Natural Resource Conservation with Peoples' Participation in the Uplands of the Maribios Volcanic Ranges of Nicaragua. II. Adaptation of Conservation Technology to Farmers[1]

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ABSTRACT

A study of traditional farming practices was made by the rapid rural appraisal method in upland watersheds of the Maribios of Nicaragua in an effort to adapt land use management and other conservation techniques to farmers' basic needs and constraints. The adapted technology was designed to keep present land use (or use according to land capability) sustainable for two distinct groups of farmers: landless/share-croppers and small farmers. *Cajanus cajan* (pigeon pea) contour alleys/hedge rows, with bases knitted by pruned branches as porous barriers, are recommended for the landless and share croppers, and a similar procedure with any local leguminous tree for small farmers. Additional land use management techniques such as double cropping, local crop rotations, mulching and minimum tillage by traditional hoe, fertilizer control, and income generating activities are recommended for both groups. Community (for landless/share croppers) or individual (for small farmers) cisterns for drinking water will need subsidies and/or incentives for seepage control material. Revegetation and modifying the farmers' traditional practice of brushwood check dams, properly repaired after heavy rains in the first year, can control most on-farm gullies. However, landless/share cropper participation, without compensation by the land owner or by externally funded programs, cannot be expected. The adapted technology package can be adopted gradually by farmers, although full benefits can be obtained only with full adoption. The package is relatively inexpensive, except for added labor, estimates of which are provided.

Key words: Traditional farming systems, rapid rural appraisal, land use systems management, agro-forestry, sustainable agricultural and forestry systems.

RESUMEN

Con el método del reconocimiento rápido de áreas rurales, se estudiaron las prácticas agrícolas tradicionales en la cuenca alta de los Maribios en Nicaragua, para adaptar técnicas conocidas de manejo y uso de la tierra —así como otras prácticas conservacionistas— a las necesidades básicas de los agricultores en el marco de sus limitaciones. Se diseñó la tecnología adaptada para mantener el uso actual de la tierra o ajustarlo a su capacidad de uso sostenible por dos grupos diferentes de agricultores: los productores pequeños y arrendatarios sin tierra. Se recomienda para los arrendatarios sin tierra el cultivo en callejones de cercas vivas en contorno de gandul (*C. cajan*) con ramas cortadas para tejer las bases como barreras porosas. Se sugiere también esta práctica a los pequeños productores, pero con cualquier árbol leguminoso. Se recomienda, así mismo, la aplicación por parte de ambos grupos de técnicas adicionales de manejo de uso de la tierra, que incluyen dos cultivos por año, rotación de cultivos tradicionales, uso del "mulch" (mantillo) y labranza mínima con el azadón tradicional, control en el uso de fertilizantes y actividades generadoras de ingreso. Las cisternas de agua potable comunitarias para los arrendatarios sin tierra o individuales y los pequeños productores necesitan ser subsidiadas e incentivadas con materiales para el control de la percolación. La regeneración vegetal y modificación de la práctica tradicional de barreras con ramas y palos, reparadas apropiadamente después de las lluvias en el primer año, pueden controlar las cárcavas en las fincas. Sin embargo, la participación de los arrendatarios sin tierra supone la compensación de parte del dueño de la tierra o de programas externos de financiamiento. El paquete tecnológico adaptado puede ser aprobado paso a paso por los productores, aunque la totalidad de los beneficios sólo puede alcanzarse con una adopción completa. El paquete no tiene un alto costo, excepto por la mano de obra adicional, cuya estimación se proporciona en este artículo.

INTRODUCTION

The analysis of appropriate land use and social diversity in the rural upland watersheds of the Western Maribios volcanic ranges was presented in Part I, which concluded that most of the watersheds (especially 3 and 4) could remain sustainable under present use or use according to land

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capability, if they are appropriately managed through soil, water and forest conservation measures.

Part II presents result of a study conducted in 1989-1990 in the same two upland watersheds; it addresses the adaptation of land use management and other natural resource conservation techniques to farmers' traditional farming practices, so as to meet their needs within current limitations and to maintain sustainability under present land use or in use according to land capability. This will help farmers to easily adopt the technology, facilitating their participation. Land classes appropriate for pasture, forestry and protected areas are not discussed.

METHODOLOGY

The rapid rural appraisal (RRA) method was used (Chambers 1987) to study and adapt the traditional practices of the upland Maribios farmers (Chambers *et al.* 1989). RRA was conducted in nine rural areas of two upland watersheds (total area 15) (800 ha). Locations of these RRA sites were given in Part I. The sites were selected so that each one represents an independent upstream microwatershed, each has a group of farmers (rather than a single farmer), so that there is a social interaction between them, and the sites represent surrounding rural areas with different land use classes.

RESULTS AND DISCUSSIONS

Traditional farming practices

Based on the RRA results, an analysis of important traditional farming practices was made with a view to adapting conservation technology to them (University of East Anglia 1991).

Traditional cropping systems

Table 1 shows the cropping systems practiced in the Maribios uplands. In general, farmers grow an annual crop of basic grains (maize, sorghum and red bean), as well as some cotton and sesame, which are export crops generally grown in the lowlands. Relay crops of maize and beans and a maize-sorghum-bean rotation are also used, though less frequently.

It can be concluded that: (a) farmers need basic crops of maize, sorghum and beans, and (b) methods of relay cropping, intercropping and crop rotation between cereals and legumes are also used by farmers less frequently (three of nine sites in Table 1) and sometimes wrongly (relay crops of two cereals, maize and sorghum, in three out of nine RRA sites in Table 1). However, appropriate crop rotations, which improve soil fertility, can be introduced with little difficulty, as the rural farming community is aware of their potential.

Table 1. Traditional cropping systems of the uplands of the Maribios, Nic.

Site (no.)	Annual crops Maize	Beans	Sorghum	Cotton	Sesame	Relay maize-sorghum	Inter-cropping maize-beans	Rotation maize-sorghum beans	Upland rice
1,2	X	X	X	X		X	X		
3[1]	X	X							
3[2]	X	X	X						
4						X	X	X	
5						X	X		
6	X	X			X				X
7	X	X	X						
8	X	X							
9	X	X	X	X					

1 Individual small farmers and share croppers
2 Collective members of cooperative

Traditional tillage systems

Detailed data on traditional land preparation and tillage systems for various crops are given in Table 2. Slashing and uncontrolled or controlled burning are common methods of land clearing before the rainy period. These are followed by three or four plowings by bullock-drawn plow for a maize or sorghum crop, or two or three plowings for planting red/white beans. Plowing is again done for weed control in all type of crops three to four weeks after crop germination. Overuse of herbicides is common among farmers in cooperatives, who get loans from banks for herbicide/pesticide/fertilizer use.

A traditional bullock-drawn hoe (*banca*) is used one or two times more in cereals for weed control. For beans, later weeding is done by spade, as vegetative growth covers almost all the planted ground in a month, making the hoe impractical for use among the bean rows. Most soils of the Maribios are sandy or sandy loam, and do not need plowing for creating a good tilth, as they automatically attain it rain. It is concluded that farmers practice very heavy tillage before crop planting, mainly for weed control. Introduction of minimum tillage using the traditional bullock-drawn hoe in place of plowing (the hoe, with its blunt blade, does not disturb the soil), and weed/crop residue mulching rather than burning, can potentially liberate manpower, control weeds, and conserve soil and water.

Fertilizer use in traditional cropping systems

Table 3 describes quantities of various fertilizers applied at several growth stages of different crops grown in the uplands. On an average, farmers use up to 125 kg/ha of composite fertilizer (10:10:10) and 285 kg/ha of urea (46:0:0) to grow maize and sorghum. For beans, 110 kg/ha of composite and up to 120 kg/ha of urea is used.

While the farmers may be using composite fertilizer only to compensate for the lack of phosphorus (all volcanic soils are phosphorous-deficient), any use of urea is definitely unnecessary. The traditional varieties of maize (NV 6), sorghum and beans do not have the genetic potential to respond to such high quantities of nitrogen fertilizer.

Soil and water conservation in traditional farming

Table 4 shows how farmers in the uplands perceive and try to control the problem of soil erosion.

Table 2 Traditional tillage systems in the uplands of the Maribios, Nic.

		Times plowing for planting				Times weeding within crop by								
Site (no.)	Land clearing	Maize/ sorghum	Beans	Sesame	Rice	Maize	Plowing Sorghum	Beans	Sesame	Hoe (banca) Rice	Spade Maize/ sorghum sesame	Beans	Beans	Rice
1,2	Slash+ uncontrolled burn	3	1			1	1				1			
3	-do-	2	2			1,H[1]	1,H	H			2,H	2,H	1,H	
4	-do-	2	2								2	1		
5	Slash+ controlled burn	3	4			1					1		1	
6	-do-	3	3			1					1		1	
7	-do-	3-4	3		3	1	3-4			1	1			1
8	-do-	3+1[2]				1					2		1	
9	-do-	3	3								2		1	
	Average	3.5	2.75		3	1	2			1	1-4	1-5	1	1
	range	2-4	1-4		3	1	3-4			1	1-2	1-2	1	1

1 Post-planting use of herbicides (H) is common in farmers associated with cooperatives.
2 With brush-wood, behind a pair of bullocks

Table 3. Fertilizer use in traditional cropping systems in the Maribios, Nic.

Fertilizer application				Fertilizer quantity (kg/ha)					Weed incorporation (no. of times)
Site (no.)	Type	Method	Crop stage	Maize or + sorghum	Beans	Cotton	Sesame	Rice	
1,2[1]	C	I	S	130	130	195			
	U	I	V(I)	130	130	130			
	U	T	F	130-195	0-195	–			
	S	I	V(II)	–	–	130			
3(a)	C	I	S	130	65	–			
(Inov)	U	I	V	260	260				
3(b)	C	I	S	130	130				
(Coop)	U	I	V(I)	97	130				
	U	T	V(II)	97	–				
	U	T	F	97	–				
4	C	I	S	130	65				
	U	I	V	130	65				
	U	T	F	130	65				
5	C	I	S	130	130				
	U	I	V(I)	130	32.5				2
	U	I	V(II)	65	–				
	U	I	F	65	–				
6[2]	C	I	S	97	97		97		1
	U	I	V(I)	97	–		97		
	U	T	V(II) orF	65-97	–		–		
7	C	I	S	130	130	130		130	
	U	I	V	130	–	130		130	
	U	I	F	130	–	130		130	
8[1]	C	I	S	130	65-130				
	U	T	F	260	35-65				
9	C	I	S	130	130	130			
	U	I	V(I)	65	–	–			
	U	I	V(II)	65	–	–			
	U	T	F	65	–	–			
Average	C	I	S	126	110	151	97	130	
	U	I	V(I)	144	68	86	97	130	
	U	I	V(II)	36	–	0	0	–	
	U	T	F	104	4-50	43	–	130	
	S	I	V(II)	–	–	–	–	–	
Range	C	I	S	97-130	65-130	130-195	97	130	
	U	I	V(I)	65-260	0-130	0-130	97	130	
	U	I	V(II)	0-197	–	0	–	–	
	U	T	F	130-195	0-195	0-130	–	130	
	S	I	V(II)	–	–	–	–	–	

1 Gramoxone herbicide used 30 days after planting.
2 Does not use herbicide, as farmers think it destroys land.

C = complete = 10:10:10
I = basal incorporated
S = planting
U = urea = 46: 0:0

T = top dressing
V = veget stage (I, II)
S = sulphate
F = flowering stage

Table 4. Traditional system of soil/water management in Maribios, Nic

Site (no.)	Land class	State of erosion	Soil texture	Farm of plowing: on contour	Farm of plowing: up & down slope	Mechanical measures of soil conservation	Gulley control
1,2	Ib	High	Sandy Loam	–	Yes	Channel terraces[1] in good condition	No
3	II	Severe	Sandy	–	Yes	–	Weed stalk placement up & down gulley
	III	Severe	Sandy	Yes	–	–	-do-
4	II	High	Sandy Loam	I plowing	All except first	–	No
5	III	High	Sandy lava		Yes	–	No
6	Ib	High	Sandy	I plowing	All except first	–	Weed stalk placement up & down gulley
7	Ib,II	High	Sandy and sandy Loam	Yes	–	Channel terraces[1] in good condition	No
8	Ib,II	High	-do-	–	Yes	-do-	Weed stalk placement up & down gulley
9	Ia,Ib	Normal	Sandy	I plowing	All except first	–	No

1 Found only with medium and large scale farmers.

In general, there is an awareness that plowing up and down the slopes creates soil erosion. For this reason, in six of the nine RRA sites, at least the first plowing is done perpendicular to the slope. The rest of the plowing is still done up and down the slope to give cross plowing to the soil. Farmers are aware of the problem of gullies, and put thicker stalks of unburned weeds into them. However, since they are put all along the gully length, the unburnt stalks do not help control erosion. It is concluded that farmer awareness and efforts in contour plowing and brush/stalk check dams can be easily modified to more correct methods of soil and water conservation.

Live fencing to control animal entry into farming areas and planting of trees on farm boundaries is also practiced by some farmers; this practice can be further improved to produce fuelwood for farm families.

Traditional tools and implements

Table 5 is an assessment of tools and implements available to the farmers.

Most often, these tools consist of only a "machete", one bullock-drawn plow, one small or large bullock-drawn hoe (*banca*) and a spade or shovel. Most soil/water conservation and agroforestry works must be achieved with these tools only. It should be noted that almost all farmers have a small or large bullock-drawn hoe, the main implement used for weed control. Since the blunt blade does not enter the soil but knocks out the weeds along the soil surface, it is an ideal implement for minimum tillage.

Crop yields in traditional farming systems

Given the above inputs, crop yields in general are low, even though the fertilizer use is quite high.

Table 5. Traditional implements in the uplands of the Maribios, Nic.

Site No.	Pair of bullocks (per family)	Type of implement (approx.) (per family)						
		Machete	Plow	Cultivator	Hoe (banca) small	Hoe (banca) big	Spade/Shovel	Bullock cart
1,2	1	1	1	0	1	0	1	0-1
3	0-1	1	0.5-1	1	0	0	1	0-1
4	1	1	1	1	1	1	0	0-1
5	2	1	1	0	0	1	1	0-1
6	1-2	1	1-2	0	1	0	1	0-1
7	1	1	1	0	1	1	1	0-1
8	0-1	1	1	0	0	1	1	0-1
9	0-1	1	1	0	1	0	1	0-1
Average	0-1.1	1	0.5-1	0.25	0.6	0.5	0.9	0.25
Range	0-2	1	0.5-2	0-1	0-1	0-1	0-1	0-1

Table 6 shows that maize yields are about 1670-2090 kg/ha on an average. Sorghum yields (in relay) are only 460-1460 kg/ha, and red bean yields vary from 560-950 kg/ha.

Yields are relatively low compared to crop genetic potential due to lack of appropriate crop management, water and soil conservation measures and other agronomic inputs such as correct rates and dates of planting, as well as misuse of herbicides/fertilizers or weeding problems.

Status of fuelwood use in traditional farming systems

Table 7 is an estimate of current fuelwood exploitation by rural families. On average, about 10-35 m^2/year of fuelwood is consumed by a rural family consisting of six to 18 family members. In addition, over 50 m^2/year of fuelwood is sold by rural-based families in 45% of the rural areas. Thus, in addition to rain-fed agriculture, fuelwood is one of the important means of survival for small farmers, the landless and share croppers. Quite often, most cash income comes from fuelwood sales.

It can be concluded that agro-forestry methods of soil and water conservation should be used rather than mechanical methods or grass hedge rows. Mechanical methods are not suitable in these uplands due to the unstable nature of the soils, and the grass hedge rows do not meet any basic needs. In addition to yielding fuelwood, the agro-forestry methods also

Table 6. Crop productivity under traditional farming systems in the uplands of the Maribios, Nic.

Site (no.)	Crop productivity (kg/ha)					
	Maize	Relay sorghum	Red beans	Cotton	Upland rice	Sesame
1,2	2 070		2 070	1 625		
3	1 950-2 500		650-1 750			
4	1 800-3 000		650-900			
5	2 275		650			
6	1 950	1 500-1 950	450			650
7	1 950-2 600	1 300	975	1 625	1 950-3 250	
8	1 050	500-1 950	450		650	
9	975-1 300	400-650	400-450			
Average	1 670-2 090	460-1 460	560-960	1 625	1 950	650
Range	975-2 600	400-1 950	400-1 750	1 625	650-3 250	650

Table 7. Present status of fuelwood use (approximate) in the uplands of the Maribios, Nic.

Site (no.)	Fuelwood use per family, (m^3/year) for family consumption (esterio)	for selling in market (esterio)	Price (US$7m³) (esterio)	Source of fuelwood	Time and method of fuelwood collection
1,2	12[2]	–	–	Private forest/ pasture lands	monthly manually
3	50[3]	50	4.28	Government and community forest	weekly manually
4	10[2]-15[3]		4.28	-do-	-do-
5	70[3]	70	4.28	Private and community forest/ pasture lands	-do-
6	15[3]	7	4.28	Government community forest	annual manually.
7	12[2]-28[3]	–	–	-do-	semi-annual manually
8	6[2]	–	–	Private/ community forest	annual, manually
9	8.5[2]	80	16.00 (house-to-house sale)	Bought from private forests	weekly, manually
Average	9.7[2]-35.6[3]	51.75			
Range	8.5[2]-70[3]	7-80	4-16		

1 Exchange rate (Nov. 1989) 1US$ = Cordoba 25 000.
2 For a family of 6-7 members.
3 For a family of 15-18 members.

help restore soil fertility if appropriate nitrogen-fixing trees (NFTs) are used.

However, not all agro-forestry and forestry systems conserve soil and water (Hamilton 1986; Nair 1986). Only those agro-forestry systems incorporating cover (mulch) and barrier effects can do so (Young 1991). Hence, alley/hedge row cropping with bases knitted by pruned branches that form a barrier should be used. Only those barriers planted by direct seeding should be selected, as all others kinds have very high labor requirements. This technique, called sloping agricultural land technology (SALT), has been successfully used in the Philippines (Celestino 1984) and Honduras (Sharma 1993) to make terraces as a low-cost alternative to mechanical construction of bench terraces. It is now being propagated in Nicaragua by a FAO/IRENA project in the Maribios (Sharma 1990b).

Further, the majority of share croppers and landless casual laborers earn their living by working on occasional short-term jobs. The opportunities for such employment are limited outside the agriculture sector. It can thus be concluded that adapted land use management and conservation technology should not only have the potential to help in sustained crop and fuel wood production, but also generate additional rural-based employment for the landless and share croppers.

Farmers' needs and limitations

The basic needs of the majority of farmers as are food, fuelwood, drinking water, and minimum cash for other needs, which can be produced in the form of fruit trees, cash crops and animals, among other activities.

But there are many other needs which affect the quality of rural life. All such needs should be considered in any rural development program. However, this paper is limited to appropriate land use management and conservation technology to sustain land use and meeting basic needs. These needs can be met by small farmers and the landless/share croppers if the following requirements are met:

- Technology management must be based on farmers' traditional practices and be easily be adopted by them, thus faciliting their participation.

- It must be low in cost, as share croppers and small farmers are subsistence farmers. Thus, appropriate management of land use itself becomes the most important ingredient in natural resource conservation, as it is the cheapest alternative. It is also the most neglected aspect in resource conservation (Sanders 1990), while millions are spent on costly, often impractical, technology around the world.

- For share-cropped lands, it must give immediate and direct benefits within a year, as such lands are often available to share croppers for only a year.

- For small farmers with title to their land, it must give immediate as well as medium- and long-term direct benefits.

- The labor requirements for technology implementation should be low, as only family labor can be expected to be used.

Based on the above requirements and the basic needs of the farmers, appropriate packages of techniques as adapted to traditional farming practices for sustaining preferred land use were developed (Sharma 1990a, 1990b). In the following discussion, pasture (class III), forestry (class IV) and protected lands (class V) are given less emphasis.

Conservation technology adaptation

Technology adaptation for easier acceptability (Chambers *et al.* 1989) is advisable for two types of farmers: (a) the landless and share croppers, and (b) small farmers; who have different land resources available to them (see Part I) and whose limitations impose different constraints on the technology. Table 8 lists various components of land use management and conservation technology for these two types of farmers, described below in detail.

Agro-forestry methods for sustained production by soil conservation and soil fertility improvement

Trees like *Leucaena leucocephala*, *Acacia mangium*, *Gliricidia sepium* and *Cajanus cajan* can conserve soil, improve soil fertility, act as windbreaks, and provide fuelwood. They can also be planted directly by seeds or stakes, so need little extra labor. These trees are well-adapted to the local Maribios conditions. However, they need to be properly planted and managed to reap full benefits. When these trees are planted along contours in double rows at suitable distances, as in alley cropping (0.3 x 0.3 x 6 m) or as hedge rows (0.05 x 1 x 3-4 m), depending on land class (Table 1 in Part I), and their bases are knitted with pruned branches, they function as continuous porous barriers across slopes, conserving soil and water (Celestino 1984; Young 1991). The extra runoff flows overland, thus not requiring any extra drainage work. Trees must be pruned annually at suitable heights for fuelwood, while branches are used for knitting the base, and the green material is applied as mulch on the alleys for soil fertility improvement.

For the landless and share croppers, alley cropping/hedge row barriers of *C. cajan* are more suitable, as they can be seeded directly and are harvested annually for seeds and fuelwood. An added advantage is that *C. cajan* provides much less competition with crops for water when compared to other trees (ICRISAT 1989), thus makes up an ideal agroforestry system for the areas with irregular rains in

Table 8. Components of conservation technology adapted to traditional farming practices for different types of farmers.

I. For landless and share croppers

Time limitation:	one year
Economic limitation:	technology to be very low cost with direct benefits within a year
Land class limitation:	Ib, II, III

Adapted package of technology:

- Alley/hedge rows of pigeon pea on contour with bases knitted by pruned branches
- Mulching and minimum tillage by traditional hoe
- Double cropping according to climate and local crop rotations
- Community cisterns and woodlots
- Propagation of home gardens, animals, cash crops
- For gulley control by revegetation, land owners participation is necessary

II. For small farmers

Economic limitation:	Technology to be low cost, with short as well as long-term direct benefits
Land class limitation:	Ib, II, III

Adapted package of technology:

- Alley/hedge rows of any chosen NFTs on contour with bases knitted by pruned branches
- Mulching and minimum tillage by traditional hoe
- Fertilizer control
- Double cropping according to climate and local crop rotations
- Live fencing
- Individual cisterns/woodlots/fruit gardens
- Propagation of animals, cash crops.
- Gulley control by revegetation and well-maintained brushwood check dams (on-farm level).

the Maribios. This reduces risks for the share croppers.

The small farmers can choose any of the locally adapted nitrogen-fixing tree (NFTs) for agro-forestry (CATIE 1986), which can be directly planted by seeds or stakes to reduce labor cost. The same trees can also be chosen for live fencing or fuelwood lots. In the latter case, and for fruit tree gardens, live grass hedge rows can be used for initial soil conservation, while cover crops or pasture can be established by the second year.

Agricultural land use management

The following land use management components of conservation technology do not represent any significant additional costs to any types of farmers. At the same time, they give direct, immediate benefits beginning in the first crop season, while also conserving soil and water and building soil fertility.

Mulching and minimum tillage by traditional hoe (*banca*)

Soil surface cover is the most important defense against erosion on sloping lands (Nair 1986). Mulching with weed cover, crop residue or tree material, rather than slash and burn, is thus important (Lal 1989). However, mulching density should not exceed 60-70% to avoid creation of habitats for pests and diseases. Mulching along with minimum tillage by the traditional hoe within the agro-forestry system becomes an essential part of land use management (Young 1991). While one plowing for weed control and another for planting may be necessary in first one or two years, after the second year only a single plowing for planting in the mulch will be needed, as by the third year the mulch itself will control weeds and the hoe will be sufficient to knock out the remaining weeds before crop planting as well as during growth. Weeding in beans will be continued to be done by spade after three to four weeks of crop growth, as is done by the farmer traditionally. Care should be taken not to leave thick weed or crop stalks on the ground, as they will hinder in cultural operations by the hoe.

Crop planning and crop rotation

Most farmers only harvest one annual crop of maize, sorghum or beans due to lack of appropriate crop planning in accordance with the twice-a-year rainfall distribution in the Maribios zone (Part I).

In areas with an irregular first rainy period, such as Leon and El Suece, farmers who traditionally harvest one annual crop in the second, more certain rainy period only should follow any of their chosen cereal crop with a leguminous crop such as red/white beans, cow pea or ground nut in the second year. However, two crops can also be harvested in such areas. Short-duration, drought-resistant crops of sorghum, maize or sesame in the first rainy period, followed by red/white beans, cow pea or ground nut in the second rainy period in the same year, will help restore fertility as well as increase income and better protect the soils with by their cover.

In areas which receive regular rains all through the year (e.g., around Chinandega), any combination of double cropping of maize, sorghum or sesame, followed by any of the leguminous crops of red/white beans, cow pea or ground nut, or their inter-cropping, or relay cropping, can be done. A third crop can also be taken toward the latter half of the second period. Even if a dry period does occur between the rainy periods, stored soil moisture should be sufficient to carry over the crops to the second humid period.

Fertilizer use and control

Excessive use of fertilizer in the Maribios has been encouraged by easy access to subsidies and bank loans for fertilizers. If correct land use management and agro-forestry methods of soil fertility maintenance are used, little or no fertilizer need be used, as volcanic soils are generally fertile. Any use of chemical fertilizers should be based on soil fertility tests, which the banks should subsidize to assure correct quantities and timing of fertilizer use, before investing in same. Fertilizer misuse can be avoided when high-yielding varieties, proven responsive to fertilizers, begin becoming available.

Other income-generating activities

Introduction of better breeds of animals, cash crops, live-fencing, fruit trees as home gardens for share croppers, community woodlots for share croppers, individual fruit gardens/woodlots for small farmers and any other rural income-generating activities will help farmers' participation in natural resource conservation by giving direct income to them.

Cisterns for drinking water

There is a general lack of drinking water in rural areas and on-farm. Water tables in the Maribios are often deeper than 100 m, making tube or open wells extremely costly. Hence, rainwater harvesting from cisterns is the only way of providing drinking water on the spot (Silva *et al.* 1984). A water-harvesting strip of 11 x 4.5 m laid on a gentle slope of < 1%, embedded with 900 plastic covered by soil, can produce up to 50 m^3 of water in a cistern. A cistern tank of 25 m^3 is sufficient to meet a family's minimum annual water needs. Since water would be harvested over the May-November period, the 25 m^3 tank capacity represents more than double the amount of rainfall effectively received. The most important problem is seepage control. A 900 plastic covered by 5 cm of concrete (1:3:5) reinforced by 1.5 x 1.5 cm chicken wire mesh or 10 cm of concrete are practical methods of sealing the cistern tanks (USDA 1969a).

The share croppers can make the cisterns jointly (among two or three families) while small farmers can make them individually. The major cost is for seepage control materials. Since these materials are expensive, a subsidy will be required as an incentive, both for the landless and share croppers as well as for small farmers. However, if the incentive is provided, it will potentially not only solve the drinking water problem, but also make peoples' participation in other components of the technology easier.

Gully control

Gullies are a symptom of improper land use over a long period of time, and can be prevented if the land is appropriately used in the entire watershed. Since gullies have already formed in the Maribios, the most economical and effective gully control is by natural regeneration of its local vegetation or by closely planting fast-growing, deep-rooted spreading grasses, vine, shrubs, bushes or trees (USDA 1969b). These also provides good grazing after a few years of establishment. To aid natural regeneration, diversion of runoff from the gully and sloping of banks (1:1) should be done.

All gullies can be reclothed with vegetation by this method, provided they are properly protected from outside runoff, animals and fire. Since the whole natural process takes a few years, the opportunity to provide protective cover by this method is frequently overlooked, and unnecessary expenditures are made for temporary structures. However, shave cropper participation cannot be expected (unless compensated for labor), as he receives no direct benefits within a year. These works need to be done by the land owner.

Often, considerable obstacles to natural revegetation, particularly in the sterile gully beds, may be encountered. To provide good seed bed conditions, live hedge rows of higher-growing grasses or fast-growing trees (for gullies with a < 20 ha watershed), or temporary structures (for gullies with a < 100 ha watershed) such as brushwood check dams, correctly modified from the farmers' practice of throwing crop/weed stalks in the gully, become necessary as an aid to establishment of vegetation. The areas above hedge rows or temporary structures collect eroded soil, which provides a good seed bed. However, most types of temporary structures (brushwood, loose-rock or woven wire loose-rock check dams) have short lives (4-5 years), and they will not serve a good purpose unless appropriate vegetation is established above and around them within the life of the structure.

Also, if left unattended during the first year, only 10-20% of the temporary structures remain functional. Periodic check-ups by the farmer after each heavy rain, and subsequent repairs as needed, are essential in the first year. That way, most on-farm gullies can be controlled at not cost beyond labor. Gullies with bigger watersheds need appropriate hydraulic structures. These are not affordable for small farmers, thus need separately funded programs.

Table 9. Estimated manpower requirements for different activities (based on 75% labor efficiency).

Activity	Manpower requirements
1. Direct manual tree seeding for agro-forestry	4-5 man days/ha
2. Direct tree seeding by bullock- drawn plow for agro-forestry	2-4 man days/ha
3. Nursery	70 man days/ha
4. Alley cropping	150 man days/ha
5. Knitting of agro-forestry trees at bases for soil conservation	5-10 man days/ha
6. Cistern, cost of material/unit	US$ 75-100
7. Cistern construction/unit	15-20 man days
8. Brush-wood check dams/unit	0.25-0.5 man days

All of the above are components of an adapted conservation technology package. They may be adopted by farmers step by step. However, full benefits of the technology are obtained only after full adoption. Some components require added manpower or costs over and above the normal activities of a farmer. An estimate of these manpower requirements is given in Table 9 (Sharma 1990b).

Participation of farmers

The adoption of conservation technology by farmers is an element designed into the technology through its adaptation to local conditions. For easier extension, to offset any added manpower or costs, and for helping update traditional concepts, appropriate incentives are necessary. They are justified by the down-stream benefits resulting from farmer actions after adoption of the technology.

CONCLUSIONS

Farmers' basic needs for food, fuelwood, water and minimum cash can be met by known land use management and other conservation techniques as adapted to their traditional practices. Knowledge of crop rotation, relay and inter-cropping, and awareness of soil conservation exists among upland Maribios farmers. In place of land preparation by heavy tillage, mulch cover with minimum tillage using the farmers' traditional bullock-drawn hoe, within appropriately managed agro-forestry systems of alley or hedge row crops with their bases knitted by pruned tree branches, as porous barriers along the contour, will conserve soil and water, improve fertility, reduce labor requirements, produce fuelwood and reduce or eliminate the need for fertilizers for presently available crop varieties. Pigeon-pea-based agro-forestry systems (with bases knitted) are suited to the landless or share croppers, as they give immediate, direct benefits to these farmers in the very first year. Improved breeds of animals, cash crops, community fuel woodlots and community cisterns are recommended for the landless and share croppers for income generation and drinking water, and the same at the individual level for small farmers.

This adapted conservation package does not represent contain excessive additional labor or extra cost, except for seepage control in cisterns and plantation activities for nurseries. An estimate of added manpower requirements has been provided. Part III (of this paper) addresses the question of incentives for peoples' participation.

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