CHAPTER 1: INTRODUCTION

1.1: Aims

The aim of this project is to model the effects of deforestation in the Southeast Asia region on climate and the atmospheric circulation. Previous modelling studies of the large-scale impact of deforestation have considered land-cover change over Southeast Asia as part of a multi-region, i.e. Amazonia, Africa and Southeast Asia, deforestation scenario [e.g. Zhang *et al*. (1996a,b)] and the results have been somewhat equivocal. These studies determine how strong the contribution of deforestation in Southeast Asia is to the overall impact. It is also not clear whether the change over Southeast Asia is dominantly contributed by local deforestation or deforestation in other regions. This project will define the potential effect of deforestation in Southeast Asia on local climates and the larger-scale atmospheric circulation based on a single region deforestation experiment.

Given the geographically-specific nature of the issue to be addressed, there is no doubt that the best approach is to use a three-dimensional general circulation model (GCM). A GCM developed by the United Kingdom Meteorological Office called the Unified Model is used in this study. Based on an ensemble approach, effects on the January and July atmosphere will be assessed and compared to previous experimental results. The two months, January and July, are taken to represent the winter monsoon and the summer monsoon, respectively. The study was conducted on a Dec Alpha (AlphaStation 250 4/266 System) workstation to explore the capability of this form of technology with the portable version of the Unified Model (version number 4.0).

1.2: Overview of Experimental Design

Since Charney proposed his theory on the dynamics of deserts and droughts in the Sahel (Charney, 1975), there has been significant scientific interest in the interaction between vegetation and climate. The essence of this interaction is that the atmospheric circulation and, therefore, rainfall may be sensitive to changes in vegetation cover near the land surface. Recent

field observations from the Amazon region have confirmed that conversion of land cover from rain forests to ranch land increases surface albedo and reduces evaporation rates (Wright *et al*., 1992; Bastable *et al*., 1993; Wright *et* al., 1996). There is no doubt that these local impacts modify the energy balance at the land-atmosphere boundary and potentially result in changing the regional climate change as well as the larger-scale atmospheric circulation.

The atmospheric circulation over Southeast Asia region is largely controlled by the two Asian monsoons, called the winter and summer monsoons. The two monsoon seasons present a useful framework for any analysis of the impacts of tropical deforestation in Southeast Asia. The changes in regional climate in this region, therefore, can be described in terms of the monsoon circulation changes.

A preliminary assessment on the sensitivity of the regional-scale circulation over Southeast Asia, and the nearby areas to tropical deforestation is based on a re-analysis of results from a previous GCM experiment using the NCAR Community Climate Model (CCM), incorporating the Biosphere-Atmosphere Transfer Scheme (BATS1e) (known as CCM1-Oz). The model performance is first evaluated by comparing between the control climate simulation with the mean observed climatology. The experiment consists of a 25-year “control” integration and an 11-year “perturbation” integration. In the "multi-region" perturbation experiment, tropical forests for the three regions, the Amazon Basin, tropical Africa and Southeast Asia, were all together converted into grassland. The regional-scale circulation impacts following deforestation are re-analysed for this study with reference to the change in the vertical velocity, divergence and vorticity fields for the two monsoon seasons. This analysis sets the scene for the single-region modelling experiment which forms the core of this study by (a) identifying key characteristics of the effect of deforestation on climate and the atmospheric circulation and (b) establishing specific hypotheses.

In this study, an ensemble of short-range model simulations made under different large-scale flow conditions is used to cater for bias errors. From the ensemble simulations, statistics define a control and perturbed climatology without the need for integrating the GCM over a very long period. To obtain statistically reliable conclusions, ten cases are used, each serving as a member of the ensemble for both the control and perturbation. Effects on the January and July

atmosphere are, therefore, assessed through ten two-month integrations with different initial conditions. Following ten control simulations which define the unperturbed climatology, a series of ten perturbation experiments is undertaken in which the land cover of the region is changed. These latter integrations will derive a perturbed climate of the region.

1.3: Thesis Objectives and Outline

This thesis has two main objectives:

- first, to review and evaluate simulations results of deforestation over Southeast Asia region based on the previous GCM experiments and develop hypotheses for this study; and
- second, to use the UK Meteorological Office's Unified Model in experiments regarding the impact of Southeast Asian deforestation on local climates and the larger-scale atmospheric circulation.

A secondary objective of this study was to explore the use of a Dec Alpha workstation in experiments using a GCM as more powerful computing platforms are not currently available for such studies in the author's institution. The research framework and thesis outline is schematically summarised in Figure 1.1. In the following paragraphs, an outline of main objectives of each chapter is given.

Chapter Two

The objectives of this chapter are to review the scale of the problem of tropical deforestation and, therefore, provide an overview regarding the present status and outlook for tropical deforestation. The tropical forest extent, the rate of conversion of these forests and the causes and processes of tropical deforestation are reviewed, providing a basis for the development of a deforestation scenario for input to the modelling study.

Chapter Three

By introducing relations between deforestation and climatic change, with descriptions of the importance of the land surface character in the climate system, the main objective in this chapter is to review the theory of the effect of deforestation on climate. Modelling the effect of deforestation is dependent on the parameterization of land surface processes. Shortcomings in

earlier modelling approaches and the potential for new strategies are reviewed.

Chapter Four

A survey of previous GCM studies of the effects of tropical deforestation is undertaken. This historical review is undertaken to compare the different features, perturbations, major developments and results of the different experiments. Hence, the objectives are to compare the impacts simulated in response to tropical deforestation in the Amazon Basin, Southeast Asia and tropical Africa, and to identify the overall character of changes.

Chapter Five

In view of the dearth of firm information related to the magnitude and direction of changes depicted in the global GCM, a special analysis is performed to specifically ascertain the Southeast Asia regional climate sensitivity to tropical deforestation. This assessment is based on a re-analysis of a subset of results from a previous global GCM deforestation experiment. The main objectives are to identify the changes in the character of the summer and winter monsoons following deforestation and these findings are used to guide the design of the diagnostic analysis of this study's model results and to develop hypotheses to be tested.

Chapter Six

This chapter introduces the theory of climate simulations using a general circulation model through an overview of the history, basis of its design and numerical formulations and common application of the parent model, the Unified Model. Though the model is used as a turnkey system in this study, understandings of the model's formulation is essential in order to design set-up and run the experiments in this study.

Chapter Seven

Descriptions of the land surface scheme of the Unified Model are given in this chapter. The objectives are to identify mandatory requirements for the model experiments, and to select a particular land surface formulation, and to identify the parameters for perturbation.

Chapter Eight

This chapter describes the experimental design developed to define the effect of Southeast Asian deforestation on local climates and the larger-scale atmospheric circulation. The simulation

procedure and a description of the control and perturbation are presented. The method of diagnostic analysis is also summarised in this chapter.

Chapter Nine

Basic results from the sensitivity study using the ensemble GCM simulations of Southeast Asian deforestation are presented and discussed in this chapter. An assessment is presented of the ensemble control simulation comparing selected simulated climatological variables with observed data. The perturbed ensemble results are presented to define the sensitivity of the local climate to the removal of the tropical forest in the region. At the grid-point scale, local climatic changes are examined with the aid of the standard Student's *t*-test. Causal mechanisms are proposed with emphasis given to changes in the radiative energy budget and hydrological processes.

Chapter Ten

The main emphasis in this chapter is on the influence of Southeast Asian deforestation on the large-scale atmospheric circulation system. The sensitivity of the large-scale circulation and the potential for Southeast Asian deforestation to generate influences outside the region are explored. A theory is proposed regarding the mechanism relating Southeast Asian deforestation and the simulated changes in the large-scale atmospheric circulation. In terms of the monsoon circulation, the results of this experiment based on single region deforestation and previous results based on multi-region deforestation are compared.

Chapter Eleven

In conclusion, major findings of the research are defined. An assessment is made of the strengths and weakness of the approach used in this study. Recommendations for future research are proposed which relate to both experimental design and methods of diagnostic analysis. A brief note regarding implications for policy is also given.