Mapping, analysis and monitoring of the natural resource base in micro-watersheds: experiences from Nicaragua[1]

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Background: about (micro)watersheds

Recently, interest in watersheds and watershed management has gained new ground. Agricultural and social sciences (eg rural sociology) in a variety of countries have moved beyond the plot, farm/household as well as community levels. The complexity of natural resource management problems have made scientists aware that the best of agronomy, ecology, policy research and socio-economic research needs to be brought together to understand resource (flow, use and degradation) dynamics. New insights and methodological tools from landscape ecology, systems theory, actor-oriented rural sociology and learning theory are brought together to provide more adequate and useful knowledge. The International Centre for Tropical Agriculture's (CIAT) "Hillsides project," to which we will refer here, is but one example of a project that uses this new approach to deal with the multiple aspects of natural resource management questions.

Watersheds are considered a useful unit of analysis and action, because they represent a basic natural system in which soil-water interdepencies condition land-use patterns at different scales, from the plot to the farm to the micro-watershed and watershed level. Hence, watersheds are a useful unit for physical reasons : they are drained by a single water course flowing downhill -irrespective of political boundaries- that holds inter-related natural resources (water, soil, vegetation) linking uplands and downstream areas. They are also a unit of multiple and interdependent, sometimes conflicting, interests.

Two key elements should be considered when dealing with watershed *management* : 1) the different interests of people in the watershed (users) are assymetrically interdependent (example : upstream use of land and water will directly affect downstream use options) and many problems related to resource management are trans-boundary (eg deforestation, soil erosion, pests and diseases) ; 2) a degree of uncertaintly exists as to the impact of this interdependence (example : downstream users do not know for sure how upstream users will behave, whether they will or will not consider downstream effects of their actions).

The issue of scale and decision-making hierarchies therefore is a complex one. There is a need to look at spatial complexity : plot-farm-minicatchment-watershed-agroecological zone-hillsides as well as at organizational complexity : individual(s)-household-usergroup-community-municipality-department-country-international system.

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[1] This paper is based on fieldwork carried out during 1997-1998 as part of a professional secondment from the International Development Research Centre (IDRC), Canada to the International Center for Tropical Agriculture (CIAT). The research in Nicaragua was funded by IDRC and the Swiss Development Cooperation (SDC).

Transboundary effects (and related assymetrical externalities, i.e. unevenly impacting on landholders or stakeholders) along these scales that characterize watersheds mean that sustainable management requires collective action in some form ; hence, the logic for building and involving local organizations as a means to change the ways in which local groups interact with each other as well as with the broader society : towards greater and more equitable control over resources -amplifying the range of options the less privileged people have (eg women, ethnic minorities, the landless)- while enhancing local people's involvement in policy making process at the regional or national levels -providing space for more people to make their voices heard, eg small farmers, women, artisans, as well as improving the quality of their involvement.

It is important to realize that the process of social organization in which people living in a watershed are emerged, does not necessarily overlap with the biophysical lines or boundaries ; for example, trade and exchange networks often connect across the wider ecoregion, eg along a mountain range, or into a neighbouring valley. The achievement of watershed management therefore is above all a matter of social relations, cooperation and coordination. Jacqueline Ashby, CIAT's director of Natural Resource Management, introduced the concept of social ecology (of watersheds) to capture this. Another way to capture this is the concept of the *social construction of watersheds*: sustained watershed management can only be achieved if coordinated land use for the benefit of the individual and the watershed community is adopted by local institutions. In other words, it will require a collective vision and the adoption of coordinated natural resource use and management practices.

With this in mind, research got underway in the Nicaraguan site of CIAT's "Hillsides" research project: the Calico River watershed in the department of Matagalpa. We will present here the development and use of one of the "Hillsides'" research tools.

First step: an appraisal of problems, conflicts, and opportunities

In September 1997, a participatory workshop on watershed management brought together a mixed group of thirty men and women (farmers, NGO staff, and local government officials) from the Calico River watershed, who identified the key problems affecting land management and the livelihoods of people in the Calico area at various levels — community, microwatershed and watershed. These problems included land degradation leading to lower yields, deforestation causing soil erosion and loss of wildlife, water scarcity, and water pollution. Survey data collected in 1997 as part of a watershed-wide study on poverty confirmed these findings. The following tables present the analysis made by the participants through a lluvia de ideas exercise, of the soils, water and forest conditions:

Soils: "Soils are the most important [resource] because we depend on them to feed ourselves."

Problems	Causes	Consequences
low fertility	inadequate practices	unproductive
lack of nutrients	deforestation	low harvests
degraded	no conservation	
prone to erosion	farmers hardly practice organic agriculture	
over-used	over-use of agro-chemicals	
contaminated	lack of reforestation	
arid	carelessness	
quality keeps going down	expansion of the agricultural frontier	
	burning without control	

Source: CIAT-Hillsides (adapted from Vernooy, 1997: 7)[2]

Water: “We need more water.”

Problems	Causes	Consequences
a lot of contamination		
bad quality		
sectors without access		
rivers dry up	over-use of agro-chemicals	
diminishing levels in wells	deforestation	reduced human consumption
shortage from February until May	burning	need to chlorinate
the Calico River dries up in the summer	no treatment	
the wells dry up in summer		
droughts		
bad management		

Source: CIAT-Hillsides (adapted from Vernooy, 1997: 8)

Forests: “If we would manage our trees well, we would not have the problem of water shortage.”

Problems	Causes	Consequences

[2] Vernooy, Ronnie. (1997) Memoria del taller “Manejo sostenible de cuencas: una introducción.” Managua, Nicaragua. CIAT. 40 p.

complete deterioration of our forests	deforestation	
extinction of native species	burning without control	
forest destruction	abuse	disappearing forests
shortage of fuelwoood	accelerated cutting	extinction of flora and fauna and precious woods
	bad management and use	
	migratory agriculture	
	lack of technical knowledge	
	lack of law enforcement	
	weakness in the law enforcers	
	lack of education	

Source: CIAT-Hillsides (adapted from Vernooy, 1997: 9)

Conflicts

The main conflict identified by workshop participants is access to and use of drinking water. Tensions have arisen between the owners of land in the upper reaches of the river and downstream communities that depend on these sources for their supply of drinking water. Downstream users complain about negligence of the landowners in terms of water source maintenance and deforestation of the surrounding areas. They are also regularly faced with threats by the landowners to cut off the water supply.

A second area of tension is between neighbouring communities where one depends on the other for its drinking water; an example of this situation occurs between Susuli, where a water source is located, and El Jicaro #2 which does not have its own source but depends on Susuli for water.

Several of the Drinking Water Committees are disliked by consumers because they stress the need for water-conservation.

Some farmers use river water illegally for irrigation, a practice prohibited by municipal law. Municipal authorities are powerless to stop this practice. Downstream users complain because water flow is reduced, limiting the amount available for domestic use and human consumption. Some people use explosives to cath fish in the Calico River, a practice many disapprove.

Access to and use of land was identified as another source of conflict. Uncertainty about the legality of the agrarian land reform process and its results continues to cause trouble, in particular for farmers organized into cooperatives. Several cooperatives in the watershed have received expropriation notices from former landowners who have returned to Nicaragua after the 1996 election of the neo-liberal,

President Arnoldo Alemán Lacayo. Landless farmers complain about the unwillingness of large landowners to rent land. The Indigenous Association of Matagalpa has a conflict with the mayor of San Dionisio about landclaims and landtaxes.

Proposed reforestation activities of areas surrounding water wells in the upper watershed by down-stream users are turned down by the owners of the land where wells are loated.

Municipality and government authorities criticize illegal loggers and fuelwood collectors. Government authorities are criticized by communities for handing out logging permits to businessmen who do not care about the area..

We examined the results of this workshop and the general analysis of the situation in the watershed in terms of opportunities for action:

- for looking at natural resource management problems at the watershed and microwatershed levels;
- for improving participation (by people from the rural communities) in decision-making at the municipality level;
- for stimulating coordination among NGOs, the Municipal Development Council and ministries (to increase the impact of efforts and avoid duplication); and
- for facilitating *concertación*, where relevant, focusing on the resolution of conflicts over natural resources and, perhaps, the development of an integrated natural resources management plan.

Second step: the 15 micro-watersheds: the methodology

The September 1997 workshop on watershed management provided a general picture of the conditions of the natural resource base at the watershed level as well as some inroads into the main issues related to use, management and conservation. However, we felt that more detail was needed to answer the questions of “What is happening, and according to whom ?” What are the problems, (research) gaps and opportunities ?” In order to get a better understanding of both the “resource and people” dynamics, we started looking for a methodological tool that would allow finding answers to these questions at the micro-watershed level.

We hypothesized that the micro-watershed level would be, both conceptually and practically, a good level or scale as it represents a space where resource flows and dynamics interplay with socio-economic relationships, such as family and labour-exchange (known as *mano vuelta*) ties. An image we used in the fieldwork was that of a puzzle in which the pieces are the micro-watersheds that together form the watershed.

Interestingly, this image was very helpful and easily understood by local people. [3]

The first micro-watershed took study place at the end of 1997, and the studies were completed in March 1998. To carry out the studies, we involved, in each of the micro-watersheds, a small groups of local key informants selected whenever possible based on their knowledge of the area. These informants included male and female farmers, local *técnicos* from the various NGO-s*, promotores* (from the NGO-s and associations) and assistant mayors better known as *alcalditos.* Male informants were in the majority, as it proved difficult to find women who were able or willing to spend a whole day with us in the field.

Factors being examined include land use (agro-ecological zones), the state of forests, water resources, crops, wildlife, domesticated animals, pastures, and local soil indicators. In addition, participants are identifying the limitations as well as opportunities for agricultural production and natural resource management in the area. Based on their findings, a set of natural resource indicators has been developed for monitoring and comparisons between different micro-watersheds.

The results of these analyses have been presented to key local decision-makers such as the mayor of San Dionisio, state agencies and NGOs operating in the watershed, as well as to the recently created Association of Community Organizations. The results will allow decision-makers to identify priority zones for action where natural resources are already in bad shape or are at high risk or, on the other hand, offer opportunities for alternatives. The analyses will also be helpful as a pre-Mitch overview of the state of the natural resource base and will allow for comparison with the post-Mitch situation.

Resource mapping

Each of the studies started with the design of a local resource map in the line of now well-known PRA mapping exercises. The maps include the borders of the area according to local definitions, the hills, principal and secondary roads and paths, the rivers, creeks, springs and reservoirs as well as the principal drinking water-pipelines, infrastructure (schools, churches, health-care centers, cemeteries, coffee-washing/drying facilities, haciendas and farms, agro-ecological zones, production systems, vegetation (forest types), and soil types. With one or two exceptions the maps gave a detailed picture of the micro-watershed landscape. They also served to define the transect for the transect walk during which a resources analysis was made (see below).

For almost all informants or cooperators this was the first time that they draw

[3] Reviewing the Spanish literature in particular, we only found a few references about approaches or tools that we considered useful, eg Fundación-Banhcafé (1996), De Campesino a Campesino/ UNAG (1997), Sertedeso/Saúl San Martín (1998) and Unión Mundial para la Naturaleza/IUCN (1997). Building upon these references, we developed a more comprehensive, participatory tool covering mapping, analysis and monitoring. At a later stage, we also included the use of certain GIS tools to strengthen the usefulness and scope (see, Vernooy Ronnie, Nohemi Espinoza and France Lamy (1999) Mapeo, analísis y monitoreo participativos de los recursos naturales en una micro-cuenca. Cali, Colombia. CIAT.).

their environment. Some did not hesitate to pick up the pencil and start sketching the maps. Others were more hesitant and in some occasions, we helped them draw the boundaries as a first step. Some of the maps resulted very detailed

Resource analysis

The maps were used to define a transect crisscrossing the major zones and production systems and passing other important resource feature of the area. During the transect walk, if possible in a site with a good overview of the landscape, a resource analysis was made by the informants facilitated by the research team. These analyses were documented in a table. An example is given below.

Table: Micro-watershed natural resources analysis of El Zapote

Water	About 80% of the community of El Zapote has direct access to drinking water. The drinking water project started originally in 1986 and in 1996 was amplified to include more families.The watersource that provides drinking water is located in Susuli (the neighbouring community); additional water comes from El Chile. Water quality is regular. In the summer season there are frequently shortages due to the low levels in the sources. February-April are the critical months. Five small creeks make up the micro-watershed; they run east-west and flow into the larger creek that originates in the Piedra Colorada micro-watershed. Only one of these small creeks retains water all year long; the other four dry up in summer. Water from the creeks is used for domestic purposes such as washing and to give to animals as well. The water is also used to mix with agro-chemicals, and farmers regularly wash their spraying bombs in the creeks after use -an important source of pollution.
Forests	Very few forest patches remain; only along the creeks small areas still exist. About 35 years ago, forest still covered most of the micro-watershed, but due to the avancement of the frontera agricola, trees were cut to make place for basic grains and pastures. Trees were also cut for construction and to satisfy the increasing fuelwood demands. Species that actually can be found include: Chaperno, Matapalo, Carao, Miliguiste and Jiñocuabo. Species that have dissappeared or of which very few amounts are left include: Chilante, Laurel, Genízaro, Madero negro, Cedro and Pochote. For fuelwood use, the most used species are: Madero negro, Guacimo and Sarguayan.
Crops and harvests	Corn and beans are the most important crops. Current corn harvests are approximately 30-40 quintales/manzana; five years ago these were 55-60 quintales/manzana. Current bean harvests are 15-25 quintales/manzana; five years ago they reached 27-30 quintales/manzana. The main reasons for this reduction in productivity are: soil fertility loss, poor soil management (no crop rotation or diversification), poor and “fatigued” crop varieties (seeds), and over-use of agro-chemicals.
Animals	Only two farmers have cows, between 20-30 heads each, the species are Brahmans and creoles. Milk, cream and cheese are sold locally only. Very few families possess horses or mules; there is not enough land to herd them. Most families own chicken, for auto-consumption (eggs and meat). Wildlife is scarce. Animales have dissappeared due to the deforestation in the area and also because of over-hunting practices. Animals that still can be found include: chameleons, squirrels, rabbits, monkeys, foxes.

Pastures	The predominant species is Jaragua, but it is in general badly maintained. A few parcels of sugarcane can be found, used for feeding of cows.
Conflicts	There is problem with the owner on whose land the watersource of the community is located: the owner is cutting the trees surrounding the source. Another problem concerns the landtenure insecurity, in partiuclar for the cooperatives. There are also some problems about land inheritance on private properties.
Organizations	CARE, Popolvuh, FAMAGRO, Ecogranos, the Indigenous Association and the Coffee-growers Association, and CIAT are present with projects in the area of agriculture and natural resource management. Local organizations include: the artesanal cooperative El Malinche (leather products), the Drinking Water Committee, the Comarca Committee, the Committee of parents, and the Community Board for Progress and Charity.
Limitations	Land shortage, lack of credit, attacks of insects (crop damage), bad roads, and not enough houses.
Advantages	Good area for basic grains production, good climate, accessible for commercialization of products.

Source: adapted from Espinoza and Vernooy, 1998: 62-63.[4]

Resource use indicators

The next and final step in the micro-watershed analysis process constituted the definition of a set of “simple to understand and use” indicators and values and the application of these indicators to the fifteen identified micro-watersheds. The set of indicators was developed through a consultative exercise: a draft set was formulated by the research team based on the findings of the combined fifteen resource analyses, reviewed and then refined with the informants, and subsequently applied by the informants to their own micro-watershed during a workshop. Values given to the indicators were tabled and grouped together by component (water, forests, crops etc.; note that soils were added based on the outcomes of the soils analyses conducted during the transect walks) in order to compare results and the table was presented to and discussed with the informants in a second workshop. (In some micro-watersheds, there are clearly distinguished agro-ecological zones; in those cases two analyses were carried out, one for the upper and one for the lower part.) The table, which can be nterpretated both horizontally by mirco-watershed and vertically by component, as prepared by the researchers, is presented below.

Table: Synthesis of natural resources indicators by component: the Calico River watershed

	Wate r	Fores	Soils	Crop s	Anim	Pastu	Wildli	Orga	Other	Total

[4] Nohemi Espinoza y Ronnie Vernooy (1999) Las 15 micro-cuencas del río Calico, San Dionisio , Matagalpa. Managua, Nicaragua. CIAT. 99 p.

El Carrizal	14	8	20	5	6	3	2	7	10	75
Quebrachal-upper part	15	9	21	6	6	4	1	7	8	77
Quebrachal-lower part	14	9	22	4	6	3	2	8	8	76
El Zarzal-upper part	5	8	20	6	5	4	2	3	10	63
El Zarzal-lower part	8	6	25	5	8	4	2	4	10	72
El Corozo	13	7	23.5	5	8	5	2	5	11	78.5
Piedra Colorada-upper	7	8	26	5	6	4	3	5	12	76
Piedra Colorada-lower	6	6	17	5	6	5	1	6	13	65
Susuli-upper part	15	8	25	6	5	5	3	5	10	82
Susuli-lower part	13	8	20	6	6	4	2	7	13	79
El Jicaro #2	9	5	20	5	5	5	2	8	11	70
El Zapote	11	6	20	3	7	5	1	7	13	73
Wibuse/El Jicaro upper	9	9	23	5	6	4	2	5	8	74
Wibuse/El Jicaro lower	9	9	23	5	6	4	2	9	12	79
Los Limones	13	7	20	7	7	6	2	7	11	80
El Junquillo-Cuchillas upper part	8	10	24	5	8	5	2	5	13	80
El Junquillo-Cuchillas lower part	7	9	18	5	6	4	2	6	10	67
El Cobano	13	5	22	6	6	7	2	8	12	81
Ocote arriba	8	8	24	5	6	4	3	5	12	75
Ocote abajo	10	5	23.5	5	3	4	2	5	9	65.5
Piedras Largas upper	7	8	24	5	3	6	2	6	8	69
Piedras Largas lower	10	7	19	5	6	5	3	9	11	75

Source: adapted from Espinoza and Vernooy, 1998:92.

Note 1: The soils components includes 12 indicators, such as fertility, color, texture, water retention capacity, structure. Values were defined by the informants in the field during the transect walks with the help of soil samples dug out in situ, at informant-selected representative soil sites/types, at least two for each watershed. The table presents average total values.

Note 2: The “Other” set of indicators include average inclination level, landtenure situation, infrastructure, electricity, access, and well-being level.

Concluding comments (pros and cons)

Natural resource management research requires an interdisciplinary perspective; for example, soils and micro-watershed analyses need to be placed within the socioeconomic context of user groups and multiple interests. It also requires understanding the interconnectedness of various levels, e.g. plot, farm, community,

microwatershed, and watershed. Users of the resources can play a key role in the analysis of resource dynamics. Farmer experimenters, local leaders, *promotores*, and extension workers can make a contribution together with the *técnicos* and researchers from NGOs and government ministries.

A combination of “diagnostic” research (dividing the watershed into agroecological zones, identification of critical areas for intervention) with participatory action-oriented research (the formation of associations of local groups, the development of indicators to be used by local people) enables a focus on providing information about the state of the resource base at various levels and the involvement of users of these resources in problem and opportunity analysis to facilitate action that can be developed quickly.

Participatory mapping and monitoring are relatively simple tools that local people can use to analyze the local situation, discuss constraints, problems, and opportunities, take action, and monitor results. The microwatershed seems to be a useful level for intervention to develop and test these types of tools.

Local-level monitoring of resource use is required to ensure compliance and regulation. To achieve better resource management practices through cooperative action, rules, and sanctions, it is important that local people and those cooperating with them have a good understanding of resource dynamics: for example, soil dynamics, nutrient flows, water cycles. Resource assessment and resource use monitoring are, therefore, key activities in any effort to improve management practices and regulatory arrangements. Monitoring will also help to raise awareness among local decision-makers about the interdependence of resources and, if carried out collectively, can easily impart skills and credibility and create a sense of ownership and confidence.

Participatory tools such as the mapping, analysis and monitoring approach described here, are time and energy consuming which in some situations may be a serious constraining factor.