"SPATIAL ECONOMIC VALUATION OF SELECTED HYDROLOGICAL FUNCTIONS IN THE RIO CABUYAL"

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1. INTRODUCTION

The hydrology of the Rio Cabuyal is defined here as:

1. the good: water, run-off
2. production: catchment area, (precipitation)

I: Environmental functions of the Rio Cabuyal

The hydrology of the Rio Cabuyal performs environmental functions which may directly or indirectly benefit humans. Following De Groot (1992), these functions can be classified as:

1.	**Regulation functions**	
1.1	Interaction with atmosphere:	Regulation of local and global energy balance Regulation of the chemical composition of the atmosphere Regulation of the chemical composition of the oceans Regulation of local and global climate (inc. hydrological cycle)
1.2	Runoff and river discharge:	Regulation of the chemical composition of the oceans Prevention of soil erosion and sediment control
2.	**Carrier functions**	
2.1	Water availability	Crop growth, animal husbandry, aquaculture, recreation
2.2	Runoff and river discharge	Crop growth, aquaculture, energy, recreation
2.3	Groundwater table	Crop growth, animal husbandry
2.4	Water quality	Aquaculture, recreation, nature conservation
3.	**Production functions**	
3.1	Water availability	Water
3.2	Runoff and river discharge	Food, water
3.3	Groundwater table	Water
3.4	Water quality	Oxygen
4.	**Information functions**	
4.1	Water availability / runoff	Aesthetic, spiritual, historic, cultural / art, scientific / educational

These functions benefit not only the local people in the Cabuyal valley, but also the global populace via the regulation functions and theorectically through the information functions (if they exist for the Cabuyal). The degree of benefit will vary considerably depending on the 'strength'or significance of the environmental function. For instance, although the regulation of the chemical composition of the atmosphere has tremendous significance for the global populace, the Rio Cabuyal only exerts a tiny influence on this function. At a local level, the production functions of the Rio Cabuyal (such as water consumption) are of more significance than the global functions. Nevertheless, the Rio Cabuyal does have a role in global regulation functions albiet of little significance.

II: Measuring the strength of the environmental functions of the Rio Cabuyal

Measuring the strength or significance of the environmental functions is a daunting task. The precise workings and dynamics of many of the regulation functions is clouded in uncertainty. As such it is very difficult to determine the role (and significance) of the Rio Cabuyal in these functions. It is easier to determine the strength of production functions, where consmuption of the good can be more easily measured.

1. Regulation functions

1.1 Regulation of local and global energy balance

Absorption of sun´s rays by water -> results in hot / cold areas (changing energy balance). Volume of water influences amount of energy absorbed.

1.2 Regulation of the chemical composition of the atmosphere

Hydrological cycle influences chemical composition of the atmosphere (CO2 is absorbed by the oceans, and rivers ?). Volume of water influences amount of CO2 absorbed in the ocean and Rio Cabuyal.

1.3 Regulation of the chemical composition of the oceans

Volume of H2O and chemical composition of the Rio Cabuyal.

1.4 Regulation of local and global climate (inc. hydrological cycle)

Volume of water (into oceans and evaporation) influences hydrological cycle, local & global climate.

1.5 Prevention (?) of soil erosion and sediment control

Increased run-off can increase soil loss. Potential soil loss, tonnes (from USLE ?).

(2. Carrier functions

(see production functions)

Crop growth, animal husbandry, ¿energy?, ¿recreation?, ¿nature conservation, ¿habitat?)

3. Production functions (consumption)

3.1 Water

Volume of water consumed through household use, agricultural (irrigation) and industrial purposes.

3.2 Food

¿Volume of crops produced without irrigation? i.e. only includes crops grown through precipitation and watertable ??

3.3 Oxygen

Net oxygen production in the Rio Cabuyal: Gross production - respiration.

4. Information functions

4.1 *Aesthetics*: Survey - ranking importance of river sections for aesthetic purposes
: Contingent valuation.
¿Scientific / edu.?
¿Spiritual, cultural / art, historic?

Any comprehensive measurement of the above environmental functions would require large quantities of physical data about the river such as: volume of water, chemical composition, sediment load, water quality, BOD, river fauna etc. These data would then have to be related to the environmental functions. e.g. the role of X cubic metres of water in the Rio Cabuyal in regulating local and global energy balance.

The measurement (if they exist) of information functions would require social/humanistic data to be collected by interviewing the local populace.

III: The economic value of the environmental functions of the Rio Cabuyal

Most of the environmental functions will provide benefits of some sort to the local and global populace. Environmental economics methods can be used to determine the economic value of these benefits.

1. Regulation functions

1.1	Regulation of local and global energy balance	(N/A)
1.2	Regulation of the chemical composition of the atmosphere	(N/A)
1.3	Regulation of the chemical composition of the oceans	(N/A)
1.4	Regulation of local and global climate (inc. hydrological cycle)	(N/A)
1.5	Prevention of soil erosion and sediment control	(Soil loss in $)

(N/A: Not sure if much valuation work has been done on these functions)

2. Carrier functions

(see production functions)
Crop growth, animal husbandry, ¿Energy?, ¿Recreation?, ¿Nature Conservation?, ¿Habitat?

3. Production functions (consumption)

3.1 Water
Market value: How much is volume consumed worth according to current market prices ?. i.e. How much would it cost to get water from alternative sources ?

3.2 Food
¿Amount and market value of crops grown without irrigation ?. - how important is water (precipitation - watercatchment and the water table) as a factor of crop production ?

3.3 Oxygen
Value of net oxygen production in the Rio Cabuyal: Gross production - respiration
(Mexico City: Oxygen producing devices selling oxygen for US$ 2 per minute - De Groot, 1992, p160 - R.De Groot, Functions of Nature, ISBN 9001 35594 3)

4. Information functions

4.1 Aesthetics

Contigent valuation:

- willingness to pay for future availability of the Rio Cabuyal
- willingness to accept compensation following loss (degradation) of the Rio Cabuyal

Accurate calculation of the economic value of many of the environmental functions would be exceedingly difficult, if not impossible without the necessary 'strength'measurements identifed in the previous section. However, if such measurements and data were available then the valuation results of other studies could be used as a basis for assigning values to Rio Cabuyal functions (benefits transfer theory).

Given the absence of the necessary data sets for the Rio Cabuyal and general lack of knowledge concerning the measurement (workings and models) of global regulation functions, no attempt will be made to measure and value regulation and information functions. Instead, an attempt will be made to demonstrate the possibilities of using GIS for spatial economic valuation, focusing on the production functions of the Rio Cabuyal hydrology.

2. METHODOLOGY

2.1 The production functions of the Rio Cabuyal

The hydrology of the Rio Cabuyal is currently used for household water consumption and crop production through irrigation and natural precipitation, run-off and the water table. In addition, the Rio Cabuyal provides water (and run-off ?) to the Rio Ovejas which has production functions downstream (current and potential).

The focus is on household water consumption and downstream use of the Rio Cabuyal.

2.2 Economic benefits from household consumption.

Two water tanks, La Esperanza and El Oriente are used to supply water to households in the Rio Cabuyal. La Esperanza is supplied with water directly from the river, whilst El Oriente is supplied through the water table (well).

The water consumed via the water tank is currently treated as a 'free' good, with locals paying a minimal charge for maintenance of the water tanks but nothing for the good itself. An estimate of market value for the good was based upon the number of consumers and the costs of supplying them from an alternative source:

Water tank	Number of consumers	Daily consumption (per head)	Benefit per 50 litres (per head)	Daily benefit (Total) (US$)	Annual benefit (Total) (US$)
El Oriente	2,100	250 litres	500 pesos	8,750.00	3,193,750.00
La Esperanza	2,800	250 litres	500 pesos	6,562.50	2,395,312.50

(Source: Rubiano, 1995, pers.com.)
(Exchange rate: US$ 1 = 800 pesos)

When the water supply from the tanks runs out, the consumers have to fetch water from the river itself, at a cost of 500 pesos per 50 litres. In the absence of more suitable data, this was taken as the benefit value of the water supplied at the water tanks. This gave figures of over US$

3 million for El Oriente tank and over US$ 2 million for La Esperanza tank. These figures are very coarse estimates and may actual undervalue the price of the good, since they only reflect labour costs for transportation, and do not include any production costs (i.e. costs of producing water).

2.3 Economic benefits from downstream consumption.

These are based on the report by (R. Knapp and others.??) which estimates the value of the water and run-off of the Rio Cabuyal into the Rio Ovejas for use downstream at about US$ 2 million.

2.4 Mapping economic benefits from household consumption.

Using GIS, economic values can be assigned to those areas (or cells) involved in the production of the good (benefit). If a cell produces a good which has economic benefits, then an economic value can be assigned to that cell. In order to do this it is necessary to identify which cells are involved in the production of the good, and their significance or role in the production of the good. In the case of the Rio Cabuyal water tanks it was necessary to determine where the water which supplies the tanks is coming from (being produced).

2.4.1 Mapping economic value for La Esperanza

La Esperanza water tank supplied by several streams. The cells producing water (production cells) for these streams

The TRACE command in ArcInfo was used to select all the streams upstream of the water tank. These were then visually overlayed on top of a DTM of the area and the catchment area for the streams was manually interpreted by following the topography of the DTM (using the SELECTPOLYGON command). The catchment area was then saved as a separate grid layer. The INTcommand was then used to convert the catchment grid to an integer grid (INT) containing the value 1 for all cells. The number of cells in this INT grid was found from the .VAT file - it contained 67,154 5 metre cells.

It was assumed that all cells 'produced'(or captured) the same quantity of the good, although in reality this is unlikely to be the case, since the volume of run-off depends upon the land cover, soil permeability and evapotranspiration. Assuming all cells have the same production value, then the benefit value per cell can be found by dividing the total benefit value by the number of productive cells :

3,193,750 (total benefit value) / 67, 154 (number of productive cells) = 47.64

So the benefit value for La Esperanza in each productive 5m cell is US$ 47.64 (per annum). The catchment grid (containing cells with value ,1) was multiplied by 47.64 to give each cell in the catchment area a value of 47.64.

2.4.2 Mapping economic value for El Oriente

El Oriente water tank is supplied by from the watertable (underground spring ?). Since there were no GIS data on the geology (or watertable) it was assumed that the water supply for the El Oriente came from higher ground.

The height of the El Oriente water tank was estimated at 2155 m. All cells higher than 2155 m were then selected from the DTM grid. Then a catchment area was selected from these cells, which only included cells whose height values increased consecutively from the El Oriente. The

number of 5 m cells in the catchment area for the El Oriente was 24, 828.

Again, the same assumption was made that all the cells in the catchment area had the same production function. The benefit value was then calculated by dividing the total benefit for the El Oriente by the number of cells:

2,395,312.5 (total benefit value) / 24, 828 (number of productive cells) = 96.48

Therefore the benefit value for El Oriente in each productive 5m cell is US$ 96.48 (per annum).

The catchment grid containing cells with value 1, was multiplied by 96.48, to give all cells in the catchment area a value of 96.48.

2.4.3 Mapping downstream economic value

The downstream benefits (current and potential ?) of water from the Rio Cabuyal were estimated at $2,000,000. In order to map the economic value of the water benefit, it is first necessary to determine the spatial variability of the production function, i.e. where is the water coming from ? Ideally, I would have liked to know how much water flows into the Rio Cabuyal from each (5m) cell in the catchment area. As these data were not available, the spatial variability of the production function taken as the variations in flow rates at different points in the river.

The production function (or strength) of three sections was calculated on the basis of the flow rate from the section:

Section	Flow Rate (May 94)	% of total flow rate	Flow rate (Sep. 93)	% of total flow rate	Average % of total flow rate
1	0.609	44.75	0.379	65	54.875
2	0.439	32.26	0.094	16	24.13
3	0.313	22.99	0.110	19	20.995

The location of the sample points 1,2 and 3 on the RIo Cabuyal was known. These were used as origin points in the TRACE command to select all the streams upstream of that point (but in the case of 2 and 3, downstream of the previous sample point). Once stream coverages for sample points 1,2 and 3 were selected, the catchment areas for these stream selections were obtained though visual interepretation (using SELECTPOLYGON) of the DTM. The catchment areas contained 5 m cells, each with the value 1. Again, as with the water tanks, it was assumed that all cells within the same catchment area contributed the same quantity of water to the Rio Cabuyal. The number of 5 m cells in each catchment area was known from the catchment area grids and was used to calculate the benefit value for each productive cell:

Section	% of total flow rate	Benefit value (US$)	Number of 5 m cells	Benefit value per 5 m cell (US$)
1	54.875	1,097,500	552, 013	1.99
2	24.13	482, 600	432, 527	1.12
3	20.995	419, 900	334, 685	1.25

The total downstream benefit value for the Rio Cabuyal was $2,000,000. This figure was then divided into the three sections on the basis of their production value (% of total flow rate). These figures were then subdivided among the number of cells in each section's catchment area to give benefit value per cell. The catchment grid for each of the three sections was multiplied by the appropriate benefit value (1.99, 1.12 and 1.25) to give three economic value maps for downstream benefits.

2.4.4 Output

The following grids were produced:

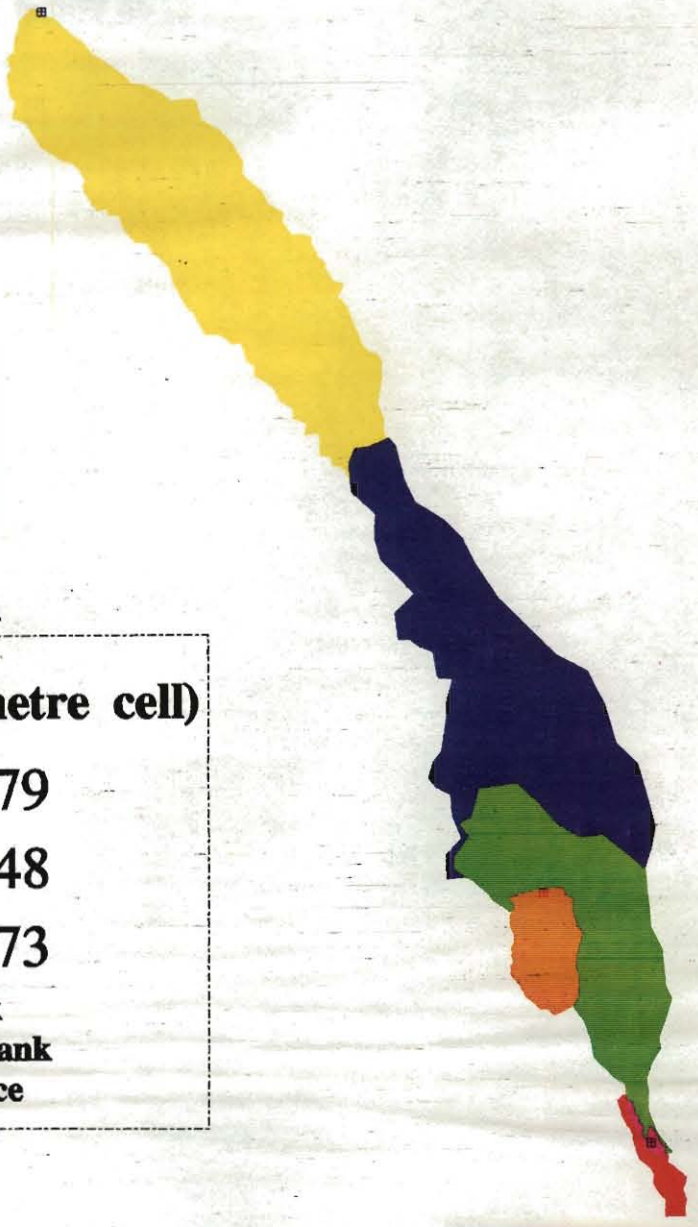
/paloma/cauca/jeremy/va	economic value of La Esperanza
/paloma/cauca/jeremy/vb	economic value of El Oriente
/paloma/cauca/jeremy/v1	downstream economic value - for river section 1
/paloma/cauca/jeremy/v2	downstream economic value - for river section 2
/paloma/cauca/jeremy/v3	downstream economic value - for river section 3
/paloma/cauca/jeremy/valt	total economic value = va + vb + v1 + v2 + v3

AML to display total economic value grid:

/paloma/cauca/jeremy/jerem.aml

Economic benefits of selected hydrological functions

CUENCA DE CABUYAL



LEYENDA

Value (US$ per 5 metre cell)

	1.12		48.79
	1.25		96.48
	1.99		97.73

- El Oriente water tank
- La Esperanza water tank
- Rio Ovejas convergence

Selected hydrological functions : estimated value of benefits

Water consumption (household use) in the Cuenca de Cabuyal: La Esperanza - $3,19[illegible]
El Oriente - $2,39[illegible]

Water consumption downstream - in the Rio Ovejas - $2,000,000

ESCALA 1:125000