Farmers' decision making on land use

– the importance of soil conditions versus other factors in the case of Río Cabuyal watershed, Colombia

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Introduction

Many studies provide evidence of farmers' detailed knowledge of their soils and of their ability to draw agronomic management implications from this knowledge (Talawar 1996; Talawar and Rhoades, *forthcoming*). As a classic example, Rounce (1949) and Malcolm (1953) documented the soil taxonomy of the Wasukuma people in Northwestern Tanzania, finding nine major soil classes and specific management practices associated with each soil type. Among the most important descriptors upon which farmers base their soil classification are soil color, soil texture and soil structure (Rounce 1949; Malcolm 1953; Ravnborg 1992; Bellon and Taylor 1993; Zimmerer 1994; de Kool 1996). Such folk soil taxonomies have been found to correlate well with so-called scientific descriptions of soil properties. In a study from Chiapas, Mexico, farmers identified and quality ranked four main classes of soils. Analysis of samples taken from these soils with respect to properties such as pH, organic matter content, and fractions of sand and clay, showed a significant correlation between these properties and farmers' quality rankings of the soils (Bellon and Taylor 1993).

Given this ability of farmers to distinguish different soil types, it is generally hypothesized that farmers would select the best soils for cultivation while leaving poorer soils as forest or natural pasture. As the soils gradually degrade as a consequence of cultivation, crop choice is expected to change from more demanding crops such as maize and beans to less demanding crops such as cassava before the soil is finally put under fallow to regenerate its fertility. Such hypotheses also guide land evaluation and land use planning, which tend to be based primarily upon soil and climatic data (Brinkman 1994; Alfaro *et al.* 1994) despite aims to also include economic and social factors (FAO 1976; Rossiter and Van Wambeke 1993).

Soil properties, and more generally bio-physical properties, are not, however, the only factors entering into farmers' decision-making process with respect to land use and crop choice. Other factors, such as market opportunities and input requirements versus availability, also play important roles (Talawar and Rhoades, *forthcoming*).

This paper examines the relative importance of bio-physical conditions versus other factors, such as concerns with markets, access to productive resources (land, labor and capital) and overall objectives, which may guide farmers' decision making with respect to land use, i.e. choice of land cover (forest, fallow, pasture or type of crops). The paper is based on a study designed to gain insight into the farmer's decision-making process and is located in the Río Cabuyal watershed, situated in the Andean hillsides of southwestern Colombia.

The study area
The Río Cabuyal watershed is situated in the Andes in southwestern Colombia at altitudes ranging from 1,200-2,200 meters a.s.l. and covers an area of approximately 7,000 hectares. Annual rainfall is just below 2,000 mm with a pronounced dry spell from June to August. The watershed is relatively densely populated (100 persons per km^2), although there are substantial variations within the watershed (see map 1).

Small-scale farming, either on owned or rented land or through day-laboring on local small-scale farms, provides the main source of income in the area. The average area cultivated is just below 2 hectares[1], and the principal crops grown are coffee, plantain, cassava, maize, beans and tomatoes. In the upper watershed, fruits are also grown. Livestock production is of minor importance and only 14% of the households owns livestock. The Panamerican Highway cuts across the middle of the watershed giving the population in the mid- and to some extent low-altitude areas relatively good access to markets in neighboring townships as well as in the bigger cities of Popayán and Cali. A majority of farmers sell at least part of their production. Of the most important crops mentioned above, more than 90% of the households sell at least one of these crops. Excluding coffee, 71% of the households sell beans, cassava, maize, plantain or tomatoes. On average, 80% of the families have access to piped drinking water and virtually all households use firewood as the primary source of energy for cooking.

Data collection
As a first step towards gaining insight into farmer decision making related to land use, workshops were held with groups of farmers in three different locations that differed with respect to altitude and thus agro-ecological conditions, accessibility and population density (see map 1). Farmers were invited to the workshops on the basis of their well-being status[2]. Since well-being in Río Cabuyal is closely associated with access to productive resources such as land, labor, and capital, this allowed us to explore whether differences in access to productive resources condition differences in the objectives which farmers pursue, the knowledge upon which decisions are based and the actual decisions made by farmers. Two workshops were arranged in each location: one including participants enjoying a high or middle level of well-being and one including participants from households classified as suffering the lowest level of well-being. One workshop, however, had to be cancelled due to lack of assistance. Hence, a total of five workshops were held, each with between five and eight participants[3].

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[1] This and the following baseline information are drawn from the 1993 household census, Río Cabuyal Watershed, Cauca Department.

[2] Based on well-being rankings conducted in the Río Cabuyal watershed to elicit local indicators of well- and ill-being, a quantifiable well-being index was constructed and coupled with information available from the 1993 household questionnaire survey from the watershed. This led to a well-being classification according to which 23% of the households (225) are classified as enjoying the highest level of well-being, 46% (441) are classified as enjoying a middle level of well-being and the remaining 31% (294) as suffering the lowest level of well-being. Among the factors that enter into the definition of well-being are the extent to which a household needs to day-labor at neighboring farms, land tenure, housing quality, household food security, ability to confront health problems, use of day-laborers, resource ownership, and crop diversity. The well-being methodology is described in more detail in Ravnborg and Guerrero (1996).

[3] The workshops were held between November 1994 and February 1995.

Workshop participants were asked to describe what they perceived to be different types of plots, using a *maqueta*[4] of the Río Cabuyal watershed as a reference point. This allowed the eliciting of local plot descriptors. Subsequently, workshop participants were asked to identify three highly contrasting plots. Each of these plots were visited and questions were asked with regard to the decision-making process, i.e. the objectives, concerns and reasons which had led to the actual land use of the specific plot.

The workshops provided insight into the conceptual and logical framework within which farmer decision making takes place. On this basis, a pictorial questionnaire (see figure 3) was developed. The aim of the questionnaire was to collect quantifiable information about the specific relationship between 1) land cover (forest, fallow, pasture or type of crop); 2) bio-physical conditions; 3) the management to which it was subjected; and 4) the reason for choosing a specific type of land cover (see figure 3, showing the questionnaire sheet).

A sample of 198 households, stratified according to well-being and altitude zone[5], was drawn from the Río Cabuyal watershed population. For each household, a maximum of four plots was surveyed with one questionnaire sheet being filled out for each plot. For households having more than four plots, the respondent was asked to select the four most contrasting plots (and uses) as the plots to be included in the survey. For households having plots under uses others than crops, i.e. fallow, pastures and forest, a maximum of two such plots and uses were surveyed. Table 1 provides a description of the sample by household well-being level. As shown in the table, the sample contains a relatively similar number of plots in crops and fallow for each of the well-being levels and a very different number of plots in pasture and forest. This reflects the fact that households with the highest level of well-being are significantly more likely to own plots in pasture and forest[6].

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[4] The maqueta is a three-dimensional, to scale, model of Río Cabuyal watershed developed by Sol y Tierra (a local NGO), Asociación de Cabildos, Norte de Cauca, Caldono, Cauca, and CIAT's hillsides project (Rubiano *et al.* 1997)

[5] Three altitude zones were distinguished: low altitude zone: <1,500 m; medium altitude zone: 1,500-1,700 m; and high altitude zone: >1,700 m.

[6] Both for pasture and forest, the distribution of households owning plots by well-being level were significantly different from the expected distribution at the 0.005 level (chi-square test) while no significant difference was found for crops and fallow.

Table 1
Sample description by household well-being level
Number of plots in sample and percent households who own plots in different land use types by well-being level

	Highest level of well-being (68 households; 210 plots)		Middle level of well-being (69 households; 179 plots)		Lowest level of well-being (61 households; 143 plots)		Total (198 households; 532 plots)	
	# plots in sample in	% households owning plots in	# plots in sample in	% households owning plots in	# plots in sample in	% households owning plots in	# plots in sample in	% households owning plots in
Crops	97	94	100	97	84	98	281	96
Pasture	31	51	17	25	6	10	54	29
Fallow	43	71	40	59	34	59	117	63
Forest	39	59	22	33	19	33	80	42
All	210		179		143		532	

Overall, 78% of the plots owned by the sample households were included in the survey, which in area terms corresponds to 63% of the area owned by the sample households. However, as shown in figure 1, the corresponding percentages vary by land use type. Greatest coverage, both in terms of number of plots and area, was obtained for forest, while lowest coverage was obtained for crops in terms of number of plots and for pasture in terms of area.

Figure 1
Sample description by land use type
Number and area (hectares) of sample plots and of plots owned by sample household but not included in the plot sample, by land use type

For households having more than one plot in crops, the respondent was asked to provide information about plots under different crops that were also considered among the most important plots to the household. Figure 2 shows the crop distribution for the plots under crop cultivation in the sample (=281) and in the Río Cabuyal watershed (=2522)[7]. Overall, the crop distribution in the sample is similar to that in the Río Cabuyal watershed as a whole, with approximately half of the plots under coffee. However, the figure shows an overweight of plots with cassava grown as a monocrop (20% in sample versus 12% in Río Cabuyal watershed) and of plots under tomato cultivation (7% in sample versus 2% in Río Cabuyal watershed). This is a reflection of the importance attached to these crops by farmers as compared to other crops such as grains (maize and beans) and cassava grown in association, often, with grains.

Figure 2
Crop distribution in sample (=281 plots) and in Río Cabuyal watershed (=2,522 plots)
Percent plots per crop

7 Source: 1993 household census, Río Cabuyal watershed, Cauca Department.

Figure 3 shows the questionnaire sheet. For each surveyed plot, the respondent was asked to first indicate the relevant land use type. Next, the respondent was asked to indicate the bio-physical conditions of the plot, its previous use and the actual management given to the plot, in terms of input and labor use, by putting a circle around the relevant options moving clockwise round the images on the questionnaire sheet. Following this, the open-ended question concerning reasons for choosing a specific crop was asked. Through the workshops, a number of possible reasons leading farmers to make specific land use choices had already been identified. These were grouped into four sets of possible reasons, corresponding to the four main land use types. Each of these pre-identified reasons had been written onto individual cards. If the reason(s) mentioned under the open-ended question was not already included among the cards, this reason was written down and given the rank "1" (important). As the final step in the questionnaire, the respondent was asked to rank the pre-identified reasons – the cards – according to their importance for making a specific choice, into three categories: 1: important; 2: no so important; and 3: not at all important. Each questionnaire sheet took approximately 20-25 minutes to fill in[8].

Figure 3
Pictorial questionnaire developed for the Río Cabuyal decision-making study

The location of the household – the house – was geo-referenced. Map 1 shows the location of the 198 households included in the survey. Since most plots are situated close to the homestead[9], this provides a rough indication of the location of the plots.

The data was entered into a database and analyzed in SPSS.

Discussion of results

Soil conditions and their importance for farmers' choices of land use type
As a first attempt towards judging the importance of soil conditions versus other factors influencing farmers' choices of land use type, the tables 2-5 below list the reasons mentioned by farmers as influencing their decision to leave a particular plot in forest, fallow, pasture or under a specific crop and their ranks in terms of importance.

8 The interviews were conducted in June – August 1995.

9 Sixty-seven percent of the 532 plots were situated within less than 10 minutes walking distance from the homestead.

Table 2

Reasons for having plots in forest, ranked in terms of importance (N=78)

Frequency of ranks and combined score. Soils related reasons are indicated in italics.

	Number of times ranked as *important* (score1=1) [1]	Number of times ranked as *not so important* (score2=2) [2]	Number of times ranked as *not important* (score3=3) [3]	Combined score ([1]*1/score1 + ([2]*1/score2 + ([3]*1/score3)
To protect the water (#64)	65	0	13	69
To have a source for firewood and building materials (#61)	54	13	11	64
To protect the soil (#62)	*41*	*37*	*0*	*60*
To give shade (#67)	19	44	15	46
Haven't had time to cut it down (#65)	0	7	71	27
The soil doesn't serve for crops (#63)	*0*	*4*	*74*	*27*
We are paid to conserve the forest (#66)	0	4	74	27

Table 3

Reasons for having plots in fallow, ranked in terms of importance (N=110)

Frequency of ranks and combined score. Soils related reasons are indicated in italics

	Number of times ranked as *important* (score1=1) [1]	Number of times ranked as *not so important* (score2=2) [2]	Number of times ranked as *not important* (score3=3) [3]	Combined score ([1]*1/score1) + ([2]*1/score2) + ([3]*1/score3)
Lack of money (#49)	62	13	35	80
Lack of money for inputs and laborers (#45)	61	8	41	79
Restore fertility (#42)	*50*	*14*	*46*	*72*
Time for fallow in cropping cycle (#51)	*32*	*14*	*64*	*60*
Prefer to cultivate other plots (#44)	21	31	58	56
No time for planting (#43)	18	16	76	51
Pays better to day-labor (#41)	9	18	83	46
Lack of laborers (#48)	0	21	89	40
Drought/ climate (#47)	0	16	94	39
Low crop prices (#46)	0	8	102	38
Lack of seeds (#50)	0	6	104	38

Table 4

Reasons for having plots in pasture, ranked in terms of importance (N=54)

Frequency of ranks and combined score. Soils related reasons are indicated in italics

	Number of times ranked as *important* (score1=1) [1]	Number of times ranked as *not so important* (score2=2) [2]	Number of times ranked as *not important* (score3=3) [3]	Combined score ([1]*1/score1) + ([2]*1/score2) + ([3]*1/score3)
Feed for horses (#91)	30	12	12	40
Feed for livestock (#92)	31	7	16	40
Livestock pays better (#95)	27	7	20	37
The soil doesn't serve for crops (#94)	*0*	*11*	*43*	*20*
Haven't had time to plant a crop (#93)	0	9	45	20

Table 5

Reasons for crop choice and their rank

Frequency of ranks and combined score. Soils related reasons are indicated in italics

Reason	Number of times ranked as *important* (score1=1) [1]	Number of times ranked as *not so important* (score2=2) [2]	Number of times ranked as *not important* (score3=3) [3]	Combined score ([1]*1/score1) + ([2]*1/score2) + ([3]*1/score3)
Having products for sale (#2)	205	31	44	235
Doesn't require a lot of inputs (#3)	169	48	63	214
Having a crop for home consumption (#1)	153	85	42	210
The crop has a secured buyer (#14)	148	78	54	205
The crop is easier to sell than other crops (#8)	138	75	67	198
Having a crop that is easier to transport (#10)	119	102	59	190
Doesn't require so much work (#4)	101	79	100	174
The crop doesn't cause health problems (#9)	99	118	63	179
Having a crop that pays better(#7)	98	62	120	169
Having a short season crop (#12)	62	53	165	144
Having a crop that improves the soil (#11)	58	69	153	144
The crop doesn't have fixed planting season (#5)	57	57	166	141
Having a crop that can be harvested all year (#13)	40	29	211	125
The crop has a stable price (#6)	18	10	252	107

Judging from these tables, the importance of soil conditions is most notable for the decision to leave a plot in forest. The reason *to protect the soil* ranked as the third most important reason for leaving a plot in forest with a combined score of 60 as compared to a score of 69 for the most important reason, *to protect the water.*

For the plots in fallow, reasons related to soil conditions ranked third and fourth. Yet, fallow is normally thought of as a means to regenerate soil fertility. In this sense, it is surprising that reasons related to regenerating soil fertility did not rank highest among the reasons for leaving a plot fallow. More important reasons for leaving a plot fallow were reasons related to lack of economic resources for cultivating the plot.

Reasons related to soil conditions seem to be of least importance for leaving plots under pasture (table 4) or under a specific crop (table 5). The reason *the soil doesn't serve for crops* ranked next to last among the five reasons mentioned for leaving a plot under pasture, whereas the reasons ranked as most important related directly to the immediate economic benefit of having pasture[10]. With respect to crop choice, none of the reasons explicitly relate crop choice to the soil conditions and only two reasons, *doesn't require a lot of inputs* (#3) and *having a crop that improves the soil* (#11) relate indirectly to soil conditions.

That soil conditions do not appear overly important among the reasons *explicitly* mentioned for choosing a specific land use type or crop is not in itself a sufficient indication of the importance of soil conditions. Like climate, farmers might very well consider soil conditions as givens at the moment of deciding upon land use. Certain land use types or crops may simply be discarded *prior* to the explicit decision-making process *due to* the *known* actual soil conditions. Supposing this to be the case, we should, however, be able to detect significant correlation between soil conditions, on the one hand, and choice of land use type and crop on the other. The remaining part of this section examines the extent to which this is the case.

In the workshops held prior to the questionnaire survey, farmers were found to characterize soil conditions according to soil color and soil structure/texture[11] as well as according to their location in the landscape and their slope[12]. These local descriptors are summarized in table 6 and were included as variables in the questionnaire survey (see figure 3).

Table 6
Descriptors of bio-physical plot conditions

Soil color	***Soil texture/ soil structure***	***Slope***	***Location***
• *black* • *reddish* • *yellow* • *brownish*	• *sandy* • *clayish* • *dusty* • *lumpy*	• *flat* • *sloping* • *very steep*	• *hillside* • *valley bottom/ depression* • *plain* • *ridge*

10 It is important to note that ranking reasons related directly to economic benefit as *important* does not preclude other reasons, such as those related to soil conditions, from also being ranked as *important.*

11 Soil color and structure were also identified as the most commonly used soil descriptors in a study later carried out by Stefanie de Kool (de Kool 1996).

12 There appeared to be no differences between the descriptors used by farmers with different levels of well-being, nor between farmers living in different zones of the watershed.

In addition to the soil descriptors, the workshops revealed the existence of decision-making rules such as 'red soils being good for cassava while bad for coffee', or 'valley bottom soils being good for maize'.

In order to summarize the soil-related features into a single variable which can subsequently be correlated with land use type, the variables soil color, soil texture, slope and location, were entered into a homogeneity analysis[13]. The scores assigned to each object – in our case, plot – according to the most important dimensions resulting from the homogeneity analysis were subsequently entered as input variables for a cluster analysis in order to identify clusters or classes of soil conditions, considering all of the soil-related features simultaneously.

Figure 4 shows the category quantifications, i.e. average object scores for objects in the same category, according to the two first – and most important – dimensions identified through the homogeneity analysis using soil texture, soil color, slope and location as input variables. The closer the points representing two categories or variable options are to each other, the more associated they tend to be; and the further a point is from the origin (the intersection between the axes), the more they differ from the average. As an example, the upper left-hand square of the figure shows that plots which have yellow and red soils also tend to have slopes between 30-70% and to be located on the hillsides. Moreover, it can be seen from the figure that slope and location largely define dimension 1 and to a lesser extent soil color, while dimension 2 is defined by soil texture. This means that slope followed by location and soil texture are the variables that discriminate most between the soil conditions of the plots, whereas soil color discriminates less.

Figure 4
Soil conditions for all plots (=532)
Category quantifications for soil-related variables

Using these two dimensions as input variables, a hierarchical cluster analysis was undertaken to classify the 532 plots. The solution with five clusters was selected. Figure 5 below represents the object scores of the 532 plots, marked by their cluster membership, according to the two dimensions calculated in the homogeneity analysis.

Figure 5
Object scores for all plots (=532), marked by soil-based cluster membership

The characteristics of these clusters are summarized in table 7. Cluster 1, which contains the majority of the plots (=272), consists of gently to steeply sloping hillside plots with black or brown, dusty soils. The plots in cluster 2 (=99) are steep to very steep plots, located on the hillsides or in the valley bottoms or depressions. They tend to have black, sandy soils. Cluster 3, which is the smallest cluster with only 36 plots, is characterized by flat plots, located on the plains or in the valley bottoms. They have black soils of mixed texture. The 40 plots in cluster 4 have red soils of mixed texture and are located on the steep or very steep hillsides. Finally, cluster 5 contains 85 plots

[13] Homogeneity analysis is available in the statistical package SPSS and is equivalent to a multiple correspondence analysis.

situated on gently sloping or flat plains or valley bottoms. Their soils tend to be black with a predominantly dusty texture.

Table 7
Description of soil-based clusters for all plots (=532)

Cluster	Predominant soil characteristics
Soil1 (=272 plots)	black/brown, dusty soils on gently to steeply sloping hillsides
Soil2 (=99 plots)	steep to very steep hillsides or valley bottom/depression plots with black, sandy soils
Soil3 (=36 plots)	black, mixed texture soils on flat plains or in valley bottoms
Soil4 (=40 plots)	red, mixed texture soils on steep to very steep hillsides
Soil5 (=85 plots)	black, dusty soils on gently sloping or flat plains or valley bottoms/depressions

Using this new soil conditions variable, we can now proceed to correlate soil conditions with farmers' actual choices of land use type.

There appears to be only vague association between soil conditions and farmers' choices of land use type. Figure 6 and table 8 present the results of a correspondence analysis between the soil-based cluster variable and land use. Figure 6 indicates some association between forest and the soil-based cluster 2. This owes to the fact that 28% of the plots under forest belong to soil cluster 2 as compared to only 9% and 16% for plots under pasture and in crops. Also plots under fallow seem to be somewhat associated to soil-based cluster 2 with 22% of the plots under fallow belonging to this cluster. None of these associations, however, appear to be statistically significant (*p=.207*). This implies that contrary to what is commonly hypothesized, choice of land use type does not appear to be correlated with soil conditions.

Figure 6
Soil conditions (soil-based clusters) by land use type for all plots (=532)
Row and column scores, resulting from correspondence analysis

Table 8
Soil conditions (soil-based clusters) by land use type for all plots (=532)
Percent plots by land use type

	Crops (n=281)	Pasture (n=54)	Fallow (n=110)	Forest (n=80)	All land use types (N=532)
Soil cluster 1	52	59	50	43	51
Soil cluster 2	16	9	22	28	19
Soil cluster 3	6	9	9	6	7
Soil cluster 4	8	11	7	5	8
Soil cluster 5	18	11	12	19	16
All clusters	100	100	100	100	100
Pearson chi-square test: *p=.207*					

Factors other than soil conditions might, however, influence farmers' choices of land use type. Distance to the plot, the farmer's level of well-being, the total area owned are among such factors. In order to assess to which extent this is the case, these variables were entered into a homogeneity analysis as well as a non-linear canonical correlation analysis together with the soil conditions and land use variables[14]. Figures 7 and 8 show the results of the homogeneity analysis and the non-linear canonical correlation analysis, respectively.

The first plot in figure 7 indicates land use to be equally related to well-being and farm area on the one hand, and distance and soil conditions on the other. It depicts the discrimination measures of the five variables included in the analysis, plotted against the two dimensions calculated in the homogeneity analysis. Dimension 1 is clearly defined by well-being and farm area, while dimension 2 is equally clearly defined by distance and soil conditions. The second plot in figure 7 provides more detail about the character of these associations. It indicates that households enjoying the highest level of well-being are more likely to have plots under pasture than other households. It also indicates that households having larger farms (above 5 *plazas*) are more likely to have plots in forest or pasture than households with smaller farms. Looking at the second dimension, it reveals that plots which are situated far from a passable road, are more likely to be left in forest than plots closer to the road. The decision to have a plot in crops or under fallow does not appear to depend on any of the variables included in the analysis (the points representing plots in crops and under fallow are both situated close to the origin).

Figure 7
Land use choice by well-being, farm area, distance from road and soil conditions for all plots (=532)
Discrimination measures and category quantifications resulting from homogeneity analysis

To explore in more detail the extent to which well-being and total farm size (which are mutually correlated), distance from the plot to a passable road and soil conditions are correlated with land use type, a non-linear canonical correlation analysis was conducted. This type of analysis allows the analysis of correlation between two or more sets of variables. In our case, the five variables were grouped into four sets: set 1 – land use; set 2 – distance; set 3 – soil conditions; and set 4 – well-being level and total farm area. Figure 8 shows the centroids plot resulting from a non-linear canonical correlation analysis, in which dimension 1 appears to be defined by distance and soil conditions and dimension 2 by well-being, total farm area and soil conditions. Pasture appears to be associated with soil cluster 3 – black soils on flat plains or valley bottoms – and highest level of well-being. Plots under forest appear to be associated with large farms (>10 *plazas*) and to a lesser extent with soil cluster 2 – steep to very steep hillsides or depressions with black, sandy soil – and plots located far from the road. As in figure 7, both the points indicating plots in crops and under fallow are situated close to the center of the graph. In conclusion, household well-being and total farm size appear to be as important in determining farmers' choices of land use type as soil conditions.

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14 Thus five variables were included in the analyses: distance to the plot from a passable road, measured in minutes; the soil-based cluster variable; well-being level, distinguishing a highest, middle and lowest level of well-being; total farm area, measured in *plazas* (1 plaza = 0.64 ha); and land use.

Figure 8
Land use choice by well-being, farm area, distance from road, and soil conditions for all plots (=532)
Centroids plot resulting from non-linear canonical correlation analysis

Soil conditions and their importance for farmers' crop choices
We now turn to consider only plots under crop cultivation and hence to examine in more detail the importance of soil conditions for farmers' crop choices. To be able to identify more subtle differences between the crop plots than the soil condition variable based on all 532 plots allows, the analysis (summarized in the figures 4 and 5) to establish the soil condition variable was repeated, just considering the crop plots (=281). A solution containing four clusters was selected.

All soil-based clusters, except cluster 4, are characterized by black or black and brown soils. With respect to soil texture (soil structure), cluster 1 is characterized by dusty soils, while the remaining clusters have mixed soil texture. Slope appears to be the variable distinguishing most between the four clusters with cluster 2 characterized by flat land and cluster 4 by slopes above 30%. Finally, with respect to location, cluster 1 and cluster 4 are both characterized by hillside plots, whereas cluster 2 and to a lesser extent cluster 3 are characterized by plots located on the plains and in the valley bottom or depressions. The characteristics of the four soil-related clusters for the crop plots are summarized in table 9.

Table 9
Description of soil-based clusters for all plots (=281)

Cluster	Predominant soil characteristics
Soil1 (=131 plots)	Black, dusty soil on gently to steeply sloping hillsides
Soil2 (=11 plots)	Black, mixed texture soil on flat plains
Soil3 (=45 plots)	Black, mixed texture soil on gently sloping plains or valley bottoms
Soil4 (=62 plots)	Red or yellow mixed texture soils on steeply sloping hillsides

Table 10 indicates that cassava is more likely to be grown on the steeply sloping, red/yellow soils in cluster 4 than other crops, and thus confirms the decision-making rules described by farmers in the workshops held prior to the questionnaire survey. Overall, however, no significant association is found between crop choice and soil-based clusters. This indicates that soil conditions are of limited importance, also when farmers choose which crop to grow.

Table 10
Soil conditions (soil-based clusters) by crop (coffee, cassava, grains, tomatoes)[15]
Percent plots per crop

	Coffee (n=138)	Cassava (n=70)	Grains (n=20)	Tomatoes (n=21)	Total (N=249)
Soil cluster 1	53	49	50	67	53
Soil cluster 2	4	4	5	5	4
Soil cluster 3	21	13	20	14	18
Soil cluster 4	22	34	25	14	25
All soil clusters	100	100	100	100	100
Pearson chi-square = 0.641					

As for the variables related to soil conditions, the variables related to crop management on the one hand (use of inputs, labor and land preparation method), and the variables related to reasons for crop choice on the other (see table 3), were submitted to separate homogeneity analyses and subsequent hierarchical cluster analyses[16].

With respect to crop management, five clusters were formed. Cluster 1 comprises plots (132) managed with no or very low levels of inputs, both in terms of nutrients and pesticides, and in terms of labor. *Gallinaza*[17] was used only on 35% of the plots and almost no day-laborers were contracted. In addition, the farmers owning plots belonging to cluster 1 dedicate a significant amount of the time to work as day-laborers on other people's farms: Only 40% of the plots in cluster 1 were managed by farmers dedicating 75% or more of their time to their own plot. The 50 plots contained in cluster 2 differ from the plots contained in cluster 1 by being managed with higher labor inputs, particularly for weeding and harvesting. Also the plots contained in cluster 3 (73 plots) receive higher labor inputs than the plots contained in cluster 1, and in addition *gallinaza* is used on half of the plots. Plots contained in cluster 4 and 5 (13 plots in each cluster) are all managed with high level of inputs both in terms of labor and nutrients. The two clusters are distinguished by the high levels of pesticide and chemical fertilizer use for the plots in cluster 4[18]. Table 11 summarizes the characteristics of these crop management clusters.

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15 Plots planted with other crops were excluded due to their low frequency.

16 In the cluster analysis for reasons for crop choice, three (instead of two) dimensions identified through the homogeneity analysis were used as input variables.

17 Chicken manure, which is the most commonly used type of fertilizer in the area.

18 This cluster is highly associated with tomato cultivation.

Table 11
Description of crop management clusters for crop plots (=281)

Cluster	Predominant crop management characteristics
Management 1 (=132 plots)	Manual land preparation, no or low levels of inputs used, no day-laborers contracted, day-laboring on neighboring farms
Management 2 (=50 plots)	Manual land preparation, no or low levels of inputs used, high use of day-laborers, do not day-labor
Management 3 (=73 plots)	Mixed land preparation, some use of *gallinaza*, contract day-laborers, day-labor on neighboring farms occasionally
Management 4 (=13 plots)	Ox-ploughing, high levels of input use, including pesticides and chemical fertilizers, contract day-laborers, do not day-labor
Management 5 (=13 plots)	Ox-ploughing, high levels of *gallinaza* use and use of pesticides, high use on day-laborers, do not day-labor

Six clusters were formed with respect to reasons for crop choice. Cluster 1 contains the majority of the plots, namely 188. The reasons that were important for crop choice for the plots contained in this cluster were *having a product sale, having a crop that doesn't require a lot of inputs,* and to a lesser extent *having a product for home consumption* and *having a crop that has a secured buyer.* Reasons related to stable price, and that the crop can be harvested all year were of least importance in deciding on crop choice for the plots in cluster 1. Cluster 2 contains 27 plots and is characterized by the importance of *having a product for home consumption* and *having a crop that doesn't require a lot of inputs.* Reasons related to marketing were of negligible importance for crop choice for plots in cluster 2. Cluster 3, which contains 29 plots, is characterized by the importance of *having a secured buyer, having products for sale* and *having a crop that can be harvested all year.* The 12 plots contained in cluster 4 are characterized by the importance of *having a crop that improves the soil* and *having a short season crop* while all other reasons were ranked as unimportant. Cluster 5, containing 22 plots, is another market-oriented cluster. The important reasons for crop choice in this cluster are *having a short season crop, having products for sale, having a secured buyer* and *having a crop that is easy to sell.* Labor and input concerns were ranked as unimportant for plots in this cluster. Finally, cluster 6 which only contains 2 plots, is characterized by the importance of market-related reasons and the insignificance of concerns with health problems and having a product for home consumption. A summary of the cluster characteristics for reasons for crop choice is provided in table 12.

Table 12
Description of reasons for crop choice clusters for crop plots (=281)

Cluster	Predominant reasons for crop choice characteristics
Reasons 1 (=188 plots)	Marketability and low input requirements
Reasons 2 (=27 plots)	Low input requirements
Reasons 3 (=29 plots)	Marketability, low input requirements and ability to harvest all year
Reasons 4 (=12 plots)	Short cycle crop and soil improvement
Reasons 5 (=22 plots)	Marketability (reasons related to input and labor used ranked as unimportant)
Reasons 6 (=2 plots)	Marketability (reasons related to home consumption and health problems ranked as unimportant)

Using the constructed variables on soil conditions, crop management and reasons for crop choice, it is now possible to analyze these variables simultaneously in order to examine the interaction between them and the extent to which they are associated with crop choice. This allows the assessment of the relative importance of soil conditions *vis a vis* other factors in determining farmers' crop choices.

As for the analysis related to land use, both homogeneity analysis and non-linear correlation analysis are conducted in relation to crop choice. Figure 9 shows two plots resulting from the homogeneity analysis, based on the cluster variables (soils, management and reasons) and the crop choice variable for the 281 plots under crop cultivation. The first plot (discrimination measures) shows a close association between actual crop choice and reasons for crop choice. Actual crop choice does not, however, appear to be associated with soil conditions[19]. The second plot shows the categories contained by each variable. The most distinctive feature is the expected close association between the decision to grow tomatoes with reason cluster 5 (market-oriented, short season and easy to sell) and crop management cluster 4, which involves high input use, particularly of pesticides and chemical fertilizers. Towards the bottom part of the plot, there appears to be an association between the choice to grow sugar cane, reason cluster 2 (home consumption and less inputs) and soil cluster 2 (flat plains or valley bottoms or depressions). The big majority of plots, however, are concentrated close to the intersection between the two dimensions. These are plots planted in cassava or coffee. To better detect possible variation between plots in cassava and coffee, a homogeneity analysis was conducted on the basis of the plots planted in only one of these two crops. Although to some extent altering the pattern of association between the four variables[20], soil conditions still appeared to be the variables *least* associated with crop choice.

Figure 9
Soil conditions, crop management, reasons for crop choice and actual crop choice for crop plots (=281)
Discrimination measures and category quantifications, resulting from homogeneity analysis

In the non-linear canonical correlation analysis, actual crop choice formed one set while the variables related to soil conditions, crop management and reasons for crop choice were defined as the second set. Figure 10 shows the centroids[21] plot, resulting from this analysis. It shows the four points representing the soil clusters located very close to the center of the plot, whereas the reason for crop choice and to a lesser extent the crop management variables are more dispersed and located more distant from the center. This reaffirms the conclusion that crop choice is *not* correlated with soil conditions but

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[19] The conclusion that crop choice is not strongly associated with soil conditions could be supposed to be a result of the smaller number of clusters considered for the soil condition variable (=4) as compared to the remaining variables (5 for management, 6 for reasons and 8 for crops). However, choosing solutions from the cluster analysis on the soil-related variables with more clusters did not change this conclusion. Nor did the exclusion from the analysis of the two plots contained in reason cluster 6 change the result.

[20] Crop choice (to plant coffee or cassava) appeared to be closer associated with management than with reasons for crop choice.

[21] The centroids are the averages of all objects belonging to the same category.

rather with reasons primarily related to marketability and concerns with input requirements.

Figure 10
Crop choice by soil conditions, crop management and reasons for crop choice for crop plots (=281)
Centroids plot resulting from non-linear canonical correlation analysis

Conclusions

Soil conditions are normally considered to be an important factor in shaping farmers' choices of land type (forest, fallow, pasture or type of crop(s)) for a specific plot. Numerous studies reported in literature provide evidence of farmers' ability to distinguish different soil types and how they deliberately determine which land use and management practice best suit a particular soil type.

Workshops conducted as part of the study reported in this paper revealed that also farmers in the Río Cabuyal watershed in the Colombian Andes possess this ability to distinguish different soil types and to determine what would be the ideal land use for each soil type. A strong correlation should therefore be expected between soil types or conditions on the one hand, and land use type or choice of crop on the other. In practice, however, our survey found this not to be the case.

First, soil conditions were only explicitly mentioned as having some importance for deciding to leave a plot in forest and to a lesser extent in fallow, while it was not mentioned as important for choosing a specific crop or for leaving a plot under pasture. Even in the case of forest and fallow, other reasons related to protecting water sources in the case of forest and lack of economic resources in the case of fallow were ranked as more important.

Second, in the case of land use type, factors such as household well-being and total farm size as well as distance from the plot to a passable road were found to be equally important as soil conditions in shaping farmers' choices of land use type. In the case of choice of crop for the plots under crop cultivation, soil conditions were of almost negligible importance. Rather than concerns with which crop is best suited to a given soil type, farmers' choice of crop for a given plot is influenced by concerns related to marketability and whether or not the crop involves high demands in terms of input and labor use.

The study reported in this paper is a case study and as such, it cannot be conclusive about the importance of soil conditions versus other factors in influencing farmers' decision-making on land use. However, it seriously questions the common emphasis on bio-physical conditions, and particularly soils conditions, in the study of land use patterns, and the often only nominal attention paid to socio-economic factors which this study found to be prominent in explaining farmers' actual land use.

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