Using GIS to Plan, Implement and Monitor Sustainable Land Use at Project Level

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1. Introduction

This paper describes the application of a Geographical Information System (GIS) in a rural integrated development project in Costa Rica. Within the project, geographical information is used to plan, implement and monitor land use. First the project area is briefly described. Secondly the Land Use Plan, "Plan de Ordenamiento Territotial" is introduced as part of the project planning process. Thirdly the strategies used to implement the POT are described and finally the monitoring of land use change and the factors affecting this change are analyzed.

2. Characterizing the area[1]

The DRIP - project is a rural integrated development project in the southern part of the Peninsula Nicoya at the pacific coast of Costa Rica. The total area of the three districts, Paquera, Lepanto and Cobano, which form the projects mandate covers 1075 square kilometers (aprox. 2% of the total area of Costa Rica). The area can be characterized by it's climate which is a transition from dry tropical to humid tropical with a dry season from December until May, temperatures have an annual mean of 27 degrees Celsius with an average annual rainfall from 1565mm in the northern part to 2688mm in the southern part. The geomorphology consist of undulating hills with small rivers and streams, the sometimes very steep hills and small valleys and floodplains. The highest point of the three district is Cerro Pozo with its 755 m above sea level. The aquifers as well as the rivers are small and tend to cause insufficient water supply during the dry season.

The population counted 15090 persons in 1992, the population density has been decreasing since 1973 from 17.9 habitants/km2 to 14.0 habitants/km2 in 1992.The main part of the populations lives in small villages near the coast. The main activity of the economic active population in 1992 is agriculture secondly in services, mainly within the area of tourism.

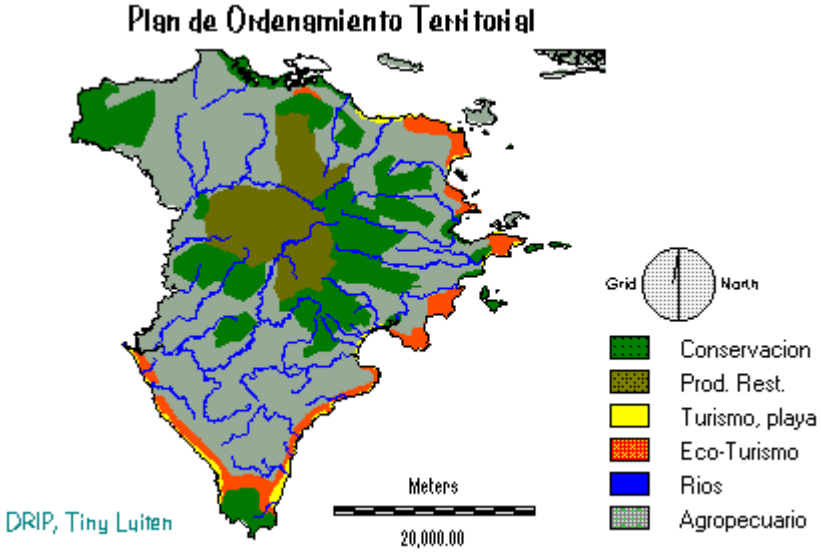
3. Planning Sustainable Land Use -The DRIP project

The three main objectives of the project are:

1. Install a local capacity to sustain the development processes
2. Increase the quality of life of those with less socio-economic resources
3. Promote sustainable use of natural resources

[1] Information from Plan de Ordenamiento Teritorial, DRIP, 1992

The project has been planned for a period of nine years starting in 1990. In 1992, during the first phase, a "Plan de Ordenamiento Territorial", POT, a kind of Land use Plan was made. The plan, based on multidisciplinary studies and integrated criteria for sustainable development used criteria's of socio-cultural, economic and agro-ecological origin to delineate five development intervention areas (see map): 1) Conservation, 2) Restricted Production, 3) Tourism, 4) Eco-Tourism, and 5) Agricultural/Extensive Grazing. The criteria of agro-ecological and socio-cultural origin were included in the map-overlay process, economic criteria were used only in the final definition of limits[2].



One of the results of the intervention map POT was a government decree describing the intention of the government to protect the delineated area for nature conservation (see implementation section). Another result was the use of it to plan and prioritize project

[2] **Maps used to delineate management areas : Satisfaction level of services (health, education and housing), Sustainability level of production systems, Land unit map (soil, geomorphology, geology, hydrology), Demographic map**

activities. A map delineating priority areas for project intervention during it's second phase has been derived from the POT map.

This analysis provoked in a change in the internal project organization structure in order to attend better to the problems of the different areas using interdisciplinary teams:

- For the first 2 management areas 'Conservation and Restricted Production': an interdisciplinary team was formed to implement the objective of more ecologically sustainable land use and increase quality of life.
- For the last management area 'Agricultural and Extensive Grazing': an interdisciplinary team was formed to implement the objective to develop the production potential of the small and average sized farms introducing agro-ecological practices.

Another two teams were formed, one to attend the small enterprises in the villages and another to work with fishermen and their families in the coastal zone. The first area became a project priority because of the third project objective as well as because of the absence of government institutes and other organizations.

4. Implementation -Project Intervention

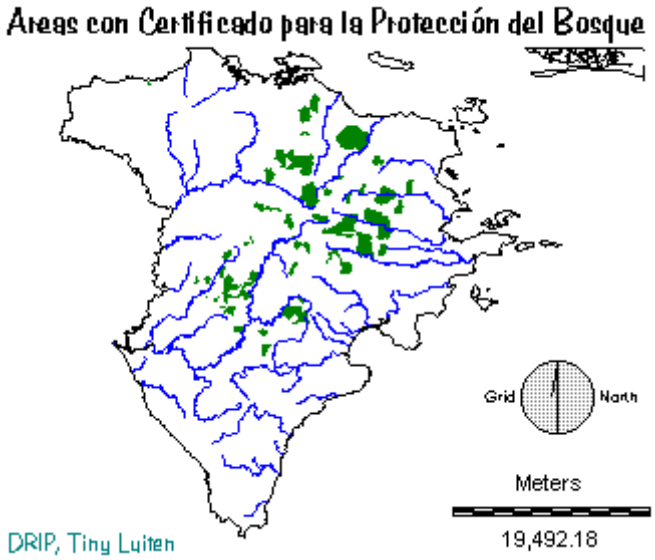
The Geographical Information System is also used to apply for government funds to actively implement the Land Use Plan, especially to indicate and prioritize areas for nature conservation like biological corridors.

The Plan indicates an area to be protected because of its characteristics. Firstly because most of the rivers have their sources in this area. Secondly because of the steep slopes it is hardly recommendable to cultivate or to use for grazing the area. Thirdly because of the almost absence of population and in fourth place because of the absence of infrastructure. The government of Costa Rica accepted the suggestion and declared this area "Zona Protectora de la Peninsula Nicoya" (ZPPN). This decree describes the intention of the government to actively protect the area. Actually the area is privately owned. Therefore the implementation of the decree depends more on decisions of the landowners than on government actions. Of course it's a priority area for government incentives directed at nature conservation, and control of illegal activities such as poaching and tree felling.

The government of Costa Rica has a incentive for natural regenerating areas called "Certificate for the Protection of Forest" (CPB), later renamed "Certificate for the Conservation of Forest" (CCB). The incentive comprises a contract in which the owner declares to protect the area in exchange for an annual payment of $45,- per hectare. The contract is annually renewed for a period up to five years in total. In 1995, the first year of existence of the certificate, there were certificates for 20.000 hectares in all of Costa Rica. To attract the assignation of some 2000 ha, equal to 10% of the total incentive, to the project area of only 2% of the CostaRican territory, a map was made using criteria for nature conservation like, density of water sources, steep slopes, soil depth, accessibility and vegetation units. The area in need of protection within the project area still covered some 20.000 ha. To prioritize within this area the concept of Biological Corridors was included in the analyses. For 1995 the incentive was given to 36 owners covering an area

of 1500 hectares, in 1996 another 2000 ha were included. The map above shows the 3500 ha with a contract.

In 1996 a new land use map has been made. With this map an implementation plan for the Biological Corridors is being made, using land evaluation and GIS techniques to indicate the most suitable path. Criteria's include food, water and protection from human interference. Criteria's are defined, analyzed and discussed within a group of inhabitants of the peninsula, some of whom also represent the ministry of natural resources, the regional ecological NGO and local ecological committees. Without this participation implementation



would be impossible because of the private ownership of land. The implementation of the plan will rest upon the local ecological committees and the regional ecological NGO who will negotiate and promote the concept with the landowners using different government incentives for landowner willing to protect the natural vegetation on their farms.

Other project activities for the Conservation and the Restricted Production areas are:

- campaigns to control forest fires
- ecological awareness
- environmental education
- incentives for the protection of water sources
- introduce and give training in the use of new production techniques besides stimulating and strengthening of the regional ecological NGO and local ecological committees.

5. Monitoring Land Use

The change in land use has been analyzed at three levels: 1)for the whole project area on three different points in time, 2) per management area during the project period 1990 until 1996 and 3) per farm also for the period 1990 - 1996

5.1 Project area

In order to obtain an idea of the changes in land use a set of aerial photos was taken in January 1996, interpreted, digitized and compared to the interpretation of aerial photos taken in January 1990. In this project period the land use has changed considerably.

Table 1 Land use types

Land use type	1984	1990	1996
Agriculture & Grazing	86 %	44.0 %	28.2 %
Regenerating	13 %	54.5 %	70.5 %
Mangrove	1 %	1.5 %	1.3 %
total	100 %	100 %	100 %

Other tendencies besides the project's influence that might have caused this changing of land use include:

1. Financial crisis in extensive animal husbandry inducing low beef price.
2. Decreasing soil fertility and soil depth because of erosion.
3. High production costs in agriculture as well as in extensive grazing
4. High labor prices - opportunities in tourism and construction
5. Government politics to stimulate natural regeneration with a financial incentive (CPB).
6. Increased presence of the ministry of natural resources due to a decentralization process.

5.2 Management area

The land use change per management area of the Land Use Plan indicate a more sustainable land use in 1996.

Table 2. Type of land use 1990 per unit of the Land Use Plan (POT)

Land Use	Conservation	Restricted Production	Eco-tourism	Agriculture & Grazing
Agriculture & Grazing	27 %	38 %	22 %	56 %
Regenerating	67 %	62 %	77 %	44 %
Mangrove	6 %	0 %	1 %	0 %
total	100 %	100 %	100 %	100 %

Table 3. Type of land use 1996 per unit of the Land Use Plan (POT)

Land Use	Conservation	Restricted Production	Eco-tourism	Agriculture & Grazing
Agriculture & Grazing	10 %	17 %	11 %	41 %
Regenerating	85 %	83 %	89 %	59 %
Mangrove	5 %	0 %	0 %	0 %
total	100 %	100 %	100 %	100 %

Standardizing the differences to the 1990 percentages the land use change is clearly different for the different areas indicated by the POT. The relative decrease in area used for agriculture and extensive grazing is largest in the conservation area while it's lowest in the area assigned for agricultural and grazing purposes.

Table 4. Difference per type of land use per unit of the Land Use Plan (POT) standardized 1990

Land Use	Conservation	Restricted Production	Eco-tourism	Agriculture & Grazing
Agriculture & Grazing	- 63 %	- 55 %	- 50 %	- 26 %
Regenerating	+ 27 %	+ 34 %	+ 16 %	+ 34 %
Mangrove	- 17 %	0 %	- 100 %	0 %

5.3 Farm

A great amount of factors influence land owners to decide upon the use of their land. An intend to find some of these factors has been made using information at farm level. At this level some physical characteristics of the farms like slope, distance to the road and property size have a strong positive relation with the relative area per farm left to regenerate.

Using a database of 1179 farms the relation between influencing factors and the area left regenerating per farm (%) have been analyzed using Idrisi for Windows and Excel. An indication of the project's influence is reflected in the difference in area left to generate per management area: Land owners within the Conservation and Restricted Production area have an average of 74% of their farm regenerating in 1996 (N=426). In 1990 this was 51%. Landowners within the Agriculture/Extensive Grazing area have an average of 57% of their farm regenerating (N=685). In 1990 this was 37%.

The tendency toward a more sustainable land use can be found in the factors that have a statistical significant relation with the area per farm left to regenerate. This analysis also confirms the applicability of some of the criteria used to delineate the management areas.

Table 5. Physical characteristics of the property

- slope:

	1990	1996	N
Average slope of 0-8%	21%	22%	74
Average slope of 8-15%	22%	37%	54
Average slope of 15-60%	25%	52%	199
Average slope of > 60%	51%	72%	824

- size of the property:

	1990	1996	N
less than 50 ha	41%	61%	674
50 ha to 200 ha	44%	67%	392
more than 200 ha	52%	75%	103

- distance to the road:

	1990	1996	N
0 to 1 km	33%	50%	683
1 to 2 km	49%	71%	308
> 2 km	55%	82%	178

6. Conclusion

The geographical information analyzed in GIS helped to indicate priority areas for the project intervention as well as for government interventions. Furthermore it helped to measure land use change as well as analyzing and quantifying factors that influenced the changes in land use. Although land use change depends on a lot of the factors influencing land owners to decide upon the use of their land, the analysis finds significant differences in percentages of regenerating vegetation per farm are in the different management areas attended by the project. Also significant differences are found related to physical characteristics, indicating a more sustainable use. Thus, the geographical information and the GIS are a very useful tool in the process of planning, implementation and monitoring of sustainable land use.