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Socio-Economic Impact of Use of Water Resources in Farming Systems: A Case of Phayao Province, Northern Thailand

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Abstract

Water resources are becoming increasingly scarce everywhere. Water should, therefore, be used for productive activities in an economically viable, environmentally sustainable and socially equitable manner. This study aims at determining the sustainability (defined broadly as the ability of a system to maintain a certain well defined level of performance or output overtime) of agricultural development under different irrigated systems in the upper part of Mae Ing river basin, Phayao Province, Northern Thailand. In this paper, the elements of sustainable agricultural development are a) increasing productivity in a stable manner b) economic efficiency and c) equitability in sharing the benefits of agricultural production. The results indicate that irrigation increases productivity in a stable manner. Irrigation improves rice productivity by 10 to 38 % in irrigated systems compared to non-irrigated system. Rice production in irrigated systems is more profitable than in non-irrigated system. The gross margin of the production resources are attributed to different resources amongst the irrigated systems. The results of the study also indicate inefficient utilization of resources even though the marginal value of productivity is higher in irrigated than non-irrigated areas. As assessment of equity in water use indicates that there is unfair distribution pointing to unequal social/economic gains from irrigation. In conclusion, irrigation -the use of water resources- may improve agricultural development in a sustainable manner with better management of irrigation.

Introduction

Sustainable agriculture has become a crucial issue in agricultural development and resource management. An important resource in this regard is water. Water resources are an essential component of the earth's hydrosphere and an indispensable part of all terrestrial ecosystems. Water requirements have steadily increased in the past, and current trends indicate that these requirements will continue to increase in the future (El-habr and Biswas, 1993). As population and economic activities grow, many countries are rapidly reaching conditions of water scarcity or facing limits to economic development (United Nations, 1992). Agriculture is by far the biggest consumer of water worldwide. In Thailand, for example, agriculture uses about 88% of total annual water.

A major use of water in agriculture is irrigation, usually as a supplementary source. Irrigation plays an important role for agricultural and economic development in Thailand. Irrigation has a positive influence on production, employment and expansion of cultivated land. Moreover, it increases cropping intensity and reduces risk and uncertainly (Doppler, 1989). But experience has shown that some irrigation projects have performed far below expectation.

Besides, irrigation has in most cases been associated with some negative effects such as water logging, salinization and water pollution. Despite all this, irrigation remains crucial in determining the sustainability of agricultural production in areas with low, inadequate and high fluctuation of rainfall.

This study aims at determining the sustainability of agricultural development under different irrigated systems in the study area. While a precise definition of sustainable agriculture is beyond the scope of this paper, three fundamental perspectives for the assessment of sustainability of agricultural development can be identified in the literature. According to Giampietro (1997), these are 1) the ecological view agricultural techniques must be environmentally sound, 2) the economic view agricultural techniques must be economical variable and 3) the social view agricultural techniques must be acceptable to farmers and society given their culture, ethics and religion. The elements of sustainable agricultural development which are examined in this paper are a) increases of productivity in a stable and sustainable manner b) efficiency and c) equitable in sharing the benefits of agricultural production.

Methodology

Irrigated systems in the upper part of Mae Ing river basin are the focus of this study. Five different systems “with” and “without” irrigation were studied. First, the non-structured weir system located in the upland area, sloppy area, which uses water from tributaries by building a weir across the tributary. The command area is quite small, about 50 to 100 rai (6.25 rai = 1 ha) per system. The second system is the weir system, which is made from permanent material, mainly concrete. The source of water is the main river, and the water is distributed to a command area, less than 3,000 rai per system. The third and fourth are the small and medium scale reservoir irrigated systems. Both are different in the size of water storage capacity, command area and management, but are supported by the government in the construction. The non-irrigated system is included in order to cover the whole watershed, in addition to making comparisons.

Primary data was obtained from a farm-family-household survey carried out in the region during the period 1994/95. A sample of 148 farm households was drawn from both the irrigated and non-irrigated areas. This was collected using a structured questionnaire, discussions as well as by direct observation. The simple random sampling technique was applied in selecting the sample households.

Farming Systems in the Study Area

A typical household head in the study area is a male, aged about 52 years old and with primary level education (Table 1). The average size of the household is about 4, and 3 of them may be considered as active labor. The active labor mainly work on the farm, except in the non-irrigated system, where off-farm activities are common. Decision making in the farm-family-household system is mainly done by the household head.

Availability of production resources of land, labor and capital play an important role in farming systems as they are directly related to the system output. Generally, farmers in the north of Thailand cultivate small pieces of land compared to other parts of Thailand (Surareks, 1985). In this area, the average land holding is about 10.3 rai, of which about 7%

is the homestead and the rest is used for agricultural activities (Table 2). Regarding land the use system, the dominant crop is rice for all systems and accounts for about 68% of the total cultivated land. The cultivated area with tree crops, field crops and vegetables varies in the different systems.

Table 1. Characteristics of farm, family and household, Phayao Province, Northern Thailand 1994/95

		Non-structured weir	Weir	Small reservoir	Medium reservoir	Non-irrigated	Total Families
		n=25	26	56	22	19	148
Household age	year	51	55	50	57	49	52
		(11.4)	(12.9)	(12.5)	(13.0)	(14.8)	(12.9)
Family size	person	3.4	4.4	3.9	3.6	3.8	3.8
		(1.2)	(1.6)	(1.2)	(1.4)	(1.5)	(1.4)
Nonactive labor	person	1.2	1.8	0.9	1.3	1.1	1.2
Active labor	person	2.2	2.6	2.9	2.3	2.7	2.6
Labor capacity	manday /yr.	485	588	658	511	615	589

Note: Number in parenthesis is standard deviation.
Source: Farm survey

Results and Discussion

In the face of increasing limited resources, the proper evaluation of performance and identification of the constraints is important in order to minimize the gap. Performance can be evaluated on several viewpoints e.g. hydrological, agronomic, social and economic approaches (Doppler, 1989). Wade (1986) quoting Spedding, et al., remarks that measures of efficiency must be placed within a given context. The context of an efficiency measure is defined by a) limiting the system for which efficiency is measured, b) specifying the outputs and inputs of concern, and c) describing the time period over which the system is analyzed. This study focuses on 5 well defined agricultural systems all with rice as a major crop and refer to the year 1994/95.

Agronomic efficiency

Output of agricultural products can be increased either by expanding the cultivated area or by increasing crop productivity. Due to the limited scope in expanding the cultivated area, increasing productivity by changing or improving on agricultural technology, is usually found appropriate. It is here, that irrigation finds its importance. To assess the performance of irrigation, the level of crop productivity and intensity are used as indicators. Cropping intensity (CI[32]) indicates how intensity of land is used. For the current analysis, productivity[33]

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[32] Cropping intensity, as a percentage of the total cultivated area is cultivated in a year.

of rice in crop year 1994/95 is used to evaluate the agronomic efficiency. Additionally, information on rice production in the last 10 years (1984/85-1993/94) collected during the survey is used to assess the level of production over time. The farmers were asked to indicate the production level of rice, the major crop, by classifying into 3 conditions, good normal and low, including the number of years in each condition. Stability is also important to measure the degree to which productivity remains constant in spite of the fluctuations in social, economic and environmental variables (Conway, 1986 cited by Maskey, 1994). The coefficient of variation (CV) is used to measure the variability, with lower CV values indicating higher stability. The results of productivity and stability of rice production are shown in Table 3.

Table 2. Land use system, Phayao Province, Northern Thailand 1994/95

Land use	Non-structured weir n=25	Weir 26	Small reservoir 56	Medium reservoir 22	Non-irrigated 19	Total families 148
Total land (rai)	9.8	9.1	10.5	12.7	8.6	10.3
	(5.5)	(5.5)	(10.9)	(8.5)	(11.0)	(9.0)
Homestead (rai)	0.7	0.7	0.7	0.5	0.6	0.7
	(0.4)	(0.7)	(0.5)	(0.3)	(0.5)	(0.5)
Cultivate land (rai)	9.2	8.4	9.8	12.2	8.0	9.6
	(5.5)	(5.3)	(10.9)	(8.4)	(10.9)	(9.0)
Crop area (rai)						
rice	5.5	7.9	6.8	9.3	4.6	6.9
field crops	3.9	0.0	0.2	1.1	0.3	0.9
trees	1.3	0.4	2.5	2.1	3.0	1.9
vegetables	0.1	0.4	0.5	0.0	0.3	0.3
Crop Intensity **	132%**	105%	109%	103%	104%	111%

Note: ** F-test is 9.45 (significant at 1%).
Source: Farm survey

The results show that there is significant difference in CI, which ranges between 103 and 132% (Table 2). This indicates that irrigation increases the cropping intensity in general. However, it is quite surprising that the CI of the medium reservoir is quite low. The low CI may be due to limited irrigation area or water availability during the dry season. The drought experienced in 1992/93 may have affected the water availability in the dry season.

[33] Productivity is defined as the output produced per unit of land resource.

The weir, small and medium reservoir systems, which have better opportunities to manage water use in agriculture due to better irrigation infrastructure (head work, main canal and laterals and distribution system), show in general better productivity and stability than the average. There is significant difference in rice productivity during the 1994/95. The results of the rice productivity in the last 10 years show that there is no significant difference in rice yield in the low water years. The opposite holds for the good and normal years. This shows that productivity improves when water is available.

Table 3. Productivity and stability of rice production in different systems, Phayao Province, Northern Thailand 1994/95

	Items	Non-structured Weir	Weir	Small Reservoir	Medium Reservoir	Non-Irrigated	F-test
Rice productivity and stability, 1994/95							
	Yield (kg/rai)	437	525**	539**	551**	398	5.11 **
	STD	(137)	(119)	(155)	(147)	(136)	
	CV (%)	31%	23%	29%	27%	34%	
Rice productivity, 1984/85-1993/94							
Yield (kg/rai) in							
	Good year	454	537*	569**	623**	412	5.27 **
	Normal year	373	400	410*	490*	268	3.05 **
	Low year	213*	188	181*	217*	82	1.7
	Average 10 yr.	378*	416*	454*	518**	274	6.27 **

Note: ** significant at 1%, * significant at 5%
Source: Farm survey

The productivity of rice may be used as an indicator of whether land is marginal or not. The lower productivity with low stability obtained from the non-irrigated system indicates that the land is marginal. The results indicate that the irrigation increases productivity in a stable manner better than the non-irrigated system. There is limited information on water quantity which is used by rice. Since the agronomic efficiency indicates only the productivity and stability, it is important to consider the profitability of the crop activities.

Gross margin analysis

Since crop production is a major activity, in income generation, it is important to assess its returns per unit of resource inputs. To do this the gross margins[34] are calculated. Gross margin can provide a measure of relative profitability of the different systems. The gross margin of production resources namely land, family labor used and capital, indicate how well

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[34] Gross margin is calculated from the total value of products less total variable costs. The value of total output was estimated, regardless of whether that output is sold, used for household consumption, used as farm input, for payment in land, or stored at the end of the year. The value of by product was not included.

the total investment in family labor and capital is remunerated. This is calculated by dividing gross margin by the amount of family labor and capital[35] required to produce that value.

Comparing the gross margin of land, family labor and capital in rice production, it is found that the highest returns are attributed to different resources in the irrigated systems (Table 4). For example, the gross margin per unit of land was highest in the medium reservoir system, while per labor was highest in the weir system. It is to be noted here that labor is used much more intensively in the irrigated systems than the non-irrigated system. The results also show that the non-irrigated system records the lowest in all parameters.

Table 4. Gross margin (GM) of production resources in crops in different systems, Phayao Province, Northern Thailand 1994/95

Gross margin	Non-structured weir (n =29)	Weir 34	Small reservoir 61	Medium reservoir 28	Non-irrigated 11	Total Families 163
Rice production						
GM/land(baht[36]/rai)	1,166	1,324	1,396	1,490	974	1,328
GM/labor(baht/manday)	49	86	68	74	37	65
GM/capital	2.98	2.39	2.56	2.90	1.86	2.58
All crops production						
GM/land(baht/rai)	2,029	2,270	2,485	1,883	1,179	2,143
GM/labor(baht/manday)	32	64	63	63	38	54
GM/capital	1.22	1.13	0.95	1.24	0.94	1.05

Source: Own calculations

Taking all crops[37] in to consideration, the analysis shows that the highest gross margin per unit of land is in the small reservoir system, implying that farmers have the greatest benefit from crop production. These results indicate differing returns in the use of resources in the cropping systems and that the irrigated systems have better returns than the non-irrigated system.

One of the living standard criteria of families is family income, which consists of farm, household and off-farm income. Farm income is obtained from crop and livestock production, while off-farm income includes the household and off-farm income. A break down of farm income by source show that about 50% of the income is from crop activities in the irrigated systems(Table 5). This in part implies that irrigation plays an important role in enhancing income. Comparing the systems with irrigation, it is clear that the system in which

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[35] Capital in this case is the variable costs of production.

[36] 25 baht = 1 $US (exchange rate in 1996)

[37] All crops include all crops which are cultivated by the family.

water is plenty (reservoir systems) have generally higher farm income. Systems with less water availability have, on the other hand higher off-farm income. This is mainly because during the dry season, some members of the family migrate to look for jobs elsewhere.

Table 5. Farm and off-farm incomes in different systems, Phayao Province Northern Thailand 1994/95

Income (baht/family/yr)	Non-structured weir n=25	Weir 26	Small reservoir 56	Medium reservoir 22	Non-irrigated 19	Average 148
Farm revenue	16,791	25,408	31,288	28,764	17,355	26,061
Crop revenue	11,136	14,814	20,229	16,560	8,446	15,690
By-product revenue	116	809	144	1,161	1,215	545
Animal revenue	1,239	4,369	3,939	3,217	2,149	3,586
Increase in value of animal stock	4,300	5,416	6,976	7,826	5,545	6,241
Farm expenses	9,616	12,471	15,912	13,226	8,732	13,032
Farm income	7,175	12,937	15,377	15,538	8,623	13,028
per total cultivated land	780	1,539	1,565	1,277	1,074	1,359
as % of Off-farm income	54%	58%	96%	113%	50%	79%
Off-farm income	13,313	22,220	15,936	13,702	17,081	16,464
Family income	20,488	35,157	31,313	29,240	25,704	29,493
Cash flow from farm income	-170	1,474	3,163	1,919	544	1,784
as % of farm income	-2%	11%	21%	12%	6%	14%

Source: Farm survey

Economic and financial efficiency

Economic efficiency refers to the allocation of resources in ways that maximize their contribution to human well-being, within the constraints imposed by the existing distribution of wealth and income (Small and Curruthers, 1981). In order to find out the efficiency of farmers' resource allocation, a production function is specified to quantify the response of rice production to irrigation. A Cobb-Douglas production function was thus estimated. From the estimated coefficients, the marginal value productivity (MVP)[38] of cultivated land is derived. Farm output (dependent variable) is measured by the value of rice products in monetary terms (baht) and the variable inputs (independent variables) include fertilizer use in kilogram, total

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38 The marginal value productivity of input, which indicates an expected increase in output resulting from the use of an additional unit of the relevant input if the level of other input remain unchanged, is determined as follows.

MVP of input i = $Y / X_i * \beta_i$

family labor requirement in manday, hired labor in manday and area in rai (Equation 1). To assess the effect of water sources, the production function of each system and for the entire sample is estimated.

Equation 1 $$Y = \beta X_1^{\beta 1} X_2^{\beta 2} X_3^{\beta 3} X_4^{\beta 4} e^u$$

When;

Y = Rice products in baht

X_1 = Fertilizer used in kilogram

X_2 = Total family labor requirement in manday

X_3 = Total hired labor in manday

X_4 = Cultivated area in rai

β_i = Input productivity coefficient

The results of the production function in each system and for the entire sample is shown in Table 6. The coefficient of determination (R^2) provides the degree of fit of production function estimates, which reflect the contribution of input variation in explaining output differentials. The R^2 for the production function is high, ranging 0.89-0.93. The overall significance of the fitted regressions is tested by using the F-test. The results indicate that the F-value indicates that the relationships are significant for all the systems.

The coefficients of the explanatory variables (β_i) in the Cobb-Douglas production function are equal to the production elasticity of the respective inputs. The production elasticity indicates the expected percentage increase in the quantity of output that would occur if the amount of the input resource is increased by one percent, while other inputs are held constant. In the weir system, for example, an increase of the area by 1% will raise output by 0.62%, holding other factors constant. Area, fertilizer used and family labor have significant effects on yield, while hired labor does not.

The sum of the elasticity denotes the relationship between output and simultaneous changes in all inputs. The sum of elasticity, from all equations, have a value less then 1.0, meaning decreasing returns to scale. The overall return to scale for rice production is less than 1 implying inefficient use or underutilization of resources. This shows the importance of managerial ability in farming systems assuming that no important inputs were omitted in this analysis.

Table 6. Cobb-Douglas production function result of rice in different systems, Phayao Province, Northern Thailand 1994/95

Input variables	Non-structured weir	Weir	Small reservoir	Medium reservoir	Non-irrigated	All sample
Area (rai)	0.57	0.58	0.99	0.67	0.66	0.80
	(4.16) **	(4.95 **	(9.38) **	(5.85) **	(2.48) *	(13.22) **
Fertilizer (kg)	0.07	0.09	0.01	0.03	0.10	0.04
	(2.50) *	(3.07 **	(0.31)	(1.07)	(1.84)	(3.68) **
Labor (manday)	0.29	0.16	-0.08	0.09	0.11	0.02
	(2.42) *	(1.51	(-1.03)	(1.26)	(0.50)	(0.40)
Hired labor (manday)	0.04	0.04	0.04	0.00	-0.03	0.03
	(0.79)	(1.27	(1.54)	(0.00)	(0.07)	(1.71)
Constant	6.51	7.19	7.88	7.67	7.05	7.61
F-test	22.1 **	43.8 **	93.3 **	31.6 **	9.9 **	160.0 **
Σ of elasticity	0.97	0.87	0.96	0.80	0.84	0.89
R^2	0.79	0.86	0.87	0.85	0.83	0.80
n	29	34	60	27	13	163
Marginal value productivity (baht) of						
Area	943	1,120	2,107	1,310	825	1,525
Fertilizer	11	14	1	5	12	8
Family labor	24	29	-12	13	9	3
Hired labor	39	28	13	0	-20	13

Note : ** significant at 1% * significant at 5% The number in parenthesis is t-value.
Source: Model results

The marginal value productivity of area, indicates the expected increase in rice output resulting from the use of an additional unit of the relevant input if the level of other input remain unchanged. The resource use efficiency is examined by comparing the MVP of various input with their respective factor costs. It is assumed that the opportunity cost of the land equals to the MVP of the non-irrigated system (825 baht). The results show that all MVPs of land in the irrigated systems are higher than the opportunity cost of the non-irrigated land. This indicates that increase productivity through irrigation is reflected in high value of irrigated land due to the inelastity of land (Maskey, 1994). The MVP of fertilizer is higher than the fertilizer price (5.20 baht/kg), in all the systems except in the small reservoir system. This indicates that less fertilizer is being used under the existing price conditions, given the level at which other resources operate. The reason behind this might be limited cash availability. The opposite was found in the case of family and hired labor (wage rate was 60 to 80 baht/manday). This shows that too much of the family and hired labor is being used under the existing price conditions given the levels at which other resources operate.

Due to the higher MVP of the cultivated land in irrigated systems as opposed to non-irrigated system, it is necessary to find out whether the farmers can afford to meet the costs. Only the recurrent cost for operation and maintenance (O&M) are analyzed in this study. The capital cost is not considered, because after a project has been built, the initial capital cost becomes sunk costs, meaning that no future decision can affect its magnitude (Small and Carruthers, 1991). Recurrent cost is the most important investment related decision because it will influence the productivity of the existing irrigation infrastructure.

The recurrent cost comprises the O&M costs which are paid by the project (60 baht/rai in wet season) in the medium reservoir system. In the small reservoir system, the costs paid by the farmers' group was about 30 baht/rai (from interview). This rate is applied to the weir and non-structured weir systems, due to lack of information on these costs in the systems. Farmers can afford to pay for irrigation services only if the MVP of the irrigated land exceeds the MVP of non-irrigated land by more than any additional costs associated with irrigation. It was found that in all irrigated systems the MVP of the non-irrigated land plus the recurrent costs are less than the MVP of the irrigated land. This means that the farmers can afford to pay.

Equity issues

Equity is defined as the evenness of distribution of the productivity of the system within society. In this study, two dimension of equity are assessed, i.e. horizontal equity with regard to water distribution to farmland and vertical in terms of productivity differences between farm categories. In the study, three systems namely, weir, small and medium reservoir systems are assessed even though the water quantity is not taken into consideration.

Vertical equity

Vertical equity examines whether an effect extends to a particular social or economic class at the expense of another. Assuming that everyone has rights to share irrigation water available in proportion to the size of land holding, the productivity of the land is tested by estimating the coefficient of land in rice production (Equation 2). This equation is the log transformation of the Cobb-Douglas production function used in the estimation of input elasticity by the ordinary least-square method.

Equation 2 $$\log (Y/X_i) = b_o + b_i \log X_i$$

When;

Y = total rice output in kilogram

X_1 = the cultivated land in rai

b_o = constant term and

b_i = gross elasticity of land

The results are shown in Table 7. The elasticity (b_i), if negative, indicates an extreme form of equitable distribution, in which the level of productivity declines as the size of holding increases; a zero value for b_i indicates a lack of association between farm size and irrigation water distribution; and a positive value indicates some degree of inequitable distribution, in which productivity increases with the size of holding (Maskey, 1994).

Table 7. Relationship between productivity and land size in the irrigated systems, Phayao Province, Northern Thailand 1994/95

	Weir	Small reservoir	Medium reservoir
Constant	2.832	2.712	2.923
Elasticity (b_i)	-0.186	0.000	-0.278
T-test	-2.61*	0.01	-4.14**
F-test	6.80*	0.00	17.16**
R^2	0.175	0.000	0.407
d.f.	32	58	25

Note: ** significant at 1% and * significant at 5%
Source: Own calculations

The elasticity (b_i) for most cases shows a decline in productivity with a 1 % increase in land holding size. The weir and medium reservoir systems have statistically significant relationships in terms of F-test. R^2 is very low in most cases and indicates that there might be other factors which affect the productivity more than the size of land. The analysis show that the small land holdings are more productive than the large ones through using irrigation facilities in the weir and medium reservoir systems. While in the small reservoir system, zero elasticity indicates a lack of association between farm size and irrigation water distribution. This can be explained by the fact that rice productivity does not depend on the size of land, but perhaps on other factors.

Horizontal equity

Horizontal equity reflects ‘micro’ considerations involving ‘fairness’ among individuals who are perceived to be equals in some sense (Small & Carruthers, 1991). In this analysis, the head- and tail-ends are used to assess the equity among them. The results are shown in Table 8.

There is a statistically significant difference in rice productivity between head and tail-end[39] in the weir and medium reservoir systems, even when water is abundant. This might be due to the differences in water allocation and distribution systems. For example, in the weir system, at the beginning of the wet season (seedling stage) rotation irrigation is used to allocate water, then later it is continuously supplied. In the medium reservoir system, rotation

[39] Head and tail-end is classified by taking the distance in the lateral canal into consideration, the plot is divided into two groups as the head and tail.

irrigation is normally practiced, in order to save water. Moreover, there are other factors which may affect equity and include such factors as topography, soil type, irrigation layout and management.

Table 8. Relationship between productivity and location of rice fields in different systems, Phayao Province, Northern Thailand 1994/95

Rice productivity	Weir		Small reservoir		Medium reservoir	
(kg/rai)	Head	Tail-end	Head	Tail-end	Head	Tail-end
Head	555	473	560	524	590	471
STD	(151.3)	(79.1)	(139.0)	(171.7)	(153.5)	(139.8)
n	13	15	30	30	14	9
T-value	1.83**		0.90		1.92**	

Note: * significant at 5%
Source: Own calculations

There is no statistically significant difference in the small reservoir system, however, plots at the end of the canal are less productive than those at the beginning of the canal. It can be concluded that in the small reservoir system the water allocation and distribution systems lead to equity along the canal. This is partly due to better management by the farmers group who benefit from the system.

The results in vertical and horizontal equity indicate that there is fairness in water distribution systems in different sizes of land holdings, but there is no fairness among the head and tail-end in the weir and medium reservoir systems. This, in part, indicates that irrigation as practiced in the region may not be socially sustainable.

Conclusions

The analysis in this paper shows that irrigated systems provide better productivity and higher stability than the non-irrigated system. Moreover, the productivity of rice increases with improved availability of water. The role of irrigation becomes even more evident through the significant difference in productivity between the irrigated and non-irrigated systems. This shows that the role of irrigation is very significant in facilitating yield. The highest gross margin of the production resources; namely land, family labor and capital in the rice production are attributed to different resources amongst the irrigated systems. The economic impact on irrigation is high in terms of the marginal value of productivity of cultivated land. As relates to equity, the study shows that smaller farms are in general more productive than larger ones. The vertical equity shows that the smaller farms are more productive than larger ones. The equity of water distribution between the head and tail-end is skewed, indicating lack of fairness. The main conclusion is that irrigation can improve sustainable agricultural development if irrigation is better managed.

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