Developing Diagnostic and Predictive Tools to Assist Farmers and Planners in Watershed Resource Management Decision Making.

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Introduction

Population and development pressures in the agricultural hillside areas of Colombia inevitably lead to soil erosion, water pollution and environmental deterioration. Overcoming these problems requires the development of diagnostic and predictive tools which can be used to derive appropriate resource management decisions. Various stages have been identified as important steps in the development of monitoring procedures to help identify the problems and predictive tools to assist in mapping out the extent of high priority areas.

1. To compile data bases for spatial analysis. Compiling and becoming familiar with existing data was a useful first step. Existing activites have been undertaken to help better identify constraints in specific sites with the aim of targeting research towards developing strategies and tools to combat soil degradation.

   Questionnaires have been developed to solicit farmers perceptions of soil constraints and soil quality and biophysical characteristics in the field are being measured. Such information data-bases can be fed into simulation models to serve as predictive tools which will assist in resource management decision making.

   However, during the analysis of existing data it was generally found that the resolution of was not always useful resulting in very crude depiction of problems areas. Therefore, it is necessary to determine prior to field investigations, the factors which are important to the problem at hand.

2. Developing a classification of the watershed to serve as a guidance for depicting important parameters and areas for data collection in a well structured monitoring framework Such preliminary diagnosis of the area can be a useful first step in watershed management.

3. Using parameters identified as important constraints to develop predictive tools. This can serve to distribute conditions in areas where field investigation has not been undertaken, but also to test the sensitivity of an area under different condition. This is undertaken by using a simple erosion model to try and map out erosion risk areas, in order to focus our attention on high priority areas.

4. Test diagnostic and predictive tools.

The first stage in an ongoing process and which to some extent has been adopted to measure various biophysical variables in the field. However, it has generally been found that data already available on the area is incomplete or too course to be able to make accurate distributative maps of biophysical variables of the area. Both questionnaire and field data have been collected in the Cabuyal Watershed. The success of these two activities and the limitation and improvements of the approach are analysed and discussed in this report.

Compilation of data bases is another limitation due to data not made easily available. However, Geographical Information Systems (GIS) provide the analytical and user friendly interface for displaying these data bases. All analytical proceedures were carried out using Arc/Info sofware on UNIX workstations while Arcview was used to display the data.

The third stage defines the objectives of this report, to develop and test a monitoring support framework consisting of easily followed steps to carry out preliminary classification and diagnosis of the problem areas to facilitate the development of predictive tools to combat resource use inefficiency and mismanagement.

The first chapter discusses the use of existing questionnaire data to identify high priority erosion risk areas. The limitations and suggestions for future questionnaire surveys are discussed. Chapter two discusses the development of a monitoring support framework, with two specific aims. To derive a computer based classification for preliminary assessment of an area at microwatershed scale. The aim is to use this to help field investigation for siting monitoring stations for data collection to compile data bases for the development of predictive tools. Secondly to be able to scale up from site measurements to diagnosis of the whole watershed. The last chapter describes the development of an erosion model to give an indication of erosion risk areas. At present it uses existing data, but in future, data collected in the field could be distributed and used in the model to obtain more accurate results.

Chapter One

Intergrating Questionnaire Data to derive Farmers Perceptions of Soil Conditions in Cabuyal

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1.0 Objectives

A questionnaire survey carried out in 1993 (see appendix 1) in the Cabuyal watershed was analysed to determine whether farmers responses to questions on soil conditions and farm practices could be used to say something about the distribution of soil erosion problems in the area. Such surveys are repeated every 5 years to determine the impact of the application of new approaches to farming. Thus this base study will be the basis on which the impact brought about by the adoption of new farming systems is assessed. The questionnaire has been analysed statistically (Maria Cecilia), however, analysis using geographical spatial analysis techniques to obtain a visual diagnosis of the distribution of soil erosion problems, could be beneficial as a quick reference for depicting problem areas.

In addition it was considered to use a map of soil conditions as derived from this data set to see whether it corresponds to a potential erosion map computed by applying an empirical erosion model. If a map showing the location of areas perceived to have soil degradation problems corresponds to potential erosion areas produced by the model, then it could be a way of crudely validating the model output.

1.1 Limitations of the Questionnaire Data

The questionnaires were answered by every farmer in the 'Veredas' in and around the Cabuyal Watershed. Each farmer may have more than one farm plot. However, generally the response they gave often encompased or was assumed to account for all farm plots. The questionnaires were geocoded on a vereda basis, (figure 2.0.1) (see appendix 2 for vereda codes) meaning that some farms where located outside the boundary of the Cabuyal river basin. This posed problems in the analysis as one was unable to locate problems on a farm scale basis. Instead it was necessary to average all farmers responses in each vereda. This of course yields a very crude interpretation of the data as it averages out soil erosion problems.

The maps were drawn by calculating the % of all farmers responses in each vereda. For example, the % of farmers in vereda number 1 answering that they experience landslides on their farm plots. Often the questions were not always direct and the response options too general. For example, when asked the conditions of their soil in each of their farm plots, the response was given as either good, regular or bad. Further, some questions are asked in a more general sense, and therefore do not correspond to each farm plot. For example, when asked if they use fertilizer or whether they keep animals it is not clear on which plot the response refers too. One would assume that they refer to the main farm. This makes it difficult to make any assertions about the actual causes of bad soil conditions on each of the farm plots.

1.2 Interpretation Assumptions

Question	Assumption taken in the Analysis
1. Section 3. Hablemos de los lotes de cultivo	
Q 13. Considera el suelo en este lote Bueno, Regular o Malo	This tells us something about the conditions of the soil, albeit very general.
Q 14. La tierra es Negra, Mexcla o colorada	Again the colour of the soil is an indication of its fertility
Q15. Desde el ultimo descanso del lote, cuantas veces ha sembrado de seguido	This gives an indication of the longevity of fallow period
Q16. Es demasiado pendiente para arar, Si o No	If farm plots are said to be steep then it is likely that they are also prone to erosion and landsliding.There should therefore be a relationship between steepness and the tendency to experience landslides (Q21)
Q 18. Encuentra lombriz con frecuencia, Si o No	Earth worm activity could be an indication of soil fertility. There should theoretically be a relationship between earthworm presence and good soil (Q13).
Q 19 Encuentra mucho helecho, si o No	Ferns are an indication of soil acidity and therefore usually bad soil conditions. Therefore, one expects to find a relationship between farms having bad soil and those where ferns are found
Q22. Tiene barreras vivas, si o no	Live barriers are a means of preventing soil erosion. Taking prevention measures should help soil fertility conditions. It is much more difficult however to link good soils with farms practicing such measures as it depends on the time perion over which they have implemented

Question	Assumption taken in the Analysis
	these practices
2. Section 4. Dificultades en las produccion	
Q 40. Que abono utiliza con mas frecuencia, Organico, quimico, ambos, a nadie	Again, the use of fertilizer should reflect better soil conditions therefore be related to Q 13.
3. Section 6. Animales domesticos criados en la finca	
Q44. Que animales domesticos cria en a finca	The assumption taken here is that big animals are more likely to cause conpaction of the soil and therefore be associated with bad soil conditions compared to small animals.
Q46. Que hacen con los excremento de los animales, abono, alimento para animales, fosa, no hacen nada	Again, the use of organic fertilizer should be associated with better soil conditions. This questions should also tie in with the question on whether they use chemical or organic fertilizers (Q 40).

1.3 Mapping Soil Conditions Using Questionnaire Data.

Even though interpretation of these maps should be taken with caution, they nevertheless indicate possible areas with soil erosion problems. This should be verified with field observations. More importantly, the analysis here indicates that if data was to be interpreted on a more local level, ie on a farm plot basis rather than averaging the responses on a vereda basis which essentially cover larger areas, then spatial analysis can potentially yield important information about the distribution of problem areas. Often soil erosion problems are localized occurences or rather begin so. If such problems could be identified then remedial measures could be suggested and implemented.

Despite only a few farmers over the whole area responded that they have bad soil conditions (less than 8%), areas appearing to have the most soil problems are not neccesarily those areas with least fertile soils. The assumption would be that a map showng bad soils will be the exact opposite in character to a map showing good soils conditions. But this is not the case. For example, in La Esperanza, despite 74.5% of all farmers responding that they have good soils, a higher % of farmers in this vereda also responded that they have bad soils, (5.7%). This of course may be true, as there may be many localized problem areas which cannot be pick out at this broad scale (figure 3.0.1 a & b).

Indirect indicators of soil fertility were taken as being earthworm activity and ferm growth, where the former is often an indication soil fertility and the latter of soil acidity, therefore infertility (figure 3.0.2a & b). Again one could assume that a map depicting high earthworm activity areas would would correspond to higher fertility areas. This however, is not clear in the maps. In Cabuyal, 60.8% of farmers reported constant sitings of earthworm activity and for the same place 20% said they had good soil on their farms. At this scale the infromation appears contradictory.

There is no clear evidence either, that the use of fertilizer results in more fertile soils. For example, figures 3.0.3a & b indicate that in veredas where the majority of farmer responded as not using any form of fertilizer, where not necessarily the same veredas where farmers claimed to have bad soil conditions. The use of fertilizers over the area can be seen in fig 3.0.4a to c. Generally less farmers use fertilizers in the upper part of the catchment. Again it is difficult to attribute good soil conditions to the use of fertilizers because (figure 3.0.1a) the reason why fertilizers are not used may be due to better soil substrate in this region.

Figures 3.0.5a –c indicate the use of animal waste as a means of fertilization. Again figure 3.0.5c constradicts figure 3.0.4c in that even in veredas where farmers claim not to use any fertilizer, they do seen to use animal waste for fertilization. Whether the farmers perceived this question to be different from the use of organic fertilizers is hard to tell.

Figures 3.0.6a & b show landslide activity and steepness of farm plots respectively. Steeper slopes tend to have a greater propensity for landsliding. This is more or less shown here but again the relationships not very clear. Of all regression analysis carried out, this shows the strongest correlation ($R^2 = 0.4$). 50% of the farmers asked in vereda #1 replied that they have steep slopes. 30% of them experience landslide activity. On the other hand in Vereda #21, only 16% of the farmers asked replied that they have plots on steep slopes and therefore this is reflected in the lower % of landslides experienced by the farmers, 14%. Biophysical analysis of the area has shown that steepness > 26° occurs in isolated patches and therefore it is difficult to narrow down the true cause-effect relationship a this scale.

The problems encountered during interpretation of this data may or may not improve with finer resolution geocoding. This highlights the problems of using data based on personal opinions for deriving concrete conclusion. Often personal opinions about state of physical conditions vary and is often subjective in nature. Therefore care should be taken to interprete the data as sensibly as is feasible.

1.4 Recomendations for future Questionnaire Surveys

- It will be much more useful if farms could be georeferenced on an individual basis and with reference to the micro-watershed they are found in, as it is the biophysical and morphological conditions of these micro-units together with farm and management practices which will affect soil conditions.

- Being able to map out responses on a farm scale basis will be much more useful without loss of detail since then one can link together cause and effect conditions instead of averaging over larger areas.

- The questions need to be much more focused in what they ask and perphaps much more technical in the response options they offer, but written in a way which will still be understandable to the farmer. For example, instead of good, regular or bad, think about what conditions make a soil good and also give some sort of scale which will make better scientific sense.

- Question formulation and interpretation of Questionnaires should be discussed with soil group PE-2.

Chapter Two

Micro-watershed Classification: A guide to identifying similar catchments for field research.

2.0 OBJECTIVES

Before investing money in field research, it is necessary to obtain an idea of the distribution of simple biophysical properties. Evaluation of the characteristics of an area will help determine where to site monitoring stations in order to obtain measurements which are both representative of the area but which also cover the whole spectrum of heterogeneity of an area. Using simple biophysical/morphological parameters perceived to be important to the research at hand, geographic spatial analysis can be used to delineate "similar areas". The ultimate objective of this approach is to avoid measurement specificity, to make local results valid for wider regions based on the assumption that similar areas will behave in similar ways. The purpose is to scale up from site measurements to watershed impact assessment.

The procedure undertaken here has great potential as a process for designing monitoring frameworks. It is simple to carry out and useful for preliminary evaluation of a study area. Carefully thought out monitoring frameworks are needed to accurately define baseline conditions. Once these baseline levels have been measured, the impact of the adoption of alternative land management systems can be assessed by comparison (E Barios) The procedure is illustrated using the Cabuyal watershed – Cauca.

2.1 METHODOLOGY

Our approach has 3 main stages for classifying an area. The first step involves delineating the digital elevation model (DEM) for the watershed. Secondly we delineate the micro-watersheds, in which sampling will be carried out. Finally we carried out the classification analysis using map layers of different biophysical / morphological properties.

(1) The first step involved delineating the topographic boundary of the Cabuyal watershed, a sub-catchment within the Ovejas Basin. All subsequent analysis is largely based on the DEM.

(2) The next step was to delimite the microwaterheds within the Cabuyal which would represent "sampling units". Using watersheds as sampling units is useful because they have clearly defined boundaries which may help track the impact of landuse change and farm practices on the hydrological processes of a watershed (E. Barrios). Principally the erosion by runoff, leaching and sheet-wash of nutrients and fertilzers are processes which can be monitored and measured at these scales. Further location of monitoring stations within the most significant microwatersheds will provide a baseline which could be applied to other similar watersheds which may perhaps be less accesible for carrying out impact assesment in the field.

(3) The third step involves defining the biophysical and morphological properties important to the study. In this case the distribution of aspect, slope and soil substrate as well as geometrical and morphological attributes of the microwatersheds were chosen. Aspect determines the amount of solar net radiation received at the vegetated surface and therefore may affect the productivity of the crops. In the tropics this influence may not be as significant and can therefore be excluded. Slope principally controls the direction of overland flow and hence of sheet erosion and nutirent wash. Soil substrate is of course important to both processes. This procedure was carried out by simply overlaying all data layer maps to obtain one map with unique classification values, each representing unique combinations of environmental properties.

The size and shape of the micro catchments is important in terms of the hydrological processes and response of the system. The morphological parameters calculated for the mirowatersheds include the area, perimeter and the coeficient fo compactability (Gravelius index). Shape factor (Kf) and drainage Density are other factors which could be considered. These were classified and maps showing micro-catchments of similar morphological classes was derived.

2.2 PROCEDURES

2.2.1 Defining the DEM of the Area

A DEM of Cabuyal was obtained by overlaying a masked layer with the layer depicting the Ovejas catchment. If a masked image could not be created then the watershed could be delineated using the hydrological commands in ARC/GRID. Principally the BASIN command can be used to delineate the boundaries of Cabuyal watershed from the Ovejas (see figure 3.2.4). First it is necessary to compute a grid showing the flow directions out of each cell using the FLOWDIRECTION command, then run BASIN. The delineated DEM provides the base map from which further analysis could be carried out (figure 3.1.1).

2.2.2 Deliniating the Micro-Watersheds

Delineation of watersheds is of fundamental importance because the charactertistics of a drainage basin controls the paths and rates of movement of water to the outlet and the magnitude and timing of outputs via streamflow, groundwater flow and evapotranspiration (Dingman 1996[i]). Runoff over the drainage area will affect cultivated areas and at the same time cultivation practices will affect these hydrological processes.

There are an infinite number of points along a stream where watersheds can be drawn for any stream. Upstream watersheds are nested within and are part of downstream watersheds. It could be argued that analysing the response of these smaller watershed units in terms of their different biophysical conditions, shape, size and drainage density will be much more useful than considering the basin as a whole. Farm plots are usually small with different crops and management practices being carried out. These factors will afffect the response of local watersheds first before impacting the basin as a whole.

We used manual and automated methods to delimit the microwatersheds (microwatershed.apr) The robustness of each method is then compared.

2.2.3 Manual Deliniation of Micro-Catchments

A previous study (J Rubiano) had manually chosen the microwatersheds which could potentially be used as sampling units. The criteria for deliming these was simply, defining the upstream contributing area from each tributary outlet which joined the main river. The micro-watershed boundary was drawn by hand in ARC/EDIT using a topographic coverage of contour lines as a guide.

- To draw the divide, start at the location of the chosen stream cross section.
- Then begin at the stream outlet, drawing the line away from either its left of right bank, always maintaining it at right angles to the contour lines.
- Continue drawing the line until its trend is generally opposite to the direction in which it began always following topographical ridges until the head of the stream, (highest area contributing to the stream) is reached.
- Then return to the starting point and trace the divide from the other bank, eventually connecting with the first line at the headwaters (figure 3.2.1).

This method produced a total of 76 Catchments with different size distributions (figure 3.2.2a). The bigger micro-catchments were further split into smaller units, as these are easier to managed and monitor resulting in a total of 90 micro catchments (figure 3.2.2b).

When drawing the watershed divide it is helpful to imagine that the divide defines the highest boundary which will ensure that water falling at this point will drop and flow downslope, eventually entering the stream network. A divide can never cross a stream.

This method is very time consuming and subjective in the placement of watershed boundaries along topographical ridges. It leaves some areas ungrouped by a watershed boundary but they could be considered to be part of the area draining directly to the main river. However, it allows you to choose and define ideal and representative catchments for monitoring. It also proves to be more robust than the automated method. However, such a proceedure is relatively simple for small catchments. For larger catchments this will be a tedious task to undertake.

2.2.3 Automated Delineation of Micro-Watersheds

Microwatersheds were also delimited using raster-based hydrological functions in ARC/GRID. This automated approach to watershed delineation allows the concomitant rapid extraction of hydrological information, but is not without computational problems. Two criteria were used to define these; considering the contributing area of every outlet feeding into the main river; considering the contributing area of only the main tributaries. The proceedure is outlined in Appendix 1. Briefly, the outlet points were selected in ARC/EDIT and saved as a coverage. This together with a grid depicting flow direction, were used to run the WATERSHED command to delineate these microwatershed polygons. The resulting grid coverage is shown in figure 3.2.3a. This identified 85 microcatchments. However the method did not seem robust enough at depicting all microwatershed boundaries (figure 3.2.4), especially of the smaller streams. Also, it appears that some of the divides cross streams.

An alternative method is to use a stream links map to delimit the micro-watersheds instead of just the outlet points. This better defines microwatersheds, but is a little unrealistic in that it also generates divides around the main river flood planes (fig 3.2.4b)

An additional trial was carried out by chosing the outlet points using the rivers coverage produced by the STREAMNET command. It was considered that these may better correspond to the flow direction coverage, used by WATERSHED to compute the analysis. However, the same problems appeared to be occuring (figure 3.2.3b). The use of this command, for delineating small catchments was tested against its use for deliminting bigger catchements. Rubiano (1997) applied the watershed command to delimit the subcatchments of Ovejas, of which Cabuyal was one of them, with better results (figure 3.2.5). Thus is can be concluded that there is a scale limitation on the efficient functioning of the command.

2.3 Choosing the Biophysical Properties

The classification of biophysical properties was based on two methods. One classification was carried out using biophysical properties of the area (bioproperties2.apr) and the other using morphological properties (morphology.apr) of the microwatersheds. Considering the morphology of microwatersheds was important because even though two microwatersheds may appear to be similar, the hydrological reponse may differ due to the geometry of the watershed. For example, the hydrograph of an elongated catchment will differ from that of a rounded watershed.

From the DEM, surface analysis was carried out to obtain maps showing the distribution of aspect and slope (figures 3.3.1 and 3.3.2 respectively). A crude soils map already exits, consisting of 5 classes (figure 3.3.3). Reclassification of these factors was carried out in ARC/GRID using RECLASS command to group together similar areas, by defining class boundaries considered important for the analysis. The aspect map was re-classed to represent two classes; aspect of north and an aspect of south (figure 3.3.4) while Slope was grouped into 3 classes (figure 3.3.5). Each class was assigned a unique number to be used as an identifier in the classified image. See table 1 for details on class sizes. The maps were overlaid to produce a classified image showing classes with unique combinations of biophysical properties (figure 3.3.5b).

Further spatial analysis was performed on a microwatershed basis. The mean slope within each microwatershed was calculated to yield a map showing micro-catchments with similar slope and aspect characteristics. These were also overlayed to produce an image which generalizes these biophysical properties on a microwatershed basis. Two maps were produced; Figure 3.3.10 shows the classification using mean slope in each microwatershed and figure 3.3.11 uses the most frequent slope distribtuion in each microwatershed. In both cases a much cruder classification of similar catchments is produced, which may be more useful for initial evaluation of similar catchments.

2.4 Morphological Properties

The two morphological properties analysed here included the area of each micro-watershed and the coefficient of compactability (or Gravelius index). Others could also be considered, such as the relative relief, shape factor and drainage density (Saenz 1995[ii]).

Figure 3.4.1 shows the area classes of all Micro-catchments in Cabuyal. The drainage area is important as this affects how much of inputs to the systems, principally rainfall is contributed to the stream discharge. Also the area will affect the rates at which overland flow, sediment and nutrients wash into the river network.

A second important factor is the Gravelius index which measures the circularity of a catchment (Figure 3.4.2). This is basically the ratio of the perimeter of watershed to the circumference of a circle whose area is equal to that of the watrshed, expressed as follows:

$$\mathbf{K_c = 0.28 * P / A^{0.5}}$$

Where:

K_c = Gravelius Index

P = Perimeter of microcatchment

A = Area of microcatchment

A perfectly circular catchment will have a value of 1. Stream discharge of circular catchments increase much more rapidly as water reaches the stream network much faster compared to elongated catchments.

2.5 Results of Classification

We can see that most of the microwatersheds have north facing slopes, only the small microwatersheds in the NE of the catchment have generally more south facing slopes (figure 3.3.6). In terms of slope, the larger microwatersheds have mean slopes less that 15 degrees., while the smaller ones, and the area which drains to the main river appear to be much steeper (3.3.7). The most frequent slope within each micro-catchment was also calculated, showing similar findings (figure 3.3.8). This of course is a generalization, reflecting the resolution of the DEM (25 meters) and localized slopes may be much steeper than this. A further map showing the frequency distribution of slope ranges within each micro-catchment shows how very few slopes have a steepness greater than 26° but may nevertheless be important locally (figure 3.3.9).

28 classes were generated in total. However, a histogram shows how 5 main important classes of biophysical combinations exits; 9,7,13,8,5 (Figure 3.3.9b).

2.6 Conclusions

- The resulting classification analysis of Cabuyal shows that it is largely homogeneous. This however may reflect the scale of the dem and also the crude soil information used in the computation of the similar areas. A finer scale soil map may yield better results
- It is important that these classes are validated by visual inspection in the field before we can confidently use them for siting monitoring stations and for carrying out impact assesment.
- The automated techniques not excecuted successfully. One reason my be the scale of the DEM, resulting in inconsistent results Automated processing should be used with caution and should be inspected with respect to the original contour lines. It appears the algorithm for automatic processing nees further develoopment before widespread application.

Chapter Three

Modelling Distribution of Potential Erosion. A case study for the Cabuyal Watershed

K Pallaris and J Rubiano

3.0 OBJECTIVE

To develop a method to obtain some idea of the potential distribution of erosion problems in the Cabuyal watershed. The aim is not to just obtain yearly averages of erosion amounts, but to simulate the distribution off erosion on a daily timestep over the area.

An empirically based erosion model was developed in PCRASTER, a raster based modelling programme developed by Utrecht university, Netherlands.

The erosion model uses distributed parameters of rainfall and (infiltration capacity) and vegetation cover.

$$\textbf{Erosion} = k^* (\text{Runoff}^{\,m}) * (\text{slope}^{\,n}) * (e^{-0.07*\text{vegetation cover}})$$

Where:

m = 2.0

n = 1.66

e = 2.71

K = 2.1

Basically we took a simple erosion model which simulates erosion of soil surface by assuming that erosion is a power function of surface runoff and slope (Thornes 1987). The Model was run on a daily timescale because of the resolution of the raindata. We could not as yet distribute soil data because do not have all information for all soil types in the area.

Vegetation was modelled in form of vegetation cover therefore a % cover for the different landuses was estimated. A coverage of no vegetation was also used to compare bare soil erosion potential and assess the effect of crop types on erosion rates.

In addition to viewing the distribution of rainfall in animated mode, the model also reports the amount of erosion over the whole catchment and at selected sample sites.The model structure can be seen in appendix one.

Additional model components

Additional model components need to be added to the model to make it a more robust and useful tool for determining the distribution of areas of potential erosion. Firstly, the soil hydrology section needs to be improved by using distributed soil parameters. Secondly, at the moment 3 random sampling sites where selected to report erosion. The aim is to define the coverage showing the micro-watersheds as sampling areas and report erosion amount in each micro-watershed.

Table 1. Landcover for different landuses

ID	Type of landuse	% cover
1	Bosque protecto / plantado	100
2	Cultivos Densos Coffee, pastures	60
3	Cultivos semile Maize & beans or casava and maize	60-80
4	Cultivos limpio Beans, maize	30-40
5	Suelo expuesto	0
6	Dencanso (fallow) usually cover with grasses	80

Rainfall Data

We took the rainfall records of three stations, San idriso, El Oriente and Domingo. A complete years data could not be found but 3 periods where selected to reflect the seasonal patterns in rainfall (table 2).

Table 2. Rainfall Periods

Period	File	Notes

Parameters Used

A general infiltration capacity value was derived based on soil parameters taken from study determinacion del indice de erodabilidad en dos suelos del depeartmento del cauca, Colombia, (Jesus A C Franco, 1994). However, better soil data is required to improve this section of the model. At the moment only one value of infiltration is used for the whole catchment. It is necessary to distribute these factors given the different soil associations.

Bulk Density (densidad real) 0.9 (0.4-1.35)
Particle density (Densidad apparente) (2.2-2.9)
Typical values for soils < 200 m in altitude, pp123.
Soil texture of soil association of Pescador, most extensive of soil associations in the area. Taking the average of the first two layers between 0-43 cm.

Sand (arena) 0.46
Silt (limo) 0.35
Clay (arcilla) 0.19
Assume soil depth of 0.5 m and soil moisture of 0

Output = 49.92 mm/hr Ksat

Results

The results show that much more erosion is occuring in the lower part, in Portrerillo, La llanada, Cabuyal, and in the middle parts of the catchment, around Pescador.

There is also a clear relationship between rain storm size and erosion potential, with rain storms over 40 mm producing erosion.

According to field observations, these are the areas where more erosion is evident. However, the model needs to be refined further before having confidence in the results.

Limitations

- Sedondary data – do not know how it was collected. Also not continuous, Need finer resolution data for modelling purposes. Some of the values of parameters used in the model need to be calibrated using field measurements.
- Course scale – data needs to be collected at greater intervals, and scale up to courser resolution.
- Need georeferenced soil parameter data in order to produce distributed results of soil data
- Monitoring and measurement needs much more care. Need to think about what the data is going to be used for.
- Soil parameters need to be much more precise in order to be able to extrapolate and model the predict. Need to be more confident in the assumption one is making.

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Appendix 1

Carrying out the Watershed command

A watershed is an area that drains water (and sediment) to a common outlet as concentrated drainage. A watershed is defined as the total area flowing to a given outlet or pour point and the pour point is the point at which water flows out of an area. The WATERSHED command in ARC-GRID determines the contributing area above a set of pre-defined pourpoints in a grid.

Usage

GRID: outgrid = WATERSHED (<dir-grid>, <source-grid>)

Where:

Outgrid = The resulting map depicting the catcments, subcatchments or microcatchments

WATERSHED = The GRID command

Dir-grid = A grid showing the direction of flow out of each cell. This is derived by using the FLOWDIRECTION COMMAND IN GRID.

Source-grid = a grid representing cells above which the contributing area or atchment will be detrmined. All cells with NODATA will be used as source cells.

- To obtain the dir-grid need to compute flowdirection using the dem as follows

GRID: flowdirection-grid = FLOWDIRECTION (<surface-grid>)

Where:

Flowdirection-grid = a grid showing the direction of flow from each cell to its steepest downslope neighbour.

Surface-grid = a grid representing the elevation surface, ie the DEM

- To obtain the source-grid; first need to select the pourpoints using ARC/EDIT, then convert this to a grid using POINTGRID command in ARC.

A) Selecting the outlet points

(i) Points will be created by clicking on the confluence between a main tributary and the main river. Hence the river network coverage will be used as a guide. First however, need to create a coverage which will contain the outlet points. To do this use the CREATE command in arc

ARC: CREATE <name of coverage to be created> <Coverage you are to use as a guide>

(ii) Start up ARC/EDIT to define the points.

ARC: ae

(iii) Need to set the river network coverage as a background coverage; bc = background coverage; rivernetwork = coverage to be used as a guide; 2 = colour symbol; be = background environment in this case is set to arcs; draw = command to plot the image

EDIT: bc rivernetwork 2
EDIT: be arc
EDIT: draw

(iv) Need to define the coverage to be edited. In this case it is the points coverage which will be updated here; edit = the command stating that a coverage is to be changed. Need to set this otherwise points will not be drawn; ef = edit features, stating that the features to be edited are points; add = the command for adding points; a cursor will appear for entering points; to end press 9. Save = saves the file with points.

EDIT: edit <outlet points>
EDIT: ef points
EDIT: add
EDIT: save

(v) once the pour points have been chosen and save to the coverage need to exit edit and build the points in ARC; build=command to build a value attribute table (VAT) for a grid; <outletpoints> = the coverage containing outlet points; points = need to specify that the file contains point data.

EDIT: quit

ARC: build <outletpoints> points

(vi) In order to carry out the watershed command need to convert the point coverage into a grid. Need to to this using POINTGRID command in arc; POINTGRID = command for the coversion; <in-coverage> = coverage containing the points; <outgrid>= the name of the grid to be created.

ARC: POINTGRID <in-coverage> <out-grid>

Cellsize: 25

Convert entire coverage y/n: y

Appendix 2

A) Bioproperties Project [/deg2/cabuyal/bioproperties.apr] – Arcview project showing the results of the classification of Cabuyal Watershed.

Name of File	Type of File	Source	Notes
Demcabuyal	Grid	KP	Dem of Just Cabuyal watershed
Cabslope	Grid	KP	Slope distribution Cabuyal
aspectcab	Grid	KP	Aspect distribution of Cabuyal
Divisomask	**Grid**	Kp	Masked image for just Cabuyal watershed
Cabslope	GRID	KP	Slope distribution in degrees within Cabuyal. Generated from SLOPE command in GRID
Cabaspect	GRID		Aspect distribution within Cabuyal. Generated from ASPECT command in GRID
Classaspect	Grid	KP	Classification of aspect distribution within Cabuyal watershed. Two classes used. Generated from RECLASS command in GRID using aspectcl.dat reclass table
Classlope	Grid	KP	Slope distribution within Cabuyal. 3 slope classes are used: 0-15, 15-26 and > 26. Generated with RECLASS using slopecl.dat reclass table.
Slopecl.dat	Remap table	KP	Lists classes for Classlope Grid
Aspectcl.dat	Remap table	KP	List classes for classaspect grid.
Class1	Grid	KP	Classification map showing areas of similarity (derived from overlay of classaspect, classlope and Cabu-gr2)
Cabu-gr2	Grid	KP	Soil map of Cabuyal. Generated by converting soil coverage Cabusuelos using POLYGRID in ARC.
Slpmean	Grid	KP	A grid showing the mean slope in each microwatershed. Generated using ZONALMEAN command in GRID. Using micwatgrd as the zone-grid.
Aspectzone	Grid	KP	A grid showing the main slope aspect in each microwatershed. Generated using zonalmajority command in GRID. Using micwtgrd as the zone-grid.
Aspectzone2	Grid	KP	A grid showing the main slope aspect in each microwatershed. Generated using the zonal majority command in GRID with the Micwat9grd, the zone-grid with more micro-watershed divisions and classaspect, the values-grid.

Name of File	Type of File	Source	Notes
Slopezone	Grid	KP	A grid showing the mean slope in each microwatershed. Generated uisng ZONALMEAN command in GRID with micwat9grd (zone-grid) and cabslope (values-grid)
Soilzones	Grid	KP	A map showing the main soil type within in microwatershed. Derived using ZONALMAJORITY command in GRID with Micwat9grd (zone-grd) and cabu-gr2 (values-grid)
Slpmaj	Grid	KP	A map showing the most frequent slope steepness in each microwatershed. Derived using ZONALMAJORITY in GRID using Micwat9grd (zone-grid) and classlope (values-grid)
Class2	Grid	KP	A map showing classification of biophysical properties within each microcatchment. Derived using COMBINE command in GRID with slpmaj, soilzones, and aspectzone2
Class3	Grid	KP	Same as class2, but using slopezone instead.
Cabusuelos	Soil coverage	JR	Soil classification map derived from Ovejas Soil Map
Modelo1	DEM	JR	Original DEM of the Ovejas Catchment

A) **Microwatershed Project [/deg2/cabuyal/microwater.apr]. Arcview project showing the results of Choosing Microwatersheds.**

Name of File	Type of File	Source	Notes
Cv3431a1	Arc coverage	JR	Coverage showing the contour lines for the catchment. Used to delimit the microwatersheds of microwat and microwat9.
Cv3204d2	Arc coverage	JR	Coverage showing the contour lines for the catchment
Cv3431a3	Arc coverage	JR	Coverage showing the contour lines for the catchment
Cv3204d4	Arc coverage	JR	Coverage showing the contour lines for the catchment
Cv3213c3	Arc coverage	JR	Coverage showing the contour lines for the catchment
Microwatgrd	Grid	KP	Grid depicting the microwatersheds of Cabuyal. Derived by converting the polygon coverage MICROWAT using POLYGRID command in ARC. Used as the 'zone grid' for extraction of data from each zone.
Microwat2	Arc coverage	KP & JR	Coverage showing the arcs defined in ARC/EDIT for delimiting the microcatchments. More divisions used here compared to microwat.
Microwat10	Polygon coverage	KP	Generated by using BUILD POLYGONS command in ARC from Microwt2 coverage.
Micwat9grd	Grid	KP	Generated by converting Microwat9 to grid using POLYGRID in Arc. Used as the zone-grid for deriving microwatershed properites
Microcat2	Grid	KP	Generation of microcatchments within Cabuyal using WATERSHED command in GRID. Computed using outlet points of the most important rivers. Used pourptsgrd as the source grid and streamnet as the river coverage to guide the choice of outlet points
Microcatgrd	Grid	Kp	Generation of microcatchments within Cabuyal uing WATERSHED command in GRID. Computed using outlet points of all the rivers whose outlet drains into the main river. Used outletsgrd as the source grid and riosdiviso as the river coverageto guide the choice of outlet points.
Pourpts	Point coverage	KP	A coverage generated in ARC/EDIT depicting the outlet points chosen to generate microcat2
outletpt	Point coverage	KP	A coverage generated in ARC/EDIT depicting

Name of File	Type of File	Source	Notes
			the outlet points chosen to generate microcatgrd
Outletsgrd	Grid	KP	Generated from outletpt using POINTGRID in ARC
Pourptsgrd	Grid	KP	Generated from pourpts uisng POINTGRID in ARC
Cabflow	Grid	KP	Flow direction of Cabuyal Watershed
Streamnet	Grid	KP	Stream distribution generated from Streamnet command
Microwat	Polygon Coverage	JR	Polygons depicting the microwatersheds of Cabuyal; delimited manually
R-Cabuy	Arc Coverage	JR	Just river Cabuyal
Riosdiviso	Arc Coverage	JR	Rivers within the Cabuyal Watershed
Wshed1	Grid	JR	Subwatersheds of Ovejas

A) Morphology Project. [/deg2/cabuyal/morphology.apr]. Arcview project showing size and shape properties of mircowatersheds in Cabuyal.

Name of file	Type of File	Source	Notes

File Name	Type of File	Origin of data	Location	Description of Contents
Agucabpen	Coverage	JR	/deg/cabuyal	Slope Polygons into hydrological area of Cabuyal
Cabuyal 4	Coverage	JR		I do not know, let me check before...
Cabsopenalt	Coverage	JR		Intersection of Slope, soils and altitude Polygons into hydrological area of Cabuyal
Cabupun	Point coverage	JR		Point data from two different questionnaire survey (J. Castaño and Cipasla)
Cabusuelos	Soil coverage	JR		Soil classification map derived from Ovejas Soil Map
Diviso	Polygon coverage	JR		Showing boundary of Cabuyal watershed only.
Estaciones	Point coverage	JR		Appears to the be two climate stations inside Cabuyal (El Oriente and Jose Domingo Farm)
Gpsdecipru	Point coverage	JR		Point data from the graphic questionnaire survey (H. Ravnborg)
Ipso	Arc coverage	JR		Polygons built with the contour lines of cabuyal (Ipsometric curve)

File Name	Type of File	Origin of data	Location	Description of Contents
Microcu				Subcatchments
Laguna	Polygon Coverage	JR		Lake in Vereda Los Quingos into Cabuyal Watershed.
Microwat		JR		Same as microcu
Microsuel		JR		Intersection of microwat and Ovejas soils map.
Nribuf10	Arc Coverage	JR		10 mts River buffer zones
Nriabuf15	Arc Coverage	JR		15 mts River buffer zones
Paloma	Point Coverage	JR		
R-Cabuy	Arc Coverage	JR		Just river Cabuyal
Riosdiviso	Arc Coverage	JR		Rivers within the Cabuyal Watershed
Slopoly		JR		Polygons of slope derived from TIN or Grid ?
Suelcabu		JR		Same as cabusuelos but check differences
Usocabu		JR		Must be one copy of the next coverages
Uso46				Land cover from 1946 aerial photographs
Usot70				Land cover from 1970 aerial photographs
Usot89				Land cover from 1989 aerial photographs
Usot94				Land cover from 1994 field recognizance using 1989 aerial photographs
Vias	Arc Coverage	JR		Main roads

Appendix 3

Classes

A) Soil Classes

Soil Type	Class Number
Farallones	1
Pescador	2
Puelengue	3
Suarez	4
Usenda	5

A) Mean Slope

Mean Slope Class	Class
5.2-8.1	8
8.1-10.9	9
11-14	10
14-17	11
17-20	12
20-23	13
23-25	14
25-28	15
28-31	16

Appendix 4

MICRO-WATERSHED	VEREDA	VEREDA	MICRO-WATERSHED
1	El Socorro	Buena Vista	59
2	El Socorro	Buena Vista	65
3	El Socorro	Buena Vista	66
4	El Socorro	Buena Vista	67
5	Palermo	Buena Vista	70
6	Potrerillo	Buena Vista	71
7	La Isla	Buena Vista	72
8	La Isla	Buena Vista	75
9	La Llanada	Buena Vista	76
10	La Llanada	Buena Vista	89
11	La Isla	Cabuyal	11
11	Cabuyal	Cabuyal	14
12	La Llanada	Cabuyal	15
13	La Llanada	Cabuyal	16
14	Cabuyal	Cabuyal	21
15	Cabuyal	Cabuyal	22
16	Cabuyal	Cabuyal	23
17	Potrerillo	Cabuyal	24
18	Potrerillo	Cabuyal	26
19	Potrerillo	Cabuyal	30
20	Potrerillo	Cabuyal	31
21	Cabuyal	Cabuyal	32
22	Cabuyal	Crucero	29
23	Cabuyal	Crucero	35
24	Cabuyal	Crucero	42
25	Potrerillo	Crucero	43
26	Cabuyal	Crucero	44
26	Potrerillo	Crucero	47
27	Potrerillo	Crucero	48
28	Potrerillo	El Cidral	58
29	Potrerillo	El Cidral	59
29	La Campina	El Cidral	60
29	Crucero	El Cidral	63
30	Cabuyal	El Cidral	86
31	Cabuyal	El Cidral	88
32	Cabuyal	El Cidral	89
33	Panamericana	El Oriente	68
34	Panamericana	El Oriente	69
35	Panamericana	El Oriente	72
35	Crucero	El Oriente	73
35	Potrerillo	El Oriente	74
36	Panamericana	El Oriente	90

MICRO-WATERSHED	VEREDA	VEREDA	MICRO-WATERSHED
37	Panamericana	El Oriente	91
38	Panamericana	El Oriente	92
39	Panamericana	El Oriente	93
41	Panamericana	El Porvenir	52
42	Crucero	El Porvenir	53
42	Potrerillo	El Porvenir	54
43	Crucero	El Porvenir	55
44	Crucero	El Socorro	1
45	Panamericana	El Socorro	2
46	Ventanas	El Socorro	3
47	Crucero	El Socorro	4
48	Crucero	El Socorro	77
49	Ventanas	La Campina	29
51	Ventanas	La Campina	83
52	El Porvenir	La Campina	84
53	El Porvenir	La Esperanza	93
54	El Porvenir	La Isla	7
55	El Porvenir	La Isla	8
56	La Laguna	La Isla	11
57	La Laguna	La Laguna	56
58	El Cidral	La Laguna	57
59	Sta Barbara	La Laguna	61
59	El Cidral	La Llanada	9
59	Buena Vista	La Llanada	10
60	El Cidral	La Llanada	12
61	La Laguna	La Llanada	13
61	Los Quingos	La Llanada	79
62	Los Quingos	La Llanada	81
63	El Cidral	La Llanada	83
65	Buena Vista	Los Quingos	61
66	Buena Vista	Los Quingos	62
67	Buena Vista	Los Quingos	90
68	El Oriente	Palermo	5
69	El Oriente	Palermo	77
70	Buena Vista	Palermo	78
71	Buena Vista	Palermo	81
72	Buena Vista	Palermo	82
72	El Oriente	Panamericana	33
73	El Oriente	Panamericana	34
74	El Oriente	Panamericana	35
75	Buena Vista	Panamericana	36
76	Buena Vista	Panamericana	37
77	Palermo	Panamericana	38
77	El Socorro	Panamericana	39
78	Palermo	Panamericana	41

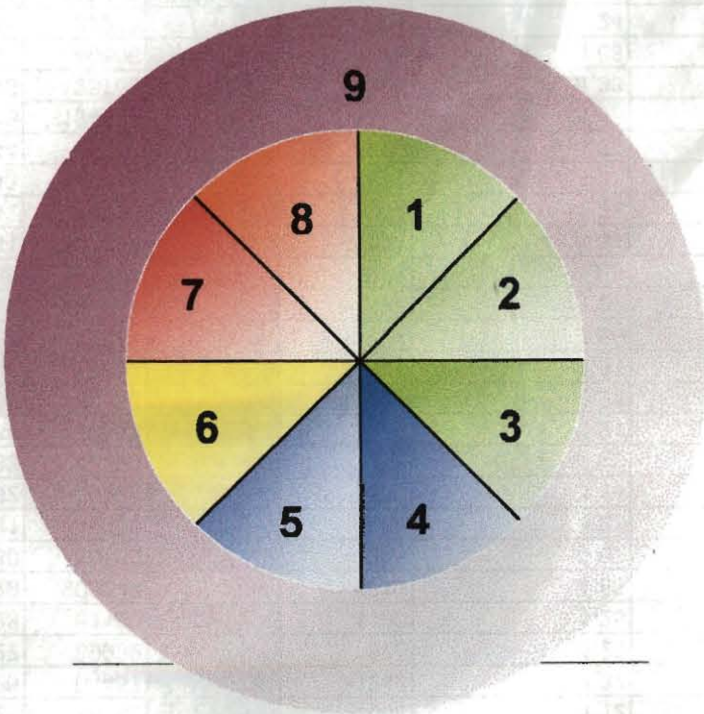
MICRO-WATERSHED	VEREDA	VEREDA	MICRO-WATERSHED
79	La Llanada	Panamericana	45
81	La Llanada	Potrerillo	6
81	Palermo	Potrerillo	17
82	Palermo	Potrerillo	18
83	La Llanada	Potrerillo	19
83	La Campina	Potrerillo	20
84	Potrerillo	Potrerillo	25
84	La Campina	Potrerillo	26
85	Sta Barbara	Potrerillo	27
86	El Cidral	Potrerillo	28
88	El Cidral	Potrerillo	29
89	El Cidral	Potrerillo	35
89	Buena Vista	Potrerillo	42
90	Los Quingos	Potrerillo	84
90	El Oriente	Sta Barbara	59
91	El Oriente	Sta Barbara	85
92	El Oriente	Ventanas	46
93	La Esperanza	Ventanas	49
93	El Oriente	Ventanas	51

Appendix 2

Code	Verada Name
1	Caimito
2	Socorro
3	La Isla
4	Palermo
5	Panamericana
6	Porvenir
7	La Laguna
8	Los Quingos
9	Ventanas
10	Santa Barbara
11	Cidral
12	Primavera
13	Buenavista
14	Crucero el Roasario
15	La Esperanza
16	El oriente
17	Pescador
18	Crucero Pescador
19	Campina
20	La llanada
21	Potrerillo
22	Cabuyal

ⁱDingman S L 1996. Physical Hydrology. Prentice Hall, London.
ⁱⁱ Saenz G M 1995. Hidrologia en la Ingenieria. Editorial Escxuela Colombiana de Ingeneieria.

Instrumentos Metodológicos para la Toma de Decisiones en el Manejo de los Recursos Naturales



1. *Elaboración de un mapa participativo para identificar y clasificar indicadores locales de calidad de suelo a nivel de microcuenca*
2. *Análisis fototopográfico de tendencias en el uso del suelo en laderas*
3. *Mapeo, análisis y monitoreo participativos de los recursos naturales en una microcuenca*
4. *Metodología de análisis de grupos de interés para el manejo de una microcuenca*
5. *identificación de niveles de vida para la construcción de perfiles locales de pobreza rural*
6. Sistemas de Información Geográfica – SIG:*Atlas de las subregiones Yorito y Sulaco, Yoro, Honduras*
7. *Identificación y evaluación de oportunidades de mercado para pequeños agricultores*
8. *Utilización de modelos de simulación para evaluación Ex-ante*
9. *Método participativo para identificar y clasificar indicadores locales de calidad del suelo a nivel de finca y microcuenca*

La Figura representa el conjunto de los instrumentos metodológicos de la serie. En el centro de la figura se encuentran ocho instrumentos que se pueden agrupar de la manera siguiente: En color verde, *Indicadores locales de la calidad del suelo; Análisis de tendencias de uso de tierra; Mapeo, análisis y monitoreo de los recursos naturales,* son los instrumentos que permiten identificar, analizar y priorizar los componentes biofísicos, o sea, los recursos naturales a nivel de finca, micro-cuenca y subcuenca.

- ✓ Realicen un análisis participativo con el apoyo de la información recolectada en los mapas y el recorrido, conforme al conjunto de componentes identificados.
- ✓ Integren los mapas participativos a un Sistema de Información Geográfica.
- ✓ Identifiquen las características de un Sistema de Información Geográfica a nivel local.
- ✓ Tomando como base el análisis del estado de los recursos naturales, puedan definir un conjunto de indicadores (con sus respectivos valores) de la calidad de los recursos naturales.
- ✓ Con el apoyo de un cuadro de indicadores de calidad de los recursos naturales identifiquen las microcuencas críticas, o áreas criticas dentro de éstas, en proceso de degradación de los recursos naturales.

Morfological information of Cabuyal Watersheds

Microwat-id	Area (m)	Area (Ha)	Perimeter	Gravelius_index2	Relative_relief
1	88855	8.9	1690	1.59	52.6
2	391725	39.2	2661	1.19	147.2
3	863449	86.3	4153	1.25	207.9
4	357851	35.8	2901	1.36	123.3
5	256701	25.7	2374	1.31	108.1
6	128961	12.9	1455	1.13	88.6
7	12286	1.2	450	1.14	27.3
8	67075	6.7	1154	1.25	58.1
9	13146	1.3	445	1.09	29.5
10	21356	2.1	641	1.23	33.3
11	33642	3.4	751	1.15	44.8
12	48215	4.8	926	1.18	52.1
13	60497	6.0	1211	1.38	50
14	86068	8.6	1400	1.34	61.5
15	58772	5.9	1148	1.33	51.2
16	35363	3.5	725	1.08	48.8
17	90415	9.0	1429	1.33	63.3
18	122524	12.3	1510	1.21	81.1
19	233047	23.3	2170	1.26	107.4
20	10348	1.0	473	1.3	21.9
21	15812	1.6	518	1.15	30.5
22	20838	2.1	619	1.2	33.6
23	27111	2.7	683	1.16	39.7
24	31176	3.1	745	1.18	41.9
25	70485	7.0	1064	1.12	66.2
26	64457	6.4	1242	1.37	51.9
27	39939	4.0	875	1.23	45.7
28	61130	6.1	1100	1.25	55.6
29	906249	90.6	6311	1.86	143.6
30	45735	4.6	816	1.07	56.1
31	18200	1.8	582	1.21	31.3
32	20429	2.0	580	1.14	35.2
33	42620	4.3	956	1.3	44.6
34	53958	5.4	1004	1.21	53.7
35	30154	3.0	778	1.25	38.8
36	18807	1.9	643	1.31	29.3
37	27884	2.8	754	1.26	37
38	121614	12.2	1578	1.27	77.1
39	138997	13.9	1999	1.5	69.5
41	103982	10.4	1504	1.31	69.1
42	84235	8.4	1262	1.22	66.8
43	147449	14.7	1811	1.32	81.4
44	25348	2.5	735	1.29	34.5
45	104566	10.5	1678	1.45	62.3
46	125763	12.6	1689	1.33	74.5
47	40606	4.1	776	1.08	52.3
48	25277	2.5	704	1.24	35.9
49	117348	11.7	1342	1.1	87.5
50	14329482	1432.9	95051	7.03	150.8
51	63492	6.3	1149	1.28	55.2
52	29271	2.9	720	1.18	40.6
53	227641	22.8	2325	1.36	97.9
54	90264	9.0	1424	1.33	63.4

Microwat-id	Area (m)	Area (Ha)	Perimeter	Gravelius_index2	Relative_relief
55	118521	11.9	1502	1.22	78.9
56	452726	45.3	2739	1.14	165.3
57	153175	15.3	1678	1.2	91.3
58	274724	27.5	2840	1.52	96.7
59	1709094	170.9	7832	1.68	218.2
60	460022	46.0	3045	1.26	151.1
61	238631	23.9	2108	1.21	113.2
62	120852	12.1	1461	1.18	82.7
63	60539	6.1	1081	1.23	56
65	476358	47.6	3351	1.36	142.1
66	348527	34.9	2810	1.33	124
67	466722	46.7	3185	1.31	146.5
68	61178	6.1	1085	1.23	56.4
69	99280	9.9	1538	1.37	64.5
70	432797	43.3	3013	1.28	143.7
71	151727	15.2	1956	1.41	77.6
72	19481	1.9	705	1.42	27.6
73	167038	16.7	2022	1.39	82.6
74	37940	3.8	885	1.27	42.9
75	38350	3.8	883	1.26	43.4
76	20491	2.0	714	1.4	28.7
77	599899	60.0	3686	1.33	162.7
78	421851	42.2	3564	1.54	118.4
79	155641	15.6	1514	1.07	102.8
81	870034	87.0	4231	1.27	205.6
82	88746	8.9	1223	1.15	72.5
83	272448	27.2	2176	1.17	125.2
84	458089	45.8	3320	1.37	138
85	460598	46.1	3086	1.27	149.2
86	159966	16.0	1714	1.2	93.3
88	137264	13.7	1683	1.27	81.5
89	944300	94.4	5402	1.56	174.8
90	373760	37.4	2802	1.28	133.4
91	191624	19.2	2097	1.34	91.4
92	1056272	105.6	5013	1.37	210.7
93	561254	56.1	3599	1.35	155.9

[i] Dingman S L 1996. Physical Hydrology. Prentice Hall, London.
[ii] Saenz G M 1995. Hidrologia en la Ingenieria. Editorial Escxuela Colombiana de Ingeneieria.

Appendix 2

Code	Verada Name
1	Caimito
2	Socorro
3	La Isla
4	Palermo
5	Panamericana
6	Porvenir
7	La Laguna
8	Los Quingos
9	Ventanas
10	Santa Barbara
11	Cidral
12	Primavera
13	Buenavista
14	Crucero el Roasario
15	La Esperanza
16	El oriente
17	Pescador
18	Crucero Pescador
19	Campina
20	La llanada
21	Potrerillo
22	Cabuyal