LAND HUSBANDRY FOR EROSION CONTROL IN THE COLOMBIAN ANDES

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Abstract
Results of a research and extension project aimed at soil building and conservation for sustainable production of Blackberry (*Rubus glaucus*) in the steeplands of Colombian Andes are presented. Technology transfer was based on an integrated participatory approach where components of land husbandry were essential. Outcomes were very promising such that the final objective of empowering alternative soil management systems in steeplands showed good potential provided the participation of local farmers. Soil and water conservation alternative technologies (SWCAT) based on management of residues and selection of "noble weeds" as protective cover showed negligible soil losses in comparison with bare soil plots, and good acceptability by farmers.

Additional Keywords: tropical steeplands, participatory research and extension, erodibility, erosivity.

Introduction
Water erosion associated with smallholder agriculture in steeplands has been frequently combated by the promotion of conventional barrier soil and water conservation (CSWC) technologies to control soil loss (Helling 1999). It has been assumed that erosion is a force in its own right, that it is the main reason for declining yields per unit area in tropical zone, and that quantities of yield lost are closely proportional to the quantities of soil eroded. Based on these assumptions, past CSWC had three chief components (Shaxson 1997): i) physical works to catch, guide and prevent damage by runoff; ii) pressures to stop people from cutting down forest, to reduce the number of domestic grazing animals, and to reduce the frequency of tillage; iii) Planning of patterns of land use according to Land Use Capability Classes based on the assessment of different degrees of hazard of erosion. However, among resource-poor small farmers of tropical steeplands none of these "conservation technologies" has been either particularly popular, or widely adopted or effective (Shaxson 1997; Obando 1999). They have proved to be uncomfortable with small farmers' livelihood systems, their capacities, resources or perceptions of productivity problems. Farmers' perceptions about soil conservation and decisions are rational. ´Their prior concerns are not related to soil erosion but rather to land shortages, increased crop production, market opportunities and family food security (Helling 1999). On the other hand, erosion research in steeplands has been historically ignored by scientific community, in part due to preconceptions created by the Land Use Capability Classification System that considers soils with slope greater than 20% unsuitable for cultivation because high susceptibility to erosion (Thurow and Smith 1998). Within this context, this research had a threefold objective: *i*) conciliate farmers' and conservationists' concerns about minimizing soil losses and runoff; *ii*) to get a better understanding of erosion process of Andisols in steeplands; and *iii*) to test different soil and water conservation alternative technologies (SWCAT) based on a land husbandry approach and their adoptability by small blackberry producers in steeplands of Colombian Andes.

Materials and methods
Figure 1 shows basic methodological scheme of this research and extension work developed during a two and a half year period (June 2001-December 2003). Basic research and technology transfer was carried out in La Concha farm of University-Enterprise Foundation of Caldas (5º12'N, 75º26W, 2100 masl) located in Neira Municipality of Caldas Department in the Central Cordillera of Colombian Andes. Experimental soils are classified as *Hydric Fulvudands* (USDA 1992). Landscape is mountainous with an isomesic temperature regime and variable slope ranging between 35% and 67%. Mean annual rainfall is about 2000 mm. Antecedent land use was fifteen years of coniferous plantation (*Pinus patula)* and native shrubs. Table 1 shows physical and chemical properties of the experimental soil determined by standard methods (IGAC 1990). Four treatments of crop and surface soil management and one reference treatment were tested as showed in Table 2. An A-frame was used to establish the contour planting lines of the blackberry crop. For maize and beans, zero tillage was applied by using a manual sowing devise called "matraca".

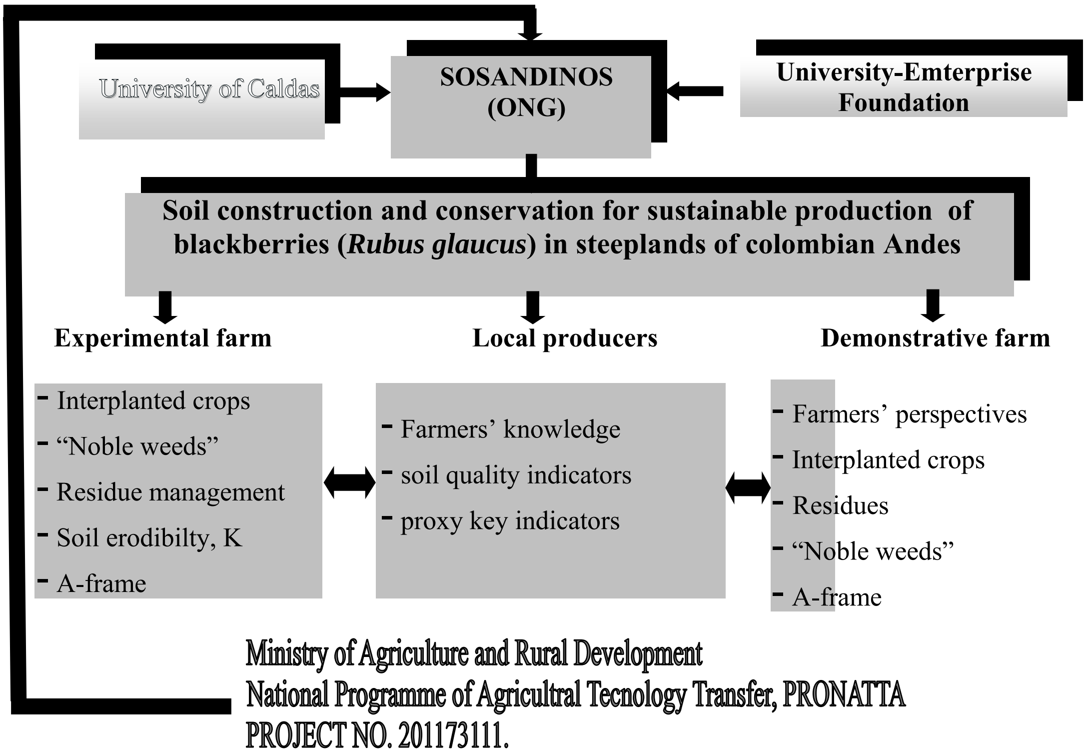

Figure 1. Main components of local research and extension

Twelve 5 m x 22 m plots corresponding to different management practices (T1, T2, T3 and T4) were installed following the recommendations of Sombatpanit (1992) cited by Hudson (1993) and three 3.6 m x 15 m reference plots (T5) were installed following the recommendations of Obando (2000). Reference plots were maintained under permanent fallow and cultivated along the slope. A completely randomized experimental layout with three replications was applied. Noble weeds were selected by application of an integrated management system involving a so-called manual "chemical hoe" (Rivera 2000) for site specific herbicide application, machete and manual pulling out of deeply rooted weeds. Field days and workshops were carried out to show surface water erosion processes to local farmers. Erosivity index (EI), erodibility index (K) and cover factor (C) were determined following the methods of (Wishmeier and Smith 1978) as described by Carmona et al (2004). Type and percentage of soil cover was assessed on a monthly basis following the method suggested by da Veiga and do Prado (1994).

Table 1. Main chemical and physical properties of the experimental soil

Organic matter (%)	12	**CIC (Cmol. Kg^{-1})**	21.5
pH	6.2	**Bulk density (Mg.m^{-3})**	0.85
Phosphorous (mg. Kg^{-1})	27.25	**Sand (%)**	64
Potassium (Cmol. Kg^{-1})	0.48	**Clay (%)**	5
Magnesium (Cmol. Kg^{-1})	2.29	**Total porosity (%)**	66
Manganese (Cmol. Kg^{-1})	36.3	**Weigh diameter of water stable aggregates (mm)**	2.9
Zinc (Cmol. Kg^{-1})	13.0	**Hydraulic conductivity (cm.h^{-1})**	21.6

Results

During the experimental period (November 2202 – November 2003) 193 storms occurred with a total rainfall of 1139 mm. 38 showers (20%) resulted to be erosive with a maximum I_{30} of 44 mm.h^{-1}. Table 3 shows monthly soil losses and Table 4 shows monthly values of rainfall, erosivity index (EI), erodibility and cover factor C Total soil losses for T1 were 144,89 Mg.ha^{-1}.y^{-1}. The annual erosivity index (R) was 2047 MJ.mm.ha^{-1}.h^{-1}.y^{-1}. Consequently, the erodibility index, K, resulted to be 0.055 Mg. ha. h. ha^{-1}. MJ^{-1}. mm^{-1}. Based on results of Dvorakova (2002) cited by Carmona et al. (2004) R is low if compared with regional data which ranged between 2046 MJ.mm.ha^{-1}.h^{-1}.y^{-1} and 21959 MJ.mm.ha^{-1}.h^{-1}.y^{-1}. The high erodibility index is likely to be markedly influenced by the high sand content and low water stable aggregate stability (see Table 1).

Table 2. Treatments and slope range

Treatment	Management practice	Slope range (%)
T1	Blackberry mono-cropping and conventional hoe tillage. Weed management with herbicides	37 - 49
T2	Blackberry inter-planted with maize (*Zea mais*) and beans (*Phaseolus vulgaris*), permanent cover, direct drill (zero tillage), selected covers of "noble weeds", management of crop residues	35 - 67
T3	Blackberry with zapallo (*Cucurbita maxima*, a variety of calabash;), permanent cover, direct drill (zero tillage), selected covers of "noble weeds", management of crop residues	41 - 44
T4	Blackberry inter-planted with maize (*Zea mais*), permanent cover, direct drill (zero tillage), selected covers of "noble weeds", management of crop residues	37 - 64
T5	Reference plot: Bare soil and cultivated along slope	48 - 52

Table 3 shows monthly soil losses and Table 4 shows monthly values of C factor. As expected, C values in most cases were less than 1, excluding T1 in September with a value of 1.09, which is likely to be associated with low contact soil cover. In fact, micro topographic features indicating accelerated water erosion (Bergsma, 2003) such as rills, small scarps, bed flux, and sedimentation surfaces were observed. Annual values of C ranged between 0.0035 and 0.15. In general, C was low, even for conventional soil management (T1), likely because the effect of contour lines of the blackberry crop which increased surface roughness. Percentage of soil cover was markedly lower in T1 (Table 5).

Table 3. Soil losses (Mg. ha^{-1}.y^{-1}) for the experimental period (mean of three replications)

Month	T1	T2	T3	T3	T5
November	1.31	0.15	0.09	0.18	15.68
December	0.00	0.00	0.00	0.00	0.00
January	0.04	0.01	0.02	0.03	0.09
February	3.44	0.02	0.02	0.01	9.68
March	5.14	0.19	0.42	0.27	57.61
April	0.26	0.02	0.02	0.02	6.29
May	0.07	0.00	0.00	0.00	5.76
June	0.04	0.01	0.01	0.00	0.35
July	0.09	0.05	0.02	0.02	0.38
August	0.25	0.00	0.01	0.00	0.65
September	5.41	0.03	0.10	0.02	4.96
October	5.51	0.04	0.04	0.00	43.45
Total	21.56	0.51	0.74	0.55	144.89

Table 4. Monthly rainfall, erosivity, erodibility and cover factor

Month	Rainfall (mm)	Erosivity†	Erodibility‡	Soil cover factor(C)			
				T1	T2	T3	T4
November	53	59	0.267	0.084	0.010	0.006	0.011
December	4	0	-	-	-	-	-
January	9	23	0.004	0.472	0.104	0.211	0.319
February	83	225	0.043	0.355	0.002	0.002	0.001
March	175	654	0.088	0.089	0.003	0.007	0.005
April	120	124	0.051	0.041	0.003	0.003	0.003
May	87	108	0.053	0.011	0.001	0.001	0.000
June	83	86	0.004	0.123	0.016	0.019	0.005
July	27	17	0.022	0.244	0.122	0.053	0.066
August	69	83	0.008	0.391	0.000	0.010	0.006
September	96	239	0.021	1.090	0.006	0.020	0.004
October	335	429	0.101	0.127	0.001	0.001	0.000
Annual Mean	1139	2047	0.055	0.149	0.004	0.005	0.004

†(Mj.mm.ha^{-1}.h^{-1}.a^{-1}); ‡ (Mg.ha.h.ha^{-1}.MJ^{-1}.mm^{-1})

Table 5. Type and percentage of cover

Type	T1	T2	T3	T4
Without cover	41.05	4.29	6.25	4.48
Residues of coniferous (*Pinus patula*) and native shrubs	27.71	44.70	39.89	50.27
Noble weeds	19.12	32.54	36.19	34.30
Interplanted crop	0.00	12.38	8.80	6.37
Blackberry crop	12.12	6.10	8.88	4.59
Total	**58.95**	**95.71**	**93.75**	**95.52**

To control 85% of soil losses a cover of 59% was needed, and to control nearly 100% of soil losses was necessary 95% of soil cover. These results agree with those found in steeplands of Honduras, where to control 90% of erosion a soil cover of 75% was needed (Shaxson, 1999) Zapallo (*Cucúrbita maxima*) is an alternative as cover crop, as long as it is interplanted or associated with ligneous crops such as Maize.

Table 6 shows enrichment ratio (ER), defined as the relation between concentration of chemical elements in eroded sediments and concentration in the original soil (Stocking, 1984). In general terms, ER values were higher than 1, except for organic matter with a value of 0.8. For the rest of elements ER ranged between 1.0 and 14.9. Elements with higher average ER were Phosphorous, Manganese and Zinc with values of 2.4, 2.4 and 4.6 respectively. ER values resulted to be low if compared with those reported by Stocking (1984), particularly for organic matter, total nitrogen, available Phosphorous and changeable potassium. However, nutrient losses might induce high impacts on crop yields as indicated in Table 7.

Table 6. Enrichment Ratio[ξ]

Treatment	Organic Matter	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu
T1	1.2	1.1	1.9	1.4	1.3	1.6	1.1	2.2	2	1.2
T2	1	1	3.2	1.1	1	1.9	1.2	1.9	1.2	1.3
T3	1.1	1.1	4.5	2.5	1.4	2.7	1.7	3	3.6	1.3
T4	0.8	0.9	1.4	1.4	1	1.2	1.2	2	1.4	1
T5	1	1	1.1	1.4	1	1	1.7	3	14.9	1
Average	**1**	**1**	**2.4**	**1.6**	**1.1**	**1.7**	**1.4**	**2.4**	**4.6**	**1.2**

[ξ]Stocking 1984

Table 7. Estimated losses of commercial fertilizers

Treatment	Organic Matter	Urea	Triple Super phosphate	KCl	MgO
	Kg. ha^{-1}				
T1	2845.9	309.3	2.0	7.5	10.4
T2	68.9	7.5	0.1	0.3	0.4
T3	111.7	12.1	0.3	0.9	0.9
T4	59.4	6.5	0.2	0.3	0.3
T5	13523.1	1469.9	5.4	22.4	33.9

Economic Impact

Table 8 shows a comparison between utilities and soil losses for different treatments of management of the blackberry crop. Conventional management (T1) reported less income and higher production costs, which it is likely to be associated to soil and nutrient losses (Table 7) and higher inputs in terms of herbicides and labor for "cleaning" (elimination of weeds by hoe and machete). As it is shown in Table 7, soil and water conservation alternative technologies (SWCAT) based on management of residues and selection of "noble weeds" as protective cover (T2, T3 and T4) showed negligible soil losses in comparison with conventional crop management (T1) and produced higher utilities for the blackberry crop (2069, 3101 y 5849 thousands COL$.y^{-1}, respectively). It is likely that higher yields in T4 were associated to a better soil quality in terms of higher soil agrodiversity, higher water retention, lower losses of nutrients, etc. In effect, (Zuluaga 2002) found lower activity of soil macrofauna in conventional blackberry mono-cropping systems; this means, hoe tillage and weed management with herbicides as the T4 experimental treatment.

Table 8. Economic analysis. Thousands of Colombian pesos ($\$.y^{-1}$)[£] and soil losses ($Mg.ha^{-1}.a^{-1}$)

Treatment	Yield	Income	Costs	Utilities	Soil losses
	$Mg.ha^{-1}.y^{-1}$	Thousands COL$.y^{-1}$			$Mg.ha^{-1}.y^{-1}$
T1					
Blackberry	4.89	4890	4462	**428**	**21.56**
T2					
Blackberry	6.36	6360	4291	2069	
Maize	0.55	1362	820	542	
Beans	0.41	1142	950	192	
Total		8864	6061	**2803**	**0.51**
T3					
Blackberry	7.39	7392	4291	3101	
Zapallo	0.59	1758	895	863	
Total		9150	5186	**3964**	**0.74**
T4					
Blackberry	10.14	10140	4291	5849	
Maize	0.54	1340	820	520	
Total		11480	5111	**6369**	**0.55**

[£]Prices of October 2003. One US dollar was about COL$2800.

Conclusions

Results demonstrated that ASWCT based on maintenance of soil properties resulting from better land husbandry enable more efficient erosion control in steeplands than physical barriers and increase sustainability production.. With a permanent cover of 90%, soil losses by water erosion are minimal. Soil erosion in Andean steeplands might not be as severe as have been reported and erosion risk depends more on management practices than on slope *per se*. Consequently, new Land Capability Classification Systems according with tropical steeplands realities are needed. This research and extension experience showed that erosion control and farmers' needs can achieved simultaneously with benefits to both people and environment.

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