



**UNIVERSITI PUTRA MALAYSIA**

**DYNAMIC APPROACH IN PREDICTING LAND PRODUCTION  
POTENTIAL FOR RUBBER: CASE STUDY IN EAST AND  
NORTHEAST THAILAND**

**(VOLUME I: TEXT)**

**SOMJATE PRATUMMINTRA**

**FK 2000 5**

**DYNAMIC APPROACH IN PREDICTING LAND PRODUCTION POTENTIAL  
FOR RUBBER: CASE STUDY IN EAST AND NORTHEAST THAILAND**

**(VOLUME I : TEXT)**

by

**SOMJATE PRATUMMINTRA**

**Thesis Submitted in the Fulfilment of the Requirements for the  
Degree of Doctor of Philosophy in the Faculty of Agriculture  
Universiti Putra Malaysia**

**June 2000**



**Dedicated  
to  
My Parents**

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in  
fulfilment of the requirements for the degree of Doctor of Philosophy

**DYNAMIC APPROACH IN PREDICTING  
LAND PRODUCTION POTENTIAL FOR RUBBER:  
CASE STUDY IN EAST AND NORTHEAST THAILAND**

By

**SOMJATE PRATUMMINTRA**

June 2000

**Chairman : Prof. Dr. J. Shamshuddin**  
**Faculty : Agriculture, Universiti Putra Malaysia**  
**Co-chairman : Prof. Dr. E Van Ranst**  
**Faculty : Science, Ghent University**

Due to environmental limitations in Thailand, rubber tree has been introduced to non-traditional areas, which have poor conditions for tree growth. Land evaluation (LE) techniques are required to solve the problems in locating land suitable for rubber. However, these are limited by some missing parameters. This study aimed to develop a crop model to predict maximum potential rubber yield, and to quantify parameters for water balance equation which has not been done in Thailand before. Twenty three soil profiles in different climatic conditions in the eastern Thailand were chosen to establish a reliable production potential model. This model was then applied to predict the land suitable for rubber production in the Northeast Thailand.

The FAO crop model, termed as Radiation-thermal Production Potential (RPP) was used to estimate the potential yield from climatic data. It was found that the estimated yield was poorly correlated with the actual rubber yield. Water balance equation was then introduced to quantify soil physical parameters to be incorporated into the model. The results indicated that: (1) crop evapotranspiration in the East Thailand averaged around 3.4 mm day<sup>-1</sup> for mature rubber (>10 years old) and 4.5 mm day<sup>-1</sup> for immature rubber; (2) the easily available fraction of soil water (p) was 0.75, and was not influenced by soil texture; and (3) crop coefficient value (Kc) changed throughout the year. The Kc changes from 0.48 to 1.08 depending upon the season and maturity of the tree. The Kc values and percentage of the available water storage were related to the leaf fall period and were used to correct the KLAI factor in the crop model. The leaf fall season is considered as the month following the month when the available water storage becomes less than 25% when the KLAI was 0.6183 (0.7 of the maximum value). During the leaf fall period, the KLAI was 0.4415 (0.5 of the maximum KLAI value). This method of calculating production potential is called Water Limited Production (WPP). It was found that the yield estimated by the WPP was highly correlated with the actual rubber yield (R=0.74-0.93). The loss of tapping days was calculated and this was applied to validate the WPP model. This improved model is called as Maximum Production Potential (MPP). The yield estimated by the MPP was also highly correlated with the actual yield (R=0.81-0.94). Upon application of this model in Northeast Thailand, the dry season was found to be longer than before the model was applied.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia  
sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

**DYNAMIC APPROACH IN PREDICTING  
LAND PRODUCTION POTENTIAL FOR RUBBER:  
CASE STUDY IN EAST AND NORTHEAST THAILAND**

**By**

**SOMJATE PRATUMMINTRA**

**Jun 2000**

**Pengerusi : Prof. Dr. J. Shamshuddin**

**Fakulti : Pertanian, UPM**

**Pengerusi Besama : Prof. Dr. E Van Ranst**

**Fakulti : Sains, Ghent Universiti**

Dihadkan oleh masalah alam sekitar, getah ditanam di kawasan bukan tradisi di Thailand. Keadaan dikawasan itu tidak baik untuk tumbesaran getah. Teknik penilaian tanah telah digunakan untuk menyelesaikan masalah tersebut dan mengesan kawasan yang sesuai untuk getah. Walau bagaimanapun, pengendaliannya telah dihalangi oleh ketiadaan beberapa data. Kajian ini bertujuan menyediakan satu model tanaman untuk meramal potensi pengeluaran getah maksimum disamping mengkuantiti parameter untuk persamaan keseimbangan air. Kajian seperti ini belum pernah dijalankan di Thailand sebelum ini. Sebanyak 23 profil tanah di wilayah iklim berbeza di timur Thailand telah dipilih untuk

menyediakan satu model pengeluaran yang tepat. Model ini kemudiannya digunakan untuk meramal kesesuaian tanah untuk pengeluaran getah di timur laut Thailand pula.

Model tanaman FAO yang bernama "Radiation Production Potential (RPP)" telah digunakan untuk mengira potensi hasil daripada data iklim. Walau bagaimanapun, hasil yang dikira melalui RPP berbeza dengan hasil getah sebenar.

Kemudian persamaan keseimbangan air telah diperkenalkan kedalam model untuk mengkuantiti parameter fizik tanah. Keputusan menunjukkan: (1) evapotranspirasi tanaman ( $ET_c$ ) untuk getah matang (>10 tahun) dan belum matang di wilayah timur Thailand masing-masing bernilai 3.4 dan 4.5 mm hari<sup>-1</sup>; (2) bahagian air tersedia ( $p$ ) untuk getah ialah 0.75 dan ianya tidak dikawal oleh tekstur tanah; dan (3) nilai koefisien tanaman ( $K_c$ ) berubah mengikut musim. Nilai  $K_c$  bagi musim luruh ( $M_{ac}$ ) ialah 0.48, manakala bagi musim pembentukan daun (April ke Jun) ialah 0.58-0.98.  $K_c$  semasa matang ialah 1.08 dan  $K_c$  di peringkat akhir pengeluaran (November) ialah 0.83. Nilai  $K_c$  dan % storan air tersedia (AWS) berkait rapat dengan waktu luruh dan ianya digunakan untuk memperbaiki faktor KLAI model tanaman ini. Nilai KLAI bagi LAI maksimum (3.8) ialah 0.8333. Musim luruh berlaku selepas storan air tersedia bernilai <25%. Di dalam musim luruh, KLAI bernilai 0.4415 (50% daripada nilai KLAI maximum). Sebelum itu, nilainya ialah 0.6183. Kaedah yang mengira potensi pengeluaran ini disebut sebagai "Water

Limited Production (WPP)". Hasil getah yang dikira melalui kaedah ini berkorelasi tinggi dengan hasil sebenar ( $R = 0.74-0.93$ ).

Kehilangan hari menoreh telah dikira daripada indeks harian dan ini telah digunakan untuk mengesahkan model WPP. Model yang diperbaiki ini disebut sebagai "Maximum Production Potential (MPP)". Anggaran hasil oleh model MPP juga berkorelasi tinggi dengan hasil getah sebenar ( $R = 0.81-0.94$ ).

Akhiraya, model ini digunakan keatas tanah getah di wilayah timur laut Thailand.  $p$  bernilai 0.75 dan  $K_c$  yang sedia ada telah digunakan untuk penentuan keseimbangan air. Didapati musim kemarau bertambah lama. Dengan menggunakan pengkalan data yang dikeluarkan oleh model tanaman ini, satu peta MPP telah disediakan untuk digunakan oleh petani di timur laut Thailand.



## ACKNOWLEDGEMENTS

I wish to express my sincere thanks and gratitude to all individuals and institutions that have contributed to make this study successful and the completion of this thesis possible.

I would like to thank very much my Promoter, Prof. Dr. E. Van Ranst, (Laboratory of Soil Science, Department of Geology and Soil Science, Faculty of Science, Ghent University) and also my Co-Promoter Prof. Dr. Ir. H. Verplancke (Laboratory of Soil Physics, Department of Soil Management and Soil Care, Faculty of Agricultural and Applied Biological Science, Ghent University). Their intelligent awareness, continuous guidance, encouragement and constructive ideas have been a constant stimulus to continue this research.

I am deeply indebted to Prof. G. Stoops, the director of International Training Center for Post-graduate Soil Scientist (Ghent University) for accepting me as a Ph.D. student in the frame of a twining program between Ghent University and Universiti Putra Malaysia and his continuous support from the beginning of this study in 1996.

I wish to express my gratitude and thanks to Prof. Dr. J. Shamshuddin, (Faculty of Agriculture, Universiti Putra Malaysia), the chairman of the Advisory Committee at UPM and my Co-promoter, for his advice, assistance and hospitality during my stay at Universiti Putra Malaysia.

The other advisory committee members, Assoc. Prof. Dr. Siti Zauya Darus (Department of Land Management, Faculty of Agriculture, UPM), and Dr. Yew Foong Kheong (Malaysian Rubber Board) are gratefully acknowledged for their constructive remarks and detailed reviews of this dissertation.

I am deeply indebted to the Rubber Research Institute, Department of Agriculture (DOA), Ministry of Agriculture and Cooperation Thailand for granting me leave to do my Ph.D. research and their financial support for the field studies.

I wish to express my gratitude and thanks to Dr. Sanit Samosorn, former Deputy Director of DOA, and former Director of Rubber Research Institute, Mr. Samer Somnak, former Director of Chachoengsao Rubber Research Centre (CRRC), for their advice and financial support this research and during the field work in Thailand.

I also express my sincere gratitude to the Department of Environmental Quality Extension, Ministry of Science and Technology, Thailand that supported me the digital base map.

I am deeply also specially indebted to all of my colleague, Mr. Chumpon Wiwatanawanitch, Mr. Nipon Thupmongkol, Mr. Yuttakorn Thammasiri, Miss. Porntip Detchudom, Mrs. Yuwadee Mitsiri, Mrs. Charuk Tipporm, Miss

Khanya Tassana and all of the staff in Tungphen Rubber Research Station and Chachoengsao Rubber Research Center, for collecting all the field data with diligence and endurance.

I am also grateful for the financial support from Flemish Inter-university Council (VI.I.R) and the Belgian Administration for Development Co-operation (A.B.O.S.).

I take the opportunity also to express my sincere thanks and gratitude to all of my friends in Belgium, Malaysia and in Thailand who supported in one way or another to complete of the thesis during my stay in Ghent, Belgium, Malaysia and during my field works study in Thailand.

I wish to express my sincere gratitude to Dr. G. Baert (Laboratory of Soil Science, Ghent University), who supported and guided me in the GIS system. My appreciation also extended to Mr. Wim Cornelis (Laboratory of Soil Physics, Ghent University), who help me in the mathematical models and Mr. Jan Restiaen (Laboratory of Soil Physics, Ghent University), who helped me to re-analyses pF curve data for all profile. I wish to thank you all staff members and technical assistance of International Training Center for Post-graduate Soil Scientist (Ghent University).

I would also like to express my sincere gratitude to all the staff members and technical assistance of Department of Land Management, Faculty of Agriculture, Universiti Putra Malaysia.

My appreciations are also extended to the rubber plantation holders for fieldwork facilities.

I am most grateful to my father, my brothers and my sisters, for supporting me and my family during my stay abroad.

Lastly but not least, I am most grateful to my wife; Porntip Pratummintra and my daughter, Kittiya Pratummintra, who have waited with patience in Thailand for the completion of my study and helped me in my literature search. This thesis dedicated to them.

**TABLE OF CONTENTS**  
**(Volume I : Text)**

	<b>Page</b>
<b>DEDICATION</b> .....	ii
<b>ABSTRACT</b> .....	iii
<b>ABSTAK</b> .....	vi
<b>ACKNOWLEDGEMENTS</b> .....	ix
<b>APPROVAL SHEETS</b> .....	xiii
<b>DECLARATION FORM</b> .....	xv
<b>LIST OF TABLES</b> .....	xxi
<b>LIST OF FIGURES</b> .....	xxviii
<b>LIST OF ABBRIVIATIONS/EQUATIONS</b> .....	xxix

**CHAPTER**

<b>I</b>	INTRODUCTION .....	1.1
	Problem Identification .....	1.2
	National Level.....	1.2
	Regional Level.....	1.4
	Local Level.....	1.4
	Farmer Level.....	1.5
	Objective of the Study .....	1.5
<b>II</b>	DESCRIPTION OF THE STUDY AREA .....	
	Location .....	2.1
	Geomorphology .....	2.3
	Landform Development in East Thailand.....	2.5
	Landform Development in Northeast Thailand.....	2.6
	Geology .....	2.8
	Geology of the Eastern Region (Southeast Coast).....	2.8
	Geology of the Northeastern Region.....	2.12
	Climate .....	2.18
	Soils .....	2.20
	Soils of the Eastern Region.....	2.20
	General Soil Features of the Northeastern Region.....	2.28
	Land Use .....	2.37
<b>III</b>	LAND REQUIREMENTS AND LAND UTILIZATION TYPE	
	History of Rubber .....	3.1
	Distribution of the <i>Hevea</i> species.....	3.2
	Distribution of Cultivated Rubber.....	3.6
	Land Use Requirement .....	3.9
	Climatic Requirements .....	3.9
	Soil and Landscape Requirements .....	3.23

<b>III</b>	<b>LAND REQUIREMENTS AND LAND UTILIZATION TYPE</b>	
	Land Utilization Type .....	3.48
	Rubber Cultivation in East and Northeast Thailand.....	3.49
	Rubber Clone Recommendation .....	3.62
	Technology Applied .....	3.64
<b>IV</b>	<b>PHYSICAL LAND RESOURCE INVENTORY OF THE STUDY AREAS</b>	
	Methodology .....	4.1
	Data Collection .....	4.1
	Sampling Design and Routine Analysis .....	4.1
	Digital Mapping .....	4.6
	Climatic Database .....	4.6
	Seasonal Weather.....	4.7
	Rainfall.....	4.9
	Temperature.....	4.10
	Relative Humidity.....	4.10
	Reference Evaporation.....	4.11
	Wind Speed.....	4.11
	Insolation.....	4.11
	Landscape and Soil Database .....	4.13
	Profile Description of the Studied Soils .....	4.13
	Physico-chemical Analytical Data .....	4.13
	Monitoring Soil Water Content .....	4.14
	Soil Series .....	4.14
<b>V</b>	<b>MODEL FOR PRODUCTION POTENTIAL ASSESSMENTS</b>	
	Concepts .....	5.1
	FAO Crop Model for Potential Yield .....	5.5
	Materials .....	5.5
	Crop Growth Model.....	5.7
	Crop Model for Rubber Potential Yield .....	5.17
	Correlation between Potential and Actual Yield .....	5.23
	Results and Discussion .....	
	Monthly Actual Yield .....	5.24
	The Calculated Radiation Potential Production .....	5.28
	The Digital Map of the RPP in East Provinces .....	5.49
<b>VI</b>	<b>ESTIMATED CROP YIELD RESPONSE TO WATER DEFICIT</b>	
	Concepts .....	6.1
	Yield Response Factor .....	6.1
	Water Requirement for Maximum Yield .....	6.2

<b>VI</b>	<b>ESTIMATED CROP YIELD RESPONSE TO WATER DEFICIT</b>	
	Parameter of the Water Balance Equation .....	6.3
	Concepts .....	6.3
	Materials .....	6.5
	Methods .....	6.7
	Results and Discussion .....	6.28
	Water Balance.....	6.28
	Easily Available Water.....	6.38
	Effect of Water Deficit on Leaf Fall and Yield.....	6.48
<b>VII</b>	<b>RELIABILITY AND VALIDATION OF MODELS</b>	
	Yield Loss Due to Tapping Day .....	7.1
	Correlation Analysis.....	7.2
	Relative Rubber Yield .....	7.2
	Results and Discussion .....	7.3
	The Maximum Production Potential .....	7.3
	Correlation Analysis .....	7.3
	Relative Rubber Yield .....	7.12
	Applying the Model to Predict MPP in Northeast Thailand...	7.24
<b>VIII</b>	<b>CONCLUSIONS AND RECOMMENDATIONS</b>	
	General Results.....	8.1
	Crop Production Potential Models .....	8.2
	Parameters of the Water Balance .....	8.3
	Recommendations .....	8.5
	<b>REFERENCES .....</b>	<b>R.1</b>
	<b>BIODATA.....</b>	<b>Bi.1</b>

## TABLE OF CONTENTS

### Volume II : Database and Calculation Results of Models

APPENDIX		Page
<b>A</b>	Profile Description, Soil Analytical Data and Soil Classification for the Studied Soil Pedons.....	A.2
<b>B</b>	The Analytical data for pF Curves and Monthly Soil Moisture Content Determination.....	B.2
<b>C</b>	Climatic Database Inventory for the Study.....	C.1
	- Monthly Climatic Data in East and Northeast Thailand...	C.2
	- Daily Climatic Data in the Studied Sites.....	C.16
<b>D</b>	Soil Database Inventory for the Study	
	- The Analytical Database for the Typical Soil Profiles.....	D.2
	- Recalculation for Soil Characteristics and Indexes.....	D.56
<b>E</b>	Example Fitting pF Curves with Van Genuchten Model in Soil Profile C9601.....	E.2
<b>F</b>	Example of the Calculation Procedures in Soil Profile C9601.....	F.1
	- Monthly Soil Water Storage.....	F.2
	- Monthly Available Soil Water Storage.....	F.2
	- Hydraulic Head Profiles and Determination of Plain of Zero Flux.....	F.4
<b>G</b>	Monthly Hydraulic Head Profiles.....	G.2
<b>H</b>	The Calculation Results of Flux Determination.....	H.2
<b>I</b>	The Calculation Results of Crop Evapotranspirations (ET <sub>c</sub> ).....	I.2





<b>APPENDIX</b>		<b>Page</b>
<b>J</b>	The Calculation Results of $K_c$ and $K_a$ .....	J.2
<b>K</b>	Example of $E_{To}$ and Water Balance Calculation in Northeast Thailand.....	K.2
<b>L</b>	The Calculation of Maximum Production Potential in Northeast Thailand.....	L.2



## LIST OF TABLES

Table No.		Page
2.1	Geology of the Eastern Region.....	2.10
2.2	Classification of the Korat Group.....	2.14
2.3	Geology of the Northeast Plateau.....	2.15
2.4	The Average Annual Climatic Data in the Study Area.....	2.19
2.5	Areas of Principal Soils Orders in the Eastern Study Area.	2.25
2.6	Areas of Principal Soil Great Groups in the Study Area.....	2.26
2.7	Areas of Principal Soil Great Groups in Northeast Region	2.31
2.8	Areas of Land Use in the Eastern Region.....	2.38
2.9	Areas of Land Use in Northeast Region.....	2.39
3.1	Climatic Characteristics of Some Major Rubber Growing Regions in the World.....	3.4
3.2	Taxa of <i>Hevea</i> Arranged in Approximate Descending Order of the Extent of their Natural Ranges in the Wild.....	3.5
3.3	Rubber Planting Area in Thailand, in 1990.....	3.8
3.4	Infiltration Rates of Textural Soil Classes in West Malaysia Soils.....	3.30



<b>Table No.</b>		<b>Page</b>
3.5	Water Holding Capacity in some Soils of Malaysia.....	3.30
3.6	Nutrient Contents of Rubber Growing Soils (0-30 cm).....	3.38
3.7	Summary of the Climatic Requirements for Rubber.....	3.43
3.8	Summary of the Landscape and Soil Requirements for Rubber.....	3.44
3.9	Determination Key for the Climatic Suitability Classification of Rubber Planting in Thailand.....	3.46
3.10	Determination Key for the Landscape and Soil Suitability Classification of Rubber Planting in Thailand.....	3.47
3.11	Land Utilization Types for Rubber Cultivation in the Different Holdings.....	3.61
4.1	Type and Source of Data Inventory in this Study.....	4.2
4.2	Climatic Data and Reference Evapotranspiration in the Study Area (average data 1989-1998).....	4.12
4.3	Physico-chemical Properties and Soil Index Calculation in The Study Area.....	4.15
4.4	The Area of Typical Soil Series in The Eastern Provinces.	4.16

Table No.		Page
5.1	The Photosynthetically Active Radiation on Very Clear Days (Ac) and the Daily Gross Photosynthesis Rate of Crop Canopies on very Clear (bc) and Overcast (bo) Days.....	5.18
5.2	Daily Average Month by Month of Astronomically Possible Sunshine Duration Hours, for the Northern Latitude.....	5.19
5.3	Maximum Assimilation Rate (Pm), Photosynthetic Quantum Yield (PQY) and Dark Respiration (DRR) of some Rubber Clones.....	5.20
5.4	Canopy Characteristics and Dry Matter Production in Twelve Years Old Hevea sp. under Two Planting Density.	5.22
5.5	Effect of Different Systems of Exploitation on Biomass Production, Harvest Index and Yield in <i>Hevea brasiliensis</i> .....	5.22
5.6	The Cuplump of RRIM 600 rubber Clone in the Study Area.....	5.25
5.7	The Corrected Cuplump with 15% Moisture Content of RRIM 600 rubber Clone in the Studied Area.....	5.26
5.8	The Calculated Actual Yield of RRIM 600 Rubber Clone...	5.27
5.9	The Correlation and Statistical Analysis of Actual Yield and Soil Index.....	5.28
5.10	The Calculated Potential Yield for RRIM 600 Rubber Clone in Profile C 9603.....	5.29

<b>Table No.</b>		<b>Page</b>
5.11	The Calculated Potential Yield for RRIM 600 Rubber Clone in Profile C 9604.....	5.30
5.12	The Calculated Potential Yield for RRIM 600 Rubber Clone in Profile C 9605.....	5.31
5.13	The Calculated Potential Yield for RRIM 600 Rubber Clone in Profile C 9606.....	5.32
5.14	The Calculated Potential Yield for RRIM 600 Rubber Clone in Profile C 9607.....	5.33
5.15	The Calculated Potential Yield for RRIM 600 Rubber Clone in Profile C 9608.....	5.34
5.16	The Calculated Potential Yield for RRIM 600 Rubber Clone in Profile CH 9601.....	5.35
5.17	The Calculated Potential Yield for RRIM 600 Rubber Clone in Profile CH 9602.....	5.36
5.18	The Calculated Potential Yield for RRIM 600 Rubber Clone in Profile CO 9601.....	5.37
5.19	The Calculated Potential Yield for RRIM 600 Rubber Clone in Profile CO 9602.....	5.38
5.20	The Calculated Potential Yield for RRIM 600 Rubber Clone in Profile CO 9604.....	5.39
5.21	The Calculated Potential Yield for RRIM 600 Rubber Clone in Profile R 9602.....	5.40



<b>Table No.</b>		<b>Page</b>
5.22	The Calculated Potential Yield for RRIM 600 Rubber Clone in Profile R 9603.....	5.41
5.23	The Calculated Potential Yield for RRIM 600 Rubber Clone in Profile R 9604.....	5.42
5.24	The Calculated Potential Yield for RRIM 600 Rubber Clone in Profile R 9605.....	5.43
5.25	The Calculated Potential Yield for RRIM 600 Rubber Clone in Profile R 9606.....	5.44
5.26	The Calculated Potential Yield for RRIM 600 Rubber Clone in Profile R 9607.....	5.45
5.27	The Calculated Potential Yield for RRIM 600 Rubber Clone in Profile T 9601.....	5.46
5.28	The Correlation of Actual and Potential Yield for RRIM 600 Clone in East Thailand.....	5.47
6.1	Pan Coefficients for Class A Pan .....	6.17
6.2	Crop Group According to Soil Water Depletion.....	6.23
6.3	Soil Water Depletion Fraction for Crop Groups and ETm..	6.23
6.4	Total Water Storage at Field Capacity, Permanent Wilting Point .....	6.29
6.5	The Available Water Storage in each Profile.....	6.30