

## Table of Contents

	<b>Page</b>
<b>Acknowledgement</b>	iii
<b>Abstract in Thai</b>	iv
<b>Abstract in English</b>	vi
<b>Table of contents</b>	viii
<b>List of Tables</b>	Xii
<b>List of Figures</b>	xviii
<b>Chapter 1 Introduction</b>	1
<b>Chapter 2 Literature Reviews</b>	5
2.1 Factors related with degradation of mandarin orchards	
2.1.1 Topography	5
2.1.2 Soil properties	6
2.1.3 Effects of orchard management	8
2.2 Spatial assessment of the mandarin orchard degradation	11
<b>Chapter 3 Materials and methods</b>	13
3.1 Study area	
3.1.1 Boundary	13
3.1.2 Topographic conditions	13
3.1.3 Climatic condition	15
3.1.4 Socio – economic status	18
3.2 Conceptual frame work	19
3.3 Research procedure	
3.3.1 Data preparation and pre-processing	20
3.3.2 Classification of mandarin orchards	22
3.3.3 Collecting data of orchard management	27
3.3.4 Collecting data of fruit yield and sizes	28
3.3.5 On farm trial	29
3.3.6 Spatial database development	32

## Table of Contents (continued)

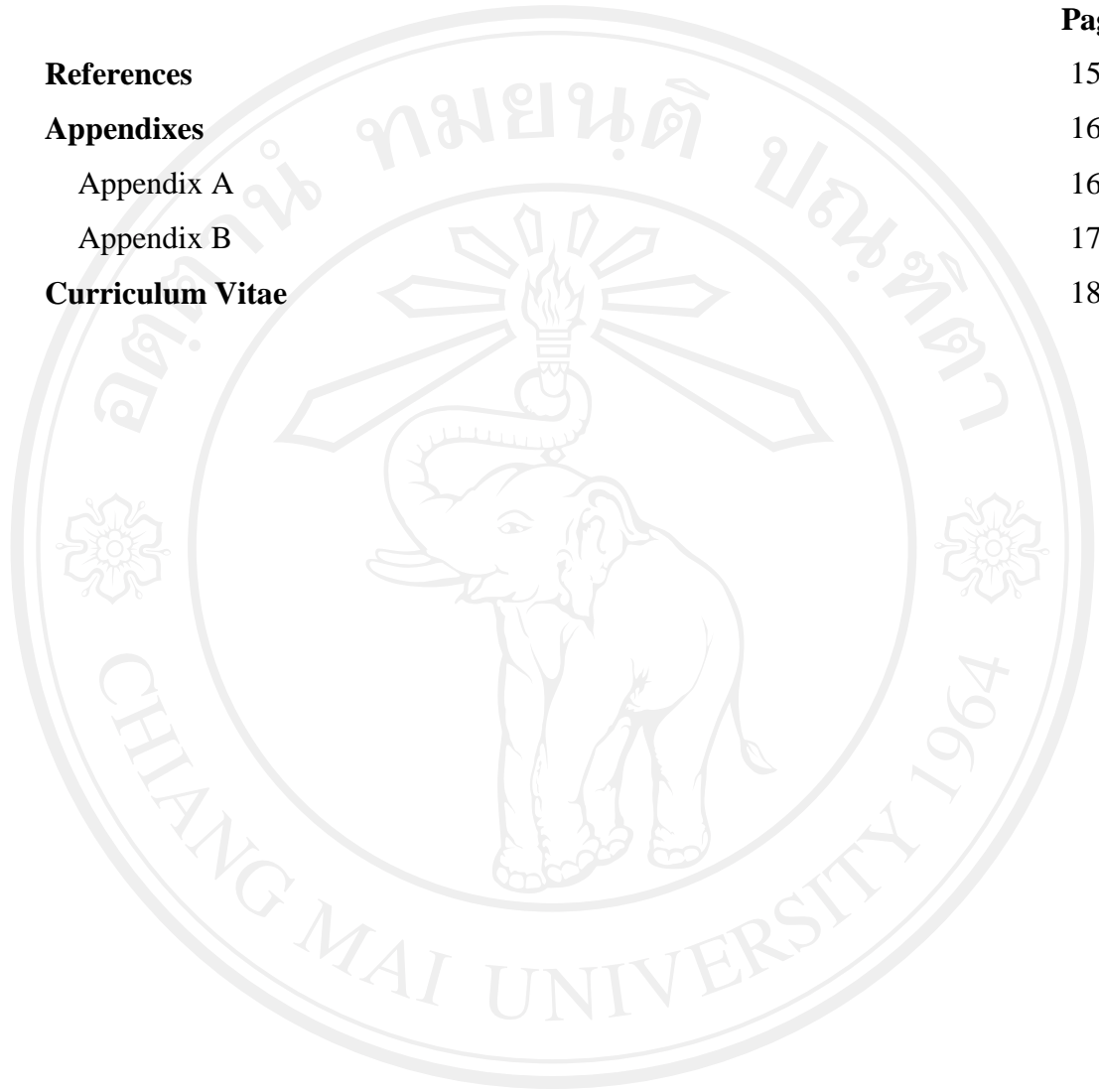
	<b>Page</b>
3.3.7 Risk assessment of the factors affecting productivity declination of mandarin of mandarin orchards	38
3.3.8 Recommendation of the proper management of mandarin orchard according to the topographical condition and soil quality of the cultivated area	40
<b>Chapter 4 Result and discussion</b>	<b>41</b>
4.1 Mandarin cultivation in Mae Soon Sub-district	
4.1.1 General information of mandarin orchards of the farmers in Mae Soon sub-district	41
4.1.2 Properties of the soils in the selected productive orchards	55
4.1.3 Plant nutrient status of mandarin trees in the selected farmers orchards	56
4.1.4 Mandarin fruit product of the selected farmers in Mae Soon sub-district	63
4.2 On farm trial on reduction of chemical fertilizer usage in mandarin orchard and the effects on yield and quality of mandarin fruits	65
4.3 Result and discussion: Spatial data base of factors affecting productivity declination of mandarin orchards in Mae Soon sub-district	71
4.3.1 Basic data of the study area	
1) Administrative boundary and village position of Mae Soon sub-district	71
2) Steam lines	73
4.3.2 Mandarin cultivated area in Mae Soon sub-district	74
4.3.3 Soil series	74
4.3.4 Topographic database : slope and elevation	79
4.3.5 Information of 50 selected mandarin orchards	84

## Table of Contents (continue)

	<b>Page</b>
4.4 Risk assessment of the factors affecting the productivity declination of mandarin orchards in Mae Soon sub- district	87
4.4.1 Risk assessment of the factors affecting the productivity declination of mandarin orchards in the 50 selected orchards	87
4.4.1.1 Factors affecting productivity declination of mandarin orchards	87
4.4.1.2 Classification of the factors contributing to deterioration of mandarin orchards	88
4.4.1.3 Weighting of the significance of analyzed factors	90
4.4.1.4 Risk assessment of the factors affecting productivity declination of mandarin orchards	91
1) Factors affecting root rot	91
2) Factors affecting plant nutrient lost by runoff and leaching	107
3) Factors affecting soil nutrient imbalance	114
4) Risk assessment of the factors effecting productivity declination of mandarin orchards	120
4.4.2 Risk assessment of mandarin cultivated areas of Mae Soon sub-district for orchard productivity declination	121
4.4.3 Proposed suitable orchard management to reduce the risk on productivity declination of mandarin trees	127
<b>Chapter 5   General Discussion and Conclusion</b>	<b>137</b>
5.1 General discussion	137
5.2 Conclusion	148

## Table of Contents (continue)

	<b>Page</b>
<b>References</b>	151
<b>Appendixes</b>	163
Appendix A	164
Appendix B	172
<b>Curriculum Vitae</b>	187



ลิขสิทธิ์มหาวิทยาลัยเชียงใหม่  
 Copyright© by Chiang Mai University  
 All rights reserved

## List of Tables

<b>Table</b>	<b>Page</b>
3.1 Methods of soil chemical analysis	25
3.2 National standard of mandarin fruit	29
3.3 Fertilizer application by farmer	31
3.4 Foliar spraying of fertilizers and algal extract by farmer practice	31
3.5 Rate of N, P <sub>2</sub> O <sub>5</sub> and K <sub>2</sub> O applied in to the soil for each treatment	32
3.6 Detail input of data	33
4.1 Mandarin plant materials used in the farmers' orchards in Mae Soon sub-district	41
4.2 The ages of mandarin trees in the farmers orchards at Mae Soon sub-district	42
4.3 Land use history of mandarin orchards in Mae Soon sub-district	43
4.4 Topographic condition of mandarin orchard in Mae Soon sub-district	43
4.5 Availability of the irrigated water for mandarin cultivation in Mae Soon sub-districts	44
4.6 The numbers of mandarin farmers in Mae Soon sub-district who used to check the qualities of the soil in their orchards	45
4.7 Criteria of the mandarin farmers for fertilizer management in their orchard	45
4.8 Fertilizer grades used by mandarin farmers in Mae Soon sub-district	46
4.9 Chemical fertilizer application rate (kg/tree) of mandarin farmers in Mae Soon sub-district	47
4.10 Rate of fertilizer application to mandarin trees with different ages by 50 interviewed farmers	48
4.11 Criteria of the farmers for foliar spraying of fertilizers in mandarin orchards	48

### List of Tables (continue)

<b>Table</b>	<b>Page</b>
4.12 Occurrence of plant nutrient deficiency in mandarin orchards of the farmers at Mae Soon sub-district	50
4.13 Status of mandarin orchards evaluated by the farmers	51
4.14 Percentage of immature harvested, fruits in comparison to the total fruit yield	52
4.15 Basic knowledge of mandarin farmers in Mae Soon sub-district	53
4.16 Causes of the orchard failure	54
4.17 Properties of the soils in 50 selected mandarin orchards	55
4.18 Guidelines for interpretation of orange tree leaf analysis based on 4 to 6 month-old flush leaves from non-fruiting twigs	57
4.19 Percentage of the mandarin orchards having plant nutrient status at different levels	57
4.20 Effect of fertilizer treatments on mandarin fruit yields at the first and second harvest, total fruit yield and the contents of soluble solid (°brix)	65
4.21 Effects of fertilizer treatments on the yields of mandarin fruits with different sizes	66
4.22 Optimum levels and average concentrations of trace elements in the index leaf samples from the forth treatment	67
4.23 Comparison of the relative cost of input on fertilizers and mandarin fruit yield among different fertilizer treatments	68
4.24 The name of soil series in mandarin cultivated area in Mae Soon sub-district	75
4.25 Drainage of mandarin cultivated areas in Mae Soon sub-district	77
4.26 Runoff of mandarin cultivated areas in Mae Soon sub dist	78
4.27 Permeability of mandarin cultivated areas in Mae Soon sub-district	79
4.28 Elevation of mandarin cultivated areas in Mae Soon sub-district	80

### List of Tables (continue)

<b>Table</b>	<b>Page</b>
4.29 Slope of mandarin cultivated areas in Mae Soon sub-district	80
4.30 Criteria for physical condition characterization of mandarin cultivated area in Mae Soon sub-district	81
4.31 Physical characterizations of mandarin cultivated areas in Mae Soon sub-district and the 50 selected farmers orchard	82
4.32 Risky classification of the factors contributing to root rot	89
4.33 Risky classification of the factors contributing to nutrient lost through leaching and runoff	89
4.34 Risky classification of the factors contributing to nutrient imbalance of the soils	90
4.35 The significant weighting of the factors affecting root rot	90
4.36 The significant weighting of the factors affecting nutrient lost by leaching and runoff	91
4.37 The significant weighting of the factors affecting plant nutrient imbalance of the soils	91
4.38 Risky classification of mandarin orchards due to productivity declination caused by root rot	92
4.39 Factors of mandarin orchards with different risky levels to root rot	92
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 sloping land	93
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	94
4.42 Comparison of mandarin orchards in the lowland with different risky levels to root rot	96



### List of Tables (continue)

<b>Table</b>	<b>Page</b>
4.43 Comparison of mandarin orchards in the foothill with different risky levels to root rot	103
4.44 Comparison of mandarin orchards in the sloping land with different risky levels to root rot	106
4.45 Comparison of mandarin orchards in the sloping land with different risky levels to plant nutrient lost by runoff area leaching	108
4.46 Risky classification of mandarin orchards due to productivity declination caused by plant nutrient lost by runoff and leaching	108
4.47 Distribution (%of the total areas at in each topographic 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	109
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	109
4.49 Comparison of mandarin orchards in the sloping land with different risky levels to plant nutrient lost by runoff and leaching	111
4.50 Classification of mandarin orchards according to the risk on plant nutrient imbalance of soils	114
4.51 Condition o soil parameters of the orchards with different risky levels	115
4.52 Distribution of the orchards with different levels of risk to soil nutrient imbalance on the lowland, the foothill and the sloping land	115
4.53 Detail comparison of three selected farmer orchards with the different risky levels to soil nutrient imbalance	117
4.54 Properties of the soils in the orchards of Mr. T. Wongsai, Mr. A. Wongjun and Mr. T. Mungjai	118



### List of Tables (continue)

<b>Table</b>	<b>Page</b>
4.55 Concentration 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 (1 <sup>st</sup> ) and July (2 <sup>nd</sup> )	118
4.56 Comparison of risky areas due to each cause of productivity declination of mandarin orchards	121
4.57 Factors affecting root rot damage, significance and risky level classification of the affecting factors	122
4.58 Factors affecting the lost of plant nutrients by leaching and runoff significance and risky level classification of the affecting factors	122
4.59 Mandarin cultivated areas in Mae Soon sub-district with different risky levels to root rot damage	123
4.60 Factors of mandarin orchards with different risky levels to root rot damage	123
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	124
4.62 Mandarin cultivated areas in Mae Soon sub-district with different risky levels to the lost of plant nutrients by runoff and leaching	125
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	126
4.64 Comparison of risky mandarin cultivated areas due to root rot and the lost of plant nutrients	127
4.65 Proposed scenarios to reduce the risk on root rot damage in mandarin orchards	128
4.66 Changes of risky area (%of the total cultivated areas) to root rot damage after application of proposed methods of orchard management	130

### List of Tables (continue)

<b>Table</b>	<b>Page</b>
4.67 Proposed methods of orchard management to reduce risk to plant nutrient lost by leaching and runoff	131
4.68 Changes of risky area (%of the total cultivated areas) to plant nutrient lost after application of proposed methods of orchard management	133
4.69 Proposed methods of orchard management to reduce the risk to soil nutrient imbalance	134
4.70 Changes of risky area (%of the total cultivated areas) to plant nutrient lost after application of proposed methods of orchard management	136
<b>Appendix</b>	
1 Soil properties of soil series	173
2 Risky classification of factors contributing to root rots each orchard	174
3 Risky classification of factors contributing to nutrient lost though leaching and runoff each orchard	179
4 Risky classification of factors contributing to nutrient imbalance each orchard	184

## List of Figures

<b>Figure</b>	<b>Page</b>
3.1 Boundary and neighboring administrative areas of the study site: Mae Soon sub-district	14
3.2 Topographic hill shade of Mae Soon sub-district	15
3.3 Average monthly rainfall in 2008-2010	17
3.4 Maximum-minimum temperature in 2007-2009	17
3.5 Conceptual framework	19
3.6 Multispectral (a) and Panchromatic (b) image of THEOS satellite	20
3.7 THOES satellite image with 15 meter resolution (a), panchromatic image with 2 meter resolution (b), false pan-sharped multispectral image (c) and true pan-sharped multispectral image (d)	21
3.8 Comparison of panchromatic image (a) and pan-shaped (b) image of mandarin orchards and other fruit tree orchards	23
3.9 Method development	34
3.10 Step for development of spatial database of basic data of study area	36
3.11 The multi-criteria analysis with GIS	39
4.1 Status of P and K in the third index leaves of mandarin trees grown in different soil condition in April 2009	60
4.2 Status of Ca and Mg in the third index leaves of mandarin trees grown in different soil condition in April 2009	60
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	61
4.4 Status of P and K in the third index leaves of mandarin trees grown in different soil condition in July 2009	61
4.5 Status of Ca and Mg in the third index leaves of mandarin trees grown in different soil condition in July 2009	62
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	62

### List of Figures (continue)

<b>Figure</b>	<b>Page</b>
4.7 Mandarin fruit yields of the selected farmers	63
4.8 Basic mandarin fruits sizes of the selected farmers	63
4.9 Administrative boundary of Mae Soon sub-district	72
4.10 Position of the villages in Mae Soon sub-district	72
4.11 Steam line and main rivers in Mae Soon sub-district	73
4.12 Mandarin cultivated area in Mae Soon sub-district in 2010	74
4.13 Soil series in mandarin cultivated area in Mae Soon sub-district in 2010	75
4.14 Drainage map layer	76
4.15 Runoff map layer	76
4.16 Permeability map layer	76
4.17 Soil depth map layer	76
4.18 Elevation map layer	79
4.19 Slope map layer	79
4.20 Physical characterization of mandarin cultivated areas in Mae Soon sub-district	83
4.21 Physical characterization of 50 selected farmers orchard	83
4.22 Map layer of soil pH of 50 selected orchards	84
4.23 Map layer of CEC of 50 selected orchards	85
4.24 Map layer of % organic matter of 50 selected orchards	85
4.25 Map layer of available P of 50 selected orchards	85
4.26 Map layer of exchangeable K of 50 selected orchards	86
4.27 Map of mandarin orchards with different levels of risk to root rot	93
4.28 Correlation coefficient of the relationship between MBC and soil organic matter	95

### List of Figures (continue)

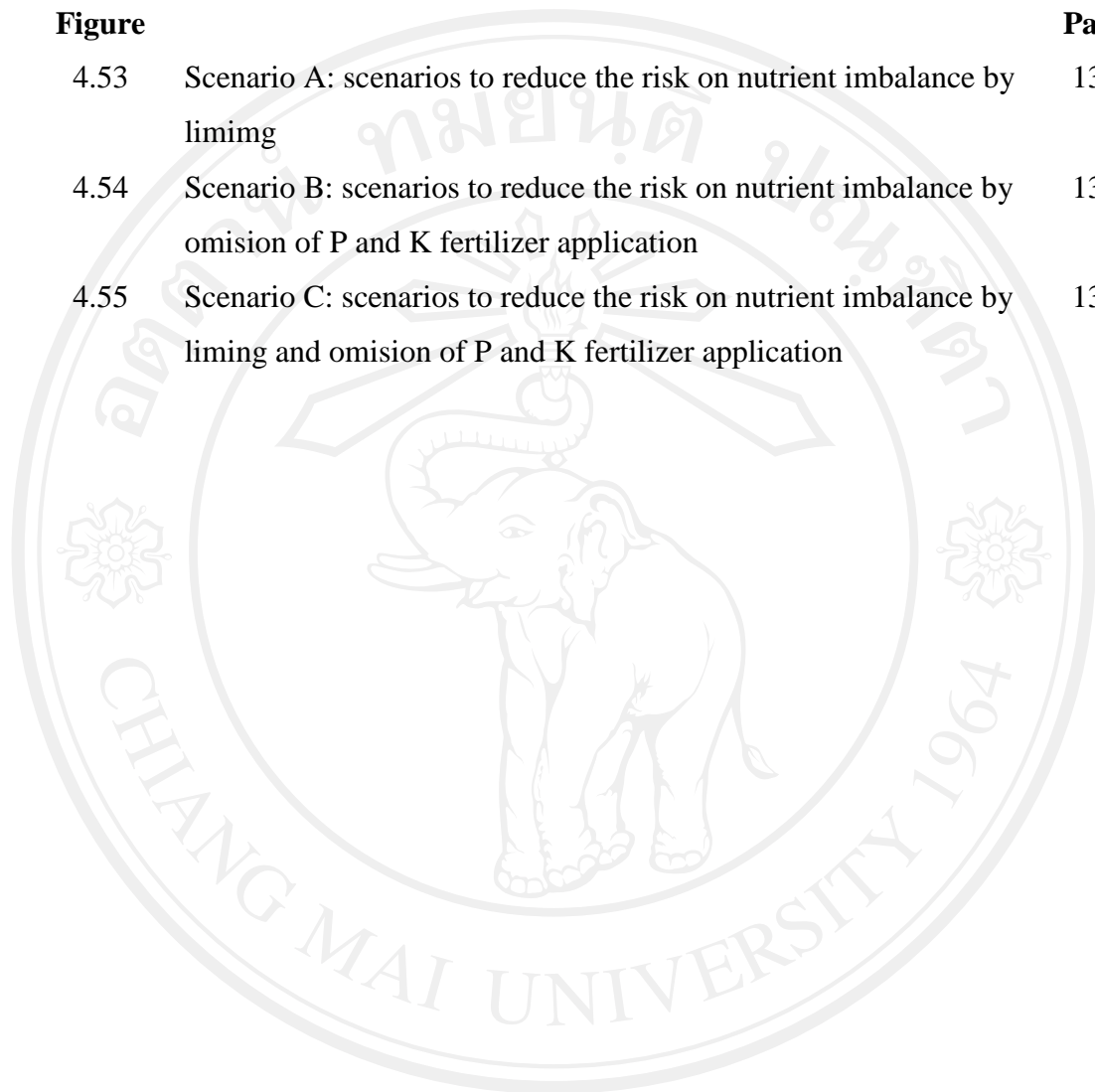
<b>Figure</b>	<b>Page</b>
4.29 Land preparation and the appearances of the trees in the middle of July 2010 in three selected mandarin orchards in the lowland; ; a and b) the orchards of K. Yana and T. Kotrakul with high bed raising, c) the orchard of R. Intatar with low bed raising	100
4.30 Friut formation 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	100
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	101
4.32 Root rot disease syptom in R. Intatar's orchard	101
4.33 Sai Numpueng mandarin trees on Cleopatra root stock in K. Yana's orchard and air layering in T. kotrakul	101
4.34 The general features of the trees in the orchards a) R. Doawee's orchards and b) L. Yawilart's orchard	104
4.35 The condition of mandarin leaves in July a) R. Doawee's orchards b) L. Yawilart's orchard	104
4.36 Fruit characteristics in January a and b) R. Doawee's orchards c) L. Yawilart's orchard	104
4.37 Some problems: a) Mg deficiency, b) die back and c) greening disease symptoms in Mr. R. Doawee's orchards	105
4.38 Mandarin trees in the orchards of Mr. U. Panya and Mr. B. Doawee cultivated on the terraces using the narrow spacing	107
4.39 The root rot infected trees in Mr. B. Dowee's orchards	107
4.40 Map of mandarin orchards with differet levels of risk to plant nutrient lost by runoff and leaching	109

### List of Figures (continue)

<b>Figure</b>		<b>Page</b>
4.41	General features of the orchards of Mr.M. Lungkana(a), Mr.K. Yana (b) and Mr. S. Sang Ai (c)	112
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)	112
4.43	Map of mandarin orchards with differet levels of risk to soil nutrient imbalance; a) northern zone and b) southern zone	115
4.44	The mandarin trees in unproductive orchard with severe greening disease symptom	120
4.45	Map of mandarin cultivated areas in Mae Soon sub-district with different risky levels to root rot damage	124
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	126
4.47	Scenario A : scenarios to reduce the risk on root rot damage by soil pH improving	129
4.48	Scenario B : scenarios to reduce the risk on root rot damage by bec raising and addition of soil organic matter	129
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	130
4.50	Scenario A: scenarios to reduce the risk on lost of plant nutrients b application of organic matter	132
4.51	Scenario B: scenarios to reduce the risk on lost of plant nutrients b liming and addition of soil organic matter	133
4.52	Scenario C: scenarios to reduce the risk on lost of plant nutrients b improving of soil permeability, liming and application of organic matter	135

**List of Figures (continue)**

<b>Figure</b>		<b>Page</b>
4.53	Scenario A: scenarios to reduce the risk on nutrient imbalance by liming	136
4.54	Scenario B: scenarios to reduce the risk on nutrient imbalance by omission of P and K fertilizer application	136
4.55	Scenario C: scenarios to reduce the risk on nutrient imbalance by liming and omission of P and K fertilizer application	137



ลิขสิทธิ์มหาวิทยาลัยเชียงใหม่  
Copyright© by Chiang Mai University  
All rights reserved