REFERENCES


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

\[
N_C(F,LQ,LS,KS,\lambda) = \left[ pf(S_i,LQ_i) - w_F F_i - w_K KS_i - w_L (LQ_i + LS_i) \right] \\
+ m \left[ H(Q_i,LS_i,KS_i) - D(Q) + G(F_i) \right]
\]

where \( m = e^{\theta} \lambda \).

The first order conditions (FOCs) for optimal control

\[
\frac{\partial N_C}{\partial F_i} = 0 \Rightarrow w_F = m_i G_F \quad \Rightarrow m_i = \frac{w_F}{G_F} \tag{2}
\]

\[
\frac{\partial N_C}{\partial LS_i} = 0 \Rightarrow w_L = m_i H_{LS_i} \quad \Rightarrow m_i = \frac{w_L}{H_{LS}} \tag{3}
\]

\[
\frac{\partial N_C}{\partial KS_i} = 0 \Rightarrow w_K = m_i H_{KS_i} \quad \Rightarrow m_i = \frac{w_K}{H_{KS}} \tag{4}
\]

\[
\frac{\partial N_C}{\partial LQ_i} = 0 \Rightarrow \left( pf_{LQ_i} - w_L \right) = m_i \left( D_{LQ_i} - H_{LQ_i} \right) \tag{5}
\]

where \( \left( pf_{LQ_i} - w_L \right) \) defines the net price \( NP_{LQ} \) giving:

\[
m_i = \frac{NP_{LQ}}{D_{LQ} - H_{LQ}} \tag{6}
\]

Current co-state equation of motion is given as below

\[
\dot{m} = - \frac{\partial N_C}{\partial S} + \delta m = \left[ pf_s + m(H_s - D_s) \right] + \delta m
\]
However, at steady state (SS), \( m = 0 \), then equation \( 7 \) becomes \( 7' \) below

\[
P_f = m[(D_s - H_s) + \delta]
\]  
(7')

At steady state, \( \dot{S} = 0 \) meaning that \( S_{r+1} = S_r = S \), entails that equation of motion \( 3 \), \[
\dot{S} = H(Q_i, LS_i, KS_i) - D(Q_i) + G(F_i)
\] reduces to

\[
G(F) = D(Q_i) - H
\]  
(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 \( m \)

\[
P_f = \frac{w_f}{G_f} [(D_s - H_s) + \delta]
\]

\[
\frac{P_f G_f}{w_f} = \delta + (D_s - H_s)
\]  
(2b)

Combining equation \( 3 \) and \( 7' \) to eliminate \( m \)

\[
P_f = \frac{w_l}{H_{LS}} [(D_s - H_s) + \delta]
\]

\[
\frac{P_f H_{LS}}{w_l} = \delta + (D_s - H_s)
\]  
(3b)
Combining 4 and 7' to eliminate $m$

$$P_{f_1} = \frac{w_K}{H_{KS}} [(D_S - H_S) + \delta]$$

$$\frac{P_{f_1} H_{KS}}{w_K} = \delta + (D_S - H_S)$$ \hspace{1cm} (4b)

Combining 5 and 7' to eliminate $m$

$$P_{f_1} = \frac{NP_{LQ}}{D_{LQ} - H_{LQ}} [\delta + (D_S - H_S)]$$

$$\frac{P_{f_1} (D_{LQ} - H_{LQ})}{NP_{LQ}} = \delta + (D_S - H_S)$$ \hspace{1cm} (5b)

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

$$P_{f_1} = w_F [(D_S - H_S) + \delta]$$ \hspace{1cm} (6b)

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

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

A. The CD production function
\[ Q = A \cdot LQ^{a_L} \cdot S^{a_S} \]  \hspace{1cm} (20)

B. The relationship between erosion \(E\) and \(Q\) (canopy) has been specified as:
\[ E_i = \phi e^{-kQ} \]  \hspace{1cm} (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 \((KS)\):
\[ c = LS^{\alpha_L} KS^{\alpha_S} \]  \hspace{1cm} (22)

Accordingly, the decay function \(M\) is specified as the additive function below:
\[ M = \left( \beta e^{-kQ} - LS^{\alpha_L} KS^{\alpha_S} \right) = \left( \beta E(Q) - C \right) \]  \hspace{1cm} (23)

The aggregate natural regeneration and decay process function \(H\) becomes:
\[ H = h - M = h - \left( \beta e^{-kQ} - LS^{\alpha_L} KS^{\alpha_S} \right) \]  \hspace{1cm} (24)

D. The depletion (or damage) function \(D(Q)\) is specified as a linear function of \(Q\):
\[ D(Q) = nQ \]  \hspace{1cm} (25)

E. The nitrogen augmenting function \(G(F)\) is specified as a linear function of fertiliser \(F\):
\[ G(F) = gF \]  \hspace{1cm} (26)
After substituting 20-26 in the objective function, the Hamiltonian can be rewritten as:

\[
N(LQ, F, KS, LS, \lambda) = e^{-\lambda} \{P(A^* LQ^{a_L} S^{a_S}) - w_F K - w_F F - w_L (LQ + LS)\} + \lambda[H - D + G]
\]

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

FOCs for above decision problem:

\[
\frac{\partial N}{\partial F} = e^{-\lambda} (w_F) = \lambda_i \frac{\partial G}{\partial F} = \lambda g 
\]

(27)

\[
\frac{\partial N}{\partial LQ} = e^{-\lambda} (A^* LQ^{a_L-1} S^{a_S} - w_L) = \lambda_i \left[ \frac{\partial H}{\partial LQ} - \frac{\partial D}{\partial LQ} \right]
\]

(28)

\[
\frac{\partial H}{\partial LQ} = H_{LQ}; \quad \frac{\partial D}{\partial LQ} = D_{LQ}
\]

\[
\frac{\partial N}{\partial LS} = e^{-\lambda} w_L = \lambda_i \frac{\partial H}{\partial LS}; \quad \frac{\partial H}{\partial LS} = H_{LS}
\]

(29)

\[
\frac{\partial N}{\partial KS} = e^{-\lambda} w_K = \lambda_i \frac{\partial H}{\partial KS}; \quad \frac{\partial H}{\partial KS} = H_{KS}
\]

(30)

\[
\dot{\lambda} = -\frac{\partial N}{\partial S}; = -(e^{-\lambda} P_A LQ^{a_L} S^{a_S}) + \lambda_i \left[ \frac{\partial H}{\partial S} - \frac{\partial D}{\partial S} \right]
\]

(31)

\[
\frac{\partial H}{\partial S} = H_s; \quad \frac{\partial D}{\partial S} = D_s
\]

\[
\ddot{S} = h - (\beta e^{-\lambda} LQ^{a_L} KS^{a_S}) - n Q + g F
\]

(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 \( \lambda^* \).

A3.1 Steady State (SS) Solutions

Assuming a SS equilibrium path \( \dot{S} = \dot{\lambda} = 0 \) the FOC can be written as derived in chapter IV (equations 16-19):
\[
\frac{P_{f_1}G_{f_1}}{w_f} = \delta + (D_s - H_s) \tag{16}
\]

\[
\frac{P_{f_1}H_{LQ}}{w_L} = \delta + (D_s - H_s) \tag{17}
\]

\[
\frac{P_{f_1}H_{KS}}{w_K} = \delta + (D_s - H_s) \tag{18}
\]

\[
\frac{P_{f_s}(D_{LQ} - H_{LQ})}{NP_{LQ}} = \delta + (D_s - H_s) \tag{19}
\]

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

\[
\frac{\partial H}{\partial LQ} = -b \beta \alpha_L \frac{Q}{LQ} \phi e^{-\lambda LQ}
\]

let \( b \phi e^{-\lambda LQ} = \zeta \)

\[
\frac{\partial H}{\partial LQ} = H_{LQ} = -\alpha_L \frac{Q}{LQ} \beta \zeta \tag{3.1}
\]

\[
\frac{\partial H}{\partial S} = -b \beta \phi \alpha_s \frac{Q}{S} e^{-\lambda LQ}
\]

\[
\frac{\partial H}{\partial S} = H_s = -\alpha_s \frac{Q}{S} \beta \zeta \tag{3.2}
\]

\[
\frac{\partial H}{\partial LQ} = \beta_s LQ^{\beta_s - 1} KS^{\beta_s}
\]

let \( LS^{\beta_s} KS^{\beta_s} = C \)

\[
\frac{\partial H}{\partial LS} = H_{LS} = \beta_s LS^{\beta_s - 1} KS^{\beta_s} = \beta_s \frac{C}{LS} \tag{3.4}
\]

\[
\frac{\partial H}{\partial KS} = \beta_s LS^{\beta_s} KS^{\beta_s - 1}
\]

\[
\frac{\partial H}{\partial KS} = H_{KS} = \beta_s LS^{\beta_s} KS^{\beta_s - 1} = \beta_s \frac{C}{KS} \tag{3.5}
\]
From equation 25

\[
\frac{\partial D}{\partial LQ} = D_{LQ} = nLQ^{a_s-1}S = \alpha_s n \frac{Q}{LQ}
\]  

(3.6)

\[
\frac{\partial D}{\partial S} = D_s = nLQ^{a_s}S^{a_s} = \alpha_s n \frac{Q}{S}
\]  

(3.7)

And from equation 26:

\[
\frac{\partial G}{\partial F} = g
\]  

(3.8)

According to the above \(H_s - D_s\), is obtained from equations 3.3 and 3.7

\[
H_s - D_s = -\alpha_s \frac{Q}{S} \beta_s - n\alpha_s \frac{Q}{S} = -\alpha_s \frac{Q}{S} (n + \beta_s)
\]  

(3.9)

Similarly \(H_{LQ} - D_{LQ}\), is obtained from equations 3.2 and 3.6

\[
H_{LQ} - D_{LQ} = -\alpha_L \frac{Q}{LQ} \beta_L - n\alpha_L \frac{Q}{LQ} = -\alpha_L \frac{Q}{LQ} (n + \beta_L)
\]  

(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

\[
\alpha_s P \frac{Q}{S} g = w_F \left[ \delta + \alpha_s \frac{Q}{S} (n + \beta_s) \right]
\]  

(16b)

Substituting for \(f_s\); \(H_{LS}\); and \(D_s - H_s\) in equation 17 to get

\[
\alpha_s \beta_L P \frac{Q}{S} \frac{C}{LS} = w_L \left[ \delta + \alpha_s \frac{Q}{S} (n + \beta_s) \right]
\]  

(17b)

Substituting for \(f_s\); \(H_K\); and \(D_s - H_s\) in 18 to get

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\[ \alpha_s \beta_L P \frac{Q}{S} \frac{C}{KS} = w_k \left[ \delta + \alpha_s \frac{Q}{S} (n + \beta \zeta) \right] \]  

(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

\[ \alpha_s \alpha_L P \frac{Q}{S} \frac{O}{LQ} (n + \beta \zeta) = \left( \alpha_L P \frac{Q}{LQ} - w_L \right) \left[ \delta + \alpha_s \frac{Q}{S} (n + \beta \zeta) \right] \]  

(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

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

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

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

\[ w_L g = \alpha_L ALQ^u S^a \left[ P g - w_f (n + \beta \zeta) \right] \]

\[ LQ^{u-1} = \frac{w_L g}{\alpha_L A S^a \left[ P g - w_f (n + \beta \zeta) \right]} \]

\[ LQ = \left[ \frac{w_L g}{\alpha_L A S^a \left[ P g - w_f (n + \beta \zeta) \right]} \right]^{\frac{1}{\alpha_L - 1}} \]  

(20b)\(^{24}\)

Substitute 20b into 16b to solve for \( S \)

\(^{24}\) Please note that \( \zeta = b \phi^{-Q} \), and \( Q \) is determined (see Brekke et al., 1999)
\[ \alpha_s P aL Q^{a_L} S^{a_L-1} g = w_F \delta + w_F [\alpha_s L Q^{a_L} S^{a_L-1}(n + \beta \zeta)] \]

\[ \alpha_s P aL S^{a_L-1} \left[ \frac{g w_L}{A \alpha_L S^{a_L} [P g - w_F (n + \beta \zeta)]} \right]^{a_L} \]

Divide through by \[ A \alpha_L S^{a_L} [P g - w_F (n + \beta \zeta)] \]

\[ \alpha_s P g = \frac{w_F \delta}{A S^{a_L-1} [A \alpha_L S^{a_L} [P g - w_F (n + \beta \zeta)]]} + \alpha_s w_F (n + \beta \zeta) \]

\[ \alpha_s [P g - w_F (n + \beta \zeta)] = \frac{w_F \delta}{A S^{a_L-1} [A \alpha_L S^{a_L} [P g - w_F (n + \beta \zeta)]]} \]

\[ S^{a_L-1} = \frac{(A \alpha_L) \frac{a_L}{a_L-1} w_F \delta}{A \alpha_L S^{a_L} [P g - w_F (n + \beta \zeta)]} \]

\[ S^{a_L-1} = \left\{ \frac{w_F \delta (A \alpha_L) \frac{a_L}{a_L-1} [P g - w_F (n + \beta \zeta)]}{A \alpha_L S^{a_L} [P g - w_F (n + \beta \zeta)]} \right\}^{a_L} \]

let \[ 1 - a_s - a_L = \gamma \]

\[ S^* = A^{\gamma} \left( \frac{a_L}{g w_L} \right)^{a_L} \left[ \frac{w_F \delta}{\alpha_s} \right]^{a_L} \left[ P g - w_F (n + \beta \zeta) \right]^{1/\gamma} \]  \[ (21.a) \]
Substitute 21a into 20b to solve for LQ

\[
LQ = \left[ \frac{g_{W_L}}{\alpha_L A [P - w_r (n + \beta \zeta)]} \left[ A^T \left( \frac{\alpha_L}{g_{W_L}} \right)^{\alpha_l} \left( \frac{\delta w_r}{\alpha_s} \right)^{\alpha_l} [P - w_r (n + \beta \zeta)]^{1/r} \right] \right]^{1/\alpha_l-1}
\]

\[
LQ = A^T \left( \frac{g_{W_L}}{\alpha_L} \right)^{1-\alpha_l-\alpha_s} \left( \frac{\delta w_r}{\alpha_s} \right)^{\alpha_l} [P - w_r (n + \beta \zeta)]^{1/r} \quad (22.a)
\]

From equations (17b & 18b) we derive

\[
\alpha_s \beta_1 P \frac{Q C}{S LS w_L} = \alpha_s \beta_2 P \frac{Q C}{S KS w_K} \quad (3a)
\]

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

\[
LS = \frac{w_K}{w_L} \beta_1 \frac{C}{KS} \quad (3b)
\]

Using equations 16b and 17b we derive:

\[
\frac{g}{\beta_1 \frac{C}{LS}} = \frac{g}{\beta_1 LS^{\alpha_l-1} KS^{\alpha_s}} = \frac{w_r}{w_L} \quad (4a)
\]
\[
LS^{\beta_1} = \frac{g^w_{\ell}}{\beta_1 w_F KS^{\beta_2}} \\
LS = \left[ \frac{g^w_{\ell}}{\beta_1 w_F KS^{\beta_2}} \right]^{\beta_1^{-1}} \frac{w_K}{w_L \beta_2} KS^{\beta_1^{-1}} = \frac{w_K}{w_L} \frac{\beta_1}{\beta_2} KS^{\beta_1^{-1}} \\
KS^{\beta_1^{-1}} = \left( \frac{\beta_1}{w_L} \right)^{\beta_1^{-1}} \left( \frac{w_K}{\beta_2} \right)^{\beta_1^{-1}} \left( \frac{w_F}{g} \right)^{1/\beta_1^{-1}} \\
KS = \left\{ \left( \frac{\beta_1}{w_L} \right)^{\beta_1^{-1}} \left( \frac{w_K}{\beta_2} \right)^{\beta_1^{-1}} \left( \frac{w_F}{g} \right)^{1/\beta_1^{-1}} \right\}^{1/\beta_1^{-1}} \\
\text{let } 1 - \beta_1 - \beta_2 = \varphi \\quad \text{(23.a)}
\]

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

\[
LS = \frac{w_K}{w_L} \frac{\beta_1}{\beta_2} \left[ \left( \frac{\beta_1}{w_L} \right)^{\beta_1^{-1}} \left( \frac{w_K}{\beta_2} \right)^{\beta_1^{-1}} \left( \frac{w_F}{g} \right)^{1/\beta_1^{-1}} \right] \\
LS^* = \left( \frac{\beta_1}{w_L} \right)^{1-\beta_1-\beta_2} \left( \frac{w_K}{\beta_2} \right)^{-\beta_1} \left( \frac{w_F}{g} \right)^{1/\beta_1^{-1}} = \left( \frac{\beta_1}{w_L} \right)^{1-\beta_1-\beta_2} \left( \frac{w_K}{\beta_2} \right)^{-\beta_1} \left( \frac{w_F}{g} \right)^{1/\varphi} \quad \text{(24.a)}
\]

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

\[
\begin{align*}
\dot{S} &= H - D + G \\
\text{at SS, } S &= 0 \Rightarrow G = D - H
\end{align*}
\]

(5a)

(5a.1)

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

\[
gF = nQ - h - \left(\beta\phi e^{-bQ} - LS^{\frac{\Delta}{\beta}} KS^{\frac{\Delta}{\beta}}\right)
\]

\[
F = \left[nQ - h - \left(\beta\phi e^{-bQ} - LS^{\frac{\Delta}{\beta}} KS^{\frac{\Delta}{\beta}}\right)\right] / g
\]

(25a)

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

\[
F = \left\{\frac{1}{rA^{\beta}}\left(\frac{w_{x}}{\alpha_{s}}\right)^{\frac{w_{x}}{\alpha_{s}}} \left(\frac{\alpha_{s} w_{x}}{w_{t}}\right)^{\frac{w_{x}}{\alpha_{s}} - 1 - n}\right\} \left[\left(Pg - w_{F}(n+\beta_{s})\right) + \beta_{s} e^{-bQ} + \left(\frac{\beta_{s}}{\beta_{s}}\right)^{n} \left(\frac{w_{F}}{\beta_{s}}\right)\left(\frac{w_{F}}{g}\right)\left(\frac{\beta_{s}}{\beta_{s}}\right)^{n} - h\right] / g
\]

(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

<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>DISTRICT</td>
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<td>NAME OF ENUMERATOR</td>
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1. HOUSEHOLD CHARACTERISTICS

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

<table>
<thead>
<tr>
<th>Household head</th>
<th>Marital status of h/h head</th>
<th>Number of Household members</th>
<th>#</th>
<th>Education level of h/h head</th>
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<tbody>
<tr>
<td>Male</td>
<td>01 Single</td>
<td>01 &lt;15 years</td>
<td>None</td>
<td>01</td>
</tr>
<tr>
<td>Female</td>
<td>02 Married</td>
<td>02 15-64 years</td>
<td>Std 1-4</td>
<td>02</td>
</tr>
<tr>
<td>Child</td>
<td>03 Polygamist</td>
<td>03 &gt;64 years</td>
<td>Std 5-8</td>
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<td>04</td>
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<td>05</td>
<td>Form 3-4</td>
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<td>Tertiary</td>
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</tr>
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2.0 **Land size, crops grown, land ownership and acquisition and period involved in soil/land conservation practices**

<table>
<thead>
<tr>
<th>Code</th>
<th>Land size</th>
<th>Land ownership</th>
<th>Land acquisition</th>
<th>Period land under cultivation</th>
<th>Land conservation methods used by h/h</th>
<th>Years involved in soil conservation</th>
<th>Code 2 Level of soil degradation</th>
<th>Code 3 If doesn’t conserve why not?</th>
</tr>
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<tbody>
<tr>
<td>01</td>
<td>Male/husb</td>
<td>01 Purchased</td>
<td>01 &lt; 5 years</td>
<td>01 Physical</td>
<td>01</td>
<td>01</td>
<td></td>
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<tr>
<td>02</td>
<td>Female</td>
<td>02 Maternal</td>
<td>02 5&lt;11 yrs</td>
<td>02 Contours</td>
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<td></td>
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<tr>
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<td>Vge headman</td>
<td>03 Paternal</td>
<td>03 11&lt;20 yrs</td>
<td>03 Marker ridges</td>
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<td>04</td>
<td>Parents</td>
<td>04 Vge headman</td>
<td>04 &gt;20 years</td>
<td>04 Box ridges</td>
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<td>07 Hedgerow grass</td>
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<td>01 mild</td>
<td>01 land is still productive though soil erosion is taking place</td>
</tr>
<tr>
<td>02 land under cultivation</td>
<td>02 moderate</td>
<td>02 land is too small to accommodate soil erosion structures</td>
</tr>
<tr>
<td>03 own land</td>
<td>03 severe</td>
<td>03 land is too small and erosion mitigation costs cannot be offset</td>
</tr>
<tr>
<td>04 rented in</td>
<td>04</td>
<td>04 land already highly degraded/eroded and erosion control measures is waste of time</td>
</tr>
<tr>
<td>05 rented out</td>
<td>05</td>
<td>05 tried erosion measures before but gains were not significant</td>
</tr>
<tr>
<td>06 borrowed</td>
<td>06</td>
<td>06 household doesn’t have enough labor</td>
</tr>
<tr>
<td>07 land under fallow</td>
<td>07</td>
<td>07 doesn’t any benefits of soil conservation practices</td>
</tr>
<tr>
<td></td>
<td>08</td>
<td>08 doesn’t know any soil conservation methods</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Code 1 Crop</th>
<th>Code 2 Cropping system</th>
<th>Area (ha/acre)</th>
<th>Land preparation (MK)</th>
<th>Weeding (MK)</th>
<th>Cost of Soil conservation (MK)</th>
<th>Soil fertility (input) Code 3</th>
<th>Amount (kg), ngolo MK</th>
<th>If doesn’t apply inputs, why not? Code 4</th>
<th>Part of crop eaten or sold before harvest (kg)</th>
<th>Harvest (kg)</th>
<th>Amount sold (kg)</th>
<th>MK</th>
<th>Gifts/ceremonies (Kg)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Code 1</th>
<th>Code 2</th>
<th>Code 3</th>
<th>Code 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>01 maize</td>
<td>07 groundnuts</td>
<td>01 fertilizer(specify type)</td>
<td>01 lack income to buy fertilizer</td>
</tr>
<tr>
<td>02 cassava</td>
<td>08 tobacco</td>
<td>02 farm yard manure</td>
<td>02 untimely availability of fertilizer</td>
</tr>
<tr>
<td>03 common beans</td>
<td>09 cotton</td>
<td>03 compost manure</td>
<td>03 unavailability /insufficient of litter or manure</td>
</tr>
<tr>
<td>04 pigeon peas</td>
<td>04 relay cropping (ulimi wakasinthasintha)</td>
<td>04 crop residues</td>
<td>04 too dry for residues to decompose</td>
</tr>
<tr>
<td>05 rice</td>
<td>05 agroforestry/tree litter</td>
<td>05 benefits from investment not appreciated</td>
<td></td>
</tr>
<tr>
<td>06 sorghum</td>
<td>06 livestock manure</td>
<td>06 don’t want to introduce land to chemical fertilizers</td>
<td></td>
</tr>
</tbody>
</table>

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

157
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
06 others (specify)
### 4.0 Assets and bank accounts of the household

(FOCUS SHOULD BE ON ASSETS AND BANK ACCOUNTS PRESENTLY HELD BY THE HOUSEHOLD)

<table>
<thead>
<tr>
<th>Code 1 productive assets</th>
<th>Code 2 personal assets</th>
<th>Accounts held by household</th>
</tr>
</thead>
<tbody>
<tr>
<td>Code 1</td>
<td>Code 2</td>
<td>Bank</td>
</tr>
<tr>
<td>01 hoe</td>
<td>01 radio/recorder</td>
<td>NBM</td>
</tr>
<tr>
<td>02 plough</td>
<td>02 bicycle</td>
<td>CBM</td>
</tr>
<tr>
<td>03 ox-cart</td>
<td>03 motorcycle</td>
<td>NBS</td>
</tr>
<tr>
<td>04 phanga knife</td>
<td>04 wall-clock</td>
<td>Post Office</td>
</tr>
<tr>
<td>05 water can</td>
<td>05 vehicle</td>
<td>SACCO</td>
</tr>
<tr>
<td>06 sprayer</td>
<td>06 modern house (brick wall and iron sheets)</td>
<td></td>
</tr>
</tbody>
</table>

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<tr>
<td>05 water can</td>
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<td>SACCO</td>
</tr>
<tr>
<td>06 sprayer</td>
<td>06 modern house (brick wall and iron sheets)</td>
<td></td>
</tr>
</tbody>
</table>
5.0 Main sources of income and expenditure for the household (calculate per annum)

<table>
<thead>
<tr>
<th>INCOME SOURCES</th>
<th>EXPENDITURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural crops (code 1)</td>
<td>MK</td>
</tr>
<tr>
<td>Agric. wage labourer</td>
<td>01</td>
</tr>
<tr>
<td>Dairy/ beef Livestock</td>
<td>02</td>
</tr>
<tr>
<td>Poultry</td>
<td>03</td>
</tr>
<tr>
<td>Land rents</td>
<td>04</td>
</tr>
<tr>
<td>Ganyu</td>
<td>05</td>
</tr>
<tr>
<td>Equipment hire</td>
<td>06</td>
</tr>
<tr>
<td>IGAs</td>
<td>07</td>
</tr>
<tr>
<td>Gifts</td>
<td>08</td>
</tr>
<tr>
<td>Aid (govt, NGOs)</td>
<td>09</td>
</tr>
</tbody>
</table>

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

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### 6.0 Access to credit/loan/grants facilities

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

<table>
<thead>
<tr>
<th>Code 1</th>
<th>Code 2</th>
<th>Code 3</th>
<th>Code 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>01 yes</td>
<td>01 seed input</td>
<td>01 MRFC</td>
<td>01 cash with interest</td>
</tr>
<tr>
<td>02 no</td>
<td>02 fertilizer</td>
<td>02 farmers' world</td>
<td>02 cash without interest</td>
</tr>
<tr>
<td>03 cash</td>
<td>03 farmers' finance company</td>
<td>03 food</td>
<td></td>
</tr>
<tr>
<td>04 food</td>
<td>04 NGOs</td>
<td>04 labor</td>
<td></td>
</tr>
<tr>
<td>05 livestock</td>
<td>05 government</td>
<td>05 same item/eg seed</td>
<td></td>
</tr>
<tr>
<td>06 donor aid</td>
<td>06 others(specify)</td>
<td>06 others(specify)</td>
<td></td>
</tr>
</tbody>
</table>
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
03 others (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)

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**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.

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**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 practices) Impact of food insecurity on productivity