AN EVALUATION OF THE SYSTEM OF RICE INTENSIFICATION (SRI) IN EASTERN INDONESIA FOR ITS POTENTIAL TO SAVE WATER WHILE INCREASING PRODUCTIVITY AND PROFITABILITY

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Decentralized Irrigation System Improvement Project in Eastern Region of Indonesia

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ABSTRACT

Over the past three years, a major donor-funded irrigation project in Eastern Indonesia has evaluated the System of Rice Intensification to assess its potential to reduce demand for irrigation water while rewarding farmers with higher production and incomes. This paper reports the results and conclusions from this assessment. In summary, comparison trials managed by 1,849 farmers on 1,363 ha and supervised by project staff have given an average SRI yield of 7.23 t/ha compared to 3.92 t/ha with conventional methods, an 84% increase. Water saving has been assessed to be around 40%, accompanied by an average reduction in costs of production per hectare of >25%. A detailed analysis of costs and benefits in the 2005 dry season in West Nusa Tenggara province calculated that the net returns per hectare with SRI methods was 6.2 million rupiah compared with 1.2 million rupiah using conventional methods. In one scheme (Batu Bulan dam irrigation), the ratio of net return was 7.3 times higher. So the economic attractiveness of SRI methods is very great, giving farmers strong incentive to accept water-saving as new norm for irrigated rice production.

I. PROJECT BACKGROUND

Since 1990, in accordance with the Government of Indonesia's policy to prioritize development in eastern Indonesia, where water resources are limited and the economy is depressed, a Small Scale Irrigation Management Project (SSIMP) has been undertaken with financial assistance from the Japan Bank for International Cooperation (JBIC). The executing agency for the project is the Directorate General of Water Resources (DGWR), Ministry of Public Works (PU) in Indonesia. The fourth phase of this project (SSIMP-IV) started in 2003, when its name was changed to the *Decentralized Irrigation System Improvement Project in Eastern Region of Indonesia* (DISIMP). This series of four SSIMPs has been under continuous management by the same consultant (Nippon Koei, NK) for over 15 years. Data on these projects are given at the top of the next page and locations where SRI methods have been evaluated are shown on the map.

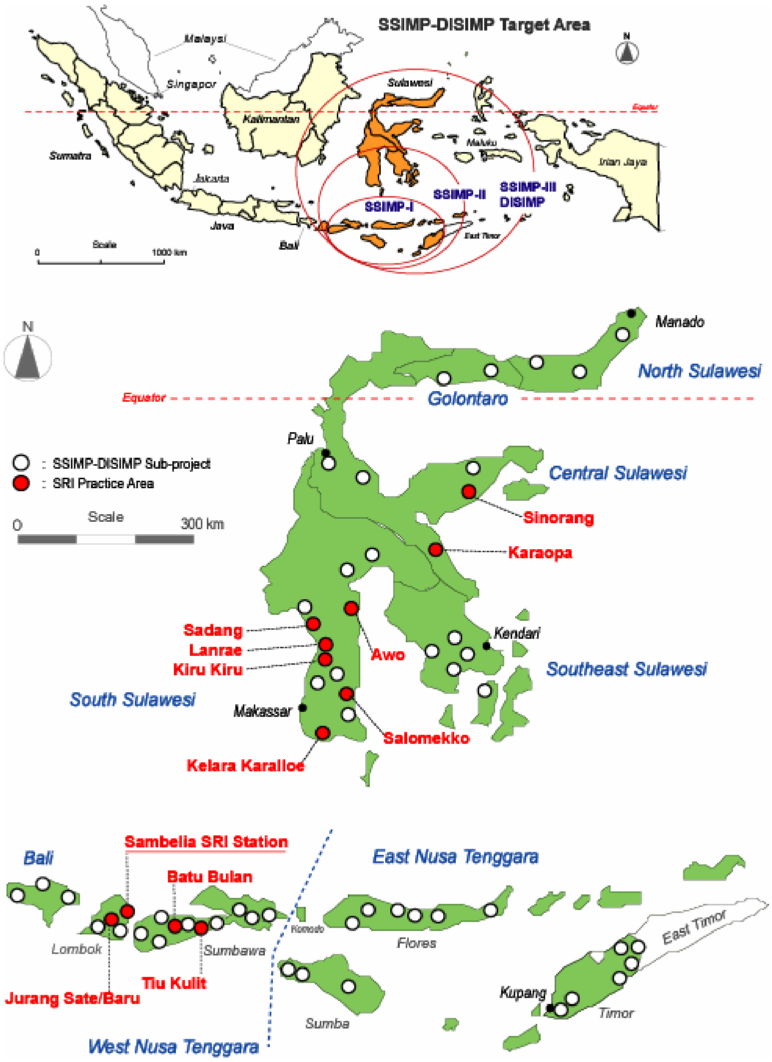
In SSIMP-DISIMP, sustainable development for poverty alleviation has been a key project objective, emphasizing quick-yielding, bottom-up, and beneficiary-participation approaches. SSIMP has been implemented with unique approaches that are expected to contribute to improving project sustainability, namely (a) comprehensive project management to cover the whole project cycle, (b) flexible project formulation to meet local needs, (c) good quality control, (d) capacity building among officials and engineers, (e) intensive guidance for beneficiaries and operators, and (f) continuous learning made possible by the project continuity provided by GOI and JBIC.

SSIMP-I (1990-1994):
3 sub-projects in 2 provinces; 3,100 ha of new irrigation, water from 2 dams and 248 wells.

SSIMP-II (1995-1998):
11 sub-projects in 3 provinces; 15,600 ha of new irrigation and water supply for 10,000 people; supply from 3 dams, 6 weirs, and 192 wells.

SSIMP-III (1998-2003):
40 sub-projects in 6 provinces; 60,342 ha of new/improved irrigation and water supply for 240,000 people, from 3 dams, 12 weirs, and 310 wells.

DISIMP (2003-2008):
27 sub-projects in 8 provinces; 130,000 ha of new/improved irrigation and water supply for 50,000 people, from 9 dams, 15 weirs, 250 wells



The quantitative results of this series of SSIMPs by 2004 amounted to new and/or improved irrigation systems for about 80,000 ha, with water supply for 250,000 people, served by 8 dams, 18 diversion weirs, 750 groundwater tubewells, and 570 km of canal networks. The number of direct beneficiaries assisted by SSIMP has reached 1.3 million.

II. SRI ACTIVITIES IN SSIMP-DISIMP SCHEMES

Since 2002, SRI methods have been tested and demonstrated in irrigation schemes completed under SSIMP as a specific measure to help promote irrigation improvements and to strengthen farmer groups. The first SRI locations were selected at the Awo weir irrigation scheme (SSIMP-II) in South Sulawesi, and the Tiu Kulit dam irrigation scheme (SSIMP-I) in West Nusa Tenggara. Owing to the great success of the SRI trials in SSIMP schemes, SRI areas are continuing to expand to cover ever larger areas and more irrigation schemes as follows:

Year 2002: 1.9 ha (6 farmers) in 4 schemes in 2 provinces
Year 2003: 15.3 ha (32 farmers) in 6 schemes in 2 provinces
Year 2004: 364.5 ha (347 farmers) in 12 schemes in 2 provinces
Year 2005: 981.9 ha (1,464 farmers) in 15 schemes in 3 provinces

By the end of 2005, SRI has been introduced in SSIMP-DISIMP scheme areas on 1,363.6 ha by a total of 1,849 farmers. In 2006, SRI is expected to be expanded to >4,000 ha in 8 provinces in eastern Indonesia.

The SRI practices followed in SSIMP-DISIMP schemes have been, in general, as follows;

Farm plots:	Plot-to-plot irrigation within SSIMP-DISIMP schemes; this is not ideal for proper water control, but it reflects the existing infrastructure conditions. If existing infrastructure is reconfigured to achieve better water control at the individual field level, further reductions in water use should be achievable.
Rice varieties:	IR-64, Ciliwung, Ciherang, and Mamberamo
Transplanting:	Single planting of young seedling (7-14 days after seeding) with wide spacing. This is usually 30 cm x 30 cm, but 27 cm x 27 cm in some locations.
Water management:	a) *Vegetative growth stage*: Intermittent irrigation without standing water ($\leq$ 2 cm) in the field. The wet-dry cycle differs by location, reflecting differences in soil type, shape and size of plot, rainfall pattern, and availability of irrigation water;
	b) *Reproductive stage*: Continuous irrigation with shallow standing water ($\pm$ 2 cm)
	c) *Drainage*: 20 days before harvest
Land preparation:	Common practices are used for puddling and leveling the plots. Small ditches are dug by farmers along the bunds and in the centers of their plots, if necessary, as this facilitates smooth irrigation and drainage operations to realize efficient intermittent irrigation.
Fertilization:	Chemical fertilizer has been applied but with a 50% reduction in quantity; also application of organic matter as available.
Weeding:	Weeding with a rotary hoe 2 or 3 times per crop season.

III. COMPARISON OF SRI VS. NON-SRI PADDY YIELD RESULTS TO DATE

From 2002 until now, SRI methods have been tested, demonstrated and expanded with the direct supervision by NK consultant experts and SSIMP-DISIMP project staff. SRI paddy yields have been measured on site and then are converted, by adjusting for moisture content, to standard ‘dried unhusked rice’ condition, with 14% moisture content.

For comparison, the yields of non-SRI paddy cultivated adjacent to SRI plots -- same variety of rice but with full irrigation -- are carefully measured by the same method and procedures as used with SRI at the same time. Records of SRI paddy yields compared with non-SRI paddy yields since the beginning of evaluation to the present are shown in Table 1.

Previous reports of these data have been of harvested paddy, not adjusted for moisture content. This adjustment does not change the ratios of reported yield difference, only absolute levels. For farmers, ratio is more important than yield (how much increase is obtained). Actually, the most important consideration is impact on net income (profitability), discussed in Section IV.

Table 1: Average paddy yields (dried un-husked rice) with SRI and without SRI practices, shown by SSIMP-DISIMP scheme from 2002 to 2005

	Name of Irrigation Scheme	SRI Area		Cropping Season	Variety of Rice	Paddy Yield (t/ha)		
		Area (ha)	Farmers			SRI	Non-SRI	Ratio
South Sulawesi								
1	Awo-1	0.20	3	DS 02/03	Ciliwung	7.15	4.35	164%
	Awo-2	5.00	18	DS 03/04	Ciliwung	6.29	3.61	174%
2	Salomekko-1	0.20	1	DS 02/03	Ciliwung	7.92	3.32	239%
	Salomekko-2	5.00	7	WS 2003	Ciliwung	6.19	3.66	169%
	Salomekko-3	5.00	10	DS 04/05	Ciliwung	6.69	3.48	192%
3	Kelara Karalloe-1	4.30	6	WS 03/04	Mamberamo	7.45	4.41	169%
	Kelara Karalloe-2	2.00	1	DS 2004	Mamberamo	8.18	4.17	196%
	Kelara Karalloe-3	217.90	145	WS 04/05	Mamberamo	7.65	3.83	200%
4	Kiru Kiru-1	1.00	1	WS 03/04	Ciliwung	8.76	3.19	275%
	Kiru Kiru-2	1.00	1	WS 04/05	Ciliwung	6.80	3.53	193%
5	Sadang-1	5.00	12	WS 2004	Ciliwung	8.11	4.55	178%
	Sadang-2	77.79	106	DS 04/05	Ciliwung	8.99	4.80	187%
	Sadang-3	164.89	183	WS 2005	Ciliwung	7.57	4.59	165%
6	Lanrae-1	3.00	4	DS 04/05	Ciliwung	6.80	4.08	167%
	Lanrae-2	10.00	10	WS 2005	Ciliwung	7.65	4.47	171%
	Total/Weighted average	502.28	508			7.79	4.25	184%
West Nusa Tenggara								
1	Jurang Sate (Lombok) -1	4.37	11	WS 04/05	Ciherang	8.48	5.58	152%
	Jurang Sate (Lombok) -2	74.95	216	DS 2005	Ciherang	6.44	3.94	164%
2	Jurang Batu (Lombok) -1	5.06	12	WS 04/05	Ciliwung	6.66	4.98	134%
	Jurang Batu (Lombok) -2	103.42	241	DS 2005	Ciliwung	5.59	2.62	213%
3	Lombok (other 8 sites)	41.24	123	DS 2005	Ciherang	5.56	3.95	141%
4	Tiu Kulit (Sumbawa) -1	1.50	2	WS 02/03	IR-64	7.37	5.10	145%
	Tiu Kulit (Sumbawa) -2	2.62	10	WS 04/05	Ciherang	9.00	4.49	200%
	Tiu Kulit (Sumbawa) -2	5.07	5	DS 2005	Ciherang	7.20	4.06	177%
5	Batu Bulan (Sumbawa) -1	0.16	1	DS 2004	IR-64	8.02	4.51	178%
	Batu Bulan (Sumbawa) -2	11.38	42	WS 04/05	Ciherang	8.45	4.73	179%
	Batu Bulan (Sumbawa) -3	61.55	128	DS 2005	Ciherang	8.30	3.95	210%
	Total/Weighted average	311.32	791			6.55	3.59	183%
Cenral Sulawesi								
1	Karaopa -1	37.00	37	DS 04/05	Ciliwung	8.10	4.02	203%
	Karaopa -1	493.00	493	DS 2005	Ciliwung	6.90	3.70	187%
2	Sinorang -1	8.00	8	DS 04/05	Ciherang	6.10	4.10	149%
	Sinorang -2	12.00	12	DS 2005	Ciherang	5.60	3.60	156%
	Total/Weighted average	555.00	555			7.10	3.81	186%
Grand Total/Weighted average		1,363.6	1,849			7.23	3.92	184%

Note: WS= Wet Season, DS=Dry Season
** = Dried un-husked rice (moisture content 14%)*

The yield-enhancing results of SRI cultivation methods have been highly impressive, achieving an average paddy yield (dried un-husked rice) of 7.8 t/ha in South Sulawesi province, 6.6 t/ha in West Nusa Tenggara province, and 7.1 t/ha in Central Sulawesi province. The yield increment ratio of SRI compared with non-SRI is about 84% on average, ranging between 45% and 175%. As seen from the 2002-2005 data, average paddy yield for the wet-season crop is higher than that of dry-season crop. However, the yield increment ratio, comparing SRI with non-SRI paddy yields, is higher in dry season as seen below:

Wet season paddy: 7.63 t/ha for SRI, while 4.21 t/ha for non-SRI (81.4% increase)
Dry season paddy: 6.96 t/ha for SRI, while 3.75 t/ha for non-SRI (85.5% increase)

The variety of rice shows almost no correlation with yield increment ratio (SRI vs. non-SRI). So far we have found that all varieties responding positively to SRI management methods, although some varieties respond more strongly than others.

IV. COMPARISON OF NET BENEFITS USING SRI METHODS

To clarify the benefits of SRI versus non-SRI cultivation, a calculation of crop budgets was made for the 2005 dry-season crop, taking data from Lombok in West Nusa Tenggara as an example. This was done without considering differences in irrigation cost. If irrigation reductions and savings are incorporated into this calculation, the favorability of SRI would be further increased.

Table 2: Crop budget analysis of SRI versus non-SRI paddy cultivation in dry-season cropping in West Nusa Tenggara Province, 2005

Item	Unit Qt'y	Unit Price (Rp)	Non-SRI		SRI		Increase (%)
			Quantity	Amount(Rp)	Quantity	Amount(Rp)	
A **Inputs (per ha)**							
1. Labor							
1.1 Human	m-d	20,000	166	3,320,000	125	2,500,000	75.3%
1.2 Animal	a-d	20,000	16	400,000	16	400,000	100.0%
2. Transportation (paddy)	kg	20	3,940	78,800	6,440	128,000	163.5%
3. Material							
3.1 Seeds	kg	3,500	50	175,000	5	17,500	10.0%
3.2 Chemical fertilizer							
- Urea	kg	1,200	250	300,000	140	168,000	56.0%
- TSP/SP36	kg	1,600	100	160,000	50	80,000	50.0%
3.3 Pesticides	lit	112,000	2	224,000	1	112,000	50.0%
4. Others	L.S.	40,000	1	40,000	1	40,000	100.0%
Total for A				**4,697,800**		**3,446,300**	**73.4%**
B **Output (per ha)**							
Crop production value	kg	1,500	3,940	**5,910,000**	6,440	**9,660,000**	**163.5%**
C **Benefits (per ha)**							
Net Return (=B-A)				**1,212,200**		**6,213,700**	**512.6%**

Note: Conversion rate: US$ 1 = Rp. 9,000 as of end 2005

As seen in Table 2, the production cost for paddy cultivation under SRI is about 24% less than that for non-SRI cultivation mainly due to a decrease in material costs, i.e., 90% reduction for seeds and 50% reduction for chemical fertilizers and pesticides. Net returns increased by about 5.1 times for SRI compared to non-SRI methods.

To see the potential for increase in income, we note that in the Batu Bulan scheme in the 2005 dry season, the net return for SRI against non-SRI increased by 7.3 times. In general, we calculate that a 50% paddy yield increase with SRI can generate more than 4 times higher net return in comparison with non-SRI cultivation under current East Indonesia economic conditions.

V. IRRIGATION METHODS FOR SRI IN SSIMP-DISIMP SCHEMES

The recommended irrigation method for SRI is intermittent irrigation with a wet-dry cycle that does not maintain standing water (maximum depth of 2 cm). The length of the dry period for SRI paddy fields differs from location to location according to soil conditions (permeability, water-holding capacity, etc.), plot size and shape, availability of irrigation water, rainfall condition, and so forth. In SSIMP-DISIMP schemes, dry period for intermittent irrigation has been determined through trial-and-error. The indicator for restarting irrigation delivery is the size of cracks appearing on the soil surface of paddy fields, especially for clay or loamy soils. Actual practice for intermittent irrigation with SRI at present is quite variable by scheme as follows:

Table 3: Intermittent irrigation with SRI in SSIMP-DISIMP schemes, 2005 dry-season cropping

Type	Intermittent Irrigation		Name of SSIMP-DISIMP Schemes
	Moist (days)	Dry (days)	
A	10	3-4	Salomekko, Sadang, Kelara Karalloe, Kiru Kiru, Lanrae
B	7	4-5	Awo
C	6	10-12	Tiu Kulit, Batu Bulan
D	4	6	Mamak
E	3	7	Jurang Sate, Jurang Batu,

In order to determine the irrigation intervals that will optimize both high paddy yields and water saving simultaneously, the project has established a research program with controlled field testing, starting in 2005, as reported in the next section.

VI. EXPERIMENT ASSESSING IRRIGATION WATER REQUIREMENTS

In order to obtain precise measurements of water use when using SRI cultivation methods in comparison with non-SRI practice, a SRI experimental station was established during June-September 2005. The water management testing program is being implemented for two years through 2007.

The general features of the station are as follows:

Name of station:	Sambelia SRI Experimental Station, DISIMP
Location:	East Lombok district, West Nusa Tenggara province
Soil condition	Sandy loam
Irrigation system:	Supply water to each plot by buried pipeline from overhead tank (5 m^3 capacity) pumping up from groundwater tubewell
Test plot:	24 plots, each 5 m x 5 m (25 m^2) in area

The first measurement of water consumption for SRI versus non-SRI was started in test plots in the Sambelia station in October 2005. To compare the effects of irrigation interval on paddy yields between SRI and non-SRI cultivation, conditions of both SRI and non-SRI lots were arranged to be equal. Applications of chemical fertilizers were at the same level for both plots (200 kg/ha of urea, 36 kg/ha of TSP, and 50 kg/ha of KCL). An outline of the observation program for the first set of tests is shown in Table 4. The pictures below show the facility and the growing crops.

Table 4: Field tests of intermittent irrigation for SRI and non-SRI practices at Sambelia Experimental Station, 2005/2006

Item	SRI		Non-SRI	
	Case-1	Case-2	Case-3	Case-4
Transplanting method				
Variety of rice	Ciherang	Ciherang	Ciherang	Ciherang
Seedlings (age after seeding)	10 days	10 days	25 days	25 days
Number of plants/hill	1	1	4	4
Spacing	30 x 30 cm	30 x 30 cm	20 x 25 cm	20 x 25 cm
Planting schedule				
Date of transplanting	11 Oct. 2005	11 Oct. 2005	26 Oct. 2005	26 Oct. 2005
Date of harvest	3 Feb. 2006	4 Feb. 2006	3 Feb. 2006	4 Feb. 2006
Irrigation during growing stage				
a. Intermittent irrigation from transplanting to 10-Dec-05				
- Wet period	5 days	10 days	Continuous	10 days
- Dry period	10 days	5 days	(none)	5 days
b. From 11-Dec-05 to 01-Jan-06	Continuous	Continuous	Continuous	Continuous
Results of measurement				
Total amount of irrigation water	816 mm	1,152 mm	1,368 mm	1,136 mm
Paddy yield (dry un-husked rice)	5.12 t/ha	4.46 t/ha	2.95 t/ha	3.40 t/ha


Irrigation supply measuring tank


21 days after transplanting (SRI)


110 days after transplanting (SRI)

Although the observation data thus far are limited and further observations are being conducted, the following findings can be reported from the first trial results above.

1. The SRI method can definitely offer higher paddy yields than non-SRI practices; there was a 75% increase with SRI in these trials.
2. SRI paddy yields decrease when the dry periods are shorter, and they increase when the dry periods are longer.
3. If intermittent irrigation is applied to non-SRI plots, paddy yield can be increased by 15% compared with continuous flow irrigation. (compare case-3 with case-4)
4. Higher paddy yields by SRI over non-SRI cultivation may be the result of the *combined effects* of (a) SRI transplanting practices, and (b) intermittent irrigation with sufficient dry periods.
5. The water-saving potential of SRI (intermittent irrigation during the vegetative growth stage) versus non-SRI cultivation (continuous irrigation) will justify ~40% reduction in water consumption at the field level during the growing stage.
6. Further savings may be found possible if experiments show that continuing some form of reduced irrigation during the reproductive stage is feasible.

VII. WATER-SAVING EFFECTS OF SRI

According to the observations on irrigation water use with SRI cultivation in SSIMP-DISIMP schemes and considering the test results reported above, it can be suggested that the SRI water-saving effects are achieved by a combination of the following three factors.

(1) Water-saving during land preparation
Land preparation (LP) is usually performed twice for both methods. The first LP method and amount of irrigation water supplied shows no difference between SRI and non-SRI. However, the second LP operation (puddling) uses more water for non-SRI paddy fields due to the practice of keeping standing water 5 to 10 cm deep. With SRI cultivation, standing water after the second LP is not necessary. The total amount of water savings at this stage is estimated to be about 800 - 1,000 m^3 per ha.

(2) Water-saving during nursery preparation
For non-SRI transplanting, mature seedlings of 25-30 days age are used. Nursery beds are commonly set at the corner of the main paddy field for easy transportation of large-sized seedlings. To supply water to nursery beds for one month, it is necessary to supply irrigation water to the whole paddy field continuously. The total amount of irrigation water supplied during nursery preparation is estimated to be 2,000-3,000 m^3 per ha. Only a small fraction of this amount of water is necessary for SRI nursery management.

(3) Water-saving by intermittent irrigation
Water consumption during the rice plants' growing season after transplanting is much less for SRI than for non-SRI practices. Through field tests and observations, the reduction is about 40%. In general, dry periods for intermittent irrigation should be shorter for permeable soils due to their lesser moisture-holding capacity. On the other hand, it is possible to extend dry periods longer with less permeable soils or with soils that have greater moisture-holding capacities. There can be more water-saving on such soils compared with permeable soils. As the application of organic fertilizer (compost) can improve the moisture- holding capacity of soils, this can also contribute to more water-saving. With the better plant root systems established by SRI methods, we may find it possible to extend intermittent irrigation beyond panicle initiation without sacrifice in yield, thereby achieving further water-saving.

VIII. LESSONS LEARNED

The main lessons learned from three years of experience with SRI cultivation in SSIMP-DISIMP schemes in eastern Indonesia are as follow:

1. SRI methods can offer higher paddy yields with lower production costs (seeds, chemical fertilizers, pesticides), therefore generating higher profits to farmers.
2. The labor burden is increased with SRI, at least initially. However, farmers are willing to overcome this disincentive by considering the countervailing positive incentives arising from the much higher productivity of SRI paddy cultivation (see Section IV).
3. Higher paddy yields can be obtained with SRI methods without using organic fertilizers, i.e., just with reduced chemical fertilizer use. While the use of organic sources of nutrients is preferable, this is not a necessary component of SRI. Biomass for composting or mulching is often not available, so if the use of organic fertilizers is

made a requirement for SRI, its expansion under current conditions is limited. Organic fertilization should be regarded as a desirable option but not as a prerequisite to practice SRI.

4. SRI cultivation saves water lowering crop water consumption requirements by 40% (variable by soil and field conditions) by applying intermittent irrigation. However, farmers will never agree to let their fields dry out without having reliable, assured access to water sources. Therefore, the introduction of SRI at the initial stage should be within irrigation areas that are in relatively good operating conditions so that SRI extension can proceed smoothly.
5. For successful introduction of SRI, the involvement of local government offices as well as of experts (consultants) is necessary for giving good technical support and advice.

The water-saving effects of SRI cultivation -- more or less 40% vs. non-SRI practices -- has been confirmed by field tests as well as by field observations in many SSIMP-DISIMP schemes sites. Unfortunately, SRI paddy plots and non-SRI paddy plots are mixed within these scheme areas like "patch work." This makes it difficult for farmers to control – and to minimize – their water applications as recommended. If all the paddy fields served by a single off-take were to be cultivated with SRI methods, it should be possible to reduce the amount of water distribution considerably more than achieved this far.

Until entire command areas practice SRI, the following measures are preferable for introduction to realize equitable water distribution and more efficient use of valuable water resources within irrigation schemes.

1. Many irrigation systems have a common problem of inequitable water distribution, i.e. the over-tapping of channel flows by upstream users resulting in water shortages downstream. The introduction and expansion of SRI in the upstream areas of schemes has the potential to generate irrigation benefits for downstream users by decreasing the water consumption of upstream farmers, and thus increasing the amount of water available for downstream areas. Thus, more sustainable and equitable water distribution within irrigation schemes can be achieved through farmers' participation in SRI, what can be called a "*sustainable participatory water-saving approach.*"
2. The expansion of SRI should be particularly attractive with groundwater irrigation. Since such water is relatively more expensive, the reduction in irrigation water requirements that SRI practices permit will be more significant economically. At the same time that pump irrigation technology makes possible more precise water control and application, SRI is creating incentives to reduce water use. This will be important where groundwater extraction is currently excessive and is lowering water tables.
3. For dam or pond irrigation schemes, *palawija* (non-rice) crops are usually recommended during the dry season to obtain more efficient use of the limited, expensive water. However, farmers have a predisposition to plant paddy during the dry season anyway, even though extension offices advise them otherwise. Due to the fact that water consumption under SRI is much less than for non-SRI cultivation, farmers can be allowed to plant paddy even in the dry season on condition that SRI methods are utilized.

The possibilities that SRI is opening up to raise the production of land, labor, capital *and especially water* used in irrigated rice cultivation should enable farmers, planners, technicians and policy-makers to refashion this sector in ways that are more beneficial, equitable and sustainable.

Achieving this potential will require further improvements in irrigation infrastructure and management capacities, to give farmers and water managers the ability to utilize *smaller but reliable amounts of water* as needed for the sustenance of crops and beneficial soil organisms. It will also require rethinking and strengthened capacities for research and extension programs and for appropriate policy formulation and implementation in the agricultural sector.

The environmental implications of such changes and redirections have not been addressed here, but one can foresee only advantages, and no disadvantages, for the conservation of natural ecosystems and biodiversity from reducing the ‘thirstiness’ of irrigated rice cultivation.