AN EROSION MODEL AS A TOOL FOR FARMERS INVOLVEMENT FOR DEFINING LAND USE STRATEGIES IN FIJI AND SAMOA

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Abstract
South Pacific islands are under increasing pressure, and the threats are primarily from human interactions. The arrival of western values in the South Pacific resulted in forest depletion and intensive agricultural production systems, which have led to increasing damage to the environment, while bringing relatively few benefits to the resource owners. The pressure to which natural resources have been subjected by these development efforts, and the substantial and sometimes disastrous degradation and depletion which have occurred, has begun to focus the attention of communities on the need to implement sustainable management of those remaining resources. At present, crop production systems practiced in South Pacific Island States range from traditional to high input production systems. The majority of the farmers in Fiji and Samoa fall within these two extremes in what will be termed moderate input production systems. The physically based model LISEM is used to quantify the losses of soil and water in two small agricultural catchments in Samoa and Fiji. To be able to communicate directly with the farmers about the effects of proposed alternative land use on the spot calculation-results will be presented during village meetings. Calibration of the model showed that results for calculated discharge matches the measured values. In both catchments, demonstration areas of alternative land use strategies are implemented. Modeling tools will be used in the negotiation process with local stakeholders to come to feasible, reliable and acceptable alternative land management and land use strategies to increase people's welfare and reduce soil degradation and environmental pollution.

Additional Keywords: soil erosion, conservation, modeling, participation

Introduction
The increasing population pressures and emerging trends of socio-economic marginalization or rural populations are putting a heavy strain on the delicate ecosystems of the Pacific Island Countries. In response to the rapidly increasing demands for food, Pacific farmers abandon traditional farming systems to adopt high input commercial production methods for short term gains, which are often unsustainable, in particular on sloping lands. The resulting erosion causes rapid depletion of soil fertility as well as pollution of ground- and open-water systems. The CROPPRO project aims to provide assistance to Pacific Island countries with the development of integrated farming approaches for sustainable crop production in environmentally constrained systems. The project specifically addresses the relation between agricultural activities and the surrounding environment, and focuses on the development of tailor-made farming approaches for major crop/soil units aiming at maximising agricultural production and minimising environmental deterioration. Special attention will be paid to knowledge transfer and participatory, culture-sensitive training for stakeholders and end-users. The project is funded by the EU, INO-DC and the Ministry of Agriculture, Nature and Fisheries of The Netherlands

On Samoa, like on the other Pacific island countries, the increasing population pressure and emerging trends of socio-economic marginalisation of rural populations put a heavy strain on the delicate ecosystems. Due to minimum tillage practices, and small farm size, the traditional agricultural systems are highly sustainable and therefore do not contribute significantly to soil erosion and degradation. Traditional agriculture is completely interwoven with the forest areas, as an integral part of the food security system of the village and provides protection against cyclones and drought. Although Samoa was the first South Pacific island nation to gain independence and the first to join the United Nations, Samoa still remains among the poorest in the world, with most of its 166000 people living at the subsistence level (http://www.undp.org). To economically develop the country, Samoa is ever more searching for ways to replace this traditional system for a cash cropping system. Besides the need for cash crops, the increasing population causes a rapid increase in food demand. Therefore, many Samoan farmers abandon traditional farming systems to adopt high input (commercial) production methods to both satisfy the need for domestic food supply and exportation of cash crops. These agricultural systems are often

unsustainable, in particular on sloping lands. The resulting land degradation (erosion) causes rapid depletion of soil fertility, and pollution (silt and agrochemicals) of ground- and open water systems (Chadwick, 2000).

Materials and Methods

Research area

Research has taken place in the Savutalele catchment on Fiji and the Alafua catchment on Samoa. Land use in both catchments is partly agriculture and forest. Agricultural land use in Fiji is mainly tarro, cassava, yam and ginger, whereas in Samoa it is mainly coconut, grazing area, bananas and mixed vegetables. The Alafua catchment is located in the north central Upolu Island of Samoa, near the capital city of Apia. It covers an area of about 2.75 km^2. The catchment area is drained through the Papaseea stream, which connects to two other streams, at a location next to the Alafua Campus of The University of the South Pacific.The average annual air temperature ranges from 27^oC in the low-lying study area to less then 20^oC at higher elevations. In the Alafua catchment heavy rains mainly fall during the rainy season from November till March. The Savutalele catchment is located ca. 7 km north-east of Suva, on the eastern part of Viti Levu, 7.2 km north-north east of the capital of Suva (approximately at latitude 18°01' S and longitude 178°30' E. The catchment differs in height between 10 and 175 m above sea level, but is quite rugged.The catchment covers an area of around 4.7 km^2 within which three villages are found: Savutalele, Vaicoba and Sakoca (map).

LISEM model

In this study, the physically based hydrological and soil erosion model LISEM (De Roo *et al*., 1996a) has been used to quantify effects of land use on discharge and soil loss. The model calculates, on a grid cell basis, water and sediment transport processes during a single-rain event within a catchment. Basic processes incorporated in the model are rainfall, interception, surface storage in micro-depressions, infiltration, vertical movement of water in the soil, overland flow, channel flow, detachment by rainfall and throughfall, transport capacity and detachment by overland flow. The model has been integrated in a raster Geographical Information System. The catchment under study has been divided in grid cells of equal sizes (in this study 5 m). For each grid cell for every time step, rainfall and interception by plants are calculated, after which infiltration and surface storage are subtracted to give net runoff. Subsequently, splash and flow erosion and deposition are calculated using the stream power principle. The stream power is calculated as water velocity * slope, and is used to calculate the transport capacity of overland flow (Jetten and De Roo, 2001). Water and sediment are routed to the outlet with a kinematic wave procedure. Infiltration can be calculated with various sub-models, according to the data availability. In this study, a finite difference solution of the Richards' equation has been used. For a detailed background description of the model, one is referred to the web-page http://www.geog.uu.nl/lisem/ and to Jetten and De Roo (2001).

Measurements

In both catchments, characteristic land use units were determined and a measuring schedule was conducted aiming at measuring all plant, soil and climate parameters conductivity, using a statistically designed Simple Random Sampling schedule. Plant and soil characteristics were measured on a fortnigtly basis. Soil physical characteristics such as saturated hydraulic conductivity, soil moisture retention curves and the water content-conductivity relationships were determined using samples taken in the catchment. Manning's n values were measured once for each land use unit. The field data were converted to input maps for LISEM using the land use map as basis. For variables that clearly also depend on soil type (eg. cohesion) a combination of land use and soil type was used to extrapolate the measurements. Rainfall was measured using 5 tipping bucket raingauges in each catchment. The raingauges were distributed throughout the catchment. Discharge and sediment concentration were measured at a flume constructed for this project.

Farmers participation

Th initial stage of the farmers' participation is the preparation of guidelines, consisting of integrated farming approaches per crop type, aiming at maximizing crop yields and minimizing pollution risk of on-site and off-site locations. These are demonstrated in on-farm demonstration trials, and further promoted during trainings, workshops and farm visits. The transfer of ownership of project outcomes to the end-users and other stakeholders will be of paramount importance to ensure the adoption and sustainability of project outcomes. The application of participatory approaches and consultative processes with farming communities and other stakeholders at all stages during the development of the farming alternatives to increase their sense of ownership and facilitate knowledge transfer to and adoption by end-users are at this moment an progress. This work may address other relevant issues in the farming community that could affect the development and adoption of the alternative farming approaches. To

be able to communicate directly with the farmers about the effects of proposed alternatives, on the spot calculation-results will be presented during village meetings

Results and Discussion

Land use map of the Savutalele catchment, Fiji is shown in Figure 1. From both study areas, the Digital Elevation Model is determined, using available topographical maps (Figure 2). In the Savutalele catchment, a total of 14 fields were identified to be representative for all land use – soil units and for the Alafua catchment a total of 7 units could be distinguished. Measurements of soil and crop characteristics have been done on these fields in the years 200 and 2003 and are still progressing. Characteristic for the soils in both catchments, having a volcanic parent material, is their very high measured hydraulic conductivity (up to 1000 cm day^{-1}), high porosity (up to 70%), and low bulk density (down to 620 kg m^{-3}). Other authors also found these remarkable characteristics in volcanic soils (Fontesa, 2003). These properties make the behavior catchment response to rain storms, in terms of soil erosion and hydrological behavior, very specific. Measured water and sediment discharge, erosion measurements and observations of overland flow during rainfall events indicate sediment transport is relatively low in relation to the intensity of the rainfall events and the steepness of the slopes.

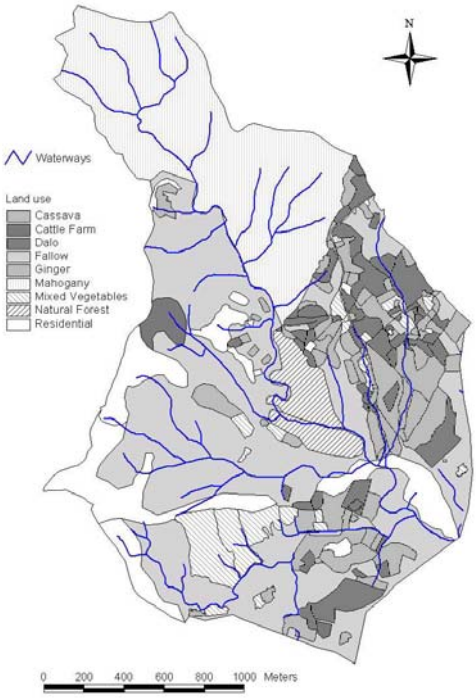

Figure 1. Land use of the Savutalele catchment, Fiji in July 2003

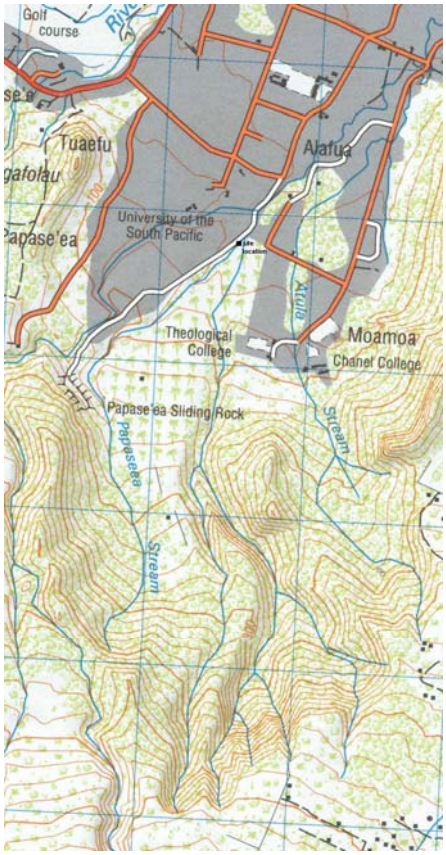

Figure 2. Topographic map of the Alafua catchment, Samoa

Results of the calibration of the LISEM model for an event on 19th April, 2003 in the Savutalele catchment is shown in Figure 3. In this figure, the measured and calculated hydrograph is shown. It shows that the calculated results match the measured hydrograph. Further analyses showed that also for other events, the simulated hydrograph is comparable to the measured ones, with increasing deviation with decreasing event size. The total amount of sediment is calculated reasonable well, but timing of peak amount is out of line in comparison with the measured sedigraph. The same procedure is now ongoing for the Alafua catchment, Samoa.

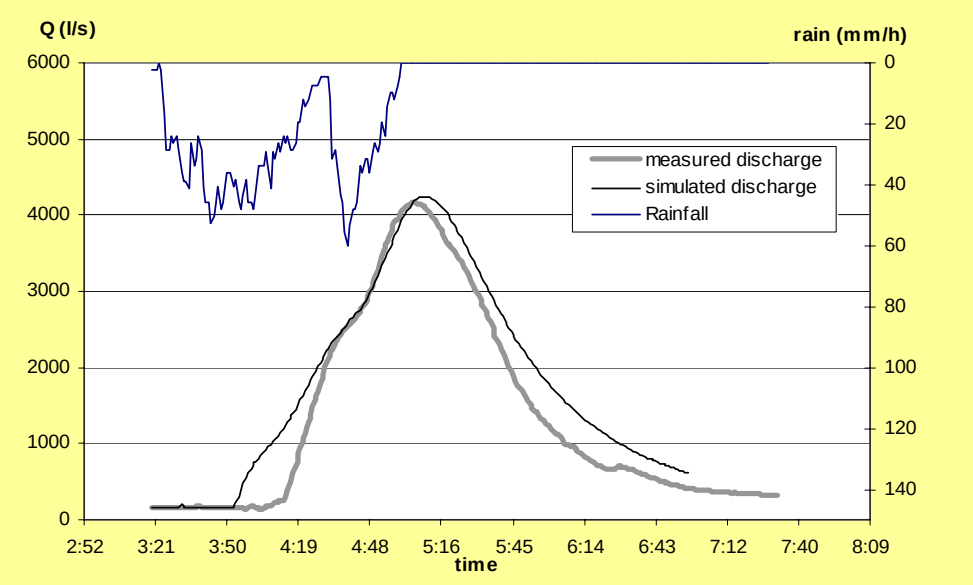

Figure 3. Measured and calculated discharge for an event on 19th April, 2003 for the Savutalele catchment, Fiji.

The land at the Savutalele catchment belongs to 2 different *mataqali*[1]. Vaicoba is within the area owned by Saula Buivanua, Sakoca and Savutalele are part of Kele Tuivesi's *mataqali*. More than half of the land is leased to Chinese farmers for a period of 4 years. The majority of the land in the Alafau catchment is owned by a Catholic College. The land use on this area is manly coconut, some cattle and bananas. A number of farmers own land lose to the major road through the catchment, and use this for local marketing. To demonstrate possibilities in terms of land management and land use to increase income and decrease soil degradation, a model farm is established in Fiji and organic farming plots are established in Samoa. The stage of the project is now to interact with the local community to define for the whole catchment alternative strategies, and to reflect results of these alternatives on the spot in terms of soil degradation. This will be done by using the LISEM model as a tool in this process.

Conclusions

The CROPPRO project is ongoing, and final results are not yet available. Nevertheless, great efforts have already been done to achieve valuable information on physical, sociological and economical data in two catchments in Fiji and Samoa. The major next challenge is to use modeling techniques as a tool in the negotiation process with local stakeholders to come to feasible, reliable and acceptable alternative land management and land use strategies to increase peoples welfare and reduces soil degradation and environmental pollution.

Acknowledgements

The work for the CROPPRO project is partly carried out by students of Dutch education institutes (eg. Wageningen University) and the USP, Samoa. Special thanks goes to Emmeke Vierhout, Clemens Drost, Sanjay Anand, Sara Eeman, Erik van der Lippe, Geraldine Klarenberg, Monique Hoeijmakers, Arthur Puls, Jos de Bijl, Yang Song, Koen Maathuis, Howard van Meer, Joris van Erve en Romano Wannyn.

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[1] A *mataqali* is an extended family, owning and using a certain area. The *mataqali* is led by a chief (which is a hereditary position), who appoints land to the different families and deals with foreign tenants (predominantly Indians and Chinese).