Characterization of Farm Mechanization Among Lowland Rice Farmers in Laguna, Philippines

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Abstract

The study was conducted to characterize farm mechanization and determine its economic effects on rice production, income and employment. Ninety rice farmers were randomly selected and classified into three types: high, intermediate, and low-mechanized farms. The results of the study show that highly mechanized farms commonly own pumps, hand tractors, power tillers, and threshers while low mechanized farms tend to rent out their farm operations. The mean horsepower values tend to be higher in land preparation and threshing. The higher the level of mechanization, the higher the output and income per hectare: highly-mechanized farms with PhP 40,446; intermediate farms with PhP36,936; and low-mechanized farms, PhP 19,965. The study also reveals that farm mechanization has a negative effect on farm labor employment. Highly mechanized farms employ the lowest number of farm labor in man-days but employ the highest number of labor on post-production activity, specifically threshing.

Keywords: *farm mechanization, rice farming, employment, input use, farm income*

Introduction

The mechanization of farms in Asia and the Philippines affects all production stages from land preparation to weeding, harvesting, and postharvest operations. Mechanization decreases the amount of time and level of effort required to finish a particular farm activity. Mechanization thus increases agricultural output generated from larger harvested area and higher yields resulting from better cultivation practices and consequently lowers per unit cost of production.

Agricultural mechanization targets the rice industry in the country. This is one of the most significant sectors of the economy, contributing 32.4% of the total value-added for the agricultural sector in the last quarter of 2015 with more than two million farmers relying on the rice industry as a major source of livelihood (PSA 2016). The central role of rice as a political good and as major staple product makes the industry an important sector in the economy. The government therefore ensures that there is enough supply of rice for the whole country. Machines and equipment along with other factors in farming and management practices form part of the government's technology-boosting strategies to increase efficiency in rice production. According to PCAARD (2009), the use and application of such machineries is one way of maximizing farm production and profit. This is also one way of lowering the cost of production with a view of becoming competitive with other rice producing countries in the ASEAN region. High labor cost comprises much of the cost of producing rice in the Philippines.

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Despite these benefits, mechanization continues to be hounded by its labor displacement-effect when hired farmers lose their livelihood because machines do a better job. This is due to the fact that the adoption of agricultural machinery increases capital input; it is expected that either the level of output should increase or the level of other inputs decrease. Such changes are likely to have an impact on employment and farm income. Thus, this paper aims to characterize different levels of rice farm mechanization and determine the effect of mechanization on output, income, and employment of lowland rice farmers in Laguna. It also seeks to determine the type of farm machines farmers adopt and their level of mechanization. Previous studies (Alviar 1969, Bastillo 1981, Tan 1981, and Sison 1983) classified farms as only mechanized and non-mechanized farms. The level of mechanization in these studies was only determined by the number of pump, hand tractors, power tiller, and thresher the farmers use. This study hopes to contribute to the literature by classifying rice farm types using horsepower level to reflect the actual level of farm mechanization in rice farming.

Conceptual Framework

A framework which characterizes farm mechanization among lowland farmers in Laguna is presented in Figure 1. The level of farm production is influenced by the farm characteristics: the level of mechanization considering ownership of farm tools and machines and horsepower values per operation, and inputs used. The level of farm machinery adoption and labor employment are affected by the machine ownership, horsepower values by operation, and farm characteristics. It may be argued that different types of machineries used in a farm have a considerable effect on the farm's degree of mechanical power adoption as well as on its level of labor input utilization.

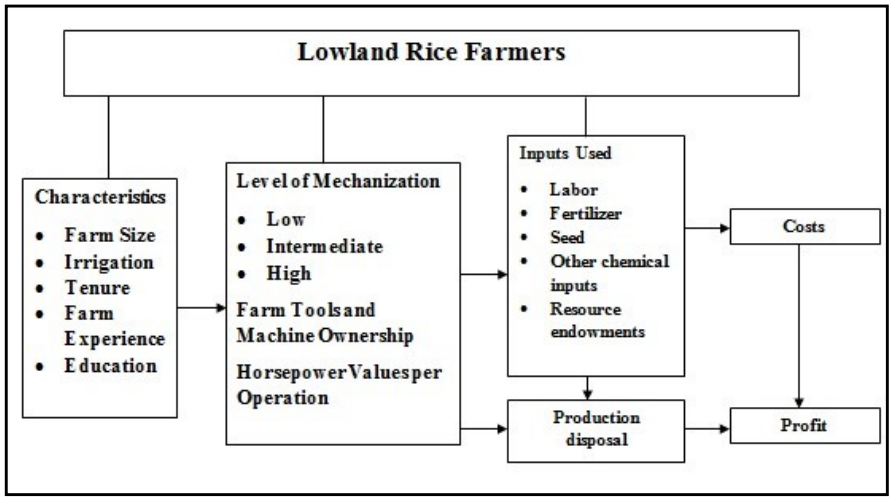

Figure 1. Framework for characterizing lowland rice farmers explaining their characteristics, level of mechanization, inputs, production disposal, costs, and income

Farm profit is affected by total farm output, output price, and relative input prices. Hence, the interrelationships of the factors that create changes in the levels of the different farm indicators are established. It may also be assumed that farm differences may arise due to variations in the level of mechanization. Here, the focus is on the level of farm mechanization and its effect on output, farm labor employment, and income.

Methodology

The study used both secondary and primary data. The primary data were obtained from a cross-sectional farm survey (90 respondents) in the municipalities of Victoria, Pila, and Sta. Cruz in the province of Laguna during the wet season, June to December 2013. Rice is one of the prominent crops grown in the province. In spite of technological developments introduced in the area, palay farmers in Laguna continue to use and adopt mechanization sluggishly in their farms. Mechanization can be a huge factor in increasing the efficiency and productive capacity of rice production in the province of Laguna.

Determining the hp/ha Requirement per Farm Operation

The required horsepower per farm operation was derived by using a series of formulas. Firstly, the horsepower per hectare (hp/ha) index was computed based on the total horsepower from the derived power sources of human, animal, and mechanical power and the total cultivated area for rice in the province. Based on this hp/ha index, the farmers' level of mechanization was determined (Table 1). This method was based on a study conducted by the Agricultural Machinery Testing and Evaluation Center (AMTEC), College of Engineering and Agro-Industrial Technology (CEAT), University of the Philippines Los Banos (UPLB) funded by the Philippine Department of Agriculture-Bureau of Agricultural Research (DA-BAR).

The hp/ha per operation was derived based on the following equation:

$$hp/ha = (1/(N)) (((\eta A * A) + (\eta B * B) + (\eta C * C) + (\eta D * D))/At) \quad (1)$$

where:

η	=	number of respondents using specific power source
I	=	{A, B, C, D}
A	=	hp from man (usage of hand tools and hand equipment only in farming
B	=	hp from man-animal (combination of animal and man for farming)
C	=	(Effe x Efft x Effb x EffpTO x Effdb) x hp from man-machine
Effe	=	efficiency of primemover (conversion efficiency of turning fuel into mechanical power) = 0.80
Efft	=	transmission efficiency (transmission of power from engine to the wheels ofthe motor vehicle) = 0.80
Effb	=	efficiency (motion source for transportation of power) = 0.95
EffpTO	=	power Take-Off efficiency (power source takings) = 0.90
Effdb	=	drawbar efficiency (transferred power to the drive wheels) = 0.75
D	=	((Effe x Efft x Effb x EffpTO x Effdb) x hp from man-machine) + hp from man-animal

N = total number of respondents

At = total area cultivated by respondents

The total hp/ha derived in Equation (1) was used to determine the total horsepower expended per hectare for all farm operations using the following equation:

$$\text{Total hp/ha} = \sum \text{hp/ha per operation} \quad (2)$$

The horsepower values per operation used in Equation (1) were summed up to obtain the total hp/ha per farm. The values were multiplied with the standard efficiency values given in the efficiency values used in Equation 1. These efficiency values were provided by the Agricultural Machinery Testing and Evaluation Center (AMTEC) and are considered standards for the country.

Since male and female differ in required power to finish an operation due to differences in their physical strength, the standard horsepower values were used: 0.10 hp for male and 0.075hp for female. In the case of draft animals, standard horsepower value is 1hp.

In order to come up with the hp values for manual and man-animal operation, the study of Amongo et al. (2012) was used as reference:

$$A = \sum (\eta m * 0.10 \text{ hp}) + (\eta f * 0.075\text{hp}) \quad (3)$$

where:

A = hp from man

ηm = number of male workers

ηf = number of female workers

The hp values for man-animal operations such as plowing and harrowing were derived using the following formula:

$$B = \frac{\sum (\eta m * 0.1 \text{ hp}) + (\eta a * 1\text{hp})}{a} \quad (4)$$

where:

B = hp from man-animal

ηm = number of operators (all operators were men)

ηa = number of animals

a = area covered

For Man-Machine Systems

For hp values for man-machine systems such as threshing or milling, the following equation was used:

$$C = \frac{\sum \eta o * \text{hp (whether male or female)} + (\eta m * \text{hpm} * \text{(applicable efficiency)}}{a} \quad (5)$$

where: C = hp from man-machine

ηo = number of operators

ηm = number of machines

hpm = hp rating of machine

a = area serviced (hectare)

These equations were used in determining the hp/ha requirement per farm operation, namely, land preparation, threshing, and drying. Based on this hp/ha requirement, the farms were then classified into low, intermediate, and highly mechanized farm (Table 1).

Table 1. Numerical index of levels of mechanization in terms of total horsepower per hectare (hp/ha) in all operations in selected municipalities of Laguna, 2013

Level of Mechanization	Horsepower/hectare (hp/ha)
Low	< 6.99
Intermediate	7.0 – 12.99
High	> 13.0

Source: Authors' estimates based on 2013 survey data and Amongo et al. 2012

Effect of Mechanization on the Level of Income

The costs and returns analysis was employed to measure the impact of mechanization on the level of income of the farmers. Total returns come from cash receipts such as the sales of palay, while non-cash receipts include stored crops, given away, home consumption, payments in kind, and custom harvest arrangements. Costs refer to labor expense, rental cost, irrigation expense, seeds, fertilizers, insecticides, and herbicides. Non-cash costs include rejects, interest, opportunity cost of capital, depreciation of machineries, and unpaid family labor. The formula used was:

$$NFI = (TR - TC) \quad (8)$$

where:

NFI = Net Farm Income (PhP)

TR = Total Revenue (PhP)

TC = Total Cost (PhP)

ANOVA was employed to determine whether there is significant difference in the level of income among the three types of farm.

Effect of Mechanization on Employment

The different farm operations for each level of mechanization were compared and analyzed through descriptive and tabular analysis. The ANOVA was used to determine the significant difference in labor utilization among farm types.

Results and Discussions

Characteristics of Farms

The general characteristics of the sample farms are shown in Table 2. Production and level of inputs used remain in favor of highly mechanized farms against intermediate and low-mechanized farms. On the average, the farm size per farmer-respondents for all farm types is 1.54 hectares with intermediate-mechanized farms being the highest which is higher than the national average of 1.14 hectares (PhilRice 2014).

The average output for all sample farms in the study is 86 cavans per hectare, slightly higher than the national average of 80 cavans (PSA 2016). The minimum is 70 cavans per hectare. This is due to the "black bug" infestation among rice farms in the area. The maximum yield is 99 cavans per hectare per cropping. Highly mechanized farms have the highest yield of 89 cavans per hectare while low-mechanized farms have the lowest with 76 cavans per hectare. The effectiveness and timeliness of work done associated with mechanization may have contributed to the high yield of mechanized farms.

Labor input for all operations using either machine or human-animal power is 27.21 man-days, on the average, for all types of farms. Low-mechanized farms have relatively higher man-days to complete farm operations, around 33 man-days or about 20% man-days higher than that needed to finish farm operations in highly mechanized farms. Labor input ranges from 13 to 38 man-days per hectare for all farm operations. Thus, mechanical power displaces labor for different operations in the farm.

The cost of fertilizer is directly related to the level of mechanization. Highly mechanized farms incur the highest cost for fertilizer (PhP 5,852) and chemicals (PhP 1,904) applied in their rice farms, as compared with intermediate and low-mechanized farms. Application of the recommended level of fertilizer is found to be essential to a more productive rice farm. Lower mechanized farmers tend to save money on their fertilizer expense, thus, they obtain lower yield than the efficient highly mechanized farm. The lower yield translates to lower income that imposes budget constraint in the use of farm inputs.

The low-mechanized farms have higher level of seed used (57 kg) vis-à-vis the highly mechanized farms (53 kg) and intermediate-mechanized farms (55 kg). As shown above, the higher seed use does not lead to higher yield due to lower soil nutrient consumption arising from physical crowding and competition.

The sources of water for all farm types are the National Irrigation Authority (NIA/communal), pumps, river, and rainfall. NIA is the most common water source for 84% of the respondents. Majority of the highly mechanized farms are dependent on it, while pumps (shallow tube well) and rainfed (river systems) as a source for highly mechanized farms comprise 71% and 100%, respectively. The high percentage of farms using pumps means that irrigation system covered in the study area is ineffective and water is scarce especially during the dry season, forcing them to spend much to irrigate their dry farm lands.

Commonly Used Farm Machines and Farming Systems

The farmers in Laguna commonly use the two-wheel hand tractor and the IRRI power tiller with moldboard, disc plow and harrow attachments. The shallow tube well is also widely adopted in the province, especially for areas where the NIA or communal irrigation could hardly reach the farms. The hand tractor, also used as a leveler for the field, is used by 27% of the farmer-respondents.

Table 2. General characteristics of sample farms by level of mechanization, selected municipalities in Laguna, wet season, June-November 2013

Characteristic	Level of Mechanization			
	High (n=69)	Intermediate (n=12)	Low (n=9)	All (n=90)
Ave. farm size	1.6	1.7	1.0	1.54
Ave. production (cavan/ha)[a]	89	80	76	85.8
Ave. labor input (man-days/ha)	23	27	33	27.21
Ave. level of fertilizer (PhP/ha)	5,852	5,334	4,811	5,668
Ave. level of chemicals (PhP/ha)	1,904	1,590	1,261	1,791
Irrigation (%)				
NIA/communal	75	13	12	76
Pump/shallow-tube well	71		-	7
Rainfed/river, etc.	100	29	-	7

Highly mechanized farms register the highest percentage of ownership for machines used with 86% for pumps, 79% for hand tractor, and 78% for power tillers and they owned the five units of thresher (Table 3). The large output and bigger farm sizes of highly mechanized farms enable them to buy such machineries. Minority ownership is observed among intermediate and low-mechanized farms. These farmers tend to rent out their farm activities to traders and cooperative in their area. In addition, farmers' perceived problems in using machines include the cost of fuel, the frequency and cost of repairs and maintenance, and the high cost of its spare parts (Bastillo 1981).

Table 3. Machine ownership of farmer-respondents by level of mechanization, selected municipalities in Laguna, wet season, June-November 2013

Machine	Level of Mechanization					
	High (n=69)		Intermediate (n=12)		Low (n=9)	
	No.	Percent	No.	Percent	No.	Percent
Pump	43	86	5	10	2	4
Hand tractor	19	79	5	21	1	4
Power tiller	14	78	4	22	-	1
Thresher	5	100	-	-	-	1

Source: Survey data, 2013

Horsepower Usage in Mechanized Farm Operations

The mean horsepower values per rice operation are highest in land preparation (plowing, harrowing and leveling) with 13.74 hp (Table 4). Threshing and chemical application are also heavily reliant on machines, with 2.25 hp and 1.30 hp, respectively. Manual operations such as harvesting of palay, transplanting of seedlings, and seed preparation are all dependent on manual labor. Man-animal mechanization system which is primarily used in land preparation and hauling operations is far behind in machine usage due to the lower efficiency of work done by draft-animals as compared with mechanical power, with 3.18 hp.

Table 4. Mean horsepower values per operation, selected municipalities in Laguna, 90 respondents, wet season, June-November 2013

Operation	Horsepower Value		
	Manual	Man-Animal	Man-Machine
Seed preparation	0.20	-	-
Plowing	-	1.09	4.81
Harrowing	-	1.04	4.40
Leveling	-	1.05	4.53
Transplanting	1.07	-	-
Chemical application	-	-	1.30
Harvesting	1.25	-	-
Threshing	-	-	2.25

Source: Authors' estimates based on 2013 survey data

Effect of Mechanization on Output and its Disposal

Average production is higher for farms using high level of mechanization, with 89 cavans per hectare, compared to intermediate and low-mechanized farms, with 80 cavans and 76 cavans, respectively (Table 5). Other shares of expenses in kind for the three types of farms do not differ significantly except for the hired labor paid in kind that is highest in intermediate-mechanized farms. This can be attributed to the combination of man-animal and man-machine systems used that is more costly in terms of in-kind payment as compared with highly mechanized farms—that is, purely mechanical—and for low mechanized farms that is labor intensive and is reliant on payment in cash. Harvester and thresher's share that is customarily 10% of the threshed palay in terms of payment, is highest among all types of farm.

Table 5. Production disposal per hectare of rice farmers in selected municipalities of Laguna, by level of mechanization, June-November 2013

Effect of Mechanization on Income

Production Disposal	Volume (cavans)		
	High (n=69)	Intermediate (n=12)	Low (n=9)
Ave. production[a]	89.00	80.00	76.00
Output sold	59.63	53.60	50.92
Seeds /fertilizers paid in kind	0.53	0.48	0.45
Hired labor paid in kind	1.43	1.55	1.30
Harvester's share	9.98	8.90	8.53
Thresher's share	8.15	7.13	6.87
Landowner's share	7.05	6.33	6.02
Rentals paid in kind	2.06	1.85	1.75
Irrigation fee paid in kind	0.18	0.16	0.15

[a] In 50 kgs per cavan

Fc = 77.49, Ft = 3.10 Significant at 1% probability level

Source: Authors' estimates based on 2013 survey data

Total net return per hectare is highest among highly mechanized farms (PhP 27,323) compared with intermediate (PhP 24,023) and low mechanized farms (PhP 18,784) (Table 6).

The cost of food and labor used per hectare is highest among low-mechanized farms due to more labor input used that results in more meals and snacks served to these farm workers. This shows that farmers adopting high level of mechanization employ lower amount of labor. Since only one or two persons are needed to operate a farm machine, labor and food costs are lower in highly mechanized farms. On the contrary, low-mechanized farms need higher quantity of manual labor, thus they incur higher cost on these items.

Lease and thresher costs are relatively high among highly mechanized farms. Highly mechanized farms have high levels of production. Since rent for threshers is, on a percentage basis, a higher level for mechanically threshed palay, this would result in higher cost for threshing. Highly mechanized farms also register the highest cost on other variable inputs such as seeds, fertilizers, and chemicals.

In spite of the high cost incurred, highly mechanized farms have higher net income than the low-mechanized farms as indicated in the ANOVA result. Similarly, farmers with intermediate level of mechanization have significantly higher level of income compared to low-mechanized farms. Hence, the increase in income for rice farms is directly related to its level of mechanization.

Table 6. Cost and return (PhP) per hectare and by level of mechanization, selected municipalities in Laguna, wet season, June-November 2013

Item	Level of Mechanization			
	High (n=69)	Intermediate(n=12)	Low(n=9)	All(n=90)
Total Gross Returns	67,408	58,882	50,306	64,138
Cash Returns	43,609	38,128	32,280	41,745
Non-Cash Returns	23,799	20,754	18,026	22,393
Cash Costs	19,864	18,516	18,015	19,216
Seeds	1,124	1,137	1,172	1,131
Fertilizers	5,852	5,334	4,811	5,679
Chemicals	1,904	1,590	1,261	1,798
Hired labor	556	636	784	584
Food	407	588	900	481
Plowing	1,542	1,762	2,174	1,621
Harrowing	1,229	1,404	1,733	1,292
Leveling	1,287	1,471	1,815	1,354
Transplanting	1,238	1,415	1,745	1,301
Machine cost	4,725	3,179	1,620	3,975
Non-Cash Costs	20,221	16,343	13,507	18,715
Landowner's share	4,964	3,480	2,187	4,488
Harvester-thresher share	6,230	5,447	4,611	5,964
Payment in kind	4,909	4,413	4,192	4,502
Lease payment	1,828	1,174	773	1,635
Irrigation	816	671	757	791
Interest on operating capital	942	787	624	890
Depreciation	532	371	363	445
Total Cost	40,085	34,859	31,522	37,931
Returns Above Cash Cost	47,544	40,366	32,291	44,922
Returns Above Non-Cash Cost	47,187	42,539	36,799	45,423
Net Farm Income	27,323	24,023	18,784	26,207

Fc=77.49, Ft=3.10 Significant at 1% probability level

Source: Authors' estimates based on 2013 survey data

Effect of Mechanization on Employment

To determine the effect of mechanization on farm labor employment, the study determined the quantity of labor employed in land preparation and post-production operation by farm type. Land preparation includes plowing, harrowing, and leveling. The percentage labor employed was compared across farm types or levels of mechanization to determine which farm type employs the highest amount of labor in these activities.

Highly mechanized farms use comparatively lower level of manual labor (32%) in their farm operations than intermediate mechanized farm (34%) and also low-mechanized farms (38%) (Table 7). This implies that as mechanization rises, the demand for labor falls. For the post-production operations which include harvesting, threshing, and other farm operations such as seed preparation, planting and fertilizer/ chemical application, highly mechanized farms employ the lowest amount of labor compared with intermediate and low-mechanized farms.

Table 7. Labor utilization per hectare by level of mechanization and by farm operation, selected municipalities in Laguna, wet season, June-November 2013

Farm Operation	Level of Mechanization					
	High (n=69)		Intermediate (n=12)		Low (n=9)	
	Man-days	Percent	Man-days	Percent	Man-days	Percent
Land Preparation	-	32	-	34	-	38
Plowing	2.79	-	3.22	-	4.41	-
Harrowing	2.55	-	2.94	-	4.03	-
Leveling	2.62	-	3.04	-	4.16	-
Post-Production	-	17	-	18	-	14
Harvesting	3.04	-	3.53	-	3.45	-
Threshing	1.01	-	1.17	-	1.15	-
Other Operations	-	51	-	48	-	48
Seed preparation	3.00	-	1.94	-	2.34	-
Planting	2.67	-	7.76	-	9.54	-
Fertilizer/chemical application	6.68	-	3.20	-	3.98	-
Total	24.36	100	26.80	100	33.06	100

Source: Authors' estimates based on 2013 survey data

Land preparation activities like plowing, harrowing and leveling, is the most significant factor in reducing labor use since it relies heavily on machine use. It is shown by the big difference of 4.2 man-days between high and intermediate, and 15.2 man-days on highly mechanized and low-mechanized farms. Mechanized planting involves high labor displacement.

The effect of this reduction in labor could lead to lower cost in terms of man-days due to the efficiency of or high horsepower of the machines. Generally, total labor employed by highly mechanized farms is lower compared to intermediate and low-mechanized farms. Highly mechanized farms employ a total of 28% and 31% per hectare and per farm, respectively. These results confirm the hypothesis that highly mechanized farms employ lower level of farm labor, displacing human and animal power.

ANOVA results show that labor input are statistically different across farm types. Using Fisher's Least Significant Difference (LSD) test, results show that high and low-mechanized farms obtain the highest difference with 3.40, followed by the difference between intermediate and low-mechanized farm with 2.16. The result concludes that labor utilization differs greatly in highly mechanized farms compared to lower levels of mechanization (intermediate and low-mechanized farms).

Table 8. Paired comparison of level of mechanization and labor input using Fisher's Least Significant Difference (LSD) test, selected municipalities in Laguna, wet season, June-November 2013

Farm Group[a]	LSD (in man-days)
High and Intermediate	1.25
High and Low	3.40
Intermediate and Low	2.16

[a] High, intermediate and low-mechanized farms with 69, 12 and 9 sample farms, respectively.
Source: Authors' estimates based on 2013 survey data

Conclusions and Recommendations

The study shows that the level of mechanization directly affects farm yield. Net farm income also increases with increasing level of farm mechanization. However, highly mechanized farms employ the lowest farm labor. Substituting farm machineries for man-animal power in certain operations, specifically in land preparation and post-production operations, results in the reduction of total labor utilization.

Increasing productivity in rice farming and agriculture would require farm mechanization. Thus, to increase the level of productivity of their rice farms, farmers have to be educated about the benefits of improved farm mechanization. A strong extension system should complement the rice research program to improve the adoption of this technology (Peña and Bathan 2014). The extension service provided to farmers must now include an important component — farm mechanization. Moreover, farmers must also be provided access to credit to encourage farm mechanization. Existing programs on the provision of farm machineries must be strengthened.

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