CHAPTER 5. EMPIRICAL RESULTS AND DISCUSSION

In this chapter, the stochastic frontier production function for each crop is estimated and the returns to scale are tested. Where the frontier production function is estimated, a technical efficiency index is calculated for each observation, and is used as a dependent variable to be estimated by a logit model using a set of explanatory variables, include farm size.

5.1. Simple Correlations among the Explanatory Variables.

The simple correlations among the explanatory variables are presented in table 5.1. Very high correlations are observed between some variables, especially between land size (LD) and seed, land and labor (LB). It is reasonable to find high correlations between land and other variables since crop production normally demands inputs on the basis of per unit of land area. If a farmer uses 20 man-days and 100 kg of seeds for a rai of land, he will normally use about 40 man-days and 20 kg of seeds for 2 rai.

However, high correlations among the explanatory variables may cause multicollinearity problems. Since the data set of the present study are generated by the agricultural systems in the study area, increasing observations will not help, as more data only result in "more of the same". On the other hand, omitting one or more variables may result in model specification errors, and hence biased estimates. The trade-off between specification error and the gain from the improvement in multicollinearity should therefore be carefully weighed.

Table 5.1. Simple Correlations among the explanatory variables

(RICE, n=193, d.f.=191)

	LD	LB	SEED	PEST	HERB	FERT1
LB	0.8640					
SEED	0.9224	0.7620				
PEST	0.5654	0.4071	0.6444			
HERB	0.7136	0.5822	0.7424	0.6667		
FERT1	0.0130	0.0024	-0.0308	-0.0391	0.1324	
FERT2	0.7440	0.5123	0.7998	0.7373	0.6886	0.0079

(Soybean, n=70, d.f.=68)

	LD	LB	SEED	FERT1	FERT2	PEST
LB	0.9196					
SEED	0.9204	0.8624				
FERT1	0.3922	0.3788	0.3797			
FERT2	0.4650	0.4441	0.4276	-0.2043		
PEST	0.8682	0.8057	0.8774	0.4594	0.4410	
HERB	0.7807	0.7047	0.7181	0.4869	0.5204	0.8465

(Potato, n=60, d.f.=58)

	LD	LB	FERT1	PEST	HERB
LB	0.9814				
FERT1	0.4606	0.4967			
PEST	0.7187	0.7148	0.5208		
HERB	0.0257	0.0588	0.0961	0.1617	
SEED	0.8760	0.8805	0.3691	0.5393	-0.1229

Table 5.1. (Cont.)

(Tomato, n=67, d.f.=65)

	LD	LB	FERT1	FERT2	FERT3	PEST
LB	0.9281					
FERT1	0.0046	0.1519				
FERT2	0.6136	0.7676	-0.1175			
FERT3	0.9330	0.8976	-0.0097	0.8317		
PEST	0.8693	0.9515	0.2773	0.7832	0.8606	
HERB	0.8540	0.7914	0.0476	0.6834	0.8060	0.7444

Garlic, n=60, d.f.=58

	LD	LB	FERT1	FERT2	PEST
LB	0.7486				
FERT1	0.4552	0.6066			
FERT2	0.6364	0.6114	0.9391		
PEST	0.5958	0.6619	0.4756	0.4962	
HERB	0.9494	0.8032	0.5760	0.6943	0.6318

Fortunately, the production model in this study is specified to be the Cobb-Douglas form, and the main objective is to investigate the size efficiency of crop production, which can be measured in terms of "returns to scale". Some researchers have noted that when multicollinearity exists, the summation of the estimated correlated coefficients is still estimated fairly precisely, even though there may be biases in one or more single coefficients of the production function (Johnston, 1984).

This is so because if one estimated parameter overestimates the true parameter, a second parameter is likely to underestimate, and vice visa (Pindyck and Rubinfeld, 1981). Therefore, in this study, explanatory variables are not to be omitted.

5.2. Ordinary Least Squares (OLS) or Generalized Least Squares (GLS) Estimates

The specified model for each crop is first estimated by OLS method. Breusch and Pagan's method is used to test heteroscedasticity against homoscedasticity. Chi-square tests show that heteroscedasticities exist in the rice and tomato models, therefore, Generalized Least Squares (GLS) method of correcting heteroscedasticity as proposed by White (1978) is employed to get the production parameters. The estimation procedure is done by using the LIMDEP program. Results of OLS or GLS estimates of production functions of each crop are presented in table 5.2. The high R squares associated with the estimate indicate that generally these models are fitted well. The elasticities[4] of production for each input are discussed in detail in the following section.

5.2.1. Labor

The elasticities of labor in the production of these five crops are small and not significantly different from zero at 10% confidence level, except for that of tomato. One reason for the relatively high value of labor elasticity in tomato production may be that the data of labor inputs

[4] Elasticity is defined as the percentage of output increase by one percent increase of input. In the Cobb-Douglas production case, elasticity and coefficient are the same.

include harvesting labor. Since tomato harvesting is labor intensive, high output demands high labor input, while this does not apply much to other crops studied. Low and insignificant elasticities of labor in crop production were also reported by many others. One possible reason is that it is caused by multicollinearity, since labor and land and other variables have high correlations. Still, there are other reasons. The most important one may be the quality of labor. High skilled laborers are able to finish the same kind of job in a shorter period than those with less skill. Another cause is that farmers may have different working efficiency, some farmers may have more break time than others, however, they report the time spent in the field. The last explanation is that there is over utilization of labor in the production of these crops.

The insignificant elasticities of labor for rice, soybean, tomato and garlic production implies that the marginal product of labor for these crops is zero. For tomatoes, at 90 percent confidence level, the marginal product of labor, calculated at mean level of inputs and outputs, is 9.6 kg per man-day.

5.2.2. Chemical Fertilizer

The elasticities of fertilizer inputs are significantly different from zero at 10 percent confidence level, except that of soybean fertilizers; urea and 13-13-21 for tomato. The elasticities of fertilizers in soybean production are negative, but not significantly different from zero. This either means farmers over-apply fertilizer in soybean production, or farmers apply fertilizer at an inappropriate time (stage of soybean development). As pointed out in the previous chapter, some farmers spray forial fertilizer as

Table 5.2. OLS or GLS Estimates of Cobb-Douglas Production Functions

Variables	Models				
	Rice (GLS)	Soybean (OLS)	Potato (OLS)	Tomato (GLS)	Garlic (OLS)
ONE	6.4114 *** (48.1)	5.6909 *** (24.9)	6.2031 *** (5.86)	7.4146 *** (23.20)	7.1263 *** (33.74)
LD	0.9298 *** (26.75)	1.0696 *** (14.47)	.5871 *** (2.35)	.7520 *** (9.514)	.8013 *** (18.85)
LB	0.0484 (1.26)	-.0832 (-1.243)	-.3657 (-1.31)	.1199 ** (1.99)	.0442 (1.23)
PEST	.0024 ** (2.23)	-.0036 (-.624)	.1350 (1.24)	.0840 *** (2.59)	.0041** (2.48)
HERB	.0058 ** (1.96)	.0049 (1.06)	.0074 (.938)	.0359 (1.57)	.0736* (1.81)
FERT1	.0061 *** (3.11)	-.0058 (-1.60)	.1740 ** (2.35)	.0031 (1.39)	.1362*** (3.26)
FERT2	.0029 * (1.65)	-.0043 (-1.13)		.0052*** (2.90)	-.0883** (-2.13)
FERT3				.0028 (.043)	
SEED			.3494*** (2.64]		
F statistics	664.20	166.13	15.10	778.76	1334.47
d.f.	(6, 186)	(7, 62)	(6, 53)	(7, 59)	(6, 53)
R squared	.9554	.9494	.6310	.9883	.9934
Adjusted R^2	.9540	.9438	.5892	.9880	.9927

Note: The table should be read by column

Value in ( ) is t ratio.

***, **, * stand for significant at α =.01, α =.05 and α =.1 respectively.

many as 4 times, and another 8 farmers apply 24.4 kg per rai of 12-24-12.

The elasticity of urea in tomato production is also not significantly different from 0. This may be that all farmers in the sample apply urea, and the variation of per hectare application is small, and the total urea application is highly correlated with operation size and other variables (table 5.1). This means multicollinearity may exist, and the insignificant coefficient may be a result of multicollinearity.

In garlic production, the elasticity of nitrogen and phosphorous are high and significantly different from 0. However, the elasticity of potassium is negative. Given that farmers use only two formulas of fertilizers, 13-13-21 and 15-15-15, this suggest that farmers would be better paid if they can shift from 13-13-21 to 15-15-15.

Fertilizer seems to be most effective in potato production, while in rice production, its effects are small. An inspection of the data and cropping systems reveals that, farmers use large quantity of chemical fertilizers in the dry season crops. There might be residue fertilizer effects from previous crops. In fact, some farmers do not apply fertilizer to their rice crop because they believe that the residue fertilizer is adequate for rice. However, it is not possible in this study to determine the exact effects of fertilizer applied to the previous crops, since the data only cover one year and information on preceding crops is not available.

5.2.3. Pesticide and Herbicide

The effects of pesticide expenditures on crop outputs are generally significantly different from 0, except that of soybean and potato. However, all elasticities are small, and that of soybean is negative, though not significant. According to farmers interviewed, if they do not find insects, farmers are not going to use any pesticide. This means they apply pesticide only when there is need. If some farmers do not find insects in their field, their crop is healthy and hence produce good yield even without pesticide spraying. Therefore, the low elasticity is plausible.

Herbicide makes a significant contribution to rice and garlic yield, although the impact is very small. However, its contribution to soybean, potato and tomato are small and not significantly different from zero.

5.2.4. Seeds

Seeds seem to be only significant in potato production, and therefore are omitted in other crop models. The elasticity of seeds in potato production is high. One reason is that the variation of per hectare seed use in rice, soybean and garlic production are small, while that of potato is high. Another reason may be that potato production use tuber as its seed, and plant population depends heavily on original plants per unit of land area. This is different from rice, which is able to make tillers and therefore increases plant density.

5.3. Returns to Scale

The estimates of returns to scale for rice, soybean, potato, tomato and garlic are, respectively, 0.9954, .9777, 0.8871, 1.0027 and 0.9732. The F tests show that all are not significantly different from one at 10 percent confidence level (table 5.3). Hence, it is concluded that there are constant returns to scale in rice, soybean, potato, tomato and garlic production.

Table 5.3. Estimates of Returns to Scale

	Model				
	Rice	Soybean	Potato	Tomato	Garlic
Returns to scale	.9954	.9777	.8908	1.0027	.9712
F statistics of constant return to scale	.043	.449	1.177	0.04	2.767
d.f.	(1, 186)	1,63	1,53	1,59	1,53
Significant level	.790	.505	.283	.98	.1021

5.4. Frontier Production Function Estimation

Using the same specification as OLS and GLS, a stochastic frontier production function is estimated for each crop through Maximum Likelihood Iteration. Results are presented in table 5.4. The estimates of soybean and potato production functions are identical to OLS estimates, and σ_u^2

= 0. This means that sampled farmers do not exhibit much difference in technical inefficiency. Therefore, frontier estimation results are only presented for those of rice, tomato and garlic crops. There is no substantial difference in the magnitudes of the coefficients between the two estimates. However, the returns to scale estimated in the frontier functions tend to be smaller than their respective OLS estimates in all crops.

The mean technical inefficiency of the sample as calculated through Eq. 3.5, $E(u) = \sigma_u \cdot (2/\pi)^{1/2}$, is .07793, .06385 and .04561, respectively, for rice, tomato and garlic. Translating them into technical efficiency index, rice, tomato and garlic farmers are 92.5, 93.81 and 95.54 percent technically efficient. This means, on average, farmers achieve as high as 92.54, 93.81 and 95.54 percent of the maximum possible output with the current level of farm inputs and technology. This suggests that there are slight possibilities to increase output through raising technical efficiency.

Individual technical inefficiency is calculated via Eq. 3.8 and is plotted in figure 2. The average inefficiency as of the mean of individual observation is .07705, .05025 and .045489 for rice, tomato and garlic crop respectively, expressed in technical efficiency index is 92.64, 95.14 and 95.60 percent respectively. It seems that average inefficiency calculated in this way is smaller than the results from Eq. 3.5.

There are 19, 4 and 4 farmers of rice, tomato and garlic growers who are less than 90 percent efficient. The most inefficient farmer in each of rice, tomato and garlic growers produces only 73.87, 82.89 and 87.36 percent of

Table 5.4. MLE of Cobb-Douglas Frontier Production Functions

Variables	Models				
	Rice	Soybean	Potato	Tomato	Garlic
ONE	6.4850 *** (38.8)	Coefficients are the same as OLS Estimates		7.2904 *** (24.33)	7.3292 *** (51.47)
LD	0.9232 *** (20.3)			.7075 *** (11.15)	.8376 *** (20.58)
LB	0.0527 (1.10)			.1516 * (1.68)	.0070 (.288)
PEST	.0024 (.894)			.0908 * (1.71)	.0057 ** (2.14)
HERB	.0049 *** (3.37)			.0287 (.763)	.0729 ** (2.25)
FERT1	.0083 ** (2.55)			.0031 *** (2.60)	.1373 *** (2.66)
FERT2	.0020 (.787)			.0061 ** (2.04)	-.0946* (-1.68)
FERT3				.0134 (.424)	
Returns to scale	.9915			1.0011	.9658
σ	.136585 *** (10.42)			.0723686 *** (6.726)	.0592208*** (5.168)
λ	1.02297 *** (2.626)			1.86142 ** (2.075)	3.69211 (1.599)

Note: The table should be read by column

Value in ( ) is t ratio.

***, **, * stand for significant at α =.01, α =.05 and α =.10, respectively.

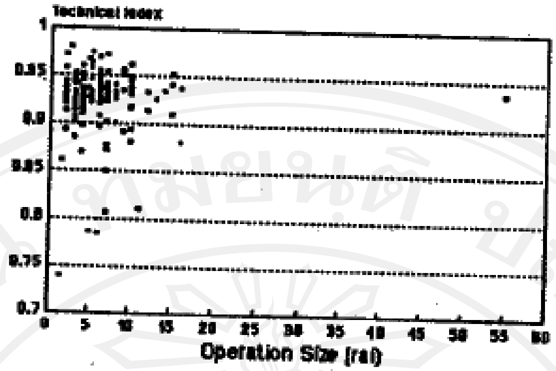

Figure 2-a.

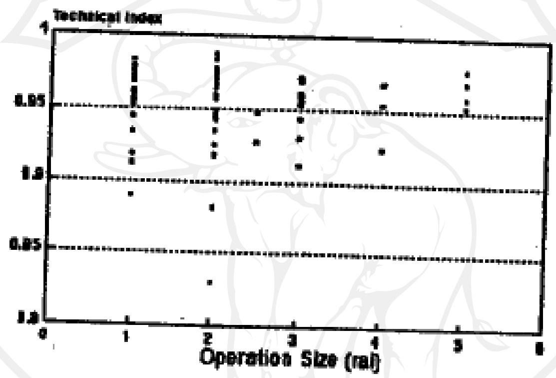

Figure 2-b.

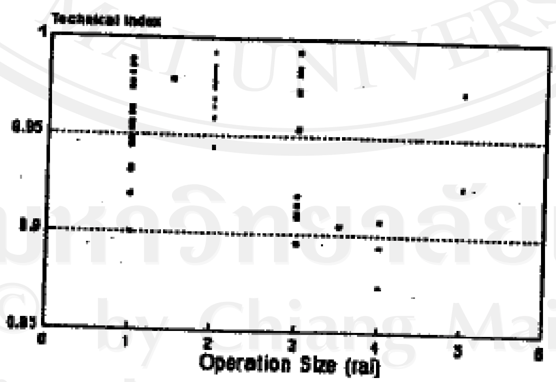

figure 2-c

Figure 2. Plotting of Technical Efficiency and Operation Size of Rice (fig. 2-a), Tomato (fig. 2-b), Garlic (fig. 2-c).

Table 5.5. Description of Sample Inefficiency and Technical Efficiency Index (TE)

	Individual calculation via Eq. 3.8					Sample mean via Eq. 3.5	
	Variable	Mean	Variance	Min.	Max.	E u	Variance
rice	- u	.077059	.001203	-.3028	-.01871	-.07793	.003313
	TE	.92637	.000927	.7387	.9815	.9250	-
tomato	- u	.050254	.000948	-.1877	-.01187	-.06365	.001477
	TE	.95142	.000811	.8269	.9882	.9381	-
garlic	- u	.045490	.001035	-.1352	-.00607	-.04561	.001187
	TE	.95601	.000820	.8736	.9939	.9554	-

maximum output producible with their bundles of inputs. The general description of technical inefficiency is presented in table 5.5.

5.5. Factors Associated with Technical Efficiency

A number of socio-economic variables are hypothesized to affect technical efficiency. For rice, these are operation size (planted area), labor input, cropping systems, distance between the field and the farm residence, and rental status. For tomato and garlic, the variables include operation size, labor input, years of growing the crop concerned, and rental status. Details of variable coding are available in Chapter 4, table 4.13.

The logit approach is employed for the analysis. The estimated results are presented in table 5.6. It is found that in the rice crop, larger farmers seem to be technically less efficient at 5 percent significance level, while in the case of tomato and garlic, larger farmers tends to be more efficient, but these coefficients are not significantly different from zero. It should be pointed out that although a 5 percent significance level is found in the case of rice, the coefficient itself is very close to zero.

Table 5.6. Logit Models of Technical Efficiency

Rice			Tomato			Garlic		
Variable	Coeff.	T-ratio	Variable	Coeff.	T-ratio	Variable	Coeff.	T-ratio
ONE	2.5044 ***	24.41	ONE	2.3676 ***	4.79	ONE	2.1471 ***	2.678
LD	-.0528 **	1.96	LD	.0214	.108	LD	.2132	.933
LB	.0027 *	1.91	LB	.0001	.030	LB	-.0027	-.443
POTATO	-.1117	-1.331	YEAR1	.0333	1.126	YEAR2	.0034	.049
TOMATO	-.0440	-.379	DIST	.0659	1.121	DIST	.2174 ***	2.745
GARLIC	-.0026	-.026	TENANT	.1544	1.007	TENANT	.4037 *	1.771
DIST	.0098	.375						
TENANT	.0096	.150						
R^2	.0434			.0503			.2346	
F statistics	1.128			.6457			3.310 *	
No. of observations	Rice = 182			tomato = 67			Garlic = 60	

Note: 1. For model specification, see table 4.13.

2. Left hand side variable is log [TE/(1-log TE)], see Equation 4.6.

3. ***, ** and * stand for significant at α =.01, α =.05 and α =.10, level respectively.

Technically, rice production in all four cropping systems is equally efficient, although rice grown after soybean seems to be more efficient than that of other crops. It is expected that soybean can fix and bring extra nitrogen to the succeeding crop, but the effects seem to be small. The reason may be that in this sample, farmers use large amount of chemical fertilizer to potato, garlic and tomato. The residue fertilizer still effects rice crop. Therefore, the difference of rice production obtained from soybean and other cropping systems are small.

More labor input for crop care is expected to bring more efficiency to the crops. This is true for rice and tomato, but not for garlic, in which the variable labor carries a negative sign. Nonetheless, the values are still small.

In this study, it is found that the tenant farmers are slightly more efficient than the owner-operators, though the coefficients are not significantly different from zero. Although unpredictable, it is not improbable to find that tenant farming is more efficient than owner-operators. It is possible that tenant farmers are more efficient since they are pushed to work hard in order to pay rent and earn sufficient income. On the contrary, owner-operators may feel more secure since they are better off and hence work less. However, the coefficient is quite small, therefore, it is still reasonable to conclude that tenant and owner-operators are equally efficient in technical aspect. This confirms the theory and results by Cheung (1969) and Ip and Stahl (1978) in the developing countries that "little or no productivity differential was found among the alternative forms of land tenure". However, it does not agree with the findings by Adams and Rask (1968) and Bardhan and Srinivasan (1971), who all report that in the developing countries tenant farmers are less efficient. This finding may be useful in policy direction, since it means that land ownership is not a sound way to improve technical efficiency.

Also unexpected is the sign of the coefficient of distance from farm field to farm residence. Generally, one will expect that the farther the field is away from the farm residence, the less effort the crop will receive, since it is more difficult for farmers to take care of it. However, in this study, results show that if the field is fartheraway, higher efficiency could be gained. Nevertheless, only in the case of garlic is the coefficient significant. One reason is that in this study, farm land is generally in the same village, and the distance is short. Farmers can reach their field easily. In the case of such a short distance,it might also be possible that some domestic livestock damage field crops if the field is too close to residential area. In fact, data indicate that there are some farmers whose field is less than 200 meters from farm residence.

The variable of years of growing crops may have two distinct effects on production efficiency. One is the experience accumulated through growing the crop. It is expected that the longer a farmer grows the crop, the more efficiency he can gain. However, this effect may become less sound in a modern agricultural society where extension networks have been widely set up. On the other hand, if a farmer chooses to practice the same cropping system year after year, soil nutrient balance may be disturbed, and soil inherited disease and pest may accumulate. The reasons of insignificant contribution of years of growing is therefore unexplained, since data in this study are not able to show which direction is more dominant.

5.6. Discussion

5.6.1. Almost Zero Marginal Productivity of Labor

The marginal product of labor almost equals zero, suggesting that farmers view their family labor as having zero wage rate, even though market wage rate of hired labor is about 50 baht per day. This phenomenon is also observed elsewhere by several researchers. Booth and Sundrum (1985) did an intensive survey on labor absorption of small farmers in the developing countries. They found that in developing countries, where underemployment is common, farmers tend to use labor until its marginal product equals zero. This is especially true in smaller farmers. In this study, there is also evidence that small farmers use more labor per rai than larger ones. Figure 3 shows this trends.

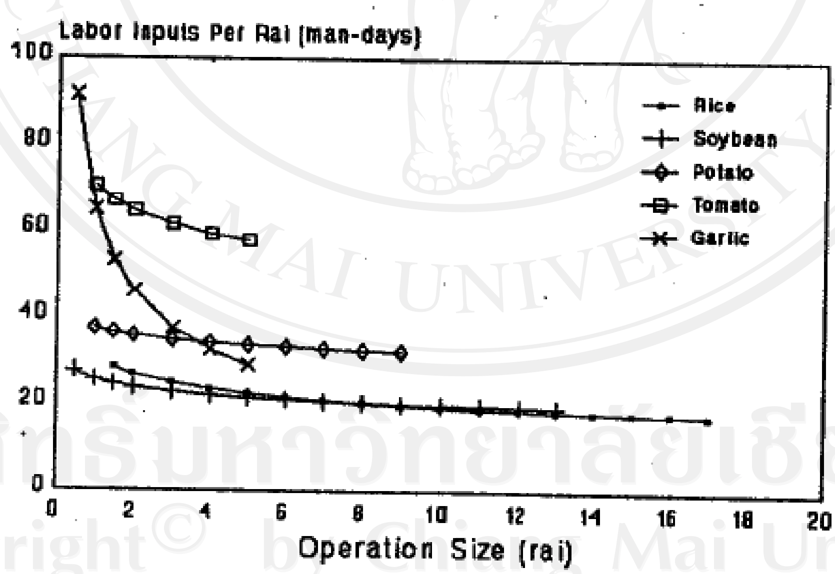

Figure 3. Operation Size and Labor Input in Crop Production

Sen (1964) finds that although a market wage rate exists , farmers still view their family labor as having much lower value in their family farm production. The reasons are mainly sociological. Firstly, although presumably the family labor would receive a market rate of wage from an employer, this rate may well be lower than the *average* product of labor on the family farm. Thus, although family income as a whole would rise if a member chose to work outside and contribute his earnings in exchange for his share of farm output, such an exchange may not be practical. This is also observed in Thailand. Farmers feel more comfortable if they work together in the field and share output on the table. On the other hand, if a farmer works for wage income, he may still work in the family farm after regular hours, he tries to "help" his family. He may have a feeling of participating in farm work. In this case, his "wage rate" of working in his family farm is well near zero. Therefore, farmers are rationale to input more labor.

A second reason concerns cultural and status constraints which prevent certain types of workers from offering themselves on the market for hired labor. This is especially true when a woman has to take care of her family. She is not able to work in the wage market, which is usually on daily or even monthly basis. However, she is able to work in her own family farm on an hourly basis.

5.6.2. Land Holding and Cropping Intensity

Although there is evidence that rice, soybean, potato, tomato and garlic production is characterized by constant returns to scale, there is also evidence to show that smaller farmers use their land more intensively. The total cropped acreage (rice and dry season crops) divided by land holding, expressed in percentage, is defined as cropping intensity.

Regression analysis shows that when farm holding increases, cropping intensity tends to decrease non-linearly (Fig. 4). This result is consistent with other findings in many developing countries (Booth and Sundrum, 1985). Therefore, decision processes of small and larger farmers are different, and small farmers are more efficient in using their land.

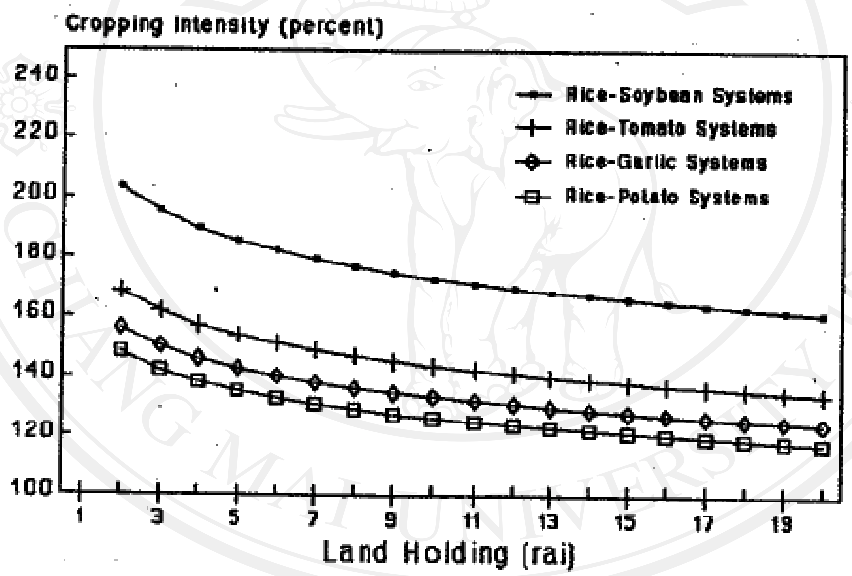

Figure 4. Cropping Intensity by Land Holding in Different Cropping Systems