# Chapter 2

# RESEARCH BACKGROUND AND OBJECTIVES

## 2.1 Background and Direction

> "If politics is the art of the possible, research is surely the art of the soluble. Both are intensely practical-minded affairs." (Peter Medawar (1915-1987) "The Act of Creation" in "New Statesman", 19 June 1964)

Before going into the aim of this research, it seems more appropriate to explain the scope and direction of this research first. In this way, readers may understand more clearly the research aim and rationale behind the approach used in this study.

When this research was first begun, the initial plan was to use the simulated future rainfall intensity output from RCM as input to one or more erosion models, in order to improve upon then-current forecasts of future erosion rates and eventually to develop a method to link RCM results and erosion models.

However, after a number of pilot simulations with models at an early stage, it became apparent that RCM rainfall data could not (and still cannot) be used directly for erosion simulations. In order to use RCM data for the approach initially proposed, the data should be able to provide rainfall intensity information on a required scale (i.e. sub-hourly) with an acceptable level of confidence. RCM data do not hold sufficiently detailed (i.e. temporally and spatially) information that can be used for erosion simulations directly, and were not reliable enough for this type of approach yet—and still they are not (Nearing, 2001; Michael *et al.*, 2005; O'Neal *et al.*, 2005).

Thus, another route was taken to resolve this issue. In order to obtain rainfall data usable for erosion modelling in terms of scale and representable as future rainfall, observed rainfall data were analysed to determine trends of rainfall intensity. Once rainfall intensity trends are determined, probable scenarios of future rainfall intensity changes can then be built by applying the trend onto observed rainfall intensity.

Rather later, more problems were identified with selected erosion models, in that there were aberrant model responses to changes in a certain aspects of rainfall intensity (See Chapter 6). This implied that there were deficiencies in the process understanding on which the models are based. Thus, the original plan had to be put on hold until both, improved erosion models and more reliable RCM rainfall data, become available.

Accordingly, the focus of the research has evolved into the evaluation of the response of erosion models to rainfall intensity changes, and implicitly the process understanding on which the models are based, using arbitrary changes in rainfall intensity. In turn, this will assist in improving the performance of erosion models with respect to changes of rainfall intensity by highlighting where the current problem exists. Consequently, greater knowledge here will, once future changes in rainfall intensity become better known, improve our ability to estimate future rates of erosion.

## 2.2 Objectives and Rationales

The main objective of this research is to investigate:

- possible implications of climate change for future soil erosion with reference to rainfall intensity changes by analysing the response of erosion models to arbitrary rainfall intensity changes, and
- implicitly the process understanding on which the models are based.

To accomplish these aims, the research was carried out in two parts:

- *Rainfall Intensity and Erosion: Model Descriptions and Responses* and
- *Implications for Model-based Studies of Future Climate Change and Soil Erosion*.

In the first part, *Rainfall Intensity and Erosion: Model Descriptions and Responses*, three process-based erosion models, WEPP, EUROSEM and RillGrow, were used to investigate their responses (i.e. runoff and soil loss rates) to various rainfall intensity conditions. The process descriptions of these models were examined in regard to how they make use of rainfall intensity.

The reason for using multiple models is to minimize the probability of uncertainty that may increase when relying on a single model (IPCC, 2001*b*). The design purposes of erosion models varies from model to model, and so do their artefacts (Favis-Mortlock, 1998*a*; Jetten *et al.*, 1999). Thus, it is problematic to use only one model, unless there are some observational data that it can be compared to, as it is not possible to know to what extent the result from the model is unique to that model (Favis-Mortlock, 1998*a*; Jetten *et al.*, 1999).

For the same reason, it was suggested that, in the study of future climate change, one should not rely on a single GCM or RCM. This is also the case for the downscaling (Mearns *et al.*, 2003; Wilby *et al.*, 2004). In such studies, the same principle—more is better than one—is always in practice (Wilby *et al.*, 2004). This principle may equally be applied to the study of soil erosion modelling.

It would have been possible to use only two erosion models. However, this may have led to another problematic situation. For example, if two erosion models show contrasting results, it will be very difficult to decide which one to accept and which one to accept not—although it may still be debatable whether the resulting conclusion is applicable to the reality even when both models agree. A good answer to this dilemma may be found in an old fisherman's saying: "Never go to sea with two chronometers; take one or *three*." Therefore, *three* erosion models were used in this study.

Comparing results from three models, instead of one or two models, may increase our chances to relate modelling results back to the real world. If all three models show similar responses—even though the chances of incurring such result are slim—to rainfall intensity changes, the agreed results among three models may possibly be related to the real world (Araújo and New, 2007). More importantly, however, when any of the models disagree, further investigation should follow to look into the model equations, programming algorithms and codes in order to find out what may have caused such disagreement. By comparing outputs from these models, we could also identify their weaknesses and, in turn, improve them for future researches.

A primary purpose of these erosion models (i.e. WEPP, EUROSEM and RillGrow) is to simulate soil erosion. Even though each model has its unique way of simulating erosion processes, the main design purpose is the same; to simulate the real-world erosion processes. Erosion models are developed in order to:

- Use them as important predictive tools for future or unmonitored landscapes;
- Study how different factors play a role in erosion;
- Understand erosion processes; and in turn,
- Minimise environmental issues caused by soil erosion.

Because of these purposes, *ideally* all erosion models should be based on similar understanding of erosion, and simulate erosion similarly. This general idea was taken into account and it was hypothesised that the models selected for this research produce similar results when a given rainfall intensity was applied to them. Yet, the reality is somewhat different from the ideal, and one may still expect that the models may produce divergent responses (Favis-Mortlock, 1998*a*; Jetten *et al.*, 1999). However, it is important to investigate this diversity of model outputs in order to identify and improve areas where our understanding is limited.

> "The purpose of models is not to fit the data, but to sharpen the questions."
> (Samuel Karlin, Eleventh RA Fisher Memorial Lecture, Royal Society, 20 April 1983)

The above statement by Karlin highlights one of reasons why many models are used in numerical and analytical studies. In most cases, a model is based on knowledge that is limited by what we already know about the process. There can be a range of different understandings of the same processes—soil erosion processes in this case. These understandings are expressed as mathematical equations, and then translated into computing languages, and finally put together as a model with which our understandings of the processes can be tested. This provides us with a complete control over affecting parameters. Generally, it is not possible to gain complete control over affecting factors with field experiments or with laboratory experiments because modifying only one factor without altering other factors is not feasible. Using a model, an individual input parameter may be isolated, adjusted and investigated to find its effects on the overall erosion process, while keeping all the remaining parameters constant. Of course, this still does not guarantee a correct prediction by the model. However, this kind of approach helps to "sharpen the questions". More focused questions from modelling studies may help to fill out, or rather to pinpoint the gap in our understanding of the processes. There have been several studies employing this type of approaches already (Favis-Mortlock and Boardman, 1995; Favis-Mortlock and Guerra, 1999; Pruski and Nearing, 2002*b*; Nearing *et al.*, 2005).

One more reason for using a model can be explained by the duration of experiments. According to Laflen (2003), in the case of erosion-plot experiments, the outcome may be very difficult to interpret unless the experiments were conducted for *a long period of time* because of high variability in the observational data. The result may not be significant unless the record is of sufficient length, treatments are greatly different, and a sufficient number of replicates is employed (Nearing *et al.*, 1999). Laflen (2003) stated "…it needs to be understood that these estimates [which are estimated using short periods of record] can have great error and that longer term records are needed to refine these estimates." He then suggested to design plots and collect the data "in such a way as to be able to use the data in evaluation of models and development of parameters that can be used to extrapolate results to the much wider climatic record than one can experience in a few years".

Hence, using a model can be a good choice of method over observational experiments in some cases like above—and may well be the only method when estimating a long-term effect which cannot be observed. For example, in the study by Favis-Mortlock *et al.* (1997), EPIC (Erosion-Productivity Impact Calculator) was used to reproduce the past erosion processes on a hillslope in South Downs, UK from 7000 BP to the present day, in order to find out the major factors influencing past soil erosion. In a case like this, modelling is clearly the only possible choice. Modelling is also the only choice for the study on impacts of future climate or land-use changes on soil erosion (Favis-Mortlock and Boardman, 1995; Favis-Mortlock and Guerra, 1999; Pruski and Nearing, 2002*b*,*a*; Nearing *et al.*, 2005).

Therefore, the first part of this study, using WEPP, EUROSEM and RillGrow, aims to investigate:

- necessary information for rainfall intensity properties to simulate soil erosion,
- responses of selected models to changes of rainfall intensity properties,
- underlying processes of the models for computing rainfall intensity properties and
- the applicability of the same models in the subsequent research.

In the second part, *Implications for Model-based Studies of Future Climate Change and Soil Erosion*, future rainfall intensity scenarios were used to estimate erosion rates using WEPP, one of the soil erosion models used in this research. WEPP is used in the second part because it is a continuous simulation model, which is capable of simulating long-term erosion taking into account the factors such as the complex overlap of temporally and spatially diverse distributions of rainfall, erodibility, soil conditions, plant cover (Nearing, 2006).

The second part of this thesis aims to:

- suggest the best possible way of investigating impacts of rainfall *intensity* changes on future erosion and
- try to test out the suggested method with intensity-change scenarios constructed previously.

## 2.3 Some Questions To Be Considered

This research intends to address the following questions:

Question 1. What role does rainfall intensity play in the process descriptions which comprise erosion models?

Question 2. Assuming that we use a model to predict erosion rates under the future climate which may have different rainfall intensities from the present, what information do we need to make predictions in terms of both climate and process understanding?

Question 3. Are we in a position to predict soil erosion under the future climate? If not, what must be done?

## 2.4 Expected Outcomes

Once all the research questions listed above have been answered, the following outcomes can be attained:

- Better understanding of the role of rainfall intensity in soil erosion model processes,
- Information requirements of rainfall intensity for soil erosion modelling,
- Probable estimation of future rainfall intensity, and
- Required criteria of rainfall data and erosion models for predicting future soil erosion.