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APPENDICES

Appendix 1: Current Hamiltonian version of the optimal control model of the soil mining problem

$$N_C(F, LQ, LS, KS, \lambda) = [P_t f(S_t, LQ_t) - w_F F_t - w_K KS_t - w_L(LQ_t + LS_t)] + m[H(Q_t, LS_t, KS_t) - D(Q) + G(F_t)]$$

where $m = e^{\delta t}\lambda_t$ (1)

The first order conditions (FOCs) for optimal control

$$\frac{\partial N_C}{\partial F_t} = 0 \Rightarrow w_F = m_t G_F \qquad \Rightarrow m_t = \frac{w_F}{G_F} \tag{2}$$

$$\frac{\partial N_C}{\partial LS_t} = 0 \Rightarrow w_L = m_t H_{LS_t} \qquad \Rightarrow m_t = \frac{w_L}{H_{LS}} \tag{3}$$

$$\frac{\partial N_C}{\partial KS_t} = 0 \Rightarrow w_K = m_t H_{KS_t} \qquad \Rightarrow m_t = \frac{w_K}{H_{KS}} \tag{4}$$

$$\frac{\partial N_C}{\partial LQ_t} = 0 \Rightarrow (Pf_{LQ_t} - w_L) = m_t(D_{LQ_t} - H_{LQ_t}) \tag{5}$$

where $(Pf_{LQ} - w_L)$ defines the net price NP_{LQ} giving:

$$m_t = \frac{NP_{LQ}}{D_{LQ} - H_{LQ}} \tag{6}$$

Current co-state equation of motion is given as below

$$\dot{m} = -\frac{\partial N_C}{\partial S} + \delta m = -[Pf_s + m(H_S - D_S)] + \delta m$$

$$\dot{m} = -\frac{\partial N}{\partial S} + \delta m = -Pf_s + m[(D_S - H_S) + \delta] \quad (7)$$

However, at steady state (SS), $\dot{m} = 0$, then equation 7 becomes 7'below

$$Pf_s = m[(D_S - H_S) + \delta] \quad (7')$$

At steady state, $\dot{S} = 0$ meaning that $S_{t+1} = S_t = S$, entails that equation of motion 3, $\dot{S} = H(Q_t, LS_t, KS_t) - D(Q_t) + G(F_t)$ reduces to

$$G(F) = D(Q_t) - H \quad (8)$$

In other words, level of replenishment required to maintain soil nutrient stock should offset the net depletion of soil nutrients measured as the net effect of depletion/ decay and regeneration $(D - H)$.

Combining 2 and 7' to eliminate m

$$Pf_s = \frac{w_F}{G_F}[(D_S - H_S) + \delta]$$

$$\frac{Pf_s G_F}{w_F} = \delta + (D_S - H_S) \quad (2b)$$

Combining equation 3 and 7' to eliminate m

$$Pf_s = \frac{w_L}{H_{LS}}[(D_S - H_S) + \delta]$$

$$\frac{Pf_s H_{LS}}{w_L} = \delta + (D_S - H_S) \quad (3b)$$

Combining 4 and 7' to eliminate m

$$Pf_s = \frac{w_K}{H_{KS}}\left[(D_S - H_S) + \delta\right]$$

$$\frac{Pf_s H_{KS}}{w_K} = \delta + (D_S - H_S) \qquad (4b)$$

Combining 5 and 7' to eliminate m

$$Pf_s = \frac{NP_{LQ}}{D_{LQ} - H_{LQ}}\left[\delta + (D_S - H_S)\right]$$

$$\frac{Pf_S (D_{LQ} - H_{LQ})}{NP_{LQ}} = \delta + (D_S - H_S) \qquad (5b)$$

if $G_F = g = 1$, then from equation 2 $w_F = m$ and equation 7' becomes

$$Pf_s = w_F\left[(D_S - H_S) + \delta\right] \qquad (6b)$$

Note that in chapter IV, 2b to 5b correspond to equations 16-19

Appendix 2:Specification of the soil-mining model and calculating reduced form solutions of the choice variables $(LQ, F, KS, LS, S \& \lambda)$at the Steady State (SS).

The following functions have been specified in equations 20-26 of chapter V:

A. The CD production function

$$Q = A * LQ^{\alpha_L} S^{\alpha_S} \tag{20}$$

B. The relationship between erosion E and Q (canopy) has been specified as:

$$E_t = \phi e^{-bQ} \tag{21}$$

C. Contribution of soil conservation to the decay process is specified in this study as CD function of soil conservation efforts through the use of labour $(LS)$and capital(KS):

$$c = LS^{\beta_1} KS^{\beta_2} \tag{22}$$

Accordingly, the decay function M is specified as the additive function below:

$$M = \left(\beta\phi e^{-bQ} - LS^{\beta_1} KS^{\beta_2}\right) = \left(\beta E(Q) - C\right) \tag{23}$$

The aggregate natural regeneration and decay process function H becomes:

$$H = h - M = h - \left(\beta\phi e^{-bQ} - LS^{\beta_1} KS^{\beta_2}\right) \tag{24}$$

D. The depletion (or damage) function $D(Q)$ is specified as a linear function of Q:

$$D(Q) = nQ \tag{25}$$

E. The nitrogen augmenting function $G(F)$ is specified as a linear function of fertiliser F :

$$G(F) = gF \tag{26}$$

After substituting 20-26 in the objective function, the Hamiltonian can be rewritten as:

$$N(LQ,F,KS,LS,\lambda)=e^{-\delta t}\left\{\left(P(A*LQ^{\alpha_L}S^{\alpha_S}\right)-w_K K-w_F F-w_L(LQ+LS)\right\}+\lambda[H-D+G]$$

where H, D and G as specified above (24, 25 and 26).

FOCs for above decision problem :

$$\frac{\partial N}{\partial F}=e^{-\delta t}(w_F)=\lambda_t\frac{\partial G}{\partial F}=\lambda g \tag{27}$$

$$\frac{\partial N}{\partial LQ}=e^{-\delta t}\left(\alpha_L P*A*LQ^{\alpha_L-1}S^{\alpha_S}-w_L\right)=\lambda_t\left[\frac{\partial H}{\partial LQ}-\frac{\partial D}{\partial LQ}\right] \tag{28}$$

$$\frac{\partial H}{\partial LQ}=H_{LQ};\ \frac{\partial D}{\partial LQ}=D_{LQ}$$

$$\frac{\partial N}{\partial LS}=e^{-\delta t}w_L=\lambda_t\frac{\partial H}{LS};\qquad \frac{\partial H}{\partial LS}=H_{LS} \tag{29}$$

$$\frac{\partial N}{\partial KS}=e^{-\delta t}w_K=\lambda_t\frac{\partial H}{\partial KS};\qquad \frac{\partial H}{\partial KS}=H_{KS} \tag{30}$$

$$\dot{\lambda}=-\frac{\partial N}{\partial S_t}=-\left(e^{-\delta t}P*A*LQ^{\alpha_L}S^{\alpha_S-1}\right)+\lambda_t\left[\frac{\partial H}{\partial S}-\frac{\partial D}{\partial S}\right] \tag{31}$$

$$\frac{\partial H}{\partial S}=H_S;\qquad \frac{\partial D}{\partial S}=D_S$$

$$\dot{S}=h-\left(\beta\phi e^{-bQ}-LS^{\beta_1}KS^{\beta_2}\right)-nQ+gF \tag{32}$$

Using the above system of FOC equations of the soil mining model (equations 27-32) one can derive reduced form solutions for the choice variables, KS^*, LS^*, LQ^* F^*, S^* and λ^*.

A3.1 Steady State (SS) Solutions

Assuming a SS equilibrium path $\left(\dot{S}=\dot{\lambda}=0\right)$ the FOC can be written as derived in chapter IV (equations 16-19):

$$\frac{Pf_s G_F}{w_F} = \delta + (D_S - H_S) \tag{16}$$

$$\frac{Pf_s H_{LS}}{w_L} = \delta + (D_S - H_S) \tag{17}$$

$$\frac{Pf_s H_{KS}}{w_K} = \delta + (D_S - H_S) \tag{18}$$

$$\frac{Pf_S (D_{LQ} - H_{LQ})}{NP_{LQ}} = \delta + (D_S - H_S) \tag{19}$$

Using specification of H given in equation 24 above one can derive:

$$\frac{\partial H}{\partial LQ} = -b\beta\alpha_L \frac{Q}{LQ}\phi e^{-bQ}$$

let $b\phi e^{-bQ} = \zeta$ (3.1)

$$\frac{\partial H}{\partial LQ} = H_{LQ} = -\alpha_L \frac{Q}{LQ}\beta\zeta \tag{3.2}$$

$$\frac{\partial H}{\partial S} = -b\beta\phi\alpha_S \frac{Q}{S} e^{-bQ}$$

$$\frac{\partial H}{\partial S} = H_S = -\alpha_S \frac{Q}{S}\beta\zeta \tag{3.3}$$

$$\frac{\partial H}{\partial LS} = \beta_1 LQ^{\beta_1 - 1} KS^{\beta_2}$$

let $LS^{\beta_1} KS^{\beta_2} = C$

$$\frac{\partial H}{\partial LS} = H_{LS} = \beta_1 LS^{\beta_1 - 1} KS^{\beta_2} = \beta_1 \frac{C}{LS} \tag{3.4}$$

$$\frac{\partial H}{\partial KS} = \beta_2 LS^{\beta_1} KS^{\beta_2 - 1}$$

$$\frac{\partial H}{\partial KS} = H_{KS} = \beta_2 LS^{\beta_1} KS^{\beta_2 - 1} = \beta_2 \frac{C}{KS} \tag{3.5}$$

From equation 25

$$\frac{\partial D}{\partial LQ} = D_{LQ} = nLQ^{\alpha_L - 1}S^{\alpha_S} = \alpha_L n\frac{Q}{LQ} \tag{3.6}$$

$$\frac{\partial D}{\partial S} = D_S = nLQ^{\alpha_L}S^{\alpha_S - 1} = \alpha_S n\frac{Q}{S} \tag{3.7}$$

And from equation 26:

$$\frac{\partial G}{\partial F} = g \tag{3.8}$$

According to the above $H_S - D_S$, is obtained from equations 3.3 and 3.7

$$H_S - D_S = -\alpha_S\frac{Q}{S}\beta\zeta - n\alpha_S\frac{Q}{S} = -\alpha_S\frac{Q}{S}(n+\beta\zeta) \tag{3.9}$$

Similarly $H_{LQ} - D_{LQ}$, is obtained from equations 3.2 and 3.6

$$H_{LQ} - D_{LQ} = -\alpha_L\frac{Q}{LQ}\beta\zeta - n\alpha_L\frac{Q}{LQ} = -\alpha_L\frac{Q}{LQ}(n+\beta\zeta) \tag{3.10}$$

Using the above information, equations 16-19 are accordingly specified as below:

Substituting for $f_s = \alpha_S\frac{Q}{S}$; $D_S - H_S$; and G_F in equation 16

$$\alpha_S P\frac{Q}{S}g = w_F\left[\delta + \alpha_S\frac{Q}{S}(n+\beta\zeta)\right] \tag{16b}$$

Substituting for f_S; H_{LS}; and $D_S - H_S$ in equation 17 to get

$$\alpha_S\beta_1 P\frac{Q}{S}\frac{C}{LS} = w_L\left[\delta + \alpha_S\frac{Q}{S}(n+\beta\zeta)\right] \tag{17b}$$

Substituting for f_S; H_{KS}; and $D_S - H_S$; in 18 to get

$$\alpha_S \beta_2 P \frac{Q}{S}\frac{C}{KS} = w_K\left[\delta + \alpha_S \frac{Q}{S}(n+\beta\zeta)\right] \tag{18b}$$

Substituting for f_S; $D_{LQ} - H_{LQ}$ and $NP_{LQ} = \alpha_L P\frac{Q}{LQ} - w_L$ in equation 19 we get

$$\alpha_S \alpha_L P \frac{Q}{S}\frac{Q}{LQ}(n+\beta\zeta) = \left(\alpha_L P\frac{Q}{LQ} - w_L\right)\left[\delta + \alpha_S \frac{Q}{S}(n+\beta\zeta)\right] \tag{19b}$$

Using specified SS optimality conditions (equations 16b-19b) plus equation 32, the reduced form solutions for choice variables LQ^*, S^*, KS^*, LS^* and F^* can be derived.

Using equations 16b &19b we derive 20b below

$$g\left(\alpha_L P\frac{Q}{LQ} - w_L\right) = w_F\left[\alpha_L \frac{Q}{LQ}(n+\beta\zeta)\right]$$

$$gw_L = g\alpha_L P\frac{Q}{LQ} - w_F\left[\alpha_L \frac{Q}{LQ}(n+\beta\zeta)\right]$$

$$w_L g = \alpha_L \frac{Q}{LQ}\left[Pg - w_F(n+\beta\zeta)\right]$$

$$w_L g = \alpha_L A LQ^{\alpha_L - 1} S^{\alpha_S}\left[Pg - w_F(n+\beta\zeta)\right]$$

$$LQ^{\alpha_L - 1} = \frac{w_L g}{\alpha_L A S^{\alpha_S}\left[Pg - w_F(n+\beta\zeta)\right]}$$

$$LQ = \left[\frac{w_L g}{\alpha_L A S^{\alpha_S}\left[Pg - w_F(n+\beta\zeta)\right]}\right]^{\frac{1}{\alpha_L - 1}} \tag{20b}$$[24]

Substitute 20b into 16b to solve for S

[24] Please note that $\zeta = b\phi^{-bQ}$, and Q is determined (see Brekke et al., 1999)

$$\alpha_S PALQ^{\alpha_L} S^{\alpha_S-1} g = w_F \delta + w_F \left[\alpha_S LQ^{\alpha_L} S^{\alpha_S-1}(n+\beta\zeta)\right]$$

$$\alpha_S PgAS^{\alpha_S-1}\left[\frac{gw_L}{A\alpha_L S^{\alpha_S}\left[Pg-w_F(n+\beta\zeta)\right]}\right]^{\frac{\alpha_L}{\alpha_L-1}} = w_F\delta + \alpha_S w_F S^{\alpha_S-1}(n+\beta\zeta)\left[\frac{gw_L}{A\alpha_L S^{\alpha_S}\left[Pg-w_F(n+\beta\zeta)\right]}\right]^{\frac{\alpha_L}{\alpha_L-1}}$$

Divide through by $AS^{\alpha_S-1}\left[\frac{gw_L}{A\alpha_L S^{\alpha_S}\left[Pg-w_F(n+\beta\zeta)\right]}\right]^{\frac{\alpha_L}{\alpha_L-1}}$

$$\alpha_S Pg = \frac{w_F\delta}{AS^{\alpha_S-1}}\left[\frac{gw_L}{A\alpha_L S^{\alpha_S}\left[Pg-w_F(n+\beta\zeta)\right]}\right]^{\frac{-\alpha_L}{\alpha_L-1}} + \alpha_S w_F(n+\beta\zeta)$$

$$\alpha_S\left[Pg-w_F(n+\beta\zeta)\right] = \frac{w_F\delta}{AS^{\alpha_S-1}}\left[\frac{gw_L}{A\alpha_L S^{\alpha_S}\left[Pg-w_F(n+\beta\zeta)\right]}\right]^{\frac{-\alpha_L}{\alpha_L-1}}$$

$$\frac{S^{\alpha_S-1}}{S^{\frac{\alpha_S\alpha_L}{\alpha_L-1}}} = \frac{(A\alpha_L)^{\frac{\alpha_L}{\alpha_L-1}} w_F\delta}{A\alpha_S\left[Pg-w_F(n+\beta\zeta)\right]}\left[\frac{\left[Pg-w_F(n+\beta\zeta)\right]}{gw_L}\right]^{\frac{\alpha_L}{\alpha_L-1}}$$

$$S^{\frac{1-\alpha_S-\alpha_L}{\alpha_L-1}} = \left\{\frac{w_F\delta(A\alpha_L)^{\frac{\alpha_L}{\alpha_L-1}}}{A\alpha_S\left[Pg-w_F(n+\beta\zeta)\right]}\left[\frac{\left[Pg-w_F(n+\beta\zeta)\right]}{gw_L}\right]^{\frac{\alpha_L}{\alpha_L-1}}\right\}$$

$$S = \left\{\frac{w_F\delta(A\alpha_L)^{\frac{\alpha_L}{\alpha_L-1}}}{A\alpha_S\left[Pg-w_F(n+\beta\zeta)\right]}\left[\frac{\left[Pg-w_F(n+\beta\zeta)\right]}{gw_L}\right]^{\frac{\alpha_L}{\alpha_L-1}}\right\}^{\frac{\alpha_L-1}{1-\alpha_S-\alpha_L}}$$

let $1-\alpha_S-\alpha_L=\gamma$

$$S^* = A^{\frac{1}{\gamma}}\left(\frac{\alpha_L}{gw_L}\right)^{\frac{\alpha_L}{\gamma}}\left[\frac{w_F\delta}{\alpha_S}\right]^{\frac{\alpha_L-1}{\gamma}}\left[Pg-w_F(n+\beta\zeta)\right]^{\frac{1}{\gamma}} \qquad (21.a)$$

Substitute 21a into 20b to solve for LQ

$$LQ=\left[\frac{gw_L}{\alpha_L A\left[Pg-w_F(n+\beta\zeta)\right]\left[A^{\frac{1}{\gamma}}\left(\frac{\alpha_L}{gw_L}\right)^{\frac{\alpha_L}{\gamma}}\left(\frac{\delta w_F}{\alpha_S}\right)^{\frac{\alpha_L-1}{\gamma}}\left[Pg-w_F(n+\beta\zeta)\right]^{\frac{1}{\gamma}}\right]^{\alpha_S}}\right]^{\frac{1}{\alpha_L-1}}$$

$$LQ^{*}=A^{\frac{1}{\gamma}}\left(\frac{gw_L}{\alpha_L}\right)^{\frac{1-\alpha_S-\alpha_L+\alpha_S\alpha_L}{\gamma(\alpha_L-1)}}\left(\frac{\delta w_F}{\alpha_S}\right)^{\frac{-\alpha_S}{\gamma}}\left[Pg-w_F(n+\beta\zeta)\right]^{\frac{1}{\gamma}} \tag{22.a}$$

From equations (17b&18b) we derive

$$\alpha_S\beta_1 P\frac{Q}{S}\frac{C}{LS}\frac{1}{w_L}=\alpha_S\beta_2 P\frac{Q}{S}\frac{C}{KS}\frac{1}{w_K} \tag{3a}$$

Eliminating common terms $\left(\alpha_S, P, \frac{Q}{S}, \& C\right)$ (we get an expression for LS

$$LS=\frac{w_K}{w_L}\frac{\beta_1}{\beta_2}KS \tag{3b}$$

Using equations 16b and 17b we derive:

$$\frac{g}{\beta_1\frac{C}{LS}}=\frac{g}{\beta_1 LS^{\beta_1-1}KS^{\beta_2}}=\frac{w_F}{w_L} \tag{4a}$$

$$LS^{\beta_1-1} = \frac{gw_L}{\beta_1 w_F KS^{\beta_2}}$$

$$LS = \left[\frac{gw_L}{\beta_1 w_F KS^{\beta_2}}\right]^{\frac{1}{\beta_1-1}}; \qquad (4b)$$

Equating 4b and 3b, we can solve for KS

$$LS = \left[\frac{gw_L}{\beta_1 w_F KS^{\beta_2}}\right]^{\frac{1}{\beta_1-1}} = \frac{w_K}{w_L}\frac{\beta_1}{\beta_2}KS$$

$$KS^{\frac{1-\beta_1-\beta_2}{\beta_1-1}} = \left(\frac{\beta_1}{w_L}\right)^{\frac{\beta_1}{\beta_1-1}}\left(\frac{w_K}{\beta_2}\right)\left(\frac{w_F}{g}\right)^{\frac{1}{\beta_1-1}}$$

$$KS = \left\{\left(\frac{\beta_1}{w_L}\right)^{\frac{\beta_1}{\beta_1-1}}\left(\frac{w_K}{\beta_2}\right)\left(\frac{w_F}{g}\right)^{\frac{1}{\beta_1-1}}\right\}^{\frac{\beta_1-1}{1-\beta_1-\beta_2}}$$

let $1-\beta_1-\beta_2 = \varphi$

$$KS^* = \left(\frac{\beta_1}{w_L}\right)^{\frac{\beta_1}{\varphi}}\left(\frac{w_K}{\beta_2}\right)^{\frac{\beta_1-1}{\varphi}}\left(\frac{w_F}{g}\right)^{\frac{1}{\varphi}} \qquad (23.a)$$

Substitute (23.a) into 3b to solve for LS^*

$$LS = \frac{w_K}{w_L}\frac{\beta_1}{\beta_2}\left[\left(\frac{\beta_1}{w_L}\right)^{\frac{\beta_1}{1-\beta_1-\beta_2}}\left(\frac{w_K}{\beta_2}\right)^{\frac{\beta_1-1}{1-\beta_1-\beta_2}}\left(\frac{w_F}{g}\right)^{\frac{1}{1-\beta_1-\beta_2}}\right]$$

$$LS^* = \left(\frac{\beta_1}{w_L}\right)^{\frac{1-\beta_2}{1-\beta_1-\beta_2}}\left(\frac{w_K}{\beta_2}\right)^{\frac{-\beta_2}{1-\beta_1-\beta_2}}\left(\frac{w_F}{g}\right)^{\frac{1}{1-\beta_1-\beta_2}} = \left(\frac{\beta_1}{w_L}\right)^{\frac{1-\beta_2}{\varphi}}\left(\frac{w_K}{\beta_2}\right)^{\frac{-\beta_2}{\varphi}}\left(\frac{w_F}{g}\right)^{\frac{1}{\varphi}} \qquad (24.a)$$

At steady state (SS) optimal level of F can be solved from state equation of motion 3 as below:

$$\dot{S} = H - D + G \tag{5a}$$

at SS, $\dot{S} = 0 \Rightarrow G = D - H$ (5a.1)

Note that H is specified in equation (24) as $h - \beta\left(\phi e^{-bQ} - LS^{\beta_1} KS^{\beta_2}\right)$ while D is specified in equation (25) as nQ. From 25, F can be calculated at SS as below:

$$gF = nQ - h - \left(\beta\phi e^{-bQ} - LS^{\beta_1} KS^{\beta_2}\right)$$

$$F = \left[nQ - h - \left(\beta\phi e^{-bQ} - LS^{\beta_1} KS^{\beta_2}\right)\right] / g \tag{25a}$$

Substituting for Q, and C (LS and KS) from equations (21.a to 24.a), we get:

$$F = \left\{ nA^{\frac{1}{\gamma}} \left(\frac{w_F \delta}{\alpha_S}\right)^{\frac{-\alpha_S}{\gamma}} \left(\frac{\alpha_S}{w_L}\right)^{\frac{\alpha_S \alpha_L^2 + \alpha_L - \alpha_L^2}{\gamma}} \left[Pg - w_F(n + \beta\zeta)\right]^{\frac{\alpha_S + \alpha_L}{\gamma}} + \beta e^{-bQ} + \left[\left(\frac{\beta_1}{w_L}\right)^{\frac{\beta_1}{\phi}} \left(\frac{w_K}{\beta_2}\right)^{\frac{-\beta_2}{\phi}} \left(\frac{w_F}{g}\right)^{\frac{\beta_2 + \beta_1}{\phi}}\right] - h \right\} / g \tag{25b}$$

Appendix 3: Dynamic costs of soil degradation and determinants of adoption of soil conservation technologies by smallholder farmers in Malawi.

Socio-economic questionnaire

Note: This questionnaire must be administered to the household head or any person in charge of field activities

ADD	
DISTRICT	
RDP	
EPA	
SECTION (T.A)	
VILLAGE	
DATE OF INTERVIEW	
NAME OF RESPONDENT	
NAME OF ENUMERATOR	
H/H ID	
CHECKED BY	

1.HOUSEHOLD CHARACTERISTICS

1.1 Table 1: Head of household, marital status, number of members and education level of head

Household head		Marital status of h/h head		Number of Household members	#	Education level of h/h head	
Male	01	Single	01	<15 years		None	01
Female	02	Married	02	15-64 years		Std 1-4	02
Child	03	Polygamist	03	>64 years		Std 5-8	03
		Widowed	04			Form 1-2	04
		Divorced	05			Form 3-4	05
		Separated	06			Tertiary	06

m

2.0 Land size, crops grown, land ownership and acquisition and period involved in soil/land conservation practices

Code 1	Land size	Land ownership		Land acquisition		Period land under cultivation		Land conservation methods used by h/h		Years involved in soil conservation	Code 2 Level of soil degradation	Code 3 If doesn't conserve why not?
01		Male/husb	01	Purchased	01	< 5 years	01	**Physical**				
02		Female	02	Maternal	02	5<11 yrs	02	Contours	01			
03		Vge headman	03	Paternal	03	11<20 yrs	03	Marker ridges	02			
04		Parents	04	Vge headman	04	>20 years	04	Box ridges	03			
05		Scheme	05	Scheme	05			Terracing	04			
06		Borrowed	06	Estate	06			**Biological**				
07		Estate	07	Others	07			Vertiver grass	05			
		Others	08					Hedgerow intercrop	06			
								Manure	07			

Code1
01 total land area
02 land under cultivation
03 own land
04 rented in
05 rented out
06 borrowed
07 land under fallow

Code 2
01 mild
02 moderate
03 severe

code 3
01 land is still productive though soil erosion is taking place
02 land is too small to accommodate soil erosion structures
03 land is too small and erosion mitigation costs cannot be offset
04 land already highly degraded/eroded and erosion control measures is waste of time
05 tried erosion measures before but gains were not significant
06 household doesn't have enough labor
07 doesn't any benefits of soil conservation practices
08 doesn't know any soil conservation methods

2.2 Crops, cost of land preparation and conservation, inputs and levels of yield

Code1 Crop	Code 2 Cropping system	Area (ha/ acre)	Land preparation (MK)	Weeding (MK)	Cost of Soil conservation (MK)	Soil fertility (input) Code 3	Amount (kg), ngolo	MK	If doesn't apply inputs, why not? Code 4	Part of crop eaten or sold before harvest (kg)	Harvest/yield (Kg)	Amount sold (kg)	MK	Gifts/ ceremonies (Kg)

Code1
01 maize
02 cassava
03 common beans
04 pigeon peas
05 rice
06 sorghum
07 groundnuts
08 tobacco
09 cotton

Code 2
01 sole/mono cropping
02 intercropping
03 crop rotation (ulimi wakasinthasintha)
04 rely cropping (ulimi wamwela)

Code 3
01 fertilizer(specify type)
02 farm yard manure
03 compost manure
04 crop residues
05 agroforestry/tree litter
06 livestock manure

Code4
01lack income to buy fertilizer
02untimely availability of fertilizer
03 unavailability /insufficient of litter or manure
04 too dry for residues to decompose
05 benefits from investment not appreciated
06 don't want to introduce land to chemical fertilizers
07 not aware of benefits
08 lack credit facility

Note: other codes may be added in an area where need be

2.5.2 If it doesn't, why not

01 yields levels have not been affected
02 extension messages have not emphasized on this problem
03 community fails to link declining yields with erosion
04 numerous problems affecting yield levels in the area over shadow effects of erosion on yield
05 erosion is not a serious problem in the area

2.6 Considering the way you use your land, would you say you have any consideration for the future generation?

01 yes
02 no

2.6.1 If yes, what do you do to preserve the quality of land for the future generation

01 practice soil conservation measures (specify)
02 apply inputs (fertilizer, manure etc) to replenish soil nutrients and maintain good quality of land
03 avoid cultivation of marginal areas
04 practice fallow system
06 others (specify)

2.6.2 If no, why not

01 we are barely surviving now and therefore can't concentrate on the future
02 land provided for our forefathers and has provided for us, so will provide for the future generation by itself
03 it is difficult to investment in soil quality when such investment can't pay off immediately (we are not beneficiaries of the investment)
04 it is the government responsibility to preserve the land/ feed its people
05 never had concern for the future generation
06others(specify)

4.0 Assets and bank accounts of the household

(focus should be on assets and bank accounts presently held by the household)

Code 1 productive assets	No.Units	Year acquired	Value bought (MK)	**Code 2** personal assets	No.Units	Year acquired	Value bought (MK)	Accounts held by household	
								Bank	Amount (MK)
								NBM	
								CBM	
								NBS	
								Post Office	
								SACCO	

Code 1
01 hoe
02 plough
03 ox-cart
04 phanga knife
05 water can
06 sprayer
07 sickle
08 wheelbarrow
09 axe
10 modern khola

Code 2
01 radio/recorder
02 bicycle
03 motorcycle
04 wall-clock
05 vehicle
06 modern house (brick wall and iron sheets)

5.0 Main sources of income and expenditure for the household (calculate per annum)

INCOME SOURCES							EXPENDITURE		
Agricultural crops (code 1)	**MK**	**Agricultural related code 2**		**MK**	**Other sources**	**MK**	**Main Expenditure**		**MK**
		Agric. wage labourer	01		Fishing	01	Food	01	
		Dairy/ beef Livestock	02		Formal employment	02	Health	02	
		Poultry	03		Pension	03	Transport	03	
		Land rents	04		Remittances	04	Housing	04	
		Ganyu	05		Carpentry	05	Land rents	05	
		Equipment hire	06		Tailoring	06	Equipment hire	06	
					IGAs	07	Remittances (gives out)	07	
					Gifts	08	Gifts (gives out)	08	
					Aid (govt, NGOs	09	Business	09	

Code1

01 maize
02 cassava
03 common beans
04 pigeon peas
05 rice
06 sorghum
07 groundnuts
08 tobacco
09 cotton

6.0 Access to credit/loan/grants facilities

Code 1	Type of loan Code 2	Source Code 3	Amount received (kg) or MK	Is amount enough?	Repayment mode Code 4	Repayment period code		If doesn't access, why not?		Credit required		Ability to pay back loan	
						.<6mo	01	No collateral	01	Inputs	01	Income from sales	01
						6mo-1yr	02	No credit institutions	02	Cash	02	Govt to assist me	02
						1-5yrs	03	Segregated because of sex	03	Food	03	Group to assist me	03
						>5yrs	04	Not aware of such facility	04	Livestock	04	Needs grant	04
								No need	05			Needs soft loan	05
								Prefer grants	06				

Code 1
01 yes
02 no

Code 2
01 seed input
02 fertilizer
03 cash
04 food
05 livestock

Code 3
01 MRFC
02 farmers' world
03 farmers' finance company
04 NGOs
05 government
06 donor aid

Code 4
01 cash with interest
02 cash without interest
03 food
04 labor
05 same item/ eg seed
06others(specify)

7. Food security and coping strategies

7.1 Do you produce enough food for your household (to be consumed throughout the year)?

01 yes
02 no

7.2 If no, how do the household supplement to cover-up the deficit?

01 purchase with own cash
02 gifts from relatives/friends
03 food for work
04 aid (govt, NGOs)
05 others (specify)

7.3 Does your family sometimes substitute some usual meals/food for less preferred food (e.g., porridge for nsima; madeya for ufa woyera etc)

01. Yes
02. No

7.3.1 if yes, how often?

01. Rarely
02. Often

7.4 What time of the year do you experience food shortage?

01 Soon after harvest (around May-June)
02 Around July
03 Around September
04 Around December
05 Around February

7.5 Does your family reduce number of meals served or reduce quantity of food per individual (in some months) as food insecurity coping mechanism?

1. Yes
2. No

7.5.1 If you sometimes reduce quantity of food and/or frequency of meals which members of the family are often affected?

01 children
02 adult women
03 adult men
04 all family members

7.5.2 In which months of the year is this practice most common?

01 Jan – Mar
02 Apr-Jun
03 Jul-Septr
04 Oct- Dec

7.5.2 Do you ever make nsima from green maize?

01. Never
02. Sometimes
03.(Almost every year)

7.3 At times, are some of your family members involved in activities below as food insecurity coping mechanism

(a) ganyu
(b) Seek temporary work off-farm?
(c) borrow grains
(d) borrow money
(e) receive food aid
(f) sell farm equipment or animals
(g) sell household assets
(h) rent or sell land

7.4 If some members seek ganyu what is the preferred payment?

01 cash
02 food
03others(specify)

7.5 Do you experience or nurse sicknesses frequently?

01 once or twice a month
02 after every two months
03 after every four months
04 after every six months
05 once a year
06 Others (specify)

7.6 Which members of the family are most vulnerable?

01 husband
02 wife
03 children
04 others (specify)

7.7 Do you experience labour shortage in the garden due to the sicknesses?

01 yes
02 no

7.8 If yes, how do you manage field activities?

01 hire private labour
02 reduce land size (area) cultivated
03 skip other field activities (specify)
04 others (specify)

Participatory Rural Appraisal (PRA) Checklist

Note: ***This checklist will be used as a discussion guide during the focus group discussions***

The focus group members should include, but not be limited to, the following:

1. Key informants in the area including staff members of organizations working in the area e.g. extension staff both for agriculture and other organizations i.e., NGOs etc

2. Farmers - need to balance the male and female farmers

3. Youths groups - both in and out of school youths

Note that each Focus group should not exceed 20 people. In cases where more than 20 people are available, it may be appropriate to have two or more focus groups.

A. Main purpose of the PRA

1 To allow smallholder farmers define in their own words and perspective the main factors that have led to the decline in land productivity;

2 To understand from smallholder farmers if they easily connect declining soil fertility and food insecurity from own experience.

3 To understand from smallholder farmers if they easily relate cultivation practices/land management and the problem of soil fertility decline. If they do, how have they changed over time, farming systems and land preservation practices in response to the threat of declining soil fertility in their area.

4 To have an influenced opinion of the smallholder farmers if the evolvement of farming systems, land preservation practices over time reflect more on the communities' concern or rather consideration for the well-being of the future generation.

5 To find out from farmers what can be done by the communities, Government and other Non Governmental Organisation to address the problem of declining soil fertility in the area and the livelihood insecurity in the short and long term.

B. The main discussion topics

B.1 Agriculture

Food crops
Cash crops
Cropping patterns
Market outlets (input and output)
Input and output prices and how they influence farmers' decision
Training needs for extension, food diversification

B.2 Soil Erosion and Declining Soil Fertility

Soil erosion problem in the area (extent or erosion and damage—declining yield levels)
Soil conservation practices/programs (specify physical and biological)
Input use and problems (specify biological and inorganic)
Access to input
Knowledge of soil erosion effects and soil conservation methods (extension)

B.3 Food security

Food production (harvest)
Adequacy of food from own production
Food purchases
Food deficit months
Coping mechanisms/ survival strategies
Other sources of income
Food distribution within the household (traditional/cultural practises) Impact of food insecurity on productivity