good condition were about 24%.

Table 4.14 Percentage of immature harvested fruits in comparison to the total fruit yield

Immature harvested fruits	General orchards		Productive orchards	
(%)	No. of orchards	%	No. of orchards	%
10-20%	28	14	8	16
20-40%	40	20	11	22
40-60%	48	24	16	32
60-80%	84	42	15	30
Total no. of farmers	**200**	**100**	**50**	**100**

When mandarin trees were infected by greening disease. According to Timmer *et al.* (2000) the leaf chlorosis could be observed. As a general rule, the pattern of the mottling is asymmetric across the leaf midrib. The intensity of mottling may vary with the relative length of time that the tree has been infected. Other symptoms including green spots within almost totally yellowed leaves. Very often, the midrib and major lateral vein of the leaf turn yellow. Finally Zn deficiency patterns almost always occur in combination with blotchy mottle and green spots symptoms. The symptoms of greening disease could be observed in the fruit (Polek, 2007). The external fruit symptoms include misshapen fruit, non uniform fruit color. The blossom end remains green as the rest of the fruit turns yellow, small and non uniform fruit size. In this study, the fruits from greening disease infected mandarin trees could not fully developed resulting in the harvested fruits products which were soft, smaller in size, having abnormal shape with the greening blossom red color at the points of the fruits. Among the 200 interview farmers, 42 had such poor quality fruit product about 60-80% while about 30% of the productive orchards had such poor quality fruit about 60-80% and 32% had about 40-60% (table 4.14).

Table 4.15 Basic knowledge of mandarin farmers in Mae Soon sub-district

Level of basic knowledge	General orchards		Productive orchards	
	No. of orchards	**%**	**No. of orchards**	**%**
good	10	5	1	2
moderate	90	45	27	54
low	72	36	22	44
very low	28	14	-	-
Total no. of farmers	**200**	**100**	**50**	**100**

The levels of basic knowledge of the owners of the orchard in Mae Soon sub-district were shown in Table 4.15. About 45% of 200 mandarin farmers had moderate knowledge and about 36% had low knowledge. For the productive orchards, 54% of the owners had moderate level of basic knowledge and about 44% had low basic knowledge.

Table 4.16 Causes of the orchard failure

Orchard failure causes	General orchards		Productive orchards	
	No. of orchards	%	No. of orchards	%
1) root rot	46	23	3	6
2) greening disease	32	16	5	10
3) insufficient nutrient supplement	24	12	4	8
4) 1,2 and 3 plus lack of irrigation water and orchard management skill	4	2	2	4
5) lack of skill, Insufficient irrigation water and Nutrient supplement	6	3	2	4
6) lack of skill, Root rot and Greening disease	16	8	3	6
7) lack of skill + Insufficient nutrient supplement	20	10	14	28
8) insufficient irrigation water + Greening disease	8	4	1	2
9) root rot + greening disease	24	12	10	20
10) root rot + greening disease + Insufficient nutrient supplement	4	2	4	2
11) root rot and other courses	4	2	2	4
12) greening disease + insufficient nutrient supplement	4	2	1	2
Total no. of farmers	**200**	**100**	**50**	**100**

In general as evident in table 4.16, the common causes of the orchard failure were root rot, greening disease, insufficient nutrient supplement or combination of lacking of skill, greening disease and root rot or root rot plus greening disease. For the productive orchards, the common causes of the orchard failure were lacking of skill and insufficient nutrient supplement and root rot plus greening diseases.

4.1.2 Properties of the soils in the selected productive orchards

Among the fifty selected productive orchards, 22 were located on the sloping land, 17 were in the foothill and 11 were in the lowland.

Table 4.17 Properties of the soils in 50 selected mandarin orchards

[1]Soil property	Optimum level	Range	The total no. of sample (%)		
			Opt. level	< Opt. level	> Opt. level
[2]bulk density (g/cm)	1.3-1.65	0.9-1.5	34	66	0
[2]total porosity (% by volume)	47.17-62.26	40.1-67.6	84	12	4
[3]soil pH	6.0-6.5	3.9-6.8	16	76	8
CEC (cmol/kg)		3.2-22.5			
EC (µs/cm)	<80	31-230	64	0	36
Organic Matter (%)	2.0-3.0	1.4-4.9	42	8	50
Available P (mg/kg)	35-60	20.1-684.5	2	4	94
Exchangeable K (mg/kg)	100-120	28-755	8	44	48
Exchangeable Ca (mg/kg)	800-1500	595.7-2,686.7	72	6	22
Exchangeable Mg (mg/kg)	250-400	56-292	2	98	0
Extractable Fe (mg/kg)	60-70	38-321	0	10	90
Extractable Mn (mg/kg)	20-60	13-40	88	12	0
Extractable Zn (mg/kg)	3-15	9.7-14.4	12	0	88
Extractable Cu (mg/kg)	3-5	1.7-27.1	38	12	50
[4]K : Mg ratio	< 3:1	0.3-9.2	86	0	4
microbial biomass C (µgC/g)		305-2968			

Sources of information : [1]Supakumnerd *et al.* (2005),), [2]Panomtaranitchagul (2008), [3]Obrega and Morgan (2008), [4]Ankerman and Large (2001).

The physical, chemical and biological properties of the soils from 50 selected orchards were shown in table 4.17. The criterion of Land Development Department, LDD (2008) was used for evaluation of soil bulk density while that proposed by Panomtaranitchagul (2008) was used for total soil porosity. Soil pH was evaluated according to Obrega and Morgan (2008). The other soil chemical properties such as electrical conductivity (EC) organic matter, available P, exchangeable K,Ca and Mg and extractable Fe, Mn, Cu and Zn were evaluated according to Supakumnerd *et al.* (2005) while K : Mg ratio was evaluated by Ankerman and Large (2001). At least 64% of the total numbers of 50 tested soils had total porosity. EC, exchangeable Ca, extractable Mn and K:Mg ratio at the optimum levels while those which were high in available P, exchangeable K, extractable Fe, extractable Zn and extractable Cu were 94, 48, 90, 88 and 50% respectively. The orchard soils which were poor in bulk density ere about 66% and those had the lower levels of soil pH, exchangeable K and exchangeable Mg than the optimum levels were 60, 76, 44, and 98% respectively. The CEC of the soils from the selected orchards were within the range of 3.2-22.5 c mol/kg and the microbial biomass C were in the range of 304 - 2968 μgC/kg.

4.1.3 Plant nutrient status of mandarin trees in the selected farmers orchards

The guidelines for interpretation of citrus leaf analysis proposed by Koo *et al.* (1984) as shown in table 4.18 were used for evaluation of plant nutrient status of mandarin trees in the selected farmers orchards. The second time of leaf sample collection in this study as in July which was the same month for collecting of 6 months old leaf samples of Koo *et al.*(1984). Thus it was assumed that the leaf samples collected in the second sampling were 6 months old leaves.

Table 4.18 Guidelines for interpretation of orange tree leaf analysis based on 4 to 6 month-old flush leaves from non-fruiting twigs (Koo *et al.*,1984)

Element	Unit of measure	Deficient	Low	Optimum	High	Excess
N	%	< 2.2	2.2-2.4	2.5-2.7	2.8-3.0	> 3.0
P	%	< 0.09	0.09-0.11	0.12-0.16	0.17-0.30	> 0.30
K	%	< 0.7	0.7-1.1	1.2-1.7	1.8-2.4	> 2.4
Ca	%	< 1.5	1.5-2.9	3.0-4.9	5.0-7.0	> 7.0
Mg	%	< 0.20	0.20-0.29	0.30-0.49	0.50-0.70	> 0.70
Cl	%	-	-	<0.2	0.20-0.70	> 0.70[1]
Na	%	-	-	-	0.15-0.25	> 0.25
Mn	mg/kg or ppm[2]	< 18	18-24	25-100	101-300	>300
Zn	mg/kg or ppm	< 18	18-24	25-100	101-300	>300
Cu	mg/kg or ppm	< 3	3-4	5-16	17-20	>20
Fe	mg/kg or ppm	< 35	35-59	60-120	121-200	>200
B	mg/kg or ppm	< 20	20-35	36-100	101-200	>200
Mo	mg/kg or ppm	< 0.05	0.06-0.09	0.10-2.0	2.0-5.0	> 5.0

[1] Leaf burn and defoliation can occur at Cl concentration > 1.0 %.

[2] ppm = parts per million.

Table 4.19 Percentage of the mandarin orchards having plant nutrient status at different levels

Element	Optimum Level*	The total no. of studied orchards (%)									
		1st sampling (April)					2nd sampling (July)				
		deficit	low	optimum	high	excess	deficit	low	optimum	high	excess
N (%)	2.5-2.7	20	12	26	12	30	54	34	12	0	0
P (%)	0.12-0.16	0	0	60	40	0	0	2	80	18	0
K (%)	1.20-1.70	0	2	20	74	4	2	4	44	48	2
Ca (%)	3.00-4.90	90	10	0	0	0	6	38	56	0	0
Mg (%)	0.30-0.49	0	0	94	6	0	0	0	82	14	4
Fe (ppm)	60.0-120.0	0	0	98	2	0	0	2	78	18	2
Mn (ppm)	25.0-100.0	0	8	90	2	0	6	16	76	2	0
Cu (ppm)	5.0-16.0	0	0	78	20	2	0	0	86	14	0
Zn (ppm)	25.0-100.0	0	6	88	0	6	0	12	82	0	6
B (ppm)	36.0-100.0	26	60	14	0	0	10	28	56	6	0

*source of information : Koo *et al.*,1984

Table 4.19 showed the percentage of the orchards having plant nutrient status at different levels. At the first time of plant sample in April in which in season mandarin fruits were about 3 months old, the concentration of P, Mg, Fe, Mn, Cu and Zn of the third leaves from non fruit bearing twigs or the index leaves in majority (at least 60%) of the orchards were at the optimum levels while 74% of the total numbers of the selected orchards had high level of K in the leaves. Thirty two percent of the total numbers of the orchard had the low and deficient level of N and those having optimum, high and excess N in the index leaves were 26, 12 and 30% respectively. Ninety percent of the total numbers of the orchards had the trees deficient in Ca and 26 and 60% were deficient and low in B respectively.

Regarding to the status of P in the index leaves of non fruit bearing twig, it was found that in April, 56% of the orchards which soils were rich in available P had the trees with the optimum level of P in the index leaves and 36% had high P level (figure 4.1). In July, the trees from high P soil were still maintained the levels of P in the index leaves at optimum or high level (Figure 4.4). In the ease of K almost the same trend as found for P were observed for both April and July as shown in Figure 4.1 and 4.4. In addition, in the orchards with low K soil, there were about 18 – 24 % of the orchards which the trees could maintain K in the index leaves at the high level in April and July respectively and those which had the optimum K level in the index leaves was about 18 and 20 % respective. The high P and K levels in the index leaves from high P soils indicated luxury consumption of these two primary nutrients by mandarin trees. The mandarin trees grown in low K soil could maintain K in the index leaves at the high or normal levels was expected to be related to K supplement by foliar spraying which were the common practices for most farmers in Mae Soon sub-district.

In the case of Ca, it was observed that the mandarin trees from the orchards which th soils contained exchangeable Ca at the optimum or high levels had low concentration of Ca in the index leaves in April (figure 4.2). It was expected that root damage might be the cause of low Ca uptake by the mandarin roots. However in July, the trees cultivated in soils with the optimum or high level of exchangeable Ca had optimum level of Ca in the index leaves (figure 4.5) which might be due to the effect of Ca supplement by foliar spraying. In the case of Mg, it was found that the trees from the orchards with low content of exchangeable Mg could maintain Mg in the index leaves in both April and July at the optimum level (figure 4.2 and figure 4.5). It was also expected that the Mg supplement by foliar spraying was the factor affecting the desirable status of Mg in the leaves under low Mg soils.

In the case of trace elements, about 2 – 6 % of the orchards with optimum levels of extractable Fe Zn Cu and Mn had the trees with high level of these trace elements in April and July (figure 4.3 and figure 4.6). It was expected that the high levels of these trace elements in the index leaves might be due to nutrient supplement by foliar spraying. In the case of the orchards with high levels of extractable Fe, Zn, Cu and Mn it was found that about 2 – 20 % of the orchards with high levels of extractable Fe in the soils had the trees with high levels of Fe in the index leaves in April and July respectively. About 12 % of the orchards with high levels of extractable Zn had the trees with high level of Zn in the index leaves. It was not surprised to see the leaves with high levels of Zn and Fe it the trees were grown in Zn and Fe rich soils but Zn and Fe supplement by foliar spraying might be surplus to the amount taken up by the roots.

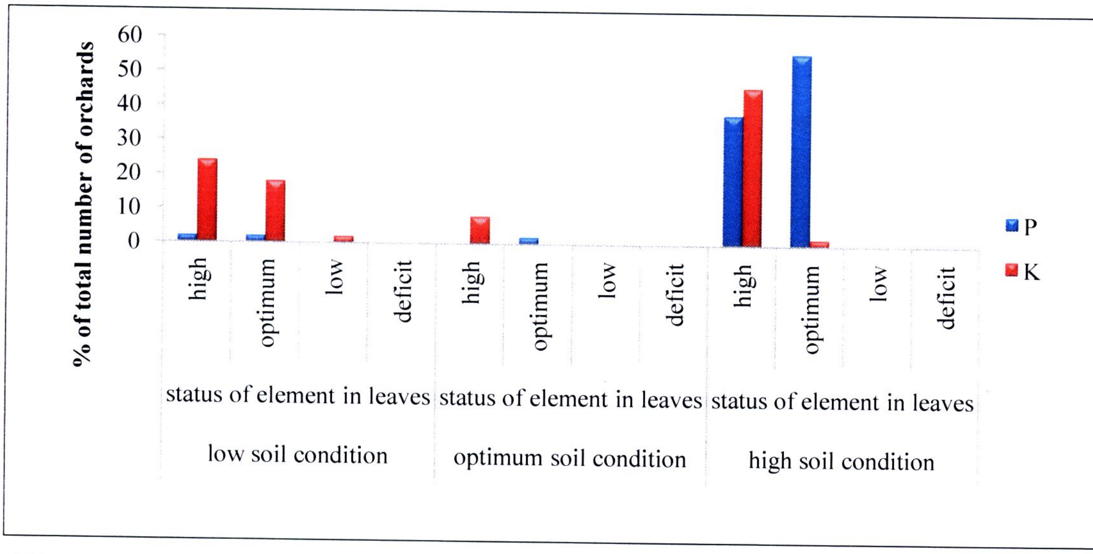

Figure 4.1 Status of P and K in the third index leaves of mandarin trees grown in different soil condition in April 2009

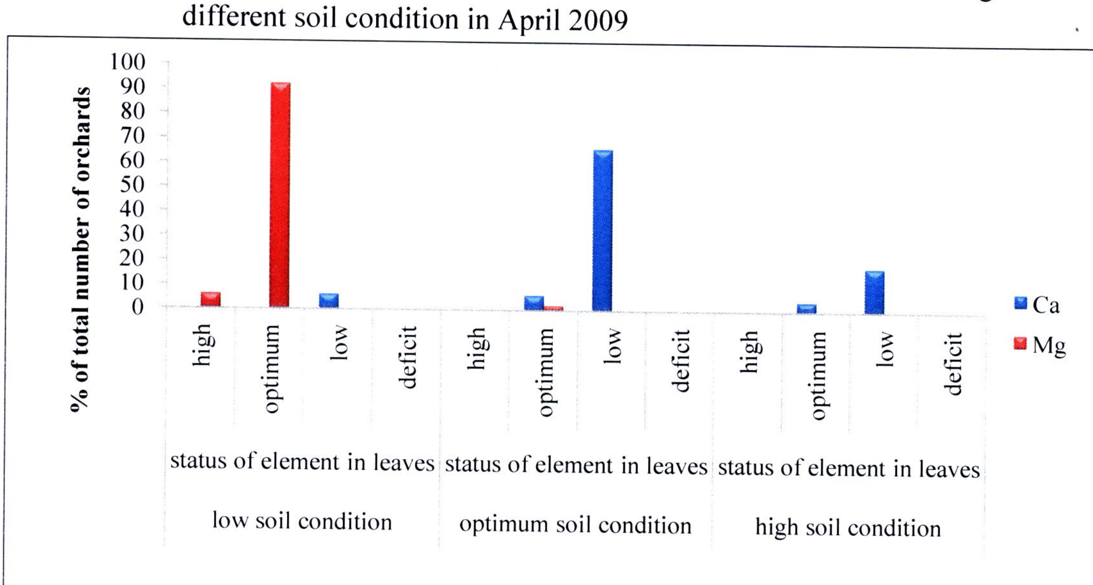

Figure 4.2 Status of Ca and Mg in the third index leaves of mandarin trees grown in different soil condition in April 2009

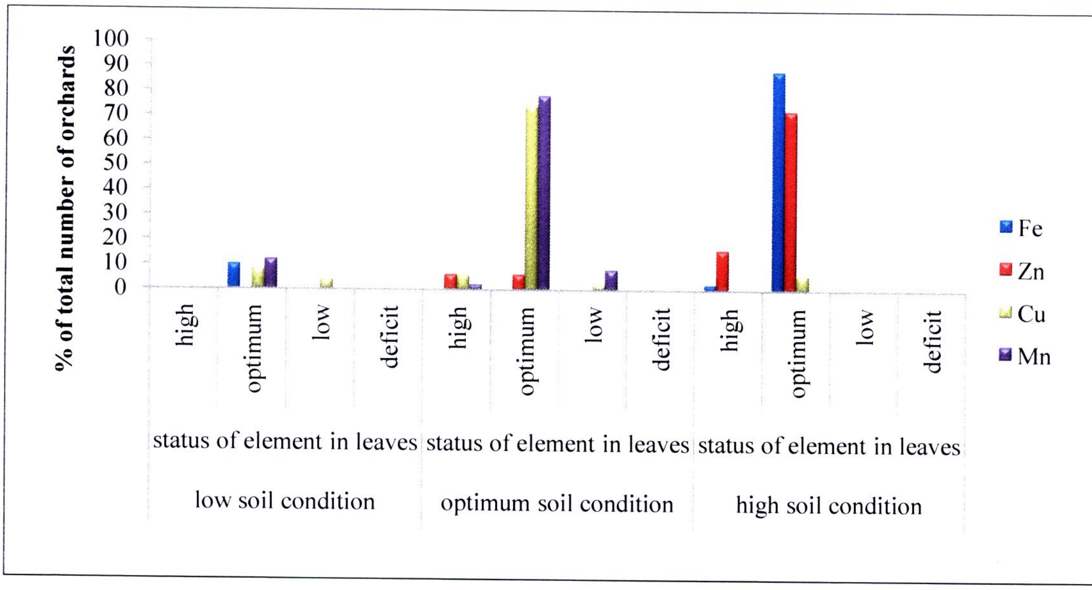

Figure 4.3 Status of Fe, Zn, Cu and Mn in the third index leaves of mandarin trees grown in different soil condition in April 2009

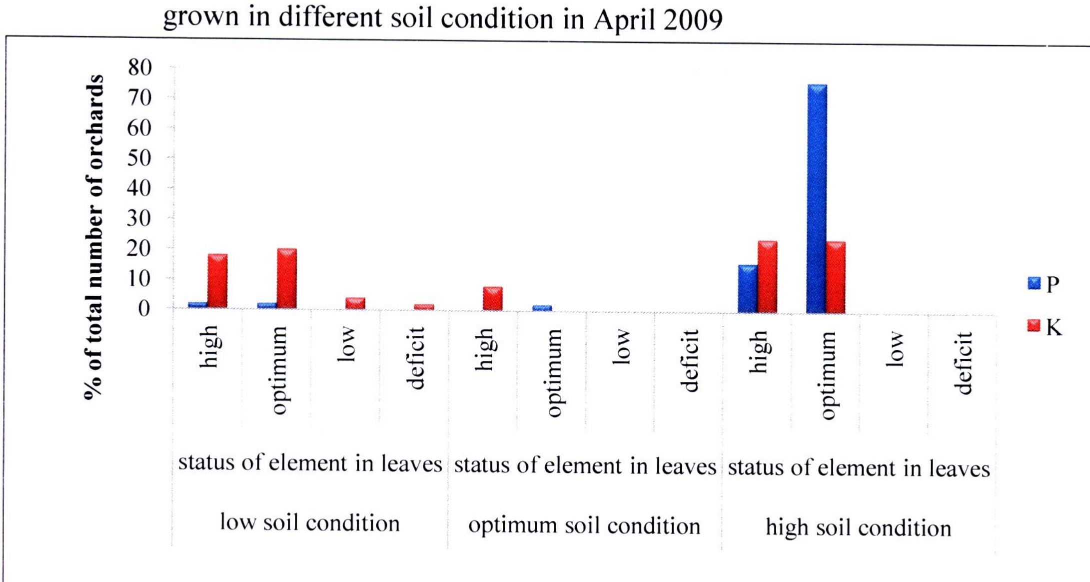

Figure 4.4 Status of P and K in the third index leaves of mandarin trees grown in different soil condition in July 2009

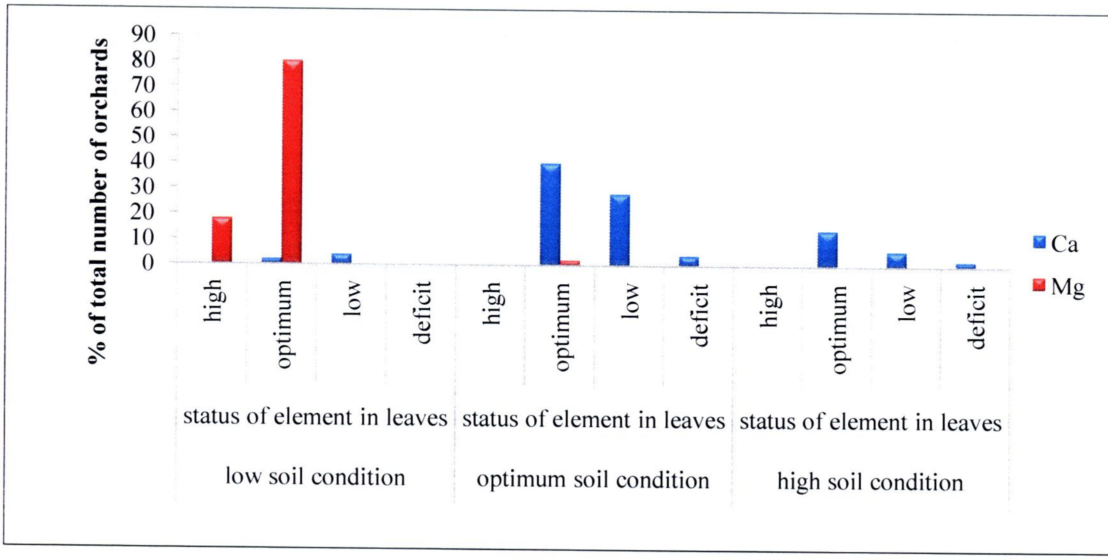

Figure 4.5 Status of Ca and Mg in the third index leaves of mandarin trees grown in different soil condition in July 2009

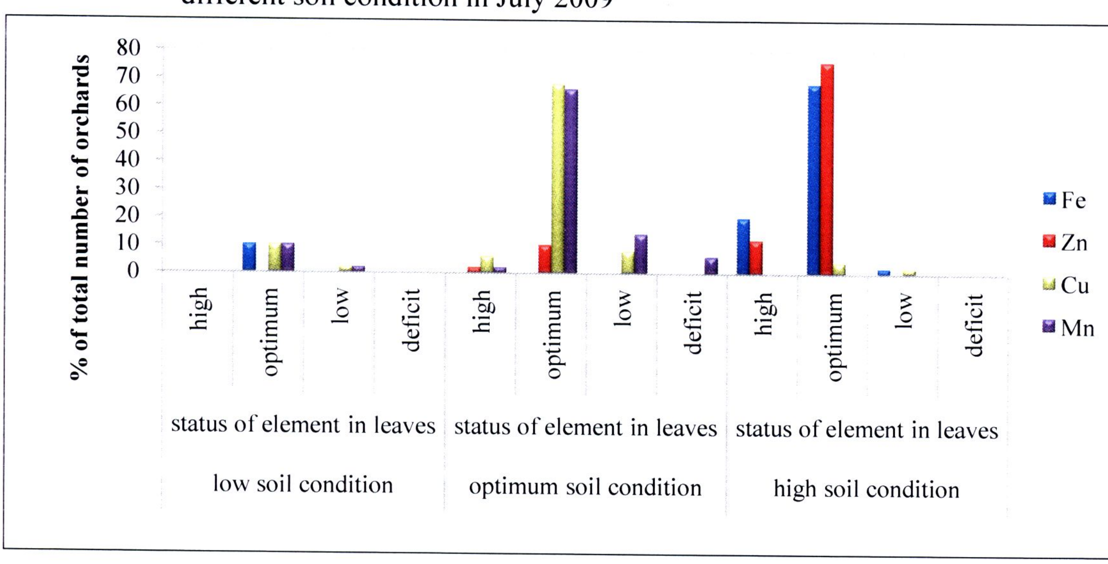

Figure 4.6 Status of Fe, Zn, Cu and Mn in the third index leaves of mandarin trees grown in different soil conditions in July 2009

4.1.4 Mandarin fruit product of the selected farmers in Mae Soon sub-district

Figure 4.7 and figure 4.8 showed the yields (kg/tree) and the basic fruit sizes of the mandarin fruit product of the selected farmers in Mae Soon sub-district respectively.

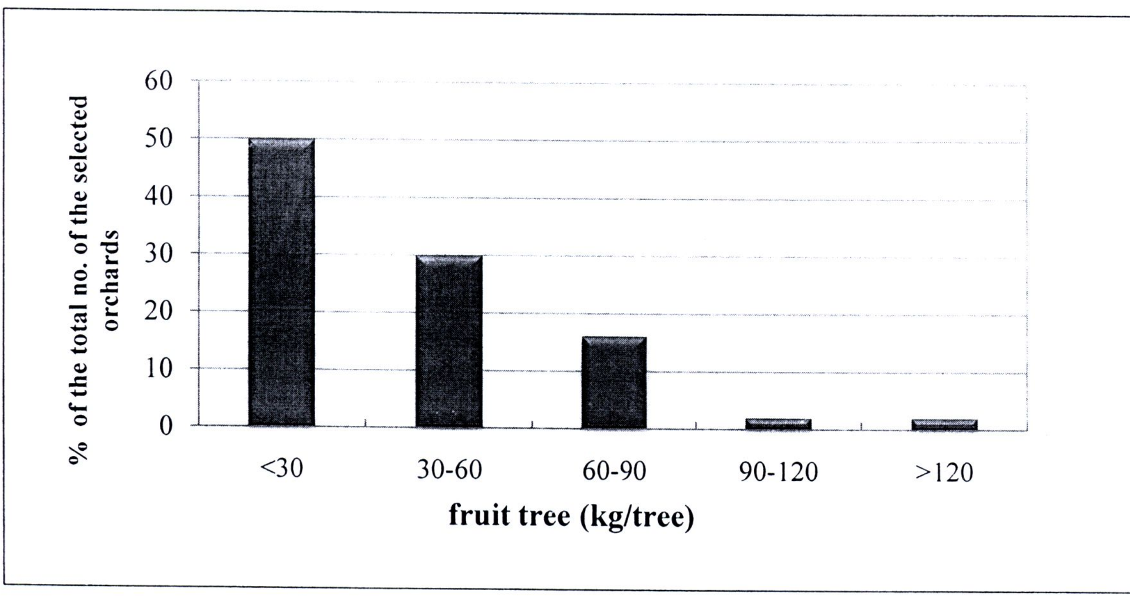

Figure 4.7 Mandarin fruit yields of the selected farmers

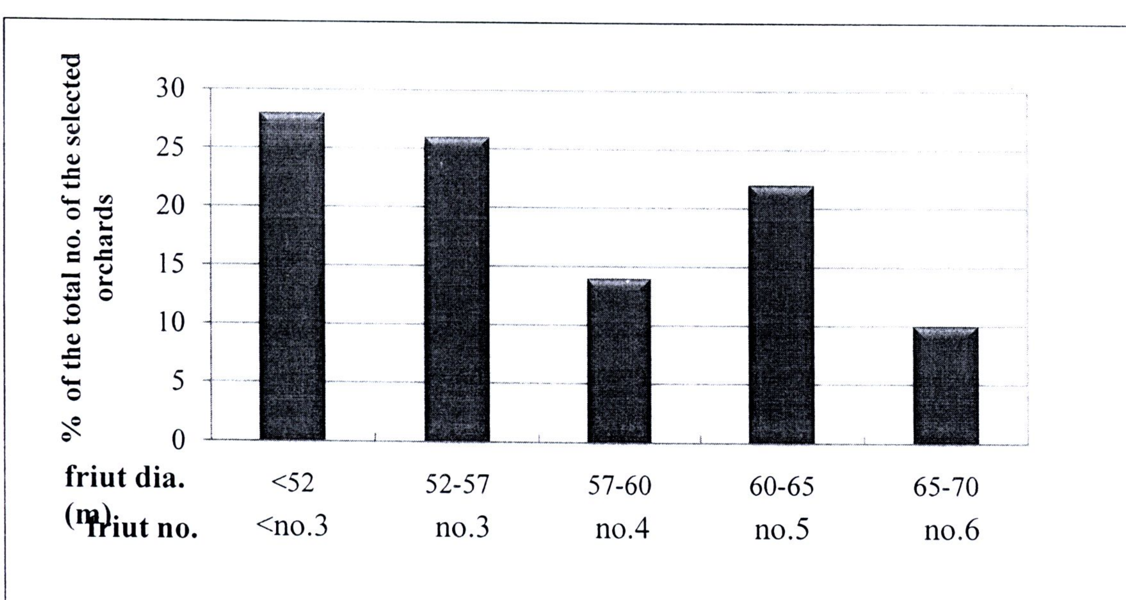

Figure 4.8 Basic mandarin fruits sizes of the selected farmers

The in season fruit yields in 2009/2011 of the selected mandarin farmers could be divided into 5 levels as follows; very high with the fruit yield above 120 kg/tree, high with the fruit yield within the range of 90-120 kg/tree, moderate with the fruit yield within the range of 60-90 kg/tree, low with the fruit yield with the range of 30-60 kg/tree and very low with the fruit yields below 30 kg/tree. About 50% of the fifty selected orchards had very low productivity and those having low fruit yields were about 30%. The orchards which could produce moderate, high and very high fruit yields were about 16%, 2% and 2% respectively.

According to the information obtained from interviewing of the middle men who bought the fruits at the farm gates and the owners of waxing plants in Mae Soon sub-district in 2010 (Unpublished data, Chiang Mai Sweet Tangerine Competiveness Project, 2009) the basic fruit sizes of in season fruit product of Fang, Mae Ai and Chaiprakarn district, Chiang Mai province for 2008/2009 were mostly fruit no.5 and no.6. (50^{th} National standard of Agricultural products and Food). From field survey, the orchards which could produce the basic fruit sizes no.4, no.5 and no.6 were 14%, 22 and 10% of the total numbers of selected farm respectively which those produced the smaller basic fruit sizes (no.3 and smaller than no.3) were about 26 and 28%. According to the information of Department of Interior trade, in October 2009 to February 2010 which was the harvesting period of in season mandarin fruit, the average selling prices of mandarin fruit were as follows ; no.6 32 baht/kg, no.5 24 baht/kg, no.4 17.5 baht/kg, the smaller fruit size 9-12 baht/kg. The small mandarin fruits were sold as the fruits for preparation of fresh mandarin juice.

4.2 On farm trial on reduction of chemical fertilizer usage in mandarin orchard and the effects on yield and quality of mandarin fruits

The effects of fertilizer treatment on mandarin fruit yields at the first and second harvest, total fruit yield and the contents of soluble solid which was the index of the sweetness of the fruits were shown in table 4.20.

Table 4.20 Effect of fertilizer treatments on mandarin fruit yield at the first and second harvest, total fruit yield and the contents of soluble solid (°brix)

Data		Fertilizer treatment				CV%
		NPK+FL	-PK+N+FL	-PK+N+fl	-PK+n+fl	
1st yield (kg/tree)	ns[2/]	27.9[1/]	25.3	26.4	27.1	28.98
2nd yield (kg/tree)	ns	47.2	63.9	56.9	55.7	25.54
total yield (kg/tree)	ns	75.1	89.2	83.3	82.8	18.98
% brix 1st harvest	ns	10.9	10.6	10.6	11.0	6.97
% brix 2nd harvest	ns	11.5	11.8	11.5	12.0	6.60

1/ means of 5 replications
2/ ns = non significant

There were no significant effects of fertilizer treatments on mandarin fruit yields at the first and second harvest including the total fruit yield. For the first harvest only 28-37% of the total fruit yield were obtained while those in the second harvest were about 62-80%. By farmer practice, mandarin trees gave total fruit yield about 75 kg/tree. Without application of P and K fertilizer and the same rate of N and foliar spraying were used (-PK+N+FL), the total mandarin fruit yield about 89 kg/tree was obtained. Reduction of the amount of fertilizer by foliar spraying and remaining the same rate of N application (-PK+N+fl) or even reduction of N application rate (-PK+n+fl), the trees still gave the total fruit yield about 83 kg/tree. The fertilizer application rates dose not have significant effects on the content of soluble solid contents of the fruit at both harvests.

At the first harvest, the content of the soluble solid of the fruits were in the range of 10.6-11 °brix while these at the second harvest were 11.5-12.0 °brix.

Table 4.21 Effects of fertilizer treatments on the yields of mandarin fruits with different sizes

Fruit size	Fruit diameter (mm)	Fertilizer treatment				CV%
		NPK+FL	**-PK+N+FL**	**-PK+N+fl**	**-PK+n+fl**	
No. 2 ns[2/]	47-52	0.11	0.52	0.94	0.34	97.53
No. 3 ns	>52-57	5.93	7.00	7.18	6.67	58.50
No. 4 ns	>57-60	13.66	15.62	18.19	13.93	35.94
No. 5 ns	>60-65	39.56	49.31	43.05	46.12	19.49
No. 6 ns	>65-70	14.45	15.87	12.42	14.58	31.94
No. 7 ns	>70-75	1.42	1.00	1.83	1.10	70.07

[1/] means of 5 replications
[2/] ns = non significant

No significant effects of fertilizer treatments on the yield of mandarin fruits at different sizes were found (table 4.21). Without P and K fertilizer applications, reduction of N rate and fertilizer application by foliar spraying (-PK+n+fl) almost the same yields of the fruits with different sizes as those by farmer rate were obtained. The yield of fruits with size 5 which was the most preferable size for the market was highest (52-56%) followed by size 5 (18-19%) and size 4 (16-20%). The rest were size 2, 3 and 7.

Table 4.22 Optimum levels and average concentrations of trace elements in the index leaf samples from the forth treatment

Trace elements[1/]	Average concentration of trace elements (mg/kg)		
	Optimum levels	30-Aug-08	30-Sep-08
Fe	60-120[2/]	118	121
Mn	25-100	69	91
Cu	5-16	5	7
Zn	25-100	348	552
B	36-100	55	71

[1/] means of 5 replications from the forth treatment
[2/]source: World Fertilizer Use Manual citrus (1992)

In August and September 2008, the status of Fe, Mn, Cu, Zn and B in the third fully mature leaves of mandarin twigs without flower and fruit bearing from the forth treatment were investigated. The average concentration of each trace element in the leaves indicated that after foliar spraying of Zn the concentration of Zn was very high (table 4.22). These data confirmed that the trace element spraying used in treatment 3 and 4 was sufficient to solve the problem of Zn deficiency.

The relative cost of input of fertilizer and relative mandarin total fruit yield were shown in table 4.23.

Table 4.23 Comparison of the relative cost of input on fertilizers and mandarin fruit yield among different fertilizer treatments

Item	**Fertilizer treatment**			
	NPK+FL	**-PK+N+FL**	**-PK+N+fl**	**-PK+n+fl**
cost of input (baht/ha)				
-soil fertilizer	49,286.25	7,683.75	7,683.75	1,100.25
-foliar fertilizer	23,260.50	23,260.50	825.00	825.00
-total fertilizer	72,546.75	30,944.25	8,508.75	1,925.25
relative total cost of input	100	42.65	11.73	2.63
cost reduction (%)		57.35	88.27	97.37
fruit yield (kg/ha)	25,346.00	30,105.00	28,114.00	27,945
relative yield (%)	100	118	111	110

By farmer fertilizer application rate the total cost of input was 72,546 baht/ha in which the fruit yield of 25,436 kg/ha was obtained. If P and K fertilizers were omitted, the cost of fertilizer applied to soil about 7,684 baht/ha was needed instead of 49,286 baht/ha as used by farmer. The foliar fertilizer application based on leaf analysis data required the input cost of 825 baht/ha while that by farmer practice needed about 23,260 baht/ha. Application of N fertilizer by consideration of N removal by fruit yield plus additional N to compensate N lost by leaching needed the cost of 1,100 baht/ha only.

The application of fertilizer according to Tr.2(-PK+N+FL), Tr.3(-PK+N+fl), and Tr.4(-PK+n+fl) could reduce the fertilizer input cost about 57 88 and 97% compared to farmer practice (Tr.1). Though less of cost of input were used in Tr.2, 3 and 4 but the total fruit yield did not reduced but increased about 18 11 and 11 percent of that from Tr.1.

In this study, the application of only N fertilizer at the farmer rate to the mandarin trees grown in the soil rich in available P and exchangeable K did not reduce the total mandarin fruit yield compared to the farmer rate in which N P and K were applied suggesting that in such soil condition no need to apply P and K fertilizer. Furthermore reduction of fertilizer usage by foliar spraying by consideration of the need from leaf analysis instead of spraying program of farmer practice did not reduce fruit yield and fruit qualities confirming the report of Kaosumain *et al.*(2002) who indicated that leaf analysis could be used for fertilizer management. The pattern of the response of mandarin trees to the fertilizer treatments in this study agreed with the reports of Chanvichit *et al.* (2007), who found that fertilizer management following the result of soil analysis could yield the same amount and quality of mandarin as in the case of farmer's practice.

Since in this study fertilizer application according to Tr.3 (-PK+N+fl) and Tr.4 (-PK+n+fl) could reduce the cost of input on fertilizer about 88 and 97% of that by farmer practice without yield reduction, we therefore recommended that in the orchard soil with high level of available P and exchangeable K, the application of P and K fertilizer were not needed. Regarding to the N application rate, in this study, the fertilizer trial did not start at the beginning of the season thus, the actual N requirement for mandarin fruit crop throughout the growing season could not be recommended. However, according to Supakumnerd *et al.* (2005) 1 kg of mandarin fruit at 10 month olds contained 1.44 g N, 0.39 g P_2O_5 and 2.09 g K_2O. This information could be used together with the soil analysis data on available P and exchangeable K in order for recommendation of the proper application rates of N, P and K for mandarin fruit production of the farmer. At present the information on nutrient lost from leaching in Thailand particularly the mandarin cultivated area in Chiang Mai was not available. In this study, we assumed that the N lost by leaching was 40% the N lost which in fact might vary with topographic, climatic and soil condition. Nevertheless, the obtained experimental result could show that the fertilizer application by reduced without fruit yield declination.

From this study we could conclude that in the soil with the higher levels of available P (>60 mgP/kg) and exchangeable K (>120 mgK/kg) than the optimum level, no P and K fertilizer applications were not needed for healthy mandarin trees. The foliar fertilizer application to mandarin trees could be managed by following the result of leaf analysis data. The amount of N application rate could be estimated by consideration of the N removal by expected fruit yield.

4.3 Spatial data base of factors affecting productivity declination of mandarin orchards in Mae Soon sub-district

The data used for developing spatial database of mandarin orchards in Mae Soon sub-district were administrative boundary of Mae Soon sub-district, village positions, steam lines, soil quality, topographic condition (slope and elevation), mandarin cultivated area in Mae Soon sub-district in 2010, orchard management of the farmers and fruit production in 2010/2011. Three symbols, point, line and polygon were used in the developed spatial database.

4.3.1 Basic data of the study area

1) Administrative boundary and village position of Mae Soon sub-district

The boundary of Mae Soon sub-district was indicated as polygons (figure 4.9) while the positions of the villages were shown as point features (figure 4.10). The total area of Mae Soon sub-district is 52,962.34 rais. There were 17 villages in this sub-district as follows ; Ban Mae Soon Luong, Ban Pang Suk, Ban Mae Soon Noi, Ban Sanpasuk, ban Pong Aor, Ban Ton Sarn, Ban Nong Yao, Ban Petch Paitoon, Ban San Din Dang, Ban San Ma Fuang , Ban San Pa Keae, Ban San Mamuoag, Ban Mai Pong Pa, Ban Santipatana, Ban Mai Chai Kasem, Ban Nong Yao Nuare and Ban Nong Yao Tai.

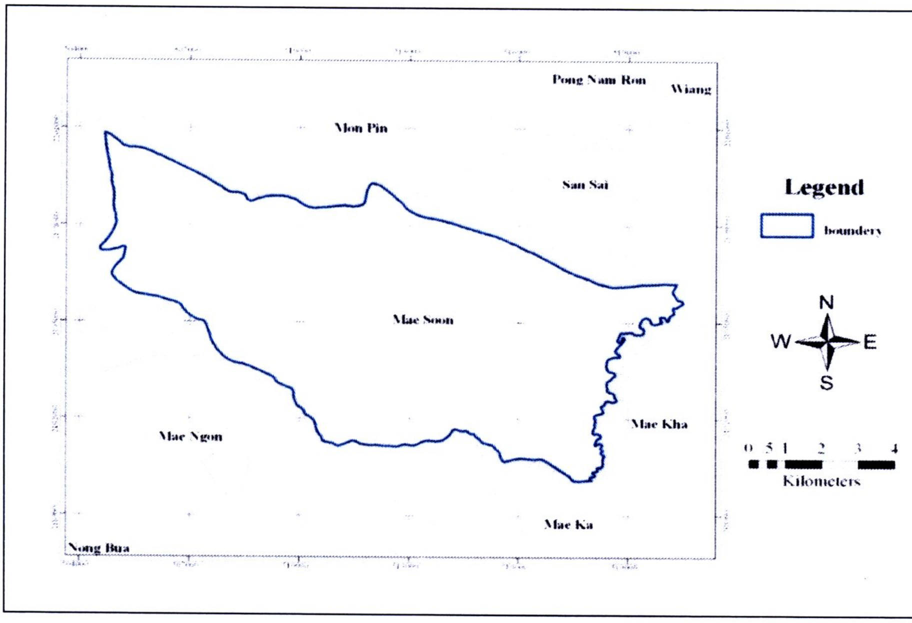

Figure 4.9 Administrative boundary of Mae Soon sub-district

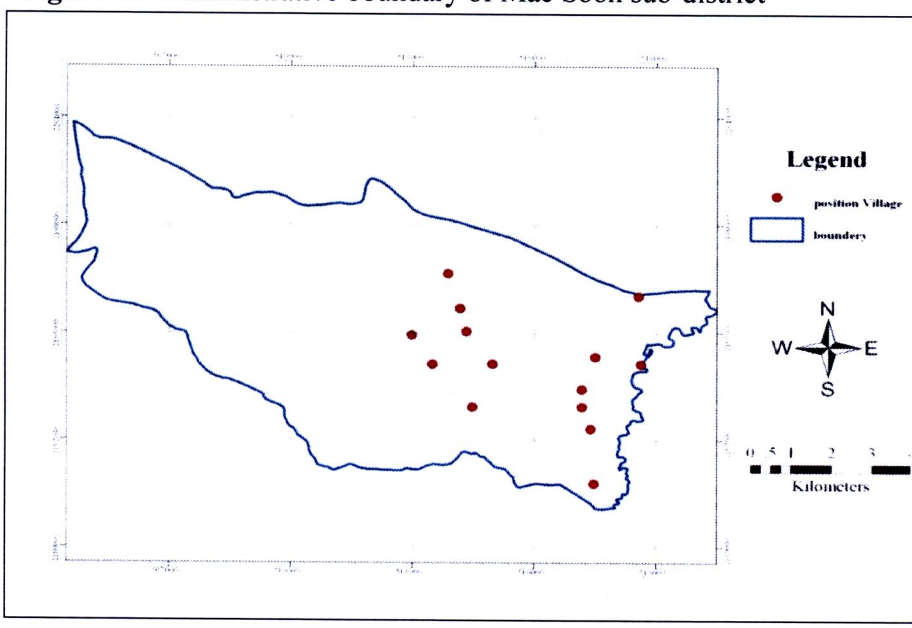

Figure 4.10 Position of the villages in Mae Soon sub-district

2) Steam lines

The map layer shown in figure 4.11 indicated the steam lines and the main river in the study area as the line features. There were 21 steam lines in the study area as follows; Huai Hia, Huai Hom, Huai Kang, Huai Ma Tai, Huai Mae Ngon Noi, Huai Mae Ngon, Huai Mae Soon Luang, Huai Nam Un, Huai Nong Bua, Huai Pa Miang, Huai Sai Khao, Huai Sai, Huai Suan Miang, Huai Ton San, Huai Yang, Nam Mae Fang, Nam Mae Soon Luang, Nam Mae Soon Noi, Nam Mueang, Nam Nong Hua and Nam Rong Pao.

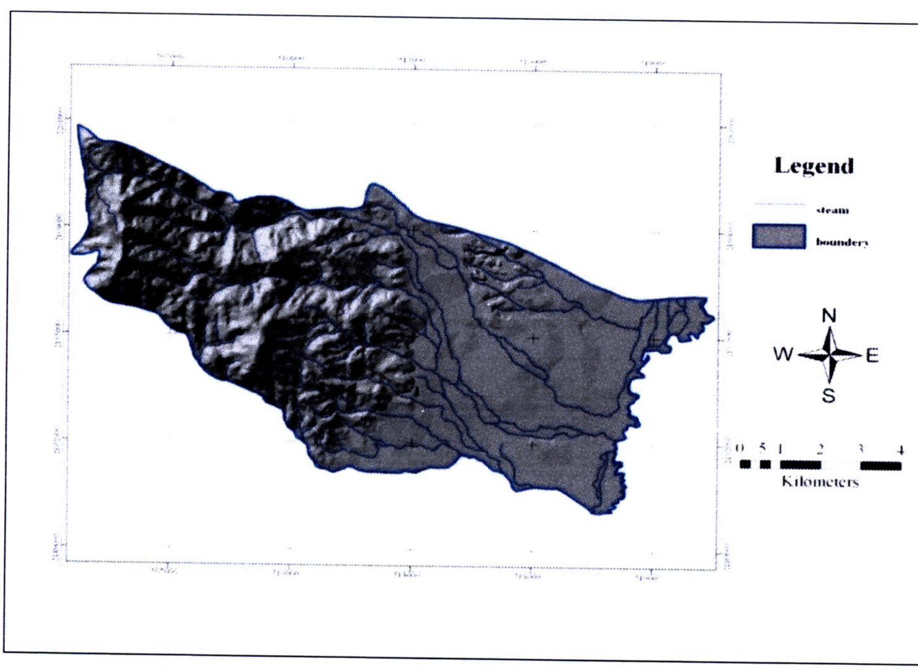

Figure 4.11 Steam line and main rivers in Mae Soon sub-district

4.3.2 Mandarin cultivated area in Mae Soon sub-district

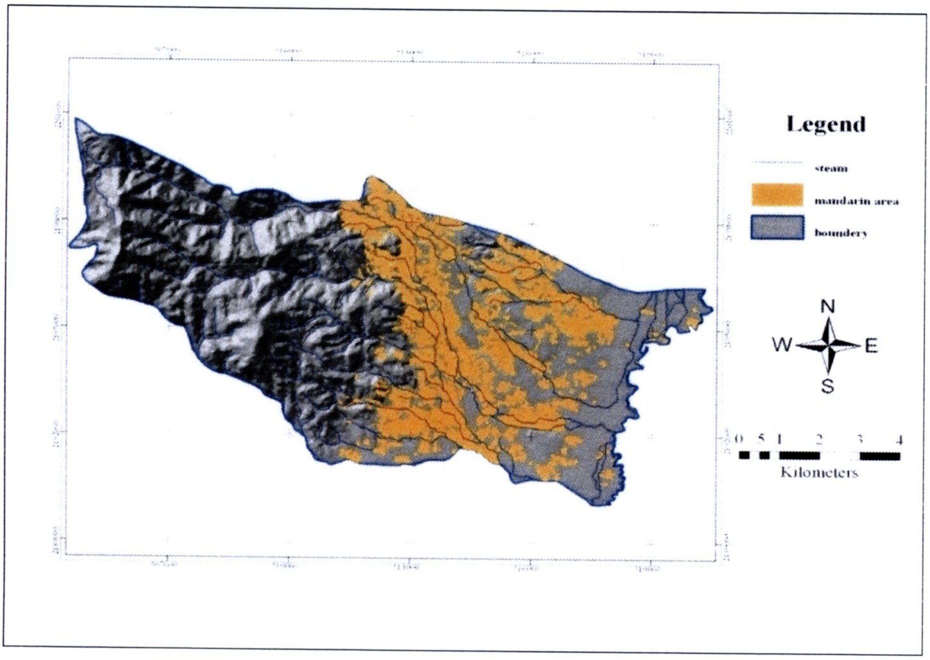

Figure 4.12 Mandarin cultivated area in Mae Soon sub-district in 2010

By the use of visual interpretation of THEOS multispectral satellite image with 15 meter- resolution incombination of with the data from field survey and the present GPS of mandarin orchard as the inputs for Arc GIS 9.2 program the map layer of mandarin cultivated areas in Mae Soon sub-district was obtained as shown in figure 4.12. The total mandarin cultivated areas were 11,156.6 rais. Most orchards were the small orchards with the size less than 100 rais.

4.3.3 Soil series

In figure.4.13, the 15 soil series in mandarin cultivated area of Mae Soon sub-district were shown as polygon features. The names of soil series were shown in table 4.24 and the description of each soil series was indicated in the appendix B.

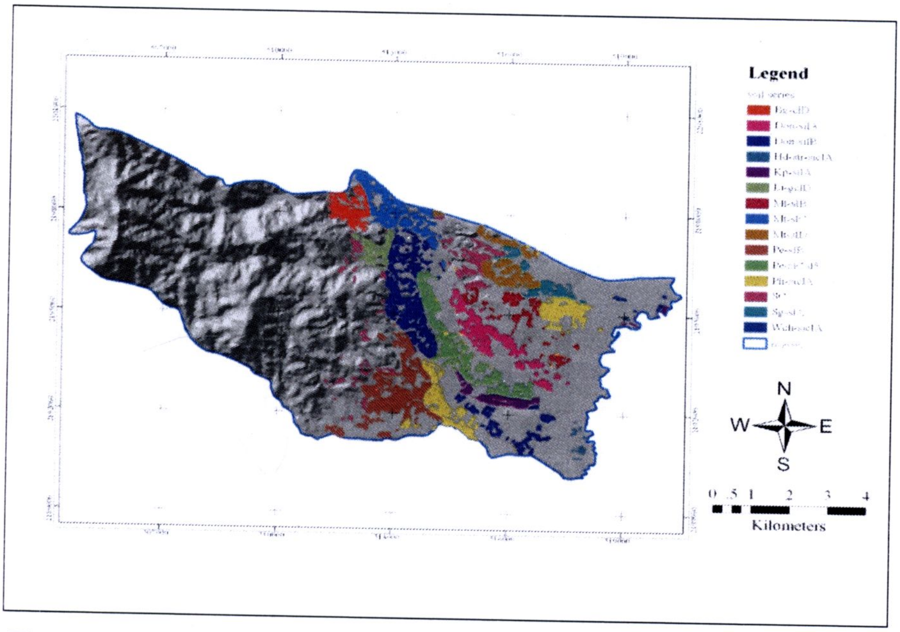

Figure 4.13 Soil series in mandarin cultivated area in Mae Soon sub-district in 2010

Table 4.24 The name of soil series in mandarin cultivated area in Mae Soon sub-district

No.	Code series	Name series	Area (rai)	%
1	Bg-clD	Ban Chong	486.3	4.4
2	Don-silA	Dong Yang En	853.7	7.7
3	Don-silB	Dong Yang En	1,875.4	16.8
4	Hd-str-siclA	Hang Dong	67.5	0.6
5	Kp-silA	Kamphaeng Phet	379.6	3.4
6	Li-gclD	Li	352.6	3.2
7	Mt-slB	Mae Taeng	505.3	4.5
8	Mt-slC	Mae Taeng	871.3	7.8
9	Mt-slD	Mae Taeng	650.8	5.8
10	Pe-slB	Phetchabun	1,501.5	13.5
11	Pe-slC/d5	Phetchabun	1,149.4	10.3
12	Ph-siclA	Phan	1,195.7	10.7
13	SC	Slope Complex	853.1	7.6
14	Sg-slA	Sai Ngam	359.1	3.2
15	Wch-siclA	Wang Chomphu	55.3	0.5
Total			**11,156.6**	**100.0**

The following soil properties, drainage, run off permeability and soil depth were selected for developing the map layers as shown in figure 4.14, 4.15, 4.16 and 4.17 respectively.

Soil drainage data, runoff data and permeability data of mandarin cultivated area of Mae Soon sub-district were obtained from the details of each soil series (LDD, 2008). Anyway, soil drainage data, runoff data and permeability data from descriptions of some soil series were adjusted according to the texture of the given soil.

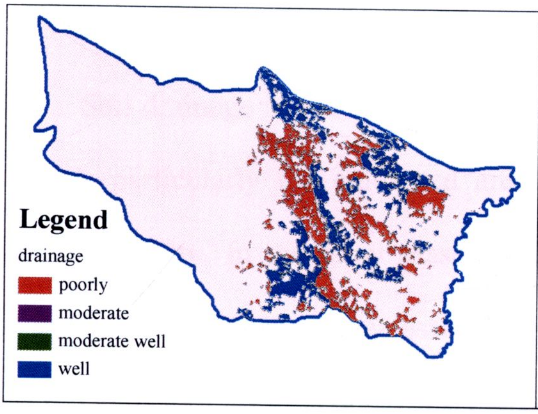

Figure 4.14 Drainage map layer

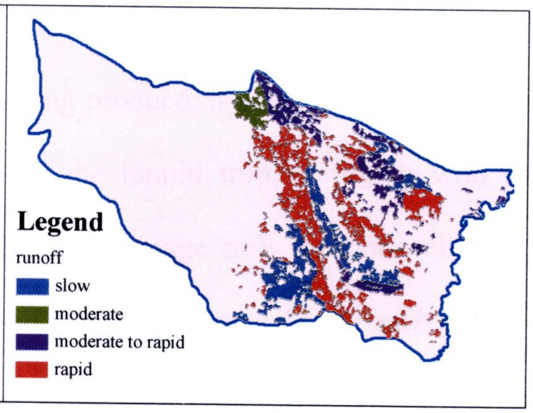

Figure 4.15 Runoff map layer

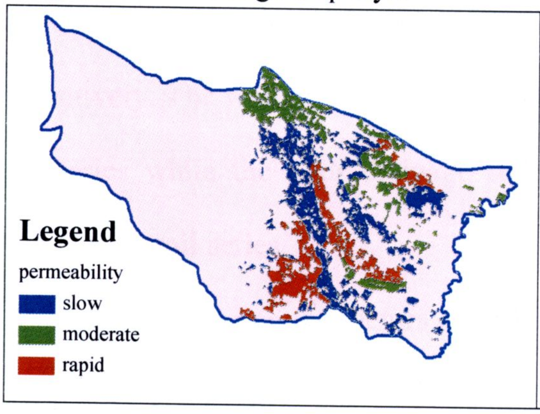

Figure 4.16 Permeability map layer

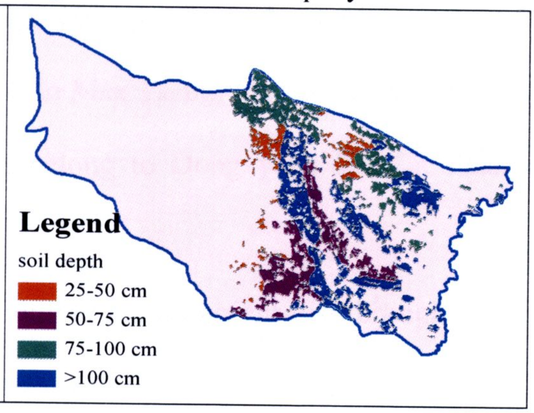

Figure 4.17 Soil depth map layer

The soil in mandarin cultivated area of Mae Soon sub-district could be classified into 4 classes as shown in table 4.25.

Table 4.25 Drainage of mandarin cultivated area in Mae Soon sub-district

Drainage	Area (rai)	%
poorly	5,198.2	46.6
moderate	541.5	4.9
moderate well	379.4	3.4
well	5,037.5	45.2
Total	**11,156.6**	**100.0**

Soil drainage is one the factors affecting productivity declination of mandarin orchards particularly the cultivated areas in the humid tropical region with high rainfall intensity. In the rainy season, the poor drainage soils are not well aerated resulting in insufficient oxygen assimilation by mandarin roots. Under such condition it is risky for root rot infection. As shown in Table 6.2 the mandarin cultivated soils in Mae Soon sub-district with poor and well drainage were about 46.6 and 45.2 % respectively. The well drainage soils belong to Mae Taeng, phetchabun and Sai Ngam soil series while the poor drainage soils belong to Dong yang En, Li, Phan and Hang Dong soil series.

Run off is one the factors contributing to plant nutrient lost through leaching. According to the report of in the sloping area with fine soil texture, plant nutrient lost by runoff was rather severe because the amount of permeable water through soil profile with fine soil texture was small. Runoff could be occurred in the soil with hard pan (Obreza and Collins, 1999).

Table 4.26 Runoff of mandarin cultivated areas in Mae Soon sub-district

Runoff	Area (rai)	%
slow	3,009.9	27.0
moderate	486.1	4.4
moderate to rapid	2,462.5	22.1
rapid	5,198.2	46.6
Total	**11,156.6**	**100.0**

Most (46.6%) of the mandarin cultivated soils in Mae Soon sub-district had rapid runoff (table 4.26). There soils were in Dong Yang En, Li, Phan, Hang Dong soil series and slope complex soil. Twenty seven percent of the total mandarin cultivated soils had slow runoff and these soils were Phetchabun and Sai Ngam soil series. There were 22.1% of the total mandarin cultivated soils which had moderate to runoff. They were the following had moderate to runoff. They were the following soil series; Mae Taeng, Kamphaeng Phet and Wang Chomphu.

Soil permeability is another factor contributing to leaching of plant nutrients below the root zone resulting in soil fertility declination. The coarse texture soil such as sandy soil have rapid permeability thus nutrient lost through leaching is likely to occur.

About 47% of the mandarin cultivated soils in Mae Soon sub-district had low permeability. These soils belong to the following soil series, Dong Yang En, Li, Phan, Hang Dong including slope complex soil. The soils with rapid permeability which were about 27% of the total mandarin cultivated soils were Phetchabun and Sai Ngam soil series. The rest which had moderate permeability belong to Mae Taeng, Ban Chong, Kamphaeng Phet and Wang Chomphu soil series (table 4.27).

Table 4.27 Permeability of mandarin cultivated areas in Mae Soon sub-district

Permeability	Area (rai)	%
slow	5198.1	46.6
moderate	2948.7	26.4
rapid	3009.8	27.0
Total	**11,156.6**	**100.0**

4.3.4 Topographic database: slope and elevation

The topographic database consisted of two map layers of elevation and slop. The spatial database of elevation was developed from Digital Elevation Mel (DEM). From DEM, the lowest elevation of Mae Soon sub-district is 480 meters and the highest elevation is 1920 meters. In the develops map layer, the mandarin cultivated areas of Mae Soon sub-district were divided into three classes according to the elevation levels as follows ; <590 meters, 590-740 meters and >740 meters as shown in figure 4.18 and table 4.28.

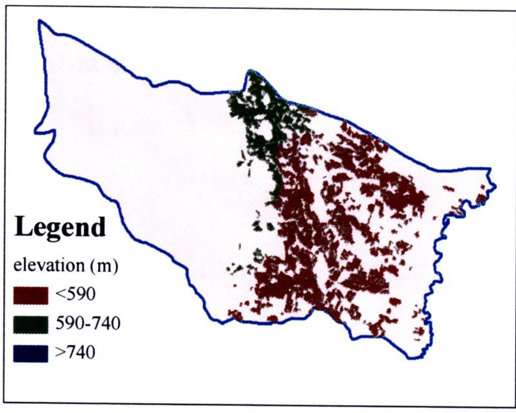

Figure 4.18 Elevation map layer

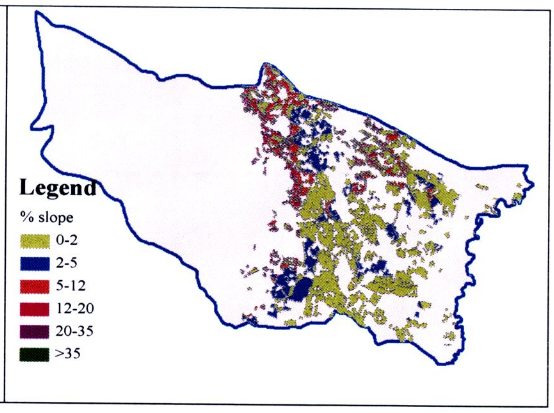

Figure 4.19 Slope map layer

Table 4.28 Elevation of mandarin cultivated areas in Mae Soon sub-district

Elevation (cm)	Area (rai)	%
<590	8,896.9	79.7
590-740	2,257.8	20.2
>740	1.9	0.0
Total	**11,156.6**	**100.0**

Most of mandarin cultivated area of Mae Soon sub-district (79.7%) had elevation less than 590 meters and about 28.2 % located on the area with the elevation within the range of 590-740 meters.

The slops map layer was also developed from DEM. The levels of slope were classified into 6 classes according to the criteria of Land Development Department (2007) as follows ; 0-2%, 2-5%, 5-12%, 12-20%, 20-35%, and >35% as shown in figure 4.19 and table 4.29.

Table 4.29 Slope of mandarin cultivated areas in Mae Soon sub-district

% slope	Area (rai)	%
0-2	6488.4	58.2
2-5	2228.7	20.0
5-12	1375.1	12.3
12-20	725.2	6.5
20-35	319.3	2.9
>35	19.9	0.2
Total	**11,156.6**	**100.0**

Most of mandarin cultivated areas in Mae Soon sub-district (58.2%) were the area with less than 5% slope. Those with the slope 2-5%, 5-12% 12-20% and 20-35% were about 20, 12.3, 6.5, and 2.9% respectively. The areas with slope more than 35% were only 0.2 %.

According to description of the Royal Institute (2001) and Land Development Department (2000), the foothill or the lowland is the area with the elevation above the local ground level not more than 150 meters and does not have high elevation above the mean sea level. It is difficult to clearly differentiate the levels among different locations in such area. Regarding to the description of the highland, it has been defined as the mountainous areas with the elevation above the local ground level more than 300 meters.

In this study, the description of the foothill and the highland as mentioned above were considered together with the observation from field survey in order to characterize the physical condition of the area as shown in table 4.30.

Table 4.30 Criteria for physical condition characterization of mandarin cultivated area in Mae Soon sub-district

Elevation	Slope (%)	Area classification
< 590 m	0 – 5	low land
	> 5	sloping land
590 – 740 m	0 – 5	foothill
	> 5	sloping land
> 740 m	0 – 5	up land
	> 5	sloping land

Based on the criteria in table 4.30, the mandarin cultivated areas in Mae Soon sub-district and the 50 selected farmers' orchard could be classified into three zones as shown in table 4.31. The map layer of physical condition of mandarin cultivated areas in Mae Soon sub-district was shown in figure 4.20 and that for the 50 selected farmer's orchards was shown in figure 4.21.

Table 4.31 Physical characterizations of mandarin cultivated areas in Mae Soon sub-district and the 50 selected farmers' orchard

Physical characterization	**Mandarin cultivated area in Mae Soon**		**50 selected farmers orchard**		
	Area (rai)	**% area**	**No. of mapping unit**	**Area (rai)**	**% area**
lowland	7,822.1	70.1	23	87.4	56.5
foothill	895.1	8.0	34	33.5	21.7
sloping land	2,439.4	21.9	46	33.7	21.8
Total	**11,156.6**	**100.0**	**103**	**154.6**	**100.0**

There were mandarin cultivated areas in the lowland about 7,822 rais which was 70% of the total mandarin cultivated area. Those located on the foothill were about 895 rais or about 8% of the total mandarin cultivated area. The orchards on the sloping 22% of the total cultivated area for mandarin.

Regarding to the 50 selected orchards, about 87 rais or 56.5% were located on the lowland while those on the foothill were 33.5 rais or 21.7% . There were the orchards on the sloping land about 33.7 rais or about 21.7%.

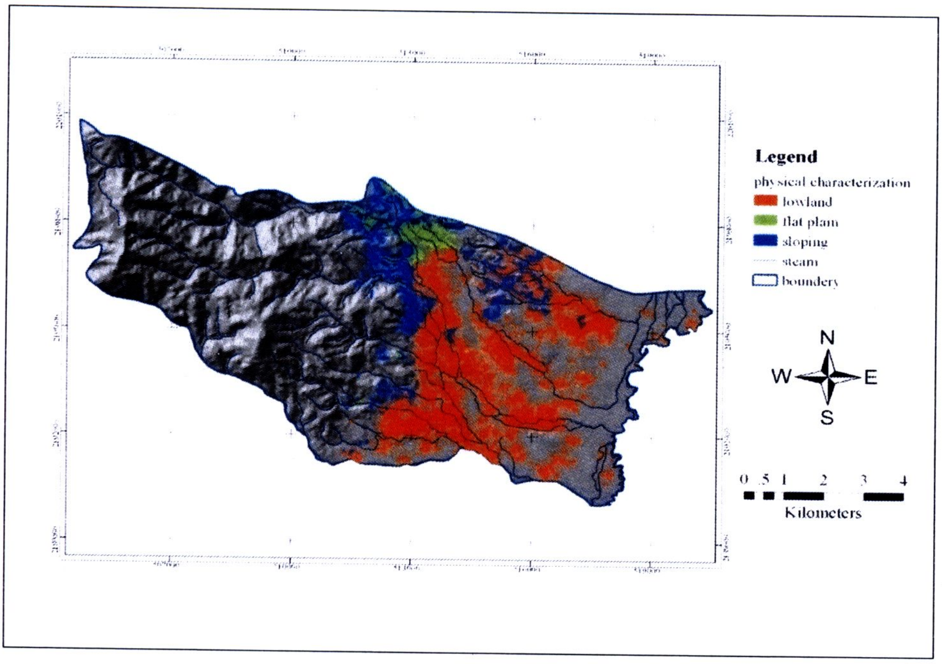

Figure 4.20 Physical characterization of mandarin cultivated areas in Mae Soon sub-district

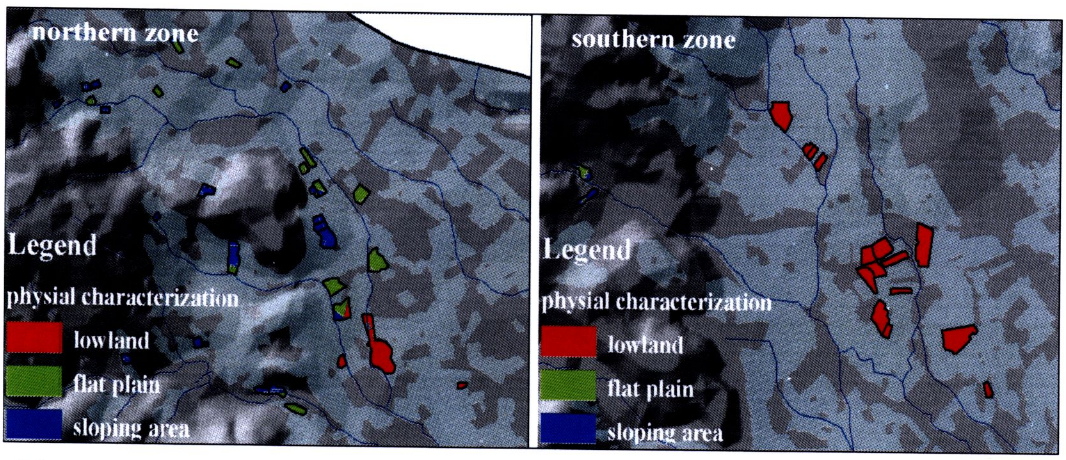

Figure 4.21 Physical characterization of 50 selected farmers orchard

4.3.5 Information of 50 selected mandarin orchards

Though the following soil chemical properties, pH, CEC, organic matter, available P, exchangeable K, Ca and Mg and extractable Zn, Cu, Mn and Fe, the physical properties such as bulk density and porosity including soil biological property such as soil microbial biomass C of the soils from all selected orchards were analyzed but only pH, CEC, organic matter, available P and exchangeable K were selected as the soil factors contributing to the productive declination of mandarin orchards. The map layer of each selected soil property were developed as shown in figure 4.22 to figure 4.26. In soil pH map layer the pH of the soils from 50 selected orchards were classified into 4 classes according to the criterion of Obreza and Morgan (2002). In CEC map layer, three classes of CEC were used following the criterion of (Maneepong *et al.*,2005).

The criterion of LDD (2008) was used for classification of soil organic matter into 5 classes as indicated in soil organic matter map layer. Only two classes of available P and exchangeable K were used in map layers by using the criteria of Supakumnerd *et al.*(2005).

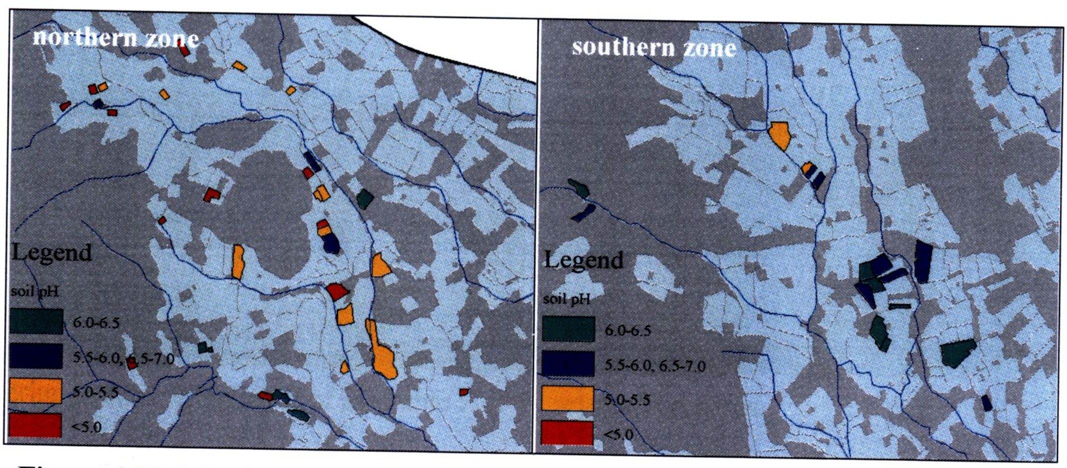

Figure 4.22 Map layer of soil pH of 50 selected orchards

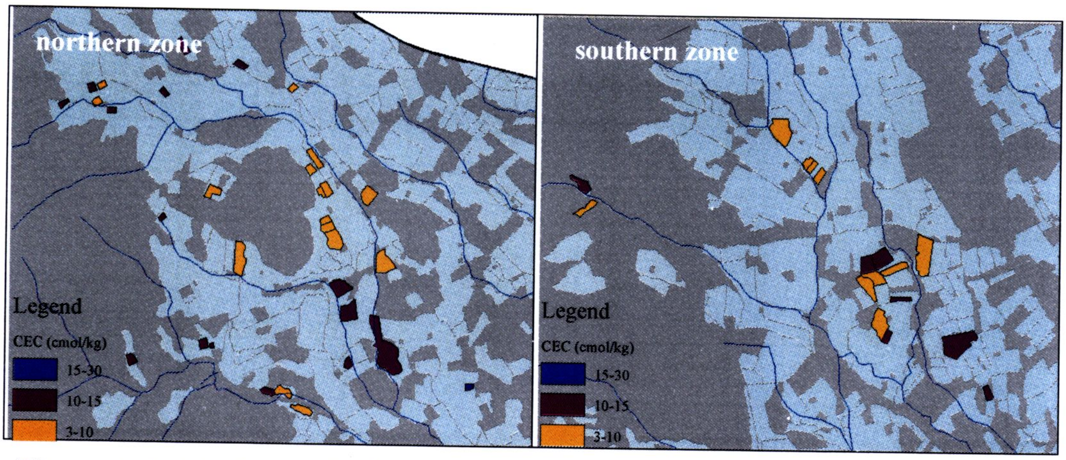

Figure 4.23 Map layer of CEC of 50 selected orchards

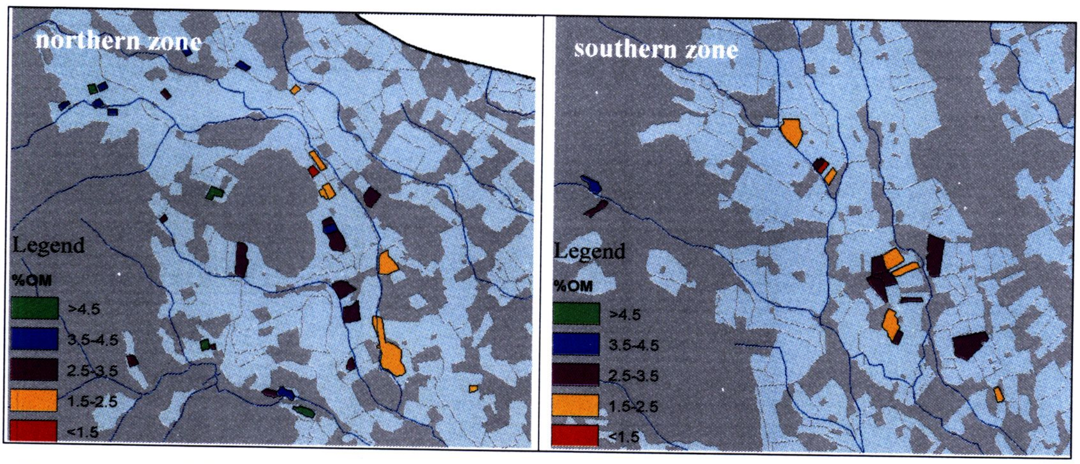

Figure 4.24 Map layer of % organic matter of 50 selected orchards

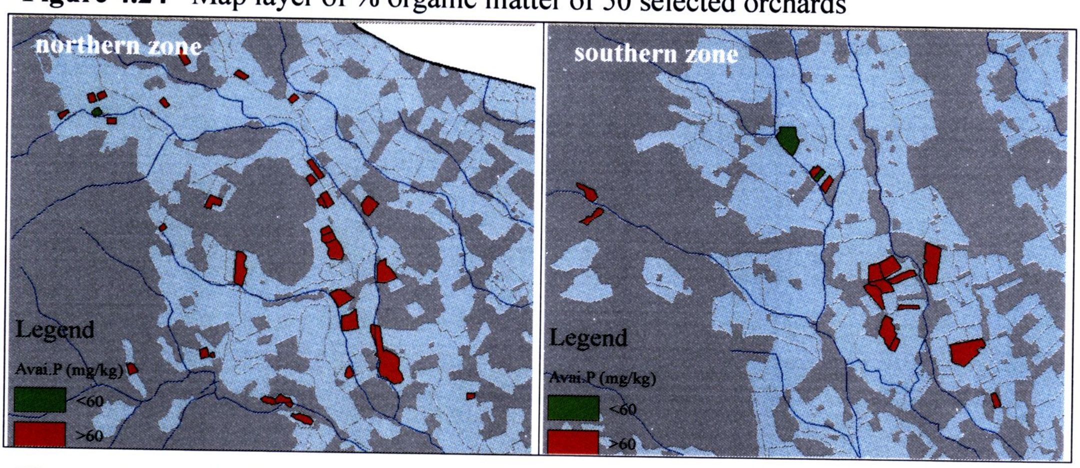

Figure 4.25 Map layer of available P of 50 selected orchards

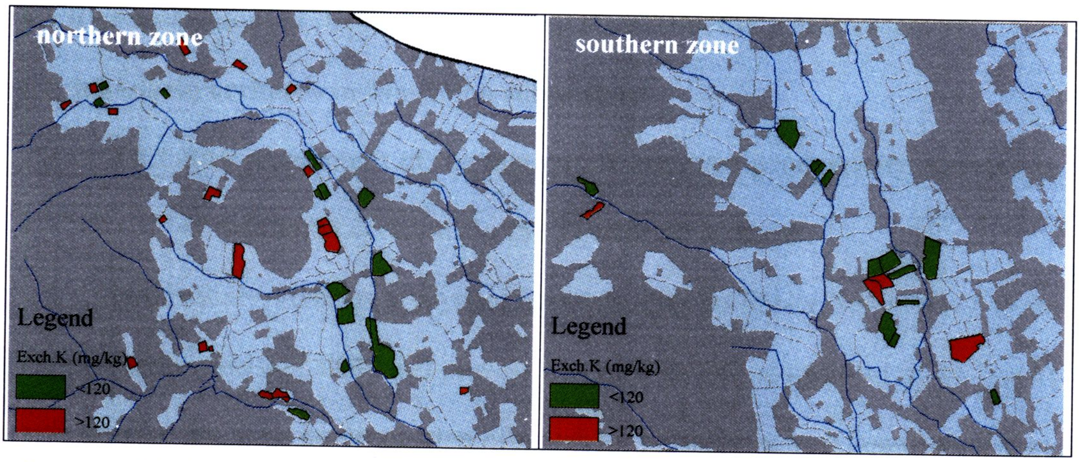

Figure 4.26 Map layer of exchangeable K of 50 selected orchards

4.4 Risk assessment of the factors affecting the productivity declination of mandarin orchards in Mae Soon sub-district

4.4.1 Risk assessment of the factors affecting the productivity declination of mandarin orchards in the 50 selected orchards

In this study, AHP or Analytical Hierarchy Process (Saaty, 1980) which is the multi-criterion decision analytical process was used for risk assessment of the factors affecting the productivity declination of mandarin orchards in Mae Soon sub-district. In this analytical process, the causes of productivity declination of mandarin orchards in the study area were selected. This first analytical step is generally known as "criterion setting" step. Then the selected impact factors were divided into different classes according to the suitability and limitation for mandarin cultivation and categorized each of them into risky classes according to its contribution to each productivity declining cause. This second analytical step is commonly known as "criterion standardization". In the third analytical step, the importance of selected factors was considered and the significance of each pair of evaluated factors was compared. The third analytical step is commonly known as criterion weighing. In the last analytical step, the risk assessments of the selected factors contribution to each cause of productivity declination of mandarin orchards were evaluated. The proper management to reduce the risk was finally proposed by synthesizing scenario according to the existing topographic condition and soil quality.

4.4.1.1 Factors affecting productivity declination of mandarin orchards

Based on the topographic condition of the study area, observation from field survey and the information obtained from farmers interview, there were three causes contributing to productivity declination of mandarin orchards in Mae Soon sub-district as follows: root rot, nutrient lost through runoff and leaching and imbalance of plant nutrients in the soils. Two mains factors related to each cause were topographic condition and soil quality.

Regarding to root rot, there were 7 influencing factors as following; slope, elevation, drainage, bulk density, soil porosity, soil pH and soil organic matter. For nutrient lost through leaching and runoff, the related factors were slope, runoff, soil permeability, soil depth, CEC, pH and organic matter. Five factors as follows, soil pH, CEC, soil organic matter levels of the avai. Pand exch. K in the soil were involved with plant nutrient imbalance of the soils.

4.4.1.2 Classification of the factors contributing to deterioration of mandarin orchards

The factors related with each deteriorating cause of mandarin orchards were classified into 5 risky classes from lowest to highest with the risky score from 0.2 to 1.0 using the same interval for division of risky class. The data from research report related with mandarin cultivation and observation from the existing condition during field survey were considered in order to classify the risky class of each factor.

The risky classes of the factors contributing to root rot were shown in table 4.32 while those related to nutrient lost though leaching and runoff were shown in table 4.33 and those related to plant nutrient imbalance of the soils were shown in the table 4.34.

Table 4.32 Risky classification of the factors contributing to root rot

Factors	Risky score					Criterion source
	Lowest (0.2)	**Low (0.4)**	**Moderate (0.6)**	**High (0.8)**	**Highest (1.0)**	
slope (%)	12-20 20-35 >35	5-12			0-2 2-5	(LDD, 1998)
soil drainage	well	moderate well	moderate		poorly	(LDD, 1998)
elevation (MSL)		590-740 >740		<590		Royal Institute (2007) and LDD (1999)
soil bulk density (g/cm^3)	<1.30	1.30-1.40	1.40-1.65	1.65-1.80	>1.80	Sagwansupyakorn, (2009)
soil porosity (% by volume)	>62.26	47.17-62.26		<47.17		Panomtaranichagul (2008)
soil pH	>6.0	5.5-6.0		5.0-5.5	<5.0	Obreza and Collins (2002)
soil organic matter (%)	>4.5	3.5-4.5	2.5-3.5	1.5-2.5	<1.5	Sagwansupyakorn, (2009)

Table 4.33 Risky classification of the factors contributing to nutrient lost through leaching and runoff

Factors	Risky score					Criterion source
	Lowest (0.2)	**Low (0.4)**	**Moderate (0.6)**	**High (0.8)**	**Highest (1.0)**	
slope (%)	0-2 2-5	5-12	12-20	20-35	>35	(LDD, 1997)
CEC (cmol/kg)	>30	15-30	10-15	3-10	<3	Maneepong *et al.* (2005)
runoff		slow	moderate	moderate to rapid	rapid	(LDD, 1997)
soil permeability		slow	moderate		rapid	(LDD, 1997)
soil depth (cm)	>100	75-100	50-75	25-50	<25	(LDD, 1997)
soil pH	>6.0	5.5-6.0		5.0-5.5	<5.0	Obreza and Collins (2002)
soil organic matter (%)	>4.5	3.5-4.5	2.5-3.5	1.5-2.5	<1.5	Sagwansupyakorn, (2009)

Table 4.34 Risky classification of the factors contributing to nutrient imbalance of the soils

Factors	Risky score					Criterion source
	Lowest (0.2)	**Low (0.4)**	**Moderate (0.6)**	**High (0.8)**	**Highest (1.0)**	
soil pH	6.0-6.5	5.5-6.0 6.5-7.0		5.0-5.5 >7.0	<5.0	Obreza and Collins (2002)
CEC (cmol/kg)	>30	15-30	10-15	3-10	<3	Maneepong *et al.* (2005)
soil organic matter (%)	>4.5	3.5-4.5	2.5-3.5	1.5-2.5	<1.5	Sagwansupyakorn , (2009)
avai. P(mg/kg)	<60				>60	Supakumnerd *et al.* (2005)
exch. K (mg/kg)	<120				>120	Supakumnerd *et al.* (2005)

4.4.1.3 Weighting of the significance of analyzed factors

The significance of each pair of the factors contributing to the deterioration of mandarin orchards were compared by the program developed by Ekasigha *et al.*(2006). The significant weighting of the factors affecting root rot, nutrient lost by leaching and runoff and plant nutrient imbalance of the soils were shown in Table 4.35, 4.36 and 4.37 respectively.

Table 4.35 The significant weighting of the factors affecting root rot

Factors	Weight
slope (%)	0.254
soil drainage	0.205
elevation (MSL)	0.049
soil bulk density (g/cm^3)	0.109
soil porosity (% by volume)	0.109
soil pH	0.205
soil organic matter (%)	0.068

Table 4.36 The significant weighting of the factors affecting nutrient lost by leaching and runoff

Factors	Weight
slope (%)	0.271
CEC (cmol/kg)	0.199
runoff	0.146
soil permeability	0.146
soil depth (cm)	0.098
pH	0.087
soil organic matter (%)	0.053

Table 4.37 The significant weighting of the factors affecting plant nutrient imbalance of the soils

Factors	Weight
pH	0.365
CEC (cmol/kg)	0.239
organic matter (%)	0.180
avai. P(mg/kg)	0.108
exch. K (mg/kg)	0.108

4.4.1.4 Risk assessment of the factors affecting productivity declination of mandarin orchards

1) Factors affecting root rot

The 50 selected orchards with the total areas of 156.4 rais could be classified into 99 mapping units according to the risk on productivity declination caused by root rot as shown in table 4.38.

Risk assessments of the factors affecting root rot were shown in Table 7.8. The topographic condition (slope and elevation), drainage, bulk density, porosity, pH and soil organic matter of the soils of mandarin orchards with each risky level were indicated in table 4.39.

Table 4.38 Risky classification of mandarin orchards due to productivity declination caused by root rot

Risky levels	No.of mapping unit	Area (rai)	% area
lowest	4	3.3	2.1
low	27	25.0	16.2
moderate	31	35.8	23.2
high	24	47.9	31.0
highest	13	42.5	27.5
Total	**99**	**154.6**	**100.0**

There were the orchards with the high risk about 31% of the total cultivated areas followed by those with the highest risk which covered about 27.5 of the total cultivated areas. The orchards with moderate, low and lowest risk were about 23.2, 16.2 and 2.1% of the total cultivated area respectively. These data indicated that most selected orchard were risky to be deteriorated by root rot damage.

Table 4.39 Factors of mandarin orchards with different risky levels to root rot

Factor	Risky levels by runoff and leaching				
	Lowest	**Low**	**Moderate**	**High**	**Highest**
slope (%)	5-12% 12-20%	0-5% 5-12% 12-20% 20-35%	0-5% 5-12% 12-20% 20-35%	0-5% 5-12% 12-20%	0-5%
soil drainage	well	poorly moderate well	poorly moderate well	poorly moderate well	poorly
elevation (MSL)	590-740	<590 590-740	<590 590-740	<590 590-740	<590 590-740
soil bulk density (g/cm^3)	1.12-1.22	0.9-1.33	0.9-1.41	0.9-1.41	1.26-1.49
soil porosity (% by volume)	52.52-57.21	47.23-67.56	46.11-67.56	43.8-66.84	40.05-51.16
soil pH	5.71-6.57	3.86-6.60	3.86-6.24	3.86-6.75	3.98-5.82
soil organic matter (%)	3-4.17	2.16-4.94	1.72-4.94	1.45-4.94	1.38-3.34

The map of mandarin cultivated areas with different risky levels for root rot damage were shown in figure 4.27.

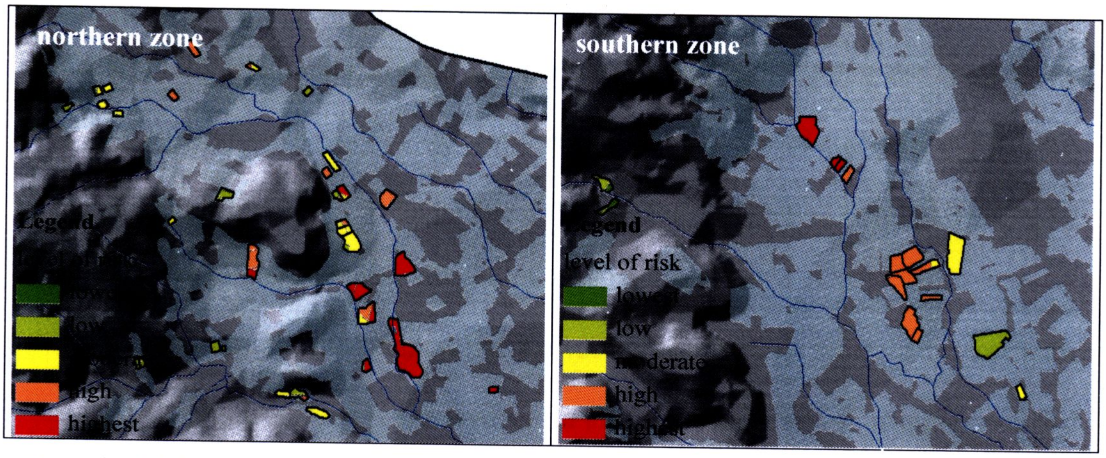

Figure 4.27 Map of mandarin orchards with differet levels of risk to root rot

In figure 4.27, the selected mandarin cultivated areas were divided into 2 zones in order to cover all studied orchards. Zone 1 showed the orchards in the northern part of Mae Soon sub-district while zone 2 showed the orchards in the southern part.

The distribution of the orchards with each risky level for root rot damage on the lowland, the foothill and the sloping land of Mae Soon sub-district were shown in table 4.40.

Table 4.40 Distribution (%of the total areas at in each topographic condition) of the orchards with different levels of risk due to root rot on the lowland the foothill and the sloping land

Risky levels	Lowland	Foothill	Sloping land
lowest	0.0	0.0	9.8
low	13.3	6.5	33.3
moderate	17.2	21.1	40.9
high	35.9	33.3	15.9
highest	33.6	39.2	0.0
Total	**100.0**	**100.0**	**100.0**

There were the orchards on the lowland and the foothill which were risky to root rot damage at the high and very high levels about 69 and 72% of the total mandarin cultivated areas in each topographical condition. None of the orchards on the sloping land were risky to root rot damage at highest level and only 15.9% were risky at high level. About 41 and 33% of the mandarin cultivated areas on the sloping land were moderately and low risky to root rot not damage.

In this study, the relationship between root rot risky score of the orchards having risk at high and very high levels with the total numbers of 47 mapping unit and microbial biomass C (MBC), organic matter content and soil pH were statistically analyzed. It was found that the scores those orchards were negatively correlated significantly with MBC, soil organic matter and soil pH as shown in table 4.41. Darby *et al.*(2006) studied the compost and manure mediated impacts on soilborn pathogens and soil quality and found out that two months after application of fresh manure solids (MS) at the rates of 16.8 and 33.6 mg/ha and composted dairy manure solids (MSC) at the rates of 28 and 56 dry mg/ha.

Table 4.41 Correlation coefficients of the relationships between root rot risky scores (RRRS) of the orchards having risk at high and very high level and microbial biomass C (MBC) soil organic matter (SOM) and soil pH

Relationship [1]	Correlation	Coefficient [2]
RRRS vs MBC	-0.43	**
RRRS vs SOM	-0.38	**
RRRS vs pH	-0.32	*

[1] n=47 [2] ** significant at P<0.01, * sig at P<0.05

Furthermore, microbial biomass C of the orchards with high and very high risk to root rot damage were positively correlated significantly with soil organic matter as shown in figure 4.28.

These experimental results supported the hypothesis that the severity of root rot damage in mandarin orchards related with the level of soil pH and soil organic matter content of the soils. The abundant of soil microbes as indicated by MBC depended on soil organic matter content and MBC also had significant influence on root rot damage.

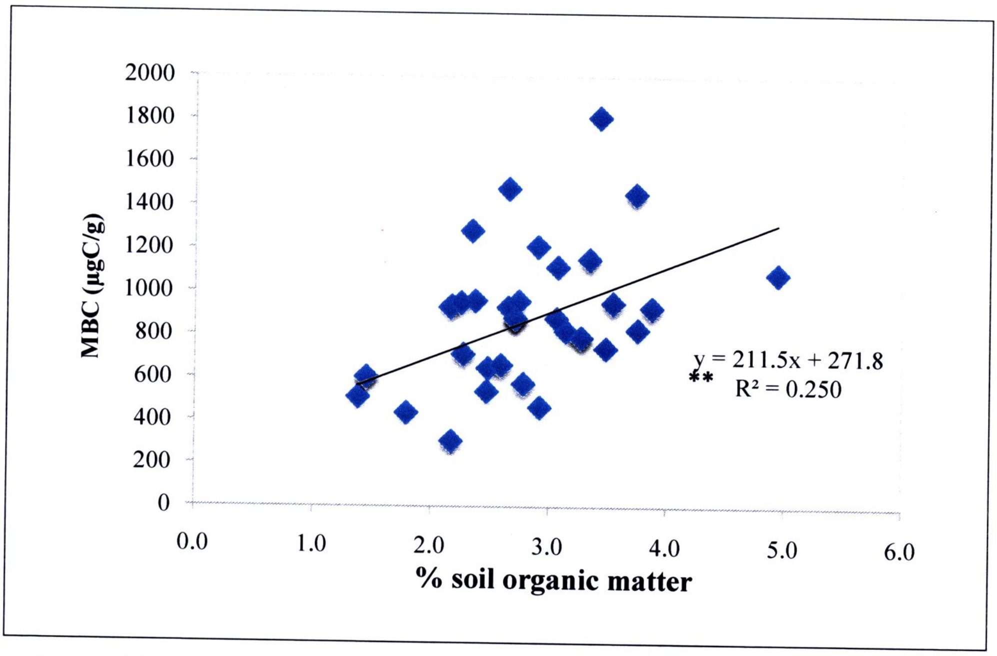

Figure 4.28 Correlation coefficient of the relationship between MBC and soil organic matter

Since there were large variation of risky levels for each influencing factor, it was therefore impossible to explain the details of all selected orchards. Thus some cases were selected for explanation as shown in table 4.42 to 4..44.

Case 1 Mandarin orchards in the lowland

Three mandarin orchards belonged to Mr.Kumpun Yana, Mrs.Rattana Intatar and Mr.Tawechai Kotrakul which were risky to root rot damage at the levels 5, 4 and 3 respectively were selected as the examples for detail comparison.

The details of topographical condition (slope and elevation), influencing soil properties including the evaluated risky levels, methods of orchard management, land use history, age of the trees, farmer's skill, orchard maintenance, fruit yield and fruit quality of each selected orchard were indicated in table 4.42.

Table 4.42 Comparison of mandarin orchards in the lowland with different risky levels to root rot

Details	Mr.K.Yana's orchard	Mr.T.Kotrakul's orchard	Mrs.R.Intatar's orchard
level of risk	5	3	4
no. of mapping unit	1	1	1
condition of influencing factors for root rot			
1) topography*			
-slope	0-5% (VH)	0-5% (VH)	0-5% (VH)
-elevation	<590 (L)	<590 (L)	<590 (L)
- drainage	Poorly (VH) (Don-silB)	Well (VH) (Pe-slC/d5)	Poorly(VH) (Don-silB)
2) soil property*			
- pH	5.0 (H)	5.7 (L)	6.28 (VL)
- bulk density	1.26 (L)	1.29 (L)	1.25 (L)
- porosity	51.16 (M)	49.68 (M)	51.61 (M)
- organic matter	2.27	2.14	2.9
3) orchard management			
-planting material	air layering and rootstock	air layering	air layering
-land preparation	high bed raising	high bed raising	Shallow bed raising
- liming	yes	yes	yes
-tillage in the rainy	none	none	none
4)land use history	paddy rice, litchi	litchi	paddy rice, litchi
5) age of the tree	12	9	7
6) farmer skill	B	B	C
7) orchard maintenance			
-time spending	full time	par time	par time
-fruit pruning	yes	no	no

Details	Mr.K.Yana's orchard	Mr.T.Kotrakul's orchard	Mrs.R.Intatar's orchard
-prolonging of fruit harvest in the previous year	yes	yes	no
-fertilizer application	high rate	high rate	low rate
8) fruit yield and fruit quality			
-yield (kg/tree)	122.61	52.47	0
-fruit size	6	3	0

*condition of some factors for each orchard and risky level (in parenthesis) were given

These three selected orchards were similar for topographical condition and all influencing soil properties to root rot damage except drainage and porosity in which the soil from Mr. Tawechai' s orchard was better than those of Mr. K. Yana and Mrs. R Intatar .

The mandarin orchards of Mr. K. Yana and Mrs. R Intatar used to be the paddy field before cultivating litchi trees and subsequently switched to be mandarin orchards. Under paddy rice cultivation, it was normal to have hard pan under the ploughed layer. (Aimrun *et al*,2010). Though the orchard of Mr. K. Yana was risky at the highest level for root rot damage but this orchard was more productive than the other two selected orchard in terms of fruit yield and fruit sizes. Mr. K. Yana could get about 123 kg of fruit yield per tree in 2010/2011 while Mr. T. Kotrakul could get only 52.47 kg of fruit yield per tree and Mrs. R. Intatar could not get any fruit yield. Based on the information obtained from farmer interview and observation from field survey, Mr, K. Yana had good skill for mandarin cultivated. This farmer was a full time mandarin cultivated farmer. Some of the trees in Mr. K. Yana were grown on Cleopatra root stock plant materials (figure 4.33) while the other two farmers used air layering as plant materials.

According to Kuaprakone *et al.*(1999) which was cited by Ounpo (2005) the commonly used mandarin planting materials by farmers were air layering which almost all were infected by greening disease and citrus tristeza virus. The disease infected air layering had weak root system and were sensitive to root rot. After transplanting those air layering, the trees were rapidly showed unhealthy symptom and finally dead. The fruit yield were low not worth for investment.

Thus it was not surprised to know that the mandarin trees in Mr. K.Yana were still productive even the trees were about 12 years old. With the better skill, the following techniques, high bed raising, fruit pruning, prolonging of fruit harvesting time, use of root stock plant materials, continuous application of fertilizer to soil and foliar spraying were used by Mr. K. Yana resulting in healthy mandarin trees in his orchards. The same techniques except the use of root stock plant material and fruit pruning were used by Mr. T. Kotrakul. Since Mr. T. Kotrakul has another business as the owner of grocery so he could not spend full time for orchard maintenance and could not prune off the excess numbers of fruits. Without fruit pruning and the excess number of fruits were remained on each tree during fruit harvest prolonging period from December (the fruits were about 10 months old to March (the fruits were about 13 months old) thus the trees could not provide sufficient nutrients for maintenance of good growth of the roots. According to Noling (2003), roots and fruits were competitive to each other for photosynthetes supplied by leaves. Thus with excessive numbers of fruit remained on the trees, the normal root growth in late February to early April could not be developed resulting in unhealthy trees in Mr. T. Kotrakul's orchard in subsequently growing season (2010/2011) as shown in figure 4.30.

When mandarin trees in Mr. T. Kotrakul's orchard had poor root development, the unhealthy trees showed the symptoms as the small yellowish erected leaves (figure 4.30), the smaller fruit size (size3) in comparison with that in 2009/2010 (size 5), and fruits showing greening disease symptom (yellowish color development from the points of the fruit) as shown in figure 4.31. Though Mr. T. Kotrakul could afford spending cost of input on fertilizer as much as that of Mr. K. Yana but with poor root systems, the trees did not respond to the applied fertilizers.

In the case of Mrs. R. Intatar' s orchard which had the risk at the level of 4 for root rot damage but this orchard was already collapsed by the end of the growing season of 2010/2011. This farmer did not have skill for mandarin cultivation. Furthermore, beside mandarin, she grew many kinds of vegetable crops such as egg plants and the other kinds of leafy vegetables. Thus she was actually a part time mandarin cultivated farmer. With insufficient skill, this farmer did not use the proper plant materials and land preparation. Furthermore she could not afford spending cost of input on fertilizers and pesticide and only low rates of applications were used.

Due to poor orchard management and poor skill, the mandarin trees in her orchards were all unhealthy as shown in figure 4.29. Most trees were infected by root rot disease as shown in figure 4.32. No fruit yield was obtained and all trees were cut down by end January 2011. The new mandarin trees were transplanted in the same orchard at the end of rainy season of 2010.

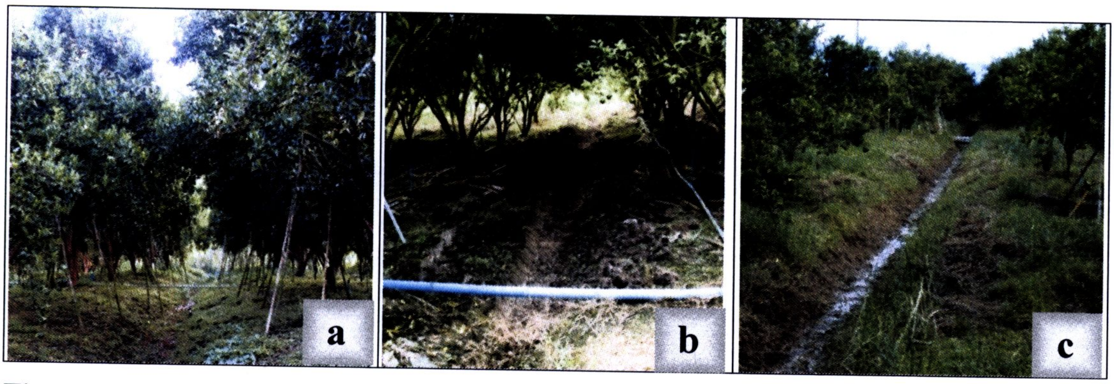

Figure 4.29 Land preparation and the appearances of the trees in the middle of july 2010 in three selected mandarin orchards in the lowland; ; a and b) the orchards of K. Yana and T. Kotrakul with high bed raising, c) the orchard of R. Intatar with low bed raising

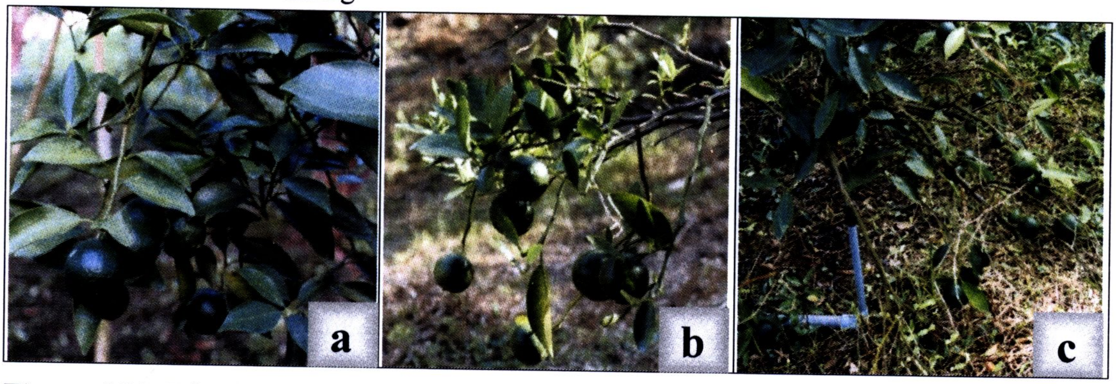

Figure 4.30 Friut formation of mandarin trees in July 2010 in three selected orchards in the lowland; a) K. Yana's orchard, b) R. Intatar's orchard, c)T. Kotrakul's orchard

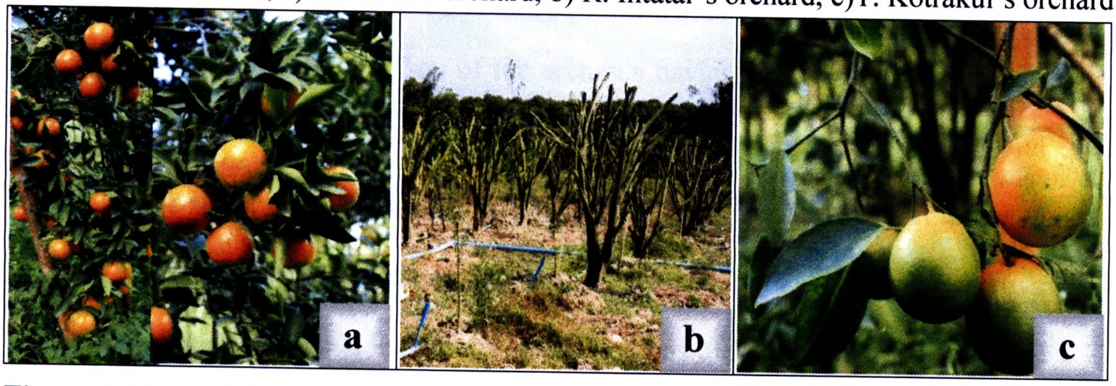

Figure 4.31 Condition of mandarin trees at friut harvesting period (January 2011) in three selected orchards in the lowland; a) K. Yana's orchard, b) R. Intatar's orchard c) friut with greening disease system in T. Kotrakul's orchard

Figure 4.32 Root rot disease syptom in R. Intatar's orchard

Figure 4.33 Sai Numpuong mandarin trees on Cleopatra root stock in K. Yana's orchard and air layering in T. kotrakul

Case 2 mandarin orchards on the foothill

The orchards of Mr. Ruruong Doawee and Mr. Luan Yawilart were selected as the examples for detail comparison of the orchards having risk on root rot damage. The details of these two selected orchards were shown in table 4.43. The general features of the trees in the orchards (figure 4.34), the condition of mandarin leaves in July (figure 4.35) and fruit characteristic in January (figure 4.36) of these two orchards were also compared including some symptoms of the unhealthy trees in Mr. R. Doawee' s orchards. According to the assessment of the influencing factors related to root rot damage, the orchard of Mr. L. Yawilart had the highest risk while that of Mr. R. Doawee had the high risk. Though the soil in Mr. L. Yawilart' s orchard was worse than that of Mr. Doawee for drainage but for soil pH, bulk density and soil organic matter, Mr. L. Yawilart's soil was better. Furthermore Mr. L. Yawilart applied compost and chemical fertilizer at the higher rates than Mr. R. Doawee. With the better orchard management, Mr. L. Yawilart's orchard was more productive than Mr. R. Doawee. He could get the higher fruit yield (74 kg/tree) and bigger fruit sizes (size 3) than Mr. Doawee who obtained fruit yield of 32 kg/tree and the fruits were smaller (<size 3). From field survey, it was observed that the mandarin trees in Mr. R. Doawee were not healthy with yellowish leaves (figure 4.35a) while those in Mr. L. Yawilart were more healthy with bigger greenish leaves (figure 4.35b). In July 2010, (figure 4.37c) the trees in Mr. R. Doawee were severely infected by root rot in which all leaves from the branches at the same side of infected roots turned yellow. Furthermore fruit dropping were also observed in Mr. R. Doawee's orchard. In January, the fruits from Mr. R. Doawee were small and the trees showed greening disease symptom while those in Mr. L. Yawilart, the fruits sizes were bigger and the leaves were still green. In addition the unhealthy trees in Mr. R. Doawee's orchards showed Mg deficiency, die back and greening disease symptoms (figure 4.37b). Though Mr. L. Yawilart's orchard was very high risky to root rot damage according to the condition of root rot influencing factors but it was observed that not more than 10% of the trees in his orchard were damaged by root rot disease the method of soil management used in Mr. L. Yawilart's orchard might be effective to reduce the risk to root rot damage.

Table 4.43 Comparison of mandarin orchards in the foothill with different risky levels to root rot

Details	Mr. R. Doawee's orchard	Mr. L.Yawilart's orchard
risk levels	4	5
no. of mapping unit	1	1
condition of influencing factors for root rot		
1) topography*		
-slope	0-5% (VH)	0-5% (VH)
-elevation	590-740 (L)	590-740 (L)
-drainage	well (VL) (Mt-slC)	poorly (VH) (Li-agclD)
2) soil property*		
-pH	4.49 (VH)	5.36 (H)
-bulk density	1.36 (L)	1.29 (VL)
-porosity	47.78 (L)	50.91(L)
-organic matter	1.45(VH)	2.16 (H)
3) orchard management		
-planting material	air layering	air layering
-land preparation	shallow bed raising	no bed raising
- liming	yes	yes
-tillage in the rainy	none	none
4) land use history	litchi	litchi
5) age of the tree	9	8
6) farmers skill	C	C
7) orchard maintenance		
-time spending	full time	full time
-fruit pruning	no	no
-prolonging of fruit harvest in the previous year	no	no
-fertilizer application	low rate	moderate rate
8) fruit yield and fruit quality		
-yield (kg/tree)	32.18	74.11
-fruit size	<3	5

*condition of some factor for each orchard and risky level (in parenthesis) were given

Figure 4.34 The general features of the trees in the orchards a) R. Doawee's orchards and b) L. Yawilart's orchard

Figure 4.35 The condition of mandarin leaves in July a) R. Doawee's orchards b) L.Yawilart's orchard

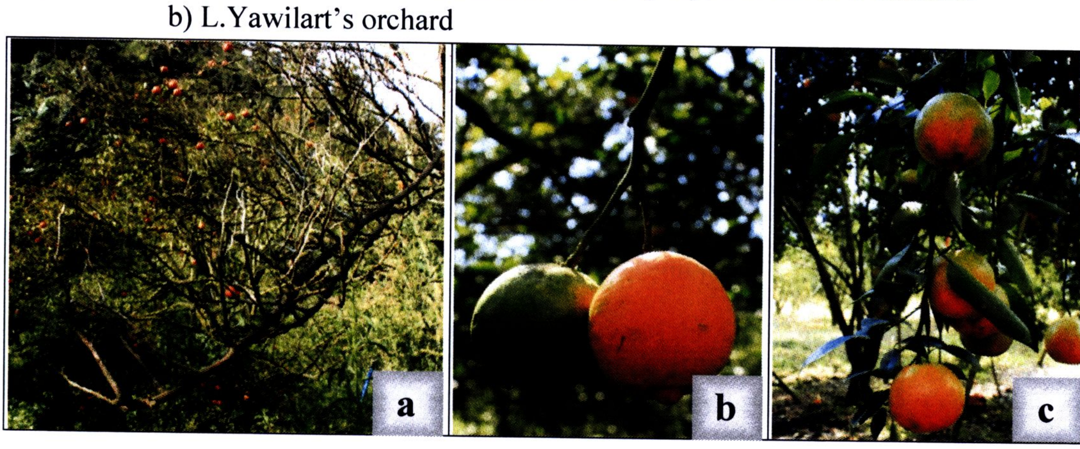

Figure 4.36 Fruit characteristics in January a and b) R. Doawee's orchards c) L. Yawilart's orchard

Figure 4.37 Some problems: a) Mg deficiency, b) die back and c) greening disease symptoms in Mr. R. Doawee's orchards

Case 3 mandarin orchards on the sloping land

The orchards of Mr. Uoonruoan Punya and Mr. Bunpot Doawee were selected as the examples for detail comparison of the orchards on the sloping land having risk on root rot damage at the low level (level 2). The conditions of the factors contributing to root rot in these two orchards were shown in table 4.44. Mandarin trees in both orchards were cultivated on the terraces using the narrow spacing (figure 4.38). Mr. U. Punya had the better skill and could afford higher input cost on fertilizer and lime than Mr. B. Doawee. Furthermore soil ploughing to improve aeration and lime application were practiced by Mr. U. Punya before the beginning of rainy season. Such cultural practices were expected to improve soil pH and soil aeration of the soils in Mr. U. Punya's orchards which resulted in decreasing of root rot disease infection. Less numbers of root rot infected trees (about 10% of the total numbers of the trees) were observed in Mr. U. Punya's orchard as compared with that of Mr. B. Doawee's one which the root rot infected trees were about 50% (figure 4.39) particularly in the area with the lower slope. Due to the better orchard management, Mr. U. Doawee could get more fruit yield (59.67kg/tree) than Mr. B. Doawee (27.5 kg/tree).

Table 4.44 Comparison of mandarin orchards in the sloping land with different risky levels to root rot

Details	Mr. U. Punya's orchards	Mr. B. Doawee's orchards
risk levels	2,4	3,4
no. of mapping unit	5	3
condition of influencing factors for root rot		
1) topography*		
-slope (%)	0-5,5-12,12-20, 20-35	0-5,5-12
-elevation(m)	590-740	590-740 (L)
-drainage	Li-gclD; poorly (VH)	Bg-clD; moderate (M)
2) soil property*		
-pH	6.57(VL)	4.44 (VH)
-bulk density	1.31(L)	1.19 (VL)
-porosity	47.23(L)	55.67(L)
-organic matter (%)	3.73(L)	3.87 (L)
-microbial biomass	1,457.05	927.87
3) orchard management		
-planting material	air layering	air layering
-land preparation	terrace	terrace
- liming	yes	yes
-tillage in the rainy	yes	no
4) land use history	litchi	litchi
5) age of the tree	12	8
6) farmer's skill	B	C
7) orchard maintenance		
-time spending	full time	full time
-fruit pruning	no	no
-prolonging of fruit harvest in the previous year	yes	no
-fertilizer application	high rate	low rate
8) fruit yield and fruit quality		
-yield (kg/tree)	59.67	27.5
-fruit size	4	4

*condition of some factors for each orchard and risky level (in parenthesis) were given

Figure 4.38 Mandarin trees in the orchards of Mr. U. Panya and Mr. B. Doawee cultivated on the terraces using the narrow spacing

Figure 4.39 The root rot infected trees in Mr.B Dowee's orchards

2) Factors affecting plant nutrient lost by runoff and leaching

The results of risk evaluation indicated that the 50 selected orchards with the total areas of 154.6 rais could be classified into 111 map units according the risky levels to the lost of plant nutrients by runoff and leaching (table 4.45). About 49% of the total area were risky to such cause at the low level which those with moderate, lowest , high and very high risk were 17.6, 17.2, 12.6 and 34% respectively. Most of the orchards on the lowland and the foothill were risky to plant nutrient lost by leaching and runoff at the low level while those on the sloping area about 57.9% were risky at the high level (table 4.46).

The locations of the selected orchards with different levels of risk on plant nutrient lost by runoff and leaching were shown in the map in figure 4.40.

Table 4.45 Comparison of mandarin orchards in the slopiing land with different risky levels to plant nutrient lost by runoff area leaching

Risky level	No. of orchard	Area (rai)	% area
lowest	10	26.5	17.2
low	31	76.1	49.2
moderate	33	27.2	17.6
high	27	19.5	12.6
highest	10	5.2	3.4
Total	**111**	**154.6**	**100.0**

Table 4.46 Risky classification of mandarin orchards due to productivity declination caused by plant nutrient lost by runoff and leaching

Factor	Risky levels				
	Lowest	**Low**	**Moderate**	**High**	**Highest**
slope (%)	0-5%	0-5% 5-12%	0-5% 5-12% 12-20%	0-5% 5-12% 12-20% 20-35%	12-20% 20-35%
CEC (cmol/kg)	7.36-22.49	5.58-14.79	3.18-14.44	3.18-14.44	6.27-11.07
runoff	-slow -moderate -rapid	- moderate to rapid -moderate -rapid	- moderate to rapid -moderate -rapid	- moderate to rapid -moderate -rapid	-rapid
permeability	-slow -moderate -rapid	-slow -moderate -rapid	-slow -moderate	-slow -moderate	-slow -rapid
soil depth (cm)	50-75 75-100 >100	25-50 50-75 75-100 >100	25-50 75-100 >100	25-50 75-100	25-50
pH	4.2-6.28	3.86-6.75	3.86-6.6	4.18-6.57	4.3-6.57
organic matter (%)	2.37-4.94	1.38-4.94	1.45-4.94	1.45-4.94	2.71-4.59

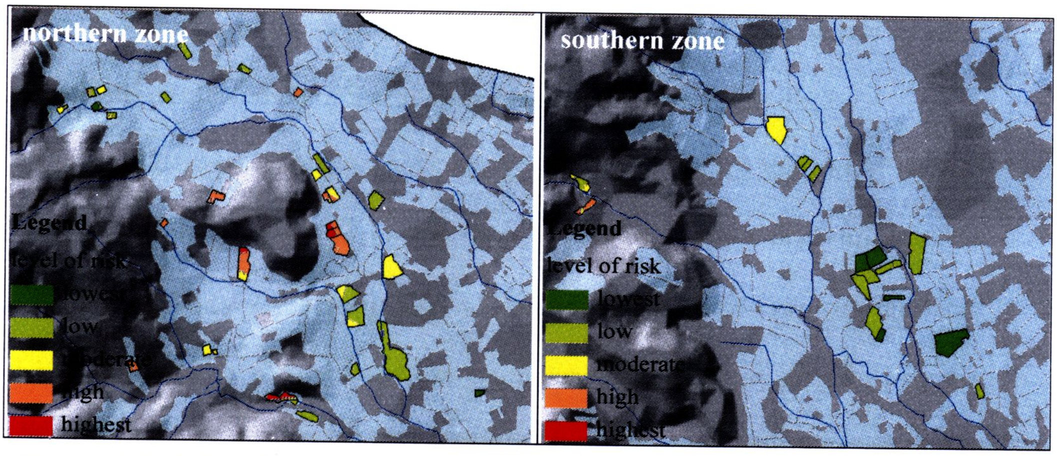

Figure 4.40 Map of mandarin orchards with differet levels of risk to plant nutrient lost by runoff and leaching

Table 4.47 Distribution (%of the total areas at in each topographical condition) of the orchards with different levels of risk due to plant nutrient lost by runoff and leaching on the lowland, the foothill and the sloping land

Risky levels	Lowland	Foothill	Sloping land
lowest	28.7	4.2	0.0
low	61.9	57.9	5.9
moderate	9.4	35.8	46.8
high	0.0	0.4	57.9
highest	0.0	0.0	15.4
Total	**100.0**	**100.0**	**100.0**

Table 4.48 The total N concentration of the index leaves of mandarin of the orchards which were high and very high risky to the lost of plant nutrients by runoff and leaching in April and July

Level	%N	In April (1st)		In July (2nd)	
		Area(rai)	%	Area(rai)	%
deficit	<2.2	3.7	15.3	9.0	36.9
low	2.2-2.45	6.2	25.6	10.2	41.6
optimum	2.45-2.75	10.1	41.5	5.3	21.5
high	2.75-3.0	0.0	0.0	0.0	0.0
excess	>3.0	4.3	17.7	0.0	0.0
Total		**24.4**	**100.0**	**24.4**	**100.0**

The distribution of the orchards with different risky levels was shown in table 4.47. The details of all studied orchards were given in the table appendix 2.

Among the essential elements for the growth of the plants, the lost of NO_3-N by runoff and leaching seems to be the most important because the amount of N required by most plants is generally high compare to the other two primary nutrients (P and K). Furthermore NO_3-N which is anion cannot be strongly adsorbed by the soils. In this study, %N in the index leaves of mandarin tree was selected as the suitable index parameter for the low of nutrient by runoff and leaching. The percentage of the total N in the index leaves of mandarin in April and July from the orchards being high and very high risky to plant nutrient lost was shown in Table. As previously mention, all of the orchards which were high to very high risky to plant nutrient lost by runoff and leaching were on the sloping area. In April before the rainy season started, the index leaves of mandarin from 41% of the total cultivated risky area contained total N at deficit (<2.2%) to low (2.2-2.45%) level. In rainy season (July), the areas in which the total N concentration of the index leaves were deficit to low increased to 78.5% supporting that during that period, the lost of N by runoff and leaching in those areas were very high (table 4.48).

The details of the factors affecting the lost of plant nutrients and the total risky score of each orchard were given in the table appendix 3.

Three orchards on the sloping land belong to Mr.Ming Lungkana Mr. Kumpun Yana and Mr.Sukit Sang Ai were selected as the examples for detail explanation. Information of these orchards was given in table 4.49. The general features of the orchards and the ratio of fruits and orchard were shown in figure 4.41 and figure 4.42 respectively.

Table 4.49 Comparison of mandarin orchards in the sloping land with different risky levels to plant nutrient lost by runoff and leaching

Details	Mr.M. Lungkana's orchard	Mr.S.Sang Ai's orchard	Mr.K. Yana's orchard
level of risk	3,4	2,3	4
no. of mapping unit	5	5	2
condition of influencing factors for nutrient lost			
1) topography			
-slope	0-5(VL) ,5-12(L) , 12-20(M)	0-5(VL) ,5-12(L) , 12-20(M)	5-12(L) , 12-20 (M)
-runoff	SC; rapid(VH)	Bg-clD; Moderate (M)	Li-gclD ; Rapid (VH)
-permeability	rapid(VH)	moderate (M)	Slow(L)
-soil depth	25-50(H)	75-100 (L)	25-50(H)
2) soil quality			
-CEC	8.21(H)	11.47(M)	8.56 (H)
-pH	5.71(L)	3.86(VL)	5.76(L)
-OM	3.0(M)	3.54(M)	3.03(M)
Exch.K	162.02(H)	239.71(H)	237.12(H)
3) orchard management			
-planting material	air layering	air layering	air layering and rootstock
-land preparation	terrace	terrace	terrace
- liming	yes	yes	Yes
4)land use history	litchi	virgin soil	litchi
5) age of the tree	9	5	12
6) farmer skill	C	B	B
7) orchard maintenance			
-time spending	fulltime	fulltime	fulltime
-fruit pruning	no	no	yes
-prolonging of fruit harvest in the previous year	no	no	yes
fertilizer application	low rate	moderate rate	high rate
fertilizer rate (kg/tree)	0.3	0.5	0.7
8) fruit yield and fruit quality			
-yield	22.0	38.59	113.97
-fruit size	<3	3	6
9) %N of the index leaves #1 and #2	2.54 (O) /2.2(L)	2.54 (O) /2.2(L)	2.93(H)/2.34(L)

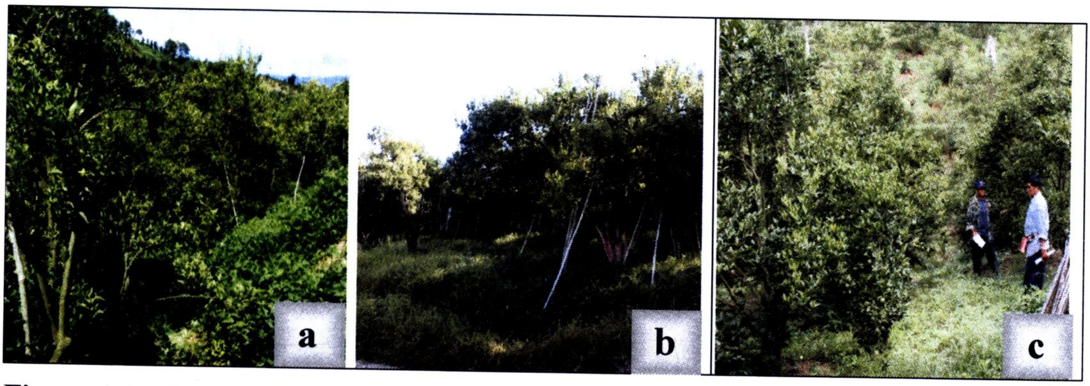

Figure 4.41 General features of the orchards of Mr.M. Lungkana(a), Mr.K. Yana (b) and Mr. S. Sang Ai (c)

Figure 4.42 Ratio of fruits and leaves of mandarin in the orchards of Mr.M. Lungkana(a), Mr.K. Yana (b) and Mr. S. Sang Ai (c)

Soil in Mr. M. Lungkana' s orchard is slope complex soil which is generally not suitable for crop cultivation according to LDD (2007) . This orchard was evaluated as the risky orchard at very high or high levels for the conditions of runoff permeability, soil depth and CEC. In 2010/2011, the trees in this orchard were about 9 year olds. Though Mr. M. Lungkana was the full time mandarin farmer but without good skill and only low cost of input was used for orchard management thus at the end of this study, his orchard has been collapsed. He could obtained fruit yield of 22 kg/tree only with the fruit sizes use were smaller than no.3 fruit size. The index leaves from Mr.M. Lungkana collected in July were low in N concentration suggesting that there was NO_3 –lost by runoff and leaching. Most of mandarin trees in this orchard showed die back symptom which is the common feature of greening disease.

In the case of Mr. S Sang Ai' s orchard, it was risky to the lost of plant nutrient by runoff and leaching at the level 2 and 3. The soil was classified as Ban Chong soil series which is deep soil with moderate runoff and permeability. Nevertheless, this soil is extremely acidic with pH of 3.86. The mixed fertilizers containing N,P and K were applied at the moderate rate (0.5 kg/tree/M). Not only acidic soil problem, the exch. K : exchangeable Mg was 3.95 which could lead to Mg deficiency (Ankerman and large, 2001). the index leaves collected in April and July showed N deficiency status (<2.0%) suggesting that NO_3-N lost by runoff and leaching might occur. At the end of growing season, Mr. S. Sangai' s orchard was also collapsed. He could get only 39 kg/tree with number 3 fruit size. During field survey, the trees in his orchard were mostly unhealthy and showed greening disease symptom. This supported Ounpo (2005) who found that the unhealthy mandarin trees in one of orchard in Fang district were all infected by greening disease.

In the case of Mr. Kumpun Yana, the soil in his orchard belongs to Li soil series which was very high to high risky to the lost of plant nutrients by runoff and leaching according to the rate of runoff and the soil depth including CEC. Nevertheless, Mr. K. Yana' s orchard was still productive. He could get fruit yield of 114 kg/tree and big fruit size (no.6). This farmer had good skill for orchard management and was a full time mandarin farmer. Fruit pruning was used, thus the trees in his orchard had the proper fruits to leaves ratio (figure4.42). He could afford applying chemical fertilizer at the high rate (0.7 kg/tree/M). Though fruit harvesting was prolonged in the previous year but the mandarin trees which were about 12 years old were still in the good condition and productive. Mr. K. Yana is the good example for indicating that with proper management, the risk could be reduced. However, in July, the index leaves also indicated N deficiency suggesting that there were NO_3-lost by runoff and leaching in Mr. K. Yana' s orchard.

3) Factors affecting soil nutrient imbalance

There were 50 mapping units for classification of the risk due to soil deterioration by imbalance of plant nutrients. Thirty four percent of the selected orchards covering the areas of 36 rais had high risk while those with low, moderate, very low and very high risk were 24, 22, 10 and 4% with the areas of 51, 46.4, 16.9 and 2.2 rais respectively (table 4.50). The ranges of pH, CEC, organic matter, avai. Pand exch. K of the soils in the orchards with different risky levels were shown in table 4.51. The distribution of the orchards with different risky levels was shown in table 4.52. The details of all studied orchards were given in the table appendix 4.

Table 4.50 Classification of mandarin orchards according to the risk on plant nutrient imbalance of soils

Risky level	No. of orchards	Area (rai)	% of the orchard
lowest	8	18.9	16.0
low	12	51.0	24.0
moderate	11	46.4	22.0
high	17	36.1	34.0
highest	2	2.2	4.0
Total	**50**	**154.6**	**100.0**

Table 4.51 Condition of soil parameters of the orchards with different risky levels

Factor	Risky level				
	Lowest	**Low**	**Moderate**	**High**	**Highest**
pH	5.52-6.57	5.64-6.75	5.0-5.76	3.86-5.47	4.49-4.8
CEC (cmol/kg)	7.07-11.13	5.64-14.79	5.58-12.73	3.18-22.49	5.81-9.47
organic matter (%)	2.59-4.82	1.38-3.73	1.79-3.75	2.17-4.94	1.45-3.14
avai.P (mg/kg)	34.75-376.01	20.84-383.36	47.85-312.8	109.44-684.7	140.31-384.83
exch.K	69.0-395.08	28.0-433.92	43.0-237.12	70.0-755.02	237.12-459.81

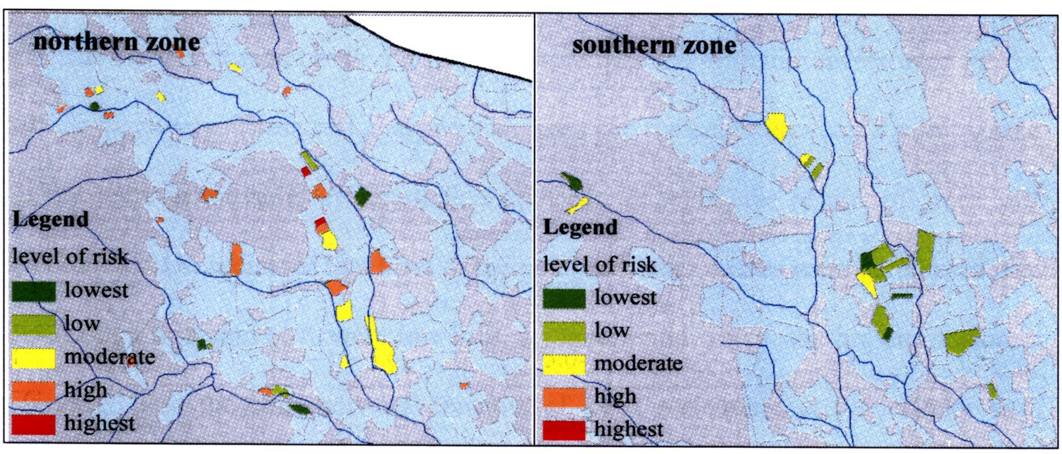

Figure 4.43 Map of mandarin orchards with differet levels of risk to soil nutrient imbalance; a) northern zone and b) southern zone

Table 4.52 Distribution of the orchards with different levels of risk to soil nutrient imbalance on the lowland, the foothill and the sloping land

level of risk	lowland		flat plan		sloping land	
	area (rai)	**%**	**area (rai)**	**%**	**area (rai)**	**%**
lowest	7.2	8.2	8.75	26.1	2.98	8.8
low	45.93	52.6	2.96	8.8	2.11	6.3
moderate	31.51	36.1	5.13	15.3	9.33	27.7
high	2.74	3.1	15.37	45.9	17.95	53.2
highest	0	0.0	1.27	3.8	1.37	4.1
total	**87.38**	**100**	**33.48**	**100**	**33.74**	**100**

According to the data in table 4.52, most of the orchards on the lowland (52.6%) had risk to plant nutrient imbalance at low level while 45.9 and 53.2% of those on the foothill and the sloping land had high risk respectively. The areas with high or very high risk were found in all topographical condition.

From the 50 selected orchards, (table 4.16) 76% of them had soil pH lower than the optimum level (pH 6.0-6.5) and 98% had high to very high content of avai. P(74-685 mgP/kg) while 48% and 44% had very high and very high exch. K content (128-755mgK/kg) respectively. There were about 98% of the total numbers of the tested orchard soils had the exchangeable Mg contents less than optimum level. Furthermore, the soils having the extractable Fe Zn and Cu more than the optimum levels were 90, 88 and 50% respectively. These soil analysis data indicated the occurrences of the imbalance of soil nutrients in the soils in the studied orchards. In April, the results of index leaf analysis (table 4.18) indicated that 90% of the analyzed index leaves were deficient in Ca, 74% were high in K and 60% were low in B. At this period which was hot dry season, it was expected that the soil moisture contents of most orchards was low. Under such condition, Ca and B assimilation by the roots which requires the suitable soil moisture are not effective though the soils are rich in exchangeable Ca and B (Foth and Ellis, 1997). In addition, only the young roots are effective for Ca assimilation (Harlin *et al*, 2005). Nevertheless in July which was the rainy season, the index leaves from most orchards had the optimum levels of essential plant nutrients. During this period, foliar fertilizers were commonly sprayed in all studied orchards. The widely used foliar fertilizers contained Mg and all essential elements (see detail in chapter 4). Since, foliar spraying of fertilizer were the common practice for all farmers, the index leaves contained the optimum levels of plant nutrients even though the soils were low in some elements.

Table 4.53 Detail comparison of three selected farmer orchards with the different risky level to soil nutrient imbalance

Details	Wongsai T.	Wongjun A.	Mungjai T.
level of risk	5	4	1
no. of mapping unit	1	1	1
condition of influencing factors for nutrient imbalance			
1) soil quality			
-pH	4.49 (VH)	4.18(VH)	6.08(VL)
-CEC	9.50(H)	12.22(M)	7.07(H)
-OM	3.14(VH)	3.48(L)	2.59(M)
avai. P(mg/kg)	140.31(VH)	177.05(VH)	112.01(VH)
exch. K (mg/kg)	459.81(VH)	275.96(VH)	112.0(VL)
3) Orchard management			
-planting material	air layering	air layering	air layering
- liming	yes	yes	yes
4) land use history	litchi	litchi	litchi
5) age of the tree	11	10	7
6) farmer skill	C	A	B
7) orchard maintenance			
-time spending	fulltime	part time	part time
-fruit pruning	no	no	no
-prolonging of fruit harvest in the previous year	no	no	no
fertilizer application	moderate rate	moderate rate	moderate rate
regular used fertilizer grades	15-15-15	46-0-0,15-15-15	46-0-0,15-15-15, 13-13-21
fertilizer rate (kg/tree)	0.5	0.5	0.7
8) fruit yield and fruit quality			
-yield	68.04	0	46.69
-size standard	6	0	5

Table 4.54 Properties of the soils in the orchards of Mr. T. Wongsai, Mr. A. Wongjun and Mr. T. Mungjai

Soil properties	Optimum level	T.Wongsai	A.Wongjun	T. Mungjai
bulk density (g/cm)	1.30-1.65	1.21	1.32	1.38
total porosity (% by volume)	47.17-62.26	52.76	49.98	43.80
soil pH	6.0-6.5	4.18	4.80	5.13
CEC (cmol/kg)		9.5	12.22	7.07
EC (μs/cm)	<80	206.7	204.5	65.8
Organic Matter (%)	2.0-3.0	3.14	3.48	2.59
avai. P (mg/kg)	35-60	177.1(H)*	384.8(H)	358.4(H)
exch. K (mg/kg)	100-120	276.0(H)	237.1(H)	677.3(H)
exch.Ca (mg/kg)	800-1500	951.2(O)	1,111.3(O)	1015.2(O)
exch. Mg (mg/kg)	250-400	100.8(L)	109.0(L)	112.1(L)
extr. Fe (mg/kg)	60-70	97.9(H)	124.8(H)	94.9(H)
extr. Mn (mg/kg)	20-60	91.5(H)	68.0(H)	61.9(H)
extr. Zn (mg/kg)	3-15	25.80(H)	24.67(H)	15.6(H)
extr. Cu (mg/kg)	3-5	5.28(O)	16.83(H)	4.0(O)
K : Mg ratio	< 3:1	2.74	2.17	6.04
microbial biomass C (μgC/g)		739.40	819.14	877.13

*level in parenthesis indicated the level, O = optimum, H= high, L= low

Table 4.55 Concentrations of nutrients in the index leaves of mandarin trees in the orchards of Mr. T. Wongsai, Mr. A. Wongjun and Mr.T. Muongjai in April (1st) and July (2nd)

Nutrient in leaves	Optimum level	April (1st)			July (2nd)		
		T. Wongsai	A. Wongjun	T. Mungjai	T. Wongsai	A. Wongjun	T. Mungjai
N (%)	2.5-2.7	2.35(L)*	1.75(D)	2.66(O)	2.41(L)	2.12(D)	2.09(D)
P (%)	0.12-0.16	0.18(H)	0.16(O)	0.15(O)	0.13(O)	0.16(O)	0.13(O)
K (%)	1.20-1.70	2.39(E)	2.03(H)	1.97(H)	1.99(H)	2.16(H)	1.66(O)
Ca (%)	3.00-4.90	2.95(O)	2.03(L)	2.17(L)	3.50(O)	2.59(L)	2.68(L)
Mg (%)	0.30-0.49	0.37(O)	0.38(O)	0.36(O)	0.45(O)	0.37(O)	0.44(O)
Fe (ppm)	60.0-120.0	115.83(O)	83.59(O)	78.74(O)	155.49(H)	84.25(O)	135.28(H)
Mn (ppm)	25.0-100.0	41.80(O)	34.19(O)	34.16(O)	64.55(O)	73.41(O)	41.99(O)
Cu (ppm)	5.0-16.0	12.22(O)	5.35(O)	6.11(O)	11.45(O)	7.89(O)	46.35(O)
Zn (ppm)	25.0-100.0	98.58(O)	69.94(O)	54.80(O)	87.39(O)	82.63(O)	49.44(O)
B (ppm)	36.0-100.0	26.84(L)	24.66(L)	27.63(L)	77.60(O)	47.73(O)	43.87(O)

*Level in parenthesis indicated the level, O = optimum, E=Excess, H= high and L= low

Three orchards on the sloping land belonged Mr. Ta Wongsai, Mr Amnui Wongjun and Mr. Taworn Mungjai were selected for detail comparison as shown in table 4.53, 4.54 and 4.55. The orchards of Mr. T. Wongsai and Mr. A. Wongjun had risk to soil nutrient imbalance at high and very high levels respectively while that of Mr. T. Mungjai was at the very low level. According to the conditions of the factors affecting soil nutrient imbalance, the soil in Mr. T. Wongsai was worse than that of Mr. A. Wongjun for CEC and organic matter content but Mr. T. Wongsai could maintain the orchard productivity even the trees were 11 years old. He could get the fruit yield of 68 kg/tree with big fruit size (size 6) while Mr. A. Wongjun could not get any in season fruit yield in 2010/2011. The fertilizer usage and method of orchard management of these two farmers were rather similar. However, since Mr. T. Wangsai was the full time mandarin farmer while Mr. A. Wongjun who was the local politician could spend only part of his time for mandarin cultivation. It was expected that Mr. T. Wongsai might spray foliar fertilizer more often than Mr. A. Wongjun resulted in the normal Ca concentrations of the index leaves in April and July. At the same period of leaf sampling, the index leaves collected from Mr. A. Wongjun were deficient in Ca. The B concentration of the index leaves collected in July from Mr. T. Wongsai was almost 2 time higher than that from Mr. A. Wongjun's orchards. In the case of Mr. T. Mungjai's orchard, though the soil was rather poor for the level of CEC and organic matter but his orchard had suitable soil pH thus his orchard is risky to soil nutrient imbalance at the low level. Furthermore Mr. T. Mungjai had good skill for mandarin cultivation and he could afford to use higher cost of input from fertilizer application at the higher rate (0.7 kg/tree) compared to Mr. T. Wongsai and Mr. A. Wongjun who applied at the rate of 0.5 kg/tree. However, Mr.T. Mungjai was a part time mandarin farmer since his major career was a trader. It was expected that the numbers of foliar spraying of fertilizer used by Mr. T. Mungjai might be less than that those used by Mr. T. Wongsai resulted in the deficient or low level of Ca content of the index leaves and the lower of B concentration in the index leaves collected inJuly. The trees in Mr. T. Mungjai which were about 7 years old gave fruit yield of about 47 kg/tree with the size 5.

It was also observed that most of the trees in the unproductive orchards in which Mr. A. Wongjun was one of them showed severe greening disease symptom (figure 4.44). Under such condition, photosynthetic activities of the small and yellowish leaves were expected to be ineffective which subsequently affected the function of the roots. The combination of the effects of greening disease and plant nutrient imbalance resulted to the poor growth of the mandarin trees as found in Mr. A. Wongjun's orchard.

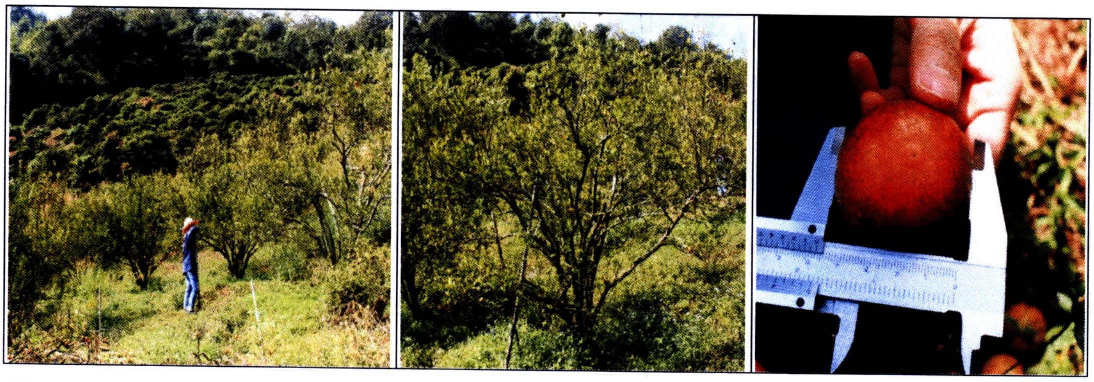

Figure 4.44 The mandarin trees in unproductive orchard with severe greening disease symptom

4) *Risk assessment of the factors effecting productivity declination of mandarin orchards*

Among the 50 selected mandarin orchards with the total cultivated area of 154.6 rais, the high and very high risky areas due to root rot (58.5%) were more than those due to the lost of plant nutrient by leaching and runoff (16.48%) and soil nutrient imbalance (24.8%) as shown in table 4.56.

Table 4.56 Comparison of risky areas due to each cause of productivity declination of mandarin orchards

Risky level	Risky area % of the total cultivated area		
	Root rot	**Plant nutrient lost**	**Soil nutrient imbalance**
lowest	2.1	17.2	12.2
low	16.2	49.2	33.0
moderate	23.2	17.6	30.0
high	31.0	12.6	23.4
highest	27.5	3.4	1.4
Total	**100**	**100**	**100**

4.4.2 Risk assessment of mandarin cultivated areas of Mae Soon sub-district for orchard productivity declination.

Only topographical factors (slope and elevation) and soil drainage were used for risk assessment of mandarin cultivated areas of Mae Soon sub-district with the total cultivated areas of 11,156.6 rais. The soil drainage data were obtained from the description of soil group (LDD, 2005). Since the risk assessment were evaluated from the topographical factors and soil drainage, thus only deteriorated causes on root rot and lost of plant nutrients by runoff and leaching were considered.

The significance or weighting of each factor having impact on root rot damage and classification or criteria of risk evaluation of the impact factors into different risky levels were shown in table 4.57 while those for the cause on plant nutrient lost by leaching and runoff were shown in table 4.58.

Table 4.57 Factors affecting root rot damage, significance and risky level classification of the affecting factors

Factors	**Weight**	**Risky level**				
		Lowest	**Low**	**Moderate**	**High**	**Highest**
slope (%)	0.528	12-20 20-35 >35	5-12			0-2 2-5
drainage	0.332	well	moderate well	moderate		poorly
elevation (MSL)	0.140		590-740 >740		<590	

Table 4.58 Factors affecting the lost of plant nutrients by leaching and runoff significance and risky level classification of the affecting factors

Factors	**Weight**	**Risky level**				
		Lowest	**Low**	**Moderate**	**High**	**Highest**
slope (%)	0.490	0-2 2-5	5-12	12-20	20-35	>35
runoff	0.231		slow	moderate	moderate to rapid	rapid
permeability	0.163		slow	moderate		rapid
soil depth (cm)	0.116	>100	75-100	50-75	25-50	<25

The results of risk assessment indicated that in the mandarin cultivated areas of Mae Soon sub-district with the total areas of 11,156.6 rais, there were the high to very high risky areas due to root rot about 73.7% and those with lowest to moderate risk were 26.3% only (table 4.59).

The data shown in table 4.60 Indicated that the very high risky area were the areas with 0-5 % slope, having poorly to moderate drainage and with the elevation below 590 m. and between 590-740 m. According to (Obreza and Collins, 1999), the areas with those conditions were not suitable for mandarin cultivation.

Table 4.59 Mandarin cultivated areas in Mae Soon sub-district with different risky levels to root rot damage

Risky level	**Area (rai)**	**% of the total cultivation**
lowest	659.6	5.9
low	1,027.3	9.2
moderate	1,252.3	11.2
high	4,190.3	37.6
highest	4,026.6	36.1
Total	**11,156.6**	**100.0**

Table 4.60 Condition of mandarin orchards with different risky levels to root rot damage

Factors	**Risky level**				
	Lowest	**Low**	**Moderate**	**High**	**Highest**
slope (%)	5-12 12-20 20-35 >35	5-12 12-20 20-35 >35	0-5 5-12 12-20 20-35 >35	0-5	0-5
drainage	-moderate -well	-poorly -moderate -well	-poorly -well	-moderate -moderate well -well	-poorly -moderate
elevation (MSL)	590-740	<590 590-740 >740	<590 590-740	<590 590-740	<590 590-740

The distribution of the orchards with different risky levels to root rot damage in Mae Soon sub-district under different topographic conditions were shown in table 4.61 Seventy percent of mandarin cultivated areas in Mae Soon Sub-district were the lowland . All of these areas had very high risk to root rot damage. In the case of the orchards on the foothill which were about 44.1% of the total cultivated areas had risk at high to very high levels. The rest were moderate risky. None of the mandarin cultivated area on the sloping land was risky to root rot damage at high to very high levels. The orchards on the sloping land were all risky to root rot damage at very low to moderate levels.

Table 4.61 Distribution of the orchards with different risky levels of risk to root rot damage on the lowland, the foothill and the sloping land in Mae Soon sub-district

Risky levels	Lowland		Foothill		Sloping land	
	Area(rai)	%	Area(rai)	%	Area(rai)	%
lowest	0.0	0.0	0.0	0.0	659.6	27.0
low	0.0	0.0	0.0	0.0	1027.4	42.2
moderate	0.0	0.0	500.1	55.9	752.3	30.8
high	4,025.0	51.5	165.5	18.5	0.0	0.0
highest	3,797.0	48.5	229.5	25.6	0.0	0.0
Total area	**7,822.1**	**100.0**	**895.1**	**100.0**	**2,439.4**	**100.0**

The map of mandarin cultivated area in Mae Soon sub-district with different levels of risky to root rot damage was shown in figure 4.45.

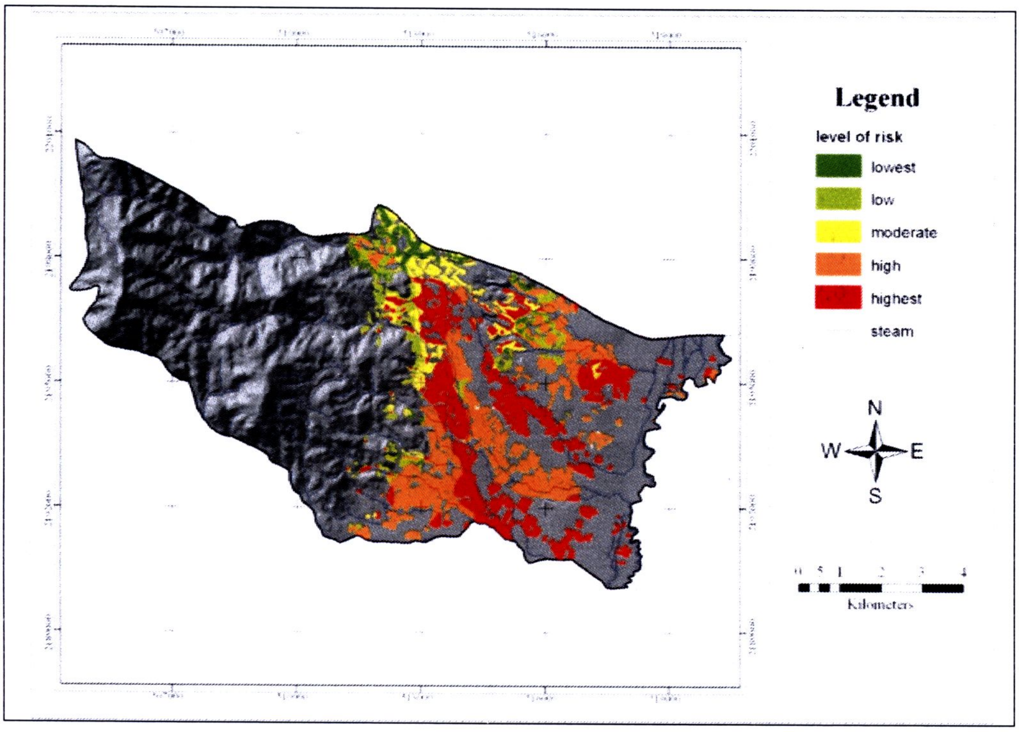

Figure 4.45 Map of mandarin cultivated areas in Mae Soon sub-district with different risky levels to root rot demage

Regarding to the risk to plant nutrient lost by leaching and runoff, most of mandarin cultivated areas (92.4%) of Mae Soon sub-district had the very low risk as shown in table 4.62. The map of mandarin orchards with different risky levels was shown in figure 4.46. The features of the mandarin cultivated areas with the very high risky levels to the lost of plant nutrients by runoff and leaching were as follows, slope > 35%, rapid runoff rate, rapid permeability and shallow soil depth (25-50cm). According to LDD (2005) such area is not suitable to be used as agricultural land but should be conserved as the watershed area.

Since most of mandarin cultivated area in Mae Soon sub-district were the lowland area (70% of the total area) and 8% were the foothill, these two topographical areas were very low risky to plant nutrient lost by runoff and leaching compared to that on the sloping land which covered 20% of the cultivated area. In the case of the mandarin cultivated area on the sloping land, most of them (93.4%) were risky to the lost of plant nutrients by runoff and leaching at the very low to moderate levels and about 6.6% were risky at high and very high levels.

Table 4.62 Mandarin cultivated areas in Mae Soon sub-district with different risky levels to the lost of plant nutrients by runoff and leaching

Risky level	Area (rai)	% of the total cultivation
lowest	10,308.4	92.4
low	395.4	3.5
moderate	292.0	2.6
high	148.5	1.3
highest	12.4	0.1
Total	**11,156.6**	**100.0**

Table 4.63 Condition of slope, runoff, permeability and soil depth of mandarin orchards in Mae Soon sub-district with the different risky level to the lost of plant nutrients due to runoff and leaching

Factor	Risky levels				
	Lowest	**Low**	**Moderate**	**High**	**Highest**
slope (%)	0-5	5-12	12-20	20-35	>35
	5-12	12-20	20-35	>35	
	12-20	20-35	>35		
runoff	-slow	-slow	-rapid	-rapid	-rapid
	-moderate	-moderate			
	-moderate to rapid	-moderate to rapid			
	-rapid	-rapid			
permeability	-slow	-slow	-slow	-slow	-rapid
	-moderate	-moderate	-moderate	-rapid	
	-rapid	-rapid	-rapid		
soil depth (cm)	25-50	25-50	25-50	25-50	25-50
	50-75	50-75	75-100		
	75-100	75-100			
	>100	>100			

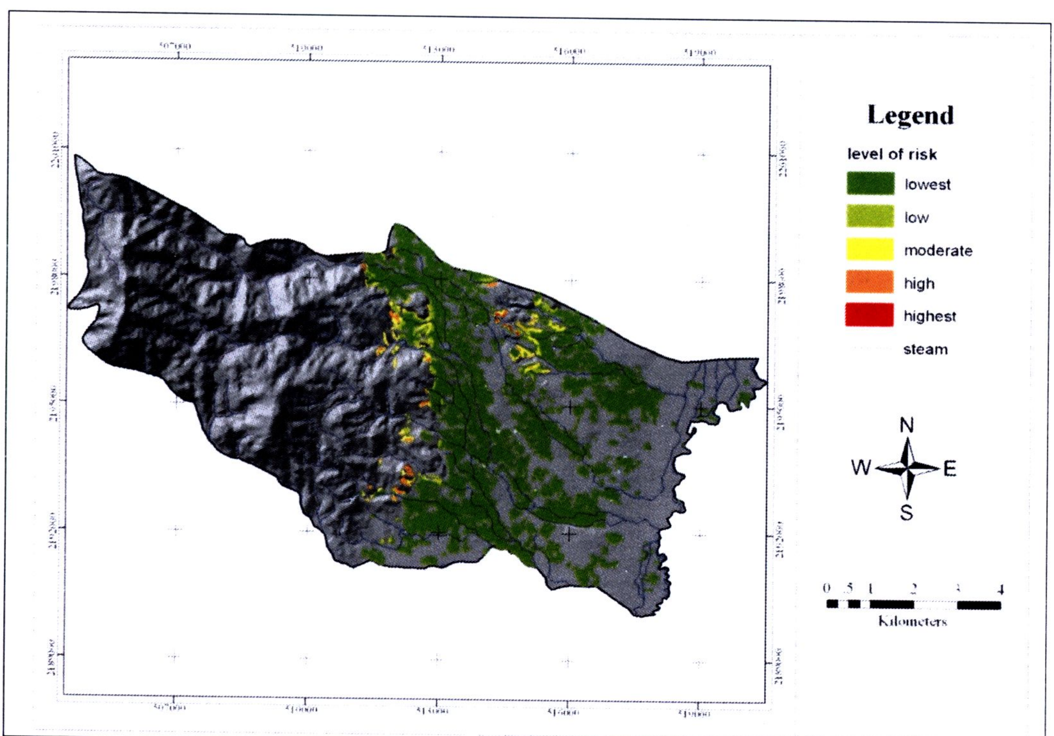

Figure 4.46 Map of mandarin cultivated areas in Mae Soon sub-district with different risky levels to the lost of plant nutrients due to runoff and leaching

When the risky mandarin cultivated areas of Mae Soon sub-district due to root rot and the lost of plant nutrient by runoff and leaching were compared (table 4.64) it was found that there were more risky areas to root rot damage (73.7%) than those from the lost of plant nutrients (1.4%).

Table 4.64 Comparison of risky mandarin cultivated areas due to root rot and the lost of plant nutrients

Risky level	% of the total cultivation	
	Root rot	**Plant nutrient lost**
lowest	5.9	92.4
low	9.2	3.5
moderate	11.2	2.6
high	37.6	1.3
highest	36.1	0.1
Total	**100.0**	**100.0**

4.4.3 Proposed suitable orchard management to reduce the risk on productivity declination of mandarin trees.

From field survey, it was observed that some orchards located in the areas with high or very high risky topographical and soil factors were still productive. The data from farmer's interviews indicated that most of the owners of the productive orchards had good orchard management. Thus, by suitable orchard management, the chances of the risky orchards to be deteriorated due to root rot, the lost of plant nutrients by runoff and leaching and soil nutrient imbalance could be reduced.

In general, pH and soil organic matter are the influencing factors for favorable population and diversity of soil microbes. Under acidic soil pH, fungi which are generally insensitive to soil pH are dominant soil microbial population while bacteria and actinomycetes dominate in the soil with higher soil pH (Vineela *et al*, 2008). Soil organic matter is the main source of carbon and energy for most heterotrophic microorganisms.

Furthermore, soil organic matter is essential for favorable physical condition of the soil because soil organic matter can bind up the soil particle to form soil aggregates (Verchot *et al.*, 2011) resulting in improvement of aeration and drainage.

According to Noling, (2003), mandarin trees will from the new roots which are effective for assimilation of plant nutrients from the soils. The growth of the young roots varied with soil texture. Furthermore, plant nutrient assimilation by the roots depended on physical condition of the roots and soil properties related with mobility of plant nutrients from soils to roots. In compact soil with shallow perch water table, the amount of oxygen is insufficient resulting in poor root distribution (Priestley *et al.*, 1988). Thus for effective plant nutrient assimilation of the root which is the aerobic required process, sufficient amount of oxygen in the soil for root respiration is essential (Glinski and Lipice, 1990). In the poor drainage soil such as Li soil series, bed raising seemed to be useful to improve drainage. Soil ploughing may be another way to improve soil aeration particularly under the tree canopy. This practice was done by one farmer (Mr. A.Punya) which was effective to maintain the productivity of mandarin trees cultivated on poor drainage soil.

The proposed methods to reduce the risk to root rot damage in mandarin orchards were shown in table 4.65.

Table 4.65 Proposed scenarios to reduce the risk on root rot damage in mandarin orchards

Scenarios	Improved factors	Methods of improvement
A	soil pH	liming to increase soil pH to 6.0-6.5 before rainy season
B	drainage	-bed raising for the orchards on the lowland and the foothill -soil tillage under the tree canopy before rainy season
	% soil organic matter	applying manure or compost to increase soil organic matter in the soil and improve soil physical properties
C	soil pH drainage %soil organic matter	combination of scenario A and B

The changes in the percentage of risky areas due to root rot damage after application of the proposed methods of orchard management were shown in figure 4.47 to 4.49.

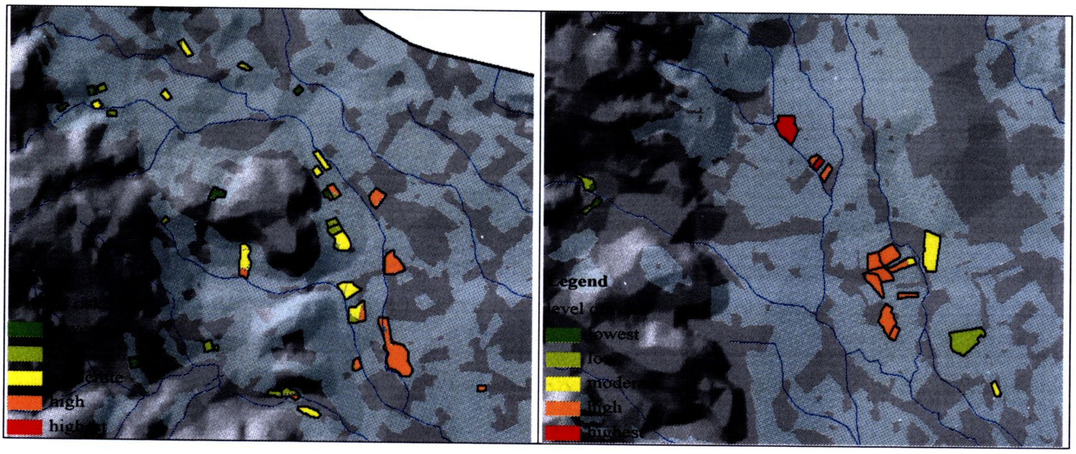

Figure 4.47 Scenario A : scenarios to reduce the risk on root rot damage by soil pH improving

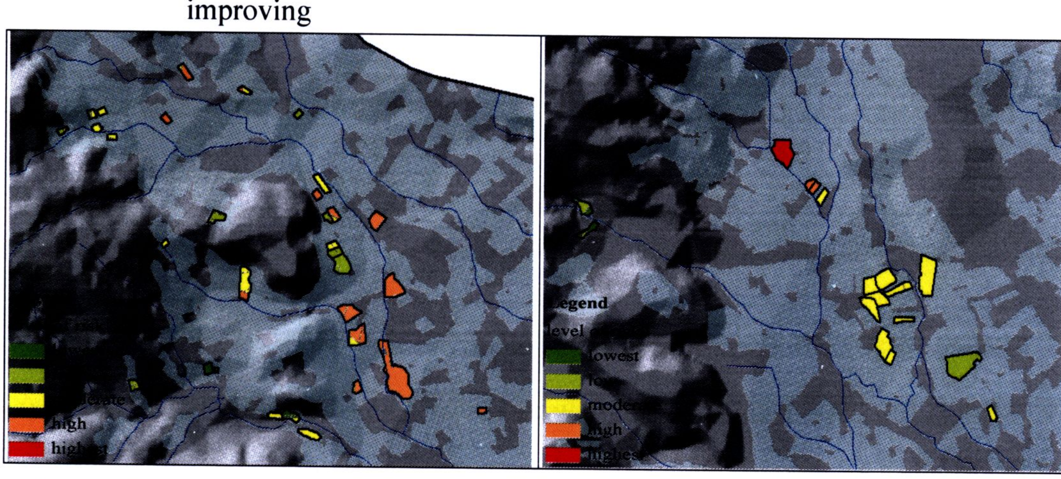

Figure 4.48 Scenario B : scenarios to reduce the risk on root rot damage by bed raising and addition of soil organic matter

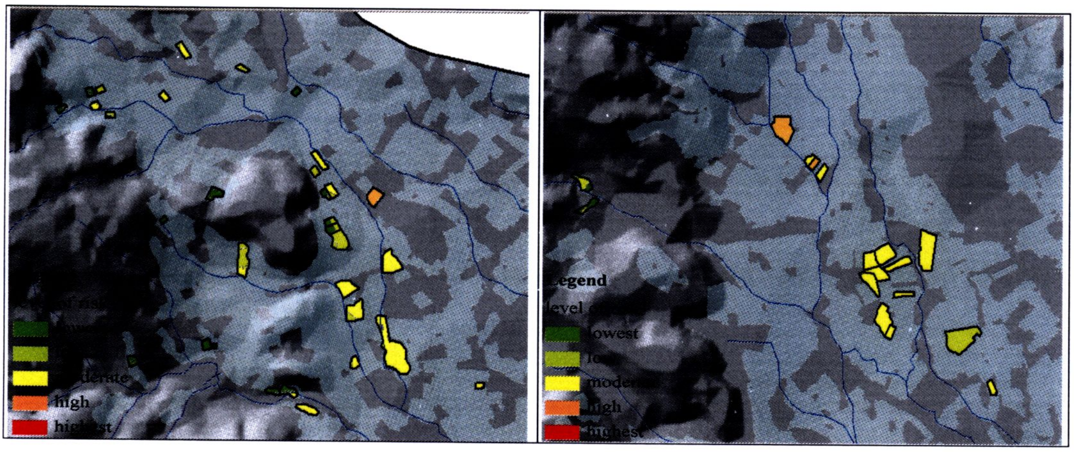

Figure 4.49 Scenario C : scenarios to reduce the risk on root rot damage by soil pH improving, bed raising and addition of soil organic matter

Table 4.66 Changes of risky area (%of the total cultivated areas) to root rot damage after application of proposed methods of orchard management

Risky level	Current situation	Scenario A	Scenario B	Scenario C
lowest	2.1	7.1	4.2	11.5
low	16.2	19.7	18.4	22.0
moderate	23.2	25.7	43.3	58.2
high	31.0	41.3	28.9	8.3
highest	27.5	6.2	5.3	0.0
Total	**100.0**	**100.0**	**100.0**	**100.0**

According to scenario A (table 4.65), the areas as very risky level reduced 77% compared to the present situation but those with high risk level were still high (41.3%). By scenario B, the areas with very high to high levels reduced 40% compared to those at the present stage. With the improvement of soil pH, soil drainage and soil organic matter content (scenario C) there would be no area with very high risky and those with high risky would reduce to 8.5% while 58.2% of the total cultivated areas would have moderate risk to root rot damage.

In the case of the risk on the lost of plant nutrients by leaching and runoff which the very high risky areas were the areas with more than 35% slope, shallow soil depth, rapid rate of runoff and permeability. In this study, slope complex soil group is risky to plant nutrient lost by leaching and runoff and it is not recommended for crop cultivation (LDD, 2007). For the risky areas, the proposed methods to reduce the lost of plant nutrient lost by runoff and leaching were shown in table 4.67.

Table 4.67 Proposed methods of orchard management to reduce risk to plant nutrient lost by leaching and runoff

Scenario	Improved factors	Methods of improvement
A	permeability	application of organic matter
B	pH	Liming to increase soil pH of the acidic soil with pH<6.0
	%organic matter	application of compost to increase CEC of the soil
C	permeability	combination of the methods from scenario A and B
	pH	
	%organic matter	

By addition of organic matter such as manure or compost into the soil particularly the soil groups with rather high sand content and rapid permeability as follows ; Mae Taeng (Mt-SIB, Mt-SIC, Mt-SID), Phetchalun (Pe-SIB, Pe-SIC/d5), and Sai Ngam (Ss-SIA), the water holding capacity of the soil would be increased and the rate of water permeating into the soil profile would be reduced (Panomtaranichagul, 2008)

When the soil is acidic, some of insoluble Ca compounds in the soil will be dissolved. The soluble Ca can be easily leached out from the soil when the soil condition is favorable for leaching (Anderson *et al.*, 2002). Ca ion has an important role for soil physical properties. With sufficient amount of Ca, the soil will be not compact and has good drainage (FFTC, 2003). Thus liming is expected to be useful for improvement of acidic compact soil because not only soil pH but also soil drainage will be increased. The addition of organic materials particularly compost can increase CEC of the soil because humus in the compost which is the organic material with high CEC can adsorb cations in the soil and reduce the lost of cations by leaching.

Figure 4.50 and 4.52 showed the map of mandarin cultivated areas from the 50 selected orchards with the different risky levels to the lost of plant nutrients after the application of the proposed orchard management according to scenario A, B and C respectively.

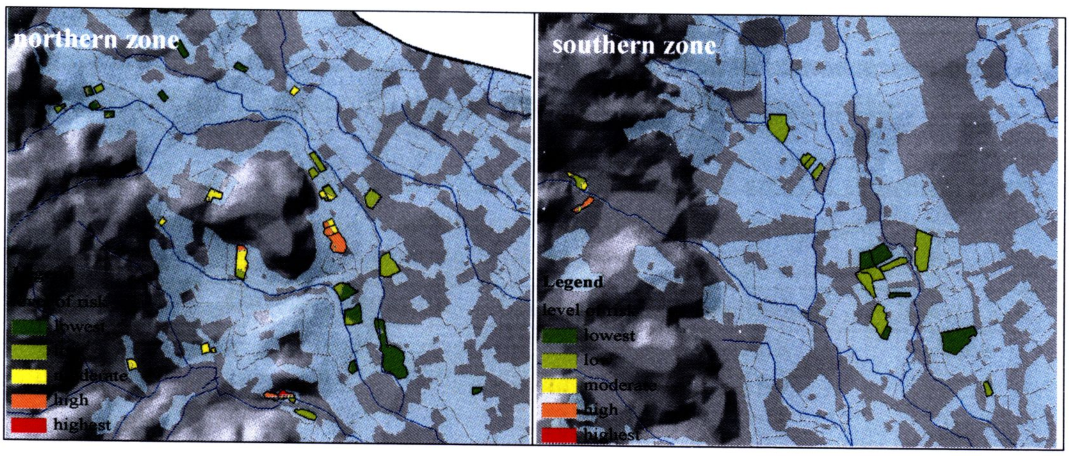

Figure 4.50 Scenario A: scenario to reduce the risk on lost of plant nutrients by application of organic matter

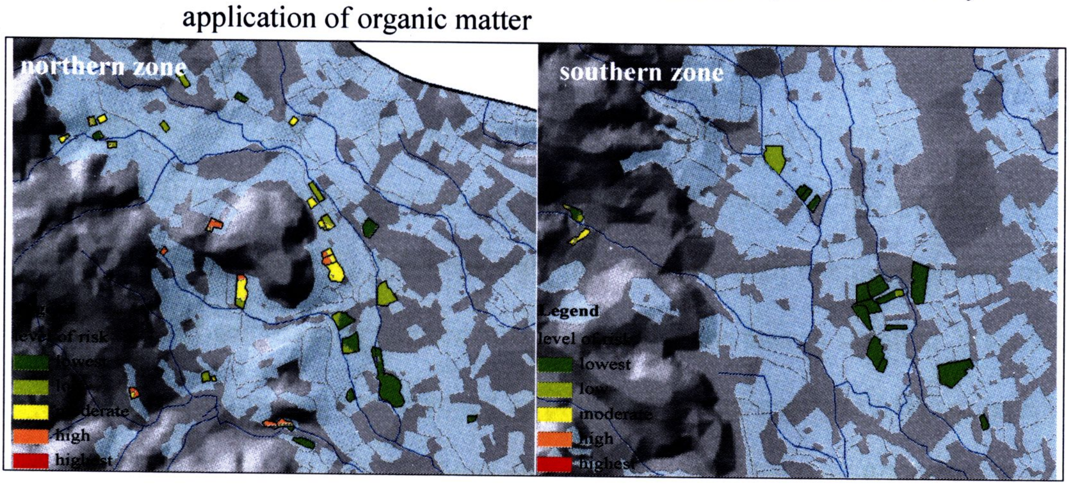

Figure 4.51 Scenario B: scenario to reduce the risk on lost of plant nutrients by limimg and addition of soil organic matter

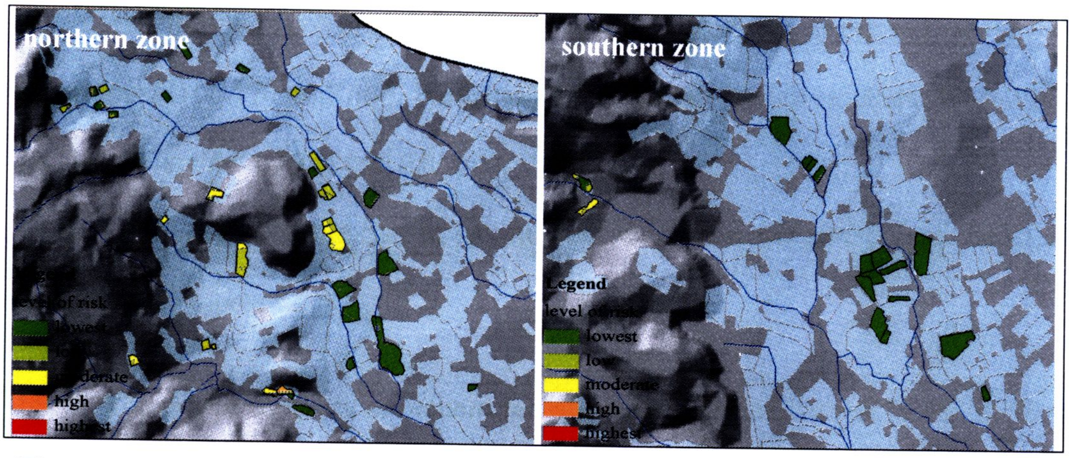

Figure 4.52 Scenario C: scenario to reduce the risk on lost of plant nutrients by improving of soil permeability, limimg and application of organic matter

Table 4.68 Changes of risky areas (%of the total cultivated areas) to plant nutrient lost after application of proposed methods of orchard management

Risky level	Current situation	Scenario A	Scenario B	Scenario C
lowest	17.2	36.9	59.8	76.6
low	49.2	44.6	21.9	12.5
moderate	17.6	10.5	12.2	10.2
high	12.6	7.2	6.2	0.8
highest	3.4	0.8	0.0	0.0
Total	**100.0**	**100.0**	**100.0**	**100.0**

Table4.68 showed the changes of risky areas after the application of proposed methods of orchard management compared with the current situation. By improvement of soil permeability (scenario A), the areas with high and very high risk to the lost of plant nutrient by runoff and leaching reduced 50% compared to the present situation. When soil pH and soil organic matter are improved as proposed in scenario B (59.8% of the total area) would be risky at the very low level and none has very high risk. With combination of all proposed methods (scenario C), 76.6% of the total mandarin cultivated areas would be risky to the lost of plant nutrient at the very low level.

In the case of risky to soil nutrient imbalance, 38% of the selected orchards were high and very high risky. Almost all orchards had the avai. Pcontent of the soils above the optimum level (35-60 mgP/kg) and 48% had the exch. K contents of the soils above the optimum level (100-170 mgK/kg). Furthermore 76% of the studied orchards had soil pH lower than the optimum level (pH 6.0 -6.5).

In order to reduce the risk to soil nutrient imbalance, the methods as shown in table 4.69 were proposed.

Table 4.69 Proposed methods of orchard management to reduce the risk to soil nutrient imbalance

No. of scenario	Improved factors	Methods of improvement
A	soil pH	liming to pH 6.0-6.5
B	available P	no P and K fertilizer application
	exch. K	
C	soil pH	combination of the proposed methods from scenario A and B
	available P	
	exch. K	

According to Supakumnerd *et al.*(2005), the optimum level of avai. Pin the soil for mandarin cultivate was 35-60 mgP/kg while exch. K was 100-120 mgK/kg. The experimental results from on farm trial of this study indicated also that in the orchard with high levels of avai. Pand exch. K, there was no need to apply P and K fertilizer since there was no significant differences of fruit yield and fruit qualities between the fertilizer treatments with and without P and K fertilizers. Furthermore without P and K fertilizer application, the farmer could reduce cost of input about 97.7% compared to that by farmer practice in which N, P and K were applied monthly at the high doses. Not only cost of input on fertilizer which could be reduced, omission of P and K fertilizer application by mandarin farmers whose orchard soils were rich in avai. Pand exch. K could reduce the risk on further increasing of avai. Pand exch. K.

For liming, in general most farmers applied lime every year after fruit harvest in February to April. However, they did not apply lime according to lime requirement by soil testing. Thus to adjust soil pH to 6.0-6.5 the farmers should test their soils for lime requirement.

When the proposed methods of orchard management were applied according to scenario A, B and C, the risky areas to soil nutrient imbalance as shown in figure 4.53 and 4.55 respectively would be found.

The changes of risky areas to soil nutrient imbalance after application of each proposed method of orchard management compared to the present situation were shown in table 4.70.

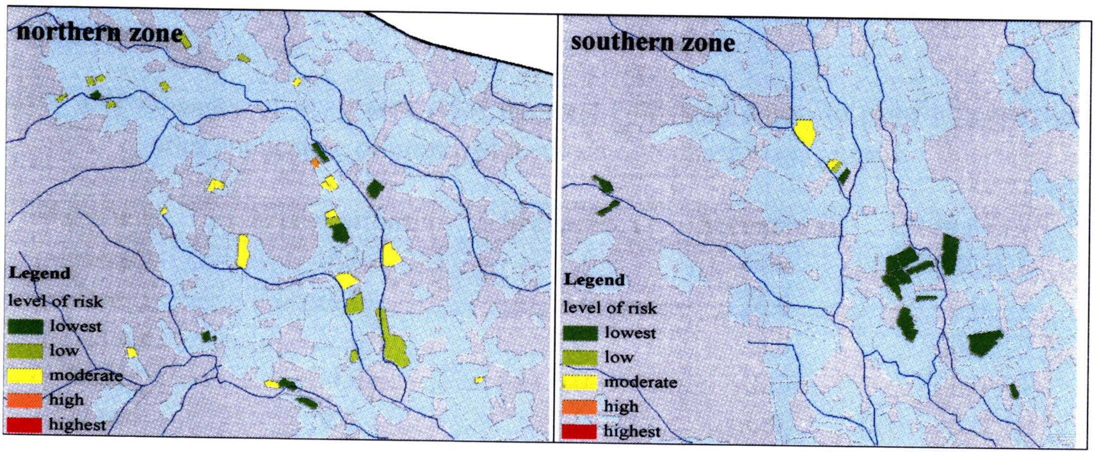

Figure 4.53 Scenario A: scenario to reduce the risk on nutrient imbalance by limimg

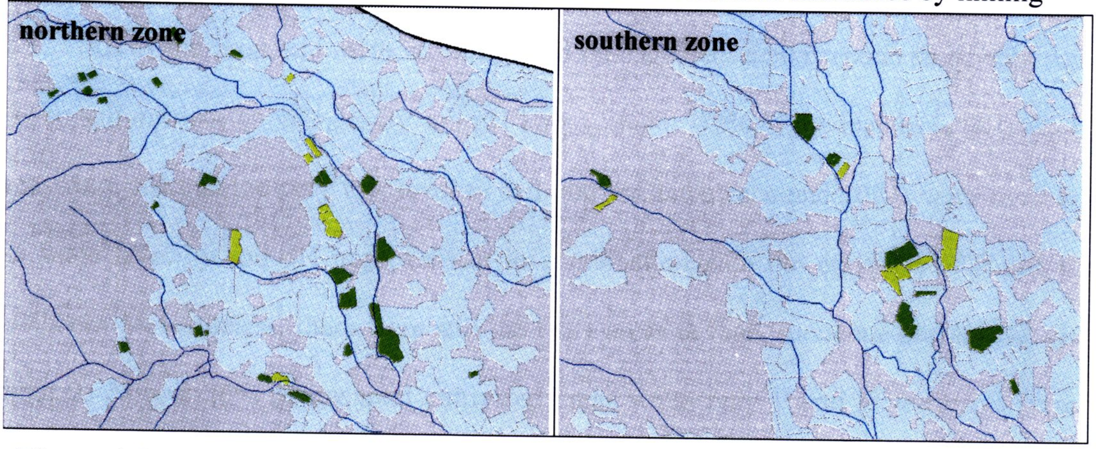

Figure 4.54 Scenario B: scenario to reduce the risk on nutrient imbalance by omision of P and K fertilizer application

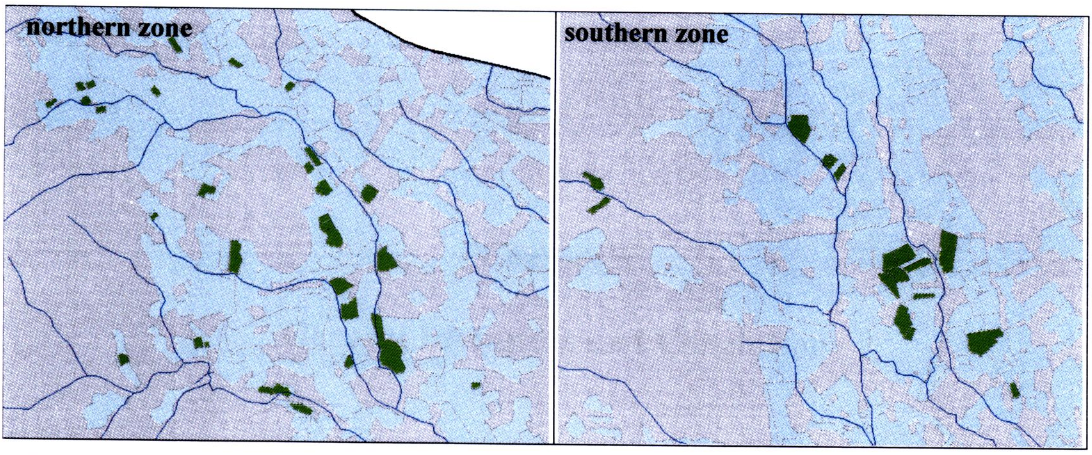

Figure 4.55 Scenario C: scenario to reduce the risk on nutrient imbalance by liming and omision of P and K fertilizer application

Table 4.70 Changes of risky area (%of the total cultivated areas) to plant nutrient lost after application of proposed methods of orchard management

Risky level	Current situation	Scenario A	Scenario B	Scenario C
lowest	16.0	72.0	44.0	100.0
low	24.0	28.0	26.0	0.0
moderate	22.0	0.0	28.0	0.0
high	34.0	0.0	2.0	0.0
highest	4.0	0.0	0.0	0.0
Total	**100.0**	**100.0**	**100.0**	**100.0**

All of the proposed methods of orchard management could reduce drastically the risk to soil nutrient imbalance. By soil pH improvement, 72% of the mandarin cultivated areas were risky at the very low level to soil nutrient imbalance and 100% were risky at the same level by soil pH improvement in combination with the omission of P and K fertilizers. Nevertheless, there were still the risky areas at high, moderate and low levels about 2, 28 and 26% of the total cultivated areas when only P and K fertilizers were omitted.