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Findings and Challenges: Can Vegetables Be Productive under Tree Shade Management in West Java?

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Findings and Challenges: Can Vegetables be Productive under Tree Shade Management in West Java?

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Abstract

Farmers in Nanggung, West Java traditionally cultivate vegetables under full sunlight. There is opportunity to expand vegetable production in the understory of agroforestry system, but farmers have limited experience with such practices. An on-farm trial was implemented to evaluate the production of 11 commercial vegetable species under three levels of tree shading in a nested design, replicated 3 times. The species included in the trial were honje (*Etlingera elatior*), terubuk (*Saccharum edule*), katuk (*Sauropus androgynus* (L.) Merrill), kenikir (*Cosmos caudatus* Kunth), kangkong (*Ipomoea aquatica* Forsskal), amaranth (*Amaranthus* sp.), chili (*Capsicum annuum* L.), egg plant (*Solanum melongena* L.), long bean (*Vigna unguiculata* (L.) Walp.), green bean (*Phaseolus vulgaris* L.) and tomato (*Lycopersicon esculentum* Miller). Twenty-five independent variables were analyzed for their effect on vegetable survival, growth and yield. Average light levels for each treatment were 482 – 540 *1000 lux (open area, control), 43 – 540 *1000 lux (medium light) and 32 – 174 *1000 lux (low light). Preliminary results indicate that vegetable production under dudukuhan (agroforestry) systems shade is a viable option for smallholder farmers, however more intensive species-specific and site-specific management is required. A program of training and extension support would help smallholders develop such deliberate management practices.

Keywords. *vegetable production, tree shade management, amaranth, kangkong, egg plant, chili, tomato, vegetable agroforestry systems.*

Introduction

Agroforestry is a dynamic, ecologically based, natural resources management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for all land users at all levels (World Agroforestry Centre, 2006). In Indonesia, most agroforestry systems are established through shifting cultivation, which complements relationships between trees and crops, and between forests and farming systems (Michon and de Foresta, 1995). Under this relationship natural forests support the livelihood of local people and at the same time forest vegetation gradually establish on farms (de Foresta et al., 2000).

Dudukuhan is a local name of agroforestry systems in Nanggung and can be divided into 4 types: 1) timber systems, 2) mixed fruit-timber-bananas-annual crop systems, 3) mixed fruit-timber systems, and 4) fallow systems. Traditionally all types of dudukuhan are managed on an extractive basis, where tree-growth scaterred in those systems with few inputs (quality germplasm, fertilizers, labor, etc) allocated to maintain or improve the system or productivity. Farmers favour this management approach because of limited land tenure, small landholding size (0.25 ha), off-farm employment opportunities, limited market access, or their limited experience with intensive tree management (Manurung et al., 2007).

Understory crops (include vegetables) can be integrated with forestry, orchard, or other agroforestry systems. Farmer use understory crops to provide earlier returns, diversity products, and/or to make more efficient use of land and labor (Wilkinson and Elevitch, 2000). In general, most of farmers have knowledge and experiences to growth vegetables on the full sunlight farming system (no shading). However, result of the SANREM-Household survey (Wijaya et al, 2007) stated that only 11% of farmers who have experiences to growth vegetables within dudukuhan systems. There is opportunity to expand vegetable production in the understory of agroforestry systems, but farmers have limited experience with such practices. According to farmer's perception, the growth and production of vegetables would be impeded and decreased when vegetables were planted within dudukuhan systems (Manurung et al, 2007).

To prove farmer's perception, an on-farm screening trial was designed to evaluate the production of vegetables in the understory of dudukuhan systems. There were 11 commercial vegetables (that produce leaves and fruits products and indigenous vegetables) was tested of the growth and yield under three different light levels that consisted of two light levels within 2 types of dudukuhan (*mixed fruit-timber-bananas-annual crop system* that represented medium light level and *mixed fruit-timber system* that represented low light level) and on the no shading (full sunlight) farming system as a control.

Study Site

Nanggung subdistrict is located on the western part of West Java province, about 100 kms away from Jakarta and about 45 km away from Bogor to the South. It covers a total area of 9723.6 ha with elevation of 400 to 1800 m.a.s.l. and consists of 10 villages. Landuse systems are dominated by agricultural and forestry practices. Table 1 illustrates the landuse systems in Nanggung. Annual rain fall is varies between 3,000 mm to 4,000 mm and the average annual temperature ranging between 22^0C and 24^0C.

Table 1. Proportion of landuse systems in Nanggung

Landuse system	**Area (Ha)**	**Percentage (%)**
Protected forest, part of the Halimun-Salak National Park	1,837.5	18.9
Paddy field	1,740.7	17.9
Dryland farm and community forest (dudukuhan systems)	1,980.5	20.4
State Forest Coorporation land	2,050.0	21.1
Road infrastructures	869.0	8.9
Other uses	1,245.9	12.8

Total population of Nanggung subdistrict at 2003 was 74,211 inhabitants within 17,187 households. Population growth from 1998 to 2003 was 3.23% per year, it is higher that West java province (2.17%). Based on ICRAF baseline study (Budidarsono et al., 2004), most of respondents (73.3%) consider themselves as farmers; engage in agriculture as their main occupation. Agricultural activities alone contribute 31.2% to the total households' income. Average family income per household was IDR 9,211,000 per year. Almost all income is spent on consumption. Having a close look at the expenditure items, the largest proportion is spent on food (43.4%) and other non-food consumption (housing, cloth, schooling, transportation, etc).

Materials and Method

An on-farm screening trial was implemented to evaluate the growth and yield of 11 commercial vegetables under two levels of tree shading and on the no shading (full sunlight) farming system in a nested design, replicated 3 times. The species included in the trial were honje (*Etlingera elatior*), terubuk (*Saccharum edule*), katuk (*Sauropus androgynus* (L.) Merrill), kenikir (*Cosmos caudatus* Kunth) are known as Indigenous vegetables, while kangkong (*Ipomoea aquatica* Forsskal), amaranth (*Amaranthus* sp.) produce leaves products, and chili (*Capsicum annuum* L.), egg plant (*Solanum melongena* L.), long bean (*Vigna unguiculata* (L.) Walp.), green bean (*Phaseolus vulgaris* L.) and tomato (*Lycopersicon esculentum* Miller) produce fruits as the main product.

All cultivation practices (land preparation, planting spacing, replacing, watering, weeding, fertilizing, pruning and harvesting) for all vegetables in each demplot (treatment) refered to the IPB - Vegetable Cultivation Manual (Susila, 2006) that showed in Table 2 as following:

Table 2. Organic-chemical fertilizers application for each vegetable (kg/ha/planting season)

Age (weeks)	Fertilizer	Chili	Egg plant	Long bean	Green bean	Kangkong	Amaranth	Tomato	Honje	Terubuk	Katuk	Kenikir
Preplant	Organic (ton/ha)	20	15	15	15	10	15	15	20	20	30	15
	Urea	199	160	112	62	187	56	199	133	133	190	47
	SP36	311	311	250	250	311	250	311	102	102	88	311
	KCL	90	90	90	90	112	90	90	130	130	88	56
4 WAP	Urea	75	80	112	62	187	56	100				47
	ZA											
	SP36											
	KCL	34	45	90	45	112	90	45				56

Note:
WAP = Week After Planting

Sites assessment has been done before trial establishment (p*re-planting time*) in 3 plots of trial to explain the structure profiles and tree-scattered maps of 2 types of dudukuhan systems, light levels, and soil characteristics (fertility-physical) is shown by Table 3 and Graph 1. The daily rainfall measurement was conducted during three months trial (Graph 2). The vegetables were planted on August 6, 2007, then data of growth and production measurements have been collected weekly until October 16, 2007. Variables of growth and production measurements included such as: 1) light levels, 2) total height of plants, 3) diameter of stem, 4) yield (kg), 5) survival rate of plant, 6) percentage of damage 7) soil-pH and 8) soil-humid relatively. The number of plants to be measured for each vegetable was formulated: *Number of plants (45) = 5 plants/replication * 3 replications/plot * 3 plots*.

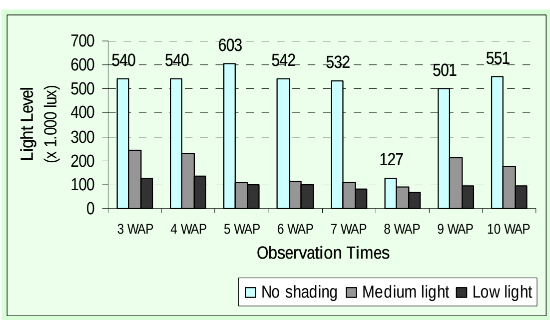
The growth and yield data of the 11 vegetables were analyzed by using the Multiple Regression analysis that is used to quantify in what independent variables and how the variables have affected to the growth and production of the vegetables function as the dependent variables. There are 25 independent variables that were employed on the Multiple Regression analysis as following: 1) tree density, 2) tree basal area, 3) tree canopy width, 4) tee canopy height, 5) soil-pH, 6) soil-humid relatively, 7) light levels, 8) survival rate of plant, 9) percentage of damage, and all soil fertility-physical characteristics (sand, silt, clay, C, N, C/N, P_2O_5, K_2O, Ca, Mg, K, Na, KTK, KB, Al^{3+}, H^+).

Table 3. Pre-planting sites assessment in 3 plots of trial

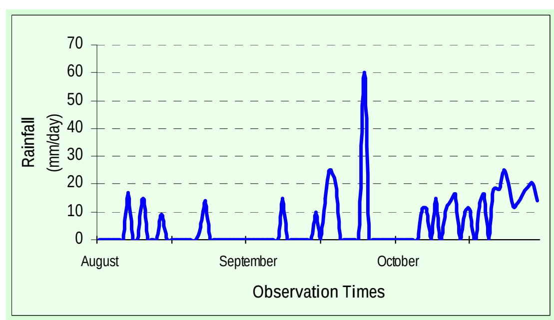
Variables	**Light levels (trial plots)**		
	Full sunlight (no shading)	**Medium light (mixed fruit - timber - bananas - annual crop system)**	**Low light (mixed fruit - timber system)**

Number of tree species	0	18	36
Tree density (per Ha)	0	400	626
Sum of stem diameter (cm)	0.0	327.8	528.5
Mean of tree height (m)	0.0	10.4	8.0
Sum of canopy width (m^2)	0.0	294.4	380.0
Sum of canopy height (m)	0.0	97.5	154.4
Sand (%)	17	17	16
Silt (%)	48	28	32
Clay (%)	35	55	52
C (%)	1.50	1.54	1.99
N (%)	0.11	0.11	0.15
C/N	14	14	13
P_2O_5 (ppm)	2.1	7.9	14.4
K_2O (ppm)	47	68	63
Ca (cmol (+) / kg)	1.69	7.39	1.92
Mg (cmol (+) / kg)	0.95	2.88	0.59
K (cmol (+) / kg)	0.26	0.15	0.31
Na (cmol (+) / kg)	0.15	0.09	0.15
KTK (cmol (+) / kg)	21.63	21.12	18.74
KB (%)	14	50	16
Al^{3+} (cmol (+) / kg)	8.92	9.14	7.71
H^+ (cmol (+) / kg)	0.41	0.66	1.16

Graph 1. Weekly light levels measurement (* 1.000lux)



Graph 2. The daily rainfall measurement during 3 months trial



According to the Multiple Regression analysis, there are around 19 of 25 independent variables were reducted automatically by the Multiple Regression models. It was caused by the Multicolinears in some independent variables, where some independent variables have some sturdy relationships with other variables. Furthermore, the SPSS vers.11 software selected the variables which would represent independent variables in the Multiple Regression models.

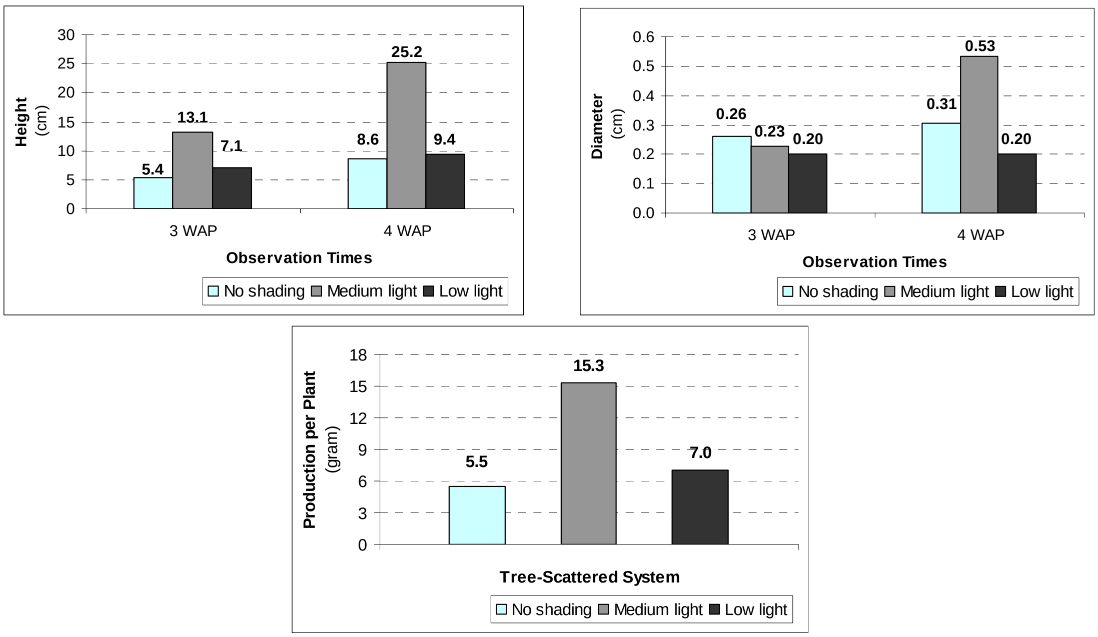
Results

- **Amaranth (*Amaranthus* sp.)**

Graph 3 shows the growth and production performances of amaranth in three plots trial. Amaranth can be completely harvested in the first four weeks after planting time. There was a significant difference between medium light plot and both no shading and low light plots on height and diameter and production of Amaranth plants, especially at week fourth after planting time. In addition, no significantly different between no shading plot and low light plot during 4 weeks of planting season.

In the medium light plot, the height and diameter of Amaranth plants went up rapidly and reached a peak of 25.2 cm and 0.53 cm, respectively compared to the no shading plot (8.6 cm and 0.31 cm). The increment of height and diameter increased double from week-3rd to week-4th measurement. While the increment increased slightly in the no shading and low light plots. Medium light and low light levels increased average Amaranth yields to 15.3 gram and 7.0 gram per plant (278.2% and 127.3% increased over the no shade control).

Graph 3. The growth and production of Amaranth during 4 weeks of planting season



Multiple Regressin models of the growth and production of Amaranth plants are showed by Table 4. There were six independent variables that affected the growth and production of Amaranth, which is soil-humid relatively, light levels, survival rate of plants, percentage of plant damaged, alkaline concentrated (KB) and soil-acids level (H^+). The percentage of plant damaged affected significantly on growth and production of Amaranth plants at the 1% level. Furthermore, the survival rate of plants and the alkaline concentrated have a significant affected on the diameter increment of Amaranth plants. Meanwhile the light levels affected the production of Amaranth plants at the 5% level. Means, raising 5% of light levels caused declining 0.027 gram per plant of leaves production.

Table 4. Multiple Regression models of the growth and production of Amaranth

Independent Variables	**Dependent Variables**		
	Height	**Diameter**	**Production**
Constant	56.468	2.087**	23.370
Soil-humid relatively	-0.440	-0.019	-0.011
Light levels	-0.024	0.000	-0.027*
Survival rate of plant	0.076	0.002**	0.020
Percentage of damaged	5.282**	0.142**	2.586**
Alkaline concentrated (KB)	0.021	-0.004**	0.006

Soil-acids level (H^+)	-14.270	-0.330	-15.979
R square	**0.903****	**0.929****	**0.840****

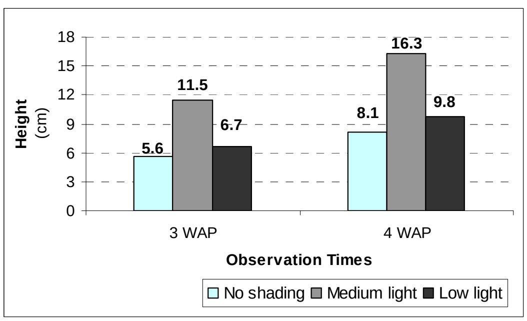
Note:
* : Significant at the 95% level
** : Significant at the 99% level

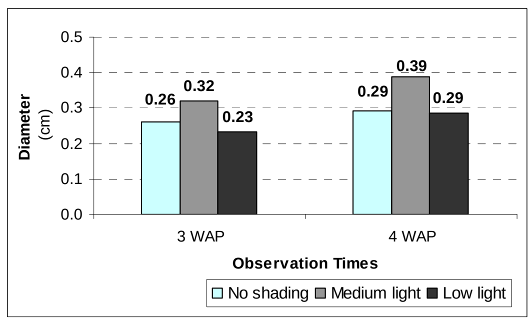
- **Kangkong (*Ipomoea aquatica* Forsskal)**

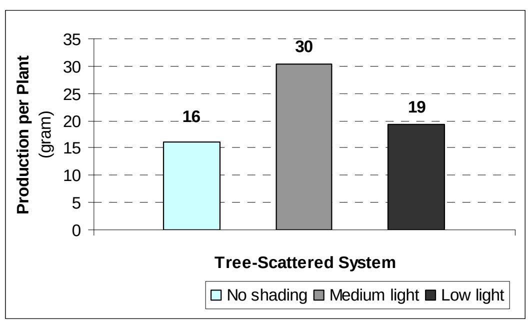
Same with Amaranth, Kangkong can be harvested in the week-4th after planting time (Graph 4). There was a significant difference between medium light plot and both no shading and low light plots on the growth and production of Kangkong plants. In addition, no significantly different between no shading plot and low light plot during 4 weeks of planting season.

In the medium light plot, the increment of Kangkong's height reached of 4.8 cm compared to the no shading plot (2.5 cm) and the low light plot (3.1 cm), respectively from week-3rd to week-4th measurement. Meanwhile, the increment of Kangkong's diameter increased slightly in all plots. Medium light and low light levels increased average Kangkong yields to 30 gram and 19 gram per plant (187.5% and 118.75%, respectively increased over the no shade control).

Graph 4. The growth and production of Kangkong during 4 weeks of planting season







Multiple Regressin models of the growth and production of Kangkong plants are showed by Table 5. The independent variables rose in the models and affected the growth and production of Kangkong plants are similar with the six independent variables. Soil-humid relatively, survival rate of plant, and alkaline concentrated (KB) have a significant affected on the increment height of Kangkong plants. Furthermore, soil-humid relatively, survival rate of plants, alkaline concentrated (KB), and soil-acids level (H^+) affected significantly at 1% level on Kangkong production. For instance, raising 1% of soil-acids level (H^+), alkaline concentrated (KB), survival rate of plant caused increasing 16.95 gram, 0.49 gram, and 0.60 gram per plant, respectively of leaves production, while the leaves production would decrease 1.19 gram per plant, when soil-humid relatively rose 1%.

Table 5. Multiple Regression models of the growth and production of Kangkong

Independent Variables	Dependent Variables		
	Height	**Diameter**	**Production**
Constant	8.574	0.409	47.273
Soil-humid relatively	-0.315*	-0.012**	-1.194**
Light levels	-0.002	0.000	0.000
Survival rate of plant	0.227**	0.007**	0.603**
Percentage of damaged	0.158	0.046*	0.597
Alkaline concentrated (KB)	0.271**	0.005**	0.497**
Soil-acids level (H^+)	5.251	0.187**	16.958**
R square	**0.724****	**0.591****	**0.682****

- **Egg plant (*Solanum melongena* L.)**

Graph 5 describes the growth and production of Egg plant plants in all trial plots. Medium light level affected significantly on the height and diameter of Egg plant by showing an upward trend during 10 weeks of planting season. In addition, the upward trend of height also occurred in both no shading and low light plots, while a stable trend of diameter occurred in these two plots. The height and diameter of plants in medium light plot hitted a peak of 61.9 cm and 1.16 cm, respectively in week-10th, compared to other plots only attained of nearly 40 cm and just over 0.6 cm in no shading plot and approximately 28 cm and 0.5 cm in low light plot. Furthermore, medium light level increased average Egg plant yields to 833 gram per plant (170.69% increased over the no shade control). Egg plant plants were able to produce about 42.82% of the full sunlight plot production under low light level.

Graph 5. The growth and production of Egg plant during 10 weeks of planting season

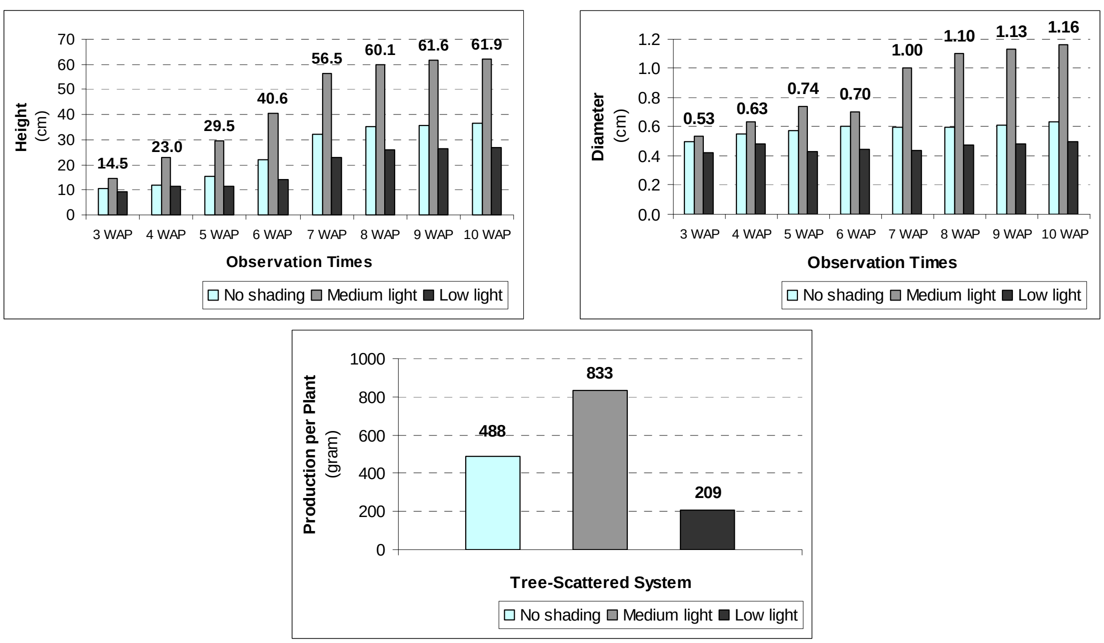


Table 6 describes the Multiple Regressin models of the growth and production of Egg plant. There are four independent variables rose in the models and affected the growth and production of Egg plant, such as soil-humid relatively, light levels, alkaline concentrated (KB), and soil-acids level. Alkaline concentrated (KB) has a very significant effect on height increment. Soil-humid relatively, alkaline concentrated (KB), and soil-acids level affected significantly on diameter increment of plants. Furthermore, alkaline concentrated (KB) and soil-acids level have a significant affected on production of plants. For instance, raising 1% of alkaline concentrated (KB) and soil-acids level (H^+) caused increasing 14.53 gram per plant of fruit production, while the fruit production would decrease by 416.58 gram per plant when soil-humid relatively rose 1%. The fruit production of Egg plant was affected by alkaline concentrated (KB) and soil-acids level (H^+) at 95.3%.

Table 6. Multiple Regression models of the growth and production of Egg plant

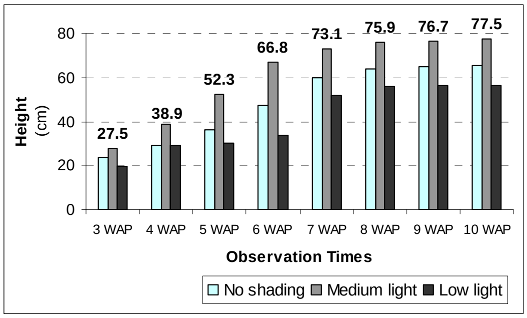
Independent Variables	**Dependent Variables**		
	Height	**Diameter**	**Production**
Constant	54.578	-0.041	881.437*
Soil-humid relatively	-0.413	0.009*	-5.833
Light levels	0.012	0.000	0.120
Alkaline concentrated (KB)	0.939**	0.014**	14.531**
Soil-acids level (H^+)	-7.280	-0.358**	-416.583**
R square	**0.897****	**0.963****	**0.953****

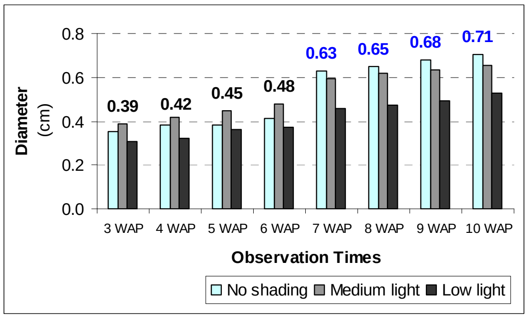
- **Chili (*Capsicum annuum* L.)**

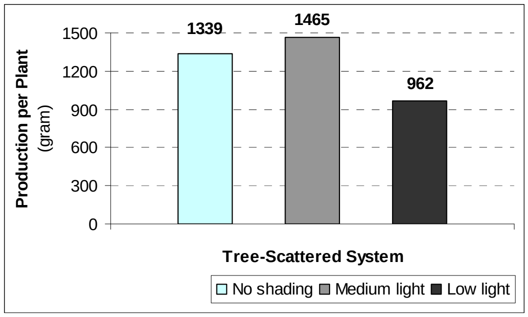
The height and diameter increment of Chili plants showed an upward trends in all trial plots (Graph 6). The height increment of Chili plants would grow higher under medium light level and it showed a significant difference to other light levels. There is no significant difference between the height increment of plants under full sunlight and low light level. While the diameter of plants under medium light level was lower slightly than under full sunlight since week-7th after planting time and it was not showed a significant difference, but both light levels showed a significant difference on diameter to low light level.

The height and diameter of Chili plants under medium light level hitted of peak of 77.5 cm and just over 0.6 cm, respectively compared to the no shading plot where the height and diameter achieved a peak of just over 60 cm and around 0.7 cm, respectively in week-10th. In addition, there was no significant difference on Chili production under medium light level and full sunlight control (1465 gram per plant and 1339 gram per plant, respectively), but Chili production (962 gram per plant) under low light level showed a significant difference to the other light levels. Although there was no significant difference on Chili production under medium light level and full sunlight plot, the medium light level increased average Chili yields to 1465 gram per plant (a 109.4% increased over the no shade control). However, Chili plants were able to produce about 71.84% of the full sunlight plot production under low light level.

Graph 6. The growth and production of Chili during 10 weeks of planting season







In Table 7, soil-humid relatively, light levels, survival rate of plant, percentage of damaged, alkaline concentrated (KB), and soil-acids level (H^+) confirmed very significantly different at 1% level to the height of Chili plants. For instance, raising 1% of light levels and soil-acids level (H^+) influenced decreasing the height of plants by 0.078 cm and 49.04 cm, respectively. The height of Egg plants was affected by those six variables at 89.0%. Chili production was not affected significantly by those independent variables. Soil-humid relatively, light levels, survival rate of plant, alkaline concentrated (KB), and soil-acids level (H^+) confirmed significantly different to diameter of Chili plants.

Table 7. Multiple Regression models of the growth and production of Chili

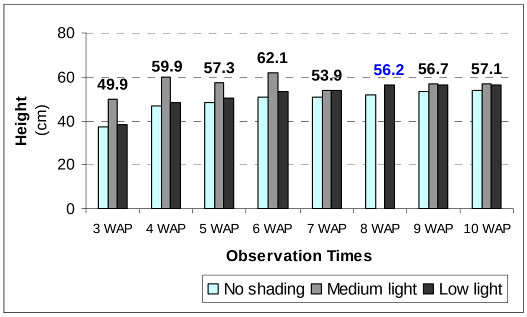
Independent Variables	**Dependent Variables**		
	Height	**Diameter**	**Production**
Constant	-225.772**	-0.541	616.902
Soil-humid relatively	1.172**	0.008*	11.895
Light levels	-0.078**	-0.001**	0.110
Survival rate of plant	2.439**	0.012**	-3.561
Percentage of damaged	0.530**	0.000	4.429
Alkaline concentrated (KB)	0.332**	-0.002*	6.843
Soil-acids level (H^+)	-49.042**	-0.630**	-345.936
R square	**0.890****	**0.782****	**0.384****

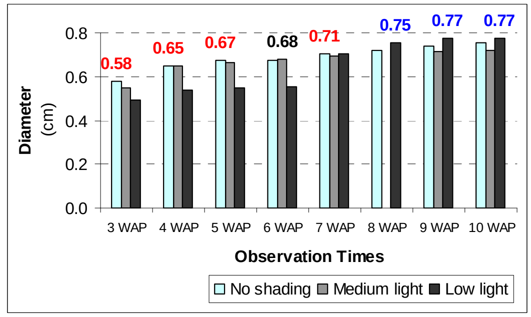
- **Tomato (*Lycopersicon esculentum* Miller)**

It can be seen in Graph 7 that the diameter of Tomato plants showed an upward trends under three different light level. The upward trends also occurred on the height of plants under full sunlight and low light levels, while the height of plants remained stable under medium light level. There was no significant difference on both growth variables under three different light level, but the diameter of plants under three light level hitted a peak of around 0.77 cm. In Graph 7, there is a week-8th data measurement was missing, namely growth of plant's diameter under medium light level. Tomato production under medium light and full sunlight levels was not significantly different (468 gram per plant and 436 gram per plant, respectively), but it was a significant difference between both light levels and low light level (319 gram per plant). Eventhough under low light level, Tomato plants were able to produce about 73.16% of the full sunlight plot production.

Almost all independent variable in Table 8 showed no significant difference on growth and production of Tomato plants, but only soil-humid relatively affected significantly at 1% level on diameter of plants. Raising 1% of the soil-humid relatively influenced increasing diameter of plants by 0.011 cm per plant.

Graph 7. The growth and production of Tomato during 10 weeks of planting season





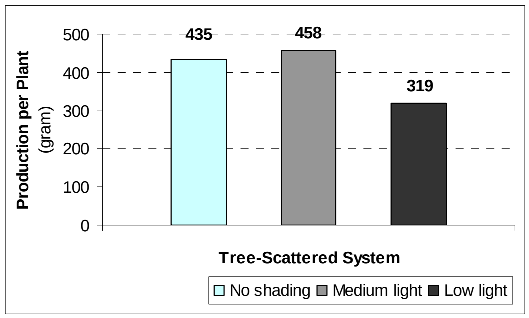


Table 8. Multiple Regression models of the growth and production of Tomato

Independent Variables	**Dependent Variables**		
	Height	**Diameter**	**Production**
Constant	63.745**	-0.235	-228.769
Soil-humid relatively	0.058	0.011**	14.784
Light levels	-0.015	0.000	-0.067
Survival rate of plant	-0.080	-0.004	-7.779
Percentage of damaged	-0.121	0.003	-5.338
Alkaline concentrated (KB)	0.051	0.000	5.211
Soil-acids level (H^+)	-0.460	0.252	90.079
R square	**0.175**	**0.400****	**0.298****

- **Long bean (*Vigna unguiculata* (L.) Walp.)**

Long bean is a leafy vegetables plant where the stem of long bean wound around the woody stick to grow normally, so it was quite difficult to release the wounded stem on the woody stick when height measurement would conduct every week. The height measurement was conducted only 2 times in week-3rd and week-4th after planting time (Graph 8). The height increment of plants increased rapidly by 96.3 cm during one week measurement. Medium light level affected significantly the height of plants compared to height of plants under full sunlight and low light levels. While the full sunlight has a significant difference with the low light level on affecting the height of plants.

In Graph 8, there is a week-8th data measurement was missing, namely growth of plant's diameter under medium light level. Diameter measurement was conducted during 10 weeks and the diameter increment showed an upward trends on three different light levels. There was a significant difference on the diameter of plants between full sunlight plot and both medium and low light levels, but there was no significant difference between medium and low light levels. Diameter of Long bean plants reached a peak of 0.61 cm on week-10th under full sunlight level.

Production of Long bean plants under full sunlight and medium light levels (448 gram and 439 gram per plant, respectively) has a significant difference with the Long bean production under low light level (287 gram per plant). Although under low light level, Long bean plants were able to produce about 64% of the full sunlight plot production.

Graph 8. The growth and production of Long bean during 10 weeks of planting season

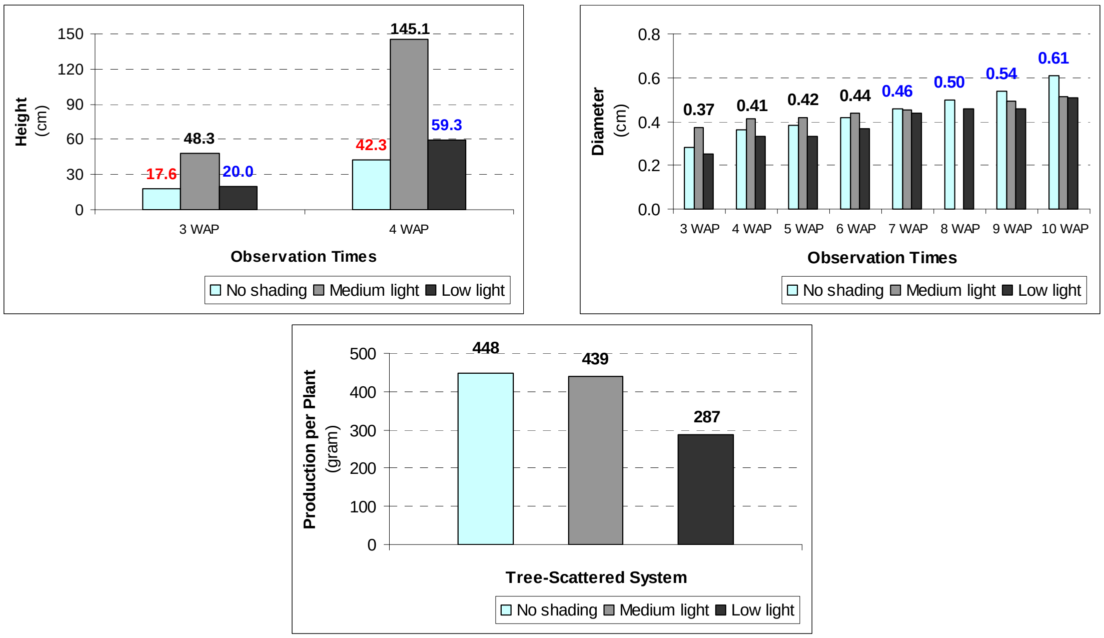


Table 9 shows that the percentage of damaged and alkaline concentrated (KB) were the main independent variables that affected significantly at 1% level on height of Long bean plants, while the percentage of plant damage was one of 6 independent variables that influenced significantly at 1% level on Long bean production. Raising 1% of the percentage of plant damage influenced decreasing production of plants by 38.69 gram per plant.

Table 9. Multiple Regression models of the growth and production of Long bean

Independent Variables	**Dependent Variables**		
	Height	**Diameter**	**Production**
Constant	-275.328	-0.296	1562.896
Soil-humid relatively	3.610	0.012	-15.051
Light levels	-0.055	0.000	0.524
Survival rate of plant	-0.257	0.000	-0.764
Percentage of damaged	8.102**	0.003	-38.693**
Alkaline concentrated (KB)	3.441**	-0.001	-1.525
Soil-acids level (H^+)	-38.775	-0.207	202.500
R square	**0.889****	**0.473****	**0.432****

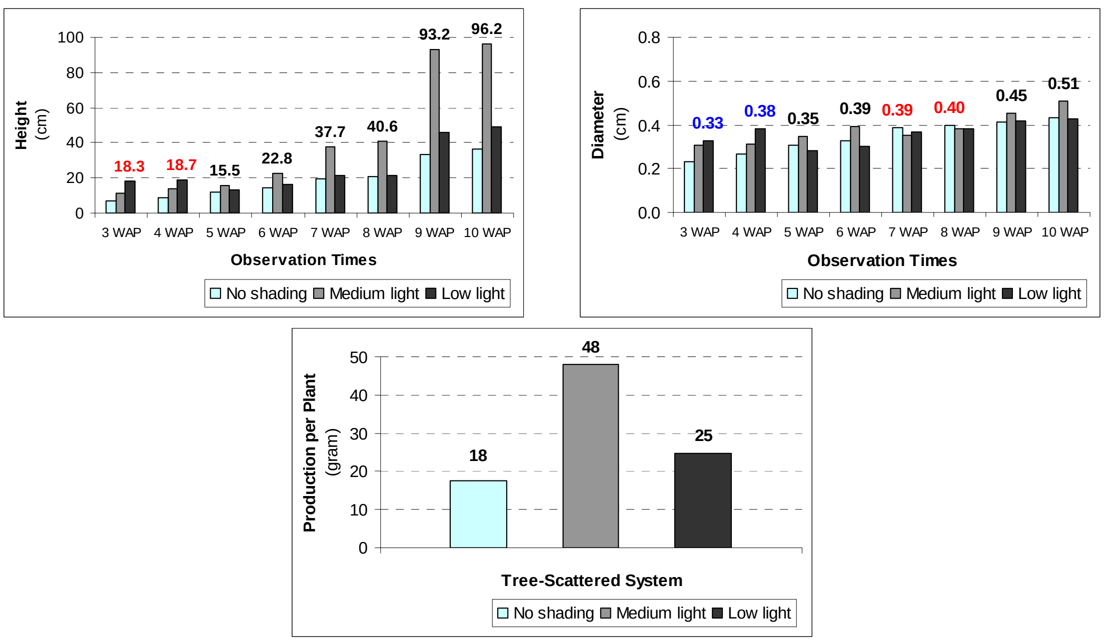
- **Katuk (*Sauropus androgynus* (L.) Merrill)**

Graph 9 shows that height of Katuk plants started to grow at about 10 cm and then went up dramatically and hitted a peak of around 96.2 cm at week-10th after planting time. Medium light level affected significantly the height of plants (96.2 cm) compared to height of plants under full sunlight and low light levels (just under 40 cm and just over 40 cm). While the full sunlight has a significant difference with the low light level on affecting the height of plants.

An upward trends was showed by the diameter of Katuk plants under three different light levels, and the diameter under full sunlight, medium light, and low light reached a peak of 0.4 cm, 0.51 cm, and 0.4 cm, respectively. In terms of diameter of plants, medium light level has a significant difference with other light level, but there was no significant difference between full sunlight plot and low light level plot.

In addition, there was a significant difference on Katuk production between three different light levels (medium light level, low light level and full sunlight control) and attained a peak of 48 gram, 25 gram, and 18 gram per plant, respectively). Medium light and low light levels increased average Katuk yields to 48 gram and 25 gram per plant (266.6% and 138.8%, respectively increased over the no shade control).

Graph 9. The growth and production of Katuk during 10 weeks of planting season



In three Multiple Regression models that is showed in Table 10, it can be seen that light levels, alkaline concentrated (KB), and soil-acids level (H^+) affected significantly at 1% level on growth and production of Katuk plants. In production model, for example, raising 1% of light levels, alkaline concentrated (KB), and soil-acids level (H^+) influenced increasing production of plants by 0.06 gram, 1.11 gram, and 36.71 gram per plant, respectively. The leaves production of Katuk was affected by those three independent variables at 78.8%.

Table 10. Multiple Regression models of the growth and production of Katuk

Independent Variables	Dependent Variables		
	Height	Diameter	Production
Constant	-178.264*	0.133	-78.990*
Soil-humid relatively	0.991	-0.002	0.385
Light levels	0.123**	0.001**	0.060**
Survival rate of plant	0.182	-0.002	0.080
Alkaline concentrated (KB)	2.215**	0.007**	1.110**
Soil-acids level (H^+)	73.765**	0.320**	36.713**

R square	0.809**	0.439**	0.788**

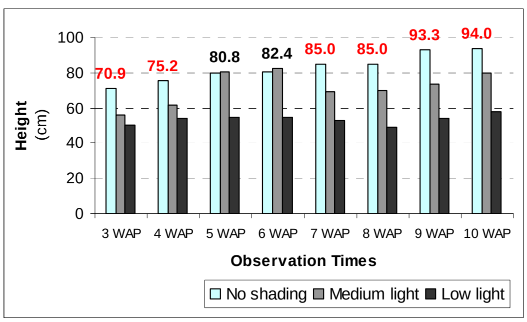
- **Honje (*Etlingera elatior*)**

The growth of Honje on height was not significantly different under three different light levels (Graph 10). Under full sunlight, the growth of height showed an upward trend and reached a peak of 34 cm. While medium light level influenced the height of plants by proving a fluctuated slightly trend. Moreover, in week-6th after planting time, the height of plants attained by 82.4 cm then went down before rose again and hitted to 80.0 cm. However, the growth of height plants under low light level remained stable that started from around 50 cm in week-3rd to nearly 60 cm in week-10th measurement.

In general, the growth of diameter under full sunlight and medium light levels have a significant difference with the diameter under low light level. The growth of diameter of plants showed a fluctuated trends under full sunlight, medium and low light levels. In no shading plot (full sunlight control), the diameter of Honje plants was around 1.57 cm on week-3rd measurement, then the growth increased rapidly and reached of 2.58 cm before dropped and rose again.

Honje (*Etlingera elatior*) is an indigenous perennial vegetable. The yield of this vegetable can be harvested started from month-8th after planting time. Limited on time and budget were our constraints to stop measurements on Honje production.

Graph 10. The growth of Honje during 10 weeks of planting season



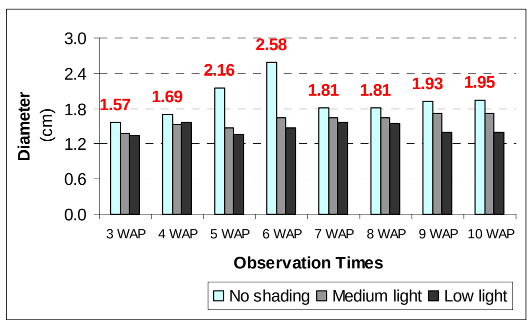


Table 11 shows the height and diameter of Multiple Regression models. Soil-acids level (H^+) affected significantly at 5% level on height and diameter of plants. Raising 5% of soil-acids level (H^+) influenced decreasing height and diameter of plants by 79.67 cm and 0.74 cm per plant, respectively.

Table 11. Multiple Regression models of the growth of Honje

Independent Variables	Dependent Variables		
	Height	**Diameter**	**Production**
Constant	-115.697	2.918	-
Soil-humid relatively	5.146	-0.007	-
Light levels	-0.144	0.000	-
Alkaline concentrated (KB)	-4.469	-0.003	-
Soil-acids level (H^+)	-79.676*	-0.741*	-
R square	**0.293**	**0.428****	**-**

- **Terubuk (*Saccharum edule*)**

In general, the growth of plant's height showed an upward trends under three different light levels, but there was no significant difference between those light levels. The height of plants reached a peak of 15.5 cm under medium light level. Meanwhile, the growth of plant's height under full sunlight and low light levels reached of just under 12 cm. In Table 12, there was no independent variable affected significantly on height of Terubuk plants.

In Graph 11, there are two data measurements were missing on week-8th, namely growth of plant's height and diameter under low light level. Besides that, there is a strange data or information where growth of plant's diameter plunged dramatically from 2.22 cm on week-7th to nil data or just under 0.50 cm on the next week measurements. Perhaps some mismeasurements occurred, where the position measurement changed and or replacing plants sample that caused by died plants. Because of these mismeasurements, the significant affected of some independent variables on diameter of plants could not use correctly (Table 12).

Graph 11. The growth of Terubuk during 10 weeks of planting season

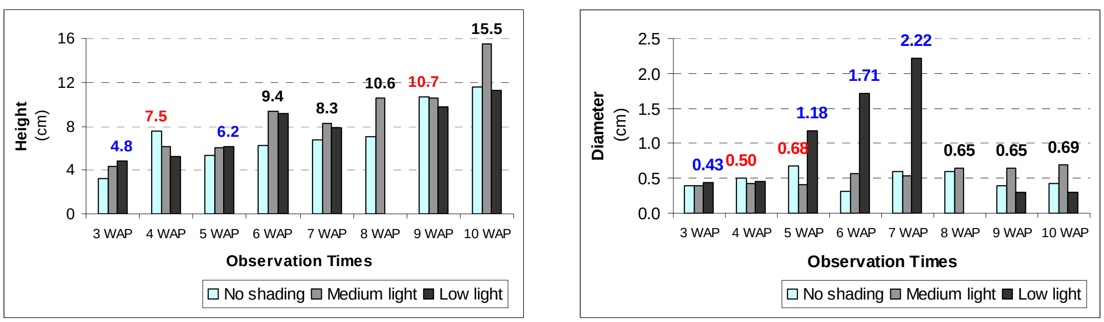


Table 12. Multiple Regression models of the growth of Terubuk

Independent Variables	**Dependent Variables**		
	Height	**Diameter**	**Production**
Constant	42.402	-1.527	-
Soil-humid relatively	-0.362	-0.025*	-
Light levels	-0.008	0.006**	-
Survival rate of plant	0.064	-0.004	-
Alkaline concentrated (KB)	0.039	0.035**	-
Soil-acids level (H^+)	-1.407	2.523**	-
R square	**0.204**	**0.778****	**-**

Discussion

In general, some vegetables showed a good performance on growth (height and diameter) and production in understory of 2 plots that represented of the mixed fruit-timber-bananas-annual crop systems and the mixed fruit-timber systems compared to the full sunlight (no shading) plot. The vegetables included were amaranth (*Amaranthus* sp.), kangkong (*Ipomoea aquatica* Forsskal), egg plant (*Solanum melongena* L.), chili (*Capsicum annuum* L.), tomato (*Lycopersicon esculentum* Miller), long bean (*Vigna unguiculata* (L.) Walp.), and katuk (*Sauropus androgynus* (L.) Merrill). In understory of the mixed fruit-timber-bananas-annual crop systems (under medium light level), the production of those vegetables over the no shade control (from 107.33% to 278.2%). Furthermore, those seven vegetables were able to produce at least about 42.82% of the full sunlight plot production under low light level.

Meanwhile, honje (*Etlingera elatior*) and terubuk (*Saccharum edule*) have a good growth. Limited on time and budget were the constraints to stop measurements on honje production, because of the yield of this vegetable can be harvested started from month-8th after planting time. In addition, most green bean (*Phaseolus vulgaris* L.) and kenikir (*Cosmos caudatus* Kunth) plants died were caused by pest (insects) attacks on the full sunlight farming system and in the mixed fruit-timber system since first three to five weeks.

The good performance on growth and production of each vegetable would have a significant relationship with the land-use history of the trial plots. The three plots of trial are owned by three different owners. The imperata grassland was the main land-use type in the full sunlight plot previously. There were around eight years where this plot was under the imperata grassland management. Limited water supply was the main reason for the owner to convert this plot (land) from the semi-irrigated paddy field to the imperata grassland system. Besides that, same situation occurred to the mixed fruit-timber plot, where according to the owner mentioned that annual crops or vegetables would not grow well in understory of tree shading and high density. In the last eight years, the owner had abandoned the plot with purposed to improve soil fertility of the plot by decomposting organic matters (leaves, branch, and fruits) on the soil surface. On the other hand, the mixed fruit-timber-bananas-annual crop plot was cultivated intensively by the owner. When the water supply limited in the last 10 years in Nanggung area, the owner had converted the plot from semi-irrigated paddy field to an annual crop farming system by increasing much organic-fertilizer and the dolomite to enhance the fertility of soil and reducing the number of unproductive-trees.

Based on the Farm and Household Economic in Nanggung area study (Budidarsono *et al.*, 2004) mentioned that typically, dudukuhan systems – which average area per plot 0.25 ha – receive little proactive management. Harvesting is the most common activity, conducted in 35.9% of dudukuhans during the period analyzed by the study. Weeding and maintenance of tree or annual crops is the second most common activity, conducted 15.1% of the dudukuhan plots. The number of person-days committed to harvesting (30 ps-d/ha) was less than the number of person-days used in weeding and maintenance (95 ps-d/ha). Chemical fertilizer was applied in only 1.4% of dudukuhans; with organic fertilizer applied to 3.1%. The average application of chemical fertilizer was very low, only 30.0 kg ha^{-1}; the average application of organic fertilizer was reasonably high (1.9 tons ha^{-1}).

Preliminary results indicate that vegetable production under dudukuhan (agroforestry) systems shade is a viable option for smallholder farmers. There are some advantages can be taken by smallholder farmers by intensifying their dudukuhan (agroforestry) systems for vegetables cultivation as following: 1) restoration of degraded lands, 2) reduction of insect or disease damage, 3) market risk may be reduced by growing a variety of products, 4) produce facilitative interactions, 5) improving individual-timber tree growth rate and stem quality, and 6) increasing carbon and nutrient sequestration. Intensifying without adding cost of production is the main purpose of smallholder farmers.

However this on-farm research needs to be replicated to other dudukuhan (agroforestry) sites in Nanggung area and in different planting season as justification to quantify the *tree-vegetable-site matching*. The results of tree-vegetable-site matching study would give appropriated options to the smallholder farmers to develop such deliberate management practices. A program of training and extension support would help smallholders develop such deliberate management practices.

Conclusion

Vegetable production under dudukuhan (agroforestry) systems shade is a viable option for smallholder farmers. However this on-farm research needs to be replicated to other dudukuhan (agroforestry) sites in Nanggung area and in different planting season as justification to quantify the *tree-vegetable-site matching*. The results of tree-vegetable-site matching study would give appropriated options to the smallholder farmers to develop such deliberate management practices.

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