"Interdependencies between upland and lowland agriculture and resource management 2008"


THE IMPROVEMENT OF SUSTAINABLE RAINFED CROP PRODUCTIVITY ON SLOPING HIGHLAND

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SIVAPONG NAREUBAN 27 8 2005
BACKGROUND

General View and Problems of Sloping Highland

Maehongson,
Northern
Thailand

Mattiga
The problems of Highland Agriculture in Northern Thailand and South East Asia

Shifting, swiddening and intensive cultivation: are the most serious problems of hill farming systems in northern Thailand. Slash and Burn: results in bare soil and increase global warming significantly.
Main objectives:
- Productivity
- Sustainability
- Profitability
- Environment
- Conservation

Safety for Health & Ecological Friendly

Mattiga Panomtaranichagul
Building a sustainable highland farming system will never be successful without broadly adopted by the stakeholders.

Farmers have no incentive to adopt soil and water conservation practices on their own behalf.
Combination of annual cash crops and fruit trees as Alley cropping systems are supposed to be the best sustainable crop production on sloping land. The integrated Bio-degradable mulching materials, Water-harvest, Anti-erosive, and Multiple-cropping systems should be the best strategies for sustainable rainfed highland agricultural system. The multi-cropping experiments will offer various choices for farmers. This research will focus on alley cropping and mulching including contour furrow cultivation.
Sustainable crop productivity and water use efficiency under highland rainfed condition is dependent on rainfall characteristics and soil water availability.

Strategies to increase the soil water storages are to reduce surface runoff, increase infiltration rate and decrease soil water evaporation. Anti-erosive contour cultural practices and surface mulching are most practical methods used to increase soil infiltrability and soil water availability on sloping land.
The main targets of this sub-project are to improve crop productivity and water use efficiency for sustainable highland rainfed agriculture. A sustainable crop production means to maintain or increase crop productivity, profitability and agro-ecological/environmental quality.

The specific aims of this sub-project are to reduce severe soil erosion and increase soil water storages on sloping land using anti erosive and water harvested cultural practices,

**Strategies to achieve these aims are using contour furrow cultivation and surface mulching to harvest water for multiple crop production in the alley - agro-forestry systems.**
The experimental sites are in Borkrai village, Pangmapa district, Mae Hongson province Northern Thailand.

This paper reports a part of the results obtained from the 3 year - field trials which were conducted during January 2004 - March 2007 in Borkrai Village, Pangmapa District, Mae Hongson Province, Northern Thailand.
EXPERIMENTAL DESIGN:

The experiment was designed as a completely randomized design with three replicates of 4 conservative cultural practices as follows.

METHODS OF STUDY
The plots were established in the farmer’s cultivated plots and the farmers were invited to participate in the experiment since April 2004. The plot preparation in both experimental sites were commenced during early May, 2004. Maize sowing was done on during the 10-15 May every year. Rice was sown in the maize row 1 month after maize sowing. Lab lab bean was sown 1 month before rice harvesting.
4 methods of Cultural practices

Conventional contour planting (CP)

Contour furrow cultivation in alley cropping with hedgerows of fruit trees (CF-AL)

Contour furrow cultivation with mulching in alley cropping with hedgerows of fruit trees (CF-M-AL)

Contour planting in alley cropping with hedgerows of fruit trees + vetiver grass (CP-AL-VG).
The mixed fruit-tree hedgerows consisted of Mango (*Mangifera indica* Linn.), Lemon, (*Citrus aurantifolia*) and Jujube (*Zizyphus jujuba* Mill.) + Ground cover with Graham Stylo (*Stylosanthes guianensis*).

The main cash crops are rotations of Sweet corn (*Zea mays*) during early rainy season, followed by Upland rice (*Oryza sativa*) during mid-late rainy season and followed by Lablab bean (*Lablab purpureus*) during late rainy season - summer respectively.

Imperata grass or Bamboo trunk panel mulching + contour furrow cultivation were used to harvest water and prevent the soil surface from rainfall impact.
The parameters to evaluate the effects of the 4 treatments on sustainable crop productivity were conducted as follows:

(i) soil chemical and physical properties were carried out 2-3 times a year.

(ii) Surface runoff and soil loss were measured after every effective rainstorm.

(iii) Soil water contents within 1 m soil depth were measured by TDR once a month.

(iv) Crop development as total dry biomass and yields were measured at different stages of crop growth and harvested at the end of each crop growing season.

Water use efficiency (WUE) of each crop was calculated based on total dry biomass and yield production per unit actual crop evapotranspiration during the growing seasons.

Only results of runoff, soil loss, soil water storages, water use efficiency and crop yields including costs of benefit return under the studied treatments in Site A are presented here.
Rice was sown between corn sowing pits 1 month after corn harvesting stage. Corn stalks and residues was applied on the ground along the sowing rows to be natural bio-degradable mulching materials for rice and lab lab bean.
RESULTS AND DISCUSSIONS
RESULTS

General view of corn growing
General crop development
General crop development
Soil surface sealing and sheet or rill erosion under conventional contour planting (CP)
Soil surface under contour furrow cultivation (CF)
General crop development on Site B
Surface runoff and soil loss

- The results showed that CP gave the highest runoff and soil loss amounts, whilst, CF-M-AL gave the lowest soil loss amount, but gave similar amount of runoff to CF-AL, CF-M-AL and CP-AL-VG during the 3 experimental years.
- The amount of total runoff and soil loss were more completely collected in 2006, consequently giving higher total amounts of runoff and soil loss compared to those measured in 2004 and 2005.

CF-IM-AL was the most effective cultural practice to conserve soil and water more than the other treatments. These were caused by mulching in the furrow and the furrow cultivation, to harvest rain water, including the hedgerow effect on reducing cascaded water down the slope, giving decreased amounts of runoff and soil loss.
Cumulative runoff under different treatments during the 3 experimental years

Cumulative Runoff during rainy seasons in 2004-2006
Borkrai, Pang Mapa, Mae Hongson

Cumulative soil loss under different treatments during the 3 experimental years

Cumulative Soil loss during rainy season in 2004-2006
Borkrai, Pang Mapa, Mae Hongson

Cumulative soil loss (kg ha\(^{-1}\))

### Total Surface Runoff and Soil Loss during growing season in 2004-2006 (Borkrai, Pang Mapa, Mae Hong Son)

<table>
<thead>
<tr>
<th></th>
<th>CP</th>
<th>CF-AL</th>
<th>CF-M-AL</th>
<th>CP-AL-VG</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Runoff (m³ ha⁻¹)</strong> (2004)</td>
<td>132</td>
<td>93</td>
<td>97</td>
<td>97</td>
</tr>
<tr>
<td><strong>Soil loss (kg ha⁻¹)</strong> (2004)</td>
<td>93</td>
<td>90</td>
<td>57</td>
<td>57</td>
</tr>
<tr>
<td><strong>Runoff (m³ ha⁻¹)</strong> (2005)</td>
<td>128</td>
<td>93</td>
<td>95</td>
<td>88</td>
</tr>
<tr>
<td><strong>Soil loss (kg ha⁻¹)</strong> (2005)</td>
<td>459</td>
<td>45</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td><strong>Runoff (m³ ha⁻¹)</strong> (2006)</td>
<td>169</td>
<td>114</td>
<td>110</td>
<td>115</td>
</tr>
<tr>
<td><strong>Soil loss (kg ha⁻¹)</strong> (2006)</td>
<td>633</td>
<td>479</td>
<td>644</td>
<td></td>
</tr>
</tbody>
</table>

**Total Rainfall**

- **2004**: 1,373
- **2005**: 1,616
- **2006**: 1,681
Generally, the highest and the lowest soil water storages tended to occur in CF-M-AL and either CP or CP-AL-VG plots respectively, compared to CF-AL plots throughout the 3 experimental years. However, inconsistency variations of stored soil water within 1 m soil depth not only depended on different cultural practices, but also depending on rainfall distributions (Figure 2).
Stored soil water within 0-1000 mm soil depth (Site A)
(1/01/2004 - 24/02/2007)

- CP
- CF-AL
- CF-M-AL
- CP-AL-VG
- Cum. Rain

Stored soil water within 0-1000 mm soil depth (Site A)
(1/01/2004 - 24/02/2007)

Maize - Rice - Bean
2004

Maize - Rice - Bean
2005

Maize - Rice - Bean
2006

Maize - Rice - Bean
2007

Julian day number from 1/Jan/2004 - 24/Feb/2007

Cumulative Rain (mm)
Stored soil water within 0-1000 mm soil depth (Site B) (1/01/2004 - 24/02/2007)

- CP
- CF-AL
- CF-M-AL
- CP-AL-VG
- Cum. Rain

Stored soil water within 0-1000 mm soil depth (Site B) (1/01/2004 - 24/02/2007)

Maize - Rice - Bean 2004
Maize - Rice - Bean 2005
Maize - Rice - Bean 2006
Maize - Rice - Bean 2007

Cumulative Rain (mm)
Crop growth and yields:

CF-M-AL gave the highest, whilst CP gave the lowest yields of sweet corn and lablab bean compared to CF-AL and CP-AL-VG. The results during the 3 years of the experiment showed that crop yields under different cultural practices were mainly regulated by rainfall characteristics.
The effects of different cultural practices on sweet corn dry yield (cob+seed)
harvested from the whole plot during rainy season in 2004, 2005 and 2006,
Borkrai, Pangmapa, Mae Hong Son (Sites A and B)
The effects of different cultural practices on Lablab bean total dry biomass and seed yield production during dry season 2005-2006

(a)

The effects of different cultural practices on Lablab bean total dry biomass and seed yield production during dry season 2006-2007

(b)
Relationships between total dry biomass production and cumulative water use of lablab bean during the 3 experimental years.
Water use efficiency of lablab bean during the 3 experimental years

Water use efficiency based on dry matter production of lablab bean under different cultural practices during late rainy - mid dry season in 2004-05, Borkrai, Pangmapa, Mae Hong Son (Sites A and B)

Water use efficiency based on dry matter production of lablab bean under different cultural practices during late rainy - mid dry season in 2005-06, Borkrai, Pangmapa, Mae Hong Son (Sites A and B)

Water use efficiency based on dry matter production of lablab bean under different cultural practices during late rainy - mid dry season in 2006-07, Borkrai, Pangmapa, Mae Hong Son (Sites A and B)
Water use efficiency of corn yields during rainy season in 2004, 2005 and 2006, Borkrai, Pangmapa, Mae Hong Son (Sites A and B)

Water use efficiency of corn yields (kg ha\(^{-1}\) mm\(^{-1}\))

- CP
- CF-AL
- CF-M-AL
- CP-AL-VG

Site A:
- 2004-05: 6.07, 8.62, 10.14
- 2005-06: 6.72, 8.77, 8.84
- 2006-07: 7.90, 8.60, 9.32

Site B:
- 2004-05: 4.10, 5.81, 6.27
- 2005-06: 6.22, 6.69, 7.61
- 2006-07: 8.15, 7.26, 7.85

Water use efficiency of lablab bean on yield production during the 3 experimental years

Water use efficiency of lablab bean (kg ha\(^{-1}\) mm\(^{-1}\))

- CP-DM
- CF-AL-DM
- CF-M-AL-DM
- CP-AL-VG-DM
- CP-Seed
- CF-AL-Seed
- CF-M-AL-Seed
- CP-AL-VG-Seed

Site A:
- 2004-05: 0.00, 2.00, 4.00
- 2005-06: 6.20, 8.47, 10.00

Site B:
- 2004-05: 3.34, 5.95, 7.44
- 2005-06: 6.17, 7.07, 8.60
- 2006-07: 9.36, 12.63, 12.86
Expected income from the annual crops and hedgerow fruit yields averaged from the 3 experimental years, Site A & B,

1) From the best cultural practice (CF-M-AL).

<table>
<thead>
<tr>
<th>Annual crops and Fruit trees</th>
<th>Yields</th>
<th>Expected Income</th>
<th>Expected Income</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Market price</td>
<td>Total (baht)</td>
</tr>
<tr>
<td>Sweet corn (kg /Rai)</td>
<td>908</td>
<td>5 (Baht/kg)</td>
<td>4,540</td>
</tr>
<tr>
<td>Upland Rice (kg /Rai)</td>
<td>320</td>
<td>8 (Baht/kg)</td>
<td>2,500</td>
</tr>
<tr>
<td>Lablab Bean (kg /Rai)</td>
<td>187</td>
<td>20 (Baht/kg)</td>
<td>3,740</td>
</tr>
<tr>
<td>Mangoes (kg /Rai)</td>
<td>215</td>
<td>15 (Baht/kg)</td>
<td>3,200</td>
</tr>
<tr>
<td>Lemon (fruit /Rai)</td>
<td>640</td>
<td>2 (Baht/fruit)</td>
<td>1,280</td>
</tr>
<tr>
<td>Jujube (kg /Rai)</td>
<td>No yield</td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>

Average Income per year 15,260
Expected income from the annual crops and hedgerow fruit yields averaged from the 3 experimental years, Site A & B,

2) From the worst cultural practice (CP).

<table>
<thead>
<tr>
<th>Annual crops only</th>
<th>Yields</th>
<th>Expected Income</th>
<th>Expected Income</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Market price</td>
<td>Total (baht)</td>
</tr>
<tr>
<td>Sweet corn (kg /Rai)</td>
<td>638</td>
<td>5 (Baht/kg)</td>
<td>3,190</td>
</tr>
<tr>
<td>Upland Rice (kg /Rai)</td>
<td>320</td>
<td>8 (Baht/kg)</td>
<td>2,500</td>
</tr>
<tr>
<td>Lablab Bean (kg /Rai)</td>
<td>96</td>
<td>20 (Baht/kg)</td>
<td>1,920</td>
</tr>
</tbody>
</table>

Average Income per year    | 7,610  |

Capital investment for the 1st year | 5,647  |
Capital investment for the 2nd year | 4,895  |
Costs of benefit return after the third year experiment from CP plot was 988 US$/ha and from CF-M-AL plot was 1,767 or 2,394 US$/ha, including or excluding costs of fruit tree cultivars and imperata grass panel respectively. This results indicated that the best strategy to develop a sustainable highland crop production appear to be composite systems, consisting of contour furrow cultivation with mulching and alley cropping with hedgerows of mixed fruit trees plus leguminous ground cover crops. The advantages of multiple crop productivity may lead to broadly adoption and applications of this composite technique to build up the sustainability of highland rainfed agriculture.

Hydrophillic polymers was applied too late, there was no rain at all after polymer application, there was no positive effect of polymer application.
The results indicated that contour furrow cultivation with mulching in alley cropping (CF-M-AL) was the most effective whilst conventional contour planting (CP) was the worst cultural practice to conserve soil and water compared to CF-AL or CP-AL-VG.

These were caused by mulching in the furrow and the furrow cultivation, to harvest rain water, including the hedgerow effect on reducing cascaded water down the slope, giving decreased amounts of runoff and soil loss, increased soil water storages and water use efficiency, leading to increasing crop productivity.

Upland rice after maize was not completely developed and failed to give yield due to late sowing date in the 1st year and pest invasion problems during the last 2 years.
Costs of benefit return indicated that the best strategy to develop a sustainable highland crop production appears to be composite systems, consisting of contour furrow cultivation with mulching and alley cropping with hedgerows of mixed fruit trees plus leguminous ground cover crops (CF-M-AL). The advantages of multiple crop productivity may lead to broadly adoption and applications of this composite technique to build up the sustainability of highland rainfed agriculture.
The plots were used for training in Sustainable Hill Farming System to the farmers during October 2006.

The success of building a sustainable hill farming system need a well understanding of the highlanders to have a sense of environmental service, the right scientific knowledge and high costs of benefit return.
Grateful Acknowledgement is made to “NRCT and DFG.” For Providing Financial Support for This Project.

Thank you for your attention