CHAPTER I

INTRODUCTION

In recent years, there has been concern all over the world that the quantity of mineral fertilizers used in agriculture is having adverse effects on the environment. Attention has been drawn to the fact that when nutrients are applied to crops they are not all taken up by the plants immediately or entirely. Moreover, some farmers might be applying inappropriate quantities of fertilizers. Different amounts of fertilizer input are required in order to maintain a given level of soil fertility depending on the type of nutrient, existing soil conditions and climate. The nutrients applied may leak over time to surrounding environment where they can cause pollution. Such losses may occur when nutrients: (1) wash out from land as a result of runoff and erosion caused by heavy rainfall; (2) leach through the soil, beyond root zone, ultimately reaching groundwater; or (3) emit to the atmosphere as volatile gases. Of the nutrients, phosphorus is of most concern in terms of lake eutrophication. Although the loss of water-soluble phosphorus through leaching is low, the addition of excessive amounts of phosphorus to the soil may lead a "saturated" condition of phosphorus and losses may increase. It is important that the phosphorus status of soils is not increased beyond a level which is compatible with both good agricultural practice and eutrophication prevention (EFMA, 1997). Also, almost all phosphate fertilizers contain traces of cadmium, with the exception of phosphate slag which is a by-product of steel production and in decreasing supply. Rock phosphate, raw material of phosphate fertilizer, contain trace amount of cadmium. The cadmium content varies considerably from source to source, revealing as much as a hundred-fold difference when extremes are compared. Fertilizers are not the only path by which cadmium enters the soil. The aerial deposition of dust from various industrial processes, as well as manuring and the spreading of sewage sludge also bring cadmium to the soil (EFMA, 1997).

Songkhla Lake is located in southern Thailand. Community surrounding the lake has long been agricultural-based. Three quarters of the catchment area (5,660 km^2) is utilized for cultivation, mainly para-plantation (60%) and rice paddy (30%). Residential area is around 3% (224 km^2) of the catchment area, and very small area is used for industry (OEPP, 2005). High application rate of fertilizers in the area is a normal practice in order to secure favorable crop yields. Because Songkhla Lake is situated in the humid tropical zone of high rainfall and runoff and also of high population, phosphorus may be released into surface water via hydrological events and/or human activities and may finally drain into the lake. Another concern is the potential contamination with cadmium because it is commonly associated with phosphate fertilizers as aforementioned. Most raw materials for fertilizers in Thailand, including rock phosphate, are imported from foreign sources, with variable cadmium contaminations, such as Korea, Germany, Romania and Norway (Agriculture Economy Office, 2002). According to Sirinawin *et al.,* (1998) average dissolved cadmium found in lake water was 0.30±0.95 ppb, ranging from 0.05 to 7.32 ppb in wet season and 0.05±0.06 ppb, ranging from ND to 0.32 ppb, in dry season. An overuse of phosphate fertilizers can, thus, easily cause a high loading of plant nutrients and cadmium to the lake water. High chlorophyll *a* in lake water had been observed for more than two decades. In the last few years, macrophyte in dry season have been observed in the middle lake. These incidents were due to the enrichment of nutrients in the lake (Sompongchaiyakul, 2005). Phosphorus is suspected to be a limiting factor for aquatic plants and cycling within the Songkhla Lake itself. An expansion of agricultural area and/or changing of crop cultivation and fertilizer application rate in the catchment could lead to an increased load of phosphorus and cadmium into the lake.

Cadmium is a highly toxic, bio-accumulative trace metal. If ingested, it can cause kidney disease and prostate cancer. Lake eutrophication and accumulation of cadmium lead to a lethal environmental and health impact. Cadmium concentration in drinking water is limited at 5 ppb (USEPA, 2005), and is 10 ppb in Thailand (PCD, 2005). Cadmium levels as low as 0.5 ppb are known to kill juvenile fish, levels of 3 ppb can kill aquatic insects while adult fish die at levels as low as 5 ppb (Vital

Statistics, 1997). Increasing agricultural activities in the catchments have the potential to increase cadmium accumulation in the lake (Sae-Eong *et al.*,2002).

Therefore, there is a need to investigate the potential loading changes due to changes in agricultural practices in the watershed. Modeling is the best way to do this. Models have the capability to simulate various scenarios and to answer what-if questions. In this study, A spatially distributed cell-based model, AnnAGNPS (Bosch *et al.*, 1998; Cronshey and Theurer, 1998; Geter and Theurer, 1998; Theurer and Cronshey, 1998; Johnson *et al.*, 2000) and TREX (Velleux *et al.*, 2006) are proposed for investigating non-point source transport of phosphorus and cadmium respectively via surface runoff from the catchments to the lake. Reliable results from the model can be expected only if good quality input data are used. Therefore, good estimates of phosphorus and cadmium at each cell available for transport must first be obtained. A substance accounting tool, Substance Flux Analysis (Baccini and Brunner, 1991; Guinee *et al.*, 1998; Kleijn *et al.*, 2000; Bouman *et al.*, 2000 and Lassen and Hansen, 2000), will be used to obtain better estimates of phosphorus and cadmium available on the land for transport by surface runoff. Though the catchments may have other land uses, this study focuses only on agricultural land use and the transport by surface runoff.

1.1 OBJECTIVES

The comprehensive objective of this research is to model the non-point source loading of phosphorus and cadmium to the Songkhla Lake from the surrounding drainage area and to develop a decision support tool for environmental management of Songkhla Lake. (Figure 1-1)

1.2 HYPOTHESES

1. The transport of phosphorus and cadmium to the Songkhla Lake can be estimated with reasonable accuracy using a distributed parameter computer model using the existing database for the Songkhla Lake Basin.
2. There is a significant load of non point source phosphorus and cadmium, contributing to the Songkhla Lake through runoff from surrounding areas.

3. Results generated for practical scenarios using the developed model can be used to support the Songkhla Lake environmental management decision making process.

1.3 APPROACH AND METHODOLOGY

Spatially distributed cell-based models, AnnAGNPS and TREX are proposed for investigating phosphorus and cadmium transport respectively via surface runoff from the catchments to the lake. Reliable results from the model can be expected only if good quality input data are used, specifically, good estimates of phosphorus and cadmium at each cell available for transport. The pollutant loads from the catchments on a cell-by-cell basis are important input to spatially distributed transport models. Therefore the loads need to be estimated as accurately as possible. Therefore, a substance accounting tool, Substance Flux Analysis (SFA), is proposed to obtain better estimates of phosphorus and cadmium available on the land for transport by surface runoff. Scenario cases will be then conducted to identify the impact of changes in agricultural practices in the area that had highest contribution of the contamination of phosphorus and cadmium. The results of the scenarios can be used as a decision and management tools for decision makes to prevent excess non-point source pollution loading to the basin. Geographical Information System (GIS) will be used at all stages of the study such as for developing the database for the non-point source model, for pre-processing of input data, and for post-processing of results. A schematic of the overall study is shown in Figure1-1.

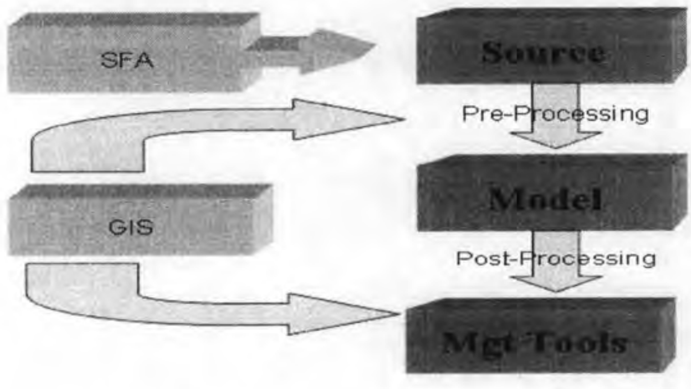

Figure 1-1 A flowchart of the overall study