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Water Use Efficiency : A Study of System of Rice Intensification (SRI) Adoption in Andhra Pradesh

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I

BACKGROUND

Agriculture accounts for 80 per cent of the total water consumption in India and about 60 per cent is consumed by paddy alone. Traditionally flooding method of irrigation is used for growing paddy with 2-3 centimetres of water on the field throughout the growing period. Paddy fields are allowed to dry-up only before the harvesting. This practice of irrigation results in large scale evaporation losses and low water use efficiency. This is in the face of inadequate and uncertain water availability becoming the major constraint on growing paddy in fragile environments. Though paddy is not a desirable crop in the water scarce environs, it remains to be the most preferred crop of the farmers in the context of distortions in output and input markets.[1] A number of new methods of paddy cultivation are being invented and promoted for improving water use efficiency in paddy cultivation. These methods include: intermittent irrigation system (IIS) or intermittent dry cultivation, integrated crop resource management (ICM), alternative wet and dry irrigation (AWDI), non-flood (NF), alternatively submerged and non-submerged (ASNS), aerobic rice, ground cover rice production system (GCRPS), plastic ground cover system (PGS), alternative system of rice intensification (SRI), etc.[2] Most of these methods have remained at their experimental stage due to their non-feasibility of adoption at the field level. For, most of these methods focus on water savings through better water management but with lower yields (Shi *et al.*, 2002). Low yields coupled with distorted (artificially low) water pricing works as a disincentive to farmers to adopt water saving practices even in the water scarce regions.

WHAT IS SRI?

The System of Rice Intensification (SRI) is a method of paddy cultivation, though some consider and treat it as a technology. SRI method totally deviates from the traditional way of cultivating irrigated paddy over centuries and hence it has different water saving capabilities. It, in fact, challenges the received wisdom of

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paddy. SRI is environment-friendly. Reduced demand for water frees up water for other users and soil that is not kept saturated has greater biodiversity. Un-flooded paddy fields do not produce methane, one of the major "greenhouse gases" that are contributing towards global warming. The methods uniqueness includes using less seeds, less water, less chemicals, etc.[3] Paddy nursery is raised using 2-3 kgs seeds per acre of paddy as against the usual 30 kgs. Transplantation of the seedling is carried out fairly early, i.e., within 2 weeks after sowing as against 4-5 weeks. Transplanting is done in wide spaces of 20/20 or 25/25 centimetre with only one seedling per spot and hence the savings on seeds. The spacious transplanting allows for the spread of the plant with more number of tillers, i.e., between 50 and 100 as against 20 and 30 in the traditional case. SRI challenges assumptions and practices that have been in place for hundreds, even thousands of years. Most rice farmers plant mature seedlings in clumps, fairly closely, with standing water maintained on the field for as large part of the season as possible with the idea of reducing the risk of crop failure.

Land is prepared in the normal way of puddling for the transplantation of SRI. Seedlings are transplanted as soon as possible after being removed from the nursery – within half an hour. Careful transplanting of seedlings when they are very young reduces shock and increases the plant's ability to produce numerous tillers and roots during their vegetative growth stage. After the transplantation irrigation is provided for SRI intermittently whenever land is dry with no standing water on the field. Scientifically, this appears to help healthy growth of plants with stronger root zone due to better availability of oxygen at the root zone than those for plants grown under traditional practices. Though it looks so simple it took so many years for the agricultural scientists and farmers to observe this aspect. After transplanting the first 60 days are the most challenging, tedious and distressing to the farmers who are new to this method of cultivation. Distressing because the paddy fields do not look like traditional paddy fields, the fields are covered with half dry feeble stems leaving the farmer with depressing feeling of 'what have I done'.[4] To add to the psychological problems, the field needs more number of weeding as against little or no weeding in the traditional case. Though weeding can be carried out with rotar weeder to reduce labour intensity, the practice is yet to establish due to the requirement of experience and skills. It is recommended that SRI needs little fertiliser and only organic manure would suffice. In fact, SRI was initiated in the 1980s in Madagascar mainly to address the fertiliser shortages. But, often farmers, as in our case, tend to apply more fertiliser in the initial stages with the perception that their paddy plants are weak and fragile. However, the scene would change once the tillers start coming after 60 days or so. SRI is expected to have 2-3 times more tillers when compared to the traditional methods. More tillers per plant are expected to compensate for the spacious transplanting as well as less number of plants. Each tiller would bear paddy, that too strong ones, and hence more yield.

The system of rice intensification (SRI) is the most acclaimed method of rice farming with claims of yield gains in the range of 2-3 times along with cost reduction. In fact, organic farming is best suited for SRI cultivation. The experience of SRI is often referred to as 'too good to be true' (Uphoff, 1999, 2000 and Uphoff and Rnadriamharisoa, 2002). SRI is a method of rice cultivation based on the synergy among several techniques like seeding on dry bed, transplanting the seedlings younger than 15 days, wider spacing (25/25 or 20/20) with single plant, intermittent irrigation with no standing water, frequent weeding, etc (Barrett *et al.,* 2003). SRI was first introduced in Madagascar during the late 1980s by a French Missionary Priest, Fr. Henri de Laulanie, S. J. Since then SRI has been widely studied, researched and debated. While a number of studies highlighted the high yield low cost of SRI, some of them raise the issue of poor adoption rates and high non-adoption rates. One reason for this could be that agricultural scientists are not fully convinced about the scientific background of SRI method and the sustainability of yields (Dobermann, 2003). As a result SRI could not find place in the normal extension support system of the agricultural departments. But, even in the areas served by extension agents devoted exclusively to SRI, only about 15 per cent of rice farmers practiced SRI after five years of its introduction and 40 per cent of the farmers who tried SRI have abandoned it (Moser and Barrett, 2002).

While some of the carefully conducted studies have identified that the reasons for low adoption and high non-adoption rates are due to high labour intensity of SRI coupled with the fact that SRI requires skills of farming, which farmers are not familiar with (Barrett *et al.,* 2003). In the context of Madagascar it was observed that SRI method requires significant labour inputs at a time of the year when liquidity is low and labour effort is already high (Moser and Barrett, 2002). Moreover, SRI requires perfect control over the water supply system. It was observed in Combodia that SRI requires intensive training with high demand for human and financial resources (Anthofer, 2004). However, the gap in terms of labour requirement tends to narrow down over the period as farmers learn by doing (improving their skills) (Barrett *et al.,* 2003; Uphoff and Rnadriamharisoa, 2002). Nevertheless, these reasons appear to be trivial in the light of high yields, low costs and high input productivities. In a study of 400 SRI and 100 traditional farmers in Combodia, high labour and land productivities were observed with 41 per cent higher yields on the plots that are close to the homestead and of higher soil quality (Anthofer, 2004). Further, it was felt that the potential of SRI in poor environments to increase yields was rather low. On the contrary, it was claimed that SRI is a promising technology for poor farming environments, while in the better endowed regions other technological options are superior to SRI (Dobermann, 2003).

Despite the controversies about its poor adoption SRI method appears to be the most water efficient method of paddy cultivation with water savings reaching up to 50 per cent when compared to the traditional method of paddy cultivation. At 50 per cent of water saving, adoption of SRI implies a 50 per cent increase in area under paddy in India, which grows paddy in 24 million hectares presently. This is a potential win-win strategy for the paddy preferring farmers especially in the water scarce fragile environments. But, one needs to crack the puzzle of low adoption of SRI in order to find ways to promote it on a large scale to achieve water use efficiency on a large scale.

This paper is an attempt to understand the dynamics of SRI cultivation in water scarce environment in India. The study is focused in a water scarce and groundwater dependent region in order to control two important aspects that go against SRI adoption. These are: (i) farmers have a natural incentive to practice water efficient methods in water scarce situations, and (ii) farmers can exercise better control over water supply in groundwater irrigation. While covering these two aspects the study focuses on the relative advantages of SRI in terms of profitability, resource use, risks, etc. The important issues in this regard include: are the differences in output and inputs between SRI and traditional methods significant? To what extent the yield gains of SRI are translated into net returns? Extent of water use efficiency in SRI, and the reasons for poor adoption or disadoption in the water scarce conditions. The paper is organised in the following manner: Section II presents the data and methods followed in the study along with the empirical model, results of the analysis are discussed in Section III and the concluding remarks in the last section.

II

DATA AND METHODS

SRI is a recent entry into India. Formal experimentation of SRI in India was started in 2002-03 and Andhra Pradesh is among the first states (along with West Bengal, Tamil Nadu, Jharkhand, Chhattisgarh and Gujarat). On-farm SRI demonstrations were organised in 22 districts of Andhra Pradesh during 2003-04 by Acharya N. G. Ranga Agricultural University (ANGRAU), Hyderabad using 291 respondents including 67 SRI farmers, 71 neighbouring farmers, 77 researchers and 76 extension workers. The experiments reported a 2 tonnes/ha yield advantage of SRI method, despite problems pertaining to transplanting, weeding, etc. The extent of water saving was 50 per cent and savings on seeds were 95 per cent. Following these experiments some of the civil society organisations have started promoting SRI methods in various districts. These organisations include Rural Development Trust (RDT), Timbktu collective, World Wide Fund (WWF), etc. Besides, a few farmers have started practicing SRI in response to reports from media and fellow farmers. Hitherto no systematic analysis of the economics of SRI is carried out. This is one of the first studies to assess the potential of SRI in terms of land and water productivities in the context of drought-prone Anantapur district of Andhra Pradesh.

Forty SRI practicing farmers spread over 12 mandals and 21 villages were identified for the purpose of the study. This sample covers a substantial portion of the farmers practicing SRI in the district. While 38 of these farmers were supported by various organisations like RDT/WWF/ANGRAU, two farmers are on their own. The supporting organisations help the farmers with methods of cultivation, provision of rotary weeders, markers, etc. Plot wise information pertaining to SRI and traditional plots was collected from these farmers along with other socio-economic and demographic data using a schedule. Data from a total of 74 plots including 40 SRI paddy plots and 34 traditional paddy plots were collected during May-June 2005. The plot wise data were analysed separately for SRI and traditional plots using descriptive statistics like averages, variances, etc. The differences between the means were tested using paired 't' test. Further, production functions were estimated to assess the input productivities and allocative efficiency at the household level.

Empirical Model

Several previous studies (De Janvry *et al.*, 1991; Pender and Kerr, 1998; Holden *et al.*, 2001; Shiferaw and Holden, 2000) have shown that when rural markets do not function well, production and investment decisions will be non-separable from consumption choices. For example, when labour, irrigation water and land markets are imperfect or missing, the household's decision price for allocation of these factors will be endogenous, i.e., the local market prices (if observed) will differ from the subjective shadow prices. In this case, non-separability implies that the endowment of labour, land, irrigation water and other fixed farm and household characteristics will determine the level of production, conservation practices and household welfare. Since we cannot rule out the possibility that some of the input markets in the study villages are imperfect, we employ the theory of farm production economics under imperfect markets and include a number of household and farm fixed factors in the estimation of production.

In this way, land productivity is likely to depend on a host of exogenous (pre-determined) and endogenous variables. The latter includes all variable input factors used on the plot. The level of use of different inputs in a given plot is an endogenous decision by the household, which will be determined based on crops grown and exogenous variables like access to input markets and water, soil types and household assets. This means that estimating land productivity using these endogenous variables would cause a simultaneity bias; the standard assumption of the independence of the regressors from the disturbance term will not hold. Because of the simultaneity problem, ordinary least squares (OLS) estimates will be biased and inconsistent. Hence, we estimate a system of simultaneous equations using three-stage least squares (3SLS), which provides consistent and asymptotically efficient estimates (Green, 1997).[5] The empirical structural model contained a system of five structural equations:

$$Y_i = y\left(LC_i, KC1_i, KC2_i, IRh_i, FS_f, Ed_f\right) \quad \text{....(1)}$$

$$LC_i = l(Y_i, S_i, KC1 - S_i, KC\ 2_i. IRh_i, FS_f, Ed_f) \quad \text{....(2)}$$

$$KC1_i = k_1\left(Y_i, KC2_i, IRh_i, LC_i, FS_f. Ed_f\right) \quad \text{....(3)}$$

$$KC2_i = k_2(S_i, KC1 - S_i, Y_i, IRh_i, LC_i, FS_f, Ed_f) \quad ....(4)$$

$$IRh_i = i(Y_i, LC_i, KC1 - S_i, S_i, KC2_i, LC_i, FS_f, Ed_f) \quad ....(5)$$

where the system of equations, respectively, represents: yield in Kgs per acre (Y_i); expenditure on labour in Rs. per acre (hired and family) (LC_i); expenditure on seeds (S_i), FYM, fertilizer and pesticides in rupees per acre ($KC1_i$); expenditure on other capital inputs such as bullocks, tractors, etc., in Rs. per acre ($KC2_i$); and number of hours of irrigation per acre (IRh_i). The plot wise information (i) was converted in to per acre basis. The structural equation system was estimated using 3SLS.[6] The explanatory variables included in the analyses were selected based on the theoretical expectations. The productivity of land (1) is modelled as a function of labour costs (LC_j), capital costs ($KC1_i$), other capital costs ($KC2_i$), number of hours of irrigation (IRh_i), farm size of the household in acres of cultivable land (FS_f) and education of the farmer in number of years of schooling (Ed_f). Among the other variables, labour cost, capital costs and hours of irrigation are dependent on the above variables in different combinations and permutations. Most of the independent variables are expected to have positive impact on the dependent variables, except perhaps the farm size of the household. Farm size is expected have an inverse relationship with land productivity following the farm size productivity debate. Education of the farmer is expected to have positive impact on land productivity. The system of equations was estimated separately for SRI plots and traditional plots. However, here the results from the production function (1) alone are discussed for the sake of brevity.[7]

III

RESULTS AND DISCUSSION

SRI paddy cultivation was introduced in Anantapur district during *kharif* and *rabi* seasons in 2003-04 by ANGRAU and also by WWF-ICRISAT in 2004-05. It is also promoted by RDT in their watershed villages since 2003-04. Besides, some progressive farmers came to know about it from the media and fellow farmers have started adopting SRI since 2002-03 itself. SRI is slowly spreading in this district. During the survey we noticed that about 10 farmers in the selected villages have abandoned SRI for various reasons. To understand irrigation efficiency of SRI a household survey was conducted during May-June 2005. This provided the opportunity to draw the experience of the farmers for three agricultural seasons since its advent. Of the 40 sample farmers, 3 adopted SRI for all the 3 years while 37 of them have adopted this method for two years. To find out the positive and negative aspects of SRI, perceptions of farmers on SRI paddy practices were also collected.

Farm Management Practices of SRI

Farm management aspects of SRI in Anantapur district reveal that farmers are not following the method as specified in number of studies. All the sample farmers use the high-yielding paddy variety seeds for SRI as well as traditional paddy plots. Therefore there is no varietal variation across plots. It was observed across the countries that SRI not only uses less seeds and water but also little or no fertilisers and pesticides. In Anantapur SRI is transplanted in single seedlings spaced at 20-25 cms. And less number of waterings is used when compared to the traditional paddy (Table 1). In the case of all other inputs the methods of application for SRI are akin to that of traditional paddy plots. In fact, farmers are applying more of chemical fertiliser as well as FYM on SRI plots when compared to traditional paddy plots. This is true for pesticides as well. However, the high labour requirements of SRI are vindicated in Anantapur case also. As a result, both labour and other input costs tend to be higher for SRI. These high costs are upsetting the yield advantages of SRI, which appear to be substantial (Table 1). Moreover, the high variations in the yields as well as costs across plots of SRI make it a risky proposition when compared to traditional paddy. On the flip side the water requirement for SRI is almost half that of the traditional paddy, i.e., 52 irrigations for SRI as against 97 irrigations in the case of traditional paddy. This should be the driving force for promoting/adopting SRI in the water scarce environments. While water use efficiency is one of the factors influencing high adoption rates, the ultimate indicator is the profitability and risk factors and the trade off between the two. Therefore, the economics of SRI needs to be examined.

TABLE 1. DESCRIPTIVE STATISTICS OF VARIOUS FARM MANAGEMENT INDICATORS

Variable (1)	Min (2)	Max (3)	Mean (4)	SD (5)	CV (6)
Area owned					
SRI	2.00	80.00	18.79	17.79	94.68
Normal	2.00	80.00	18.79	17.79	94.68
Area under paddy					
SRI	0.10	9.00	1.34	1.80	134.33
Normal	0.25	22.00	4.55	5.49	120.66
Yield					
SRI	0.32	48.00	29.43	10.82	36.77
Normal	16.00	30.00	22.85	3.66	16.02
Seed (kgs)					
SRI	0.50	5.00	2.46	1.26	51.22
Normal	10.00	80.00	34.97	12.96	37.06
Fertiliser (kgs)					
SRI	40.00	625.00	220.68	158.33	71.75
Normal	25.00	590.00	192.07	133.32	69.41
Fertiliser value					
SRI	180.00	3180.00	1205.05	798.98	66.30
Normal	350.00	3180.00	1267.58	759.36	59.91

(Contd.)

TABLE I *(Contd.)*

Variable (1)	Min (2)	Max (3)	Mean (4)	SD (5)	CV (6)
Value of FYM					
SRI	125.00	3000.00	1239.59	779.95	62.92
Normal	408.16	3000.00	1204.09	674.67	56.03
Value of pesticides					
SRI	20.00	1000.00	345.46	317.82	92.00
Normal	33.33	1000.00	290.01	295.21	101.79
No. of irrigations					
SRI	12.00	120.00	51.98	65.85	66.33
Normal	*9.00*	*360.00*	*97.07*	*73.19*	*74.01*
Bullock labour days					
SRI	0.67	20.00	5.62	4.18	74.38
Normal	0.38	12.00	3.05	2.84	93.11
Bullock labour value					
SRI	100.00	2250.00	660.11	511.45	77.48
Normal	115.38	2400.00	633.24	541.99	85.59
Tractor hours					
SRI	0.86	7.00	2.19	1.54	70.32
Normal	0.61	7.00	1.78	1.38	77.53
Tractor value					
SRI	350.00	2800.00	784.59	531.97	67.80
Normal	35.00	2800.00	615.90	561.09	91.10
Total value of product					
SRI	176.00	28359.00	15881.12	7196.84	45.32
Normal	6562.50	21000.00	14038.03	3480.17	24.79
Value of by-product					
SRI	181.82	2250.00	1620.42	768.70	47.44
Normal	400.00	2800.00	1106.93	920.87	83.19
Family labour days male					
SRI	15.20	370.00	92.50	81.34	87.94
Normal	9.00	400.00	77.65	79.51	102.40
Family labour days female					
SRI	3.00	90.00	16.40	18.79	114.57
Normal	0.80	38.57	5.95	7.59	127.56
Hired labour days male					
SRI	2.22	42.00	8.86	7.73	87.25
Normal	0.80	25.50	4.23	4.98	117.73
Hired labour days female					
SRI	1.60	16.00	5.97	3.55	59.46
Normal	0.50	8.00	2.75	2.14	77.82
Family labour cost (Imputed)					
SRI	1125.00	13050.00	3185.00	2554.00	68.18
Normal	940.00	15569.23	2479.00	3716.20	97.89
Hired labour cost					
SRI	187.50	4470.00	747.37	794.35	106.29
Normal	75.00	800.00	313.60	239.41	76.34
Total operational cost without family labour cost					
SRI	480.00	10091.33	6271.29	1982.36	45.78
Normal	2030.00	9515.71	5756.72	1592.30	36.80
Total operational cost with family labour cost					
SRI	480.00	23141.33	9456.29	4123.01	51.05
Normal	3610.00	18584.62	8235.72	4132.17	50.87

(Contd.)

TABLE I *(Concld.)*

Variable (1)	Min (2)	Max (3)	Mean (4)	SD (5)	CV (6)
Net returns without family labour cost					
SRI	1004.00	27656.00	11230.25	6547.30	56.68
Normal	1130.00	19062.00	9388.24	3948.10	40.65
Net returns with family labour cost					
SRI	325.00	26136.00	7804.83	6343.02	81.27
Normal	587.88	16102.22	5915.12	4182.58	70.71

Source: Based on the field survey.

Economics of SRI

As indicated earlier, SRI is better yielding though it involves high costs and risk when compared to traditional methods of paddy. However, the differences in some of the variables may not stand statistical rigour. Paired 't' tests were carried on all the important indicators. As per the tests differences in yields, seed, number of irrigations and labour use are statistically significant while other costs and net returns are not (Table 2). This indicates that yield gains of SRI are not translated into profits. This is not solely, as observed in the earlier studies, due to high labour inputs in the SRI method. It is clear that farmers in Anantapur are using more of non-labour inputs as well. From the farmers' perspective SRI is only as profitable as traditional paddy. But, SRI demands more of capital inputs and hence appears to be a risky choice. On the other hand, water savings are substantial in the case of SRI. SRI not only requires less number of irrigations but also less number of total hours of irrigation. This implies less pressure on the precious groundwater resources as well as energy requirements for pumping groundwater. Groundwater resources are depleting rapidly in these regions imposing huge costs on the farmers (Reddy, 2005). Judicious promotion and adoption of SRI could result in sustainable and efficient use of scarce water resources.

TABLE 2. DIFFERENCE BETWEEN MEANS OF SRI AND TRADITIONAL METHODS FOR IMPORTANT VARIABLES

Variable	Means		't' Statistic
	SRI	Traditional	
(1)	(2)	(3)	(4)
Seeds (kgs/acre)	2.46	34.97	15.80*
Number of irrigations per acre	52	97	2.75*
Number of hours of irrigation per acre	121	537	7.08*
Total labour use (days/acre)	108	86	1.07
Other costs of production (Rs./acre)	6271	5757	1.22
Yield (kgs/acre)	2943	2285	3.38*
Net Returns to own land and family labour (Rs./acre)	11230	9136	1.43
Net Returns to own land (Rs. / acre)	7805	5915	1.36

Note: * Indicates level of significance at 1 per cent level.

While improved water use efficiency deserves immediate attention from social perspective, the concern for it at the individual level is rather limited. This is mainly due to the market and policy failure in appropriately pricing the water resources. In the absence of realistic/cost-based/scarcity-based pricing the externalities associated with water resource depletion are not internalised. Hence, there is no incentive for the individual to care for water use efficiency. Presently, farmers can pump water at almost zero marginal cost. For, neither water nor power (electricity) to pump water is priced. The only cost farmer incurs is the maintenance of the motor, apart from the interest on the capital costs. Water can be priced for improved use of efficiency without substantially affecting the profit margin much in the water scarce regions (Shiferaw *et al.*, 2005).

In the event of volumetric pricing of water or even energy in the present case would convert SRI into a profitable choice when compared with traditional paddy. In the absence of such appropriate water pricing policies in the short run, improving the profitability of SRI could come in hand for achieving water use efficiency. While the average productivity of water is highly in favour of SRI, returns on capital are in favour of traditional paddy due to free water and power (Table 3). To what extent the high capital cost on SRI are justifiable in the light of substantial evidence that SRI needs little of capital inputs like chemical fertilisers. Does this mean that farmers in Anantapur are spending unnecessarily on the fertiliser and other capital inputs? If so what could be the reason behind this behaviour? Whether the high input intensity of SRI is warranted or not can be examined, if we look at the allocative efficiency in the production function.

TABLE 3. AVERAGE PRODUCTIVITIES OF LABOUR, CAPITAL AND WATER

Variable	Means		't' Statistic
	SRI	Traditional	
(1)	(2)	(3)	(4)
Labour (kgs/day)	*27.25*	*25.67*	*0.831*
Capital (kgs/Re.)	1.27	2.63	2.836*
Water (Kgs. /hour)	103	05	3.027*

Note: * Indicates level of significance at 1 per cent level.

The production function estimates[8] reveal some interesting aspects (Table 4). In the case of traditional paddy all the variables, except education of the farmer, have the expected signs. Level of education of the farmer has a significant negative impact on land productivity. It is somewhat surprising that even in the case of SRI, which requires highly skilled human resources this variable turned out to be negative. This indicates that formal education is not a necessary condition for carrying out skilled farm operations. Moreover, in most of the cases SRI is widely supported by extension network of the support organisations like ANGRAU, RDT, WWF, etc. Labour costs have a positive impact on land productivity in the case of SRI while it is not significant in the case of traditional paddy. The significant and positive coefficient (positive marginal product) in the case of SRI indicates that there is scope for increasing labour use in SRI method. Average as well as marginal productivities of labour are positive and high for SRI when compared to traditional paddy. In the case of capital Cost one (Seed + FYM + Fertiliser + pesticides) SRI has revealed negative marginal productivities while traditional paddy is associated with positive marginal product of capital one. This clearly indicates that farmers are using inputs like fertiliser in excess of requirement. Reduction in the use of these inputs would enhance SRI's productivity and hence profitability.

The farmers are using more irrigation than required in the case of SRI while the opposite is true in the case of traditional paddy.[9] In the absence of water pricing this could go against the adoption spread of SRI. For, the greater use of irrigation on traditional paddy would increase the productivity with little or no addition to costs. On the other hand, the reduction in irrigation would enhance land productivity with little impact on costs. Note that the marginal gains from the reduced irrigation application on SRI plots are substantially greater than that of the marginal gains due to the additional application of irrigation in traditional paddy. This indicates that there is greater scope for improving water use efficiency and environmental sustainability. The positive relationship between farm size and productivity reveals that access to groundwater is biased in favour of the large farmers in water scarce regions. Even in the case of SRI despite high labour costs the large farmers are more productive than the small farmers who are expected to have more of family labour.

TABLE 4. 3SLS ESTIMATES OF YIELD FUNCTION OF SRI AND TRADITIONAL PADDY

Variable	SRI		Traditional	
	Coefficient	'Z' Value	Coefficient	'Z' Value
(1)	(2)	(3)	(4)	(5)
Constant	40.80999*	4.785	17.40821*	8.44
Labour cost	0.001409*	4.26	0.0002316	1.56
Capital cost 1	-0.0038317*	2.80	0.0015026*	3.19
Number of irrigations	-0.0366594*	3.04	0.0037985**	2.02
Capital cost 2	0.000445	1.08	0.0000398	0.55
Farm size	0.23364*	2.64	0.0563383***	1.64
Education	-0.785109***	1.80	-0.366049**	2.14
R^2	0.22 (40)		0.24 (34)	

Note: *, ** and *** indicate levels of Significance at 1, 5 and 10 per cent levels respectively. Figures in parentheses are number of observations.

Thus the existing production conditions indicate that SRI has the potential to become profitable through reallocation of resources, especially labour, capital and irrigation. This could be done only through awareness building and extension support. Unless SRI becomes significantly profitable, farmers would continue to adopt traditional paddy despite greater water saving through SRI. In the absence of realistic water pricing (including power) farmers seem to care least for water use efficiency even in scarcity conditions. At the same time it is rather intriguing that farmers are using more of priced inputs on SRI plots. One possible explanation is that the market distortions coupled with imperfect information. In order to arrive at possible explanations we tried to get the farmers perceptions about SRI regarding the reasons for its success and failure.

Farmers' Perceptions about SRI

Our discussions with the farmers regarding the prospects of SRI revealed that the most positive aspect of SRI is water saving. Some farmers are of the opinion that SRI can be cultivated with less amount of water and therefore, is suitable for those areas where limited irrigation facilities are available. On the other hand, normal paddy cultivation requires continuous water supply and the danger of losing the crop persists, if irrigation sources dry up. They are assured minimum yield that would sustain their household, if they adopt SRI method of paddy cultivation. The traditional perception of the farmers on paddy cultivation is that it requires large and continuous water supply. But after observing the results of SRI (cultivated by some of the progressive farmers in small fields on experimental basis) perceptions of the people have started changing. Normal paddy cultivation requires 25-30 kgs of seed where as SRI cultivation needs only 2 kgs. Since it is sown in wide gaps green cover was not visible as in the case of normal paddy fields. Initially SRI farmers were disappointed at this but later they were happy that the spread was healthy and good with more number of tillers. The farmers also view adoption of SRI as a risk hedging strategy. SRI can be grown even in the low rainfall years. In such conditions farmers prefer to grow in small plots to meet their household needs. They are positive about the rotary weeder that can be conveniently used in the SRI plots due to the spacing and thus reducing the labour intensity.

However, farmers seem to have serious concerns about SRI adoption. One of the apprehensions of SRI farmers is that after transplantation they need to take extreme care of the crop. If the pump set breaks down it takes time for repairs. The water stress withstanding capacity of the SRI is very low due to the method of planting single seedling and intermittent irrigation. Under such a situation, the seedling may dry and die with a small stretch of dry spell. In the case of normal paddy, plants are transplanted in bunches of 3-5 and sufficient water is given and the farmers need not worry about irrigation and survival problems at least for some days at a stretch. This problem forced many farmers to revert back to traditional methods of paddy cultivation. Farmers have also reported that SRI is nor suitable for low lands and down streams, as the incidence of heavy rains after transplantation washes away the weak saplings. And getting replacement seedlings of same age is difficult. Replacement with less or more aged seedlings leads to growth imbalance and results in problems during harvesting.

Some farmers' view is that weeding is the main problem in SRI. Weeding with rotary weeder takes more time and requires skills. Small plots of land are not suitable for rotary weeding. Large farmers also apprehend that it takes time to get used to the weeding machine. During *rabi* season yield is less because of intense cold that prevents plant growth. But this is mainly due to lack of proper management practice and awareness, as some of the organisations are promoting SRI during rabi (November-March) season. It is to be noted that 23 plots are sown in *kharif* season, whereas 21 are sown in *rabi* and 7 plots during summer season.

The main problem, however, is the risk factor that is more psychological than real. This could be one of the reasons for undue use of high input and irrigation use. SRI plots do not look like paddy fields for at least 50 to 60 days. The farmers tend to get disheartened at the sight of it, as they are used to flush paddy fields from the first week of transplanting onwards. In their eagerness to see the paddy fields green, farmers tend to use more fertiliser and water. Paddy is known as a lazy man's crop, while SRI demands the attention and efforts that are associated with commercial crops. If these efforts are not adequately rewarded, as in the case of commercial crops, farmers get disheartened and abandon SRI. Besides, in their eagerness to promote SRI it was propagated that SRI gives 2-3 times higher yields. Agricultural extension personnel and scientists informed the farmers that SRI cultivation would give 70-80 bags of yield per acre. But due to lack of proper supervision, monitoring and advice, the results have not come on the expected lines. Now farmers have become skeptical about SRI practice. The farmers are disappointed when the high expectations are not realised on the field. Moreover, the profitability of SRI as against traditional paddy is rather marginal. It is one of the main reasons for low adoption rates. Another reason for low adoption rate could be that lack of government support and involvement in the whole process. Government agencies are yet to get convinced about SRI and take necessary action. In the absence of government involvement the reach of civil society organisations is very limited.

IV

CONCLUSIONS

While it is too early to establish the superiority of SRI, our study provides some indicators regarding its potential. Our analysis does vindicate the yield advantages of SRI, but caution needs to be exercised in exaggerating the gains. In fact, the hype about substantial yield gains is unfounded and in a way appears to be detrimental to its spread. On the other hand, SRI in its present form of farm management has no economic advantage to the farmers in terms of net returns. The farmers do not see any extra benefit towards their efforts and risk. However, this aspect could be addressed with more efficient allocation of resources.

Hitherto SRI is being promoted as a land saving method while its water saving characteristic has been made secondary. From our analysis it becomes clear that the prime gain from SRI is its water saving rather than its yield improving capability. Unless this aspect is realised and given importance while promoting SRI, it would be hard to visualise the greater spread of SRI. This could be one of the reasons for low adoption and high dis-adoption rates across the countries. It is true that farmers adopt a particular variety or method for economic reasons, but this perception could be changed through awareness building and extension support. The gains from water saving or improved water use efficiency need to be given high priority over yield gains, especially in the water scarce regions.

Another advantage of SRI is its high labour intensity. Most of water scarce regions are characterised with low employment rates and high seasonal migration. Given the double benefits of labour intensity and water saving nature the Government should actively promote SRI, especially in the water scarce regions. One reason for hostility towards SRI from the agriculture department side is that they are not convinced about the yield advantages of SRI. Though their perception is valid to some extent, we argue that the department should look beyond the traditional way of promoting land saving technologies. It is high time that priorities are shifted towards water saving and water use efficiency as well, which holds the key to future growth, especially in the rainfed regions. Unless government starts caring about water use efficiency in agriculture it is unlikely that the attitude of farmers would change. Policy initiatives should be aimed in the direction of changing farmers approach towards water. The policies could be in the form of incentives/dis-incentives or creating awareness. In the long run the policy should aim at treating water as an economic good when used for productive purposes like irrigation.

Apart from moving towards judicious pricing of water in the long run, in the short and medium terms, the policy initiatives should be aimed at strengthening the extension network. The extension support system should work towards awareness building in terms of water use efficiency and improving allocative efficiency of other inputs. This would automatically reduce costs and enhance the profitability of SRI. Care should be taken not to put undue emphasis on yield gains due to SRI. Some damage has already been done in this regard. To change the mindset of the farmers and to encourage them to take up SRI. Government should organise awareness generation campaigns. Measures are also needed to address the large farm bias in the adoption of SRI. This would encourage large number of small and marginal farmers to come forward to take up SRI cultivation.

NOTES

1. Minimum support price policy is effectively implemented in the case of paddy along with wheat. Input subsidies on water, fertilisers, power, etc., encourage farmers to grow paddy. Besides, paddy is also known as a lazy persons' crop with low supervision costs.

2. For details and review of these methods see Shi *et al*. (2002).

3. Aerobic rice appears to be gaining prominence in this regard, but research indicates that its yields are on the lower side when compared to lowland rice (Bouman, *et al*., 2002).

4. In fact, we observed in one or two families this has to led quarrels between wife and husband, i.e., wife accusing the husband why has deviated from the normal method of paddy cultivation and spoiled the crop and losing one season's income.

5. The estimation procedure uses the covariance matrix of disturbances in 3-SLS is almost identical to the Seemingly Unrelated Regression Estimation (SURE) method. As with SURE, the use of covariance matrix improves the efficiency of 3-SLS estimator.

6. OLS estimates are also carried out. But, 3-SLS estimates are found to be more consistent in terms of explanatory power and levels of significance.

7. Estimates of the complete system of equations along with OLS estimates can be obtained from the authors on request.

8. Though we have estimated the system of equations (five), here we present only the production function for sake of brevity. However, the estimates of other equations can be obtained from the authors.

9. The average number of irrigations used is 52 for SRI as against 97 for the traditional paddy.

REFERENCES

Anthofer, Jurgen (2004), "The Potential of the System of Rice Intensification (SRI) for Poverty Reduction in Combodia", http://www.tropentag.de/2004/abstracts/full/399.pdf, accessed July 2005.

Barrett, Christopher B., Christina M Moser, Joeli Barison and Oloro V.McHugh (2003), "Better Technology, Better Plots or Better Farms? Intensifying Changes in Productivity and Risk Among Malagasy Rice Farmers", Annual Meetings of the American Agricultural Economic Association. July.

Bouman, B. A. M .; Yang Xiaoguang., Wang Huaqi., Wang Zhiming., Zhao Junfang., Wang Changgui and Cheng Bin (2002), Aerobic Rice (Han Dao): A New Way of Growing Rice in Water-short Areas", Proceedings of the 12th International Soil Conservation Organisation Conference, 26-31 May, Beijing, China.

De Janvry, A., Fafchamps, M. and Sadoulet, E. (1991), "Peasant Household Behavior with Missing Markets: Some Paradoxes Explained", The Economic Journal 101:1400-1417.

Dobermann, A (2003), "A Critical Assessment of the System of Rice Intensification (SRI)", Working Paper, University of Nebraska, Lincoln.

Green, H.W. (1997), *Econometric Analysis*, Third Edition. Prentice-Hall Inc, New York.

Holden, S.T., Shiferaw, B. and Pender, J. (2001), "Market Imperfections and Land Productivity in the Ethiopian highland", *Journal of Agricultural Economics*, Vol. 52, No. 3, pp.53-70.

Moser, Christina M. and Christopher B. Barrett (2002), "The Disappointing Adoption Dynamics of a Yield Increasing, Low External Input Technology: The Case of SRI in Madagascar", *Science Direct Agricultural Systems*, November.

Pender, J.L. and Kerr, J.M. (1998), *Determinants of Farmers' Indigenous Soil and Water Conservation Investments in Semi-arid India*, Agricultural Economics, Vol. (19), pp. 113-125.

Reddy, V. Ratna (2005), "Costs of Resource Depletion Externalities: A Study of Groundwater Overexploitation in Andhra Pradesh, India" Environment and Development Economics (Cambridge), Vol. 10, Part-IV, August.

Shi Qinghua, Xiaochun Zeng, Muying Li, Xueming Tan and Fengfeng Xu (2002), *Effects of Different Water Management Practices on Rice Growth*, International Irrigation Research Institute (IRRI), Los Banos, Philippines.

Shiferaw, Bekele, V. Ratna Reddy, Suhas P. Wani, G.D. Nageswara Rao (2005), "Irrigation Investments, Shifting Cropping Patterns and Groundwater Depletion in Indian Semi-Arid Villages: The Effect of Alternative Water Pricing Regimes", Unpublished Paper, ICRISAT-Nairobi, Kenya.

Shiferaw, Bekele and Holden, S. T. (2000), "Policy Instruments for Sustainable Land Management: The Case of Highland Smallholders in Ethiopia", Agricultural Economics, Vol. 22, No. 3, pp. 217-232.

Uphoff, N. (1999), "How to help Rice Plants Grow Better and Produce More: Teach Yourself and Others, CIIFAD, Conell University, Ithaka, New York.

Uphoff, N. (2000), "Questions and Answers About SRI", CIIFAD, Conell University, Ithaka, NY.

Uphoff, N. and R. Rnadriamharisoa (2002), "Proceedings of a Thematic Workshop on Water-Wise Rice Production", April 2002, IRRI, Los Banos, Philippines.