CHAPTER 5. GENERAL DISCUSSION AND FUTURE PERSPECTIVES

Upper course of the Chaguana river, Ecuador

5.1. INTRODUCTION

The research in this thesis was supported under the framework of Project 4 of the VLIR-ESPOL Research Programme. This project was aimed, among others, to develop tools to help in the development of decision support systems for Integrated River Basin Management in Ecuador. A first step in the VLIR-ESPOL project involved the determination of potential environmental impacts produced from pesticide usage in the banana sector, and potential conflicts between productive sectors in the basin.

This thesis, as part of that project, was mainly focused on the evaluation of modelling tools that could help in predicting pesticide concentrations at specific points in the selected basin. The decision of evaluating models instead of developing new models was based on the fact that it usually requires a long time to produce a reliable tool to be applied in the field. Besides, there were two important facts that supported this decision:

1. There was no previous experience in Ecuador regarding modelling agrichemicals at a regional level (basin). Therefore, the logistics for agrichemical modelling issues in Ecuador are not well prepared to develop a new modelling tool without facing considerable obstacles.
2. The research was restricted to 4 years to produce an outcome that could generate interest at the management level of river basins. Thus, awareness was to be produced in Ecuadorian institutions, the private sector and society to join efforts for modelling as a tool for Integrated River Management.

The selected basin can be used as the starting point to perform further research as some basic important data have been collected and processed in the present thesis. The Chaguana river basin can also be used as a pilot basin for the development of an Integrated River Basin Management Programme in Ecuador.

5.2. METHODOLOGY

As said at the beginning of this thesis, the main goal of this research was to develop procedures and to group existing methodologies that could help the Ecuadorian environmental modelling scientist in processing information under poor data conditions, such as the Ecuadorian environment. All data needed for hydro-environmental modelling was structured in such a way that modellers should not spend too much time seeking ways to improve or realize how to get to specific data normally required for the majority of water quality models.

This thesis used ArcView version 3.2 as a GIS platform for data processing. The use of this platform presents advantages and disadvantages. The main advantage is that models can be linked to the platform in order to input data, run the model and/or process output results. The main disadvantage is that ArcView is not as complete a GIS platform as ArcInfo, ERDAS or ArcGis. Despite the GIS platform used, some procedures should sometimes be programmed or done in third-party software such as add-on external graphical user interfaces or object oriented internal databases (Bian *et al.*1996). Although this task is not difficult, an extra effort should be dedicated to accomplish it.

5.3. POOR DATA CONDITIONS

The present research faced several challenges due to the lack of available, updated and reliable data required to perform a modelling assessment of the selected basin. Donigian and Huber (2001) have stated that the required data for basin modelling can be divided in three groups for an easy understanding of the problem: system parameters, transformation parameters and input variables. However, it can also be overwhelming to deal with so many data at the same time. The analysis turns to be more complex when the majority of the data is not easily available or does not exist at all such as the case of the Chaguana river basin.

In this research, it was necessary to develop a complete GIS-based procedure to process all gathered information and obtain the minimum amount of data required to run models for predicting pesticide concentrations in a river basin. Spatial analysis and data aggregation were the main procedures applied in the data processing step. Some Avenue (ArcView Macro Language) scripts were developed or modified to ease the work. In addition, interpolation techniques such as *Kriging* and *Spline* were applied to develop raster maps which later were aggregated to obtain the required data.

Kriging interpolation was used to derive the soil and the topography (DEM) raster maps because it was the most suitable technique to be applied on those cases. Residuals between observed and estimated values were within acceptable ranges (r^2 between 0.7 and 0.85). The DEM was built based on digitized contour lines from scanned information and soil maps were obtained from the interpolation of soil sampling points. Burshtynska and Zayac (2002) have demonstrated that the Kriging method can produce optimal results for DEM construction without giving any further information, but considering extra data, the differential spline method can give a higher accuracy when dealing with soft surfaces. The latter method was not applied in the current research because it requires some extra information that was difficult to obtain (extra elevation points measured in “flat” areas).

The climatic maps (precipitation and temperature) were produced by applying Spline interpolation. This technique has been recommended worldwide to derive climatic spatial data (Hutchinson and Bishof 1983, Hutchinson 1996, Hutchinson and Corbett 1993). In addition, this method has been applied successfully in irregular terrains with high elevation difference such as in the Chaguana river basin. However, it has been more used on a continental scale (Kesteven and Hutchinson 1996)

As mentioned before, the research achieved to create a structure of several procedures by searching several methodologies that can be applied in related projects where data was the main limiting issue. This group of procedures should be considered as a starting point because it only deals with hydrology and agricultural components of a river basin. In an integrated river basin management framework, other components, such as economics and legal issues, should be added to improve the data generation procedure.

5.4. PESTICIDE USAGE IN ECUADOR

In 1999, 6040 tons out of 14000 tons of the imported pesticides were used in the Ecuadorian banana sector. This amount is grouped in 30 different chemical families distributed among 250 trade marks. The application rate is still below other banana countries such as Panama and Costa Rica (UNEP, 2000). However, more research should be done in the near future regarding the following related aspects:

- The current Ecuadorian Environmental Management Law has a gap in the pesticide regulation because it only controls 4 out of the 30 chemical groups used in Ecuador.
- Ecuador does not have sufficient installed capacity to detect and monitor pesticide concentrations in several media (water, soil, sediments and organic tissues).

These two issues can create potential problems for future research, environmental tool development and law application as the Ecuadorian society is not well prepared to face pesticide pollution problems. However, this thesis can serve as a starting point in searching solutions for those issues.

Although pesticides can help to increase the agricultural productivity of the country, it is also important to control their use in a more efficient way. The probability of polluting Ecuadorian rivers is directly related to the lack of scientific knowledge on how these chemicals move in the environment as clearly stated by Ongley (1996). This research is putting an initial step in the Ecuadorian society to increase that knowledge.

This thesis has only assessed some pesticides used in the banana sector. More scientific research should be done in other Ecuadorian agricultural activities such as cocoa, sugarcane, rice and palm. It should be a fact that the more knowledge is collected regarding pesticide fate from those activities, the less the related conflicts arising from the potential pollution in a river basin will be.

5.5. ENVIRONMENTAL BASELINE OF CHAGUANA RIVER BASIN

As mentioned before, there was no information regarding the environmental quality of the Chaguana river basin. The present research began to fill this gap by performing water quality sampling campaigns. Although sampling was too limited, it can be considered as an environmental baseline, which can be increased with future research.

By analysing the monitored environmental parameters, it can be concluded that the environmental quality in the Chaguana river basin is still within the majority of acceptable quality standards. The measured levels of conventional pollution (organic matter, solids content, and conductivity) were below the maximum allowable concentrations at the moment of the sampling campaigns. The monitored pesticide concentrations were below 6 ppb, and thus not exceeding the mean toxicity levels, reported by Jolliet *et al.* (1998), that could affect the aquatic biota normally living on those water bodies. However, such pesticide levels are above the maximum recommended concentrations for water consumption (European and United States environmental limits). As the people living in the Chaguana basin do not have potable water systems, they may be taking water directly from the river. Therefore, there is a potential risk to human health but its evaluation was out of this thesis scope.

5.6. PESTICIDE FATE MODELLING

Two groups of models were evaluated: screening and integrated models. The results from the screening models were used to help in planning the sampling campaigns. Propiconazole and Imazalil were evaluated. Based on the model outcomes, imazalil affects more the water compartment than the others. Therefore, there is more chance to find this pesticide in river water. Regarding propiconazole, it affects more the soil compartment. However, the soil surface is influenced by erosion, and eroded particles with attached pesticides finally reach the surface water bodies. Therefore, water samples for pesticide analysis were taken during sampling campaigns instead of soil samples. Some river bed sediment samples were obtained just to confirm that other pesticides were present in the sediment instead of imazalil and propiconazole.

The main model evaluated in this thesis was AGNPS (Agricultural Non Point Sources). The main drawback of the model is the loss of information because of data aggregation in the evaluated cells (Matamoros *et al.* 2004, *in press*). This can be decreased by increasing the number of evaluated cells in a basin. However, a large number of cells would lead to the need for an overwhelming amount of values that are not available and they should be estimated.

The flow calibration of the model was restricted to three gauging stations whose data were only recorded between 1979 and 1983 (there was no data for 1981). In addition, rainfall data was only available as total monthly values. A synthetic daily rainfall data set was generated with those monthly values, the monthly maximum 24-hour precipitation and the number of rainfall days in a month. That synthetic daily rainfall data corresponds to the period when flow data is available.

As a measured of quality of the flow predictions, the coefficient of efficiency E (Nash and Sutcliffe 1970) ranged from 0.37 to 0.73. The higher value corresponds to the gauging station which has a larger drainage area (middle course of the Chaguana basin). Although the flow data set is small, a good prediction can be achieved for basins with a large drainage area. In other studies, such as in Grunwald and Frede (1999), coefficient of efficiency can reach over 0.9 for smaller basins than the Chaguana river, but with a better rainfall data set.

The sediment calibration was done based only on the four measurement days (11 November 2001, 30 March 2002, 5 July 2002 and 14 November 2002). Due to the lack of rainfall information for those days, precipitation was estimated by using inverse modelling techniques with the flow predictions obtained in the previous step. Although the use of this technique implies potential risks of getting wrong results, it can be useful in problems with a very small data set such as the Chaguana river basin.

The sampled branch of the Chaguana river showed a high coefficient of efficiency (0.88) for the sediment predictions. That was not the case for the sampled Zapote river where this coefficient was zero. This low agreement between measured and predicted values is related to the fact that flow calibration in this stream was also worse, and there was less sampled data in the Zapote river than in the Chaguana river. The information loss by data aggregation during the creation of AGNPS cells can also be the cause for this low agreement in the Zapote area.

Regarding pesticide modelling, the main difficulty was to estimate at what moment farmers sprayed propiconazole. A reference application planning obtained from one farmer was used for this. A trial and error procedure was applied to know which farms supplied the pollutant at the moment of the measurement campaign.

The SWAT model gave a better assessment for the basin probably because the tool includes the use of Hydrological Response Units (HRU's) in the evaluated sub-basins. These HRUs significantly decrease the loss of information in the sub-basin, because more than one soil and landuse type can be used for each evaluated unit.

The imazalil assessment was not possible to be done neither with AGNPS nor with SWAT. Imazalil is discharged as point source pollution, and both models only predict pesticides from non-point sources (runoff process). Both AGNPS and SWAT have a module to include point source pollution. However, none of them considers point source pollution for pesticides.

5.7. FUTURE PERSPECTIVES

The use of a natural resource, such as water, can create complex conflicts that usually demand actions from the Government, who could not be prepared to face them. The Government should take advantage of the type of research conducted in this Ph.D. study to improve the knowledge of issues such as non-point pollution.

The recent Ecuadorian Environmental Management Law should be updated and improved regarding agrichemicals by considering all chemical families used in Ecuador. Most of the pesticides not considered by the Law can produce significant toxic levels in water, soil and air, which should be determined by proper scientific research.

The Ecuadorian Government should learn from other countries' experiences such as the EU Water Framework Directive. This can be an opportunity to increase the research cooperation agreements between European Universities and Institutions with Ecuador.

Any improvement should be done together with the decision to invest in laboratory capacity to monitor agrichemical products. Currently, Ecuadorian labs can detect less than 25% of the total agrichemical products imported to Ecuador. Lab equipments are very expensive, and they require highly trained personnel. However, this is another opportunity to create training programmes with foreign universities, such as Ghent University, which have the adequate experience in analysing agrichemicals.

Regarding the modelling of the Chaguana basin, it is advisable to perform more sampling campaigns during the year, as the model was calibrated only for 4 rain events in the year. The Zapote river should be assessed with more sampling points to have the same characterisation level as the Chaguana river.