RIPARIAN STRIP MODEL FOR EXTENSIVE FARMING ACTIVITIES: THE CASE OF FINCA LA VEGA, COSTA RICA

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Abstract

There is an inseparable relationship between forest, water and soil. The main objective implies the generation of a Forest Buffer Strip where vegetation grows naturally on the banks of streams; in this way it is possible to regulate flows, impact on water quality, and recovery of vegetation and associated ecosystems. In addition, it contributes significantly to the implementation of a mechanism to reduce the sediment transport affecting agricultural production. In order to design this Model Strip field visits and evaluations in the riverbed and its banks were carried out with the purpose of determining significant elements such as estimating the amount of sediment washed, the ideal width of the strip, flow measurements, average biomass produced by the recovering forest, among others. For data analysis, mathematical modeling was applied to provide necessary information to design and implement a viable, functional and replicable model for farms with similar characteristics and conditions.

Keywords: agriculture, forest buffer strips, floods, ecosystems

Resumen:

Existe una relación inseparable entre el bosque, el agua y el suelo. El principal objetivo de esta investigación implica la generación de una franja de bosque donde la vegetación crece de forma natural en las orillas de los ríos, de esta manera es posible regular los flujos, el impacto en la calidad del agua, y la recuperación de la vegetación y los ecosistemas asociados. Además, contribuye significativamente a la implementación de un mecanismo para reducir el transporte de sedimentos que afectan la producción agrícola. Para el diseño de este Modelo de la Franja de visitas de campo y evaluaciones en el lecho del río y sus riberas con el propósito de determinar los elementos significativos, tales como la estimación de la cantidad de sedimentos arrastrados, el ancho ideal de la franja, las mediciones de flujo, la biomasa promedio producida por el bosque en recuperación, entre otros. Para el análisis de los datos, se aplicaron modelos matemáticos para proporcionar la información necesaria para diseñar e implementar un modelo viable, funcional y reproducible para fincas de similares características y condiciones.

Palabras Clave: agriculture, forest buffer strips, floods, Ecosystems

INTRODUCTION

In the context of integrated watershed management, erosion causes sedimentation processes, leading to the silting of rivers and water bodies, they accelerate the processes of desertification, losses and significantly decreases fertility and soil productivity, resulting in a decline in crop production, with the consequent impoverishment of the rural population and promoting rural-urban exodus. Soil loss as a function of water erosion and the development of mathematical models designed to assess these processes, are used as important tools to advance sustainable forest management.

Forest buffer strips correspond to the artificial version of the gallery forests, and they are essential to the rivers banks and reservoirs. They foster the transfer of runoff into the lower soil horizons and the retention of the products of erosion and dissolved salts as a decisive influence on reducing the rates of rise of water bodies and the improvement of water quality and regulation of flows. A Forest Buffer Strip is considered optimal of an width when it absorbs the surface runoff water coming from the top of the slope and in the form of rain, so that, during the rainfall, the volume of water reaching the river network is a none or minimal. The length of the slope and the characteristics of vegetation, soil and slope become elements that are derived from the study of river banks by drawing perpendicular profiles to both sides, from the water's edge to the line the first watershed in the entire river network (Herrero, 2003). This profile consists of a method of sampling and provides a greater accuracy calculation, given that the morphometric characteristics, soil and vegetation are variables to be found along the river, as a fundamental premise is required to divide its course into sections with characteristics as uniform as possible, thereby decreasing the variations and thus the probable error.

METOHODOLOGY

First Stage: Data collection for creating model strips, vulnerability and risk data should be generated in the basin.
a. An experimental parcel was established in a high farming activity area (livestock and grains).
b. A collection of information from the suspended solids and temperate along the basin were carried out in summer and in winter seasons in selected sampling spots.
c. An analysis of the mainstream coverage of the basin was performed.
d. Measurements of the slope of the basin were conducted.

Second Stage: Development of maps to characterize the basin:

• Thematic maps on a scale 1: 25000 and 1: 10000, using Geographic information systems (GIS) platforms were designed.

Third Stage: Analysis of information and generation of suggested model.

This stage is been conducted and some information and results have been generated.

Potential Erosion in the area

The type of soil determines the potential erosion; it is the thickness of organic horizon with the possibility of being lost due to accelerated erosion as a result of the alteration of natural conditions and under an operating system without practicing soil conservation measures. The determination was made using the same formula, derived from the universal equation:

Ep (t / ha / year) = $R * K * LS$

Where:

Ep: Erosion potential; R: Factor of precipitation; K: topographic factor, LS: Factor relief. The universal equation is a mathematical model developed in the USA by Wischmeier and Smith in 1974.

Current Erosion:

Current erosion of the area was determined with the deduction of the formula. It takes into account the vegetation factor (c) for each type of soil. Besides direct observations were made in the field: Ea (t / ha / year) = R * K * LS * c W: Current Erosion; R: Factor of precipitation; K: Topographic Factor, LS: Factor relief. To evaluate erosion soil loss, the methodology proposed by FAO in 1999 was applied.

Determining the width of the forest buffer strips

To determine the width of the strip, it was used the formula proposed by Herrero in 2003:

$$a = \frac{L\,(i - Wm)}{(Wf - Wm)}$$

Where:

a - forest strip width (m); L - Length of the slope measured from the water's edge to the first watershed in horizontal projection (m) i - maximum intensity of the rainfall rate for a given probability (mm / min.) Wm - average infiltration rate soil on the slope (mm / min); Wf - Infiltration rate of the soils of the forest strip (mm / min).
The length of the slope measured from the water's edge to the first watershed in horizontal projection (L) was determined by the formula.

For profiles of a single stretch/section of the river:

$$L = l \cos \alpha$$

For profiles of more than one stretch/section: $L = l_1 \cos \alpha_1 + l_2 \cos \alpha_2 + l_3 \cos \alpha_3$

Where:

l_1, l_2, l_3 inclined lengths of each subsection (m)

$\alpha_1, \alpha_2, \alpha_3$: angle of inclination of each subsection

Infiltration rates of soils in the forest strip (Wf).

The selection was made taking into account that forest plantations created as buffer forest stripes should include soil conservation measures and others that increase the infiltration capacity, the value assumed in this case was the maximum value from Table 1, provided by Herrero et al (2003).

Average infiltration rate of soil profile (Wm).

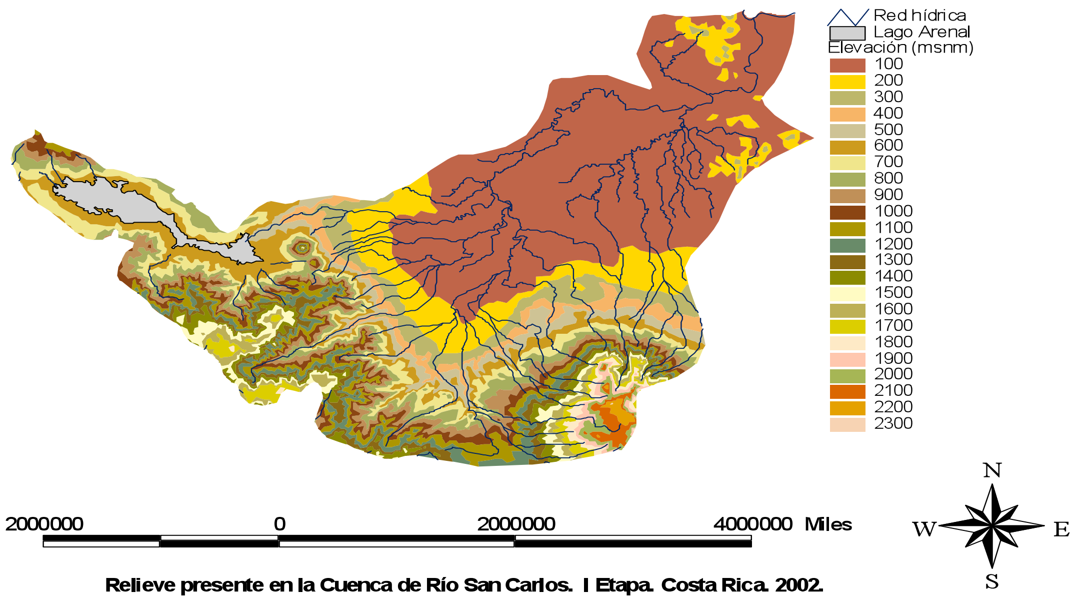
It was selected taking into account the characteristics of each profile in terms of soil type, vegetation, use, etc.

$$Wm = W_1 * L_1 * \cos \alpha_1 + W_2 * L_2 * \cos \alpha_2 + ...+ W_n * L_n * \cos \alpha_n$$

Characterization of research area

The San Carlos River Basin is located in the northeastern region of Costa Rica, between the north Lambert coordinates 425683 - 519405 and 307315 -236810, with an area of 3122.1 km2. The main constituent counties are San Carlos, San Ramon, Alfaro Ruiz (Alajuela) and Tilarán, Guanacaste. There are also small portions of Valverde Vega and Naranjo (Alajuela) and Sarapiqui in Heredia.
Using an approximation of the number of people in those districts where 100% of its area is not within the basin and adding the inhabitants of the districts that are completely in it, and considering the information derived from 2000 census. The total population of the San Carlos River Basin is about 134 000 inhabitants.

Map 1. Digital Elevation Model



Relieve presente en la Cuenca de Río San Carlos. I Etapa. Costa Rica. 2002.

Table 1. Description of the morphological features of the San Carlos River.

Characteristics	Value
1. Surface (S)	3122.1 Km2
2. Perimeter (P)	333.4 Km
3. Length of main channel (Lr)	141.2 km
4. Maximum height	2320 m.s.n.m
5. Minimum height	20 m.s.n.m

Source: Chaves (2002).

The capacity of land use relates to their productive potential. In Costa Rica, Decree No. 23214-MAG-MIRENEM of June 6, 1994, establishes the "Methodology for the Determination of Capacity for Land Use in Costa Rica". Under this decree the classification system comprises three levels: classes, subclasses and management units. A Class is defined as land groups with similar conditions in the relative risk of deterioration limitations for use in a sustainable manner. Classes range from I to VIII, and limitations on use intensity increased progressively in the same direction, that is, Class VIII does not allow any agricultural, livestock and forestry productive activity, so it should be used only the protection of resources.

Table 2. Capacity to use different activities

Class	Usability
A	Agricultural use Classes I, II, III, IV y V
VF	Natural forest management or natural regeneration VI: Reforestation or permanent crops VII: Mane natural forest or natural regeneration VIII: Protection

Subclasses of usability are defined by the limitations of erosion, soil, drainage and climate. Management units constitute a subdivision of subclasses that indicate the specific factors that limit their use in agriculture and forestry (Chaves, 2002).

Table 3. Forest change in the basin of 86 to 97

Land use	Area (Km2)	% Of total basin area
Forest cover	1074,4	34,4
Non-forest cover	1569,0	50,3
Water	91,8	2,9
Loss of forest	120,9	3,9
Forest recovery	150,0	4,8
Total	**3122,1**	**96,3**

Forestry cover in 1997, using remote sensing, estimated that the area had a forest cover of 34.4 percent, and deforestation close to one percent per annum. (Geo-Costa Rica, 2000).

It was also determined that agricultural and livestock productions have been developed without any planning. The same has happened with reforestation programs, protection of water resources and biodiversity, where a prioritization criterion has been applied instead of a plan of Land Management.

Soils

To determine the land use an analysis of soil maps in 1: 25000. It was determined that most of the soils in the basin under study correspond to Andisols that are characterized by volcanic materials. Also in the working area of the basin production of tubers, plantains and extensive livestock farming is representative. The soil type favors these productive activities.

Results and analysis in the experimental plot.

The fundamental goal is to determine model, which provides the ideal size of the strip to reduce sediment flow into the riverbed, and remains friendly to the productive activities of the basin.

Figure 1. San Carlos River Basin

The research is being conducted in an experimental area on an agricultural production farm, its activity is focused on rice production and cattle fattening. Experimental measurements of area being made, to register the decrease of sediment and solids retention due to overflowing of the river, because certain months of the year that rainfall causes large floods.

Description of selected work area

Details of the study area over the annual runoff in the basin:

Aspect	
Average annual runoff	**2811.5 mm.**
Annual Flow	**278 m^3/ seg.**
Annual Rainfall	**4039 mm**
Average slope of work area	**5%**

According to previous research this basin is contaminated as a result of the large amount of chemicals used in production or for vaccine activity where all waste is introduced into the riverbed. As a result of this contamination, the main channel waters are in a condition of pollution that are neither suitable for direct consumption by the population of this area, or use in agricultural irrigation in the lower basin.

The vegetation is determined by local ecological factors in the basin, soil and climatic characteristics, different microenvironments, relief, and the human use of different vegetation communities affected, among which stand out the vegetation small gallery forests. The vegetation is distributed throughout the river system of the basin, it has high degree of anthropization resulting from the expansion of intensive agriculture, population growth, and pasturage and cutting down of species of economic value. It is important to highlight the presence or hydroelectric plants along the basin causing disturbances in the hydrological regime and erosive influence on vegetation.

Figure 2. Intensive farming in the riverbanks

Vegetation is represented in several layers, trees, shrubs and herbaceous. This vegetation is distributed as follows: in the upper basin it is a covered by protected forest areas, the middle area consists predominantly of patches of gallery forest which are covered by shrubs and herbaceous, and at bottom of the basin pasture, devoted to extensive agriculture, is concentrated.

This project is conducted on an experimental area intended to have a natural regeneration process to protect and prevent the banks of river from erosion. It is expected to obtain forest strips where native species from the basin grow naturally.

Figure 3. Natural regeneration areas.

Width of a forest strip.

Areas with the greatest erosive weakness in the basin corresponds to the banks of rivers, different factors converge; involving runoff from the upper parts of the slopes, lateral erosion produced by the river flow. Therefore, strips in both sides of the riverbed become essential areas to decreases the process of erosion and sediment transport in the river, thereby influencing in a decisive way the water quality and regulation of the flow (Herrero, 2003). After calculating the width of the forest strip in the experimental area it was possible to determine that the strip with natural regeneration corresponds to 37.89 meters.

In addition these regulatory and anti-erosion, the strip provides a range of environmental and social benefits. Among those benefit it is possible to mention:

• Extension of the life of the reservoirs by reducing the rate of siltation.

• Improving water quality by mitigating the pollution load carried by surface water.

• Protection of the riverbanks and river flows.

• Soil protection against erosion.

• Stabilization of flows and reduction of flood levels

• Improving the conditions for aquatic fauna since the stripe keeps water temperature lower and more stable.

• Provide shelter and food for wildlife.

• Strips promote biodiversity.

• Protecting crops against plague, diseases and damaging winds.

• Enhancement of the Landscape by providing natural regeneration from endemic species.

Conclusions

- Data and satellite referencing was obtained from the study area, facilitating the creation of maps with essential information to development and maintenance of the buffer forest strips.

- Describing and studying the status of buffer forest strips in these particular areas facilitates the follow up of species to be planted.

- With the data register obtained it is undemanding to keep track and improve land use in the sector under study.

- Designing and testing a strip model, help apply the scientific principles and the learned lessons, in order to implement similar methodologies in other areas of the country.

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