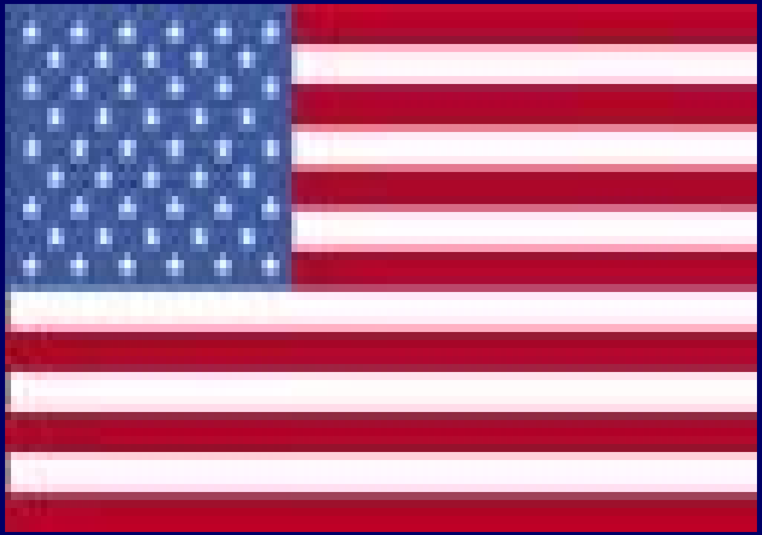
Sustainable Agricultural and
Natural Resources Management
Collaborative Research Support Program

Agroforestry and Sustainable Vegetable Production in Southeast Asian Watersheds

Northern Virginia
Virginia Tech Center
September 1, 2009

North Carolina Agricultural
and Technical State University

Strong Partnership



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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. <u>Objectives</u>

- <u>Physical and Biological Sciences (first one)</u>
- <u>Social Sciences (five others)</u>

TMPEGS

Technology

'complementarity'

Marriage

Nineteen years this December lornamyluv

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World Vegetable Centre

World Agroforestry Centre

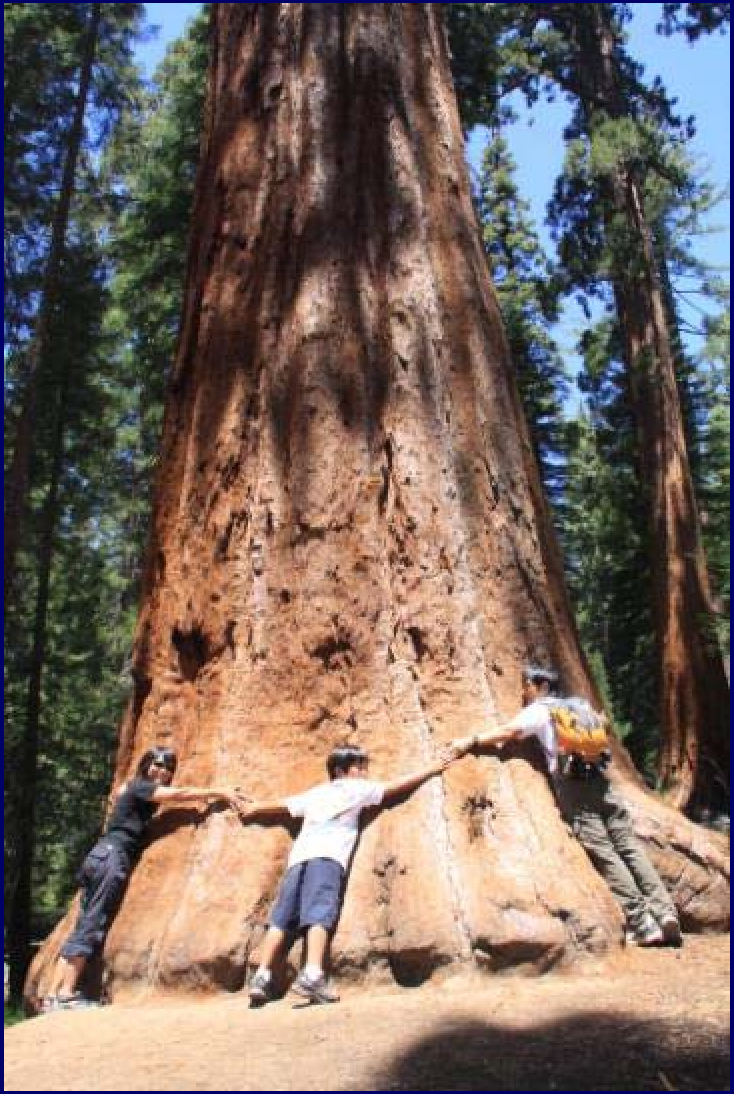
TRANSFORMING LIVES AND LANDSCAPES

Agustin Mercado
'developed the hypothesis'
The World Agroforestry Centre

Manuel Palada
The World Vegetable Centre

Technologies enhancing the marriage

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

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Vegetable Agroforestry

Vegetable-Tree

VT

Complementarity

Vietnam

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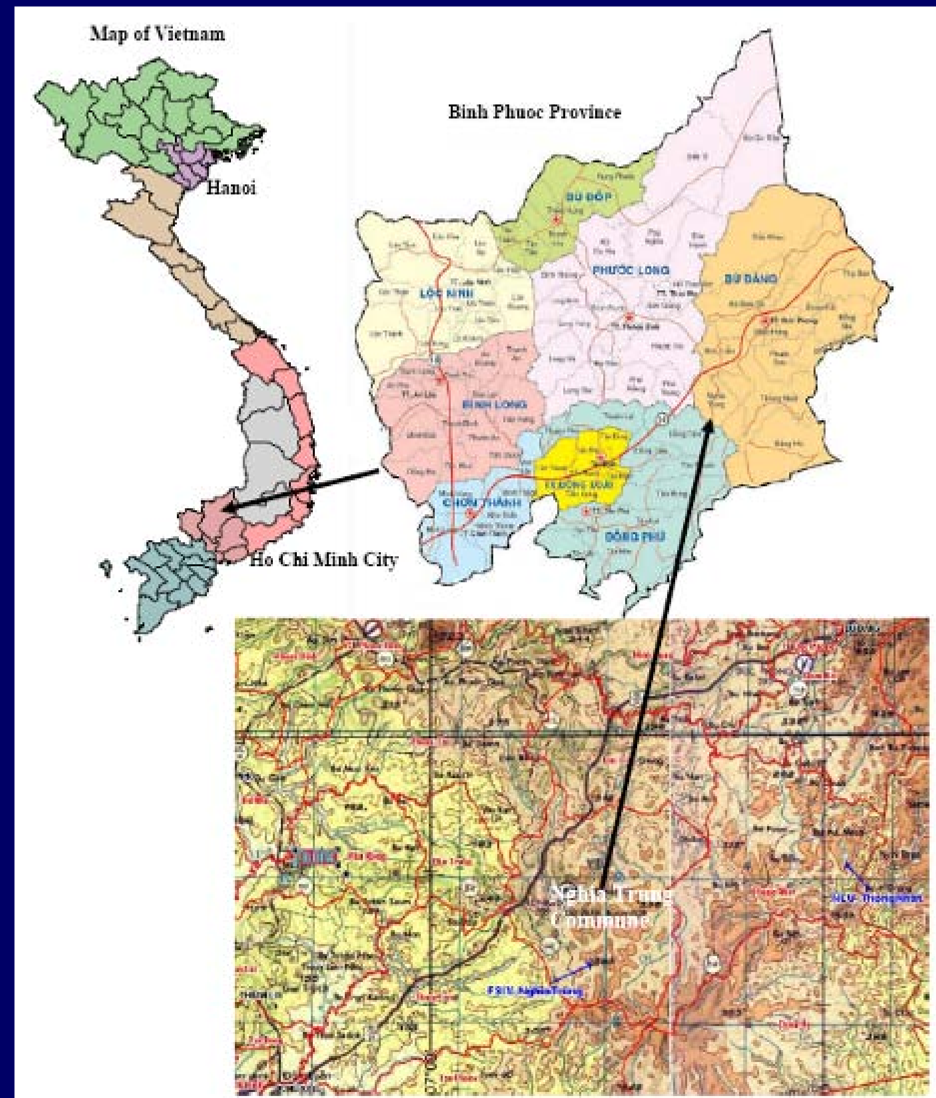
Vietnam

- **Binh Phouc Province**
- **Watershed drains in Ho Chi Minh City (Saigon)**



Vietnam

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Can vegetables thrive under Cashew-trees that there is reasonable yield?

- ***Vegetables for home gardens***
- ***Savings with their vegetable purchases***

Vegetable Yield Under Cashew

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Researcher Managed (8 vegetables – replicated 3 times)

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

Vietnam - Cashew

Vietnam - Cashew

Vietnam - Cashew

Vietnam: Cashew - Vegetables

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

Vietnam: Cashew - Vegetables

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Farmer Managed – 3 replications

Done during:

- Wet season
- Dry season

Studies from June to Sept. 2008

Studies from June to Sept. 2008

Medium Light

Studies from June to Sept. 2008

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Measured

- Number of leaf/plant
- Plant height
- Fresh weight
- Yield

Vegetables that were done in three different times

Kangkong

Amaranth

Results for Kangkong

Kangkong Kg/100m^2	Full light	Medium Light	Low light
Experiment Station	232^a	101^b	37^b
Wet season (farmer)	100^a	90^b	86^c
Dry season (farmer)	89^{ab}	96^a	73^c

Results for Kangkong

Kangkong Kg/100m^2	Full light	Medium Light	Low light
Experiment Station	232^a	101^b	37^b
Wet season (farmer)	100^a	90^b	86^c
Dry season (farmer)	89^{ab}	96^a	73^c

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- Vegetables thrive and have reasonable yield
- Noticeable difference during the wet and dry seasons

Results for Amaranth

Amaranth	Full light	Medium Light	Low light
Experiment Station	124[a]	71[b]	53[b]
Wet season (farmer)	101[a]	83[b]	60[c]
Dry season (farmer)	85[b]	101[a]	64[c]

Results for Amaranth

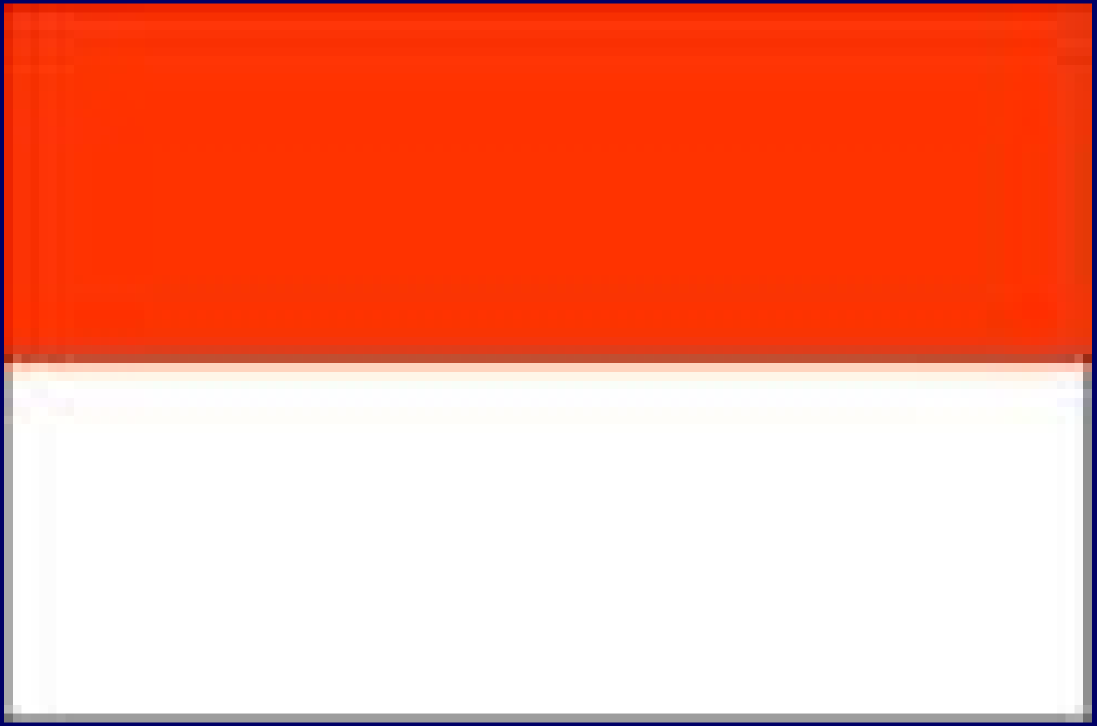
Amaranth	Full light	Medium Light	Low light
Experiment Station	124[a]	71[b]	53[b]
Wet season (farmer)	101[a]	83[b]	60[c]
Dry season (farmer)	85[b]	101[a]	64[c]

- 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



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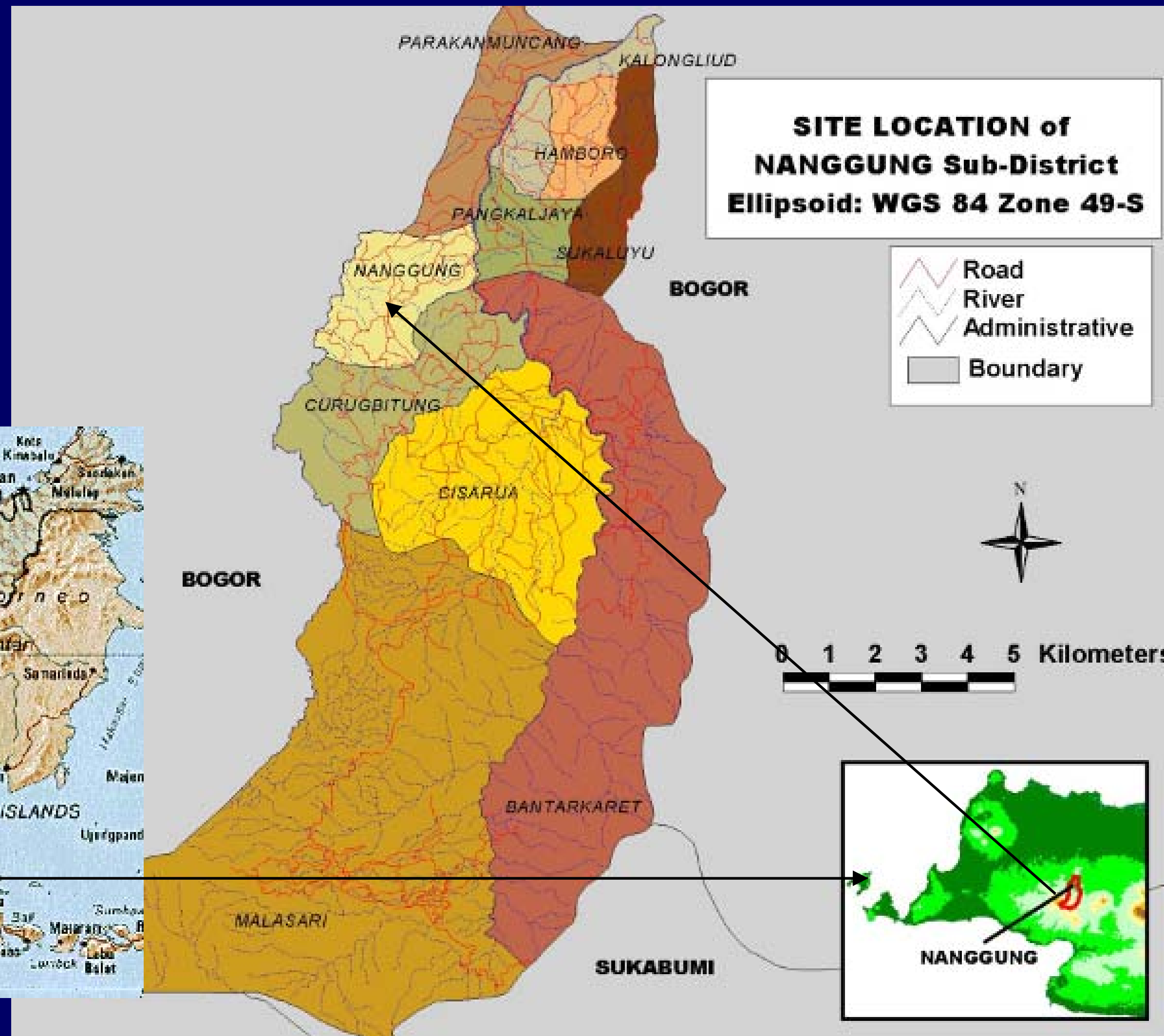
Indonesia

- Nanggung
- Watershed drains in Jakarta



Vegetable-Tree
VT
Complementarity
Indonesia

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Tree system here is mixed

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

Low light

Low light

Indonesia – mixed tree species

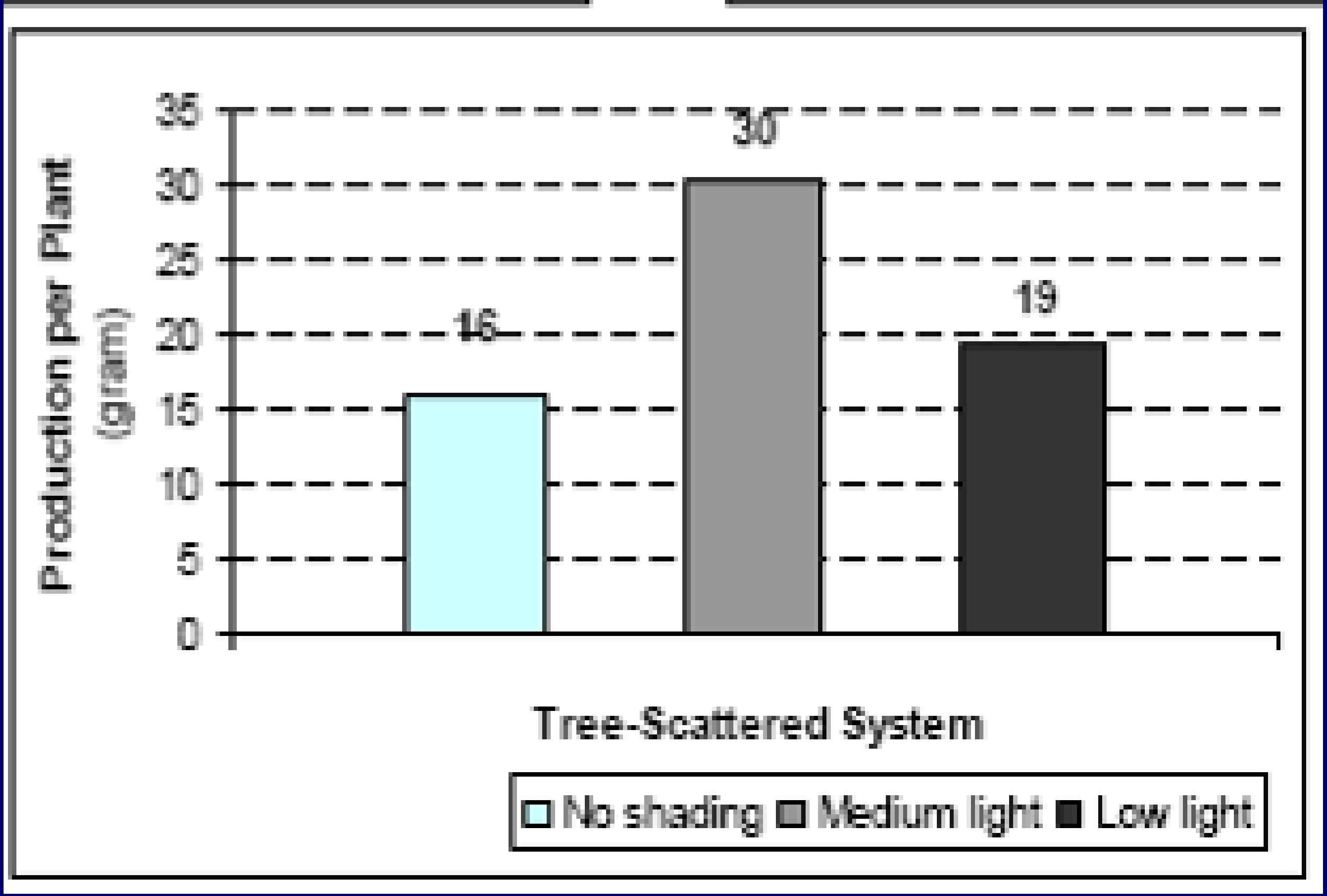

Medium light


Medium light

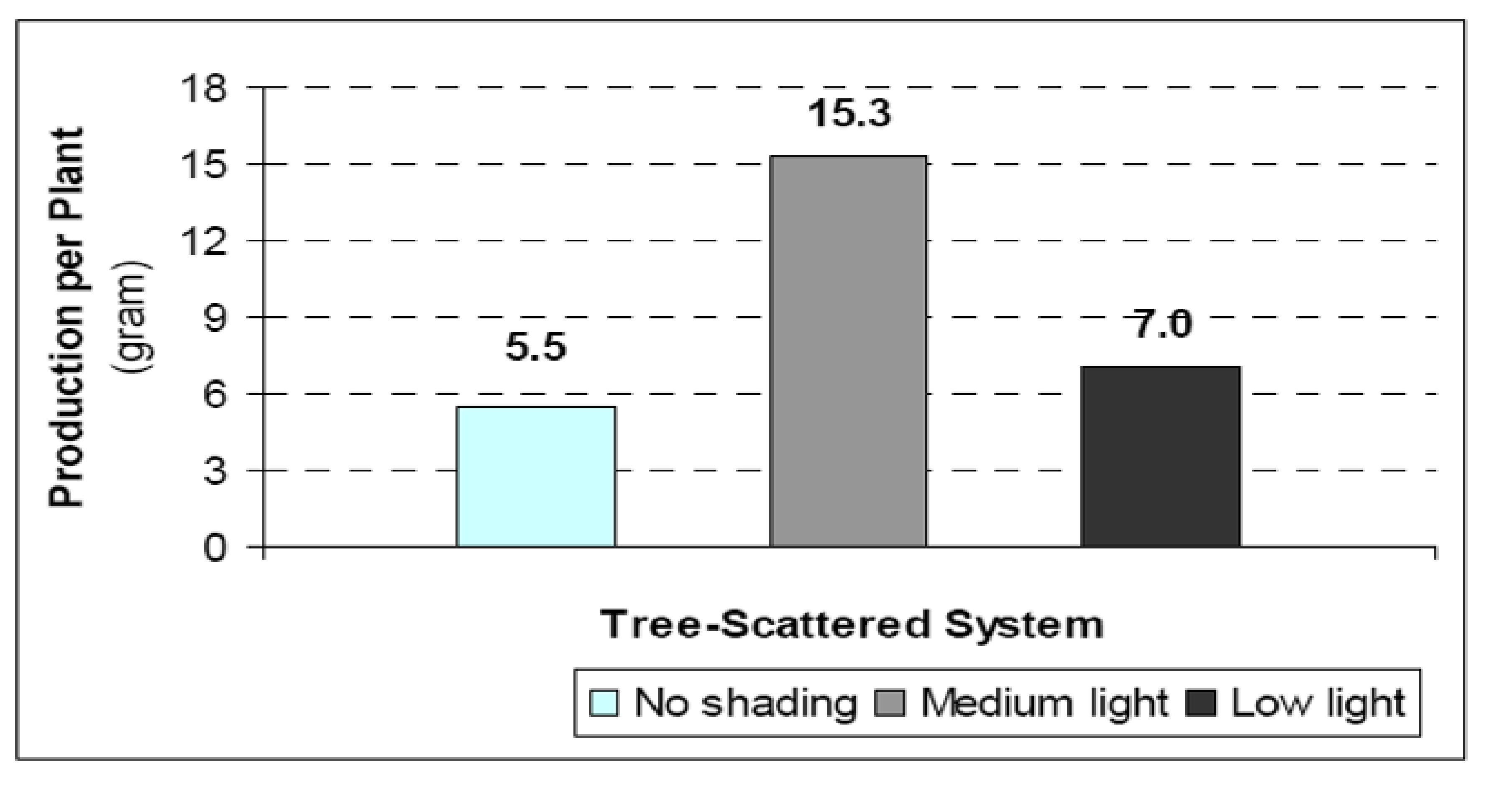
Indonesia – mixed tree species

	
High Light	High Light

Kangkong (dry season in Indonesia)



Amaranth (Dry season in Indonesia)



Vegetables	Medium light (%)
Amaranth	280
Kangkong	190
Eggplant	171
Chili	109
Tomato	105

When compared with high light or no shade conditions

Can vegetables thrive under tree-mixed system that there is reasonable yield?

Yes

Philippines

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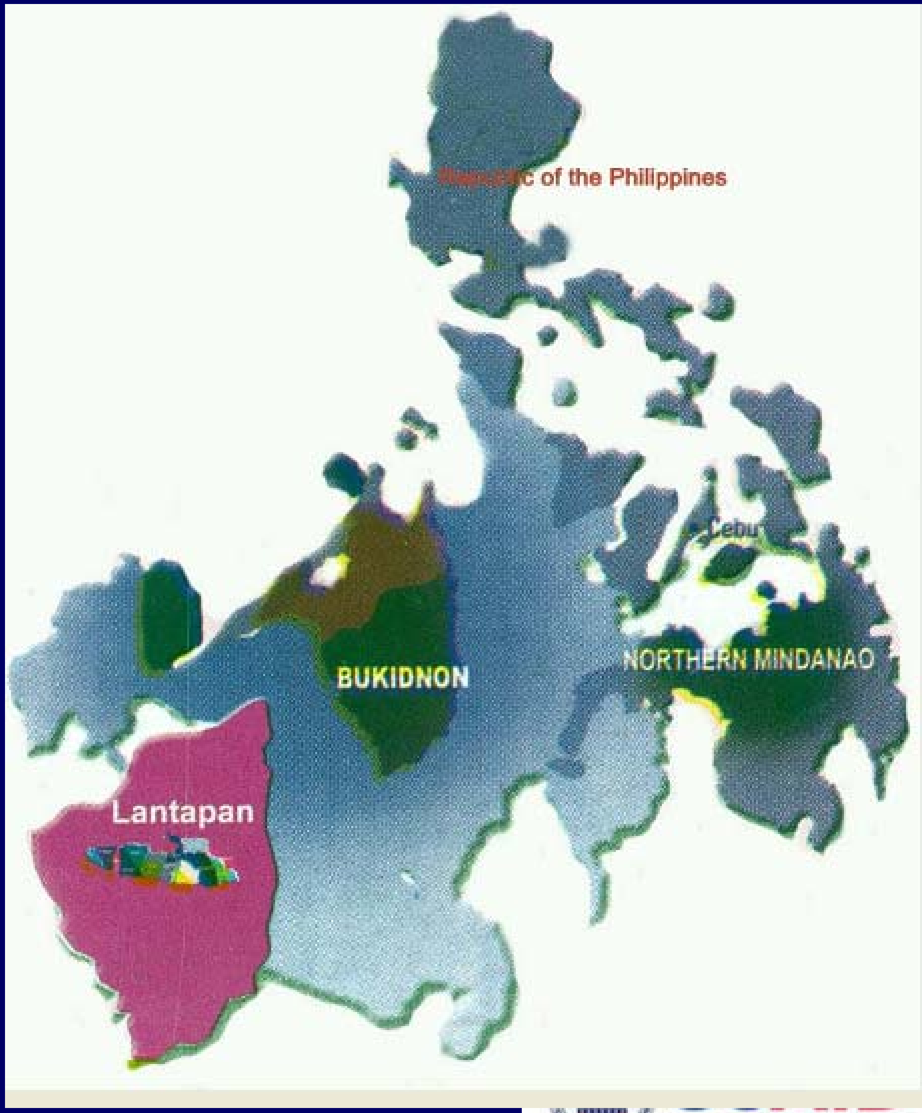
Philippines

- Lantapan, Bukidnon, Island of Mindanao
- <u>Watershed drains in a hydroelectric power plant</u>



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Vegetable-Tree
VT

Complementarity

Philippines

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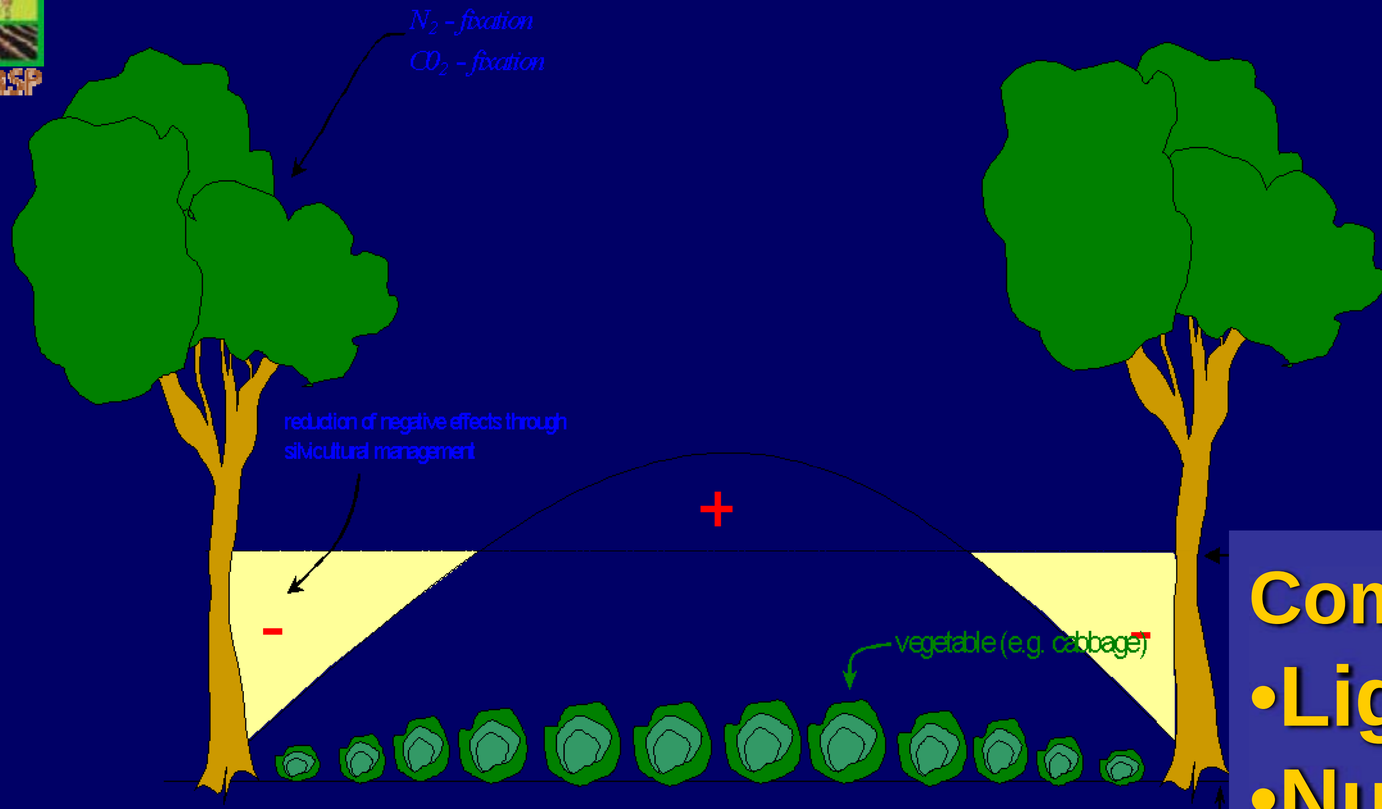
Can vegetables be more productive under tree-based systems?

Yes *for unique vegetable tree combinations*



Competition:
- Light
- Nutrient
- Water

Quantification of optimum tree spacing for vegetable production

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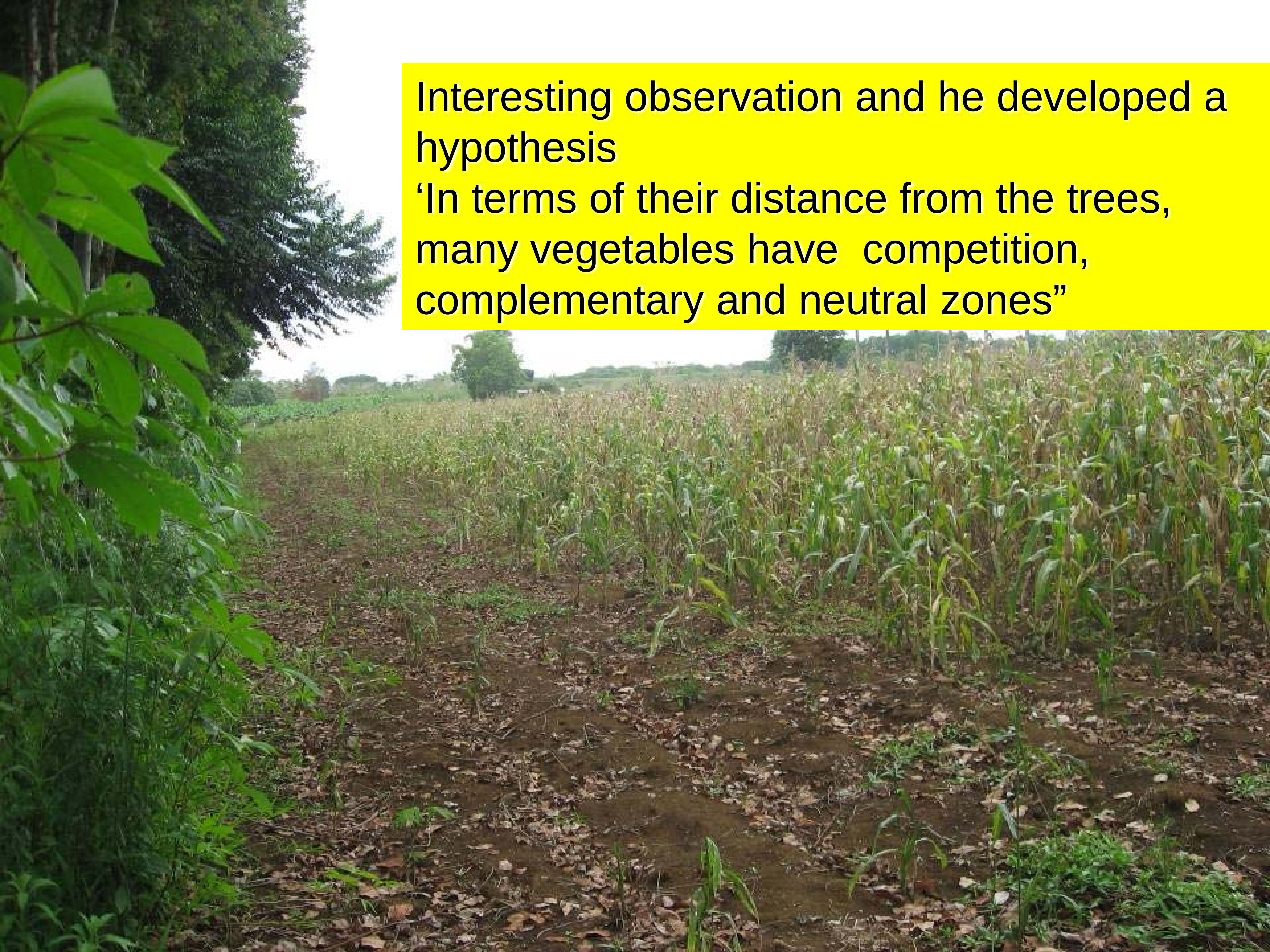
Interesting observation and he developed a hypothesis: Dr. Jun Mercado

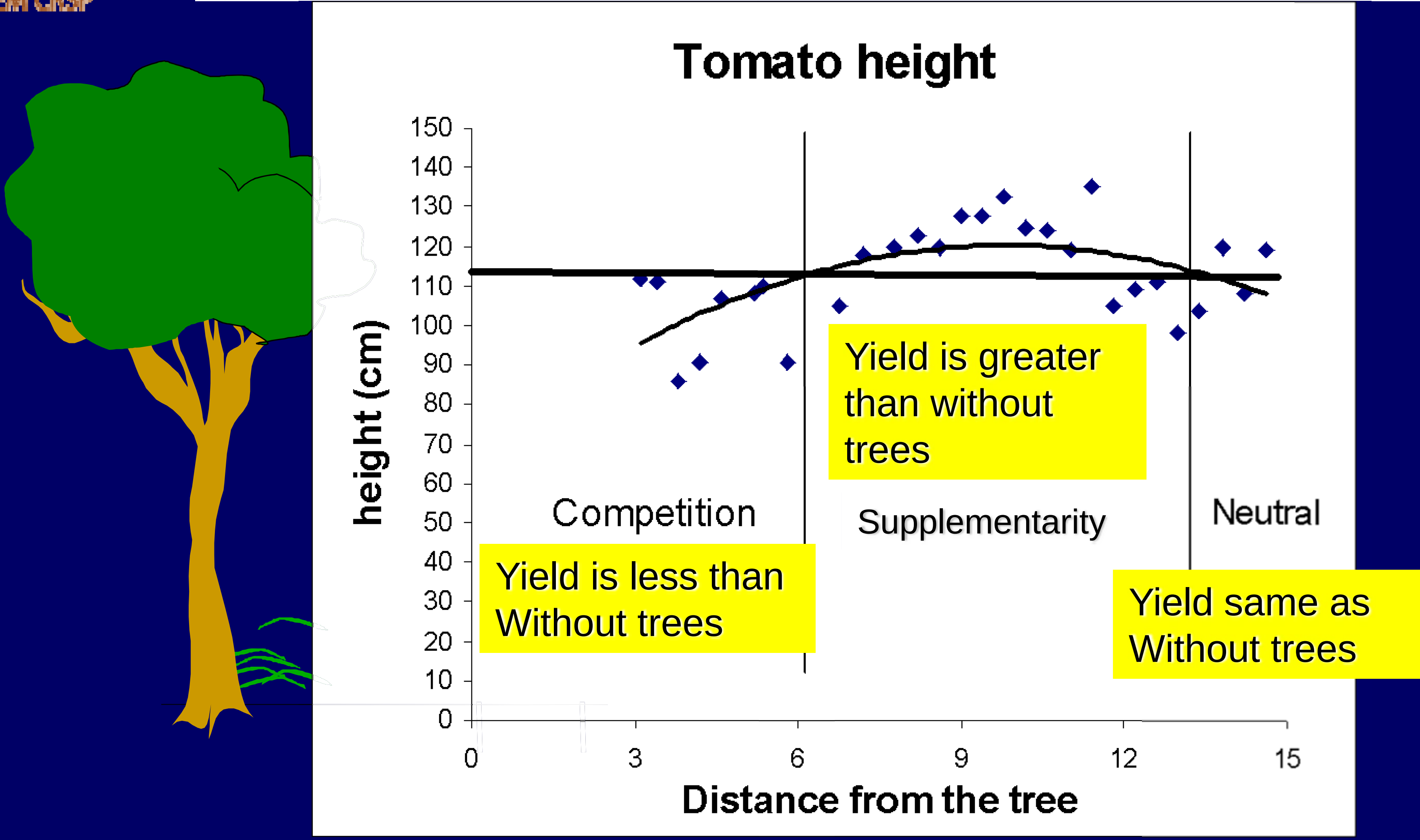
Interesting observation and he developed a hypothesis: Dr. Jun Mercado Measured and Observed in Bukidnon, Philippines vegetable growth

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



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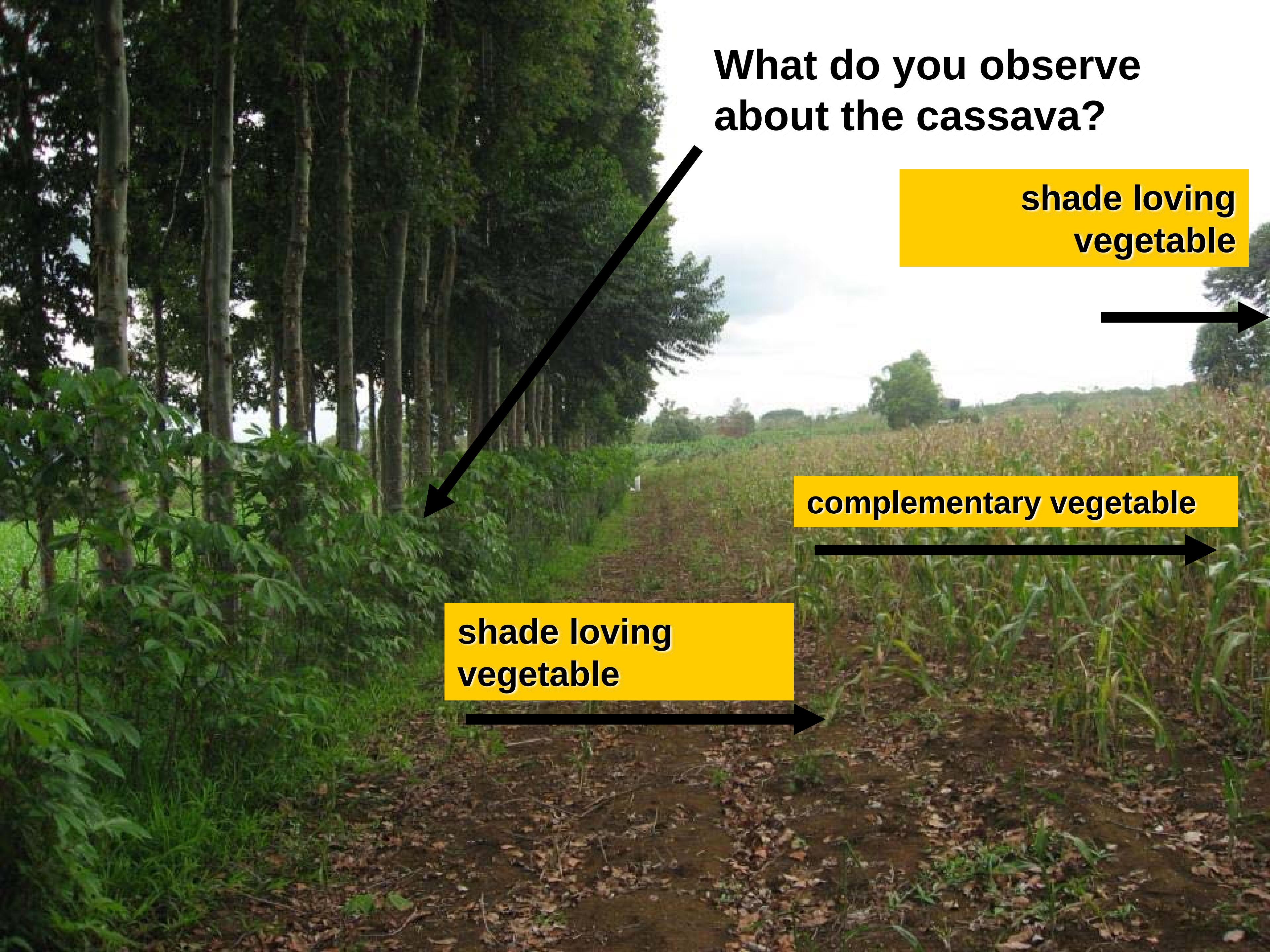
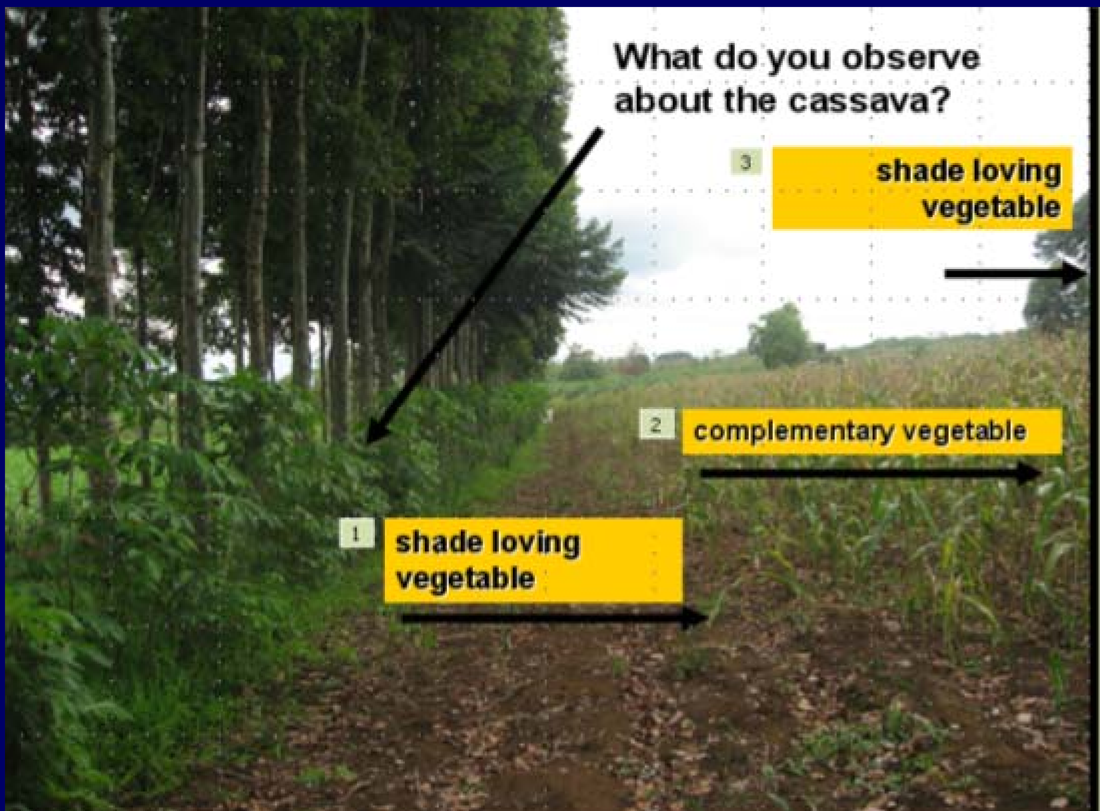
25 Indigenous Vegetables
5 commercial vegetables
Light, Nutrient and Moisture
Interaction
Replicated three times
EXPERIMENT


What do you observe about the cassava?
shade loving vegetable
complementary vegetable
shade loving vegetable

Maximizing vegetable yield with a tree bonus



Philippines

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Indigenous Vegetables

Indigenous Vegetables

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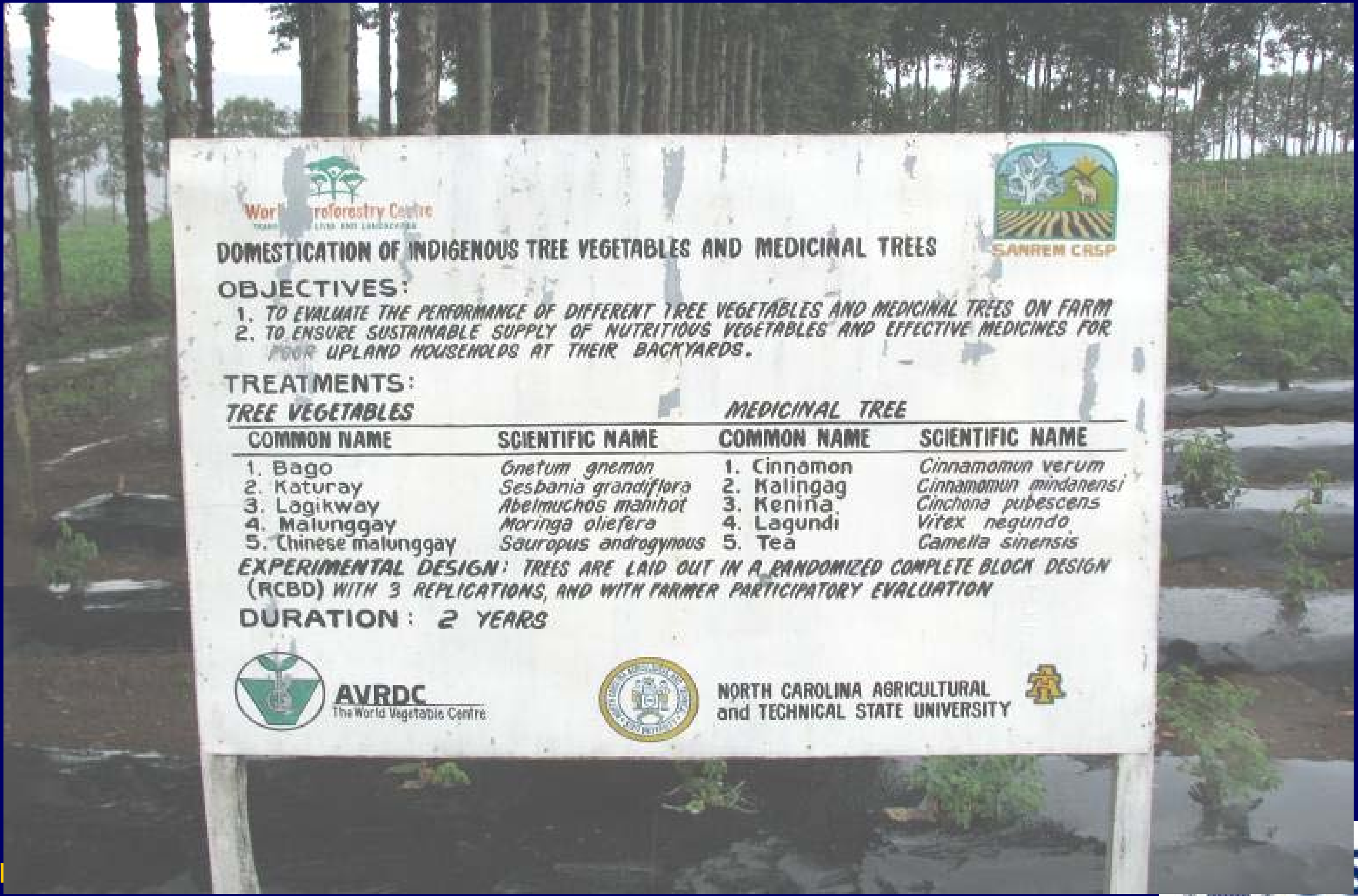
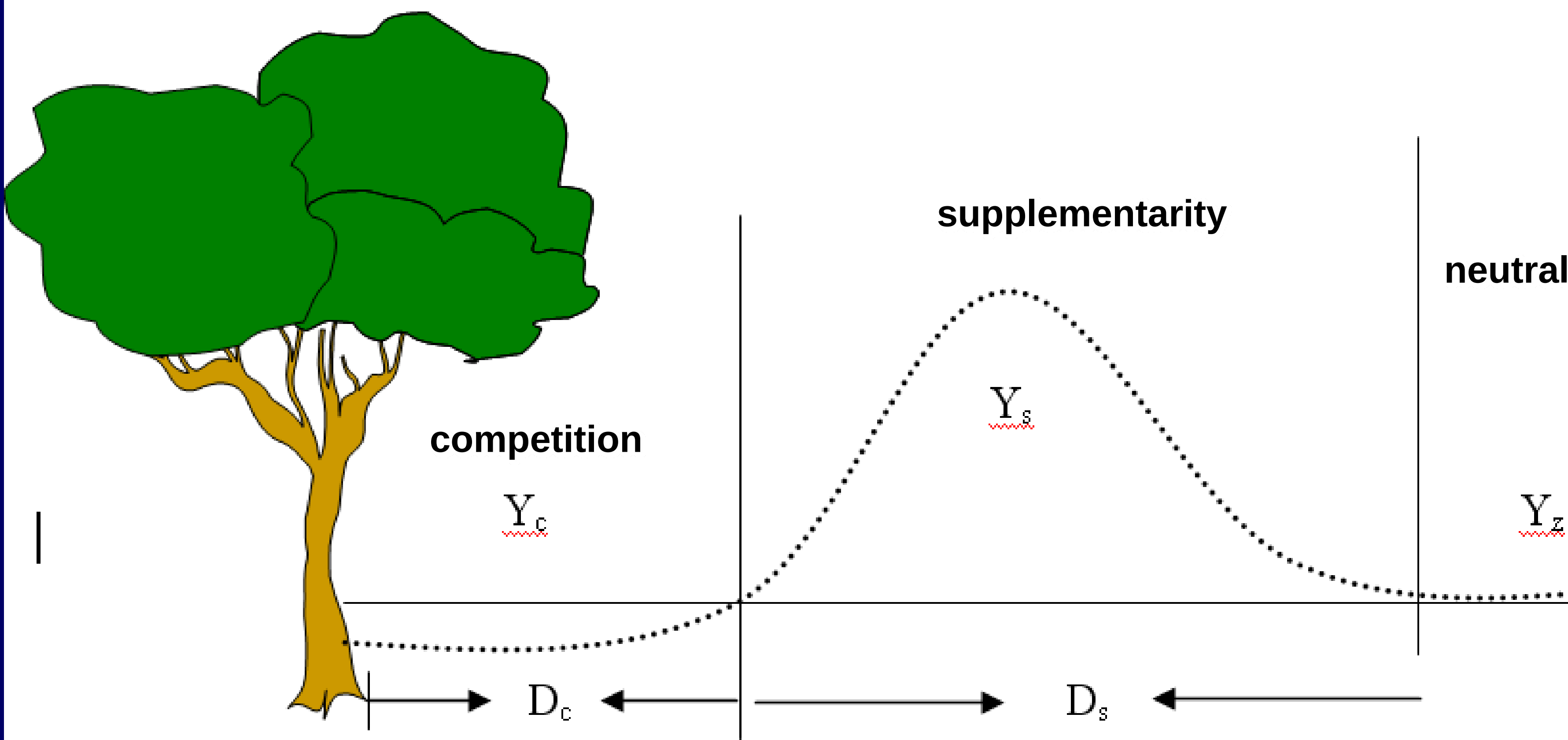
Conventional Vegetables

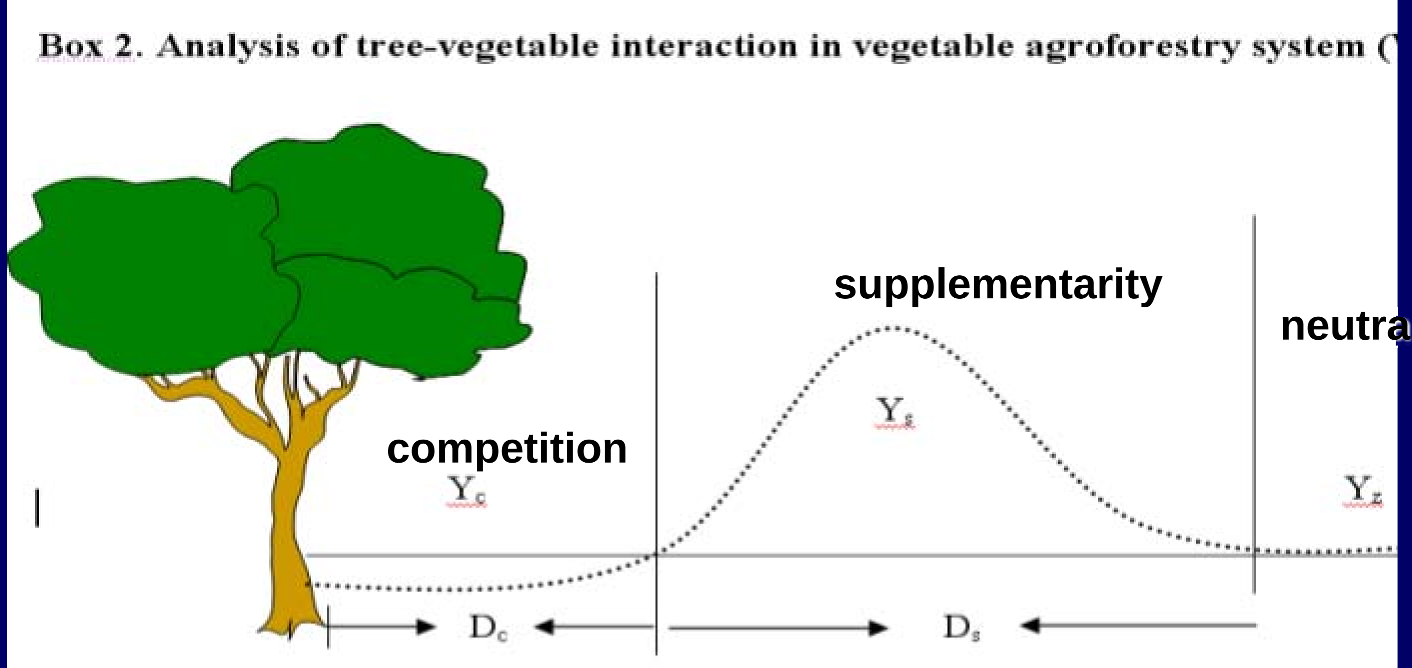
Medicinal Vegetable Trees



Medicinal Vegetable Trees

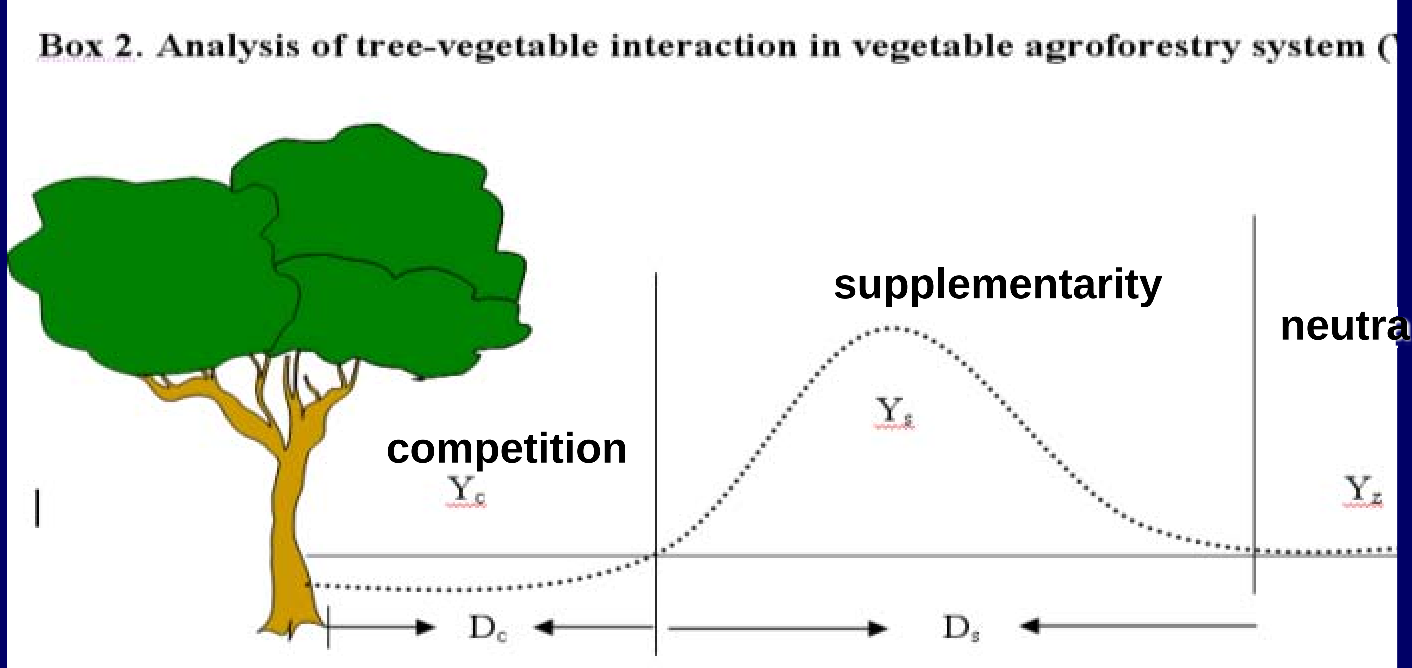
Box 2. Analysis of tree-vegetable interaction in vegetable agroforestry system (





Species	Variety	Yc		Ys		Yz		Dc		Ds	ARY	PY (%)
Amaranthus	TOT 1800 Indonesia	2.3	de	5.0	d-f	3.5	de	6.6	a	8.8	1.1	10
Amaranthus	TOT 2272 Taiwan	5.5	c-e	12.7	b-e	7.3	c-e	4.1	a	11.8	1.9	90
Amaranthus	TOT 4141 Vietnam	6.4	b-d	13.9	b-e	10.9	b-d	5.5	a	9.1	1.2	20
Amaranthus	TOT 5474 Taiwan	4.6	c-e	9.9	c-f	7.1	c-e	4.7	a	10.5	1.3	30
Amaranthus	TOT 7278 Banglades	9.6	e	18.8	a-c	14.0	a-c	7.4	a	8.3	1.0	0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Wet season



	Variety	Yc		Ys		Yz		Dc		Ds		ARY	(%)
Amaranthus	TOT 1800 Indonesia	7.0	b-e	13.4	c-e	11.8	c-e	6.4	a-c	8.3	a-c	0.9	-7
Amaranthus	TOT 2272 Taiwan	11.4	a-c	21.8	a-e	18.2	ab	6.8	a-c	8.3	a-c	0.9	-7
Amaranthus	TOT 4141 Vietnam	6.3	c-f	13.6	c-e	9.4	d-g	6.6	a-c	7.9	a-c	1.1	10
Amaranthus	TOT 5474 Taiwan	4.5	d-g	10.3	c-f	10.7	c-f	3.0	c	8.3	a-c	0.8	-17
Amaranthus	TOT 7278 Bangladesh	11.2	a-c	15.4	b-d	14.1	b-d	4.2	a-c	10.4	de	1.0	0
Jute	TOT 3504	8.9	a-d	16.3	a-c	13.7	b-d	6.9	a-c	7.9	a-d	1.0	0

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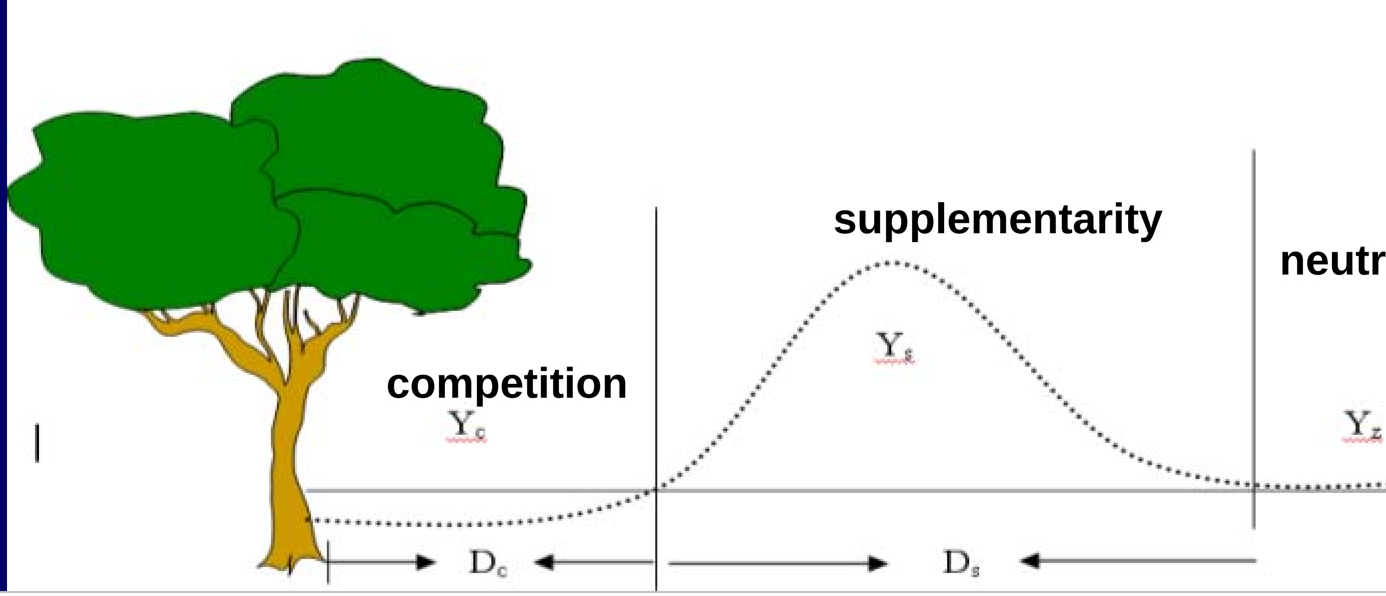
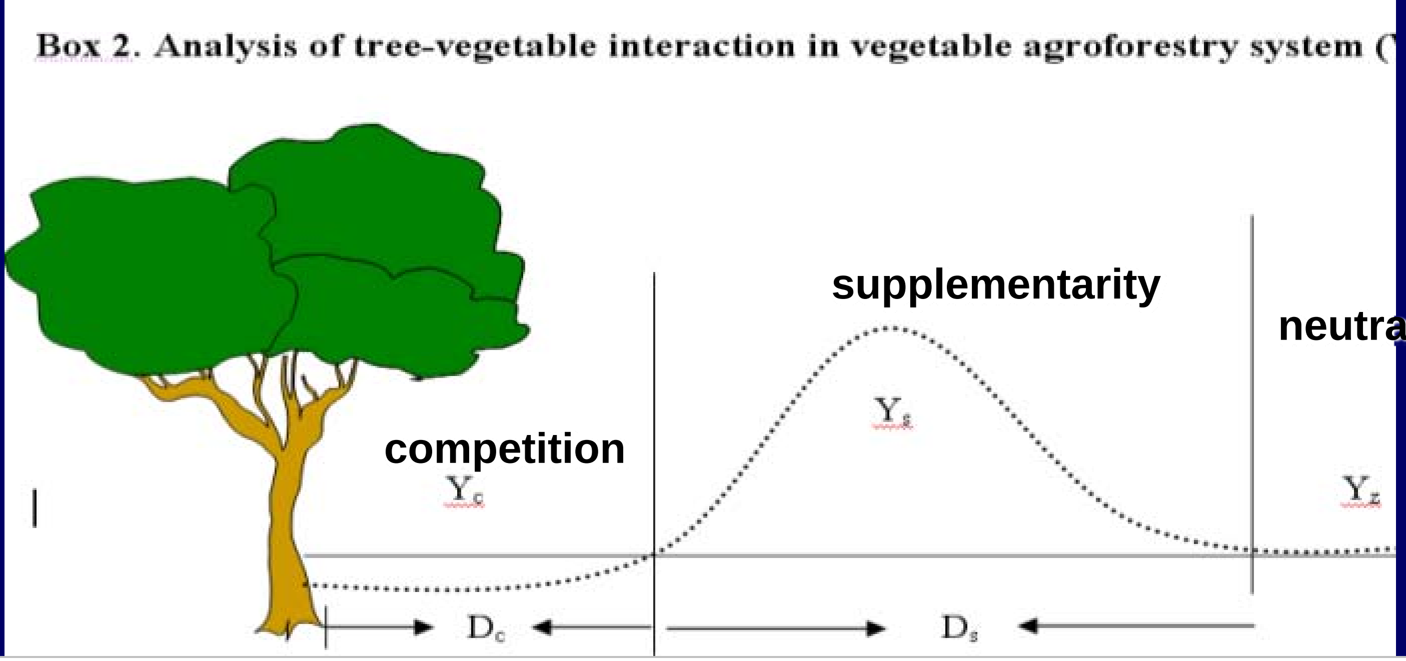
Dry season

Box 2. Analysis of tree-vegetable interaction in vegetable agroforestry system (



Performance indices of 5 commercial vegetable species under tree based system													
Eucalyptus torillana as tree hedge. Lantapan, Bukidnon. Wet season 2007.													
Vegetables	Variety	Yc		Ys		Yz		Dc		Ds		ARY	PY (%)
Chinese cabbage	Blues	12.4	a	30.6	a	20.0	a	3.6	a	11.4	ab	1.4	37
Cabbage	Resest crown	8.9	b	16.0	b	12.0	b	4.6	a	8.2	b	1.1	13

Wet season



Performance indices of 5 commercial vegetable species under tree based system													
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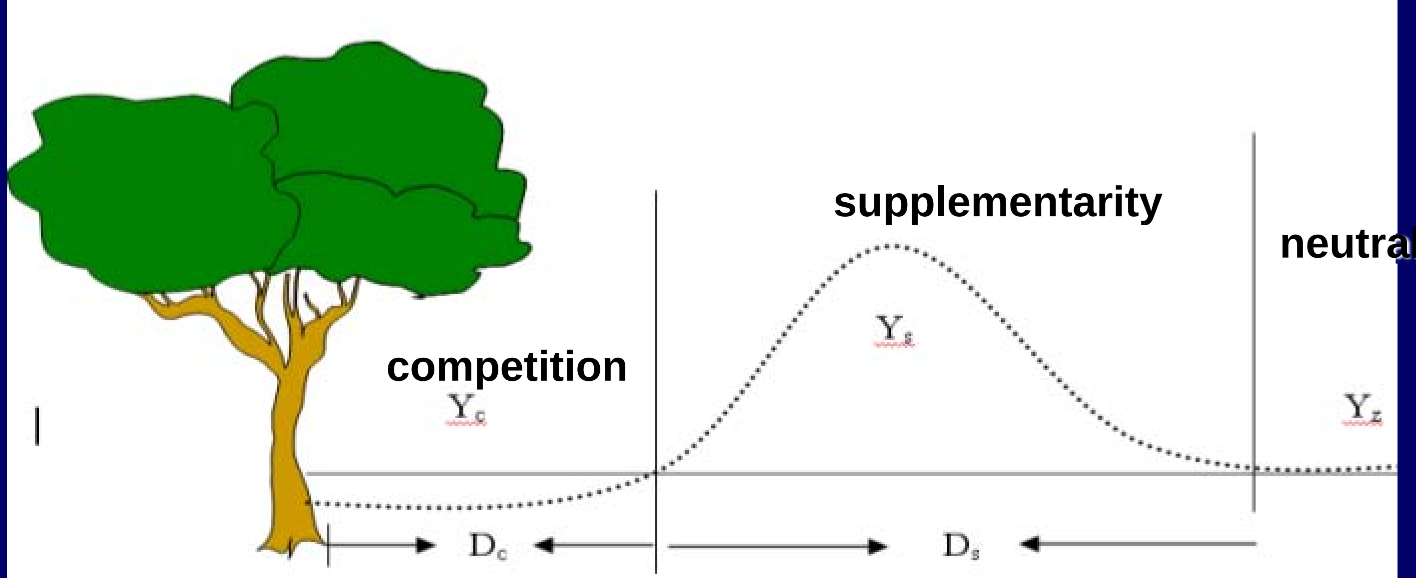
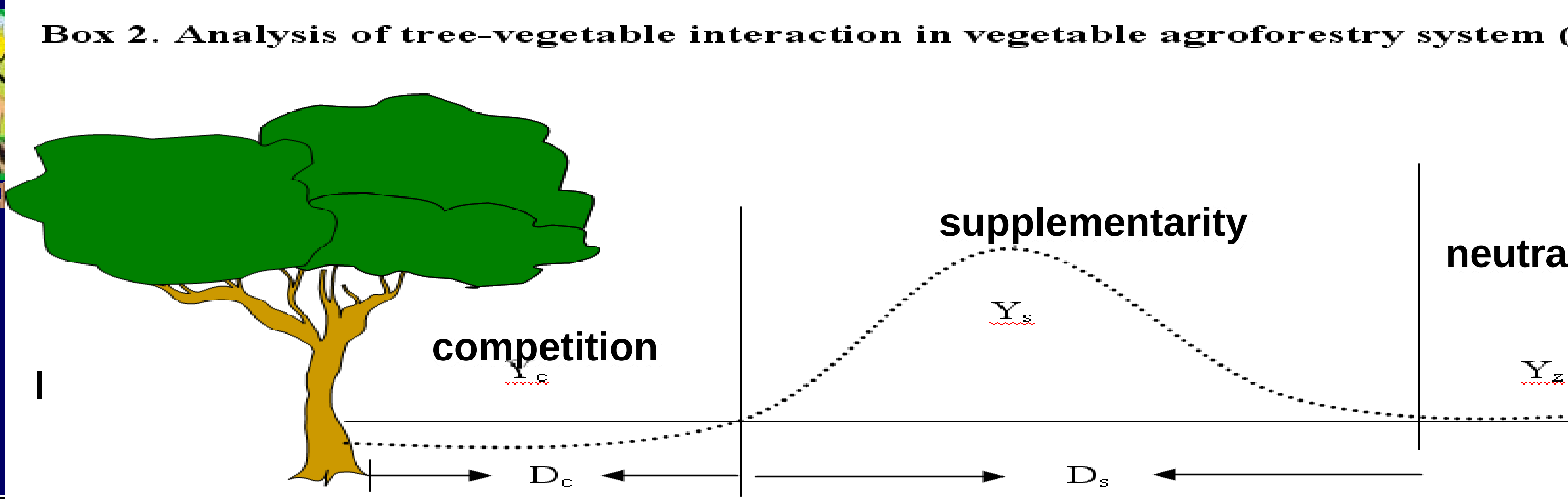
Vegetables	Variety	Yc		Ys		Yz		Dc		Ds		ARY	PY (%)
Chinese cabbage	Blues	12.4	a	30.6	a	20.0	a	3.6	a	11.4	ab	1.4	37
Cabbage	Resest crown	8.9	b	16.0	b	12.0	b	4.6	a	8.2	b	1.1	13

Box 2. Analysis of tree-vegetable interaction in vegetable agroforestry system (



Vegetables	Variety	Yc		Ys		Yz		Dc		Ds		ARY	PY (%)
Tomato	WVCT-1	5.8	c	11.1	c	7.7	bc	1.2	a	15.1	a	1.4	40
Bellpepper	9950-5197	2.2	d	3.6	d	2.7	c	4.6	a	11.4	ab	1.2	20
Carrots		1.0	d	1.9	d	1.3	c	1.8	a	6.3	b	1.4	37

Wet season



Variations in competition and supplementarity zones

								Dc		Ds		ARY	PY (%)
Chinese cabbage	Blues	12.4	a	30.6	a	20.0	a	3.6	a	11.4	ab	1.4	37
Cabbage	Resest crown	8.9	b	16.0	b	12.0	b	4.6	a	8.2	b	1.1	13
Tomato	WVCT-1	5.8	c	11.1	c	7.7	bc	1.2	a	15.1	a	1.4	40
Bellpepper	9950-5197	2.2	d	3.6	d	2.7	[illegible]	4.6	a	11.4	ab	1.2	20
Carrots		1.0	d	1.9	d	1.3	[illegible]	1.8	a	6.3	b	1.4	37

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

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Recommendation of design guidelines for steep slopes

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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 Enterprises (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 drum reservoir served as water supply for the IDE drip system. A sub-main of 10 m with adjustable slope and lateral-sub holder of 10 m were fabricated to enable slope variations during laboratory experiments. The drip system was operated at pre-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 coefficient. 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 followed a linear relationship with either head or slope. The CU and DU decrease substantially at submain slopes steeper 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 most upstream lateral may be considered to be recommendable from both hydraulic and practical standpoints. 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 agronomical, agrotechnical, and economical advantages for efficient use of water and labor (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 microtubes 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 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 operated 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 kits 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. It is being

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Table 3. Coefficient of uniformity and emission uniformity at various heads at 0% slope.

Head (m)	Mean Coefficient of Uniformity, CU (%)	Mean Distribution Uniformity, DU (%)
1.0	64.8	45.0
1.5	69.8	50.4
2.0	69.9	51.0
2.5	64.6	43.8
3.0	71.0	53.5
3.5	70.4	50.0

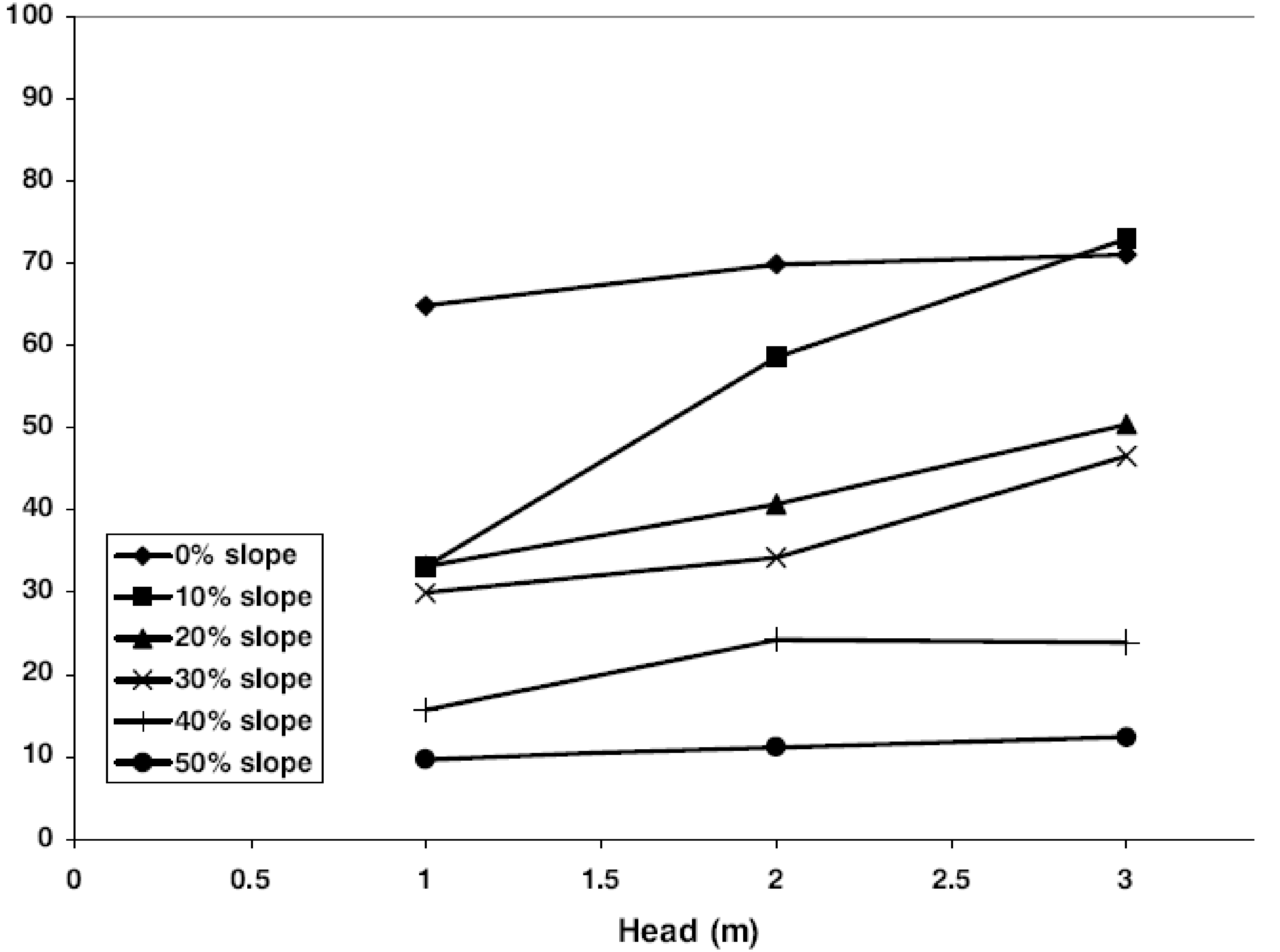

Figure 4. Effect of head on coefficient of uniformity at various slopes.

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No[illegible]
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WITH DRIP IRRIGATION EXPERIMENTAL PLOT
(100 sq m)

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RESULTS

Cabbage

Farm	Crop Yield (kg/m2)	
	With Drip	Without Drip
Binahon	3.59	3.39
Lucbo	4.5	2.42
Quidlat	5.26	4.32
Tabliso	3.12	1.96
Average	4.12	3.02

Chinese cabbage

Farm	Crop Yield (kg/m2)	
	With Drip	Without Drip
Binahon	4.95	3.72
Lucbo	4.13	3.24
Quidlat	6.03	3.27
Tabliso	1.13	0.86
Average	4.06	2.77

Tomatoes

Farm	Crop Yield (kg/m2)	
	With Drip	Without Drip
Binahon	7.17	5.72
Ladera	1.08	0.76
Lucbo	3.10	2.58
Padla	4.07	3.5
Average	3.86	3.14

Pepper

Farm	Crop Yield (kg/m2)	
	With Drip	Without Drip
Binahon	2.19	1.59
Lucbo	0.93	0.61
Quidlat	0.63	0.29
Tabliso	0.79	0.54
Average	1.14	0.76

All Crops

Crop	Average Crop Yield (kg/m^2)	
	With Drip	Without Drip
Cabbage	4.12	3.02
Chinese cabbage	4.06	2.77
Tomato	3.86	3.14
Bell pepper	1.14	0.76

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**

Summary of Findings from Field Experiments (cont'd.)

- 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)

monitored.

Biter gourd planted with and without Arachis Pintoi as a cover crop

Reduced tillage prototype

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Reduced tillage prototype

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and Technical State University

Motor driven

Weakness

No inputs from community

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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

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Policy

'incentives'

Municipality had passed an Incentive based policy on conservation agriculture

TMPEGS

E

nvironmental &
conomic-social impact

'it works'

Pesticide Use and Farmers' Health Costs in Cashew Production Systems in Vietnam.

SANREM CRSP

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.

Preventive spraying is the main method

Many farmers have poor or no protection

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North Carolina Agricultural and Technical State University

Pesticide Use and Farmers’ Health Costs in Cashew Production Systems in Vietnam.

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:

$$LnY = \alpha_0 A + \alpha_1 LnLab + \alpha_2 LnDoseH + \alpha_3 LnDoseI + \alpha_4 LnNPK + \alpha_5 LnDensity + \alpha_6 LnAge + \alpha_7 Year2006 + \alpha_8 Year2007 + \alpha_9 EroSoil$$

where:

LnY	= natural logarithm of yield
LnLab	= natural logarithm of labor
LnDoseH	= natural logarithm of total dosage of all herbicides
LnDoseI	= natural logarithm of total dosage of all insecticides
LnNPK	= natural logarithm of total N, P, Kb fertilizers
LnDensity	= natural logarithm of tree density
LnAge	= natural logarithm of tree age
Year2006	= 1 if year 2006 and = 0 if otherwise
Year2007	= 1 if year 2007 and = 0 if otherwise
EroSoil	= 1 if eroded soil and = 0 if otherwise

Methodology *(continue)*

Health cost function:

$$LnHC = \beta_0 \ln A + \beta_1 LnTODOSE + \beta_2 LnNA + \beta_3 LnAGE + \beta_4 LnWTHT + \beta_5 SMOKE + \beta_6 DRINK$$

where:

LnHC	= log of health costs of farmers
LnTODOSE	= log of total dosage of all pesticides used
LnNA	= log of number of applications of pesticides/ year
LnAGE	= log of farmers' age
LnWTHT	= log of farmers' weight by height
SMOKE	= dummy for smoking
DRINK	= dummy for drinking alcohol

Estimated production function for cashew

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

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

No significant impact on cashew yield.

Estimated health cost function

SANREM CRSP

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

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

Pesticide dose and number of pesticides use significantly influence farmer's health costs

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Findings

SANREM CRSP

- 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, 2009

North Carolina Agricultural
and Technical State University

Invitation

Google SWAT-SEA

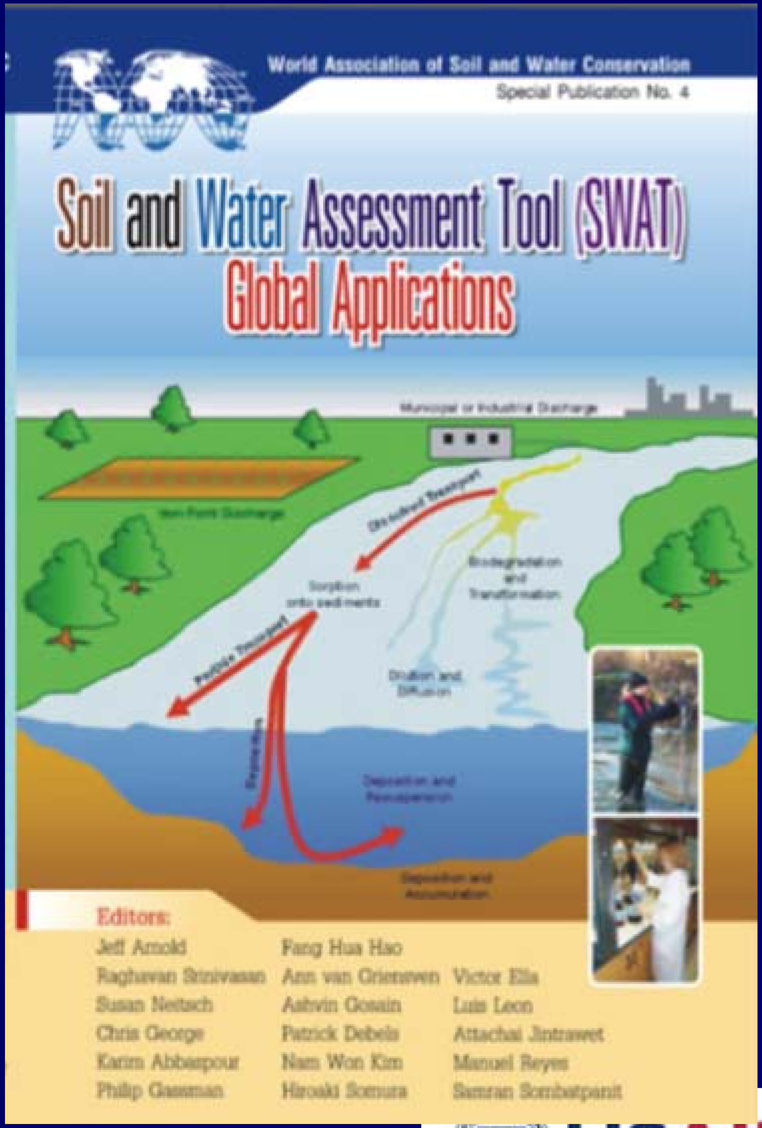
http://ssc.hcmuaf.edu.vn/

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 book: Soil and Water Assessment Tool: Global Applications. Editors (Arnold et al, 2009). Published by the World Association of Soil and Water Conservation.

In review International Agricultural Engineering Journal.

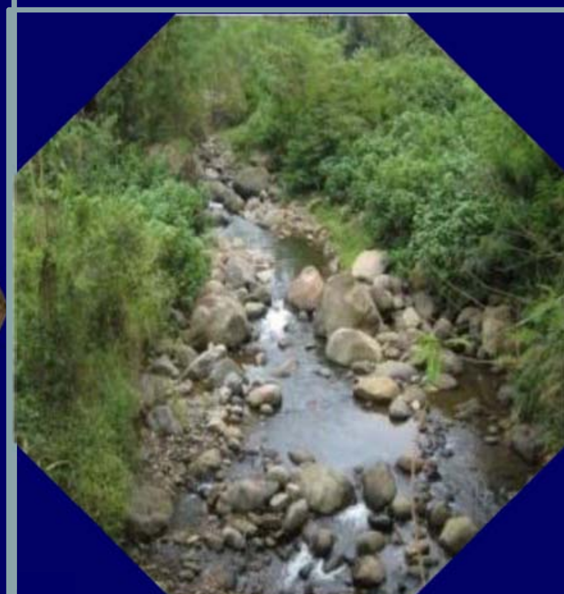


Background

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.

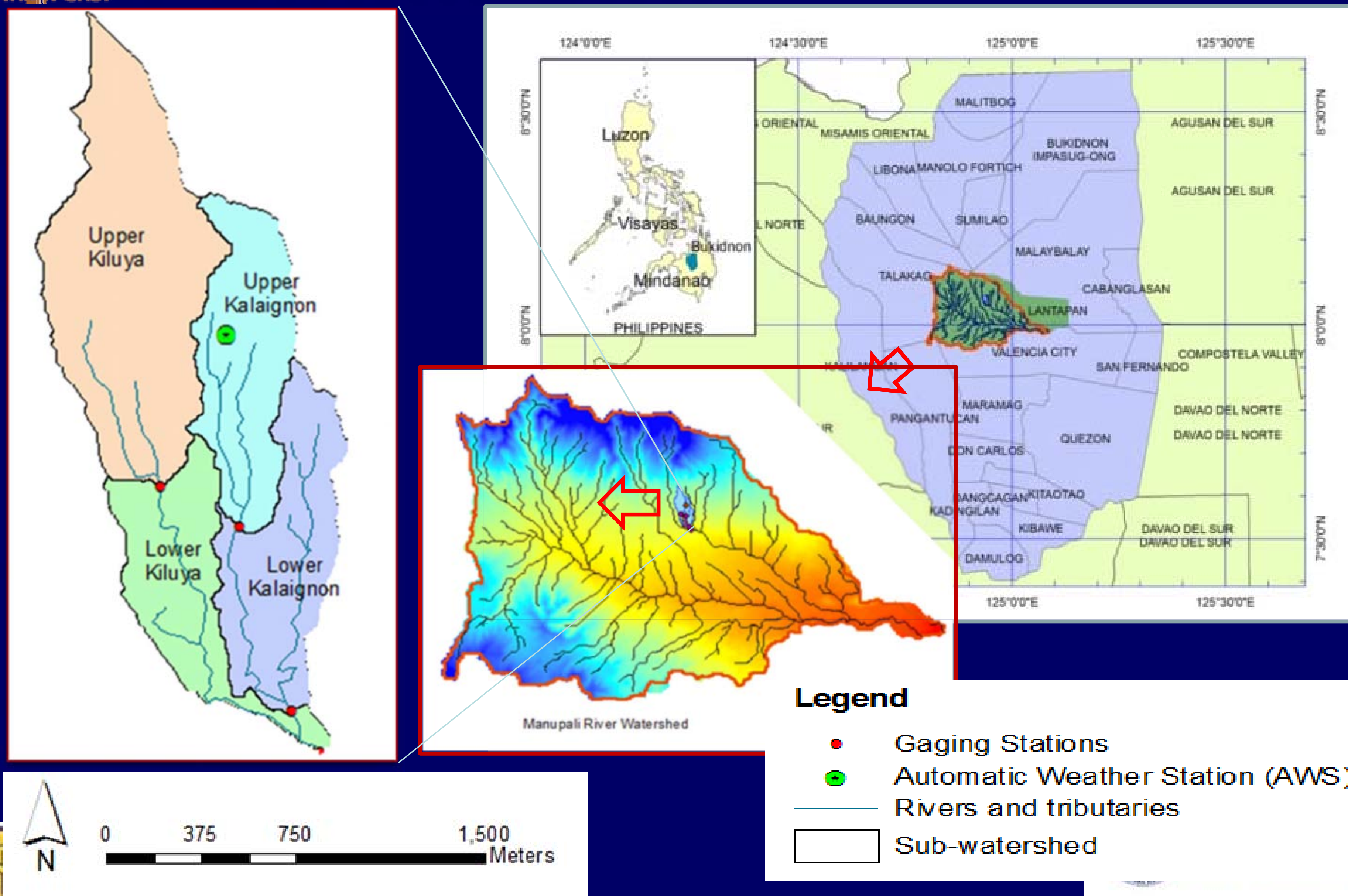


Objectives

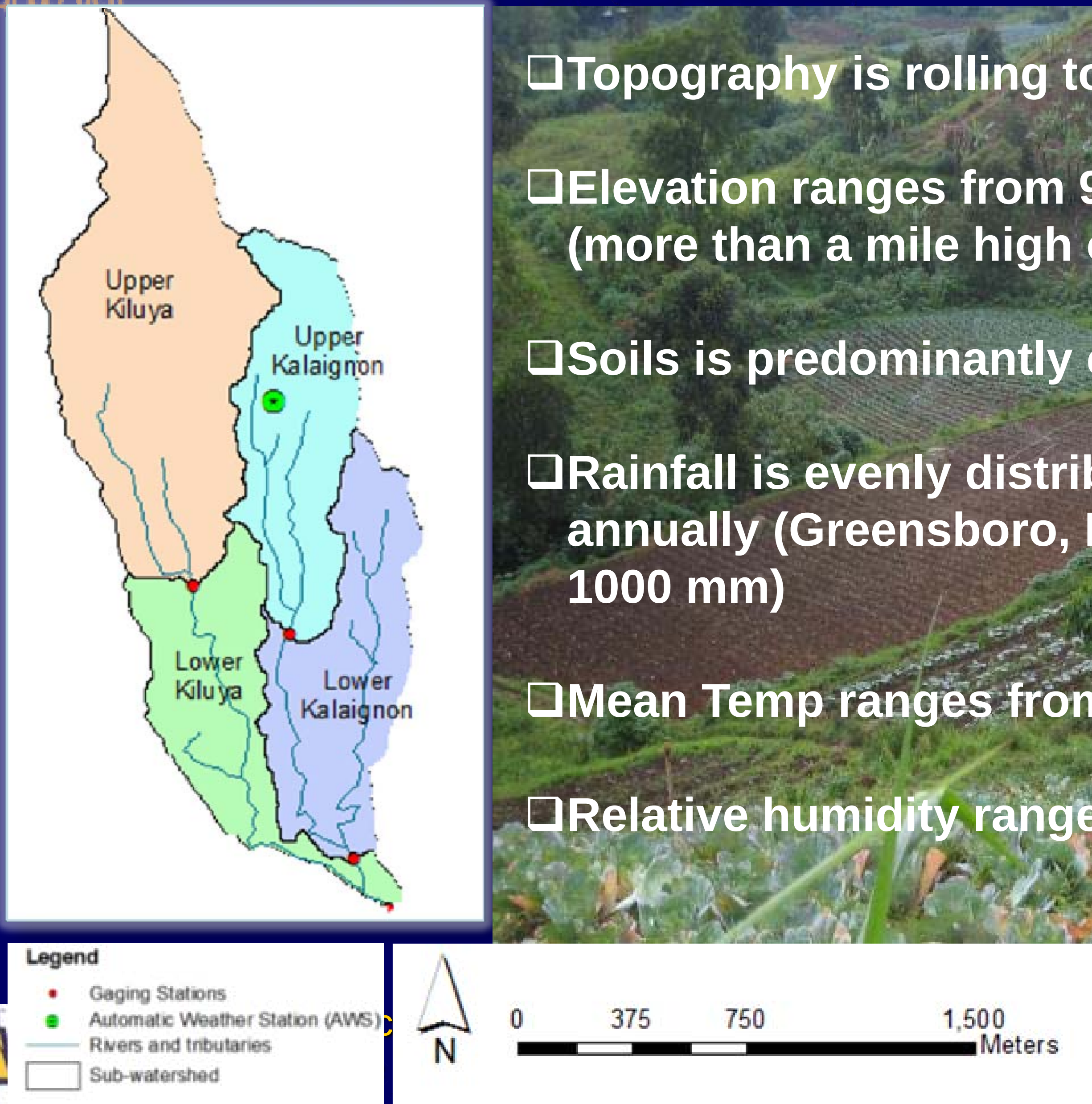
- To determine the effects of various land use patters on runoff and sediment yield in selected sub-watersheds of the Manupali river using the SWAT model.

- 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



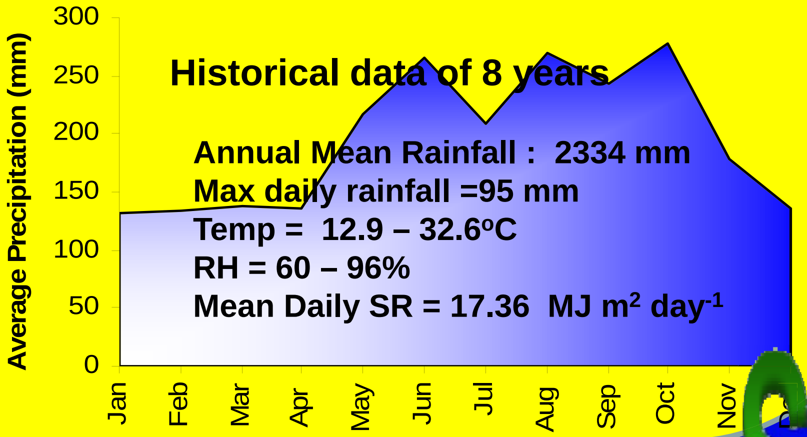
The Study Site



- 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^{o}C to 28^{o}C
- Relative humidity ranges from 86% to 98%

Model development and calibration

Precipitation and Climate



Annual Mean Rainfall : 2334 mm
Max daily rainfall =95 mm
Temp = 12.9 – 32.6°C
RH = 60 – 96%
Mean Daily SR = 17.36 MJ m^2 day^{-1}

Soil Properties

Soil Type

Extracted from soil map of Bukidnon

Soil Series and Relative Area

Adtuyon Clay: 46.72%
Kidaapawan clay-clay loam: 18.53%
Forest soil : 34.75%

SWAT

Topography and Stream

Digital Elevation Model

Prepared by digitizing a 1:50,000 scale map with contour interval of 20m and rasterized into 10 x 10 m using ENVI.

Elevation range: 900 – 2000 m

Average slope: 41%

Stream Density

Stream line created and extracted from DEM

Land Use/Vegetation

Land Use Classification

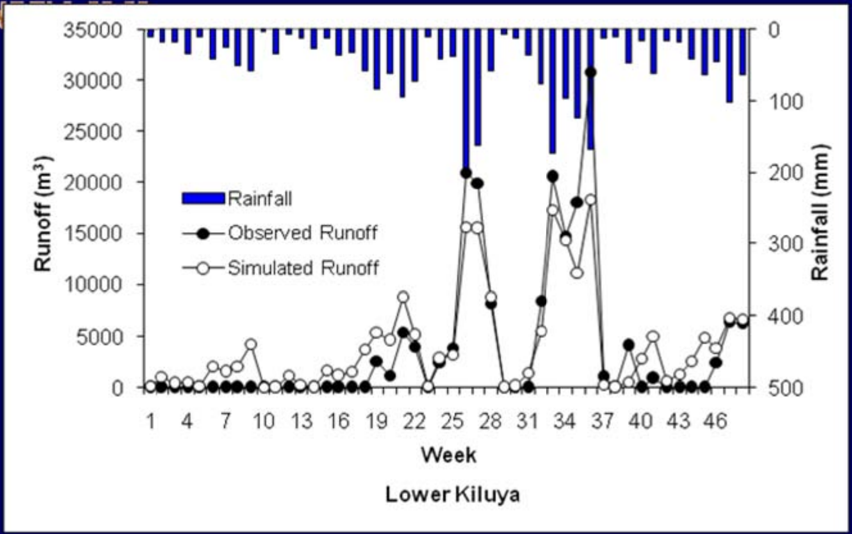
- Agricultural – 29.5%
- Pasture/Grassland – 53.0%
- Forest – 16.8%
- Foot path – 0.7%

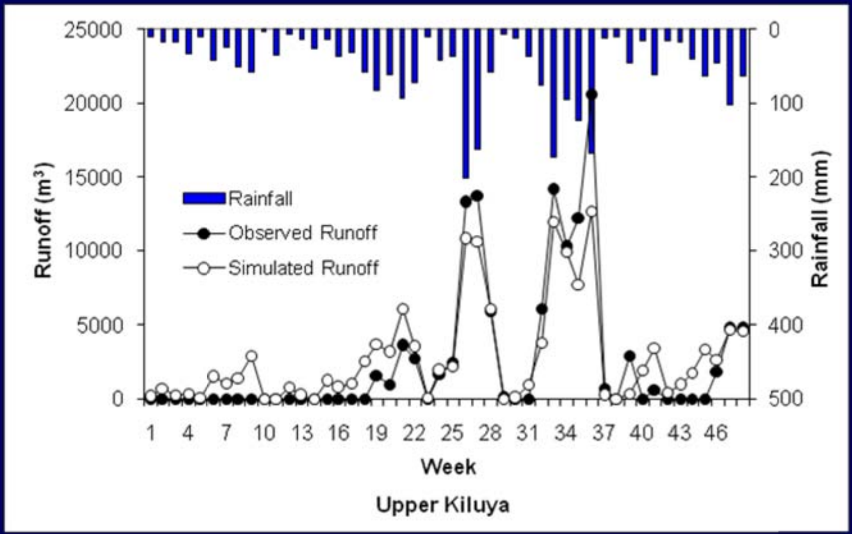
Agricultural Crops

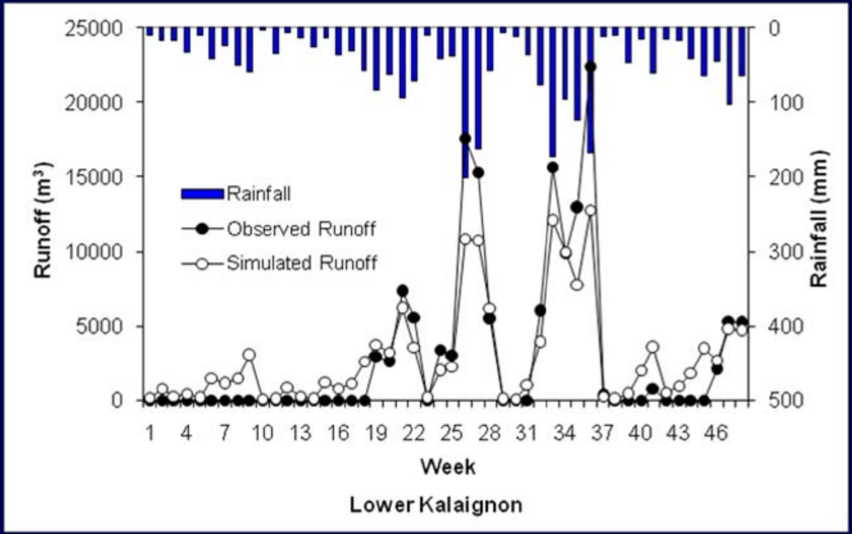
Corn, tomato, cabbage, potato and bell pepper

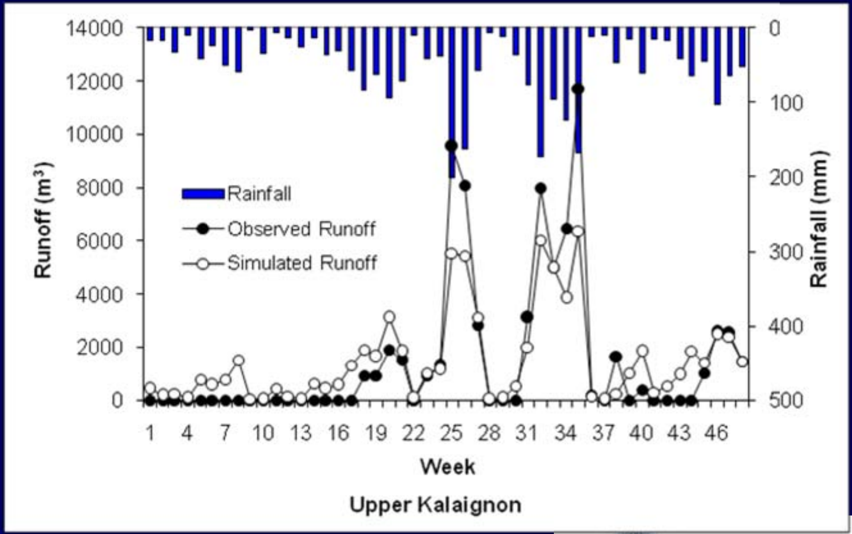
Physically-based not well-defined parameters (e.g. CN2, C factor, infiltration, SPCON, and SPEXP) were adjusted to provide better fit between the observed and simulated runoff volume and sediment yields.

Prediction of runoff volume

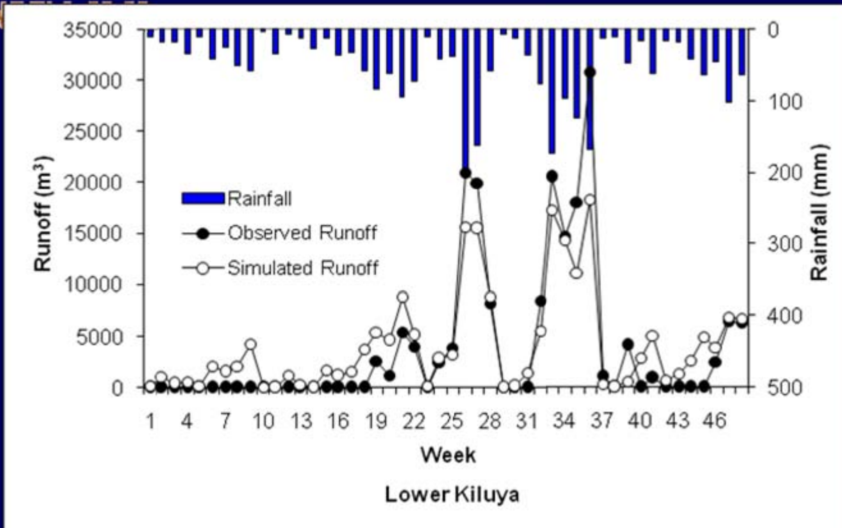


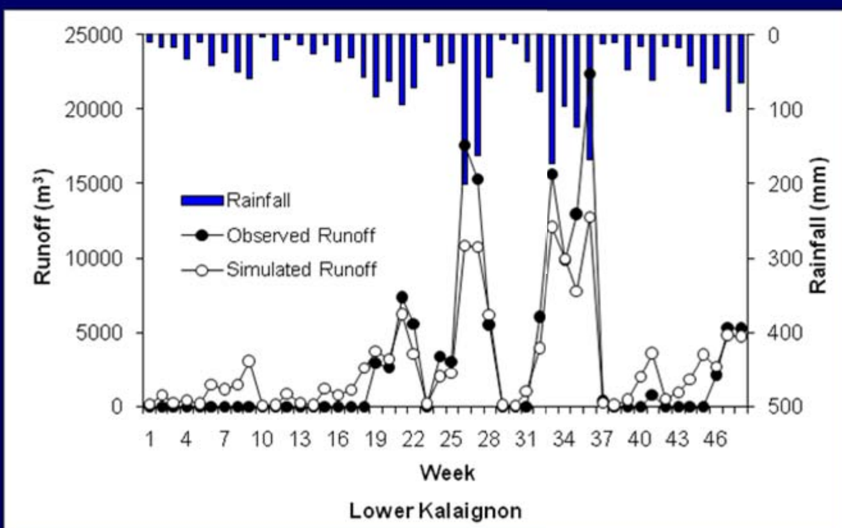






Prediction of runoff volume

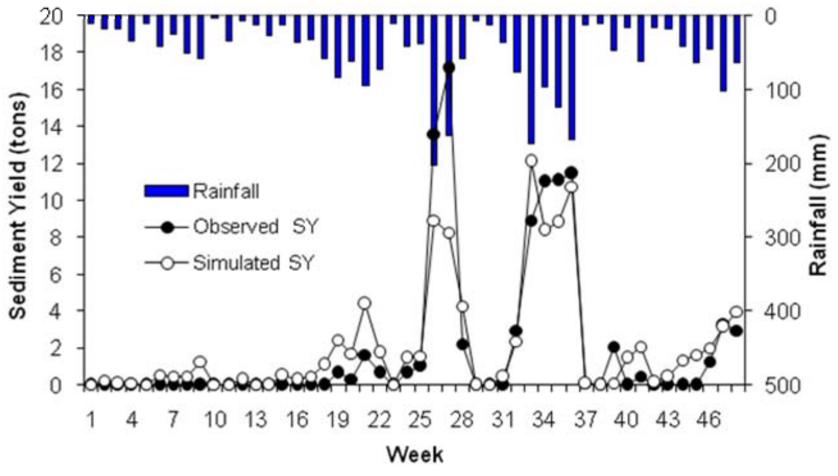




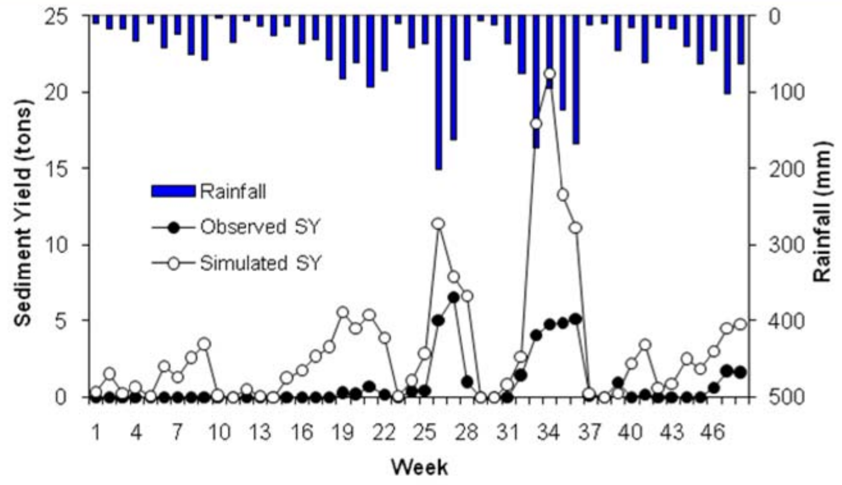
WATERSHED	WEEKLY MEAN RUNOFF VOLUME (m^3)		RMSE	R^2	NSE
	Observed	Simulated			
Lower Kiluya	3809	4098	3014	0.88	0.82
Upper Kiluya	2610	2820	1977	0.88	0.83
Lower Kalaignon	2992	2848	2368	0.90	0.80
Upper Kalaignon	1470	1449	1323	0.87	0.77

- ❑ 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

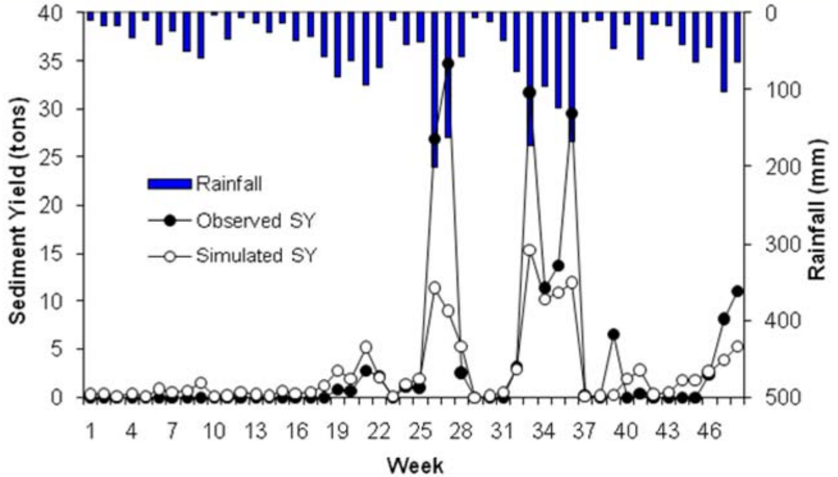
Prediction of sediment yield



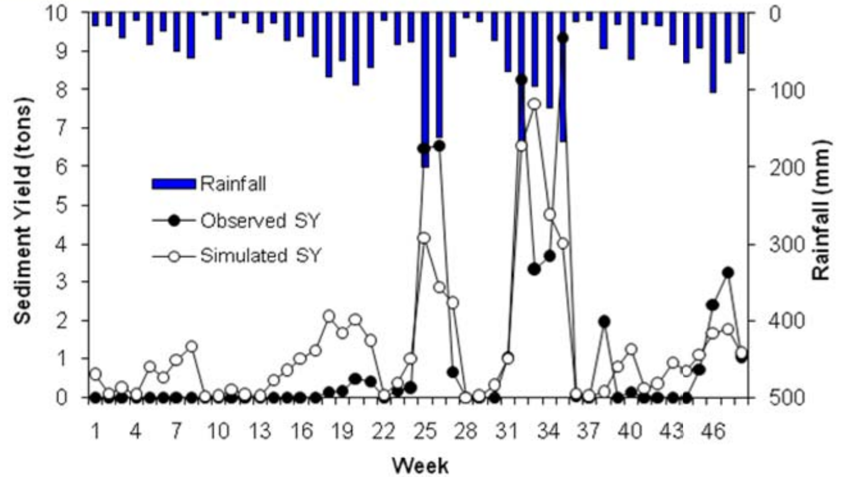
Lower Kiluya



Upper Kiluya

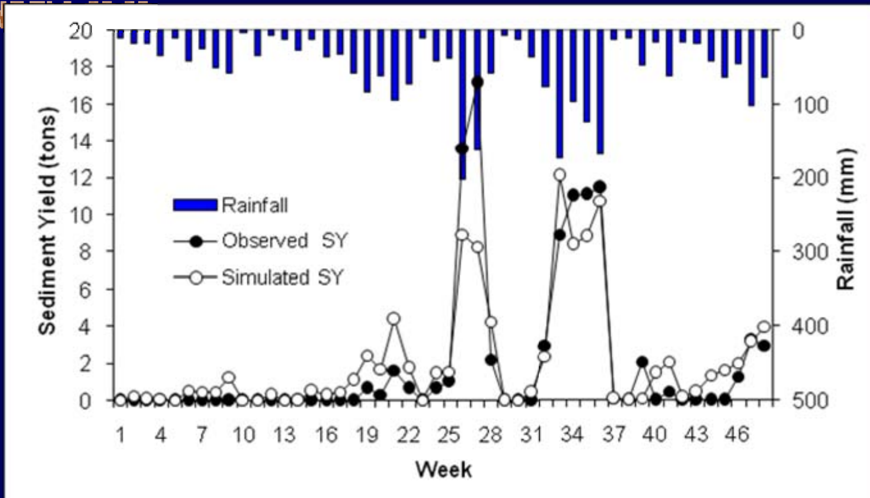


Lower Kalaignon



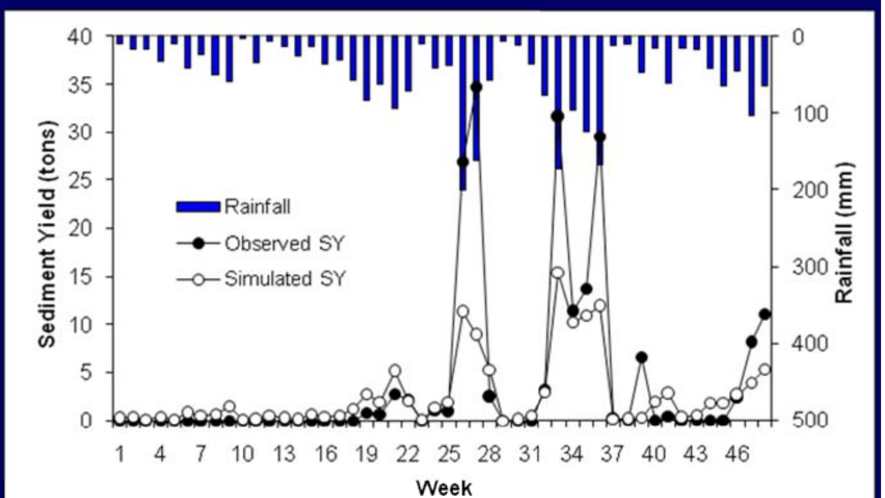
Upper Kalaignon

Prediction of sediment yield



Lower Kiluya

WATERSHED	WEEKLY MEAN SEDIMENT YIELD (tons)		RMSE	R^2	NSE
	Observed	Simulated			
Lower Kiluya	1.95	2.09	1.84	0.82	0.8
Upper Kiluya	0.84	3.39	4.17	0.7	-5.16
Lower Kalaignon	3.96	2.53	5.83	0.8	0.55
Upper Kalaignon	1.03	1.12	1.45	0.58	0.58



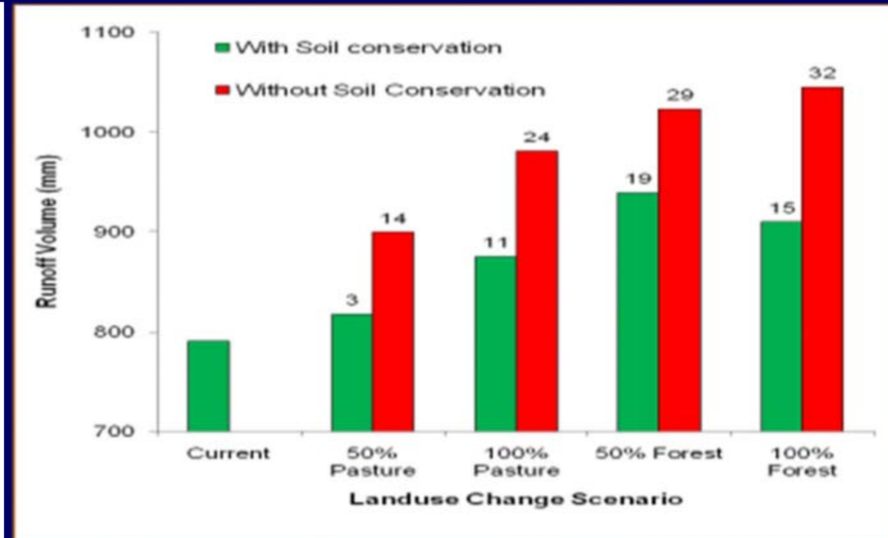
Lower Kalaignon

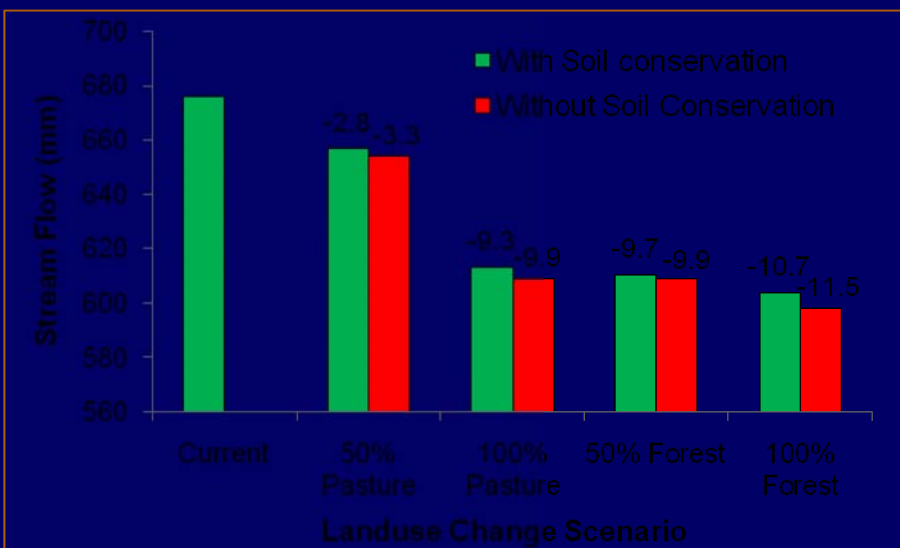
- ❑ Except for Upper Kiluya, simulated and measured sediment yield showed good agreement with R^2 ranging from 0.50 to 0.80
- ❑ SWAT model showed adequacy to predict the temporal distribution of sediment yield with NSE values ranging from 0.55 to 0.80
- ❑ Despite the differences, the overall adequacy of the model indicates its usefulness to predict the effects of land use changes in the area.

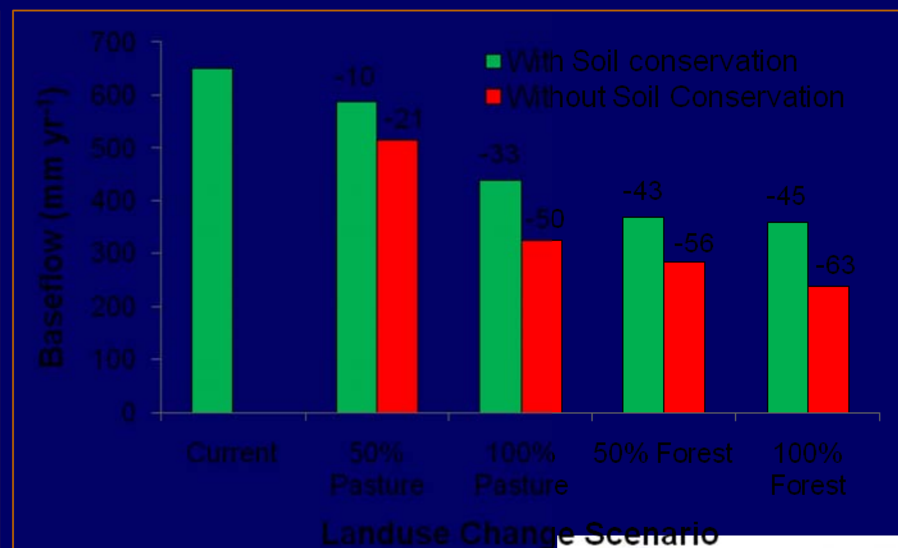
Simulation of hydrologic impacts of land use change

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







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Gender

'equity'

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Scaling-up

'contagiousness'

Questions