Agroforestry and Sustainable Vegetable Production in Southeast Asian Watersheds

Northern Virginia
Virginia Tech Center
September 1, 2009
Strong Partnership
Strong Partnership
Outline

1. Problem Statement
2. Objectives
3. Promising Results
4. Questions and Discussions
Problem Statement

Communities in many forest and vegetable producing watersheds in Southeast Asia are suffering from poverty, and forest, soil and water resources degradation

Lantapan, Philippines
May 2007
Outline

1. Problem Statement

2. Objectives
   - Physical and Biological Sciences (first one)
   - Social Sciences (five others)
TMPEGS Technology ‘complementarity’
Marriage

Nineteen years this December

Iornamyluv
Agustin Mercado ‘developed the hypothesis’
The World Agroforestry Centre

Manuel Palada
The World Vegetable Centre
Technologies enhancing the marriage

North Carolina Agricultural and Technical State University
Technologies enhancing the marriage
Vegetable-Tree
VT
Complementarity
VIDIN - Technologies

V - Vegetable-Agroforestry
I - Indigenous Vegetables
D - Drip Irrigation
I - Integrated Pest Management
N - No-Tillage
VIDIN - Technologies

V - Vegetable-Agroforestry
I – Indigenous Vegetables
D – Drip Irrigation
I - Integrated Pest Management
N – No-Tillage
Vegetable Agroforestry

Vegetable-Tree VT

Complementarity

Vietnam
Vietnam

• Binh Phouc Province
• Watershed drains in Ho Chi Minh City (Saigon)
Vietnam

Cashew-Cashew-Cashew
In Bin Phouc Province
Can vegetables thrive under Cashew-trees that there is reasonable yield?
• Vegetables for home gardens
• Savings with their vegetable purchases
Vegetable Yield Under Cashew
Researcher Managed
(8 vegetables – replicated 3 times)

- Extension Center at Binh Phuoc Province
  - Amaranth
  - kangkong
  - okra
  - bitter gourd
  - French bean
  - eggplant
  - Tomato
  - Kangkong
Vietnam - Cashew

Three Treatments
Vietnam - Cashew

Low light
‘in between cashew trees’
Vietnam - Cashew

Medium light
‘in between cashew rows’
Vietnam: Cashew - Vegetables

Full light or no shade
Vietnam: Cashew - Vegetables

Average yield of cashew trees located between two vegetable rows was recorded to be 17% more than average yield without vegetables planted.

Medium light
‘in between cashew rows’
Vietnam: Cashew - Vegetables
Farmer Managed – 3 replications

Done during:
– Wet season
– Dry season
Studies from June to Sept. 2008

Full Light
North Carolina Agricultural and Technical State University

Studies from June to Sept. 2008

Medium Light
Studies from June to Sept. 2008

Low light
Measured

- Number of leaf/plant
- Plant height
- Fresh weight
- Yield
Vegetables that were done in three different times

Kangkong
Amaranth
## Results for Kangkong

<table>
<thead>
<tr>
<th></th>
<th>Full light</th>
<th>Medium Light</th>
<th>Low light</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Experiment Station</strong></td>
<td>232&lt;sup&gt;a&lt;/sup&gt;</td>
<td>101&lt;sup&gt;b&lt;/sup&gt;</td>
<td>37&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Wet season</strong></td>
<td>100&lt;sup&gt;a&lt;/sup&gt;</td>
<td>90&lt;sup&gt;b&lt;/sup&gt;</td>
<td>86&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>(farmer)</td>
<td>89&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>96&lt;sup&gt;a&lt;/sup&gt;</td>
<td>73&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
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### Results for Kangkong

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</tr>
</tbody>
</table>

- Vegetables thrive and have reasonable yield
- Noticeable difference during the wet and dry seasons
## Results for Amaranth

<table>
<thead>
<tr>
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<th>Low Light</th>
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</thead>
<tbody>
<tr>
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<td>71&lt;sup&gt;b&lt;/sup&gt;</td>
<td>53&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Wet season (farmer)</td>
<td>101&lt;sup&gt;a&lt;/sup&gt;</td>
<td>83&lt;sup&gt;b&lt;/sup&gt;</td>
<td>60&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Dry season (farmer)</td>
<td>85&lt;sup&gt;b&lt;/sup&gt;</td>
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</table>
### Results for Amaranth

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</tr>
</tbody>
</table>

Vegetables thrive and have reasonable yield

Noticeable difference during the wet and dry seasons
Can vegetables thrive under tree-mixed system that there is reasonable yield?  
Yes
Indonesia

- Nanggung
- Watershed drains in Jakarta
Vegetable-Tree
VT
Complementarity
Indonesia
Tree system here is mixed

Inside the forest
Tree system here is mixed
Tree system here is mixed
Can vegetables thrive under tree-mixed system that there is reasonable yield?
Nested Design

- Experimental unit is one shade condition with vegetables replicated within the experimental shade conditions
- We can compare performance of vegetables within a shaded condition
Indonesia – mixed tree species
Indonesia – mixed tree species

| Medium light | Medium light |
Indonesia – mixed tree species
Kangkong (dry season in Indonesia)

![Bar chart showing production per plant under different light conditions.](chart.png)
Amaranth (Dry season in Indonesia)
<table>
<thead>
<tr>
<th>Vegetables</th>
<th>Medium light (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amaranth</td>
<td>280</td>
</tr>
<tr>
<td>Kangkong</td>
<td>190</td>
</tr>
<tr>
<td>Eggplant</td>
<td>171</td>
</tr>
<tr>
<td>Chili</td>
<td>109</td>
</tr>
<tr>
<td>Tomato</td>
<td>105</td>
</tr>
</tbody>
</table>

When compared with high light or no shade conditions.
Can vegetables thrive under tree-mixed system that there is reasonable yield?

Yes
Philippines
Philippines

- Lantapan, Bukidnon, Island of Mindanao
- Watershed drains in a hydroelectric power plant
Philippines
Vegetable-Tree
VT
Complementarity
Philippines
Can vegetables be more productive under tree-based systems?

Yes for unique vegetable tree combinations
Quantification of optimum tree spacing for vegetable production

Competition:
- Light
- Nutrient
- Water

Factors:
- Light competition
- Nutrient competition
- Water competition

Reduction of negative effects through silvicultural management

Vegetable (e.g., cabbage)
Interesting observation and he developed a hypothesis: Dr. Jun Mercado
Interesting observation and he developed a hypothesis: Dr. Jun Mercado Measured and Observed in Bukidnon, Philippines vegetable growth
Interesting observation and he developed a hypothesis
‘In terms of their distance from the trees, many vegetables have competition, complementary and neutral zones’
Eucalyptus-tomato interaction under boundary planting system

Yield is greater than without trees

Yield is less than without trees

Yield same as without trees
25 Indigenous Vegetables
5 commercial vegetables
Light, Nutrient and Moisture Interaction
Replicated three times
EXPERIMENT
What do you observe about the cassava?

- shade loving vegetable
- complementary vegetable
- shade loving vegetable
Maximizing vegetable yield with a tree bonus
Philippines
Philippines
Indigenous Vegetables
Indigenous Vegetables
Conventional Vegetables
# Medicinal Vegetable Trees

## Objectives:
1. To evaluate the performance of different tree vegetables and medicinal trees on farm
2. To ensure sustainable supply of nutritious vegetables and effective medicines for upland households at their backyards.

## Treatments:

<table>
<thead>
<tr>
<th>Tree Vegetables</th>
<th>Scientific Name</th>
<th>Medicinal Tree</th>
<th>Scientific Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Bago</td>
<td>Gnetum gnetum</td>
<td>1. Cinnamon</td>
<td>Cinnamomum verum</td>
</tr>
<tr>
<td>2. Katuray</td>
<td>Sesbania grandiflora</td>
<td>2. Kalingag</td>
<td>Cinnamomum mindanensis</td>
</tr>
<tr>
<td>4. Malunggay</td>
<td>Morinda oleifera</td>
<td>4. Lagundi</td>
<td>Vipex negundo</td>
</tr>
<tr>
<td>5. Chinese malunggay</td>
<td>Saurous androgynus</td>
<td>5. Teá</td>
<td>Camellia sinensis</td>
</tr>
</tbody>
</table>

**Experimental Design:** Trees are laid out in a randomized complete block design (RCBD) with 3 replications, and with farmer participatory evaluation.

**Duration:** 2 years

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North Carolina Agricultural and Technical State University
Medicinal Vegetable Trees

North Carolina Agricultural and Technical State University
Box 2. Analysis of tree-vegetable interaction in vegetable agroforestry system (VASCAP)
Box 2. Analysis of tree-vegetable interaction in vegetable agroforestry system (Wet season)

<table>
<thead>
<tr>
<th>Species</th>
<th>Variety</th>
<th>Yc</th>
<th>Ys</th>
<th>Yz</th>
<th>Dc</th>
<th>Ds</th>
<th>ARY</th>
<th>PY (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amaranthus</td>
<td>TOT 1800 Indonesia</td>
<td>2.3</td>
<td>de</td>
<td>5.0</td>
<td>d-f</td>
<td>3.5</td>
<td>de</td>
<td>6.6</td>
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<tr>
<td>Amaranthus</td>
<td>TOT 2272 Taiwan</td>
<td>5.5</td>
<td>c-e</td>
<td>12.7</td>
<td>b-e</td>
<td>7.3</td>
<td>c-e</td>
<td>4.1</td>
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<tr>
<td>Amaranthus</td>
<td>TOT 4141 Vietnam</td>
<td>6.4</td>
<td>b-d</td>
<td>13.9</td>
<td>b-e</td>
<td>10.9</td>
<td>b-d</td>
<td>5.5</td>
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<tr>
<td>Amaranthus</td>
<td>TOT 5474 Taiwan</td>
<td>4.6</td>
<td>c-e</td>
<td>9.9</td>
<td>c-f</td>
<td>7.1</td>
<td>c-e</td>
<td>4.7</td>
</tr>
<tr>
<td>Amaranthus</td>
<td>TOT 7278 Bangladesh</td>
<td>9.6</td>
<td>e</td>
<td>18.8</td>
<td>a-c</td>
<td>14.0</td>
<td>a-c</td>
<td>7.4</td>
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</tbody>
</table>

North Carolina Agricultural and Technical State University

Wet season
Box 2. Analysis of tree-vegetable interaction in vegetable agroforestry system (Jayatilaka et al., 1999).

<table>
<thead>
<tr>
<th>Variety</th>
<th>Yc</th>
<th>Ys</th>
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<th>Dc</th>
<th>Ds</th>
<th>ARY</th>
<th>FY</th>
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</thead>
<tbody>
<tr>
<td>Amaranthus</td>
<td>7.0</td>
<td>13.4</td>
<td>11.8</td>
<td>6.4</td>
<td>8.3</td>
<td>0.9</td>
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<tr>
<td>TOT 1800 Indonesia</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amaranthus</td>
<td>11.4</td>
<td>21.8</td>
<td>18.2</td>
<td>6.8</td>
<td>8.3</td>
<td>0.9</td>
<td>-7</td>
</tr>
<tr>
<td>Taiwan</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
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<tr>
<td>Amaranthus</td>
<td>6.3</td>
<td>13.6</td>
<td>9.4</td>
<td>6.6</td>
<td>7.9</td>
<td>1.1</td>
<td>10</td>
</tr>
<tr>
<td>Vietnam TOT 4141</td>
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<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Amaranthus</td>
<td>4.5</td>
<td>10.3</td>
<td>10.7</td>
<td>3.0</td>
<td>8.3</td>
<td>0.8</td>
<td>-17</td>
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<tr>
<td>Taiwan TOT 5474</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Amaranthus</td>
<td>11.2</td>
<td>15.4</td>
<td>14.1</td>
<td>4.2</td>
<td>10.4</td>
<td>1.0</td>
<td>0</td>
</tr>
<tr>
<td>Bangladesh</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Jute TOT 3504</td>
<td>8.9</td>
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<td>6.9</td>
<td>7.9</td>
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</table>

Dry season
Box 2. Analysis of tree-vegetable interaction in vegetable agroforestry system (SANHISIP) – competition, supplementarity, neutral.

Performance indices of 5 commercial vegetable species under tree based system.

Eucalyptus torillana as tree hedge. Lantapan, Bukidnon. Wet season 2007.

<table>
<thead>
<tr>
<th>Vegetables</th>
<th>Variety</th>
<th>Yc</th>
<th>Ys</th>
<th>Yz</th>
<th>Dc</th>
<th>Ds</th>
<th>ARY</th>
<th>PY (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinese cabbage</td>
<td>Blues</td>
<td>12.4</td>
<td>30.6</td>
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<td>3.6</td>
<td></td>
<td>11.4</td>
<td>1.4</td>
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<tr>
<td>Cabbage</td>
<td>Resest crown</td>
<td>8.9</td>
<td>16.0</td>
<td>12.0</td>
<td>4.6</td>
<td></td>
<td>8.2</td>
<td>1.1</td>
</tr>
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### Box 2. Analysis of tree-vegetable interaction in vegetable agroforestry system

[Diagram showing competition and supplementarity]

Performance indices of 5 commercial vegetable species under tree based system

Eucalyptus torillana as tree hedge. Lantapan, Bukidnon. Wet season 2007.

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<tr>
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<td>Resest crown</td>
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<td>16.0</td>
<td>12.0</td>
<td>4.6</td>
<td>8.2</td>
<td>1.1</td>
<td>13</td>
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</table>
### Box 2. Analysis of tree-vegetable interaction in vegetable agroforestry system (Wet season)

<table>
<thead>
<tr>
<th>Vegetables</th>
<th>Variety</th>
<th>Yc</th>
<th>Ys</th>
<th>Yz</th>
<th>Dc</th>
<th>Ds</th>
<th>ARY</th>
<th>PY (%)</th>
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</thead>
<tbody>
<tr>
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<td>WVCT-1</td>
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<td>11.1</td>
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<td>15.1</td>
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<td>2.7</td>
<td>4.6</td>
<td>11.4</td>
<td>1.2</td>
<td>20</td>
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<tr>
<td>Carrots</td>
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<td>1.0</td>
<td>1.9</td>
<td>1.3</td>
<td>1.8</td>
<td>6.3</td>
<td>1.4</td>
<td>37</td>
</tr>
</tbody>
</table>

**Wet season**
Box 2. Analysis of tree-vegetable interaction in vegetable agroforestry system (CVS).

Variations in competition and supplementarity zones.

<table>
<thead>
<tr>
<th>Vegetables</th>
<th>Competition</th>
<th>Supplementarity</th>
<th>Neutral</th>
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<tbody>
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<td>Chinese cabbage</td>
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<td>30.6 a</td>
<td>20.0 a</td>
</tr>
<tr>
<td>Cabbage</td>
<td>8.9 b</td>
<td>16.0 b</td>
<td>12.0 b</td>
</tr>
<tr>
<td>Tomato</td>
<td>5.8 c</td>
<td>11.1 c</td>
<td>7.7 bc</td>
</tr>
<tr>
<td>Bellpepper</td>
<td>2.2 d</td>
<td>3.6 d</td>
<td>2.7 d</td>
</tr>
<tr>
<td>Carrots</td>
<td>1.0 d</td>
<td>1.9 d</td>
<td>1.3 d</td>
</tr>
</tbody>
</table>

Supplementary notes: Dc, Ds, and PY (%).
Indigenous vegetables

Indonesia
• Katuk
• Terrubuk & 4 more

Philippines
• Malunggay and 15 more

Vietnam
• Cu Nang
Experiment with Cu Nang planted in 7-year old rubber plantation
Experiment with Cu Nang planted in 4-year old rubber plantation

Harvesting of Cu Nang
Drip Irrigation

• Vietnam home gardens – there was increase yield
• Indonesia – there was no difference got rained out
• Philippines – let me elaborate a bit
Drip irrigation design
Drip irrigation

Victor Ella’s poster
Recommendation of design guidelines for steep slopes
EFFECT OF HYDRAULIC HEAD AND SLOPE ON WATER DISTRIBUTION UNIFORMITY OF A LOW-COST Drip Irrigation System

V. B. Ella, M. R. Reyes, R. Yoder

ABSTRACT. Assessment of the effect of topography and operating heads on the water distribution uniformity in drip irrigation systems is important in irrigation water management and could serve as the basis for optimizing water use efficiency and crop productivity. This study was carried out to evaluate the effect of hydraulic head and slope on the water distribution uniformity of a low-cost drip irrigation system developed by the International Development Enterprise (IDE), a non-profit organization dedicated to ending poverty in the developing world. The drip system was tested in the laboratory for water distribution uniformity under varying system heads and slope conditions. A sub-main of 10 m with adjustable slope and lateral-sub-holders of 10 m were fabricated to enable slope variations during laboratory experiments. The drip system was operated at specified operating heads of 1.0, 2.0, and 3.0 m for sub-main slopes of 0%, 10%, 20%, 30%, 40%, and 50% and 0% slope for the laterals. The discharge in each emitter was monitored for each chosen slope through direct volumetric measurements. The water distribution uniformity was then evaluated using the Christiansen’s method and Merriam and Keller’s method. Mathematical relationships were developed to characterize the effect of slope and head on uniformity coefficients. We found that the coefficient of uniformity (CU) and the distribution uniformity (DU) generally increase with increasing heads and decrease with increasing slope. The coefficient of uniformity generally follows a linear relationship with either head or slope. The CU and DU decrease substantially at submain slopes greater than 30%. For a level surface, a head differential of 0.5 m does not cause significant change in either CU or DU. For all slopes tested, we found that a head of 3.0 m with respect to the junction of the upstream lateral may be considered to be recommendable from both hydraulic and practical standpoint. On the basis of the results, appropriate recommendations were formulated to minimize non-uniformity of water distribution under field conditions in sloping drip-irrigated lands.

Keywords: Drip irrigation, Coefficient of uniformity, Distribution uniformity, Christiansen’s method, Merriam and Keller’s method.

Drip irrigation technology has been in existence for many years. Its potential benefits and advantages over other irrigation methods are well-known. It is applicable for wide ranging types of crops, soil, topography, and climate. It offers special agronomic, agrochemical, and economical advantages for efficient use of water and land (Keller, 2002). The use of drip irrigation for dry season cropping and for supplemental irrigation during periods with unreliable rainfall occurrences could increase cropping intensity and sustainability of agricultural production and consequently increase the income of farmers. However, one of the major limitations of the conventional drip systems is the prohibitive initial cost. The evolution of low-cost drip irrigation systems may consequently pave the way for greater adoption of this technology by poor farmers and contribute to efforts in alleviating poverty in agricultural communities in developing countries.

The most cost-effective of the drip irrigation technologies that have evolved include the drip kit for small plots developed by the International Development Enterprise (IDE), a non-profit organization dedicated to ending poverty in the developing world. The drip system basically consists of microlines serving as emitters inserted into plastic tube (layflat tape when empty) laterals connected to polyethylene sub-main pipes which in turn can be connected to a drum or water reservoir (fig. 1). The manufacturing cost for this type of drip system is relatively low making the whole package more cost-effective than conventional drip systems. The system can be opened by elevating the drum reservoir at appreciable head thereby eliminating the need for a pumping unit and consequently reducing the cost of operation. The typical operating head of the IDE drip kit ranges from 1.0 to 3.0 m (Keller, 2002).

The IDE drip irrigation technology has gained popularity in developing countries not only because of its low cost but also of its simplicity in design and installation.
Table 3. Coefficient of uniformity and emission uniformity at various heads at 0% slope.

<table>
<thead>
<tr>
<th>Head (m)</th>
<th>Mean Coefficient of Uniformity, CU (%)</th>
<th>Mean Distribution Uniformity, DU (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>64.8</td>
<td>45.0</td>
</tr>
<tr>
<td>1.5</td>
<td>69.8</td>
<td>50.4</td>
</tr>
<tr>
<td>2.0</td>
<td>69.9</td>
<td>51.0</td>
</tr>
<tr>
<td>2.5</td>
<td>64.6</td>
<td>43.8</td>
</tr>
<tr>
<td>3.0</td>
<td>71.0</td>
<td>53.5</td>
</tr>
<tr>
<td>3.5</td>
<td>70.4</td>
<td>50.0</td>
</tr>
</tbody>
</table>
Figure 4. Effect of head on coefficient of uniformity at various slopes.
# Cabbage

<table>
<thead>
<tr>
<th>Farm</th>
<th>Crop Yield (kg/m²)</th>
<th>With Drip</th>
<th>Without Drip</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binahon</td>
<td>3.59</td>
<td>3.39</td>
<td></td>
</tr>
<tr>
<td>Lucbo</td>
<td>4.5</td>
<td>2.42</td>
<td></td>
</tr>
<tr>
<td>Quidlat</td>
<td>5.26</td>
<td>4.32</td>
<td></td>
</tr>
<tr>
<td>Tabliso</td>
<td>3.12</td>
<td>1.96</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>4.12</td>
<td>3.02</td>
<td></td>
</tr>
</tbody>
</table>
## Chinese cabbage

<table>
<thead>
<tr>
<th>Farm</th>
<th>Crop Yield (kg/m²)</th>
<th>With Drip</th>
<th>Without Drip</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binahon</td>
<td>4.95</td>
<td>3.72</td>
<td></td>
</tr>
<tr>
<td>Lucbo</td>
<td>4.13</td>
<td>3.24</td>
<td></td>
</tr>
<tr>
<td>Quidlat</td>
<td>6.03</td>
<td>3.27</td>
<td></td>
</tr>
<tr>
<td>Tabliso</td>
<td>1.13</td>
<td>0.86</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>4.06</td>
<td>2.77</td>
<td></td>
</tr>
</tbody>
</table>
## Tomatoes

<table>
<thead>
<tr>
<th>Farm</th>
<th>Crop Yield (kg/m²)</th>
<th>With Drip</th>
<th>Without Drip</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Binahon</td>
<td>7.17</td>
<td>5.72</td>
<td></td>
</tr>
<tr>
<td>Ladera</td>
<td>1.08</td>
<td>0.76</td>
<td></td>
</tr>
<tr>
<td>Lucbo</td>
<td>3.10</td>
<td>2.58</td>
<td></td>
</tr>
<tr>
<td>Padla</td>
<td>4.07</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>3.86</td>
<td>3.14</td>
<td></td>
</tr>
</tbody>
</table>
## Pepper

<table>
<thead>
<tr>
<th>Farm</th>
<th>Crop Yield (kg/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>With Drip</td>
</tr>
<tr>
<td>Binahon</td>
<td>2.19</td>
</tr>
<tr>
<td>Lucbo</td>
<td>0.93</td>
</tr>
<tr>
<td>Quidlat</td>
<td>0.63</td>
</tr>
<tr>
<td>Tabliso</td>
<td>0.79</td>
</tr>
<tr>
<td>Average</td>
<td>1.14</td>
</tr>
</tbody>
</table>
## All Crops

<table>
<thead>
<tr>
<th>Crop</th>
<th>Average Crop Yield (kg/m²)</th>
<th>With Drip</th>
<th>Without Drip</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cabbage</td>
<td>4.12</td>
<td>3.02</td>
<td></td>
</tr>
<tr>
<td>Chinese cabbage</td>
<td>4.06</td>
<td>2.77</td>
<td></td>
</tr>
<tr>
<td>Tomato</td>
<td>3.86</td>
<td>3.14</td>
<td></td>
</tr>
<tr>
<td>Bell pepper</td>
<td>1.14</td>
<td>0.76</td>
<td></td>
</tr>
</tbody>
</table>
Summary of Findings from Field Experiments

- Higher crop yield under drip irrigated crops than rainfed crops (with all other production inputs the same for both treatments)
- Relatively larger size of produce under drip irrigated over rainfed
- Higher plant height under drip than under rainfed
Comparison of means using t-tests at 5% level of significance indicate that the crop yield is significantly different under drip irrigated and rainfed areas for Chinese cabbage but not significantly different for cabbage, tomato and bell pepper.
CONCLUSION

- The low-cost drip irrigation technology is highly adaptable to VAF systems in the Philippines.
- The IDE low-cost drip kit has a great potential for adoption in Philippine upland watersheds for sustainable vegetable production.
- The low-cost drip irrigation system can potentially increase crop yield and farmer’s income and alleviate poverty.
Integrated Pest Management
No-Tillage
Cover crop (perennial peanut Indonesia)
Cover crop (perennial peanut, Philippines)
Arachis Pintoi (Vietnam)

Biter gourd planted with and without Arachis Pintoi as a cover crop.
Reduced tillage prototype
Reduced tillage prototype
Motor driven
Weakness

No inputs from community
TMPEGS

Marketing

'value chain'
Philippines

Farmers requested a survey:

- Chinese cabbage
- Cabbage
- Carrots
- Tomato
- Bell pepper
Vietnam

Found that vegetables no potential to be marketed hence vegetables for home garden

Emphasize the cacao-cashew
Indonesia – World Vegetable Center

• Found Market of katuk
TPMEGS

Policy

‘incentives’
Municipality had passed an Incentive based policy on conservation agriculture
Environmental & economic-social impact

‘it works’
The problem: Intensified cashew production, increased use of pesticides caused negative externalities.

Research questions:
(1) How current pesticide use endangers farmers’ health;
(2) Whether the marginal gain from reduced pesticide use could surpass the marginal loss in cashew productivity and farmers’ benefits.
Objective:
This study was conducted to determine the impact of pesticides on cashew yield and estimate the health costs caused to farmers by pesticide use.

Methodology:
The Cobb-Douglas function was employed to examine pesticide productivity on cashew production.
A health cost model was applied to quantify farmer’s health cost in relation to their use of pesticides.
Data from the survey of 80 randomly-selected cashew farmers for year 2006, 2007 and 2008.
Methodology (continue)

Cobb-Douglas production function in log-linear form:

\[ \ln Y = \alpha_0 A + \alpha_1 \ln \text{Lab} + \alpha_2 \ln \text{DoseH} + \alpha_3 \ln \text{DoseI} \\
+ \alpha_4 \ln \text{NPK} + \alpha_5 \ln \text{Density} + \alpha_6 \ln \text{Age} \\
+ \alpha_7 \text{Year2006} + \alpha_8 \text{Year2007} + \alpha_9 \text{EroSoil} \]

where:

\( \ln Y \) = natural logarithm of yield  \\
\( \ln \text{Lab} \) = natural logarithm of labor  \\
\( \ln \text{DoseH} \) = natural logarithm of total dosage of all herbicides  \\
\( \ln \text{DoseI} \) = natural logarithm of total dosage of all insecticides  \\
\( \ln \text{NPK} \) = natural logarithm of total N, P, K fertilizers  \\
\( \ln \text{Density} \) = natural logarithm of tree density  \\
\( \ln \text{Age} \) = natural logarithm of tree age  \\
\( \text{Year2006} \) = 1 if year 2006 and = 0 if otherwise  \\
\( \text{Year2007} \) = 1 if year 2007 and = 0 if otherwise  \\
\( \text{EroSoil} \) = 1 if eroded soil and = 0 if otherwise
Methodology (continue)

Health cost function:

\[ \ln HC = \beta_0 \ln A + \beta_1 \ln \text{TODOSE} + \beta_2 \ln \text{NA} + \beta_3 \ln \text{AGE} + \]
\[ + \beta_4 \ln \text{WTHT} + \beta_5 \text{SMOKE} + \beta_6 \text{DRINK} \]

where:
\[ \ln HC = \] log of health costs of farmers
\[ \ln \text{TODOSE} = \] log of total dosage of all pesticides used
\[ \ln \text{NA} = \] log of number of applications of pesticides/ year
\[ \ln \text{AGE} = \] log of farmers’ age
\[ \ln \text{WTHT} = \] log of farmers’ weight by height
\[ \text{SMOKE} = \] dummy for smoking
\[ \text{DRINK} = \] dummy for drinking alcohol
Estimated production function for cashew

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Coefficient</th>
<th>Standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>6.469</td>
<td>0.342</td>
</tr>
<tr>
<td>Log of labor use</td>
<td>0.022</td>
<td>0.030</td>
</tr>
<tr>
<td>Log of total herbicides</td>
<td>0.039</td>
<td>0.015**</td>
</tr>
<tr>
<td>Log of total insecticides</td>
<td>-0.001</td>
<td>0.017</td>
</tr>
<tr>
<td>Log of total NPK</td>
<td>0.025</td>
<td>0.009***</td>
</tr>
<tr>
<td>Log of number of tree</td>
<td>0.107</td>
<td>0.054**</td>
</tr>
<tr>
<td>Log of tree age</td>
<td>0.025</td>
<td>0.057</td>
</tr>
<tr>
<td>Dummy for year 2006</td>
<td>0.070</td>
<td>0.057</td>
</tr>
<tr>
<td>Dummy for year 2007</td>
<td>0.221</td>
<td>0.058***</td>
</tr>
<tr>
<td>Dummy for eroded soil</td>
<td>-0.511</td>
<td>0.068***</td>
</tr>
<tr>
<td>Nr of observations</td>
<td>240</td>
<td></td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.35</td>
<td></td>
</tr>
</tbody>
</table>

***, **, * Statistically significant at the 1%, 5%, and 10%.
# Estimated health cost function

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Coefficient</th>
<th>Standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>12.772</td>
<td>1.334</td>
</tr>
<tr>
<td>Log of total dosage</td>
<td>0.161</td>
<td>0.060***</td>
</tr>
<tr>
<td>Log of number of applications</td>
<td>0.193</td>
<td>0.091**</td>
</tr>
<tr>
<td>Log of age</td>
<td>0.196</td>
<td>0.098*</td>
</tr>
<tr>
<td>Log of weight by height</td>
<td>-0.643</td>
<td>0.376*</td>
</tr>
<tr>
<td>Dummy for smoking</td>
<td>0.222</td>
<td>0.056***</td>
</tr>
<tr>
<td>Dummy for drinking</td>
<td>0.232</td>
<td>0.060***</td>
</tr>
<tr>
<td>Nr of observations</td>
<td>72</td>
<td></td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.63</td>
<td></td>
</tr>
</tbody>
</table>

**Statistically significant at the 1%, 5%, and 10%.

Pesticide dose and number of pesticides use significantly influence farmer’s health costs.
Findings

- Preventive spraying is the main pest management method among cashew farmers.
- Insecticides however do not have significant impact on cashew yield.
- Total pesticide dose and number of times the farmers had contact with pesticides significantly influence their health costs.

Implication:

Convince farmers to reduce pesticide use on cashew will help them increase production efficiency through reducing production and health costs.
SWAT
Simulating Hydrologic Effects of Land Use in Selected Upland Watersheds in the Philippines Using the SWAT model

N. R. Alibuyog, V. B. Ella, M. R. Reyes, R. Srinivasan, C. Heatwole and T. Dillaha

2009 Annual International ASABE Meeting
Reno, Nevada
June 24-26, 2009
Second International Soil and Water Assessment Tool Conference, Ho Chi Minh City (old name Saigon), Vietnam, January 4-7, 2011
Paper has been published


In review International Agricultural Engineering Journal.

North Carolina Agricultural and Technical State University
Conversion of native forest to agricultural lands is very common in the Philippines. Driven by the growing population and increasing demand for food as well as the short-term benefit derived from productive forest lands.
Manupali river watershed is a typical example that has undergone land conversion and is presently undergoing environmental degradation and causing off-site pollution and sedimentation of rivers, reservoirs and hydropower dams.
Objectives

- To determine the effects of various land use patterns on runoff and sediment yield in selected sub-watersheds of the Manupali river using the SWAT model.

- Specifically, it aimed to parameterize, calibrate and use the SWAT model in simulating the effects of various land use patterns on runoff and sediment yields.
The Study Site

- Topography is rolling to hilly
- Elevation ranges from 900 m to 2000 m (more than a mile high or about 6500 ft)
- Soils is predominantly clayey
- Rainfall is evenly distributed – 2347 mm annually (Greensboro, NC, rainfall is about 1000 mm)
- Mean Temp ranges from 17°C to 28°C
- Relative humidity ranges from 86% to 98%
Physically-based not well-defined parameters (e.g. CN2, C factor, infiltration, SPCON, and SPEXP) were adjusted to provide better fit between the observed and simulated runoff volume and sediment yields.
Prediction of runoff volume

North Carolina Agricultural and Technical State University
Simulated and measured runoff volumes matched well with $R^2$ ranging from 0.76 to 0.83.

SWAT model showed enough adequacy to simulate runoff volumes (NSE values ranges from 0.87 to 0.90).

The hydrologic processes were modelled realistically and can be extended to simulate hydrologic processes at various land use change scenarios.
Prediction of sediment yield

North Carolina Agricultural and Technical State University
Except for Upper Kiluya, simulated and measured sediment yield showed good agreement with $R^2$ ranging from 0.50 to 0.80.

SWAT model showed adequacy to predict the temporal distribution of sediment yield with NSE values ranging from 0.55 to 0.80.

Despite the differences, the overall adequacy of the model indicates its usefulness to predict the effects of land use changes in the area.
To assess the effects of land conversion in the study area, the calibrated model was run to simulate various scenarios of land use changes on

- runoff volumes
- sediment yields
- baseflows
TMPEGS

Gender

‘equity’
TMPEGS

Scaling-up

‘contagiousness’
Questions