Strict *In-situ* Conservation of *Coffea arabica* Genetic Resources in Yayu Forest: Econometric Analysis and Options for Effectiveness of the Strategy

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Abstract

Strict in situ conservation is one of the strategies to protect Coffea arabica genetic resources in its natural habitat. Nevertheless, the strategy adds considerable conservation cost to local households. This leads to conflicts and ineffective implementation. Thus, it is vital to identify policy tools to resolve the problems. The results of econometric analysis depict the existence of significant heterogeneity among households regarding their obedience to the strategy and associated costs. The paper indicates a range of interventions such as creating sense of belongingness, improving household income and reducing settlement closer to the conservation area to enhance effectiveness of the strategy.

Keywords: *In situ* conservation, effectiveness, *Coffea arabica*, genetic Resources, Ethiopia

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Introduction

Degradation of wild genetic resources and declining intra-crops genetic diversity may lead to complete loss of production in a dynamic environment. Domesticated plants are at risk due to people's preference for desired traits such as tender leaves, large seed, good taste and so on (Vietmeyer, 1996). Conservation can last long only when it has value to the local community (e.g. Spiteri and Nepal, 2006; Barrett *et al.*, 1998). On the contrary, most of the conservation interventions carried out in developing countries cost the local households than benefiting (Adams *et al.*, 2004). In effect, any such conservation strategies remain ineffective and unaccepted by the communities at the grassroots level. Moreover, despite the growing global interests in conservation of wild genetic resources, especially during the past one and half-decade, there have been scant studies on how to enhance compliance of local households to the different conservation strategies.

The arabica coffee of Ethiopia has a very wide variability in its character both over locations and within populations; as the country is the place of its origin and endowed remnants of the wild coffee (Paulos and Demel, 1999). It has enormous economic benefits given the potential of getting plant materials to develop disease resistant, high yielding and desired quality coffee varieties from the wild populations (Hein and Gatzweiler, 2006). However, the natural habitat of *Coffea arabica* gene pool, coffee forest, continues diminishing due to encroachment in demand of intensified coffee production, over-extraction of forest products and extensive staple crop cultivation (Dereje, 2007). Spontaneous settlement of immigrants to the area, because of decline in soil fertility elsewhere, also contributes to the problem (Tadesse, 2003). On the other hand, promotion of improved coffee cultivars leads to genetic uniformity and monoculture (Edilegnaw, 2004). It threatens the perpetuation of on-farm coffee diversity. Thus, with increasing adoption for improved cultivars, current prevalence of coffee diseases, and climate change make preservation of the wild populations of *Coffea arabica* imperative.

So far, even if different strategies are implemented to conserve the coffee forests, little have been achieved in reversing the situation in the area for various reasons. Among others, lack of participation of local community in the conservation process is well acknowledged for ineffectiveness of the strict *in situ* conservation. The rural households harvest fuel wood, timber, wild fruits and coffee, medicinal plants, spices, and other non-timber forest products from the forests to meet their subsistence and cash needs. The strict *in situ* conservation prevents access to these forest products from the protected area. As a result, it accrues high opportunity cost to the local households, unlike the participatory conservation strategy (Aseffa *et al.*, 2007). This gives rise to conflict of interests between biodiversity conservation efforts of the conservationists and local households' struggle for survival. Some of the local households cannot afford to abide by the rules and regulations of the conservation strategy. In effect, the conservation strategy remained ineffective and degradation of the wild coffee genetic resources is continuing.

Indeed, it is known that no strategy can avoid the inevitable cost of conservation. But, failure to measure and lack of providing attention to cost of conservation may lead to unworkable policies and strategies (Kramer *et al.*, 1995). The choice for a conservation strategy need to be based on detailed analysis of its efficacy and possibilities to mitigate conservation cost. However, costs involving *in situ* conservation of *Coffea arabica* and possible options to enhance the effectiveness of the strategy are not yet examined. The purpose of the this study is, therefore, (1) to describe the strict *in situ* strategy underway in conservation of wild populations of *Coffea Arabica,* (2) to examine determinants of compliance to the strategy and cost of conservation to the local households, and (3) to pinpoint policy instruments to enhance effectiveness of the strategy.

Conceptual Framework

Local households' decision to comply with the rules and regulations of the strict *in situ* conservation strategy is conceptualized in a framework of the agricultural household model (De Janvry *et al.*, 1991; Singh *et al.*, 1986). A unitary household model is used in various case studies related to *in situ* biodiversity conservation and sustainable use of natural forests (e.g. Van Dusen *et al.*, 2007; Dayal 2006; Winters *et al.*, 2006; Pattanayak *et al.*, 2004; Köhlin and Parks, 2001). This paper adapted the model to explain underlying reasons for heterogeneity among households in coffee forest areas regarding their compliance to and costs of the conservation strategy. Households' decision to comply with the strategy is made in an economic environment of incomplete inputs and outputs market; households' production depend on what they intend to consume. Obviously, forest products extraction decision of the household is a utility maximization decision. The utility function of a representative household is specified as:

$$MaxU = u(C_f, C_o, C_m, L_l; \gamma) \quad \text{------------------------------(1)}$$

Where C_f and C_o refer to consumption of semi-forest coffee and other forest products, respectively, while C_m refers to consumption of own produced agricultural products and purchased commodities. L_l refers to home time such as time spent in social activities and sleeping, while γ is a set of household characteristics that shift utility. The utility maximization function is subjected to technological constraints embedded in the production functions, labour and budget constraints.

Production depends on factor inputs such as land size(A_i), human labour (L_j), and managerial capacity approximated by household characteristics (γ). In the case of coffee forest-related activities, whether a household abides by the conservation rules (D) and the resource endowment of coffee forest plots (G) are additional factors affecting the level of production. The general form of agricultural production and forest products extraction functions are given as

$$Q_i = q_i(L_i, A_j, D_s, G_s; \gamma) \quad \text{------------------------------(2)}$$

Where $i = a, f, xf, o$; $j = a, f$, and $s = f, o$ such that the subscript a refers to agricultural production outside the conservation area, while f refers to semi-forest coffee produced under minimum management obeying the rules and regulations of the conservation strategy. Whereas, xf is the subscript to indicate extra quantity of semi-forest coffee produced and additional labour input used in semi-forest coffee intensification in the case of households non-obedient to the rules and regulations of the strategy. Similarly, o refer to other forest products extraction from the conservation area illegally.

The labour constraint of a household with total labour, L, is given as the sum of labour allocated to agricultural activities (L_a), semi-forest coffee production under minimum management (L_f), intensification of semi-forest production (L_{xf}), forest products extraction (L_o), and home time (L_l). This is mathematically specified as:

$$L = L_a + L_f + L_{xf} + L_o + L_l \quad \text{-------------------------------(3)}$$

The budget constraint incorporates the monetary value of cost of not obeying the rules and regulations of strict *in situ* conservation strategy, in simple term 'penalty'. Although, some components of the penalties are determined exogenously through the judiciary procedures, yet they are related directly to the type and quantity of forest products harvested (or the level of negative externalities induced by a household). Assuming theoretical effective enforcement[1], the penalty is incorporated on expense side of household, the budget function, while possible income from forest coffee and other forest products such as spices and wild honey is considered on the revenue side. Accordingly, household's budget constraint is presented as:

$$((Q_f + Q_{xf}) - C_f)P_f + (Q_o - C_o)P_o + (Q_a - C_a)P_a + WL_w + R \geq P_m C_m + K(Q_{xf}, Q_o) \quad \text{---(4)}$$

Where P_f refers to price of forest coffee, P_o is price of other forest products harvested from the conservation, P_a is price of agricultural commodity, P_m is price of purchased commodity, W is market wage and L_w labour allocated to work on others farm or non-farm activities. R refers to external income such as remittance. The remaining variables are defined earlier. Note that Q_{xf} and Q_o refer to the extra quantity of semi-forest coffee and other forest products that the local households harvest when they do not comply with the rules and regulations of the conservation strategy, respectively. K refers to penalty to a household for negative externalities induced on the coffee forest biodiversity.

In addition, households' decision is subjected to non-negativity constraint of consumption and production quantities, and inputs use. The lagrangian for household's utility maximization problem is:

$$\begin{aligned}\ell &= u(C_f, C_o, C_m, L_l; \gamma) \\ &+ \lambda_b\left[\left((Q_f + Q_{xf}) - C_f\right)P_f + (Q_o - C_o)P_o + (Q_a - C_a)P_a + WL_w + R - P_m C_m - K(Q_{xf}, Q_o)\right] \quad \text{---}(5) \\ &+ \lambda_l\left[L - L_a - L_f - L_{xf} - L_o - L_l\right] - \lambda_i\left[Q_i - q_i(.)\right]\end{aligned}$$

The subscript $i = a, f, xf, o,$ of *lambda* (λ_i) refers to the shadow value of the respective functions. The lagrangian multiplier for the budget function (λ_b) refers to the marginal utility of income or the marginal cost of penalty. Assuming corner solutions, the first derivative of lagrangian function with respect to the variable of choices yield the optimal level of respective outputs and inputs. For our purpose, by rearranging the optimal conditions derived with respect to quantity of extra quantity of semi-forest coffee produced under intensified management (Q_{xf}) and its labour input (L_{xf}), we can get $\lambda_l + \lambda_b \frac{\partial K}{\partial Q_{xf}} \frac{\partial q_{xf}}{\partial L_{xf}} = \lambda_b P_f \frac{\partial q_{xf}}{\partial L_{xf}}$. It is analogous for other forest products extraction from the conservation area, $\lambda_l + \lambda_b \frac{\partial K}{\partial Q_o} \frac{\partial q_o}{\partial L_o} = \lambda_b P_o \frac{\partial q_o}{\partial L_o}$. These are the conditions for households to be engaged in prohibited activities in the conservation area. It indicates that local households' decision for intensification of semi-forest coffee or illegal extraction of forest products from the conservation area equate costs of the activity with marginal value product of labour engaged in the illegal activities. In brief, the local households' decisions equate the cost of obedience to the conservation strategy to the monetary value of penalties for illegal activities. Cost of obedience to the strict *in situ* conservation includes forgone benefits from the conservation area due to the prohibitive rules and regulations and cost due to damages by wildlife.

In contrast, local households quit undertaking prohibited activities in the conservation area, $Q_{xf} = 0$ if $\lambda_{xf} < \lambda_b \left(P_f - \frac{\partial K}{\partial Q_{xf}} \right)$ and $Q_o = 0$ if $\lambda_o < \lambda_b \left(P_o - \frac{\partial K}{\partial Q_o} \right)$. In other words, a household complies with the rules and regulations of strict *in situ* conservation if the shadow value of extra quantity of semi-coffee forest produced under intensification is less than the marginal utility of income from additional semi-forest coffee minus marginal utility cost of penalties, of course, if this holds for extraction of other forest products as well. It also dictates us that it is possible to increase effectiveness of the strategy by increasing either the marginal utility of labour and marginal cost of illegal activities through penalties or using policy tools that reduce marginal utility of income and shadow value of the coffee forest-related activities. In addition, it indicates that the level of conservation cost to a household also depends on their level of obedience to the strategy, coffee forest, and household characteristics.

Accordingly, the reduced-form of household's decision to comply with the rules and regulations of the strict *in situ* conservation strategy and the level of conservation cost, with econometrically testable simultaneity relations, is specified below. Household's obedience to the strategy is a binary decision that can be specified as a probability model for empirical estimation:

$$\Pr(D=1) = \Pr\left[\lambda_i < \lambda_b \left(P_i - \frac{\partial K}{\partial Q_i} \right) \right] = d(\psi, G, \gamma) \quad \text{-----------------------} (6a)$$

Where D refers to obedience of the local household to the strategy, ψ is total cost of conservation to a household, which is equivalent to forgone net benefits of being obedient to the strategy. While G and γ refer to natural coffee forest and household characteristics, respectively. On the other hand, the conservation cost, ψ, depends on household's obedience to the conservation strategy; resource endowment of the coffee forest and characteristics of the households.

$$\psi = f(D, G, \gamma) \quad \text{-----------------------------------} (6b)$$

The next section provides details on the empirical procedures. It describes dependent and independent variables, the data and data sources.

Econometric Model Specification

The random utility model states that a household participates in a given activity if the utility from participation is greater than that of not participating. The model is base to estimate the obedience decision of households using two-stage approach (Van Dusen *et al.*, 2007). The econometric model estimates of equation $(6a)$ and $(6b)$ to identify determinants of household's obedience to the conservation strategy (D_i) and the level of conservation cost incurred (ψ_i). Factors influencing cost incurred by local households can be estimated using ordinary least squares (OLS) technique but there is a possibility of simultaneity bias. To start with, endogeneity is anticipated since preceded theory and prior evidences tell us that households' decision of obedience depends on the conservation cost they incur and the cost of conservation in turn depend on the level of obedience to the strategy. Moreover, it is likely that self-selection problem occurs since only portion of the sampled households obey the conservation rules and some households do not incur cost of conservation. In such a case, the ordinary least square estimation of determinants of conservation cost yield inconsistent estimators of parameters.

The econometric problems can be handled econometrically using two-step estimation methods (Greene, 2003; Woodridge, 2002; Maddala, 1893). At the first stage of the model, the dependent variable, household's obedience to the conservation strategy, is a dummy variable while conservation cost in the second stage is continuous. In equation (7), the focus is on determinant of households' obedience, their decision to collect forbidden products and in protected location or abiding by the rules of the strategy. This can be estimated using binary choice, probit regression model. Following Maddala (1983) probit model is specified as:

$$D_i^* = \alpha + \delta X_i + \varepsilon_{1i} \text{-------------------------} (7)$$

Where $D_i = 1$ *if* $D_i^* > 0$, the household's obedience to strict *in situ* conservation strategy

$D_i = 0$ *if* $D_i^* \leq 0$, otherwise.

X_i are exogenous variables where i=1,2,....,16.

δ is vector of parameters to be estimated ;

α is the intercept term;

ε_{1i} are the disturbance terms.

In the second stage, determinants of conservation cost to farm households in montane rainforest with *Coffea arabica* were identified using equation (8). Cost of conservation to a household depends on its level of obedience to the strategy. This implies that residuals of obedience and cost of conservation may correlate. Therefore, the predicted value of obedience to the conservation strategy was included as an explanatory variable in the identification of determinants of cost to farm households in conservation. Accordingly, the regression model can be further specified as:

$$\psi = \gamma + \beta_i X_i + \nu \hat{D}_i + \varepsilon_{2i} \text{ ------------------------ } (8)$$

Where ψ is total cost incurred by households due to *in situ* conservation of *Coffea arabica;*

X_i = explanatory variable as defined earlier in equation (1);

$\hat{D}_i$ = the predicted obedience in conservation strategy;

β_i and ν are coefficients of parameters to be estimated;

γ is the intercept term;

ε_{2i} is the random term.

Definition of Explanatory Variables and Hypotheses

The dependent variable, in the first stage, is households' obedience to the rules and regulations of strict *in situ* conservation strategy. Obedience refers to respecting rules and regulations of the strategy while others are non-obedient. Obedience to or compliance with the strategy is captured in three different ways in the survey questionnaire. First, respondents were inquired whether they respect the rules and regulations of strict *in situ* conservation strategy. This strategy prohibits forest products extraction from the core zone and intensification and expansion of semi-forest coffee production in the buffer zone except slashing of under-growing weeds. Secondly, their responses were crosschecked as to whether the farmers harvested from core zone or not. Third, it was verified based on how they managed their forest/semi-forest coffee in the buffer zone in 2003/04. In the second stage, the dependent variable is the total cost that accrues to a local household due to *in situ* conservation of *Coffea arabica*. Furthermore, based on *a priori* knowledge and theoretical framework developed, the explanatory variables are explained as follows:

Household characteristics like family size, age and level of education of the household head, his/her being native to the conservation area, as well as asset holding such as livestock and landholding are expected to affect households' compliance to the conservation strategy. Having large family size may imply that the household has enough labour supply to harvest forest products. These households may not respect the rules and regulations of strict *in situ* conservation strategy (Mappatoba and Birner, 2004; Hegde and Enters, 2000). So, the variable is hypothesized to have negative relation with obedience to strict *in situ* conservation and positively to cost of conservation. On the contrary, elderly household heads are less dependent on natural forest (Köhlin and Parks, 2001). Hence, age of household head is expected to be associated positively with compliance to the strategy and negatively to cost of conservation. Literate farmers prefer alternative activities to collection of forest products (Hegde and Enters, 2000). They incur less and less cost of conservation, as they get literate. Thus, level of education of household-head is hypothesized to be associated positively with obedience to the conservation strategy. In addition, households native to the area may have more concerned about natural forest because of a stronger 'sense of place' and social attachment. Thus, this variable is expected to have positive effect on obedience despite the level of conservation cost that accrues to them (Mappatoba and Birner, 2004).

Asset holding of the local households have implication on their compliance to the strategy and the conservation cost accrues to them (Pattanayak *et al.*, 2004). Specifically, total livestock holding in tropical livestock units (TLU) is expected to have negative relationship with obedience in its conservation and to have positive influence on cost incurred at household level due to conservation of the area. This is because free grazing is the main source of feed in most developing countries like Ethiopia. Households with large number of livestock derive more benefit from natural forest (Mburu *et al.*, 2003). Land size used for production has effect on farm households' obedience in conservation intervention (Konyar and Osborn, 1990). The variable crop landholding is expect to be associated positively with obedience to the rules and regulation of the strategy and negatively with cost of conservation since they are less dependent on the natural forest for their livelihood (Pattanayak *et al.*, 2004). Households with large ratio of *de facto* holding in the conservation area are hypothesized to depend more on the natural forest *Coffea arabica*, while those with more landholding out of the conservation area depend more on their private land.

Moreover, geographical characteristics of the conservation area in relation to homestead of the households influence their compliance with the conservation strategy. Households who settled closer to the conservation area are more dependent on the natural forest (Degnet, 2005). So, we hypothesized that they are less compliant and bear higher cost of conservation as compared to households that reside in distant areas (Köhlin and Parks, 2001). Particularly, having farm plot adjacent to conservation area is expected to have negative relationship with obedience in strict *in situ* conservation strategy while it is hypothesized to influence conservation cost positively.

Household's decision to respect rules and regulations of the conservation program is influenced by their relative return from the area before conservation (Konyar and Osborn, 1990). It indicates *ex-ante*[2] difference among households in their level of dependency on the coffee forest. This difference is captured as lagged benefits that households harvest from conservation area in the form of timber and non-timber forest products before demarcation of the coffee forest (in ETB[3] per year). Lagged benefit is expected to influence obedience to the conservation strategy negatively and the conservation cost positively. Besides, better-off households are less dependent on the natural forest (Pattanayak *et al.*, 2004). Thus, household annual income is expected to have positive relation with obedience conservation strategy, but negative with cost of conservation.

The other categories of the explanatory variables of households' obedience are proxy for future expectation such as demand and perception regarding various implications of the conservation strategy. These include variables like value of farm implements and timber forest product that a household requires and intensity of wild beasts from the conservation area that attack private property. These variables are expected to have negative influence on obedience with strict *in situ* conservation strategy.

Table 1. Definition of the dependent and explanatory variables

Variables	**Description**	**Expected sign**	
		Obedience function	Cost function
Total cost	Total cost of strict *in situ* conservation of *Coffea arabica* to household in ETB per household.		Dependent variable
Obedience	Dummy with 1, if the household respect rules and regulations of the strict *in situ* conservation strategy; 0, otherwise.	Dependent variable	+
Family size	Family size in number.	-	+
Age	Age of household head in years.	+	-
Head's education	Dummy with 1, if the household head attended formal education; 0, otherwise.	+	-
Native	Dummy with 1, if the household is native to the area; 0, otherwise.	+	+
Oxen	Number of oxen owned in 2003/04.	+	-
Livestock	Total livestock holding in 2003/04 in TLU.	-	+
Proximity	Distance of home of household from conservation area in walking hours.	+	-
Adjacent plot	Dummy with 1, If the farmer have farm plot(s) in or adjacent to the conservation area; 0, otherwise.	-	+
Lagged benefit	Benefits to the household as NTFPs before the natural forest was brought under conservation in ETB.	-	+
Cropland	Area of land under crop production in 2003/04 in ha.	+	-
Implement	Value of farm and other implements that household demands from the conservation area per year in ETB.	-	NA
Perception	Dummy with 1, if the household perceives that conservation of *Coffea arabica* is beneficiary; 0, otherwise.	-	NA
Damage by wildlife	Loss on households' property due to wildlife attack from conservation area in 2003/04 in ETB.		NA
Income	Total income of household in 2003/04 in ETB.	+	-
Ratio of conserved land	The ratio of land in the conservation area to the total land of the household in hectares.	-	+

Source: Author's work (2005)

Note: NA is not applicable, + and – signs indicate the positive and negative association with the dependent variables.

Sampling and Data Collection

The study was conducted in Yayu-Hurumu district of Iluababor Zone located in Southwestern Ethiopia. The Yayu national priority forest area is found in this area encompassing about 20,000 hectares and about half of it is under strict protection for coffee genetic resource conservation. The national priority area constitutes both forest and semi-forest coffee, which make about 25 and 75 per cent of the forest, respectively (Agrisystems, 2001). The specific site, Yayu area, was selected for this study purposively mainly because of the prevailing conflict between the interest of the local community and biodiversity conservation objectives. In the area, coffee production is the main economic activity followed by annual crops production and livestock rearing.

Regarding data collection procedures, a two-stage random sampling technique was adopted to sample respondents from the purposively identified district. In the first stage, four sample PAs[4] were selected randomly. In the second stage, a total of 105 households were sampled using probability sampling based on the number of farm households in each PA, so that each sample units would have equal chances of being selected. Both primary and secondary data sources are used in this study. We generated the primary data through focus group discussions and interviews with sample households using structured questionnaire. The questionnaire consisted of different parts to get information on household composition, land holding and other assets endowment, land allocation to different crops, area of coffee under different management practices, benefits that the local households extract from the coffee forest before and after establishment of conservation strategies, and so on. Moreover, Institute of Biodiversity Conservation was the main source of secondary data on the strict *in situ* conservation strategy.

Context of the Conservation Strategy and Characteristics of Sampled Households

The Yayu coffee forest is brought under strict *in situ* protection strategy since 1997/98 to preserve wild *Coffea arabica* gene pools. The protected area has two parts, buffer and core zones, with different purpose and use rights. The strategy permits local households with *de facto* land holding to produce coffee in the buffer zone without intensive management. However, the strategy strictly prohibits extraction of forest products from the core area as it is meant for preservation of forest coffee genetic resources. During the discussions held with the local households, some of them reported that their forest coffee plot is already demarcated to the core zone of the conservation area. They also noted that they used to live on their plot brought under before the villagisation program of the Derg regime. They are still paying tax for those plots. Nonetheless, the understanding of the local government is that the forestland belongs to the State. This has created sense of tenure insecurity to the farmers. This will have a clear negative impact on sustainable use of forest coffee land in the buffer zone. Besides, most of them pointed out that the idea of buffer zoning is a strategic move, which may force them to abandon their coffee forestlands eventually. This implies that there was no adequate and reliable information flow between the forest managing agencies and the local people on the rules and regulations of the conservation strategy. The demarcation process lacked transparency and sufficient discussion was not made with the local community.

The result from the sampled household survey shows that about 71 per cent of the respondents expect that they will benefit from conservation of *Coffea arabica* in the natural forest. But they do not agree with prohibition of managing their coffee in the buffer zone. They stated that in the absence of management such as under slashing the coffee plants would be taken over by the tree canopy and stop to bear coffee cherries. Out of the sample respondents, about 95 per cent had never attended meetings held to discuss on forest coffee conservation in 2003/04. This can be the reason why about 56 per cent of the respondents are not well aware of the idea of coffee conservation in this area. About 46 per cent of the total respondents who have farm plot adjacent to the conservation area do expect that the demarcation of conservation area will expand to their land. Thus, the house holds characteristics variables such as average family size in adult and man equivalent family members with different age category and dependency ratio is not significantly different between obedient and non-obedient households to the conservation strategy (Table 2).

About half of obedient households are illiterate while most of the non-obedient households have attended only primary education. Although the chi-square test indicated that there is statistically insignificant difference among categorized education levels with respect to obedience to the strict *in situ* conservation, the variable, education of household head, is further considered as dummy in econometric model to see its combined effect with other variables on obedience. An average distance from conservation area to home of farm household is found to be significantly different between obedient and non-obedient households to strict *in situ* conservation at 5 per cent probability level.

Table 2. Age structure and farming experience of sampled respondents (mean values)

Variables	**OB**	**NOB**	**t-value**	**All cases**
Age group <15	3.28	2.89	-0.506	2.81
15-64	3.19	3.44	-0.730	3.35
≥65	0.22	0.19	0.271	0.20
Dependency ratio	1.08	1.05	-0.173	1.06
Age of household head	46.08	48.09	-0.708	47.38
Farming experience	22.76	26.09	-1.246	24.91
Head's education			χ^2 value	
Illiterate	51.4	36.8	2.675	41.9
Primary	35.1	51.5		45.7
Secondary	13.5	11.8		12.4
Distance to conservation area	0.93	0.59	2.236**	0.72

Source: Authors' own calculation (2005)
** Statistically significant at 5% probability levels.
Note: OB = Obedient households; NOB= Non-obedient households

In the 2003/04 production year, those households who complied with the rules and regulations of strict *in situ* conservation generated more income (757 ETB) from plantation coffee as compared to non-obedient household (376 ETB) of the same area. This difference is significant at 10 per cent probability level. Besides, mean income from off-farm activity in strict *in situ* conservation was about 278 ETB for obedient and 67.4 ETB for non-obedient household. This is significantly different between the two groups at 10 per cent probability level. This implies that households with more income from plantation and off-farm activities are more likely to respect the rules and regulations of strict *in situ* conservation strategy.
Particularly, the non-timber coffee forest products constitute 44 per cent of income of obedient households while the percentage rises to 62 for non-obedient households, which is statistically significant at 5 per cent probability level. This implies that the levels of dependency on the coffee forest vary significantly between obedient and non-obedient households. This in turn indicates that effective implementation of the conservation strategy will result in considerably disproportionate loss of income of the households. This is a challenge for sustainability of *in situ* conservation of *Coffea arabica* under strict conservation strategy. The average incomes of household from different sources are presented in Table 3.

Table 3. Average income of sampled households in 2003/04 production year

Sources	OB	NOB	t-value	All cases
Forest coffee$^{\pi}$	1041.2	1174.9	-0.529	1127.8
Planted coffee$^{\varphi}$	757.0	376.0	1.677*	510.3
NTFPs	121.1	48.9	0.716	74.3
Crops	185.00	205.0	-0.249	197.9
Livestock	158.2	185.5	-0.269	175.9
Off -farm activities	277.9	67.4	1.871*	141.6
Total income	2540.5	2057.8	1.202	2227.9
Ratio of income$^{\omega}$	0.44	0.62	-2.667**	0.56

Source: Authors' own calculation (2005)

*, **Statistically significant at 10% and 5% probability levels, respectively.-+

Note: π Includes forest and semi-forest coffee since it is harvested from forest; $^{\varphi}$ Includes garden and coffee planted on farmland; ω Refers to ratio of income from NTFPs including wild coffee to total income of household.

Determinants Obedience to the Strict *In Situ* conservation Strategy and Cost of Conservation

The econometric result in Table 4 presents the sign, magnitude and significance level of the estimated parameters for the determinants of obedience to and cost of strict *in situ* conservation. The model is estimated after purging the endogeneity problem following Smith and Blundell (1986) and Maddala (1983:242). We found that multicollinearity[5] among the explanatory variables included in the model is not a serious problem. Moreover, heteroskedasticity is taken care of in the software while fitting the econometric model. The result of the two-stage estimation shows that the model fits data very well. This is indicated by per cent of correctly predicted observations and the chi-square test. The model predicted about 74.29 per cent of the total observations correctly and chi-square test is also significant at less than one per cent.

Among the variables hypothesized, the model output shows that six variables have significant relation with obedience, and four variables are associated significantly to the level of conservation cost, at less than or equal to 10 per cent probability level. Households' obedience in strict *in situ* conservation strategy is affected significantly by education, being native to the area, distance of homestead from the conservation area, getting farm plot adjacent to the conservation area, total income, and ratio of conserved land. In the second stage of analysis, it is apparent from Table 4 that variables such as being native to the area, benefits prior to implementation of the conservation strategy, the income level of household and their level of obedience to the rules and regulation of the strategy are important determinants of the level of cost accrued by the local households.

In the first stage, the model output depicted significant and negative relationship between education and households' obedience in strict *in situ* conservation. The possible explanation for their reluctance to respect the rules and regulations of the strategy is that most of the educated household heads are conscious about the high opportunity cost of strict *in situ* conservation, especially with the increasing farmland scarcity. Besides, household head's being native to the conservation area has shown positive and significant, at 10 per cent probability level, relationship with obedience in the strategy. This implies that households who are native to the conservation area give more value to the natural resource and are more likely to respect the rules and regulation of the strict conservation strategy than immigrants. Their strong attachment to the physical landscape and the associated 'sense of belongingness' might also explain the result.

Table 4. Determinants of obedience to and cost of strict *in situ* conservation strategy

Variables	**Obedience**		**Cost**	
	Coefficient	t-value	Coefficient	t-value
Constant	0.19564	0.228	499.659	0.673
Family size	-0.49694	-0.736	48.767	0.873
Age	-0.01232	-1.006	4.072	0.390
Head's education	-0.37512	-2.210**	25.486	0.177
Native	0.58069	1.615*	687.317	2.371**
Oxen	0.18337	0.768	-230.349	-1.187
Livestock	-0.06842	-0.854	71.827	1.100
Distance	0.62896	2.364***	-265.351	-1.209
Adjacent	-0.82437	-2.299**	9.145	0.031
Benefit	0.00008	0.764	0.502	5.752***
Cropland	-0.01683	-0.654	10.413	0.503
Implement	0.00013	0.145	-	-
Perception	0.41444	1.218	72.545	0.268
Wildlife attack	0.00016	0.391	-	-
Income	0.00015	1.695*	-0.181	-2.496***
Ratio of conserved land	-1.12197	-1.968**	-166.984	-0.347
Participation	-	-	-1067.302	-3.686***
Log likelihood function	-53.53			
Restricted log likelihood	-68.13			
Chi-squared	29.21***			
Adjusted $-R^2$			0.3561	
F-value			5.11***	
Valid cases.	105			
Correctly predicted observations	74.29			

Source: Authors' own calculation

*, **, ***Statistically significant at 10%, 5% and 1% probability levels, respectively.

Distance of households' residential location to the conservation area depicted a positive and significant relation, at 1 per cent probability level, with obedience to strict *in situ* conservation strategies. This implies that it is much more difficult for households living closer to conservation area to respect the rules and regulations of the conservation strategy. Similarly, having plot(s) in or adjacent to the conservation area also showed negative association with the level of obedience in strict *in situ* conservation strategy, which is significant at 5 per cent probability level. Local people who owned farm plots adjacent to the conservation area are unlikely to respect the rules and regulations of strict *in situ* conservation strategy. This is because households residing adjacent to the conservation area tend to collect forest coffee and non-timber forest products from the conservation area. Moreover, the ratio of land under *de facto* ownership of household in the conservation area to the total land holding of the household, showed negative and significant relation with obedience at 5 per cent probability level. This implies that households with landholding in the conservation area tend not to comply with the rules and regulations of the strategy.

The total income of the households is considered as an indicator of their livelihood and status in the society. Income is found to have significant and positive relationship with obedience in strict *in situ* conservation of *Coffea arabica*. This implies that the better-off households are likely to respect the rules and regulations of strict *in situ* conservation strategy. This is because households with better income may have other income sources than coffee forest-based activities.

On the other hand, the second stage of the model showed that being native to the conservation area has positive and significant relation, at 5 per cent probability level, with the cost of strict *in situ* conservation strategy. This implies that respecting the regulations of the conservation strategy results in considerable costs to native local people. Similarly, the benefits from the conservation area took the expected positive sign and highly significant at less than 1 per cent level of significance. This implies that households that were dependent on the conservation area for non-timber forest products are more affected by the conservation intervention than others. On the other hand, income of a household is found to have negative relation with the cost of conservation strategy, which is significant at 1 per cent probability level. This implies that households with better livelihood situations are less dependent on the natural forest with *Coffea arabica*. This means, conservation of natural forest results in lower cost for such households.

Finally, household's obedience to the strategy showed negative and highly significant relationship with cost of conservation. As per the definition of obedience in strict *in situ* conservation, this implies that rules and regulations of strict *in situ* conservation of *Coffea arabica* is respected only by those households who incur significantly less cost in this strategy. This is in line with the result of the study undertaken in Madagascar, Ranomafana national park to estimate the cost incurred by the local community (Ferraro, 2001). In general, the model elicited that obedience to strict *in situ* conservation strategy of coffee forest resulted in considerable cost of conservation to the local people. This is basically due to considerable loss of benefits in strict *in situ* conservation area by the local people and absence of alternative interventions to off-set these losses.

Conclusions and Policy Implications

Strict *in situ* conservation is one of the important strategies to maintain *Coffea arabica* and other coffee forest biodiversity in their natural habitat. Nevertheless, the strategy induces additional conservation cost to the local households as compared to community-based conservation strategies due to its prohibitive rules that limit access to non-timber forest products. This creates conflict between the intervention for biodiversity conservation and struggle for survival, which puts sustainability of the strict *in situ* conservation efforts, in Yayu area, under question mark.

Results of the descriptive statistics revealed that more than half of the sampled households are not well aware of the idea of coffee conservation in this area. Most of the households reported that they had never attended meetings held to discuss about forest coffee conservation. Households with different level of education showed considerable difference regarding their obedience to the rules and regulation of the strategy. The sampled household heads with no formal education and those with secondary school level education demonstrated propensity for respecting the rules and regulation of the strategy, while the household heads with primary school level education did not do so. This implies the possibility of using formal education that can improve households' access to non-farm income, knowhow of intensive cultivation and risk hedging capacity as policy tool.

Furthermore, the outputs of the econometric model indicated the possibility for enhancing effectiveness of the strategy through training to build 'sense of belongingness' and to convincing households how best the genetic resources can be used in improving their livelihood, for instance, through 'benefit sharing'. It also reveals the need to reduce settlement closer to the conservation area and assigning responsibilities of patrolling illegal activities to each households owned farm plot(s) in or adjacent to the conservation area. In addition, improving households' income, and replacing alternative plots or compensating households whose plots are delineated as part of the conservation area is found to be an important tool to enhance effectiveness of the strategy. The compensation intervention should be based on lagged benefits for equity reason. As a final point, we found that households who comply with the rules and regulations of the strategy are those with significantly less conservation cost. So, it is important to design strategies that reduce cost of conservation by allowing sustainable use of patches crucial for the livelihood of the local households considering their comparative advantages.

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Endnotes:

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[1] For simplicity we assumed the probability that illegal extractors caught to be 1, $P = 1$. In the case of ineffective enforce, the function include the probability of being caught to be $0 < P < 1$.

[2] Refers to difference among households while the conservation areas were under state ownership, but belongs to some farm households by *de facto*.

[3] ETB refers to Ethiopian Birr. At the time of survey 1 ETB = 0.12 US dollars.

4. PA refers to the smallest administrative unit in the area, also known as *Kebele*.